Tsunami Emergency Planning in Australia

Australian Government
National Emergency Management Agency

Australian Institute for Disaster Resilience

The Australian Institute for Disaster Resilience acknowledges the Traditional Owners of Country throughout Australia and recognises their continuing connection to land, waters and culture. We pay our respects to Elders past and present.

This handbook was produced on the lands of the Wurundjeri people of the Kulin Nation.

Australian Disaster Resilience Handbook Collection

Tsunami Emergency Planning in Australia

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Australian Disaster Resilience Handbook Collection

The Australian Disaster Resilience Handbook Collection provides guidance on national principles and practices for disaster resilience.

The Handbook Collection:

- provides an authoritative, trusted and freely available source of knowledge about disaster resilience principles in Australia
- aligns national disaster resilience strategy and policy with practice, by guiding and supporting jurisdictions, agencies and other organisations and individuals in their implementation and adoption
- highlights and promotes the adoption of good practice in building disaster resilience in Australia
- builds interoperability between jurisdictions, agencies, the private sector, local businesses and community groups by promoting use of a common language and coordinated, nationally agreed principles.

The Handbook Collection is developed and reviewed by national working groups representing a range of state and territory agencies, governments, organisations and individuals involved in disaster resilience. The collection is sponsored by the National Emergency Management Agency.

Access to the Handbook Collection and further details are available on the Australian Disaster Resilience Knowledge Hub (the Knowledge Hub):

www.knowledge.aidr.org.au/collections/handbook-collection

Australian Emergency Management Arrangements

Community Engagement for Disaster Resilience

Communities Responding to Disasters: Planning for Spontaneous Volunteers

Community Recovery

Disaster Resilience Education for Young People

Emergency Planning

Evacuation Planning

Flood Emergency Planning for Disaster Resilience

Health and Disaster Management

Incident Management

Land Use Planning for Disaster Resilient Communities

Lessons Management

Managing Exercises

Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia

Planning for Animals

Public Information and Warnings

Safe and Healthy Crowded Places

Systemic Disaster Risk

Tsunami Emergency Planning in Australia

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Glossary

TERM	DEFINITION
Australian Tsunami Advisory Group (ATAG)	An advisory committee of the Australian-New Zealand Emergency Management Committee, which deals with national tsunami issues, including the implementation of the Australian Tsunami Warning System (ATWS).
Australian Tsunami Warning System (ATWS)	The Australian Tsunami Warning System is an end-to-end tsunami warning and emergency response system. The ATWS involves key national, state and territory partners and organisations in: earthquake detection tsunami assessment and warning emergency response and recovery.
Australian Warning System (AWS)	A nationally consistent multi-hazard warning system for emergency services to use when warning communities of expected consequences and potential hazards. The warning system comprises of warning levels, calls to action, hazard icons, colours and shapes. AWS was endorsed by the Australia New Zealand Emergency Management Committee (ANZEMC) in March 2021.
Bathymetry	The study and mapping of sea floor topography.
Inundation	The wetting of land areas that would otherwise be dry (e.g. because of a tsunami, a storm surge or a river flood). Properties and communities that are submerged by flooding. Inundation is one of the 3 primary sources of risk in the context of flooding (the other 2 are isolation and indirect effects).
Maximum inundation	The maximum water depth on land reached by a tsunami (or modelled tsunami) at each location across a community and throughout the duration of the tsunami. Maps of maximum inundation produced from modelling can be used as a planning tool by emergency managers to understand more detail about the tsunami. E.g. what infrastructure and services would potentially be damaged during a tsunami. Also see Inundation distance and run-up.
Inundation distance	The maximum distance from the coast reached by a tsunami (or modelled tsunami).
Moment Magnitude (M_w)	A measure of the energy released by an earthquake. There are several different scales for measuring the magnitude. The Moment Magnitude is based on the size and characteristics of the fault rupture and can be determined from long-period seismic waves.
Paleotsunami	A tsunami that occurred before the existence of written historical records.
Run-up	The maximum vertical height for locations on land, above mean sea level, that the sea attains during a tsunami (measured in metres).
Rupture area	The area of a fault over which earthquake slip occurs.
Seismometer	A seismometer is an instrument that responds to ground displacement and shaking, such as those caused by earthquakes, volcanic eruptions and explosions.
Subduction zone	The place where 2 tectonic plates come together, one being pushed below the other.

TERM	DEFINITION
Tectonic plate	According to the theory of plate tectonics, the outer part of the earth may be divided into several rigid plates that move relative to each other over time. Most earthquakes occur at the boundaries between the plates. These rigid plates are termed tectonic plates.
Topography	Describes the natural and artificial physical features of an area of land.
Tsunameter (Deepwater tsunami buoy)	A tsunami detection instrument capable of detecting tsunami in the deep ocean.
Tsunamigenic	Phenomena that generate a tsunami, such as undersea earthquakes, sedimentary deposit or other feature.
Wave amplitude	A measure of half of the wave height from peak-to-trough. It should be recognised that tsunami waves are typically not symmetrical.
Wave height	The vertical distance between the trough and the crest of a wave.
Wavelength	The mean horizontal distance between successive crests or troughs of a wave pattern.
Wave period	The time taken for one wavelength to pass a given point.

Further tsunami terms are available through the IOC Tsunami Glossary **https://tsunami.ioc.unesco.org/en/glossary**

Contents

Australian Disaster Resilience Handbook Collection iii

Acknowledgements iv

Glossary v

Chapter 1: Introduction 1

Purpose of this handbook 2
Audience 2
Handbook context 2
Disaster policy context 2
Hazard risk context 3
Further reading 3

Chapter 2: Foundations 4

Key points 5
What is a tsunami? 5
Tsunami characteristics 5
How is a tsunami generated? 7
Other sources of tsunamis 8
Impacts of tsunamis 8

Chapter 3: Why do we need to plan for tsunamis in Australia? 10

Key points 11
Australian tsunami context 11
Tsunami risk 12
Tsunami risk management 14
Maritime communities 14
Land-based communities 16

Chapter 4: Planning to reduce risk from a tsunami 17

Key points 18
Introduction 18
Tsunami risk mitigation 19
Tsunami detection methods 19
Emerging detection techniques 20

Chapter 5: Tsunami warning systems **23**
Key points 24
Introduction 24
Australian Tsunami Warning System: roles and responsibilities 25
Tsunami warning procedures 26
Tide impact on warnings and tsunami 29
Communicating tsunami warnings to the public 29
Communication channels 30
Australian Warning System 31

Chapter 6: Preparedness for effective response **33**
Planning considerations for response 34
Crisis management 36
Tsunami evacuation 37
Key considerations for tsunami emergency planning 42
Tsunami signage 43
Capability development 43
Community engagement for tsunamis 43
Tsunami exercising 44

Chapter 7: Planning for recovery **46**
Introduction 47
Impact and needs assessment 47
Public information 47
Consequences of tsunami impact 48
Psychosocial impacts of tsunami 48
Planning for longer term recovery 48
Continuous improvement 49

Appendix 1: Australian State and Territory Tsunami Plans **50**

References **52**

Chapter 1: Introduction

Purpose of this handbook

This handbook is a guide to nationally agreed principles and good practice for tsunami emergency planning. The handbook draws on the emergency planning principles found in the *Emergency Planning Handbook* and positions them within the context of tsunamis. The purpose of the handbook is to enhance the knowledge and capacity of policy makers and emergency planners in risk reduction and emergency planning for tsunamis in Australia.

This handbook is not intended to be prescriptive or offer exhaustive guidance, recognising the variability in context, policy and processes between jurisdictions. Rather, it outlines good practice approaches developed over decades of experience in tsunami planning and preparedness around Australia, and internationally. It draws on national and international science, strategies, policies, guidelines, standards and doctrine related to tsunami.

This handbook outlines key scientific information and good practices for managing tsunami risk including:

- risk reduction
- risk assessment
- warning systems
- emergency planning
- community engagement
- response
- recovery.

The handbook supports policy makers, emergency planners, coastal land managers and communities in developing risk management strategies to address the risks associated with tsunamis.

Audience

The handbook is intended for those who prepare communities for tsunami events; in both leading and supporting organisations. The handbook is written for a wide audience, recognising that the responsibility for tsunami mitigation, preparedness, response and recovery is shared among a broad stakeholder group in the coastal zone. The content is written for Australian Tsunami Advisory Group (ATAG) member organisations, as well as for local, state and territory governments, port authorities, the oil and gas industries, boating and marine users and the tourism sector. The handbook may also be useful for communities who live in tsunami risk areas, recognising that there is a shared responsibility to be engaged and prepared.

Handbook context

Tsunami Emergency Planning in Australia is part of the Australian Disaster Resilience Handbook Collection. The 2025 edition updates the 2018 edition. The updated content in this edition includes:

- expanded content on tsunami risk reduction including land use planning considerations and nature-based solutions
- the adoption of the Australian Warning System (AWS)
- learnings from the 2022 Hunga Tonga–Hunga Ha'apai volcanic eruption and tsunami
- considerations from national tsunami Exercise Bombora conducted in 2022
- improvements to tsunami modelling, mapping and visualisation
- a greater recognition of diversity in at-risk populations
- expanded content on tsunami recovery.

This handbook draws on several key outputs from the relevant UNESCO Intergovernmental Oceanographic Commission (IOC) Intergovernmental Coordination Groups, with reference to Australia's role in planning for tsunami. These outputs are highlighted to support Australian emergency managers in developing tsunami preparedness activities. This handbook also recognises the ongoing work of the Indian Ocean Tsunami Warning and Mitigation System (IOTWMS), established following the 2004 Indian Ocean tsunami, and the Pacific Tsunami Warning and Mitigation System (PTWS). The Australian Tsunami Warning System (ATWS) was also established following the Indian Ocean Tsunami.

Companion resources are currently available online to support the use and implementation of this handbook. These will be revised as priorities and capacity allow, to reflect developments in the science and emergency risk management of tsunami. These resources include:

- Guideline 1: Tsunami hazard modelling guidelines (*note: these guidelines were issued in 2018 and do not contain research findings since then*).
- Tsunami: The Ultimate Guide https://knowledge.aidr.org.au/resources/the-ultimate-guide-tsunami

Disaster policy context

International efforts to reduce disaster risk are governed by the United Nations Sendai Framework for Disaster Risk Reduction (Sendai Framework). Australia is a signatory to this Framework. Australia has several national disaster policy frameworks that outline how to build resilience, reduce risk, prepare for effective response and recover from disasters. These are the:

- National Strategy for Disaster Resilience
- National Disaster Risk Reduction Framework (NDRRF)
- Australian Disaster Preparedness Framework (ADPF)
- Australian Disaster Recovery Framework (ADRF)
- Australian Government Crisis Management Framework AGCMF).

This handbook aligns with priority 1 of the NDRRF 'Understanding Risk'. It also aligns with 'Planning' and 'Community Planning, Capacity and Resilience Building' national capability requirements identified in the ADPF. The national arrangements for emergency management in Australia are detailed in the *Australian Emergency Management Arrangements* handbook.[1] Each state and territory is responsible for emergency management in its jurisdiction and the Australian Government provides a supporting and coordinating role. Arrangements for managing tsunami emergencies in each state and territory are listed in Appendix 1.

Hazard risk context

In Australia, people have been living with natural hazards for at least 65,000 years. Individual and societal wellbeing, functioning, prosperity and resilience, rely on interconnected systems to deliver essential services.[2] These systems can be disrupted by natural or human-made hazards. Severe hazards, such as tsunami, can cause systems to fail and can overwhelm individual and community capacity. When this happens, hazards turn into disasters.

Disaster risks are systemic. Risks must be understood in the context of broader societal processes. These processes include:

- economic conditions
- supply chain disruptions
- health and wellbeing challenges
- experience with natural hazards
- levels of social cohesion
- political instability
- technological shifts
- the state of the environment, including climate change.

These interconnected processes can influence an individual's, organisation's or community's ability to prevent, prepare for, respond to and recover from disaster events. Systems, hazards and where people live are all decisions that people have made, whether that be individuals, organisations or governments. This is why disasters should not be referred to as 'natural' disasters.[3]

Disasters can affect people's:

- health and wellbeing
- livelihoods
- educational outcomes
- relationships and sense of safety
- spiritual and cultural connections and practices
- connections to community
- levels of trust and social cohesion.

Disasters can also have a severe impact on animals, the environment and the functioning of ecosystems.

Disasters often disproportionately affect some communities and members of society.[4] People living with disability, women, children, people who identify as LGBTQIA+, people from culturally and linguistically diverse (CALD) backgrounds, those experiencing homelessness, mental illness or poverty often experience disasters differently.

Disasters, such as those caused by tsunamis, can also impact the future liveability and economic viability of communities, industries and environmental values.[5] Disasters are becoming more costly due to increases in the number and value of assets at risk and the costs of reconstruction. There is also the increasing severity and frequency of many natural hazards due to climate change. There is a greater recognition that these costs can be long term and intangible.[6] Recovery from disasters is complex and can take years to decades.[7]

Further reading

This handbook should be used in conjunction with state and territory emergency plans and materials, as well as other publications in the Handbook Collection, including:

- *Australian Emergency Management Arrangements*
- *Community Engagement for Disaster Resilience*
- *Community Recovery*
- *Emergency Planning*
- *Evacuation Planning*
- *Land Use Planning*
- *Planning for Animals*
- *Public Information and Warnings.*

The Australian Disaster Resilience Handbook Collection can be found on the AIDR Knowledge Hub.

Chapter 2: Foundations

Key points

- A tsunami is a series of waves. The first wave is often not the largest. Depending on how it was generated, tsunami waves may be observed for just a few hours to over 24 hours after the triggering event.
- The most common cause of a tsunami is a large undersea subduction zone earthquake.
- Tsunamis can also be caused by events such as submarine landslides, volcanic eruptions, land or ice slumping into the ocean, meteorite impacts and the weather when the atmospheric pressure changes rapidly.
- Tsunamis are much more destructive than regular wind-driven waves for a given wave height because the huge, flooding body of water of a tsunami can continue to rush onto land for an extended period of time.
- The impacts of a tsunami will vary widely. The impacts will be determined by how the tsunami was generated, the distance between the source and the point of impact, the tsunami's orientation and magnitude, and the nature of the nearshore and onshore ecology and topography. The impacts will also be determined by the kinds of land use, infrastructure and numbers of people living, visiting or working in the path of the tsunami.

What is a tsunami?

The name tsunami is derived from the Japanese words 'tsu' meaning harbour, and 'nami' meaning wave. The word tsunami is now used internationally to describe a series of long period, full depth waves travelling across the ocean.

Historically, tsunamis have been referred to as 'tidal waves' or 'seismic sea waves.' However, the term 'tidal wave' is misleading and should not be used to describe a tsunami event. Although a tsunami's impact upon a coastline is influenced by the tidal level at the time of arrival, tsunamis are unrelated to the tides. Tides result from the gravitational influences of the moon, sun and planets.

Similarly, the term 'seismic sea wave' is misleading. 'Seismic' implies an earthquake-related generation mechanism. However, an earthquake is only one of several ways that a tsunami can be generated.

Tsunami characteristics

A tsunami is different from a normal ocean wave. The effects of wind-driven ocean waves are seen only near the surface of the ocean. By comparison, tsunami waves involve the movement of water to the seafloor. In the deep ocean, tsunami waves have extremely long wavelengths. There can be up to hundreds of kilometres between wave crests (see Figure 1) compared to hundreds of metres for wind-driven waves. This makes tsunamis much more destructive than wind-driven waves. The huge, flooding body of water of a tsunami can continue to rush onto land for an extended period of time, from a few minutes to up to an hour. This is compared to just seconds for wind-driven waves.

The speed and size of a tsunami is controlled by water depth. In the deep ocean, tsunami waves may go unnoticed by ships or from the air. As the wave approaches land, it reaches shallow water and slows down. As the front of the wave begins to slow, the rear of the wave – still in deeper water – continues to move slightly faster. This causes the wave to 'bunch up' on itself. The wavelength becomes shorter, and the body of water becomes much higher (see Figure 2). This effect is called shoaling.

The time between the successive wave crests of a tsunami is known as the wave period. Wave crests can be a few minutes to over 2 hours apart, compared to a few seconds for wind-driven waves. In most cases, the first tsunami wave is not the largest. Subsequent waves, sometimes the fifth or sixth, can be many times larger.

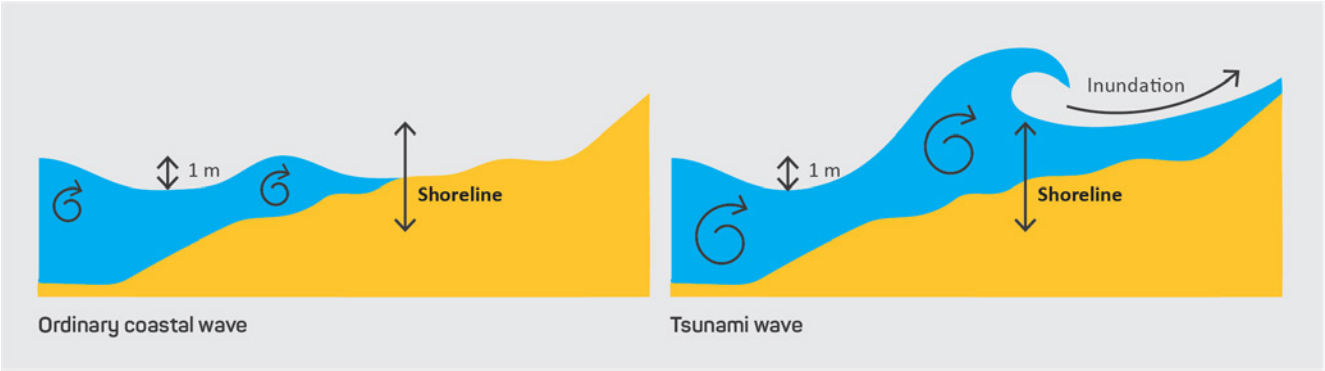

Figure 1: Wave behaviour of a coastal (wind-driven) wave compared to that of a tsunami wave.

Source: National Emergency Management Agency, NZ (2025) Tsunami Evacuation: Director's Guideline for Civil Defence Emergency Management Groups [DGL 08/25].

When a tsunami wave runs onto land, the run-up height above sea level that it reaches can be up to double the wave amplitude at the shoreline. This is because the long wavelength pushes water uphill (see Figure 3). The largest run-ups typically occur where there are narrow valleys on a steep slope, funnelling a tsunami wave into a small area. Narrow bays, inlets and estuaries may cause funnelling effects that enhance tsunami magnitude.

The flooding produced by a tsunami can vary significantly. This is due to the many factors that influence tsunami magnitude at the coast and tsunami behaviour onshore, such as:

- the topography of the coastline
- the bathymetry of the ocean floor
- reflection of waves
- tides
- wind-driven waves.

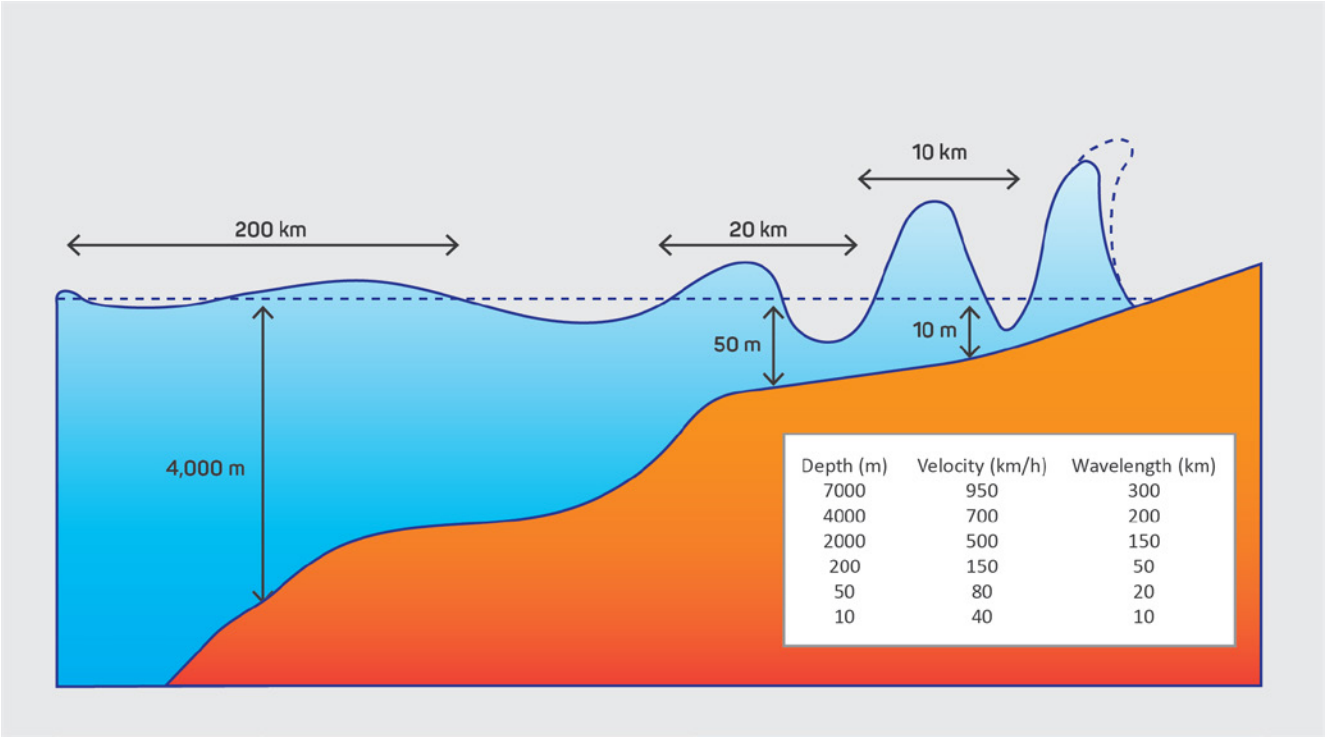

Figure 2: Schematic tsunami wave height and depth characteristics in the open ocean and near shore.

Source: Intergovernmental Oceanographic Commission. Fourth Edition. Tsunami Glossary, 2019. Paris, UNESCO. IOC Technical Series, 85. (IOC/2008/TS/85 rev.4).

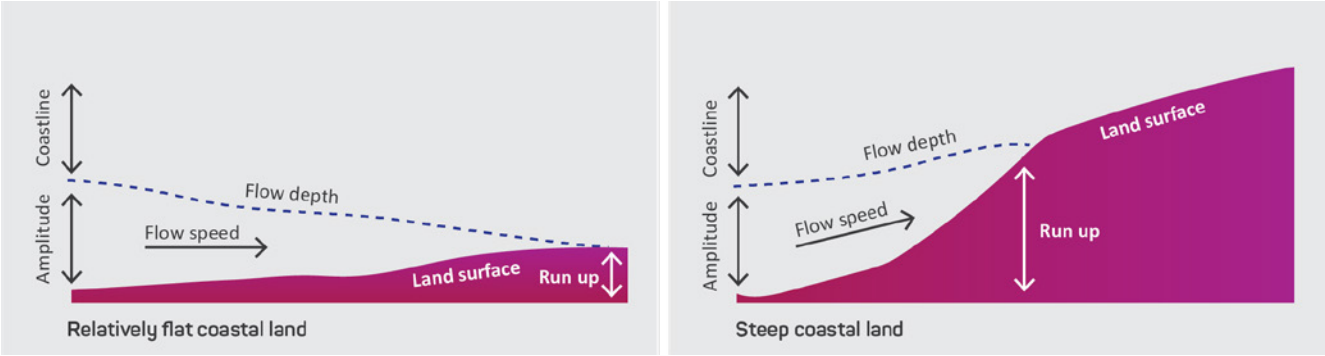

Figure 3: Run-up height and inundation distance on flat coastal land compared to steep coastal land for a tsunami of the same wave amplitude at the coast.

Source: Ministry of Civil Defence and Emergency Management, NZ (2016) Tsunami Evacuation Zones [DGL 08/16].

Tsunamis can travel large distances with limited energy losses. This means that tsunamis can have sufficient energy to traverse entire oceans (see Figure 4). In the deep ocean, a tsunami can travel at more than 900 kilometres per hour. In shallow water close to the coast, tsunami waves slow down to about 40 kilometres per hour.

Internationally, the 2011 Japan tsunami reinforced the importance of tsunami risk management and emergency planning. It brought about key changes in scientific knowledge, including the understanding of:

- maximum possible earthquake magnitudes along tectonic plate boundaries
- how displacement variability in earthquake rupture can significantly affect tsunami inundation.

As a tsunami approaches, natural signs may sometimes (though not always) be observable near the coast such as:

- The ground may shake in coastal regions, indicating a large undersea earthquake that could cause a tsunami directly or indirectly, by triggering a submarine landslide.
- As the tsunami approaches the shoreline, the sea may withdraw from the beach (like a fast-falling tide) before returning as a fast-moving tsunami.
- A roaring sound may precede the arrival of a tsunami.

How is a tsunami generated?

The most common cause of a tsunami is an undersea earthquake resulting in a sudden rise or fall of a section of the earth's crust under or near the ocean. Most commonly, tsunamis are generated by earthquakes that occur in trenches along subduction zones. Subduction zones are areas on the earth where 2 tectonic plates meet and move towards one another, with one sliding underneath the other (see Figure 5).

An earthquake creates an explosive vertical motion between the 2 plates that can displace the overlying water column, creating a rise or fall in the level of the ocean above. This rise or fall in sea level is the initial impulse that generates tsunami waves.

The path of a tsunami is never symmetrical. The waves do not radiate out uniformly in all directions from the earthquake hypocentre, like the ripples from a rock thrown into a pond. Instead, tsunamis predominantly propagate out at right angles to the orientation of the trench within the subduction zone at which the earthquake occurred.

Multiple factors determine the path of a tsunami, including the bathymetry of the seafloor, the depth of water through which the tsunami travels, and the size and shape of the earthquake that caused it.

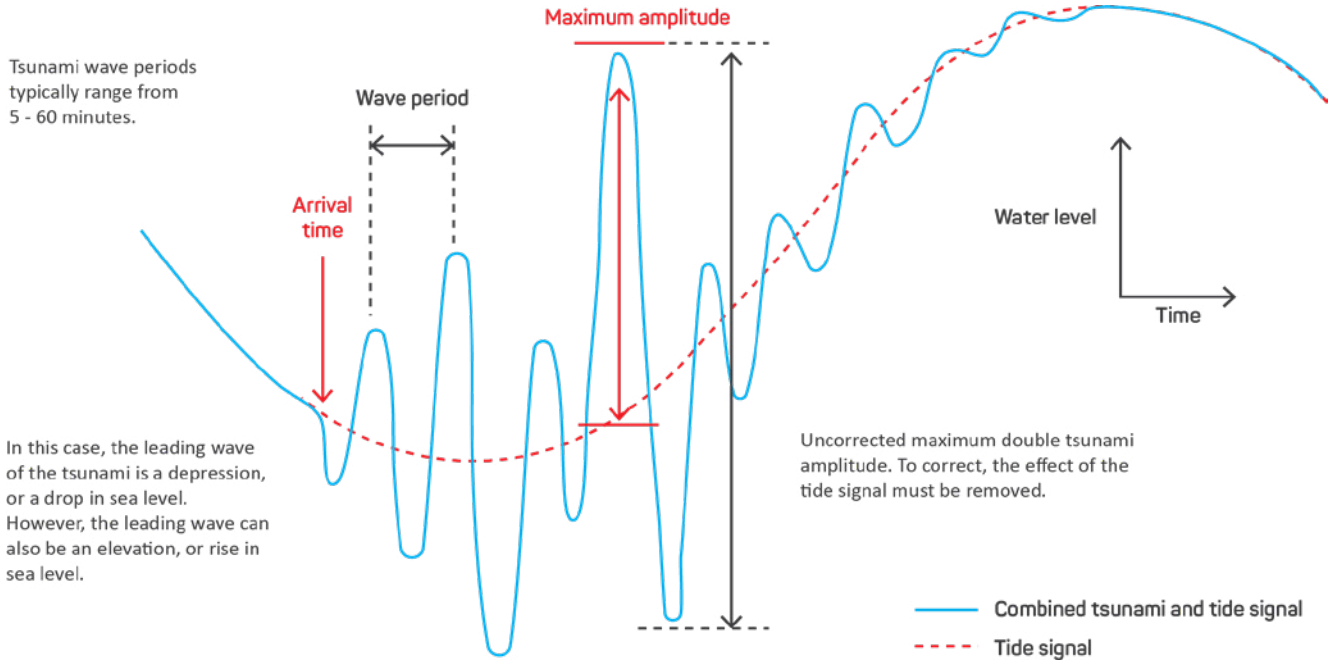

Figure 4: Tsunami wave level over time.

Source: Intergovernmental Oceanographic Commission. Fourth Edition. Tsunami Glossary, 2019. Paris, UNESCO. IOC Technical Series, 85. (IOC/2008/TS/85 rev.4).

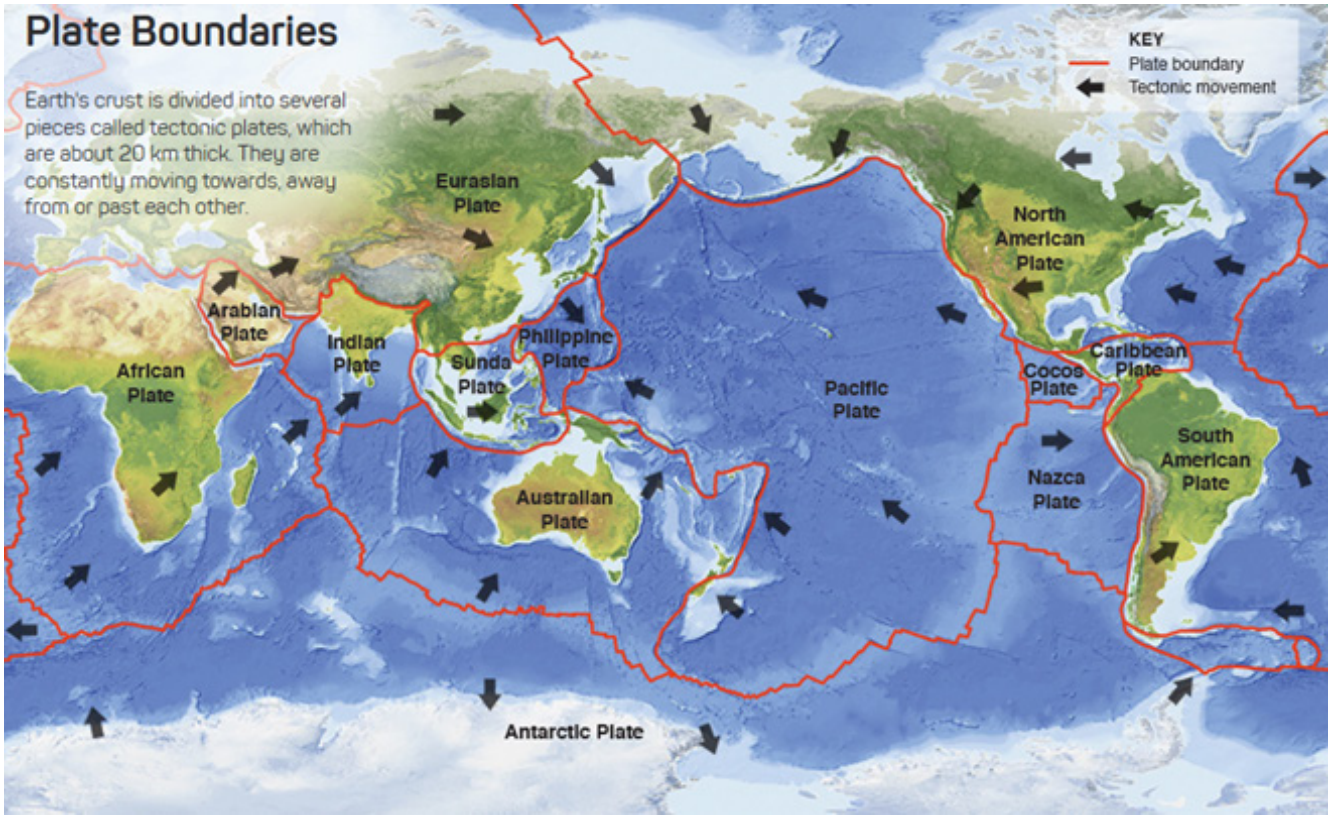

Figure 5: Global Subduction Zone Map

Source: Tsunami: the Ultimate Guide (AIDR)

Other sources of tsunamis

Tsunamis can also be caused by:

- submarine landslides
- volcanic eruptions
- land or ice slumping into the ocean, typically from sea-facing glaciers on the face of a continental shelf or Antarctica
- meteorite impacts
- the weather when the atmospheric pressure changes very rapidly.

Examples of large tsunamis in recent history:

- Northern Sumatra Indonesia on 26 December 2004
- Java Indonesia on 17 July 2006
- Solomon Islands on 2 April 2007
- Northern Chile on 14 November 2007
- Samoa on 29 September 2009
- Chile on 27 February 2010
- Japan on 11 March 2011
- Tann Fiord Alaska on 17 October 2015
- Sulawesi Indonesia on 28 September 2018
- Tonga on 15 January 2022
- Greenland Fjord on 16 September 2023.

Impacts of tsunamis

The impacts of a tsunami can vary widely. A small tsunami may result in unusual tides or currents that can endanger swimmers or cause damage to vessels and marinas. A large tsunami can cause widespread flooding, loss of human and animal life and destruction of infrastructure and ecosystems in the path of the tsunami. Large tsunamis can cause strong rips and currents in oceans worldwide for up to several days after the initial triggering event. The impacts of a tsunami will also be determined by the types of infrastructure and the density of the population living, working or visiting the area affected by a tsunami. The health, social, economic and environmental impacts of a large tsunami can be felt for years to decades.

Effects of tides on a tsunami

The tide varies significantly around Australia with the size of the tide and the frequency varying with location. Further, tide times and tidal ranges also vary daily for any given location. For Land Inundation Threats, the tide level at the time of arrival of the tsunami may affect the extent of inundation. On the open coast, a tsunami coinciding with a high tide is likely to result in greater inundation than if the tsunami was to coincide with low tide which may have significantly reduced inundation.

However, current speeds generated by the tsunami may be greater if the tsunami coincides with low tide than with

high tide. For regions with larger tidal ranges, these effects are exacerbated. In estuaries, tsunamis occurring at high tide are also more likely to cause inundation, however, tsunamis coinciding with a low tide are more likely to cause higher maximum current speeds, with the fastest current speeds occurring at the shallowest water depths (with some exceptions).

These generalisations are useful to understand potential impacts but should be considered only as general guides as the effects of tsunami and how they interact with tides is typically site specific. However, this information allows authorities to better understand the potential effects of tides on the impacts of the tsunami beyond the general guidance issued in a tsunami alert.

Other considerations: consecutive and compounding hazards

It is important to note that hazards do not necessarily occur in isolation. A tsunami could occur at the same time as an imminent or ongoing hazard event, such as a flood, severe storm or cyclone. The impacts of the tsunami could therefore be compounded, for example, by adding to any existing flood water height or it could arrive during large wave conditions associated with a storm surge.

Chapter 3: Why do we need to plan for tsunamis in Australia?

Key points

- Subduction zone earthquakes to the north and east of Australia are the primary source of tsunami hazard.
- Australia's highest offshore hazard risk is in north-west Western Australia, where the Australian coast is exposed to tsunamis generated off the coast of Indonesia.
- While dozens of tsunamis have been observed in Australia, they have primarily generated marine hazards with only a few instances of locally significant inundation and coastal erosion. However, there is the potential for larger impact tsunamis to occur.
- The average return intervals of large tsunamis are very uncertain due to observational data limitations and understanding of key tsunami triggers.
- The consequence of a tsunami impacting Australia will vary by location. A tsunami may impact remote areas with low and isolated populations, densely populated zones and offshore infrastructure such as oil and gas fields.

Australian tsunami context

Understanding tsunami risk in Australia helps emergency managers and at-risk communities to prepare more effectively for a tsunami. Australia has not experienced a catastrophic tsunami disaster on the scale of either the 2004 Indian Ocean tsunami or the 2011 Japan Tohoku earthquake in recent history. However, Aboriginal and Torres Strait Islander oral history, storylines and geological evidence, indicate that larger tsunamis and significant inundation events have occurred in Australia in the past.[8]

Storylines of the Gunditjmara people of Victoria.

'They describe this gigantic wave coming very far inland and killing everybody except those who were up on the mountain tops, and they actually name all the different locations where people survived… core samples [were taken] from locations between 500m and 1km inland, and at each spot, they found a layer of ocean sediment, about 2m down, indicating that a tsunami likely washed over the area hundreds, or possibly thousands, of years ago.'[9]

Australia is surrounded to the north and east by some 8,000 kilometres of active tectonic plate boundaries capable of generating tsunamis that would reach Australia in as little as 2 to 4 hours. Other plate boundaries across the Pacific basin, such as the South American subduction zone, can also generate tsunamis that would reach Australia in 14 to 18 hours. Figure 6 illustrates the subduction zones immediately surrounding Australia.

Australia has a predominantly coastal population, with 87% of people living within 50 kilometres of the coast. This equates to more than 22 million Australians and means that a significant proportion of the population is exposed to tsunami risk.[10] The exposed population can also swell during peak holiday periods, due to large numbers of domestic and international tourists spending leisure time at the beach.

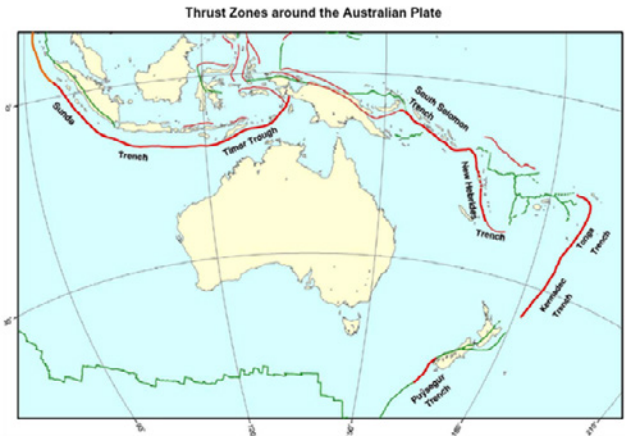

Figure 6: Subduction zones along tectonic plate boundaries (shown in red) surrounding Australia. These zones have the potential to generate a tsunami that may impact the Australian coast.

Source: Geoscience Australia http://www.bom.gov.au/tsunami/about/atws.shtml

On 14 July 2019, a magnitude 6.6 earthquake occurred 210km off the coast of Broome.

Irrespective of the 'No threat' tsunami bulletin, beaches in Broome were closed and several coastal areas self-evacuated. Approximately 200 members of the Bidyadanga Community (the closest community to the earthquake epicentre 180 km south of Broome) chose to evacuate. Analysis suggests the decision to self-evacuate was based on several triggers. It was reported that community members observed a rapid retreat of the tide. Other people attributed the long and strong ground movement to a tsunami. There is also strong evidence suggesting that oral tradition in the region recounts a powerful tsunami hitting the Kimberley coast in the 17th century, generating waves that travelled up to 35 km inland.[11]

Tsunamis also pose a risk to Australia's onshore and offshore coastal infrastructure such as windfarms, oil and gas installations, ports and industrial and commercial complexes, and recreational and commercial fishing and boating. A tsunami may also damage or destroy Indigenous cultural sites and natural environments including coral reef systems, fisheries and coastal ecosystems.

The Joint Australian Tsunami Warning Centre (JATWC) is responsible for tsunami warnings for Australia from all sources. If a tsunami is not generated by an earthquake, the JATWC will source data from reputable sources such as the Volcanic Ash Advisory Centre, regional government volcano observatories and the Australian Government's National Situation Room (NSR) to make an assessment before issuing an alert or warning.

Chilean Tsunami 23 and 24 May 1960: Impact on New South Wales (NSW)

The largest tsunami to have affected the NSW coast in recent times was in May 1960 after a 9.5 magnitude earthquake in Chile resulted in a 1 metre tidal fluctuation at Fort Denison in Sydney Harbour. This caused widespread damage to marine infrastructure along the NSW coast including damage to boats, wharves, jetties and beaches. Since 2007, up to 8 tsunami events have been observed in NSW, including tsunamis originating from earthquakes off the Solomon Islands, New Zealand, Chile and Japan.

Penetration of the tsunami occurred along NSW coastal harbours and rivers. A number of observations along waterways were from areas more than 10km inland from the coast. These observations were on the Lower Hawkesbury, Port Jackson, the Georges River and the Clyde River.[12]

River/Bay	Upstream location	Distance upstream from coast
Lower Hawkesbury	Bobin Head	21 km
Lower Hawkesbury	Berowra Mouth	22 km
Port Jackson	Iron Cove	13km
Georges River	Pleasure Point	28km (21km from river mouth)
Clyde River	Nelligen	14km

Wave heights recorded for this tsunami in NSW were:

Recording site	Metres	Original observation
Newcastle tide gauge	1.07m	3 feet 6 inches
The Spit Sydney	1.22m	4 feet
Fort Denison Sydney	0.76m	2 feet 6 inches
Cronulla CSIRO Laboratories	1.37m	4 feet 6 inches
Eden tide gauge	1.68m	5 feet 6 inches

Most of the damage caused by the tsunami was due to the strong currents created in rivers, bays and channels, not by tsunami run-up. This demonstrates that a tsunami does not need to exceed the high-water mark to cause damage and disruption to marine infrastructure.[13, 14]

There is no formal requirement to establish specific detection or monitoring capabilities for non-seismic tsunami sources in Australia, since these are less-frequent events for which it is difficult to establish detection capabilities. As a result, it may not be possible to provide early warning for tsunamis generated by non-seismic sources.

Tsunami risk

Risk assessment in Australia

Risk assessment is a key element of risk management. However, it does not remove uncertainty entirely because each event is unique. There are limits to the applicability of historical observations in forecasting future events. Australian Standard AS/NZ ISO 31000:2018 *Risk management – Guidelines* provides principles, a framework and a process for managing risk. It can be used by any organisation regardless of its size, activity or sector. Australia's risk assessment environment is evolving, with significant work being undertaken in the states and territories. Current examples of state or territory emergency risk assessments can be found in Appendix 1.

Increasingly, it is understood that disaster risk is systemic in nature, and that impacts of hazards, such as tsunamis, can cascade through interconnected systems. While current risk assessment processes are not developed to undertake system risk assessments, principles-based guidance in the Systemic Disaster Risk handbook can help planners start to think about these hazards through the lens of systemic risk.

Hazard

The companion to this handbook, Guideline 1: Tsunami hazard modelling guidelines, outlines current knowledge of tsunami hazards in Australia and the evidence for historical and prehistorical tsunami events.

Probabilistic Tsunami Hazard Assessment (PTHA)

The PTHA models the frequency with which tsunamis of any given size occur around the entire Australian coast (offshore, in water depths from 20 to 1000 metres) due to subduction earthquakes in the Indian and Pacific Oceans. The PTHA also provides modelled tsunami data for hundreds of thousands of earthquake-tsunami scenarios around Australia. The most

recent version of the PTHA is 2018 and this version has been used in onshore assessments conducted since 2018 in NSW, WA and QLD.

Further information on PTHA is available from Geoscience Australia.

Exposure

Exposure refers to elements that are at risk from a tsunami event. This could include:

- individuals
- dwellings
- households and communities
- animals
- buildings and structures
- social and critical infrastructure assets
- agricultural assets including livestock
- environmental assets
- cultural assets
- business activities.

Exposure information refers to the location and the characteristics, or attributes, of each element – the detail of what is at risk. This information is fed into a natural hazard risk analysis to identify the at-risk elements in a location. The more information that is known about each element, the greater the level of understanding will be with regards to how that element is likely to be impacted when subjected to natural and artificial hazards.

Australian Exposure Information Platform (AEIP)

To assist in planning for tsunami events, planning organisations have access to the AEIP. The AEIP allows users to access comprehensive, nationally consistent Exposure Information. The AEIP enables users to access the National Exposure Information System (NEXIS) and the Natural Hazard Exposure Information Framework. NEXIS includes 'elements' on buildings, businesses and people, public facilities and infrastructure assets, agricultural commodities and environmental holdings within Australia. The AEIP produces exposure reports providing a detailed statistical summary of the 'elements' within a user-defined area of interest.

Indian Ocean Tsunami 26 December 2004: impact on Western Australia (WA)

On 26 December 2004, an earthquake near northern Sumatra, Indonesia, generated a tsunami that tragically led to approximately 227,000 deaths in 14 countries. The impacts in WA were significantly less than in these countries. While there were no reported fatalities, impacts were experienced in the marine environment across large stretches of coastline, with localised inundation of several coastal towns. The tsunami impacted people, buildings, roads and boats in WA.

Modelling from the JATWC suggests this tsunami would have been classified as a moderately large marine warning event in the Geraldton coastal zone in Midwest WA.[15]

The tsunami caused dramatic fluctuations of the sea level of up to 2.2 metres range in WA, which decayed over 4 to 5 days. Tidal movements were visibly disturbed across most of the WA coastline from the northwest - Port Hedland, to the southeast - Esperance.[16]

Impacts on people in WA included:

- More than 100 people were rescued when crossing to and from Penguin Island, south of Perth, via a sandbank extending from the island to the mainland.
- People were swept out to sea. This includes two campers being washed into the ocean inside their tents at d'Alambre Island near Dampier in the northwest. Three people had to be saved after being swept away near Busselton, while one man was rescued by boat 200 metres off Flinders Bay, near Augusta in the southwest.
- Geraldton had some of the most significant impacts in WA.

Infrastructure impacts included:

- Water flooding the fish and chip shop at Fisherman's Wharf to 0.8 metre depth and flooding in the adjacent car park, including water reaching the running board of a 4WD.
- Water flowed down a coastal road with a more than 0.3 metre depth.
- A boat was sunk, and the tsunami caused havoc with other boats in the harbour.[17, 18, 19]

This event reminds us that many WA coastal communities are potentially exposed to tsunamis generated by earthquakes near the south coast of Indonesia.[20] Even a tsunami only classified as a marine warning can have an impact on people. If a tsunami is classified as a land warning affecting WA, it could cause even more significant impacts than the 2004 event, highlighting the importance of being prepared for this hazard.[21, 22]

Note: AEIP information is not intended for operational purposes at the building or individual feature level. Rather, it provides aggregated exposure information at existing administrative or geographic boundaries.

Vulnerability

Vulnerability is an integral factor in understanding the extent of risk. There is no single definition for vulnerability. The term is generally used to describe the impact of a hazard on people, infrastructure and the economy, taking into consideration the capacity of a person, structure or system to cope with that impact. That is, the concept of vulnerability explores how large an effect a hazard of a certain severity, such as a tsunami, will exert on a particular element at risk.

Tsunami risk management

Conducting a tsunami risk assessment typically relies on an understanding of:

- the sources that generate tsunamis
- the movement of a tsunami through the ocean
- the behaviour of a tsunami as it reaches the coast and flows onshore.

This forms part of the risk assessment about the potential impact of a tsunami, together with information about the specific communities that may be at risk. Developing an understanding of the nature of a potential hazard is a crucial step in the early stages of a risk management program. However, to understand the impact of a hazard, a comprehensive understanding of the communities that it may affect is also important.

Communities are diverse and often changing. The context of each community will be different. People have dynamic inter-relationships, with a range of attitudes and behaviours at the individual, household and collective levels. Emergency managers need to understand these attitudes and behaviours, including a community's perceptions of different risks, their personal priorities, of emergency management and any past experiences with disaster events to be able to support communities to build resilience and reduce vulnerability to risks.

In assessing tsunami risk in Australia, an initial hazard analysis will usually identify 2 broad levels of threat: Marine Threat and Land Inundation Threat. These correspond to 2 broad communities likely to contain elements at risk: maritime communities and land-based communities. Aspects of these communities may overlap. E.g. a resident of a land-based community may participate frequently in marine activities. If a land threat is issued, the marine threat is also implied. A marine threat may result in localised coastal erosion.

Maritime communities

Maritime communities have a direct exposure to the impacts of a tsunami. Maritime communities include:

- Aboriginal and Torres Strait Islander communities and cultural sites
- island and remote coastal communities
- ports that underpin national, state, territory and local economies
- marinas
- international and domestic cargo vessels
- defence and border protection vessels
- commercial vessels such as public transport, maritime search and rescue, research, tourist and fishing vessels
- aquaculture industry, including fish farming and oyster growers
- fishing grounds
- offshore infrastructure, including wind turbines, oil and gas installations
- recreational fishers, sea kayakers, boaters and yachters (including those in coastal river systems and lagoons)
- persons whose primary residence is their boat, such as yachts and houseboats
- beachgoers
- surfers, swimmers and scuba divers
- surf lifesaving clubs and volunteer lifesavers
- coastal campgrounds, caravan parks and cafes
- domestic and international tourists.

Physical and geographical features in a marine environment can influence the way a tsunami affects an area. A tsunami may expose maritime communities to fast running currents and significant wave action on and near beaches and estuaries. Examples of tsunami effects include wave reflection, wave refraction, attenuation and enhancement of effects in open coastlines, bays and estuaries.

Tsunamis are a risk to marinas, moorings, navigation aids, ports and offshore infrastructure, as the sudden surge of water and current speeds may be well above those associated with normal tides and wind-driven waves. In many cases, damage is unavoidable. For vessels (for example boats, ships, jet skis or houseboats), the best advice may be to securely tether vessels to moorings. This advice is informed by past events as several vessels were lost in marinas along the coast of WA during the 2004 Indian Ocean tsunami and in NSW from the 1960 Chilean tsunami.

The surge associated with tsunami waves can wash debris into vessels, propel them into other vessels and obstacles or capsize them. People who remain onboard a vessel when a tsunami arrives will be at risk.

Hunga Tonga-Hunga Ha'apai Eruption 15 January 2022: Impact on Australia

Following the eruption, tsunami warnings and advisories were issued for Tonga, America Samoa, Fiji, Vanuatu, New Zealand, United States, Canada, Japan, Chile and Australia. For Australia, land threat warnings were issued for Norfolk Island and Lord Howe Island, whilst marine threat warnings were issued for the area south of Sandy Cape (Queensland) to Southeast Cape (Tasmania). An evacuation order was issued for low-lying parts of Lord Howe Island. Warnings were downgraded the following day. This was the first land threat warning issued for New South Wales.

The tsunami was recorded on tidal measurement instruments across the Pacific as shown in the table below.

Recorded tsunami wave heights

Location	Maximun tsunami height (metres)
Port Villa (Vanuatu)	1.18
Suva Viti Levu (Fiji)	0.36
Rarotonga (Cook Islands)	0.74
Nukualfoa (tonga)	1.19
Pago Pago (American Samoa)	0.55
Jackson Bay (New Zealand)	1.14
Australia: Norfolk Island Gold Coast Twofold Bay Port Kembla Lord Howe Island	 1.27 0.82 0.77 0.65 0.5
Japan: Kochi, Shikoku Island Kagoshima Iwate Northern Okinawa Iwate	 0.8 1.2 1.2 3.0 - warning 3.0 - warning
United States: Hanalei, Hawaii Kauai, Hawaii Adak, Alaska Monterey, California	 0.8 0.5 0.3 0.2

The largest tsunami waves at Norfolk Island were recorded close to six hours after the eruption. At Lord Howe Island the Bureau of Meteorology reported observations of 1.10 m waves at Ned's beach and unusual currents and waves. Whilst at Derwent Park, Hobart a 50 cm surge was observed in a marina. Unusual tidal activity was also reported at Crescent Head, Lord Howe Island, Gunnamatta Bay (Sutherland), Maroubra, Sawtell and Mogareeka Inlet (Tathra). The Bureau of Meteorology reported that a mass rescue had occurred at Sawtell due to the sudden drop in tide. A tsunami warning remained current for the NSW coast at 7:02pm AEDT on the 16th of January.[23]

A tsunami may also cause significant coastal erosion and pollute local waterways by depositing vegetation, structural debris and chemicals or pose a risk to the broader environment through damage to oil and gas industry installations. This may result in the release of hydrocarbons triggering an ecological disaster.

Analysing maritime communities presents some challenges. Data sourcing can be problematic due to the highly mobile and transitory nature of these communities. While some data may be obtained from organisations such as local councils, Aboriginal Land and Sea Councils, sea rescue groups, yacht, fishing and surf lifesaving clubs, results may only reflect a limited sample of the target audience.

To develop strategies for maritime communities, emergency managers should explore social science research approaches to understanding these communities such as focus groups. Resource-intensive research such as on-beach interviews may be necessary to obtain sufficiently reliable data. This type of research has been used effectively by fisheries authorities and coastal planners. Liaising with these organisations may be valuable when conducting a community analysis.

For further information on tsunami preparedness for maritime communities, see Chapter 4.

Land-based communities

Land-based communities include residents, visitors, commerce and industry that may be exposed to land-based inundation and other onshore effects of a tsunami.

In many cases, data on these communities will be available through the Australian Bureau of Statistics, local government records, academic research and other publicly available data sources. This data may be analysed as a broad indicator of demographic or socio-economic factors, highlighting insights into potential capacities and vulnerabilities at an individual or household level. The Australian Disaster Resilience Index can also provide insights into some of the factors that enhance or constrain resilience at an Statistical Area Level 2 scale.

When used alongside hazard data such as inundation and flow-rate mapping, community data informs priorities in developing risk treatment options. Emergency management strategies that consider the unique characteristics and values of a community can reduce the impact of catastrophic tsunami events that cause significant inundation, and support recovery.

A catastrophic event may result in the interruption of multiple services within a community. This might include causing disruption to local government services, medical services, telecommunications, sporting and social clubs, family and neighbourhood networks, shopping, banking and fuel supplies. In this context, the functionality and morale of a community are impacted, and regular support networks become fractured. These collective or networking vulnerabilities affect the community's ability to cope with the effects of an emergency. In larger events, collective vulnerabilities may exert significant influence on media and political processes, affecting emergency management priorities.

For more information on identifying, understanding and engaging with individuals and communities in at-risk locations consult the *Community Engagement for Disaster Resilience* Handbook.

Chapter 4: Planning to reduce risk from a tsunami

Key points

- Tsunami risk may be mitigated through the preservation and restoration of natural ecosystems, the use of structural defences and land-use planning.
- Emergency preparedness for tsunami includes emergency planning, capability development, community engagement and exercising.
- Tsunami emergency plans should be developed with community involvement where an identified tsunami hazard is likely to pose a risk to life or property.
- Evacuation planning is a critical component of emergency plans and should be regularly exercised with learnings incorporated into emergency procedures.

Introduction

Tsunamis can be triggered by a range of causes and impact Australia's mainland, offshore territories and islands. The possibility of an event triggering a tsunami is always present. Therefore, monitoring and preparedness are continuously required.

Global tsunami preparedness is maturing, from the establishment and operation of robust warning systems like the ATWS, to building community resilience through prevention and mitigation strategies. Building and maintaining community resilience involves community engagement, knowledge sharing, capacity and capability development.

Preparing for the potential impacts of a tsunami is essential to ensuring communities are ready to

respond effectively to tsunami emergencies when they occur. Emergency managers can support community preparedness through emergency planning, emergency management capability development, community engagement, exercising for different scenarios and the establishment of warning systems including AWS.

Planning for tsunamis in the Australian context has developed incrementally since the 2004 Indian Ocean tsunami. Before this event, little was known about Australia's exposure to tsunami risk, and few emergency plans were available to specifically guide emergency response to tsunamis.

There is a recognised need to improve the capability to manage emergency responses to tsunami events. Plans are now available at various levels to assist with preparedness. It is important that emergency managers involved in managing responses to tsunami utilise these resources to strengthen their understanding of tsunami science, tsunami risk, warning systems and tsunami emergency plans.

Science-informed risk reduction for earthquake-generated tsunamis in WA

Large offshore earthquake-generated tsunamis in Australia are most likely offshore of WA. Tsunami poses some of the highest risks to WA's built environment across all the considered natural hazards.[24] The absence of evidence-based tsunami evacuation maps in WA is a vulnerability noted in 5 successive Indian Ocean-wide tsunami exercises (2014 – 2023). Also, there are no spatially extensive products to inform communities which areas are at risk to help inform land use planning and mitigation. Integrating mitigation activities into land use planning is the most effective strategy for reducing the long-term impact of tsunamis.

Given the offshore hazard, risk and lack of tsunami mitigation products, the WA Department of Fire and Emergency Service (DFES) and Geoscience Australia created a partnership. This partnership aims to better understand what earthquake-generated tsunamis will do when they come onshore and use this knowledge to design tsunami risk reduction strategies for specific areas along the WA coast.

The resulting WA Tsunami Inundation Modelling Project is developing Australia's most spatially extensive regional-scale tsunami evacuation maps, which are informed by high-resolution probabilistic modelling of earthquake-generated tsunami inundation (flooding of land areas). These maps are being developed from southwest to northwest WA—Dunsborough to Onslow, including Greater Perth. The project will also deliver products to help inform land use planning in the same area. The project started in 2021 and will continue until 2028.

If the proposed warning zones developed under this project were implemented in Greater Perth, they would reduce the evacuated population by 80% and help reduce the risk of over-evacuation.

The project is developing tsunami risk reduction strategies, including:

- accurately determining which communities require evacuation
- identifying safe zones and evacuation routes
- more targeted communications and planning for those in the evacuation zone
- WA tsunami awareness guide
- operational crew exercises.[25]

Tsunami risk mitigation

Nature-based risk mitigation

Nature-based solutions to support hazard risk mitigation include preserving and restoring mangroves, seagrasses, and coastal dunes. Research regarding natural barriers to reduce tsunami impacts is still developing. However, a recent report on ecosystem-based disaster risk reduction from the United Nations Office for Disaster Risk Reduction (UNDRR)[26] indicated that natural barriers such as sand dunes and their associated plant communities can dissipate wave energy and act as barriers against large waves, currents, storm surges and tsunamis depending on the wave magnitude. Similarly, coastal wetlands, such as mangroves and saltmarshes, can absorb low magnitude wave energy, reduce wave heights and reduce erosion from storms and high tides.

What can be done to protect the coast from tsunami?

'Healthy ecosystems act as a natural barrier, with dense mangrove and scrub forest responsible for saving many lives and properties in Sri Lanka during the 2004 Indian Ocean tsunami. In a similar manner, after Typhoon Haiyan in 2013, the Philippine Government initiated a significant project to replant a large portion of the impacted coastal area with mangroves. This initiative aimed to establish a robust natural barrier against storms, flooding, coastal erosion, and powerful waves. Offshore reefs can also act as natural barriers and have a significant role in reducing impact on the community, as shown during the 2007 Solomon Islands event. UNDRR has produced a guideline dedicated to nature-based solutions, acknowledging them as crucial and effective measures to reducing risk. These solutions are often easy to implement, cost-effective, and can engage local communities.'[27]

Structural risk mitigation

Structural risk mitigation measures can be used to complement nature-based disaster risk reduction measures. Structural measures include dykes, offshore breakwaters and adding tsunami gates to existing seawalls. Measures that prevent or reduce the impact of a tsunami may be classified into 3 types, depending on their location and protecting function. These measures are:

- a partial barrier located in the nearshore zone reducing the impacts of tsunamis before they reach the shoreline
- a full barrier at the shoreline preventing the inland movement of tsunamis
- a partial barrier at the shoreline reducing the impacts of tsunamis on crossing the shoreline.

Full or partial barriers are physical interventions that may mitigate the risk of a tsunami up to a certain wave height. The design must be robust, functional and reliable, and ensure the continuity of multiple uses of the existing natural environment. Consideration should be given to costs, ongoing maintenance and effective operation. It is also important to minimise negative impacts on socioeconomic, livelihood and environmental issues in establishing these measures.[28]

Land-use planning for risk mitigation

Introducing land-use planning measures is another option to mitigate tsunami risk. Measures such as managed retreat to gradually relocate people and infrastructure out of an at-risk area, and development setbacks are examples. Development setbacks may also have complimentary benefits in reducing risks from coastal erosion, storm surge inundation and tsunamis, as well as support ecological restoration along the shoreline.

Development setbacks are intended to direct new development or redevelopment out of hazard areas and to protect nature-based mitigation features such as beaches and dunes by restricting development beyond a designated setback line. While development setbacks may be effective for disaster prevention and risk reduction regarding the built, it does not eliminate risks to coastal visitors and users who may be in the coastal zone during a tsunami.[29]

Tsunami detection methods

Detection and early warnings are critical factors in reducing the impacts of disasters, including tsunamis. Since the 2004 Indian Ocean tsunami, significant progress has been made in understanding tsunami mechanisms, and an advanced network of tsunami observing systems have been developed and deployed.

Types of detection methods

Seismometers

A seismometer measures earth's vibrations at a single location over time. A seismometer can record the distinguishable pattern of vibrations caused by an earthquake – known as seismic waves – and determine the size or magnitude of an earthquake and the time at which it began to rupture. The location of the initial point of earthquake rupture can be computed using a minimum of 3 appropriately positioned seismometers. This point is called the epicentre on a map, or the hypocentre where the depth of the point is also depicted.

The speed of the fastest seismic wave through the earth is approximately 8 kilometres per second. A network of seismometers placed at close distances around the seismically active zones, complemented by a network of seismometers at greater distances around the globe, can be used to determine the preliminary earthquake characteristics within approximately 10 minutes of an initial earthquake rupture.

Tsunameters

Tsunami buoys or tsunameters observe and record changes in sea level in the deep ocean and confirm the existence of tsunamis generated by undersea earthquakes. Most tsunameters currently deployed are Deep ocean Assessment and Reporting of Tsunami (DART™) buoys.

Each tsunameter consists of a sea-bed bottom pressure recorder (or BPR) and a surface buoy. The BPR measures the pressure of the water column above it. The BPR is very sensitive to the passage of even a small tsunami wave, accurate to one millimetre, because tsunami waves cause the entire water column to oscillate. The surface buoy acts as a relay station, receiving recorded tsunami observations from the BPR via sonar signals, and radioing the information via satellite to a global network of tsunami warning centres, including the JATWC.

The tsunami detection system has 2 operating modes: standby and event. The system generally operates in standby mode, routinely collecting sea level information at high frequency and reporting to the satellite every 6 hours, for data intervals of 15 minutes. The tsunameter enters event mode when it detects a change in water column weight due to the passage of a tsunami wave or seismic signals on the sea floor. In event mode, the device reports the sea level data recorded at one-minute intervals to the satellite every 5 to 7 minutes for the following 3 hours. This supports rapid verification of a possible tsunami.

Placement of tsunameters

Tsunameters are placed as close to potential earthquake epicentres as possible to support early detection of tsunamis. However, they should be placed at a sufficient distance from any potential earthquake epicentres to minimise overlap between an earthquake signal and a tsunami wave signal, and to avoid being damaged by an earthquake.

To offset the effects of the harsh ocean environment, each tsunameter station has in-built communication redundancy. In addition, 2 tsunameters are deployed near each other in each ocean area, mitigating the risk of losing vital information should one tsunameter fail. Currently 6 tsunameters are deployed: 2 in the Indian Ocean, 2 in the Coral Sea, and 2 in the Tasman Sea. The life cycle of a tsunameter is approximately 2 to 4 years. The Bureau of Meteorology's maintenance program involves the replacement of the surface buoy and the sea-floor pressure sensor every one to 2 years.

Australia also accesses data from other countries participating in the IOTWMS and the PTWS. In turn, data from Australia's tsunameters and coastal stations are made freely available to the international community and the tsunami warning centres of other countries in real-time. Figure 7 provides a snapshot of the global DART network in February 2025.

Tide gauges

Coastal sea level gauges consist of sensors (acoustic, radar and/or water pressure) to measure variation in the water level at strategic locations around the Australian coastline and offshore regions. They are installed at practical locations, such as on piers near the coast. Some require higher specifications for climate change monitoring purposes; all require real-time sea level reporting capabilities for effective tsunami monitoring.

Approximately 40 nationally supported tide gauges are deployed along Australian coastlines and 14 in south-west Pacific countries. They form the Australian coastal sea level network, the second key component of the broader Australian Supported Sea Level Monitoring Network operated by the Bureau of Meteorology (see Figure 8). Observations from sea level gauges verify a tsunami's existence and local effects and provide information to help determine when a tsunami threat has passed. States and territories also operate additional tide gauges at the jurisdictional level.

Note: The Australian Supported Sea Level Monitoring Network has 2 components – an Australian deep ocean sea level network (denoted by red triangles) and an Australian coastal sea level network (denoted by green triangles).

Emerging detection techniques

While earthquake and tsunami detection capabilities have improved in Australia and worldwide, significant uncertainties remain in detection, measurement and forecasting.

Many of these uncertainties are being addressed through a new generation of ocean-sensing capabilities:

- Bottom pressures can be measured over dense, multi-sensor grids, linking stand-alone systems with emerging capabilities such as commercial fibre-optic cables.
- Coastal radars and infra-sound sensors can be used to help detect tsunamis; the increasing number of coastal sea-level gauges can better verify forecasts.
- A growing array of Global Navigation Satellite System (GNSS) sensors such as the Global Positioning System (GPS) can provide solid-earth motion data needed to precisely define the source of a tsunami.
- GNSS systems can detect ionospheric disturbances caused by tsunami waves – a potentially significant tsunami detection capability over wide ocean areas.

These new capabilities will enable quicker, more accurate tsunami detection and measurement. When combined with state-of-the-art modelling and computational resources, they should greatly reduce and help quantify uncertainties associated with forecasting tsunamis. Figure 9 provides a schematic illustration of what future, enhanced ocean observation capabilities in tsunami detection might look like.

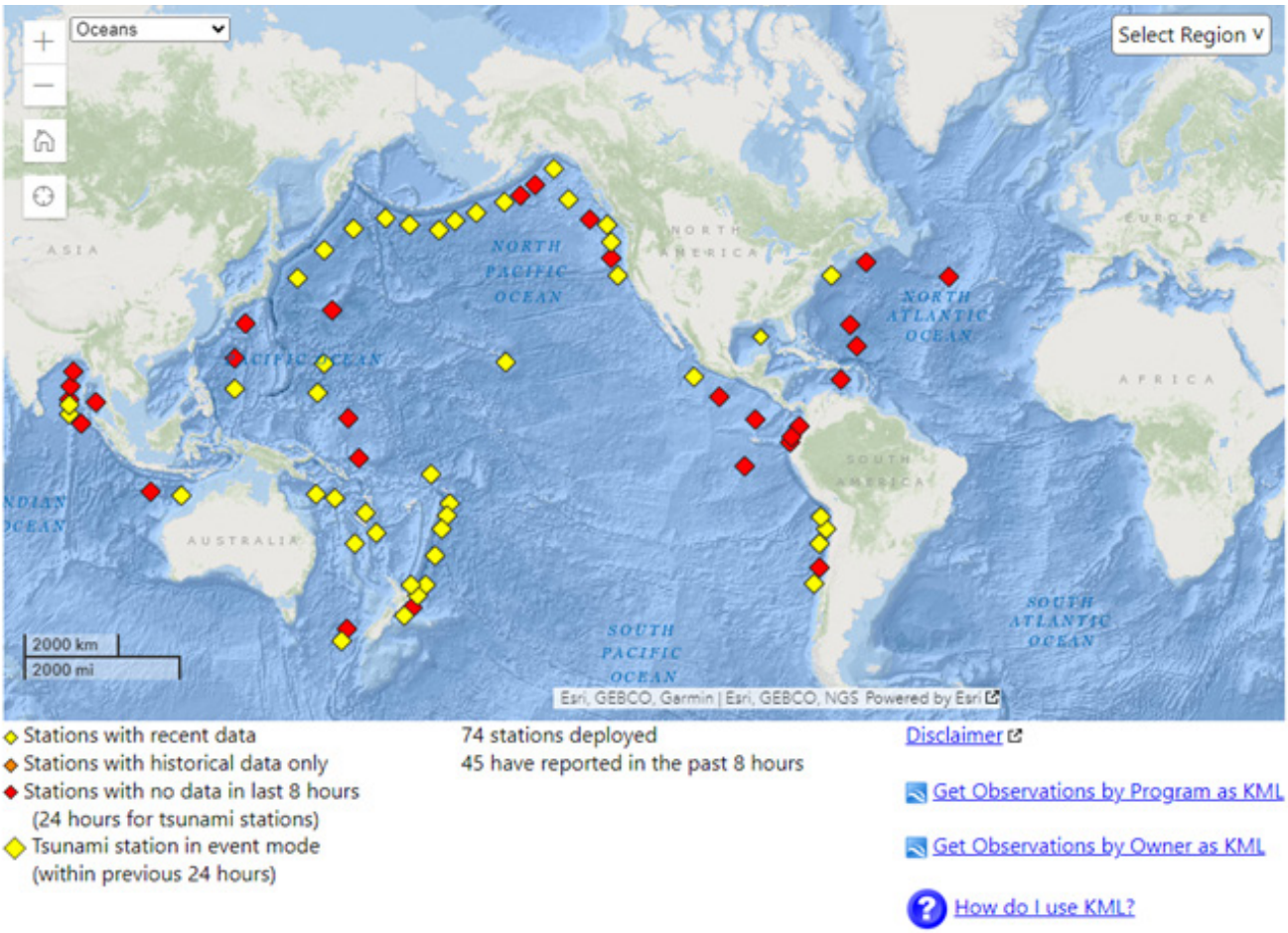

Figure 7: Global DART Tsunameter Network including six Bureau-operated DARTs in February 2025.

Source: Bureau of Meteorology.

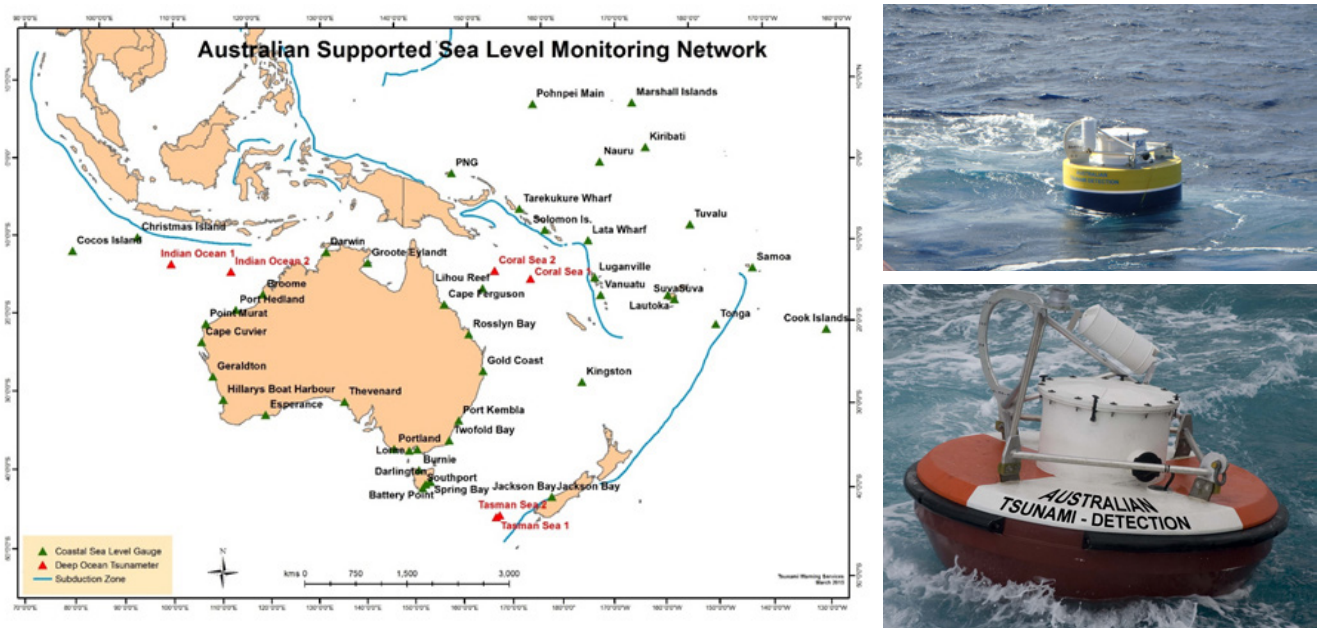

Figure 8: Australian Supported Sea Level Monitoring Network operated by the Bureau; examples of a tide gauges and a DARTTM buoy.

Source: Bureau of Meteorology.

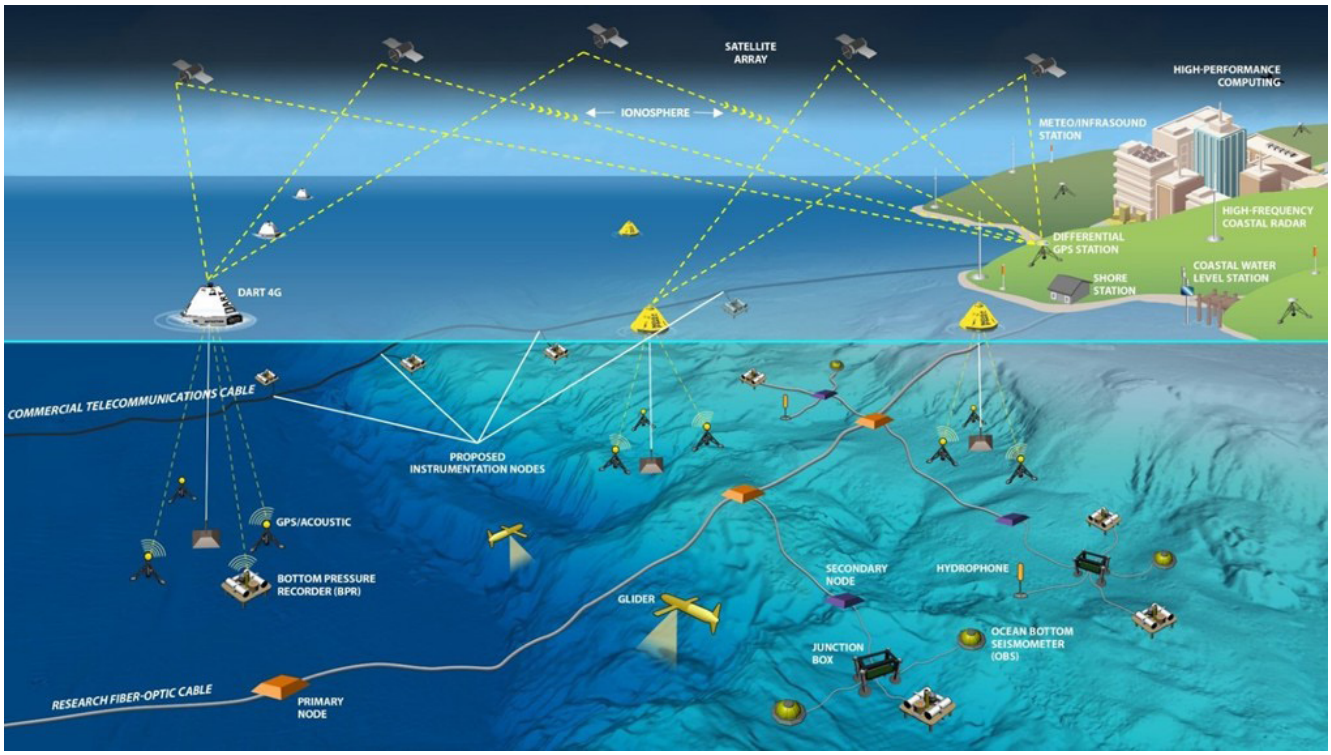

Figure 9: A schematic illustration of possible future global ocean observations to reduce uncertainties in tsunami forecasts.

Source: The Pacific Marine Environmental Laboratory of the United States NOAA.

Chapter 5: Tsunami warning systems

Key points

- Australia has a 24/7 ATWS.
- The JATWC provides tsunami alerts within 30 minutes of a significant undersea earthquake.
- The JATWC continuously monitors for earthquakes and tsunamis, utilising Australian and global networks of seismometers, coastal tide gauges and deep ocean tsunameters.
- There are 3 levels of tsunami warnings: No Threat, Marine and Immediate Foreshore Threat, and Land Inundation Threat.
- Tsunami warnings are disseminated to the public through multiple channels.

Introduction

Australian Tsunami Warning System Project

The ATWS centres on the JATWC, operated jointly by Geoscience Australia in Canberra and the Bureau of Meteorology in Melbourne and Brisbane who are connected via data and video links. The JATWC provides 24/7 continual tsunami monitoring, detection and warning services for the Australian community.

An Australian Tsunami Working Group (ATWG) was formed during the project to coordinate the ATWS establishment. On completion of the project, the ATWG transitioned to the ATAG. ATAG provides national leadership in the coordination of programs and projects relating to tsunami capability development, promoting research, information, knowledge management and education in Australia.

The JATWC is an integral part of broader global efforts to address tsunami threat. The Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO) is mandated by the United Nations to coordinate the global end-to-end tsunami early warning and mitigation system. The system has 3 pillars:

- risk assessment and reduction
- detection, warning and dissemination
- awareness and response.

There have been 4 Intergovernmental Coordination Groups (ICGs) for the Indian Ocean, Pacific Ocean, Caribbean, and North-east Atlantic and Mediterranean Seas established by IOC-UNESCO to address particular regional needs. In addition, a working group on Tsunamis and Other Hazards Related to Sea-Level Warning and Mitigation Systems (TOWS-WG) was formed to provide global tsunami coordination to ensure coverage to vulnerable coastal regions of participating member states, while ensuring a high standard of service and interoperability.

As Australia is located between the Indian and Pacific Oceans, it has actively taken part in the ICGs for both basins as a member state. This has included vastly expanding the Australian tsunami monitoring networks; sharing seismic and sea level data with other member states; and participating in ocean-wide exercises in both the Indian and Pacific Oceans (IOWave and PacWave exercises, respectively).

Australia has made a significant contribution to the establishment of the Indian Ocean Tsunami Warning and Mitigation System (IOTWMS):

- The Bureau of Meteorology funds and hosts the ICG/IOTWMS Secretariat Office in its WA state office.
- The JATWC acts as one of the 3 Tsunami Service Providers (TSPs) in the IOTWMS. The JATWC provides detailed, real-time tsunami information to the 27 other National Tsunami Warning Centres in the IOTWMS, assisting them in issuing warnings to their coastal communities.

Australian Tsunami Warning System: roles and responsibilities

The ATWS is an end-to-end tsunami warning and emergency response system. The ATWS involves key national, state and territory governments and organisations in:

- earthquake detection
- tsunami assessment and warning
- emergency response and recovery.

Geoscience Australia (GA) operates a national network of seismic stations and accesses data from international monitoring networks. GA performs real-time seismic analysis, advising the Bureau of Meteorology within 10 minutes of the magnitude, location and characteristics of any earthquake with the potential to generate a tsunami of impact to Australia or countries in the Indian, Pacific and South Atlantic Oceans.

Based on this information, the Bureau of Meteorology National Operations Centre determines the possible tsunami threat and the expected tsunami arrival times using a library of pre-computed earthquake and tsunami scenarios generated from a tsunami propagation model. The Bureau also verifies tsunami generation using its Australian coastal and deep ocean sea level networks, as well as sea level data from international networks.

The Bureau of Meteorology then issues tsunami warnings for the Australian coastal areas assessed to be under threat. It also issues detailed threat information in bulletins to the National Tsunami Warnings Centres of countries in the Indian Ocean.

Tsunami warnings are issued using the weather communication infrastructure of the Bureau of Meteorology state and territory forecasting centres (SFCs). Warnings are disseminated to emergency management organisations, relevant government organisations, media outlets and the public in affected states and territories. The SFCs are the primary liaison point for state and territory emergency services during tsunami events.

In the event of a tsunami, state and territory (including offshore) emergency services take charge of the tsunami emergency response in their jurisdictions, liaising closely with their respective SFCs. This includes providing timely emergency advice to the public; an emergency evacuation warning may be issued following a Land Inundation Threat Warning. If an event threatens to overwhelm the emergency response capability within a particular jurisdiction, federal assistance can be sought through the National Emergency Management Agency (NEMA).

NEMA maintains and is the steward of the NSR and the National Coordination Mechanism (NCM), which provides whole-of-government situational awareness and crisis coordination to inform national decision-making during a tsunami event.

During a tsunami event, the NSR works closely with the JATWC. The NSR:

- provides 24/7 situational awareness, impact analysis and decision support to the Australian Government
- acts as the physical location of the Australian Government Joint Inter-agency Crisis Coordination Team (CCT)
- feeds information into the NCM.

The CCT is a whole of Australian Government all-hazard crisis management capability located within the NSR. The CCT is activated during times of domestic and international crises and provides strategic planning and coordination of the Australian Government response to an incident. The CCT is guided by the Australian Government Crisis Management Framework (AGCMF) and operates through the activation of national plans, such as the Australian Government Disaster Response Plan (COMDISPLAN). The CCT supports whole-of-government executive decision-making through the response, relief and early recovery phases of emergency management. Depending on the incident type, the CCT will include department and organisation liaison officers from areas contributing to delivering and coordinating operational outcomes.

The NCM is the peak crisis coordination mechanism for shared situational awareness, national coordination and synchronisation of effort during tsunami responses requiring Australian Government involvement. The NCM may bring together relevant Australian, state, territory and local government officials, the private sector, peak bodies, not-for-profit organisations and eminent individuals for coordination, communication and collaboration during tsunami response and early recovery.

More broadly, NEMA works to improve public awareness and preparedness for tsunamis in Australia including through national level exercises.

Australian Antarctic Division

The Australian Antarctic Division functions as the emergency service in tsunami events for the Australian Antarctic Stations (Mawson, Davis and Casey). The Tasmanian State Emergency Service is responsible for emergency response on Macquarie Island.

The media plays an important role in disseminating warning messages to the wider community. While traditional media such as television and radio continue to be the key mass broadcasters, social media platforms are increasingly important as channels for disseminating warning messages. The Australian Broadcasting Corporation (ABC) is the national emergency broadcaster.

Organisational roles

Many other organisations have roles in providing advice and assistance during tsunami events. For example, Surf Life Saving Australia has an important role in advising and guiding beach or marine users to safety when there is a tsunami threat. Port authorities perform a similar role in a shipping context.

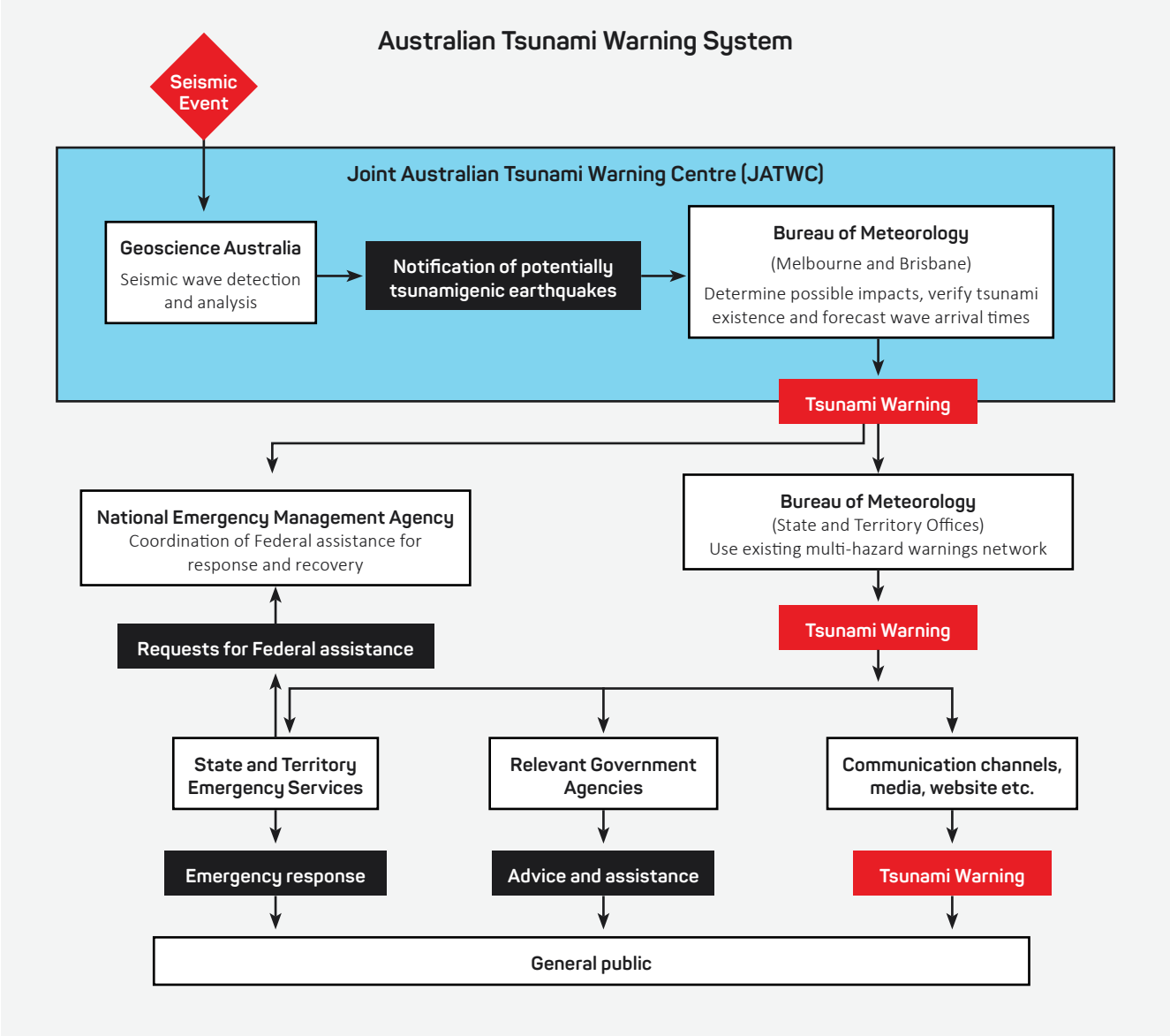

Figure 10: Schematic illustration of the Australian Tsunami Warning System (ATWS).

Source: Joint Australian Tsunami Warning Centre (JATWC). Image adpated from the Bureau of Meteorology www.bom.gov.au/tsunami/about/atws.shtml

Tsunami warning procedures

JATWC operations

The JATWC warning operations typically involve the following steps, illustrated in Figure 11.

Detect earthquake

Duty seismologists at GA monitor a network of seismometers worldwide to detect earthquakes. If GA is alerted to a seismic event that could cause a tsunami, such as an undersea earthquake, it immediately reports the event to the Bureau of Meteorology.

Assess tsunami potential

Duty tsunami incident staff at the Bureau of Meteorology determine the potential tsunami threat using sophisticated tsunami prediction models. These models are pre-computed for different earthquake locations and magnitudes around the globe and stored in a scenario database.

A decision support tool is used to efficiently select the most suitable scenario to match the detected earthquake. The associated tsunami wave height, speed, and direction determine the threat levels to all Australian coasts.

Issue National Tsunami Watch or National No Threat Bulletin

If the Bureau determines the tsunami has the potential to seriously impact Australia, the JATWC will issue a National Tsunami Watch. Otherwise, it will issue a National No Threat Bulletin.

Monitor tsunami

If a National Tsunami Watch has been issued, the JATWC will monitor tsunami waves from a global network of deep ocean tsunami detection stations (or buoys) and coastal sea level monitoring stations, many of which are operated by the Bureau of Meteorology. The deep ocean stations measure tsunami waves in the open ocean, while the coastal stations detect sea level changes close to shore.

Issue tsunami watches/warnings or watch cancellation

If a tsunami is confirmed by sea level observations and/or credible eyewitness reports, or if there is an impact anticipated for a particular state or territory within 90 minutes, the JATWC will immediately issue warnings for the affected states and territories. These warnings are repeated on hourly cycles, with the last product in each cycle being a National Tsunami Warning Summary.

If a tsunami has not been confirmed and the potential impact is 90 minutes away or further, the JATWC will issue state or territory-based Tsunami Watches upon the hourly update cycle. The JATWC will cancel the watches/warnings and stand down its operation where:

- no tsunami has been observed
- an observed tsunami is too small to warrant a warning
- threat-level waves are no longer anticipated from the observed tsunami.

Tsunami warnings and schedule

Figure 11 shows the warnings and schedule following the detection of an earthquake.

Australian tsunami warnings are also available on the Bureau of Meteorology website at **www.bom.gov.au/tsunami**.

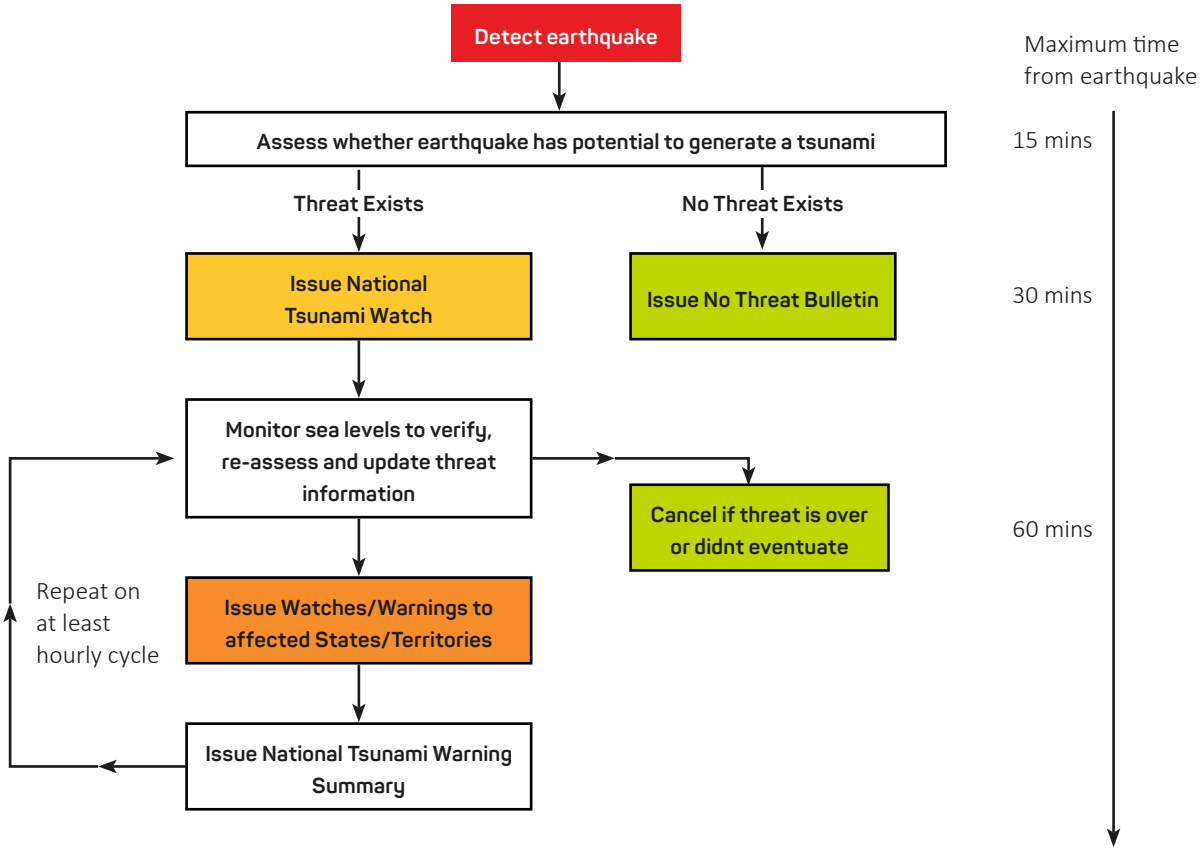

Figure 11 Tsunami warnings and schedule.

Source: JATWC. Image courtesy of Bureau of Meteorology.

Threat levels

Issued tsunami warning products reflect the following 3 variables of a potential tsunami:

1. severity
2. certainty
3. urgency

To simplify the number of variations that can exist based on these 3 variables, a simple, two-tiered categorisation is used to decide whether a Standard Emergency Warning Signal (SEWS) should be issued. The 2 tiers use simple, intuitive phrases based on end-user needs (see Table 1).

Table 1: Tsunami threat levels

THREAT	DESCRIPTION	SEWS
Marine and immediate foreshore threat	Warning for marine areas	No SEWS
Land inundation threat	Warning for land and marine areas	Use SEWS

Standard Emergency Warning Signal (SEWS)

SEWS is the distinctive siren signal in Australia reserved exclusively for alerting the public to an urgent message related to an imminent threat to life and safety. The SEWS can be heard in this emergency warning used in a bushfire event:

www.youtube.com/watch?v=0ukhVKFLRQg

For more information on warnings, consult the *Public Information and Warnings* Handbook on the Knowledge Hub.

Determining factors for a JATWC response

Internationally, it is widely recognised that earthquakes have the potential to generate tsunamis where they:

- are located under the ocean or within 200km of the coast
- are located at subduction zones
- are at least of magnitude 6.5
- have a depth shallower than 100 kilometres
- trigger a submarine landslide.

It is not uncommon for some Australian coastal communities to feel tremors and ground shaking caused by small local or near-field earthquakes that will not cause tsunamis. To minimise community concern, the JATWC will issue a national No Threat Bulletin for widely- felt earthquakes, even where the magnitude is below the 6.5 magnitude threshold. The 30-minute target time for responding does not apply in these cases, due to the additional time required to receive 'felt earthquake' reports from the public.

The JATWC will respond to all earthquakes that meet these criteria in the Pacific, Indian and South Atlantic Oceans. The JATWC's target time to issue a tsunami National Watch or No Threat Bulletin is within 30 minutes of an earthquake occurring.

Given that both the Australian mainland and Tasmania are more than 2 hours away from any major earthquake fault line, most Australian communities will be warned at least 90 minutes before the arrival of a tsunami's first wave. Some Australian offshore islands and territories are closer to fault lines and may have less than 90 minutes to respond to a JATWC warning. Globally, efforts are underway to reduce tsunami warning response time in countries closer to fault lines, such as Japan and Indonesia.

The JATWC is responsible for tsunami warnings for Australia from all sources. If a tsunami is not generated by an earthquake, the JATWC will source data from reputable sources such as the Volcanic Ash Advisory Centre, regional government volcano observatories and the NSR to make an assessment before issuing an alert or warning.

Australian offshore island territories

Australian offshore island territories are considered separately from the mainland because:

- the bathymetry effects may be different (e.g. there may be no continental shelf), meaning the closest tsunami model grid point can be at a substantial depth.
- the geographical distance to these island territories warrants a separate warning for each.

The island territories and the responsible Bureau of Meteorology SFCs are listed in Table 2.

Table 2: Australian offshore island territories and Bureau of Meteorology SFCs

Island territory	Location of corresponding Bureau SFC
Willis Island (Coral Sea)*	Queensland
Lord Howe Island (Pacific Ocean)	New South Wales
Norfolk Island (Pacific Ocean)	New South Wales
Christmas Island (Indian Ocean)	Western Australia
Cocos Islands (Indian Ocean)	Western Australia
Macquarie Island (Antarctica)**	Tasmania

* While no public tsunami product is issued for Willis Island, the Queensland SFC provides timely advice to Bureau of Meteorology staff on the island in the event of a tsunami threat.

**The Australian Antarctic stations (Mawson, Davis and Casey) are treated as 'mainland' from an assessment perspective (that is, they are part of the Antarctic continent), but as offshore territories from a product issue perspective.

Tide impact on warnings and tsunami

Tsunami warnings contain threat levels, determined by comparing predicted tsunami amplitudes at coastal locations against pre-determined threat thresholds. This method does not account for tide levels. The complexity and variability of tidal effects are such that it is not practical to include them in standard tsunami warnings.

The difficulties in providing real-time advice are logistical rather than scientific; there are too many variables in both tide times and locations to allow them to be incorporated into tsunami warnings. Tide times and tidal ranges vary every day for any location. To describe the effect accurately, warning centres would need to prepare multiple messages for relatively short stretches of coast. Further, this information would need to be provided for the many hours or days the tsunami effects were expected to persist as, even at one location, each tidal cycle is different from the one that precedes it.

Accordingly, no adjustments are currently made to account for tides. In parts of Australia where there are large tidal ranges, it would be appropriate for emergency response organisations to provide some guidance to the public about the effect of tides. Emergency service organisations should seek guidance on the varying effects of tides on the tsunami threat.

Communicating tsunami warnings to the public

JATWC tsunami warning product suite

The product suite for an Australian tsunami event includes 3 primary product types: bulletins, watches and warnings (see Table 3).

Bulletins

The purpose of a tsunami No Threat Bulletin is to reassure people and organisations that the JATWC is aware of an earthquake and that it has been assessed as having no threat potential to Australia.

These bulletins provide positive assurance that the implications of an earthquake have been assessed and determined to be of no threat, removing doubt for the Australian community. The No Threat Bulletin is targeted at audiences who may have received unqualified or unverified warnings from other sources, or who may have interpreted a tsunami impact on another country as having potential impact on Australia or its territories.

No Threat Bulletins are also issued for local earthquakes that are widely felt by coastal communities to alleviate concern about the possible generation of a tsunami.

Watches

In an event where an earthquake may have generated a tsunami, but it is yet to be confirmed, a National Tsunami Watch provides detail on the hazard and guidance on how people and organisations should respond to the possible threat. The National Tsunami Watch also notifies people and organisations that further, specific information will be issued as it becomes available. This enables people and organisations to take protective action and monitor the situation.

Watches also allow emergency management organisations to begin planning and preparation for when a hazard might eventuate.

Warnings

Tsunami warnings convey whether the existence of a tsunami has been confirmed.

Warnings are issued for each affected state and territory rather than at a national level. This allows for more detailed information and liaising between Bureau of Meteorology SFCs and relevant state and territory emergency management organisations. Warnings convey the severity of the threat for different coastal forecasting districts (either a Marine and Immediate Foreshore Threat or a Land Inundation Threat). The Australian offshore territories are treated as separate, individual entities.

For detailed Marine and Immediate Foreshore Threat and Land Inundation Threat messaging, see the section in this chapter on key public safety advice messages.

Some states and territories may be the subject of a warning, while others remain on a watch. For some states and territories, there may be no threat at all. A consolidated National Tsunami Warning Summary capturing the status of all Australian watches and warnings is produced at the end of each issue cycle of the individual watches and warnings.

When a tsunami threat has passed, watches and warnings are cancelled through the issuing of Cancellation messages. After all cancellations have been issued, an event summary message is issued.

Table 3: Tsunami warning products.

MESSAGES: TYPES AND PURPOSE	MESSAGES: LAYOUT AND CONTENT
National No Threat Bulletin: To advise people that the earthquake has been assessed and that no tsunami threat exists.	**Product Identifier:** Identify type product/auto notifier **Media Instructions:** How urgently message/s should be broadcast. Use of Standard Emergency Warning Signal (SEWS) or not **Message Title and Issue:** Time Type, date/time and number sequence of message **Headline Message:** Key message: e.g. No Threat, Potential Threat, Threat **Summary:** What, where and when the threat is **Threat Information:** Level of threat, coastal areas affected, time of Arrival **Community Response Advice:** What action people should take **Next Update Time:** When the next update will be issued **Where the Public can get Further Information:** Web and telephone details for further/latest information
National or State/Territory Watch: To advise people that a tsunami threat may exist and that they should look out for further updates.	
State/Territory Warning: To advise people that a tsunami threat does exist and to advise them of the level of threat and action they should take. Marine = blue, land = red.	
National Warning Summary: To provide the public, media and emergency authorities with the status of tsunami warnings nationally.	
Event Summary: To provide the public, media, emergency authorities and government with summary information that can be used in post-event analysis.	

Source: JATWC, Bureau of Meteorology, available at www.bom.gov.au/tsunami/about/tsunami_warnings.shtml

Dissemination protocols

Bulletins, watches and warnings disseminated by the JATWC are subject to the following protocols:

- Tsunami No Threat Bulletins and National Tsunami Watches are issued to the Bureau's tsunami dissemination list.
- Tsunami warnings and cancellations are issued to national responsible bodies (such as Australian Government entities) and to the 'at threat' states and territories only.
- National Warning Summary and Event Summary Bulletins are issued to the Bureau's tsunami dissemination list.
- All messages are posted on the JATWC website at **www.bom.gov.au/tsunami** to provide a consolidated overview of the status of current warnings.

Communication channels

The JATWC issues national level tsunami warnings for all affected states and territories. Warning information includes which coastal zones are affected, what the expected timing is for the arrival of the tsunami, the level of threat and generic community safety advice about what actions to take. The JATWC website provides freely accessible coastal threat graphics, indicating states and territories currently under threat and the specific coastal zones (see Figure 12).

State or territory emergency services are then responsible in their individual jurisdictions for disseminating more specific public advice on actions to take in each area. Speed is crucial when disseminating tsunami warnings and is key to saving lives.

Warnings are communicated to the public using a variety of communication channels ranging from traditional media (such as radio and TV) to digital and social media platforms. Other channels key to tsunami warning dissemination may include:

- the internet (specifically, the JATWC webpage)
- Bureau of Meteorology Weather Mobile Application
- AWS through state based public hazard alert apps and websites (via state or territory emergency services)
- Emergency Alert (a telephone and text-based warning system)
- 1300 TSUNAMI telephone service
- low flying aircraft or drones equipped with warning systems e.g. public address systems, mobile telephone alerting
- Marine Rescue Vessel public address systems and the Regional Harbour Master
- marine satellite phone
- community notices in identified hubs
- distribution through established community liaison networks, partnerships and relationships
- field dissemination through doorknocks and beach evacuations.

New technology for warnings: use of drones to disseminate warnings

Redland City Council Local Disaster Management Group have an arrangement with Point Lookout Surf Lifesavers to use their drone to warn beach goers and those further down the coast who are camping and are outside of mobile telephone coverage.

Australian Warning System

The AWS is a national approach to information and warnings during emergencies like bushfire, flood, storm, extreme heat and severe weather. The AWS provides a standard, nationally consistent approach to warning icons and terminology.

www.australianwarningsystem.com.au

Case Study – New South Wales (NSW) AWS example

Due to the potential for very short warning times and large-scale impacts of a tsunami, there are only 2 AWS levels generally applicable in the event of a tsunami – Advice (Yellow) and Emergency Warning (Red). Each of these warning levels has a set of action statements.

WARNING LEVEL		ACTION STATEMENT
	Advice	Stay informed Reduced Threat: Return with Caution Monitor conditions
	Emergency Warning	Avoid the area Evacuate Now/Before (time)

Note: Given the travel time of a tsunami, it is highly unlikely a 'Watch and Act' warning would be issued by NSW State Emergency Service in the event of a tsunami.[30]

For more information on communication channels and warnings dissemination, consult the *Public Information and Warnings Handbook* on the Knowledge Hub.

Key public safety advice messages

To assist the community, tsunami threats in tsunami warnings are categorised into 3 tiers, with associated community response requirements. The related advice and community response instructions provided within tsunami warnings have been determined in consultation with emergency management organisations in Australia (see Table 4).

State and territory emergency service organisations are responsible for providing safety messages to the public. To assist affected communities to act quickly, the JATWC also disseminates public safety messages as part of its tsunami warnings. These public safety messages are nationally consistent and endorsed by all state and territory emergency service agencies through the ATAG mechanism (see Table 4).

There are 3 types of JATWC tsunami warnings: No Threat, Marine and Immediate Foreshore Threat and Land Inundation Threat.

No Threat

There is no evidence of a tsunami.

Marine and Immediate Foreshore Threat

This type of warning warns of potentially dangerous rips, waves and strong ocean currents in the marine environment, and the possibility of some localised overflow onto the immediate foreshore. Such tsunamis could pose a threat to swimmers, surfers, people in small boats and anyone in or near the water close to shore.

Marine Threat is the most frequently experienced tsunami warning level for Australia. While this warning typically does not require evacuations of land areas, people should get out of the water and move away from the immediate water's edge.

Land Inundation Threat

This type of warning warns of major land inundation and flooding to low-lying coastal areas, in addition to very dangerous waves and strong ocean currents in the marine environment.

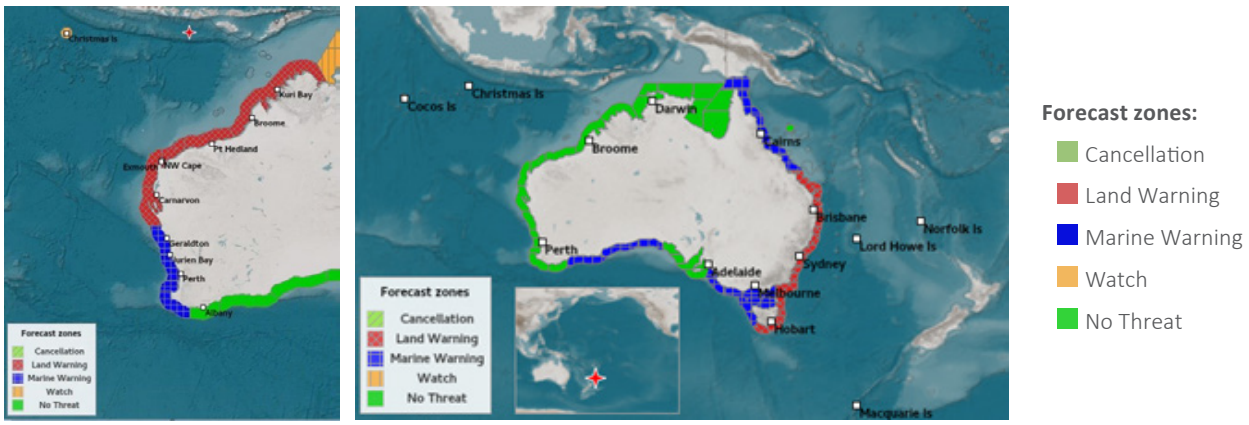

Figure 12: Examples of different tsunami warning levels along the west and east coasts of Australia based on two different hypothetical earthquake scenarios.

Source: JATWC. Image courtesy of Bureau of Meteorology.

Land Inundation Threat is extremely dangerous to people in the marine environment and low-lying coastal areas. While rare, it is still possible to occur in Australia.

SEWS would need to be broadcast in this type of event, urging the public to take immediate actions, and stay up to date with emergency response advice from their local authorities. People in affected areas should go to higher ground at least 10 metres above sea level or move at least one kilometre inland. In a land inundation event, an evacuation order is likely to be issued by the emergency response organisations which could vary between states and territories.

For more information on planning for an evacuation, consult the *Evacuation Planning Handbook*.

For more information on tailoring and constructing warning messages, consult the *Public Information and Warnings Handbook* and the Companion Guideline 1: Warning message construction: Choosing your words.

Table 4: Key public warning messages

Note: While these public safety messages are nationally consistent, as agreed by ATAG, safety advice in some offshore islands and territories have been tailored to better suit local geographical and environmental conditions.

MARINE AND IMMEDIATE FORESHORE THREAT	LAND INUNDATION THREAT
Evacuations from communities may not be required, but people are advised to get out of the water and move away from the immediate water's edge of beaches, harbours, marinas, coastal estuaries, and rock platforms. Boats in harbours, estuaries or shallow coastal water should return to shore. Secure your boat to moorings and move away from the waterfront. Vessels already at sea should stay offshore in water at least 25 metres deep until further advised. Do not go to the coast to watch the tsunami as there is the possibility of dangerous, localised flooding of the immediate foreshore. Check that your neighbours have received this advice.	The responsible agency has issued an evacuation warning for low-lying parts of coastal towns and villages from point A to point B including X Coastal Zone and Y Coastal Zone. People are strongly advised to go to higher ground, at least ten metres above sea level, or if possible, to move at least one kilometre away from all beaches, marinas, harbours and coastal estuaries. Take only essential items that you can carry including important papers, family photographs and medical needs. It will be in your own interest to walk to safety, if possible, to avoid traffic jams. If you cannot leave the area, take shelter in the upper storey of a sturdy brick or concrete multi-storey building. Boats in harbours, estuaries or shallow coastal water should return to shore. Secure your boat to moorings and move away from the waterfront. Vessels already at sea should stay offshore in water at least 25 metres deep until further advised. Do not go to the coast to watch the tsunami. Check that your neighbours have received this advice.
CAUTION: Tsunami waves are more powerful than beach waves of the same size. There will be many waves, and the first wave may not be the largest.	

Chapter 6: Preparedness for effective response

Planning considerations for response

Emergency managers should develop an understanding of the key phases, tasks and potential levels of impact associated with tsunami. It is essential emergency managers affirm the protection of life and the minimisation of disruption to the functioning of communities as operational objectives. These objectives should be supported by workable operational strategies.

Consider the following in-principal response strategies for tsunami operations:

- protect and preserve life
- establish and operate tsunami warning systems
- issue community information and warnings
- coordinate the evacuation of affected communities with consideration for their welfare
- protect critical infrastructure and assets essential to community survival during an emergency
- protect residential property
- protect assets and infrastructure that support individual and community financial sustainability, and that support community recovery post-incident
- protect the environment with consideration to its cultural, biodiversity and social values
- manage the transition from response operations to recovery.

It should be recognised that any tsunami operation will require a coordinated, multi-organisation effort under the control of a designated lead organisation. Organisations with different skills and resources can be matched with tasks best suited to their capabilities. Remote and rural areas provide unique challenges as there may be few resources available to provide warnings and respond to the impact of a tsunami. Tsunami planning needs to engage with Aboriginal and Torres Strait Islander communities to gain an understanding of cultural knowledge about tsunami risk and include cultural considerations in the response and recovery process.

Tsunami response operations can be separated into 3 key phases:

1. pre-impact (warning)
2. impact
3. post-impact.

Table 7: Typical actions in each key phase of tsunami response operations

PRE IMPACT	The pre-impact phase is defined as the period before the impact of a tsunami. This phase could extend from hours to days. This phase includes both marine and land-based activity. This phase consists of precautionary tasks focused on the protection of life and property, such as: · warning and evacuation · operational readiness · provision of accommodation and welfare for displaced people · protection and pre-deployment of resources · restriction of access to areas likely to be impacted. The ability of emergency services to complete these actions will depend on the warning time and available resources. During this phase it will be important to prepare to undertake actions in subsequent phases; in particular, to ready resources involved in search and rescue and the treatment of the sick and injured if a major impact is anticipated.
	Typical actions · evaluation of real-time tsunami information · formulation and dissemination of Tsunami Watches, Warnings and Bulletins · warning and evacuation of threatened communities and waterways to safe areas · provision of accommodation and relief for displaced people · management of pets and companion animals belonging to displaced persons · direction of pre-deployment of resources to staging areas outside the likely impact area · direction of protection of emergency land and marine resources by removing them from the likely impact area

PRE IMPACT	**Typical actions (cont.)** · monitoring of likely impact areas · restriction of access to likely impact areas · securing of evacuated areas · traffic management · management of waterways, including the coordination of high-risk and essential vessels to deep water where sufficient warning time is available · management of the media including the establishment of a joint media information centre.
IMPACT	The impact phase is characterised by the impact of a series of separate waves over several hours. During this phase, it will be difficult to undertake many activities directly within at-risk areas due to the dangers posed by the impact of further waves. Activities within this phase will be focused on: · warning · reconnaissance and monitoring · urgent rescue · relief for evacuees · preparation for response activities during the post-impact phase.
	Typical actions · monitoring and reconnaissance of likely impact areas (if it is safe for emergency services to do so) · detection of tsunami impact by tide gauges or tsunami buoys, or by other means · formulation and dissemination of Tsunami Warnings · continued warning and evacuation of threatened communities and waterways to safe areas (during a period of successive waves) · provision of accommodation and relief services for displaced people · management of pets and companion animals belonging to displaced people · management of the media · traffic management · securing evacuated areas · search and rescue activities for people trapped and/or injured by the destructive impact of the tsunami (if safe to do so) · search and rescue activities for people from the sea and estuaries (if safe to do so).
IMMEDIATE POST-IMPACT	The post-impact phase begins upon advice that the destructive potential of a tsunami has ceased, and that it is safe for emergency services to enter affected areas (if there are any). The scale of post-impact phase activities will depend on the size of the tsunami event that has occurred. Activities conducted during this phase may include: · reconnaissance and monitoring · search and rescue · treatment of the sick and injured · relief provision · disaster victim identification · response to fire and hazmat incidents · disease control · provision of advice to the community · mass casualty management.

IMMEDIATE POST-IMPACT	**Typical actions** · formulation and dissemination of Tsunami Warning Cancellation advice, indicating that the destructive potential of the tsunami has ceased, and that it is safe for emergency services to enter the impact area · reconnaissance of areas likely to have been impacted and establishment of access · formulation and dissemination of Tsunami Warning Cancellation advice, indicating that the destructive potential of the tsunami has ceased, and that it is safe for emergency services to enter the impact area · reconnaissance of areas likely to have been impacted and establishment of access · search and rescue activities for people trapped and/or injured by the destructive impact of the tsunami · search and rescue activities for people from the sea and estuaries · response to fire incidents · response to hazardous materials incidents · treatment of the sick and injured · provision of accommodation and welfare services for displaced people · disaster victim identification and registration · provision and coordination of mental health and psychosocial support to people who have been directly or indirectly affected.

Crisis management

A major tsunami can cause significant loss of life and destruction over a wide area with the potential to affect multiple states or territories as well as neighbouring countries. The event would be novel for Australia and could have a short lead time, and the effect could be catastrophic.

Catastrophic disasters

The Australian Disaster Preparedness Framework (Department of Home Affairs, 2018, p. 5) defines a catastrophic disaster as:

'…what is beyond our current arrangements, thinking, experience and imagination (i.e. that has overwhelmed our technical, non-technical and social systems and resources, and has degraded or disabled governance structures and strategic and operational decision-making functions).'

A major tsunami event would require a large-scale multi-organisation operation. The lack of previous experience with such an event and its novel and cascading consequences could significantly strain state, territory and national emergency management frameworks.

The approaches to developing the capacity and capability to manage the response, relief and recovery to events of this size and complexity are set out in the principles of best practice strategic crisis management arrangements for catastrophic disasters by Natural Hazards Research Australia.

Best practice principles for catastrophic disaster crisis management arrangements[31]

1. Arrangements must allow for a nationwide approach
2. Arrangements must allow for a collaborative and coordinated approach
3. Arrangements must allow for decentralised decision making and distributed execution supported by centralised strategic coordination
4. Arrangements must allow for flexibility, improvisation and scalability
5. Arrangements must allow for the integration of civilian and emergent capability
6. Arrangements must promote and embrace foresight and sense making
7. Arrangements must be supported by capability
8. Arrangements must foster interoperability
9. Arrangements must be supported by planning processes
10. Arrangements must be responsive and support elected officials decision making and crisis leadership

Tsunami evacuation

In almost all cases where tsunami warnings are issued, movement of people from at-risk areas is likely to be necessary. However, the scale of evacuation required will vary depending on the magnitude of the tsunami anticipated. The severity of the threat is indicated by categorising (stratification) tsunami warnings into Marine and Immediate Foreshore Threat and Land Inundation Threat; these warnings are issued through the ATWS. It is important to consider that when another natural hazard event such as a flood or bushfire is already occurring, planned tsunami evacuation routes may be impacted and only able to handle a reduced capacity or not be usable.

Marine and Immediate Foreshore Threat

A Marine and Immediate Foreshore Threat is likely to necessitate moving people out of the water and away from the immediate water's edge of harbours, coastal estuaries, rock platforms and beaches. Such an evacuation could be undertaken with assistance of all emergency services as well as organisations such as Surf Life Saving clubs, Port Authorities and Volunteer Marine Rescue groups.

The safety of people on vessels should also be considered. Boats in shallow water are particularly vulnerable to tsunami; boats in deep water, in the open ocean, are likely to be safer as long as weather and sea conditions remain favourable.

People on vessels in harbours, estuaries or in shallow coastal water should return to shore, secure their vessels and move away from the waterfront. Vessels already at sea should stay offshore in deep water until advised it is safe to move closer to shore. Marine-based radio may be used to provide advice to boats that have this equipment available.

Land Inundation Threat

Where there is a Land Inundation Threat, it will likely be necessary to consider large-scale evacuation of low-lying coastal areas. Public safety advice messages from the JATWC for a Land Inundation Threat will, with the approval of individual jurisdictions, include additional advice to the public regarding evacuation. This may include an instruction to evacuate to higher ground, at least 10 metres above sea level, or, if possible, one kilometre from all beaches and the water's edge of harbours and coastal estuaries.

The land inundation evacuation zone should be treated as a conservative rule of thumb; detailed inundation modelling is required to more accurately determine the areas requiring evacuation in individual communities.

Evacuation arrangements for a tsunami should be contained within emergency response plans for local communities. It is best practice to produce maps of likely areas to be evacuated which also define evacuation routes, assembly areas for the public to gather, and evacuation centres.

In addition to advice contained within the JATWC tsunami warnings, lead organisations may need to prepare more detailed, localised emergency warnings. Locally specific information will allow community members to relate more easily to the advice given and take necessary action. Such emergency warnings can be written in advance and adjusted to suit the circumstances on the day.

Where a major evacuation occurs in a coastal community, it may be necessary to advise people to walk or cycle to safety to mitigate the risk of traffic jams. Before giving this advice, emergency managers should consider the distance people may be required to walk and the likelihood of traffic delays.

Some people may be unable to evacuate in time or become trapped by a tsunami. In such cases, they should be encouraged to shelter in the upper storey of a sturdy brick or concrete multi-storey building.

Emergency warnings can be communicated to the public in a variety of ways, including:

- broadcast media
- doorknocking
- public address systems (mobile and fixed)
- mass telephone dial systems
- sirens
- the internet and social media
- two-way radio.

Critical resources required for the emergency response to a tsunami may also need to be evacuated if they are located within potential impact areas. This applies particularly to Surf Life Saving clubs and Marine Rescue Organisations that will need to move trailer-able equipment to higher ground. Plans should define staging areas for the movement of emergency equipment.

> For further information about evacuation planning, consult the *Evacuation Planning Handbook*.

Tsunami - Advise Return with Caution

Jurisdictional response organisations will coordinate the safe return of communities to tsunami-affected areas when the immediate danger to life and property has passed.

This will normally occur when a warning cancellation is issued by the JATWC confirming the destructive impacts of a warned tsunami will not eventuate or have ceased, and that it is safe to return to potential impact areas. The lead response organisation will normally consult with the JATWC through the Bureau of Meteorology's regional forecasting centre.

An 'all clear' will also be issued following the impact of a destructive tsunami when it has been assessed that evacuees can return to impacted areas. Often an appropriate recovery coordinator and committee will issue an Advice - Return with Caution.

Several considerations will determine whether residents and businesses are able to return to a safe environment, including:

- electrical safety checks of houses and buildings, power poles, wires and street transformers and re-energising before reconnection
- gas line purging and re-lights of household services
- cleaning and reconnection of sewer services, subject to service availability of the street mains
- water supply purging, subject to service availability of the street mains
- assessment of any damage to roads and bridges
- assessment of hazardous materials in buildings or on thoroughfares
- assessment of public health concerns
- assessment of suitability for access by residents, emergency services and response organisations.

NSW State Emergency Service tsunami response January 2022

NSW State Emergency Service (SES) is the hazard lead for tsunami in NSW. The tsunami that followed the eruption of the Hunga Tonga-Hunga Ha'apai volcano resulted in the JATWC issuing a tsunami warning for NSW, Queensland and Victoria.[32]

In NSW a Marine and Immediate Foreshore Threat Warning was initially issued for Lord Howe Island (2000hrs Saturday, 15 January) followed a short time later by a Marine and Immediate Foreshore Threat Warning for the entire NSW coastline (2036hrs).

At 2118hrs the warning for Lord Howe Island was upgraded to a Land Threat. This was the first land-based tsunami threat for NSW with the NSW SES as the combat agency.

Lord Howe Island has a very small NSW SES Unit, which is supported by the Port Macquarie Unit on the mainland. The Island does have a tsunami plan, and this was enacted by the NSW SES and the Local Emergency Operations Controller on the island. The plan had been exercised in the previous 12 months.

NSW SES issued an Emergency Warning – Evacuate Now for low-lying parts of Lord Howe Island at 2200hrs on 15 January. There were 50 residents that were evacuated to higher ground on the island.

At 1017hrs on 16 January, the Land Threat Warning for Lord Howe Island was downgraded to a Marine and Immediate Foreshore Threat Warning and evacuated residents were allowed to return home.

The Marine and Immediate Foreshore Threat Warning for Lord Howe Island was cancelled at 1956hrs on 16 January but remained in place for the remainder of NSW until 2207hrs that day.

With the tsunami threat warnings covering most of the east coast of Australia, NSW SES worked with agencies in Queensland, Victoria and Tasmania to ensure unified messaging to communities and a shared approach to the use of the Emergency Alert system.

NSW SES Units along the mainland coast were activated throughout this period to be ready to respond to any impact and to assist in warning the community of the marine based threat. The NSW SES State Command Centre was opened to coordinate response activities and liaise with all other emergency management stakeholders.

Observations:

- With a tsunami threat covering multiple states, it is important to liaise with all jurisdictions involved to ensure all communities receive relevant, unified and timely messages. This is particularly important with cross-border communities.
- The demand for the use of Emergency Alert in a similar event will be extensive and will require joint risk assessment between jurisdictions to identify priority areas for messaging.
- Having an established and exercised tsunami plan was beneficial to the smooth and efficient response activities on Lord Howe Island.

Ensuring emergency plans incorporate tsunami risk

Effective tsunami planning involves a range of stakeholders developing tsunami plans and procedures. These stakeholders include:

- national, state and territory governments
- transport authorities
- port authorities
- critical infrastructure owners and operators
- local governments
- Aboriginal and Torres Strait Islander land and sea councils
- local community groups, like lifesaving clubs
- local businesses, like tourism operators and those with animals in their care
- education institutions
- health services.

An emergency plan can be defined as an action plan required for a specific hazard, critical task or special event. An emergency plan is prepared when the management arrangements necessary to deal with the effects of the hazard, critical task, system failure or special event differ from the general coordination arrangements set out in the main or supporting plans for the area. Integrating tsunami planning into broader emergency management planning is encouraged to reduce duplication of effort.

Tsunami emergency plans should be holistic in scope; encompassing arrangements for all necessary activities and for magnitudes assessed to create a credible hazard for the area. The development of plans should involve all organisations likely to play some part during and after tsunami emergencies. People involved in the planning process are more likely to understand, accept and use the tsunami emergency plan. Consultation with affected communities is also vital to ensure community ownership of the plan. The establishment of a planning committee consisting of key stakeholders may assist in developing the plan in a consultative manner.

Planning for tsunamis enables a proactive response to tsunami emergencies, by understanding the areas at risk and the actions that should be undertaken to reduce the risks to life and property. The priority should always be the protection of life. Figure 13 shows how a continuous emergency planning process can be adopted in a multi-hazard context.

When developing a tsunami plan, planners should develop an accurate understanding of the available tsunami risk information, in order to understand the nature of the threat as fully as possible. Throughout the planning process, it is important that any need for further risk information is identified. It may be necessary to seek further information through detailed modelling before the risk can be fully understood.

Strategies and arrangements detailed within tsunami emergency plans should link with established warning

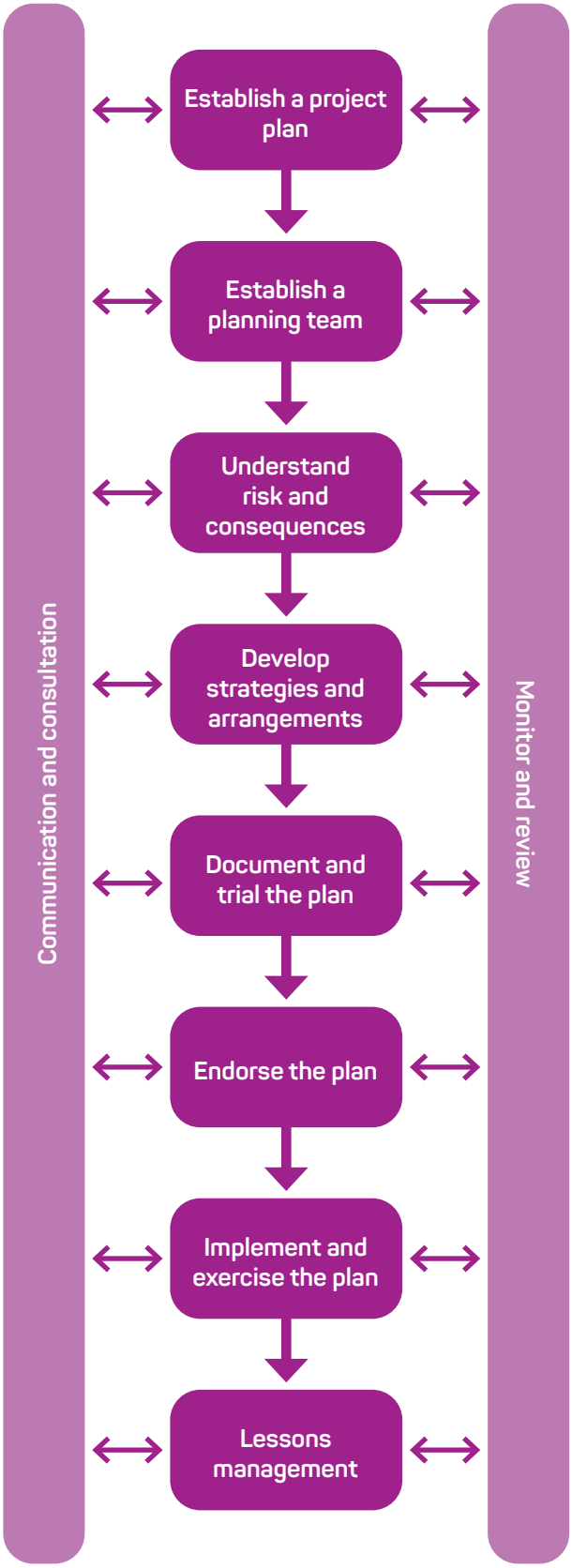

Figure 13: Continuous emergency planning process – Emergency Planning Handbook

systems, to ensure guidance is given as to how to respond to different types of tsunami warning products. Emergency plans that cover tsunami risk should cover strategies for preparedness, response and the initiation of recovery following a tsunami. Tsunami intelligence systems, mapping and visualisation tools should complement the plan to support a broader understanding.

Plans should be documented and distributed to relevant stakeholders. Plans need to be 'kept alive' to ensure they remain effective. This can be done through a regular review cycle, exercising, training and promoting community engagement and ownership.

Supporting policies, procedures and operational doctrine can be developed to support emergency plans. These provide further, detailed guidance for undertaking required actions, and can be used to clearly communicate operational objectives and strategies of the lead organisation in an operational context. Plans may be written in advance and subsequently modified before their release during tsunami response operations.

Tsunami planning should consider response and recovery and include risk mitigation and risk reduction measures. A tsunami emergency plan should follow the comprehensive prevention, preparedness, response and recovery (PPRR) approach to emergency management. A tsunami plan may be part of an all-hazard integrated emergency management planning process. The tsunami plan may be a sub-plan or an annex to a local emergency/disaster plan or a state/territory emergency or disaster management plan. Tsunami plans may also be developed by community groups and businesses.

Consider the following in planning for a tsunami:

- Prepare and maintain plans, including through reviews and exercises.
- Train emergency management personnel and operations centre and field staff.
- Develop response protocols for multi-organisation effort, under the overall control of a designated lead organisation for tsunami incidents.
- Ensure appropriate organisations and officers are aware of and prepared to fulfil their responsibilities.
- Divide tsunami response operations into phases: pre-impact (warning), impact and post-impact.
- Develop a tsunami Concept of Operations aligned to the ATWS Marine Threat and Land Inundation Threat categories; distinguish between the varying impacts of tsunamis.
- Decision-making framework for evacuation triggers – ensure the tsunami emergency plan follows a documented Concept of Operations or framework outlining when and how evacuation decisions are made based on tsunami severity and response timelines.
- Develop and maintain tsunami intelligence systems that complement emergency plans.
- Real-time evacuation monitoring and adaptation strategies – a tsunami emergency plan can leverage real-time tracking, AI-driven traffic management, or geospatial monitoring to adjust evacuation plans dynamically.
- Develop arrangements for fire and hazardous material incident planning, structural collapse and landslide incident planning in the context of a tsunami.
- Develop emergency management strategies for waterways including marinas, boat ramps and ports.
- Conduct response and recovery exercises to test arrangements.
- Integration of multi-hazard evacuation scenarios – any tsunami emergency plan must address or refer to the relevant mitigation strategies for overlapping risks such as storm surges, coastal flooding, or other natural hazards.
- Evacuation Time Estimation (ETE) and clearance benchmarking – in localised tsunami plans consideration should be given to a structured approach to estimating evacuation times for different scenarios.
- Work with communities to plan and prepare for, respond to, and recover from tsunamis in their area, including through community engagement strategies and awareness campaigns.
- Utilise the Disability Inclusive Emergency Management Toolkit to support the needs of people with disability and ensure disability inclusion is part of emergency preparedness planning.
- Utilise the Planning Evacuations with Indigenous Communities resource to support engagement with Aboriginal and Torres Strait Islander peoples.
- Develop protocols for warnings including the use of Emergency Alert (mobile and telephone-based warning messaging service).
- Understand the importance of informing the media and its role in disseminating emergency warnings to the public.
- Utilise social and traditional media, mapping and visualisation tools as essential components of Australia's Total Warning System.
- Make arrangements for the issuance of an 'all clear' or cancellation message.
- Develop arrangements for the design, production and distribution of information resources and online tools, including:
  - tailored tsunami risk information (where applicable)
  - actions to prepare homes, businesses and other property before a tsunami
  - warnings and triggers for the safest actions to take to manage the impacts and consequences of a tsunami
  - advice on how to plan for animals
  - key components of the emergency plan.
- Use maps to mark at-risk areas, evacuation centres and assembly areas for people and animals.

- Vertical evacuation strategies – local authorities should evaluate the installation of preventative mitigation measures such as vertical evacuation options for high-density urban areas where horizontal evacuation may not be feasible.
- Plan for evacuation centre management and relief and recovery arrangements.
- Incorporate evacuation route maps into plans, and arrangements for pre-deployment of resources to staging areas outside the impact area.
- Develop arrangements to redeploy resources to staging areas outside the impact area.
- Build the search and rescue capability of emergency service organisations.
- Monitor potentially affected areas and undertake rapid damage assessments. Restrict access to and maintain the security of evacuated areas.
- Post-evacuation logistics and re-entry planning – a tsunami emergency plan should detail protocols for managing displaced populations, re-entry procedures, or post-event recovery efforts.

Tsunami Ready Recognition Program

To assist countries in building tsunami resilience, IOC-UNESCO developed the community-based Standard Guidelines for Tsunami Ready Recognition Program (TRRP).[33] This is now globally adopted, and contributing to the UN Ocean Decade 2021-2030 for achieving 'A Safe Ocean'. The Ocean Decade aims to make 100 percent of communities at risk of tsunami prepared for and resilient to tsunami by 2030.

Table 5: IOC-UNESCO Tsunami Ready Indicators

TSUNAMI READY INDICATORS	
i	**Assessment (ASSESS)**
1	ASSESS -1 Tsunami hazard zones are mapped and designated
2	ASSESS -2 The number of people at risk in the tsunami hazard zone is estimated
3	ASSESS -3 Economic, infrastructural, political and social resources are identified
ii	**Preparedness (PREP)**
4	PREP - 1 Easily understood tsunami evacuation maps are approved
5	PREP - 2 Tsunami information including signage is publicly displayed
6	PREP - 3 Outreach and public awareness and education resources are available and distributed
7	PREP - 4 Outreach or educational activities are held at least three times a year
8	PREP - 5 A community tsunami exercise conducted at least every two years
iii	**Response (RESP)**
9	RESP - 1 A community tsunami emergency response plan is approved
10	RESP - 2 The capacity to manage emergency response operations during a tsunami is in place
11	RESP - 3 Redundant and reliable means to timely receive 24-hour official tsunami alerts are in place
12	RESP - 4 Redundant and reliable means to timely disseminate 24-hour official tsunami alerts to the public are in place

For further information on Emergency Planning, consult the *Emergency Planning Handbook*.

For further information on Australia's Total Warning System, consult the Public Information and Warnings Handbook Companion Document – Australian Warning System **www.australianwarningsystem.com.au**.

For further information on Managing Exercises, consult the *Managing Exercises Handbook* and the associated companion resources.

For further information on Evacuation Planning, consult the *Evacuation Planning Handbook*.

Key considerations for tsunami emergency planning

A tsunami plan should consider marine and land-based assets and users who may be at a greater risk from a tsunami (see Table 6). People should not remain on small boats or other small vessels during a tsunami. The safety of ocean-capable vessels and their crew depends on water depth and the distance from shore (should relocation be required to minimise potential damage from tsunami). Where warning time allows, access to moored and trailer-able boats may need to be managed to enable removal of valuables and securing of boats before the predicted arrival of a tsunami.

As a general principle, large vessels will be safer the further they are away from the coastline, and the deeper the water they are in. Where warning time allows, ocean-capable vessels may be instructed by port authorities to move to deep water offshore. Large vessels already at sea may be instructed to remain offshore in deep water.

It may be difficult for smaller vessels to move to deep water if concurrent severe weather is occurring or predicted. Further, vessels relocating to deep water may be required to remain at sea for more than 24 hours while a tsunami event unfolds.

Example: Tourism sector

Australia's coastal strip plays a substantial role in the national tourism industry. The coastal strip includes:

- water based activities such as swimming, surfing, boating, kayaking and fishing activities
- waterfront resort rental housing, beach camping and caravan parks
- beaches and walking trails
- remote bushwalks and camping areas
- low elevation airfields within tsunami inundation zones.

These activities attract transient visitors who may have little knowledge of tsunami risks. They may also have limited knowledge of evacuation routes and safe zones, no local connections and be unaware of local sources of information. In addition, some of these areas may have limited mobile reception or ability to receive communications, thus requiring different methods to distribute warnings. Preparing for and responding to tsunami risk must involve establishing programs that effectively engage and communicate with the tourism sector. This could include linkages with tourism information centres, tourism associations, networks and special interest groups.

Tourism disaster resilience
Queensland has created an online platform to assist the tourism industry plan for future disasters. Queensland Tourism Resilience Platform: **www.qra.qld.gov.au/news-case-studies/case-studies/queensland-tourism-resilience-platform**

Table 6: Marine- and land-based assets and users

MARINE-BASED ASSETS AND USERS	· Boats and their crew in shallow water (commercial, recreational, live aboard, emergency service agencies such as Marine Rescue and SES) · Beach users, including swimmers, surfers, sunbathers, sea kayakers, paddle boarders, and fishers · Divers and snorkelers · Surf Life Saving Clubs · Aquaculture industries · Submarine power, telecommunications, fuel and water supply lines · People and facilities in ports, harbours and marinas · Sewerage outfalls
LAND-BASED ASSETS AND USERS	· People and property in caravan parks and camping areas in low-lying coastal areas and beaches or on floodplains in tidal river/creek areas · People with physical or mental health conditions who may require additional assistance during an emergency · People with cognitive and intellectual disabilities, dementia and non-verbal communicators · Users of wheelchairs, mobility scooters, mobility aids · Culturally and linguistically diverse people whose first language is not English · Aboriginal and Torres Strait Islander communities · Residential, commercial, community and industrial buildings and their occupants in low-lying coastal areas or on floodplains in tidal river/creek areas · Motorists and vehicles on low-lying coastal roads · Low-lying coastal farmland including animals and crops · Institutions such as schools and hospitals located in low-lying coastal areas · People in coastal parks and reserves · Coastal infrastructure including roads, bridges, power, water, gas, sewerage and telecommunications · Sites of cultural and historical significance in low-lying coastal areas

Tsunami signage

Tsunami signage (see Figure 14) was adopted in Australia in 2005 following a government decision to develop an advanced ATWS.

In 2008, the International Organization for Standardization (ISO) approved international signage for tsunami hazard zones, evacuation areas and evacuation buildings. ISO 20712 on water safety signs and beach safety flags provides guidance on safety signs that provide information about aquatic hazards and the action necessary to avoid those hazards, including signage for tsunami hazard areas.

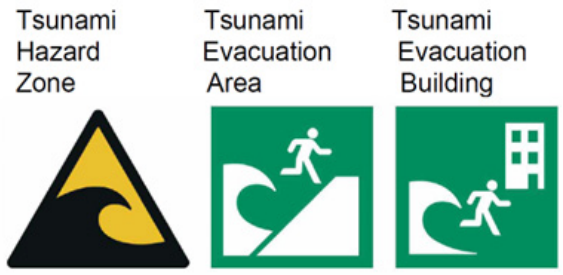

Figure 14: Three Tsunami warning signs adopted by Australia.

Source: Bureau of Meteorology

Capability development

Capability development refers to the process through which individuals, the community and organisations obtain, strengthen and maintain their capabilities to set and achieve their objectives. Principle components of capability development include:

- assessing capacity assets and needs
- defining appropriate strategies
- conducting training and education based on these strategies
- conducting exercises
- monitoring and evaluating implemented strategies.

Community engagement for tsunamis

Community engagement is crucial to building community resilience to any hazard type. Community engagement refers to working with communities to improve PPRR in relation to tsunamis.

Community engagement for the tsunami hazard is made more difficult by unfamiliarity with the hazard. Additionally, many coastal communities have experienced so many other hazards that they may not be able to engage effectively with tsunamis as a risk due to hazard fatigue. Some coastal communities may have people who were impacted by the 2004 tsunami and for whom discussion about tsunami may trigger trauma experiences from the past.

Community understanding of tsunami risk

Research funded by the Bushfire and Natural Hazards Cooperative Research Centre in 2016[34] found:

- community members did not know of the Australian Tsunami Warning Centre or how they would receive a tsunami warning
- community members perceived low tsunami risk, prompting participants to question the need for resources to be directed to tsunami risk
- community members identified that warnings should include:
  - what areas were likely to be affected by the tsunami event
  - what actions people should take
  - how long until the tsunami arrives (at each specific coastal location)
  - where to evacuate to (e.g. location of evacuation centres in each area).
- community members emphasised the need to focus on the local implications of tsunami risk.
- community members suggested that planning would be improved by discussing tsunami risk management with those associated with other regularly occurring coastal and ocean hazards.

Community engagement programs aim to empower people by using training, tools and knowledge, and promoting the shared responsibility for building a more resilient community.

Consider the following aspects of community engagement:

- Develop an informed understanding of tsunamis to prepare accurate community awareness tools.
- Clearly define the message or messages for communication.
- Identify key stakeholder groups and develop a suite of community awareness tools to engage groups across the community, including communication in languages other than English and accessible communication that accommodates people with disability.
- Co-design with stakeholders in the development of community awareness materials.
- Evaluate community awareness tools with target audiences.
- Utilise public participation principles, research and best practice in the development and delivery of community engagement planning and programs.
- Engage communities throughout PPRR cycle.

- Build a culture where community engagement and operational response are seen as equally important complementary strategies for emergency management.
- Conduct preparedness campaigns, such as Get Ready Weeks, in association with World Tsunami Awareness Day which occurs every year on 5 November.
- Leverage tsunami events internationally to draw attention to local risks. Consider using anniversary events from international tsunami events as well.

World Tsunami Awareness Day

In December 2015, the UN General Assembly designated 5 November as World Tsunami Awareness Day, calling on countries, international bodies, and civil society to raise tsunami awareness and share innovative approaches to risk reduction.

World Tsunami Awareness Day was the brainchild of Japan, which due to its repeated experience, has over the years built up major expertise in areas such as tsunami early warning, public action and building back better after a disaster to reduce future impacts. The UN Disaster Risk Reduction (UNDRR) facilitates the observance of World Tsunami Awareness Day in collaboration with the rest of the United Nations system.[35]

For more information on community engagement consult the *Community Engagement for Disaster Resilience Handbook*.

Tsunami exercising

Exercises provide an opportunity to ensure plans are workable and effective. They also help to educate emergency services, functional areas, supporting organisations, local government and the community about emergency management arrangements for tsunamis. Exercises can also be used as a tool to assist in the development of tsunami emergency plans by identifying required strategies and responsibilities.

Exercises can identify deficiencies in a plan, both in terms of its procedural adequacy and its effectiveness in communicating with those who will be managing a tsunami when it occurs. Exercising should be done regularly. Exercises should vary in context and extent, given that no single test can adequately simulate all aspects of emergency response. All organisations need to be involved in the exercise process, and all parts of the plan should be exercised regularly. Where possible, communities should be involved in exercises. Learnings from exercises help inform capability in other response capabilities and build a culture of high-performing teams and productive working relationships (see Case Study Exercise Bombora).

Figure 15: New South Wales State Emergency Service conducting tsunami community awareness activities with beachgoers at Manly.

Source: New South Wales State Emergency Service.

Case study: Exercise Bombora August 2022[36]

In August 2022, Exercise Bombora was held in Brisbane. Exercise Bombora was a one-day national catastrophic tsunami exercise that aimed to examine the impact of a tsunami along the east coast of Australia between Queensland and NSW. The purpose was to determine whether current capabilities, plans and arrangements for crisis response and early recovery were adequate or whether further development was needed.

Exercise Bombora was jointly planned by Queensland Fire and Emergency Service, NSW SES and NEMA. There were over 150 participants from 50 agencies at national, state, territory and local government level.

Considerations that emerged from the exercise included the need to:

1. Undertake a national review of tsunami response plans, procedures and capabilities.
2. Utilise appropriate coordination mechanisms to convene an annual meeting to facilitate increased national collaboration on tsunami preparedness.
3. Review strategic resource planning processes to ensure a staffing profile is scalable and capable for rapid activation.
4. Consider establishing generic bilateral assistance arrangements for international support.
5. Undertake further work to examine inundation threat and warning capability and provide sufficient information to anticipate public evacuation requirements.
6. Develop a national tsunami community engagement strategy.
7. Update current warning and emergency messaging procedures to incorporate a catastrophic tsunami.
8. Increase awareness of the National Emergency Declaration, particularly with states and territories, as a mechanism for calling the nation to action and removing red tape during times of catastrophic disaster.

For past international tsunami exercises, visit the International Tsunami Information Center **https://tsunami.ioc.unesco.org/en/exercises**

For information on managing and conducting exercises in Australia, refer to the *Managing Exercises Handbook.*

The IOC Manuals and Guides: How to Plan, Conduct and Evaluate UNESCO/IOC Tsunami Wave Exercises at **http://unesdoc.unesco.org/images/0021/002189/218967e.pdf** (PDF 1.0MB) has been developed to aid countries in planning, conducting, and evaluating a tsunami exercise at a national or provincial level.

Chapter 7: Planning for recovery

Introduction

The following elements of tsunami present a challenge for emergency response and recovery:

- Low level of community awareness of the risk and appropriate response actions.
- Rare occurrence – few operational staff will have the opportunity to develop experience in response.
- Potential to cause wide-scale damage along an entire coastline.
- Potential to isolate island communities.
- Potential to generate global media interest.
- Tsunami risk areas include remote and rural areas where resources are extremely limited.

Successful recovery requires a planned, coordinated and adaptive approach between community and partner organisations. It should be based on a continuing assessment of impacts and needs. Impacted individuals in communities are key stakeholders and should be at the forefront leading or driving the recovery process in their community.

The recovery process from disasters is often long, complex and challenging. Recovery is the complex process of individuals, communities and society impacted by a disaster, working to resolve the impacts that the event has had on them. These impacts will be often across the 4 recovery environments of built, social, economic and natural.

Successful recovery works across each of the environments in an integrated and sustainable way as they are all interconnected. A range of organisations will often be needed to assist in the recovery phase of a tsunami. Preparation for recovery should begin during the pre-impact phase; recovery operations will begin concurrently with impact period response operations. The National Principles for Disaster Recovery and the Community Recovery Handbook provide guidance on principles and good practices in recovery.[37, 38]

Recovery planning, coordination and management takes a needs-based focus – that is, managing for the consequences and resulting needs of community and individuals, not the hazard itself. Hence, they can be generalised to a range of hazard situations. It will be important to contextualise these generic arrangements to the impacts of the tsunami.

Impact and needs assessment

Damage, impact and needs assessments are critical components of recovery planning. Damage assessments need to be conducted early. Impact and needs assessments will need to be repeated as needs will change over time and can often be staged, based on urgency. Assessments can also be challenging as not all the data are readily available or easily collated.

Public information

Public information can guide those threatened by or affected by hazards to take appropriate actions to manage or reduce the impacts of an emergency. Public expectations and emotions are heightened during and after an emergency. If there is a significant impact from a tsunami, the public interest is likely to be high, given the novel nature of the hazard. Communication strategies should be planned to assist affected communities in understanding what has happened, what resources are available and advice on how to manage the practical and psychosocial impacts of the tsunami.

Australian Red Cross' *Communicating in Recovery Handbook* provides additional guidance on managing public information in recovery.

Recovery from a tsunami has many commonalities with significant flooding, though there are some additional considerations particularly around intrusion of saltwater. A tsunami may also be far more powerful than floodwaters.

New Zealand's NEMA provides the following good practice advice for tsunami recovery:

Returning home after a tsunami

- If you have evacuated, it may not be safe to return home even when the water has returned to normal. Listen to emergency services and authorities and don't return home until they tell you it is safe to do so.
- Stay out of buildings if water remains around them. Tsunami water, like floodwater, can undermine foundations, causing buildings to sink, floors to crack, or walls to collapse.
- When re-entering homes or buildings, use extreme caution as floodwaters may have damaged buildings. Look before you step. After a tsunami, the ground and floors are covered with debris, including broken bottles and nails. Floors and stairs that have been covered with mud can be very slippery. Look for broken utility lines and report them to appropriate authorities.

Food safety after a tsunami

- When ocean water comes ashore, it can carry microorganisms (bacteria, viruses, parasites) and chemicals that can contaminate food and negatively affect human health.
- Throw away all food and drinking water that has come in contact with tsunami floodwater, including those stored in containers. It is impossible to know if containers have been damaged and the seals compromised.
- Avoid drinking or preparing food with tap water until you are certain it is not contaminated. Follow any boil water notice instructions from your local authorities.

Consequences of tsunami impact

There may be a broad range of consequences that need to be managed in a tsunami recovery. These include:

Social consequences

- damaged and destroyed residential properties and displaced residents
- injured and deceased persons
- missing persons whose bodies may not be recovered
- psychosocial impacts
- loss of social networks
- loss of companion animals
- global media interest
- job losses and economic impacts
- impacts on educational performance.

Environment consequences

- saltwater impacts on vegetation and farmlands
- saltwater impacts on freshwater storage
- coastal erosion
- shoreline changes including loss of vegetation
- large amount of potentially contaminated debris requires collection and disposal
- extended duration shoreline cleanup
- biodiversity loss
- destruction of cultural sites.

Economic consequences

- damage and disruption to businesses, industry and supply chains
- damage to marine aquaculture
- damage to, and loss of commercial vessels
- damage to fisheries
- disruption to tourism and related infrastructure
- damage to farmlands
- commercial property damage
- areas become uninsurable.

Built consequences

- damage to harbours, moorings and jetties
- damage to break walls
- damage to roads and bridges
- utility damage – wastewater treatment plants, pipes, electricity, telecommunications
- damage to buildings.

Psychosocial impacts of tsunami

Like other hazards, tsunamis will have short, medium and long-term psychosocial effects. These may include impacts on quality of life and wellbeing through to anxiety, depression and post-traumatic stress disorder. Planners should also recognise that tsunami events could trigger reactions in survivors of and responders to the Indian Ocean Tsunami, and other tsunamis.

Planning for longer term recovery

The recovery process for events of this nature will unfold over months and years into decades and any proactive pre-event planning for large scale events such as tsunamis, should take this into account. Once the urgent needs are managed, and uncertainties about the future are reduced, the focus will turn to planning for longer-term recovery.

Given the longer-term consequences of these disaster impacts, recovery organisations must have strategies to provide ongoing support to the wider community. Those who work with businesses and industry may need to assist with business planning, financial counselling, and financial support such as loans and grants.

Longer-term planning may include decisions to rebuild to avoid future hazard-related losses, to relocate to another less risk prone location, or to make improvements to emergency plans such as changing evacuation procedures or business processes. Some may decide to invest in new risk mitigation approaches or make improvements to structures.

Communities may plan memorials to acknowledge the losses and help community members grieve. Arranging community events and ways for communities to come together to commemorate a shared event can be good for building connections and sharing stories, as well as learning and developing new networks. The *Community Recovery Handbook* provides guidance on good practices.[39]

Memorials and services that acknowledge all losses, including animals and the environment, can be good healing opportunities and opportunities to support communities. These may also take the form of community-building activities, such as working bees or replacement of animal facilities.

Recovery planning needs to consider the diverse needs of different entities. It should also be supported by ongoing needs assessments.

Learning from the Great East Japan Earthquake

'On March 11, 2011, an earthquake of magnitude 9.0 occurred in the Pacific Ocean off the coast of Japan's Tohoku region. The quake shook the ground as far away as western Japan and lasted for several minutes. A half hour later, a tsunami of unprecedented force broke over 650 km of coastline, toppling sea walls and other defences, flooding more than 500 km^2 of land, and washing away entire towns and villages. The devastation left some 20,000 people dead or missing, with most of the deaths caused by drowning. The tsunami levelled 130,000 houses and severely damaged 270,000 more. About 270 railway lines ceased operation immediately following the disaster, and 15 expressways, 69 national highways, and 638 prefectural and municipal roads were closed. Some 24,000 hectares of agricultural land were flooded. The areas worst hit were the Fukushima, Iwate, and Miyagi prefectures.'[40]

To collect lessons from this event for use globally, The World Bank produced an extensive report: Learning from *Mega Disasters – The Great East Japan Earthquake*.[41] This report provides insights into the multitude of response and recovery issues. Some of the issues covered include:

- warnings and evacuation
- performance of structures
- urban and land use regulation
- residential relocation
- debris Management
- livelihood and job creation
- reconstruction.

Further information can be found in the *Community Recovery Handbook*.

Continuous improvement

A successful outcome for managing tsunamis is no different to success in other areas of emergency management.[42]

- The best outcomes result from reducing risks and mitigating potential impacts.
- Having individuals understanding their risks and responsibilities and being supported in disaster risk reduction, preparedness and planning are key.
- Early supportive, participatory and inclusive engagement is strongly encouraged.
- Building and maintaining connections with individuals, communities and the organisations that live, visit and work along Australia's coastline helps to build momentum in planning and preparedness.

The planning activities outlined in the handbook should be tested regularly by conducting exercises. Guidance on exercising can be found in the *Managing Exercises Handbook*. Resources for recovery exercising can be found in the Recovery Exercising Toolkit available on the AIDR Knowledge Hub.

After action reviews should be run, which feed into lessons management. These activities should involve all stakeholders, including emergency management organisations, to get a full picture of what worked well, what needs improvement and what the root causes of issues may be that can be learned from and fixed for next time. Lessons management activities are an excellent way to understand and improve operational processes for future exercises and emergencies. Guidance on this can be found in the *Lessons Management Handbook.*

Appendix 1: Australian State and Territory Tsunami Plans

NSW

NSW (New South Wales Government) (2025) *Tsunami emergency sub plan*, New South Wales Government. **https://www.nsw.gov.au/rescue-and-emergency-management/sub-plans/tsunami**

Victoria

EMV (Emergency Management Vicotria) (2025) *SEMP Tsunami Sub-Plan*, Emergency Management Victoria. **https://www.emv.vic.gov.au/responsibilities/state-emergency-management-plan-sub-plans/semp-tsunami-sub-plan#:~:text=The%20SEMP%20Tsunami%20Sub%2DPlan,the%20community%2C%20infrastructure%20and%20services**

Queensland

Get Ready Queensland (2025) *Tsunami* , Queensland Government.
https://www.getready.qld.gov.au/getting-ready/understand-your-risk/types-disasters/tsunami

Queensland Fire Department (2025) *Tsunami evacuation areas for Queensland*, Queensland Fire Department.
https://www.fire.qld.gov.au/prepare/tsunami/evacuation-areas

Get Ready Queensland and Queensland Fire Department (2024) *2024 Tsunami Guide for QLD*, Queensland Fire and Emergency Services. **https://www.disaster.qld.gov.au/__data/assets/pdf_file/0019/339301/Tsunami-Guide-For-Queensland.pdf**

Western Australia

Government of Western Australia (2023) *State Hazard Plan – Tsunami,* Government of Western Australia.
https://www.wa.gov.au/government/publications/state-hazard-plan-tsunami

Tasmania

Tasmania State Emergency Services (2025) *Tsunamis*, Tasmania State Emergency Services.
https://www.ses.tas.gov.au/during-an-emergency/tsunami/

Examples of state or territory emergency risk assessments:

Get Ready Queensland and Queensland Fire Department (2023) *Disaster Risk Assessment for Queensland*, Queensland Fire and Emergency Services.
https://www.disaster.qld.gov.au/__data/assets/pdf_file/0020/436070/2023-State-Disaster-Risk-Report.pdf

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NSW (New South Wales Government) (2024-26) *State Disaster Mitigation Plan*, NSW Reconstruction Authority.
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