Tsunami Emergency Planning in Australia

Australian Institute for
Disaster Resilience

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Cover images, clockwise from top: New South Wales State Emergency Service conducting tsunami community awareness activities with beachgoers at Manly, Sydney (image: NSW SES); New South Wales State Emergency Service conducting Exercise Puysegur Surge on the inaugural World Tsunami Awareness Day (2016), Manly, Sydney (image: NSW SES); tsunami DART™ buoy (image: Bureau of Meteorology).

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 consultative committees representing a range of state and territory agencies, governments, organisations and individuals involved in disaster resilience. The collection is sponsored by the Australian Government Department of Home Affairs.

Access to the Handbook Collection and further details are available on the Australian Disaster Resilience Knowledge Hub (the 'Knowledge Hub'; https://www.knowledge.aidr.org.au/handbooks).

Handbook 1	Disaster Health
Handbook 2	Community Recovery
Toolkit 2-1	Community recovery checklists
Toolkit 2-2	Further resources for community recovery
Toolkit 2-3	Community recovery case studies
Handbook 3	Managing Exercises
Handbook 4	Evacuation Planning
Handbook 5	Communicating with People with a Disability: National Guidelines for Emergency Managers
Handbook 6	National Strategy for Disaster Resilience: Community Engagement Framework
Handbook 7	Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia
Guideline 7-1	Using the National Generic Brief for Flood Investigations to Develop Project Specific Specifications
Guideline 7-2	Flood Emergency Response Classification of the Floodplain
Guideline 7-3	Flood Hazard
Template 7-4	Technical Project Brief Template
Guideline 7-5	Flood Information to Support Land-use Planning

Guideline 7-6	Assessing Options and Service Levels for Treating Existing Risk
Practice Note 7-7	Considering Flooding in Land-use Planning Activities
Handbook 8	Lessons Management
Handbook 9	Australian Emergency Management Arrangements
Handbook 10	National Emergency Risk Assessment Guidelines
Guideline 10-1	National Emergency Risk Assessment Guidelines: Practice Guide
Resource 10-2	NERAG Online Training Program
Handbook 11	**Tsunami Emergency Planning in Australia**
Guideline 11-1	Tsunami hazard modelling guidelines
Online resource	Tsunami: The Ultimate Guide
Handbook 12	Communities Responding to Disasters: Planning for Spontaneous Volunteers
Handbook 13	Planning Safer Communities – Land Use Planning for Natural Hazards
Handbook 14	Incident Management in Australia
Handbook 15	Safe and Healthy Crowded Places
Guideline 15-1	Crowded Places Checklists
Reference	Crowded Places Further Resources
Handbook 16	Public Information and Warnings
Guideline 16-1	Warning Message Construction: Choosing your words
Guideline 16-2	Warnings Republishers

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Australian Capital Territory State Emergency Service – Graham Ible, Operations and Capability Coordinator

Australian Antarctic Division – Chris Gallagher, Field Support and Emergency Management Coordinator

Bureau of Meteorology – Dasarath Jayasuriya, General Manager Public Safety; Jeff Perkins, National Manager Flood Tsunami and Storm Surge; and Yuelong Miao, Manager of Tsunami and Storm Surge

Department of Fire and Emergency Services, Western Australia – Stephen Gray

Department of Home Affairs, Emergency Management Australia – Brian Foo, Director of Operations, Australian Government Crisis Coordination Centre

Emergency Management Norfolk Island – Milton Bradley, Emergency Controller

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Contents

List of figures

List of tables

List of case studies

Preface

Purpose

This handbook is a guide to the key principles of tsunami preparedness. Its purpose is to enhance the capacity and knowledge of emergency managers with regards to emergency planning for tsunami in Australia.

The handbook outlines the key scientific information and principles of risk assessment, warning systems, emergency planning, community education, response management and recovery, in the context of tsunami. The handbook may assist emergency and coastal managers to develop emergency risk management strategies to deal with the threat of tsunami.

> Further information about the emergency management of tsunami in individual jurisdictions is available from the responsible agency in each state or territory. These agencies are also members of the Australian Tsunami Advisory Group (ATAG) and are listed on the Knowledge Hub at www.knowledge.aidr.org.au/resources/australian-tsunami-advisory-group/

Context

This handbook replaces *Manual 46: Tsunami Emergency Planning in Australia (2010)*.[1] It reflects updated terminology, and enhanced capacity and knowledge regarding emergency planning for tsunami in Australia and internationally. In particular, the handbook reflects key developments that followed the 2011 Japan tsunami:

- The United Nations General Assembly designated 5 November as World Tsunami Awareness Day to promote a global culture of tsunami awareness.
- The earthquake and tsunami science community revisited assumptions on maximum magnitude earthquakes, resulting in a renewed focus on tsunami hazard assessments globally.

The updated content also reflects:

- changes in the strategic environment
- the advent of social media and online communication platforms
- interactions with international warning and mitigation systems
- refinement of emergency management arrangements for tsunami
- developments in science, systems and operations
- enhanced knowledge sharing and partnerships
- greater recognition of tsunami among emergency management leaders
- more tsunami exercising in a multi-agency, multi-hazard context
- improvements to tsunami modelling, mapping and visualisation.

> For more information on emergency management arrangements in Australia, consult Australia's Emergency Management Arrangements Handbook at www.knowledge.aidr.org.au/em-arrangements-handbook

This handbook references a number of key outputs from the relevant Intergovernmental Coordination Groups, with reference to Australia's role.[2] These outputs are highlighted to support Australian emergency managers in developing tsunami preparedness activities.

The handbook also recognises the ongoing work of the Indian Ocean Tsunami Warning and Mitigation System (IOTWMS), established following the 2004 Indian Ocean tsunami.

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1 The Manual Series is undergoing a comprehensive review, managed by the Australian Institute for Disaster Resilience. The process will see each manual either updated and incorporated into the Australian Disaster Resilience Handbook Collection or another doctrine collection, or archived.

2 The UNESCO Intergovernmental Oceanographic Commission (IOC) has been mandated to facilitate the coordination of the international tsunami warning and mitigation system. More information is available at: http://itic.ioc-unesco.org/index.php?option=com_content&view=category&layout=blog&id=2002&Itemid=2002.

More broadly, this handbook reflects the core themes of the *National Strategy for Disaster Resilience* (2011), which in turn reflect the Australian Government's commitment to the Sendai Framework:[3]

- leadership and coordination
- understanding, communicating and managing risk
- empowering individuals and communities
- building partnerships
- supporting capabilities to build disaster resilience.

> More information on community awareness for tsunami and associated research is available from the Bushfire and Natural Hazards Cooperative Research Centre at www.bnhcrc.com.au/research/hazard-resilience/240

Australian Tsunami Advisory Group (ATAG)

Tsunami planning in Australia is overseen by the Australian Tsunami Advisory Group (ATAG), an expert advisory group for the Australia-New Zealand Emergency Management Committee (ANZEMC) and its sub-committees. ATAG provides national leadership in the coordination of programs and projects relating to tsunami capability development; promoting research, information and knowledge management and education in Australia.

ATAG membership includes representatives from Australia's state and territory emergency management organisations and agencies, the Bureau of Meteorology, Geoscience Australia, the Australian Government Department of Home Affairs, Surf Life Saving Australia, and representatives from New Zealand.

> More information about ATAG, including its Terms of Reference and membership, is available at www.knowledge.aidr.org.au/resources/australian-tsunami-advisory-group/

Scope

This handbook outlines nationally agreed principles for tsunami planning and preparedness in Australia. It draws on national and international strategies, policies, guidelines, standards and doctrine related to tsunami.

The handbook is designed for use by those with roles in preparing communities for tsunami; in both lead and supporting agencies. The handbook is written for a broad audience, recognising that the responsibility for managing tsunami risk is shared among a broad stakeholder group in the coastal zone. The content is written not only for ATAG member organisations, but also for local and state government, port authorities and the oil and gas industries. The handbook is also written for communities who live with the risk of tsunamis, recognising that they too have a responsibility to be prepared.

The handbook provides broad guidance on key aspects of tsunami preparedness – it is not intended to offer exhaustive guidance. It does not seek to define or describe current practices, which may vary considerably between jurisdictions. Rather, the handbook is principles-based: it outlines good practice approaches developed over many years of experience in tsunami planning and preparedness around Australia.

The handbook is presented in five chapters:

1. Introduction to tsunami
2. Australian tsunami hazard and risk
3. Tsunami warning systems
4. Tsunami detection methods
5. Emergency preparedness for tsunami

Two companion resources are currently available online to support the use and implementation of this handbook. These will be revised to reflect developments in the science and emergency risk management of tsunami.

- Guideline 1: Tsunami hazard modelling guidelines (PDF 4.39MB)
- Online resource: Tsunami: The Ultimate Guide

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

- Australia's Emergency Management Arrangements
- National Strategy for Disaster Resilience: Community Engagement Framework
- Community Recovery
- Evacuation Planning
- Public Information and Warnings.

The complete Handbook Collection is housed on the Knowledge Hub at www.knowledge.aidr.org.au/handbooks.

3 https://www.unisdr.org/we/coordinate/sendai-framework

Terms referenced in this handbook

Bathymetry

Undersea topography

Inundation

The wetting of land areas that would otherwise be dry (for example, as a result of a tsunami, a storm surge or a river flood).

> **Maximum inundation** refers to the maximum water depth on land reached by a tsunami (or modelled tsunami) at each location across a community, 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, for example, that infrastructure and services that would potentially be damaged during a tsunami.
>
> *See also* **Inundation distance** and **Run-up height**.
>
> **Inundation distance** refers to the maximum distance from the coast reached by a tsunami (or modelled tsunami).

Run-up

The maximum vertical onshore elevation that a tsunami wave reaches at a particular site.

Rupture area

The area of a fault over which earthquake slip occurs.

Seismometer

Devices attached to or buried in the ground which convert earthquake vibrations into an electrical signal.

Subduction zone

Region at the boundary of two tectonic plates, where the plates are moving towards each other (converging) and one plate is sinking underneath the other. Subduction zones tend to host the largest earthquakes on earth.

Tectonic plate

According to the theory of plate tectonics, the outer part of the earth may be divided into a number of rigid plates which move relative to each other over time, with most earthquakes occurring at the boundaries between the plates. These rigid plates are termed tectonic plates.

Topography

The relief or terrain of the landscape.

Tsunameter

A deep ocean tsunami detection sensor.

Tsunamigenic

1. Phenomena that generate a tsunami, such as undersea earthquakes.
2. Sedimentary deposit or other feature caused by a tsunami.

Wave amplitude

Half of the peak-to-trough wave height. (In much of the tsunami literature, this term is also used informally to refer to 'maximum water level,' although that definition is uncommon in other fields.)

Wave height

The vertical distance from the wave peak to the wave trough. (In much of the tsunami literature, this term is also used informally to mean the 'maximum water level,' although that definition is uncommon in other fields).

Wavelength

The distance between two successive wave crests at an instant in time.

Wave period

The time between the arrival of two successive wave crests at a given site.

Wave propagation

Any of the ways in which waves travel.

> Further tsunami terms are available through the IOC Tsunami Glossary (IOC 2016) at http://itic.ioc-unesco.org/index.php?option=com_content&view=article&id=1868&Itemid=2435
>
> Refer also to the Australian Disaster Resilience Glossary at www.knowledge.aidr.org.au/glossary.

Chapter 1: Introduction to tsunami

Key points

- Tsunamis are unrelated to the tides, although the impact of a tsunami on a coastline is dependent on the tidal level at the time of impact.
- The most common cause of tsunami is an undersea earthquake that results in a sudden rise or fall of a section of the earth's crust under or near the ocean.
- Tsunamis can also be caused by events such as submarine landslides; volcanic eruptions; land or ice slumping into the ocean (typically from the face of a continental shelf or Antarctica); meteorite impacts; or even the weather, when the atmospheric pressure changes very rapidly.
- Tsunamis are much more destructive than normal waves because the huge, flooding body of water of a tsunami can continue to rush onto land for an extended period of time.
- A tsunami is a series of waves; the first wave is often not the largest. Depending on how it was generated, a tsunami may be observed for many hours after the event. In some instances, a tsunami may be observed for over 24 hours after the event.
- The impact of a tsunami will vary widely. The impact will be a function how the tsunami was generated; the distance between the source and the point of interest; and the nature of the nearshore and onshore topography.

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.

In the past, 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 dependent on the tidal level at the time it strikes, 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. An earthquake, however, is 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; tsunami waves involve the movement of water all the way to the seafloor.

Further, in the deep ocean, tsunami waves have extremely long wavelengths – of up to hundreds of kilometres between wave crests (see Figure 1). This makes tsunamis much more destructive than normal 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 – 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 be unnoticed by ships or from the air. As the wave approaches land, it reaches shallow water and begins to slow 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.

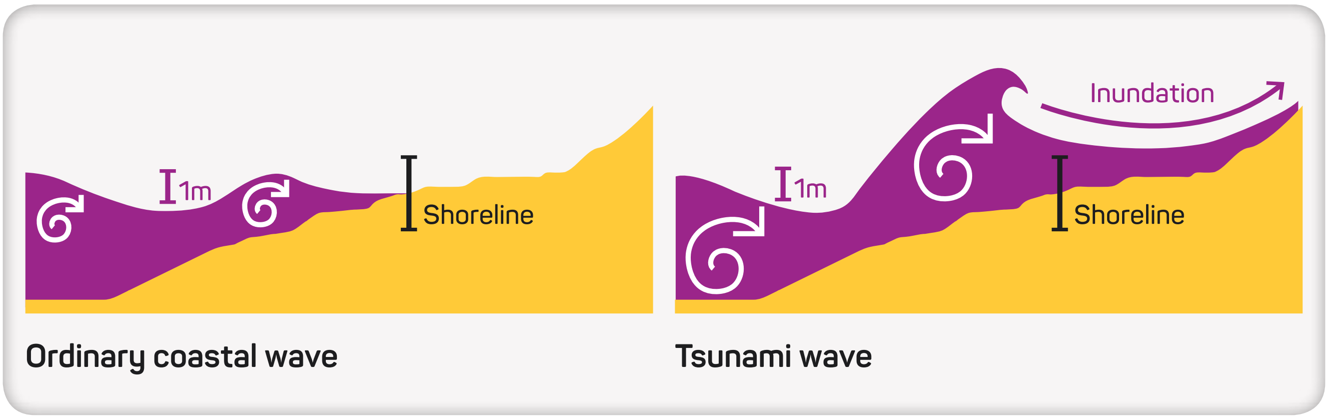


Figure 1 Wave behaviour of a coastal (wind-driven) wave compared to that of a tsunami wave. Source: Ministry of Civil Defence and Emergency Management, New Zealand, Tsunami Evacuation Zones: Director's Guideline for Civil Defence Emergency Management, at www.civildefence.govt.nz/assets/Uploads/publications/dgl-08-16-Tsunami-Evacuation-Zones.pdf (PDF 4.03MB).

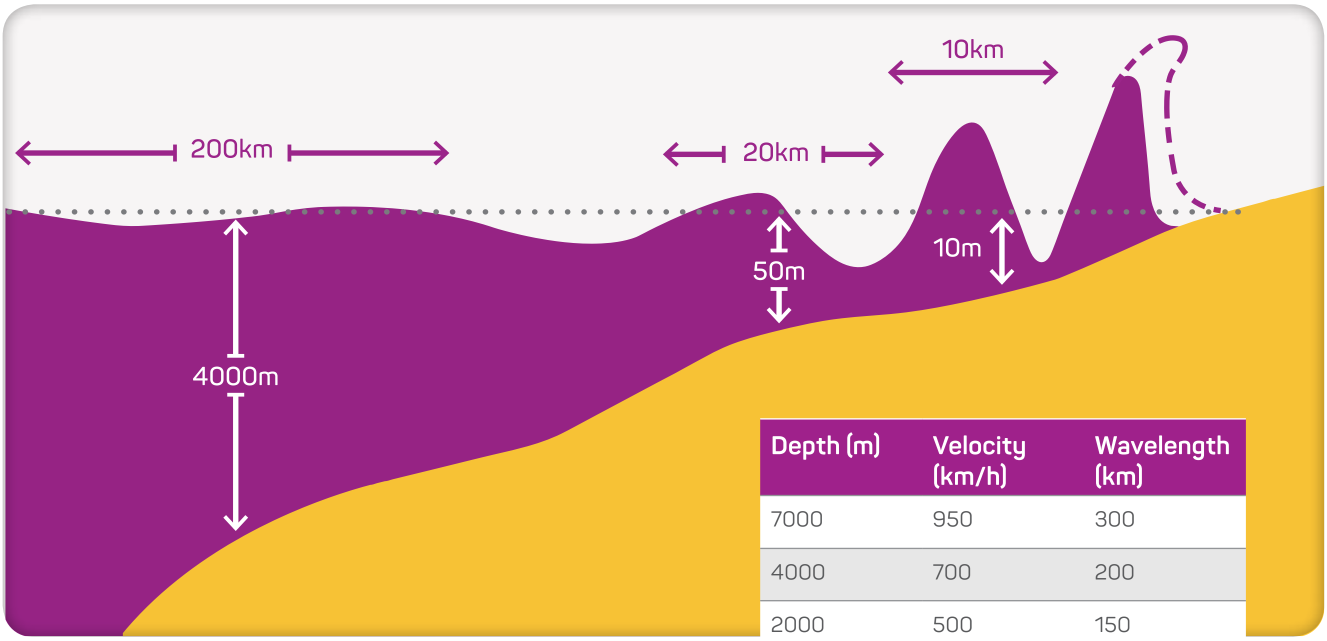


Figure 2 Schematic tsunami wave characteristics in the open ocean and near shore. Source: Tsunami Glossary, courtesy of International Tsunami Information Center.

Depth (m)	Velocity (km/h)	Wavelength (km)
7000	950	300
4000	700	200
2000	500	150
200	150	50
50	80	20
10	40	10

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

When a tsunami wave runs onto land, the run-up height above sea level that it reaches can be up to double the at-shore amplitude, 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.

The flooding produced by a tsunami can vary significantly. This is due to the many factors that influence tsunami magnitude at the coast, such as the configuration of the coastline; the shape of the ocean floor; reflection of waves; tides and wind-driven waves. Narrow bays, inlets and estuaries may cause funnelling effects that enhance tsunami magnitude.

In the deep ocean, a tsunami can travel at more than 900 kilometres per hour – comparable to the speed of a passenger jet. In shallow water close to the coast, tsunami waves slow down to about 40 kilometres per hour – comparable to the speed of a racing cyclist.

Tsunamis can travel large distances with limited energy losses; tsunamis can have sufficient energy to traverse entire oceans (see Figure 4).

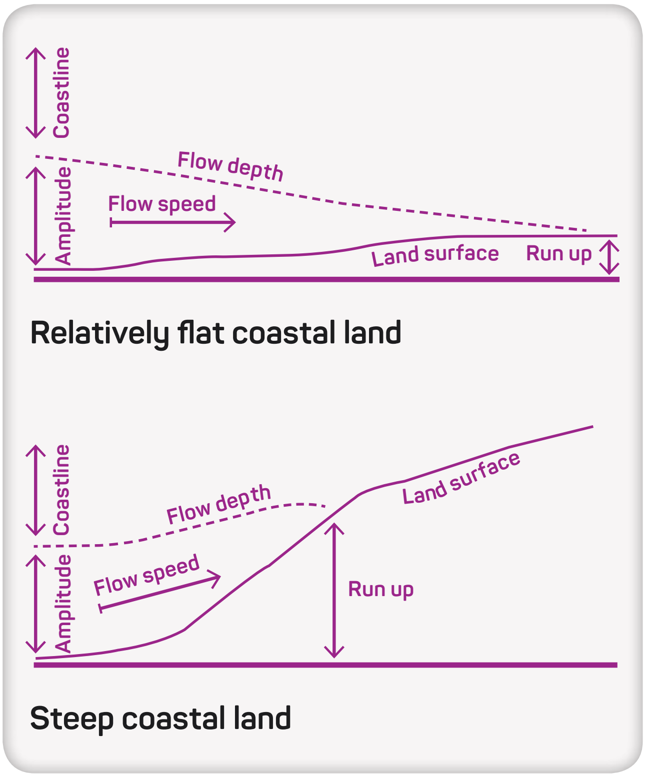


Figure 3 Run-up height and inundation distance on flat coastal land compared to steep coastal land for a tsunami of the same wave amplitude at the coast. Source: Ministry of Civil Defence and Emergency Management, New Zealand, Tsunami Evacuation Zones: Director's Guideline for Civil Defence Emergency Management, at www.civildefence.govt.nz/assets/Uploads/publications/dgl-08-16-Tsunami-Evacuation-Zones.pdf (PDF 4.03MB).

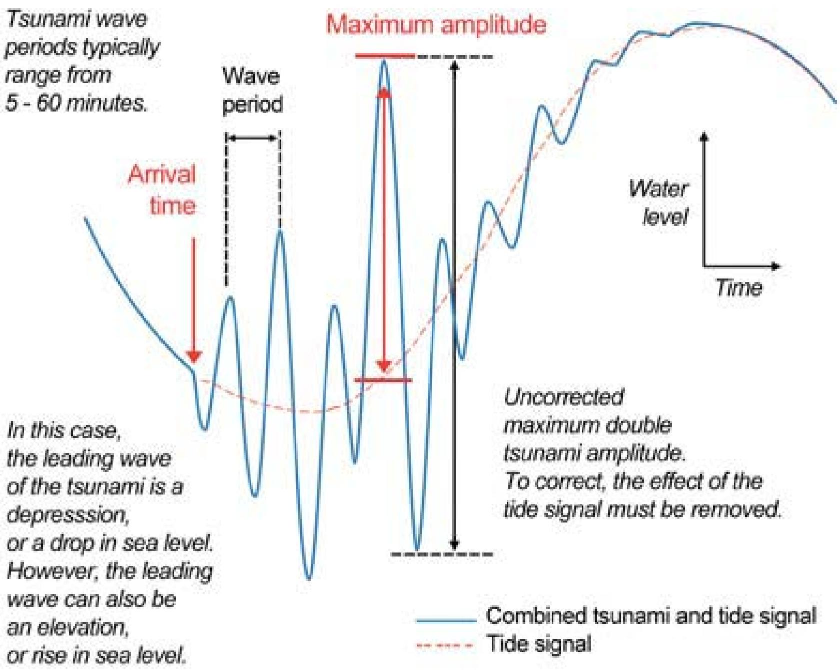


Figure 4 Tsunami wave level over time. Source: Tsunami Glossary, courtesy of International Tsunami Information Center.

How is a tsunami generated?

The most common cause of 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. Typically, tsunamis are generated by earthquakes that occur in trenches along subduction zones – areas on the earth where two tectonic plates meet and move towards one another, with one sliding underneath the other. Figure 5 illustrates the subduction zones surrounding Australia.

An earthquake creates an explosive vertical motion between the two 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 Australian Tsunami Warning System only monitors and detects tsunamis generated by undersea earthquakes. For more information, see Chapter 3: Tsunami warning systems.

Other sources of tsunami

Tsunamis can also be caused by submarine landslides; volcanic eruptions; land or ice slumping into the ocean (typically from the face of a continental shelf or Antarctica); meteorite impacts; or even the weather, when the atmospheric pressure changes very rapidly. Figure 6 provides a breakdown of tsunami event sources based on the historical tsunami event database of the National Centers for Environmental Information (NCEI, formerly NGDC) of National Oceanic and Atmospheric Administration (NOAA). For approximately ten per cent of the data, the cause of the tsunami could not be unambiguously identified.

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. Rather, tsunamis predominantly propagate out at right angles to the orientation of the trench within the subduction zone at which the earthquake occurred.

The finer details of a tsunami's path are determined by multiple factors, 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.

Bathymetry

Oceanic equivalent of topography – it measures the depth of the ocean floor from the water surface.

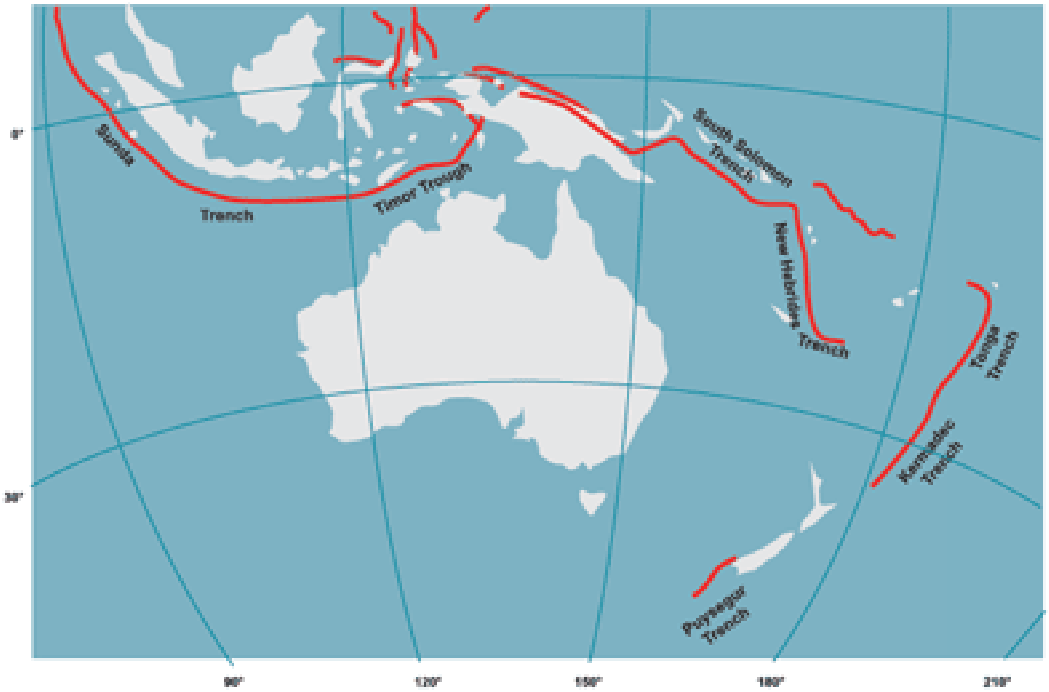


Figure 5 Subduction zones along tectonic plate boundaries (shown in red) surrounding Australia. These zones have the potential to generate a tsunami that may impact on Australian's coast. Source: Geoscience Australia; available at www.bom.gov.au/tsunami/about/atws.shtml

The impact of a tsunami can vary widely. A small tsunami may result in unusual tides or currents that can endanger swimmers or cause damage to boats and marinas. A large tsunami can cause widespread flooding and destruction; examples include the tsunami events that occurred off the west coast of Northern Sumatra on 26 December 2004; in Samoa on 29 September 2009; and in Japan on 11 March 2011. Large tsunamis can cause strong rips and currents in oceans around the world for up to a few days after the initial earthquake.

Natural signs

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

- The ground may shake in coastal regions, indicating a large undersea earthquake.
- As the tsunami approaches the shoreline, the sea may withdraw from the beach (like a very low and fast tide) before returning as a fast-moving tsunami.
- A roaring sound may precede the arrival of a tsunami.

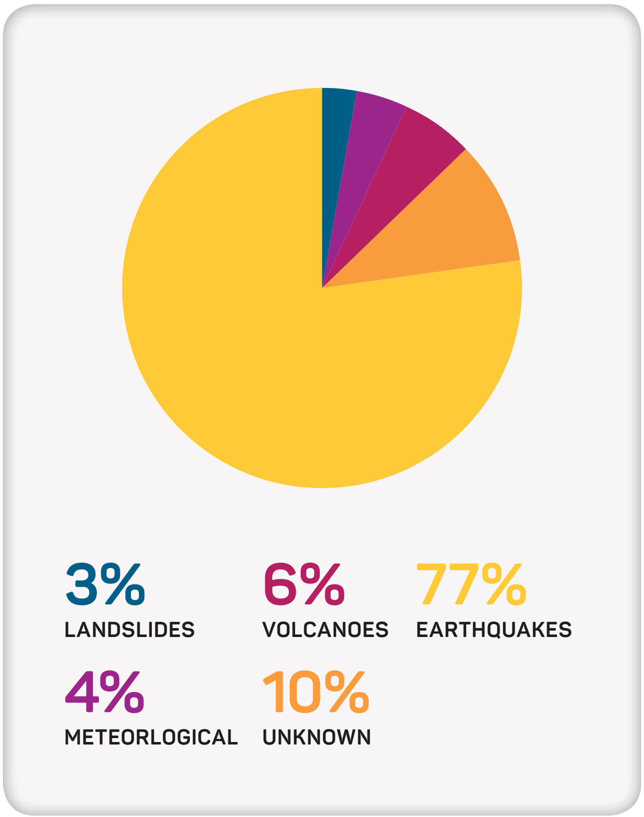


Figure 6 Tsunami event sources based on a historical tsunami event database. Source: Adapted from National Centers for Environmental Information (NCEI, formerly NGDC) of National Oceanic and Atmospheric Administration (NOAA). Image courtesy of Surf Life Saving Australia.

Chapter 2: Australian tsunami hazard and risk

Key points

- While dozens of tsunamis have been observed historically in Australia, they have primarily generated marine hazards with only a few instances of locally significant inundation. However, there is the potential for larger events to occur.
- Australia's historical tsunami record is not a reliable guide to our tsunami hazard, because the written history is short compared with the estimated frequency of damaging tsunamis. The geological record suggests that energetic marine inundations have occurred at some sites in the last few thousand years. It is difficult, however, to determine whether these deposits represent tsunamis or storm surges.
- The average return intervals of large tsunamis are very uncertain due to limitations both of observational data and in our understanding of key tsunami sources (such as earthquakes and landslides). Modelled tsunami average return intervals in hazard studies should generally be interpreted as 'nominal' or 'indicative' only.
- Subduction zone earthquakes to the north and east are the main source of tsunami hazard for Australia.
- Australia's highest offshore hazard is in north-west Western Australia, where the Australian coast is exposed to tsunamis generated off the coast of Indonesia.
- Methods for reducing tsunami risk include warning and mitigation.

What is a tsunami?

Australia has never experienced a catastrophic tsunami disaster on the scale of either the 2004 Indian Ocean tsunami or the 2011 Japan tsunami. However, the tsunamis that have impacted Australia during historical and pre-historical times are evidence that a genuine tsunami risk exists. Understanding tsunami hazard in Australia helps emergency managers and at-risk communities to mitigate the risk more effectively.

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 within two to four hours. Further, 50 per cent of Australians live within seven kilometres of the shoreline, which means a considerable proportion of the population is exposed to tsunami hazard. The exposed population can swell during peak holiday periods due to large numbers of domestic and international tourists spending leisure time at the beach.

The 2011 Japan tsunami reinforced the importance of tsunami risk management and brought about key changes in scientific knowledge, including the understanding of:

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

Tsunami risk

Risk assessment in Australia

The National Emergency Risk Assessment Guidelines (NERAG) provide a contextualised, emergency-related risk assessment method consistent with the Australian Standard AS/NZS ISO 31000:2009 *Risk management - principles and guidelines* (Australian Institute for Disaster Resilience, 2010). Risk assessment is key to risk management – however, it does not remove uncertainty entirely. Each event is unique; there are limits to the applicability of historical observations in forecasting future events.

For further information on the National Emergency Risk Assessment Guidelines (NERAG), consult the handbook at www.knowledge.aidr.org.au/nerag-handbook.

Hazard

Current knowledge of tsunami hazard in Australia, and the evidence for historical and pre-historical tsunami events, is outlined in the companion to this handbook, Guideline 1: Tsunami hazard modelling guidelines.

Probabilistic Tsunami Hazard Assessment of Australia

The Probabilistic Tsunami Hazard Assessment (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) as a result of 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. Further information is available from Geoscience Australia at www.ga.gov.au/ptha.

For further information, including principle-based guidelines on tsunami hazard modelling methodologies and data, consult Guideline 1: Tsunami hazard modelling guidelines at www.knowledge.aidr.org.au/media/5640/tsunami-planning-guidelines.pdf (PDF 4.39MB).

Exposure

Exposure refers to the elements at risk from a tsunami event. This could include individuals; dwellings, households and communities; buildings and structures; public facilities and infrastructure assets; agricultural commodities; environmental assets; and business activities.

Exposure information refers to the location and 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 how that element is likely to behave when subjected to natural and artificial hazards.

Comprehensive, nationally consistent exposure information is available from Geoscience Australia at www.ga.gov.au/scientific-topics/hazards/risk-and-impact/nexis.

Note: NEXIS 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 with consideration to 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 understanding:

- 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 understanding 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 an important step in the early stages of a risk management program. However, to understand the impact of a hazard, you should also develop a comprehensive understanding of the functioning of communities that it may affect. No community is a static target for research; each community functions with dynamic inter-relationships, exhibiting attitudes and behaviours on both individual and collective levels. Emergency managers need to understand these attitudes and behaviours – including a community's perception of emergency management and its past experience with disaster events – in order to support communities to build resilience and reduce vulnerability to risks.

In assessing tsunami risk in Australia, an initial hazard analysis will usually identify two broad levels of threat: Marine Threat and Land Inundation Threat. These correspond to two broad communities likely to contain elements at risk: maritime communities and land-based communities. Elements of these communities may overlap. For example, a resident of a land-based community may participate frequently in marine activities.

Maritime communities

The second broad at-risk group, maritime communities are exposed to fast-running tides and currents and/or significant wave action on and near beaches. Maritime communities are more mobile and transitory than land-based communities and may include tourists, recreational fishers, boaters, yachters, swimmers, surfers, foreshore fossickers and beach campers. This group may include tourists from outside the local area or from overseas, who may be particularly unfamiliar with warning arrangements in Australia.

In many parts of Australia, the exposure of maritime communities to the marine risks of tsunami can occur frequently (every few years) and may become the key focus of emergency management programs.

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

To develop strategies for maritime communities, emergency managers should explore social science approaches 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.

Tsunamis present a risk to boats and other vessels. The surge associated with tsunami waves can wash debris into vessels, propel them into other boats and obstacles, and/or capsize them. Any people who remain onboard a vessel when a tsunami arrives will be at risk.

Tsunamis also present a risk to marinas, moorings, ports and other marine-based infrastructure, as the sudden surge of water and current speeds may be well above those associated with normal tides and waves. In many cases, damage is unavoidable; the best advice may be to securely tether boats to moorings. A number of boats were lost in marinas along the coast of Western Australia during the 2004 Indian Ocean tsunami.

You should always prioritise life over property damage. Leave the area as soon as a Tsunami Warning is issued; ensure you are outside the area at risk well before the first wave arrives.

For further information on tsunami preparedness for maritime communities, see Chapter 4: Tsunami detection methods.

Further information is also available in the Guidelines and Best Practices for Tsunami Hazard Analysis, Planning, and Preparedness for Maritime Communities at http://itic.ioc-unesco.org/index.php?option=com_oe&task=viewDocumentRecord&docID=18495, developed by the National Tsunami Hazard Mitigation Programme in the United States.

Land-based communities

Land-based communities include residents and elements of commerce and industry that may be exposed to flooding and other on-shore effects of a tsunami. These communities can be integrated into conventional risk management initiatives.

In many cases, significant 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 vulnerabilities at an individual or household level.

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

Cities Project Perth

Several case studies illustrate the value of tailoring emergency management strategies to an individual community, such as the partnership between Geoscience Australia and emergency management agencies on the Cities Project Perth (Jones et al 2005). Further information is available from Geoscience Australia at: www.ga.gov.au/ausgeonews/ausgeonews200512/index.jsp.

This concept is also illustrated in the tsunami program outlined in Case study 3.

A catastrophic event may result in the breakdown of multiple cohesive factors within a community, causing disruption to local government services; sporting and social clubs; family and neighbourhood networks; shopping, banking and fuel supplies; and other elements. In this context, the functionality and morale of a community is invariably lowered and normal 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 imperatives, which can in turn affect emergency management priorities.

For more information on identifying and analysing collective vulnerabilities, consult the National Strategy for Disaster Resilience: Community Engagement Framework Handbook at www.knowledge.aidr.org.au/community-engagement-framework-handbook.

Chapter 3: Tsunami warning systems

Key points

- Australia has an active, 24/7 Australian Tsunami Warning System (ATWS), with clear roles and responsibilities for tsunami warning centres and emergency response agencies.
- A partnership between the Bureau of Meteorology and Geoscience Australia, the Joint Australian Tsunami Warning Centre (JATWC) provides tsunami alerts within 30 minutes of a significant undersea earthquake.
- The JATWC continuously monitors earthquake and tsunami, utilising Australian and global networks of seismometers, coastal tide gauges and deep ocean tsunameters.
- There are two levels of tsunami warnings: Marine Threat and Land Inundation Threat.
- Marine Threat is for dangerous rips and waves, and ocean currents. The key safety advice is to get out of water.
- Land Inundation Threat is for possible flooding to low-lying coastal areas in addition to danger in the marine environment. The key safety advice is to go to higher ground or move inland.
- Tsunami warnings are disseminated to the public through multiple channels; from traditional media such as television (TV) and radio, to websites, social media and other digital channels.
- The JATWC is one of the three Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO)-designated Tsunami Service Providers for the Indian Ocean Tsunami Warning and Mitigation System (IOTWMS). The JATWC provides tsunami threat information to the other 27 National Tsunami Warning Centres in the Indian Ocean.

Introduction

As a direct result of the 2004 Indian Ocean tsunami, the Australian Government identified a need to be able to warn the Australian population of such phenomena, to minimise loss of life and the economic impact on the Australian population should it be impacted by a tsunami event. An informal Australian Tsunami Alert System (ATAS) had been in operation at that time, but it had limited capabilities in tsunami monitoring and warning.

Between 2005-09, the Australian Government committed $68.9 million to establish an Australian Tsunami Warning System (ATWS; see Case study 1). This involved:

- establishing the Joint Australian Tsunami Warning Centre (JATWC) with 24/7 monitoring and warning capacity for Australia
- upgrading and expanding sea-level and seismic monitoring networks around Australia and in the Indian and South West Pacific Oceans
- implementing national education and training programmes on tsunami
- assisting the Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO) in developing the existing Pacific Tsunami Warning and Mitigation System (PTWS) and establishing an Indian Ocean Tsunami Warning and Mitigation System (IOTWMS)
- providing technical assistance to scientists, technicians and emergency managers in South-West Pacific and Indian Ocean countries, to support capacity development.

Case study 1: Australian Tsunami System Project Warning

The Australian Tsunami Warning System (ATWS) centres on the Joint Australian Tsunami Warning Centre (JATWC), operated jointly by Geoscience Australia in Canberra and the Bureau of Meteorology in Melbourne 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 Australian Tsunami Advisory Group (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 three pillars:

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

Four Intergovernmental Coordination Groups (ICGs) for the Indian Ocean, Pacific Ocean, Caribbean, and North-east Atlantic and Mediterranean Seas have been 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 Western Australian state office.
- The JATWC acts as one of the three 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 Australian Tsunami Warning System (ATWS) is an end-to-end tsunami warning and emergency response system. The ATWS involves key national and state and territory partners and agencies in earthquake detection; tsunami assessment and warning; and emergency response and recovery (see Figure 7).

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 (the ‘Bureau’) within ten 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 Ocean.

Based on this information, the Bureau’s 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 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's state and territory forecasting offices (SFCs). Warnings are disseminated to emergency management agencies, relevant government organisations, media outlets and the public in affected states and territories. The SFCs are the main liaison point for state and territory emergency services during tsunami events.

Australian Tsunami Warning System

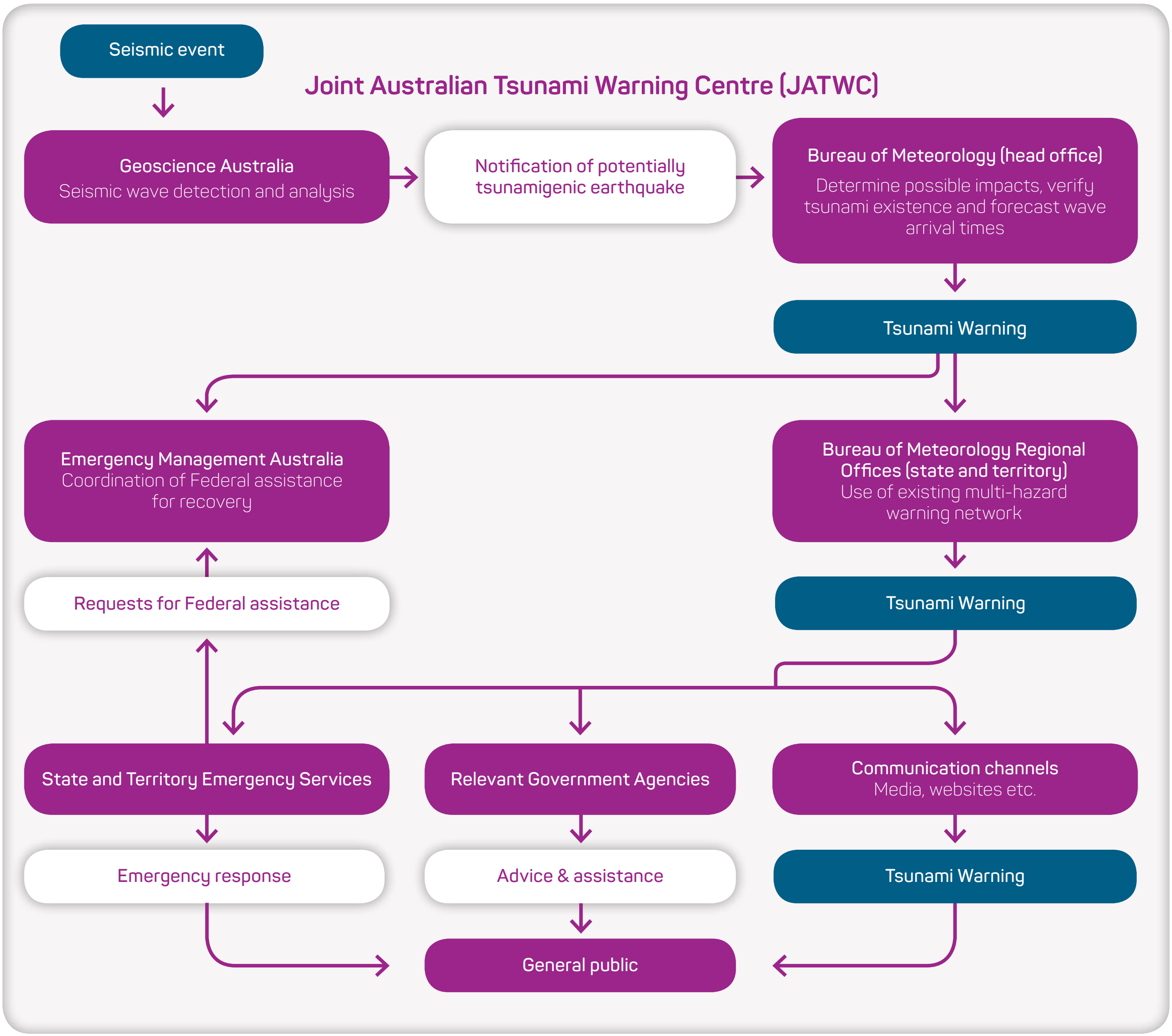


Figure 7 Schematic illustration of the Australian Tsunami Warning System (ATWS). Source: Joint Australian Tsunami Warning Centre (JATWC). Image courtesy of the Bureau of Meteorology, available at www.bom.gov.au/tsunami/about/atws.shtml

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 evacuation order 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 will be sought through Emergency Management Australia (EMA).

The Australian Government Crisis Coordination Centre (CCC) provides whole-of-government situational awareness to inform national decision making during a tsunami event. The CCC is part of the Department of Home Affairs and is managed by EMA.

During a tsunami event, the CCC works closely with the JATWC.

During a tsunami event, the CCC:

- provides upward reporting to the Australian Government
- facilitates activation of the National Crisis Committee if required
- coordinates logistical Australian Government assistance to state and territory emergency services if required.

More broadly, EMA works to improve public awareness and preparedness for tsunami in Australia.

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 (TV) and radio continue to be the key mass broadcasters, social media platforms such as Twitter and Facebook are becoming increasingly relevant as channels for disseminating warning messages.

An agency's role

Many other agencies 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.

Tsunami warning procedures

Joint Australian Tsunami Warning Centre operations

The Joint Australian Tsunami Warning Centre (JATWC) warning operations typically involve the following steps, illustrated in Figure 8.

Detect earthquake

Duty seismologists at GA monitor a network of seismometers from around the globe 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.

Assess tsunami potential

Duty tsunami incident staff at the Bureau 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 are used to 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 operated by the Bureau. The deep ocean stations measure tsunami waves in the open ocean while the coastal stations detect sea level changes close to shore.

Issue Tsunami Warning Cancellation 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, 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.

Need Emergency Advice? Please listen to your local radio and TV announcements or call **1300 TSUNAMI (1300 878 6264)** for latest warning information.

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

Tsunami Warnings and Schedule

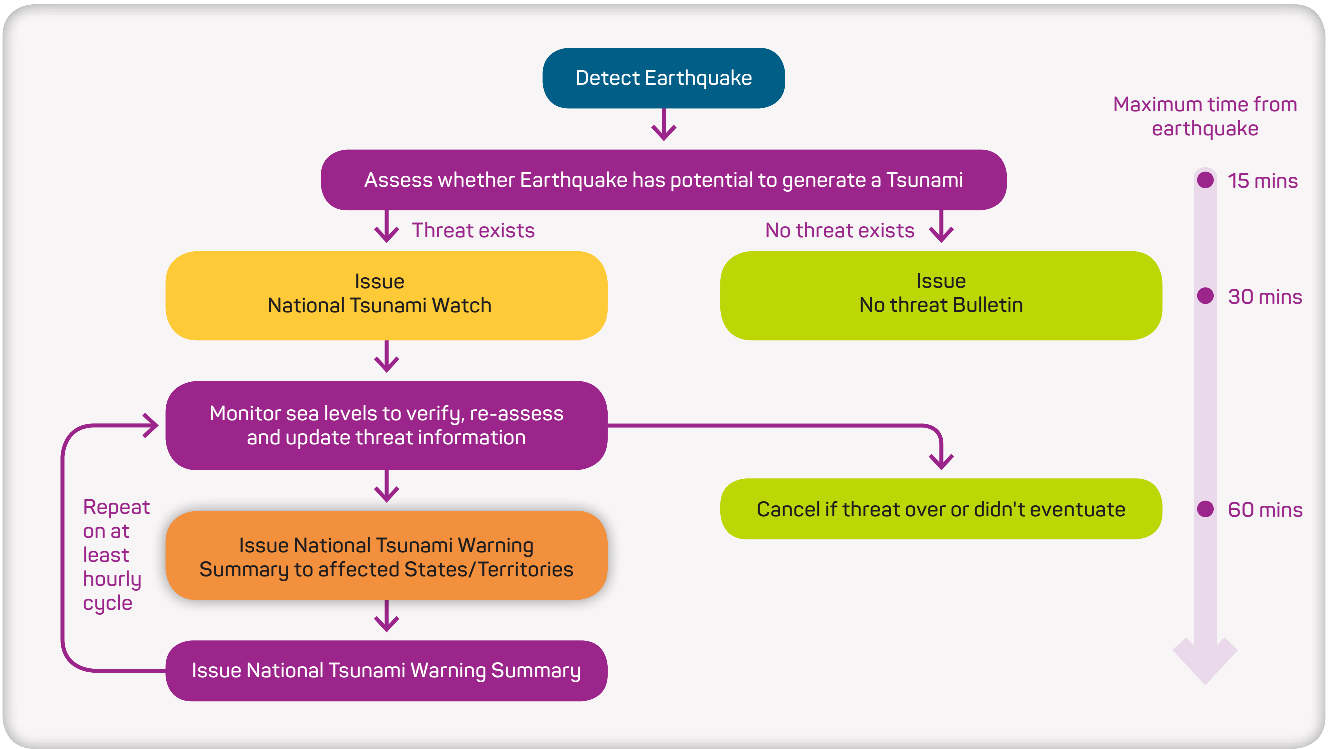


Figure 8 Tsunami warnings and schedule. Source: JATWC. Image courtesy of Bureau of Meteorology, available at www.bom.gov.au/tsunami/about/tsunami_warnings.shtml.

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

Threat levels

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

1. severity
2. certainty
3. urgency

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

The threat level is assessed separately for each Australian coastal zone, based on the predicted tsunami wave amplitudes in each zone.

Table 1: Tsunami threat levels

Threat	Description	SEWS
Marine 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.

For more information on the SEWS, consult the Public Information and Warnings Handbook at www.knowledge.aidr.org.au/warnings-handbook.

Determining factors for a JATWC response

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

- are located under the ocean or near the coast
- are at least of magnitude 6.5
- have a depth no greater than 100 kilometres.

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, based on the following breakdown:

- 10 minutes for GA to issue the first earthquake alert to the Bureau
- 20 minutes for the Bureau to assess the tsunami threat and issue the first national tsunami message.

Given both the Australian mainland and Tasmania are more than two 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 tsunami operations focus on seismic tsunami events. While other sources such as volcanic eruptions and undersea landslides are also capable of generating tsunamis, there is a significant lack of understanding and detection capability globally to deal with such non-seismic tsunami events. The JATWC does, however, have basic procedures in place to issue warnings for non-seismic events. In these events, warnings are issued to nearby coastal zones based on observed tsunami waves, without the guidance of tsunami model predictions.

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.

Australian offshore island territories

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

- the bathymetry effects may be different (for example, 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 corresponding responsible Bureau SFCs are listed in Table 2.

Table 2: Australian offshore island territories and Bureau 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 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 a tsunami

For Land Inundation Threats, tide levels may affect the extent of inundation. However, the complexity and variability of tidal effects are such that it is not practical to include them in standard tsunami warnings. 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 agencies to provide some guidance to the public about the effect of tides (see Case study 2).

Case study 2: Effect of tides on a 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 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 – emergency service agencies should seek guidance on the varying effects of tides on the tsunami threat.

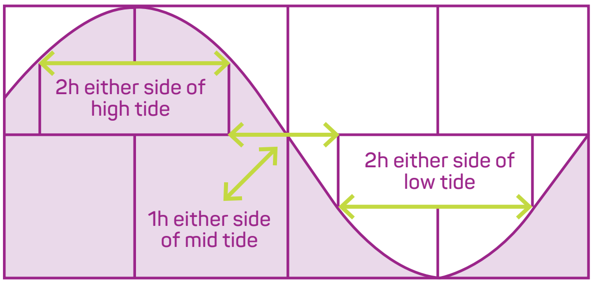
During each monthly tidal cycle, there are periods of several days when tides are neap, with only a very small variation between high and low tides. During these periods, tides will generally have a limited effect on a tsunami.

At other times, the effect of the tide can vary significantly along a coastline. To describe the effect accurately, warning centres would need to prepare multiple messages for relatively short stretches of coast. It would also be necessary to describe the tidal effects in short time periods: two hours either side of high tide time; one hour either side of mean tide time; and two hours either side of low tide time. 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.

The only practical approach to the problem is to provide generic guidance notes to support state agencies – more realistically, local authorities – to take responsibility for determining tidal influences at the local level. This guidance would need to be based on the pragmatic development of a reference table, itself based on the predicted tidal range on the actual days of tsunami threat. A suggested approach is detailed in Table 3.

Table 3: Effect of tides on a tsunami for different daily tidal ranges (see also Figure 9)

Daily tidal range	2 hours either side of high tide	1 hour either side of mid tide	2 hours either side of low tide
Less than three metres	Minor increase of tsunami	No effect on tsunami	Minor reduction of tsunami
Three to five metres	Moderate increase of tsunami	Minimal effect on tsunami	Moderate reduction of tsunami
Over five metres	Major increase of tsunami	Minor effect on tsunami	Major reduction of tsunami



Definition of Terms used above on the effect to tsunami	
Minimal	Less than 0.1 metres
Minor	0.1 - 0.5 metres
Moderate	0.5 - 1.0 metres

Figure 9 Daily tide cycle. Source: Australian Institute for Disaster Resilience.

In theory, coastal zones would need to be subdivided into relatively homogeneous sections, where the variation in tide times was less than one-and-a-half hours and the variation in tidal range for the day was less than one metre. This subdivision of a zone would need to be calculated if either criterion were reached.

In practice, the only practical approach is to use the table above for each zone, accepting the limited risk of the need to subdivide any coastal zones around Australia.

The tidal variations at Hay Point on the northern central Queensland coast, over a six-week period, are a useful illustration (see Figure 10).

The local authority would need to use different rows from Table 3 to determine the effect of the tide for any particular day.

It would not be practical or realistic to expect local authorities to predetermine tidal ranges for all zones, for all days into the future. However, it is essential that appropriate officers within local authorities have:

- a basic understanding of tidal variations
- copies of tide tables, which they know how to use.

This will allow a relatively efficient determination of the likely effects of tides on a tsunami in their local area.

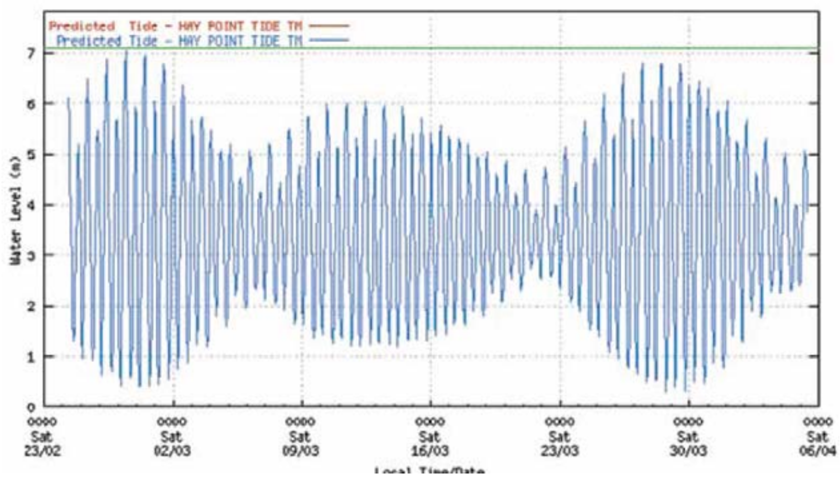


Figure 10 Tidal variations at Hay Point, Queensland. Source: Australian Institute for Disaster Resilience.

Communicating tsunami warnings to the public

JATWC tsunami warning product suite

The product suite for an Australian tsunami event includes three primary product types: Bulletins, Watches and Warnings (see Figure 11).

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 and/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 liaison between Bureau SFCs and relevant state and territory emergency management organisations. Warnings convey the severity of the threat for different coastal forecasting districts (either a Marine Threat or a Land Inundation Threat). The Australian offshore territories are treated as separate, individual entities.

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

Messages: Types and Purpose	Messages: Layout & ContentMessages
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
National or State/Territory Watch: To advise people that a tsunami threat **may exist** and that they should look out for further updates	**Media Instructions:** How urgently message/s should be broadcast. Use of Standard Emergency Warning Signal (SEWS) or not
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	**Message Title and Issue:** Time Type, date/time and number sequence of message
National Warning Summary: To provide the public, media and emergency authorities with the status of tsunami warnings nationally	**Headline Message:** Key message; eg. No Threat, Potential Threat, Threat
Event Summary: To provide the public, media, emergency authorities and government with summary information that can be used in post-event analysis	**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

Figure 11 Tsunami warning products. Source: JATWC. Image courtesy of Bureau of Meteorology, available at www.bom.gov.au/tsunami/about/tsunami_warnings.shtml.

Some states and territories may be the subject of a Warning whilst 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.

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 nationally including to offshore territories.
- 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 nationally.
- All messages are posted on the JATWC website at http://www.bom.gov.au/tsunami to provide a consolidated overview of the status of current warnings.

Communication channels

Speed and accuracy are key success factors in disseminating tsunami warnings. 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 include:

- the internet (specifically, the JATWC webpage)
- Emergency Alert (a telephone-based warning system)
- 1300 TSUNAMI telephone service
- low flying aircraft equipped with public address systems
- Marine Rescue Vessel public address systems
- marine satellite phone
- community notices in identified hubs
- distribution through established community liaison networks, partnerships and relationships.

For more information on communication channels and warnings dissemination, consult the Public Information and Warnings Handbook at: www.knowledge.aidr.org.au/warnings-handbook.

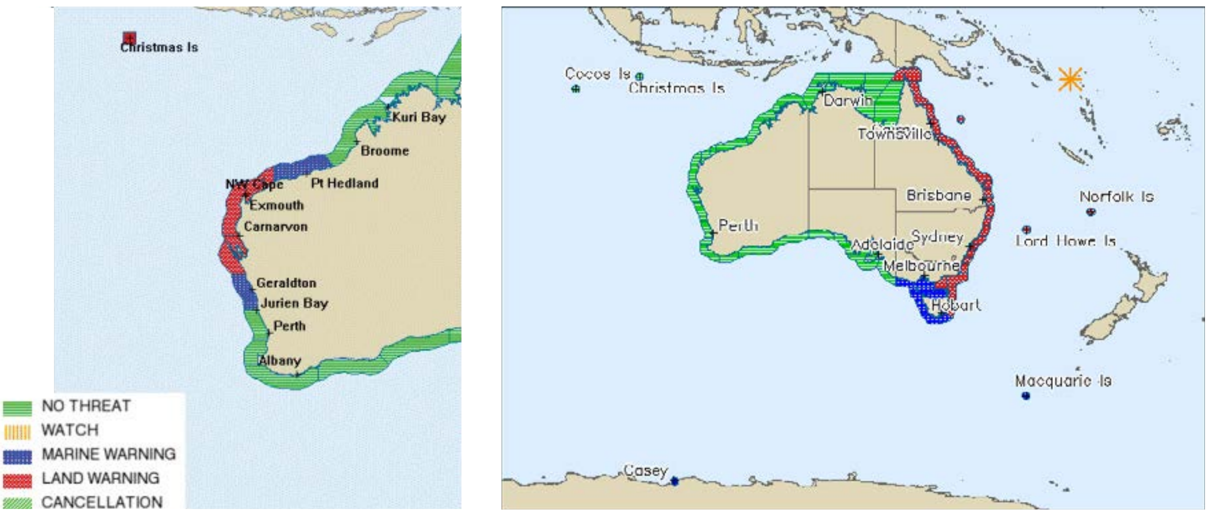


Figure 12 Examples of different tsunami warning levels along the west and east coasts of Australia based on two different hypothetical earthquake scenarios. Source: JATWC. Image courtesy of Bureau of Meteorology.

The JATWC website provides freely accessible coastal threat graphics, indicating states and territories currently under threat and the specific coastal zones at www.bom.gov.au/tsunami/index.shtml (see Figure 12).

Key public safety advice messages

To assist the community, tsunami threats in Tsunami Warnings are categorised into two 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 agencies 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 Australian Tsunami Advisory Group (ATAG) mechanism (see Table 4).

There are two types of JATWC tsunami warnings: Marine Threat and Land Inundation Threat.

Marine Threat

This type of warning advises of potentially dangerous waves; strong ocean currents in the marine environment; and the possibility of some localised overflow onto the immediate foreshore. Marine tsunamis can cause dangerous waves, and strong, unpredictable ocean currents and rips; posing 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 type is unlikely to necessitate major evacuations of land areas, the danger of Marine Threats should not be underestimated; particularly to those who spend time in the ocean.

Land Inundation Threat

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

Land Inundation Threat is a less frequent, but extremely dangerous, threat. SEWS would need to be broadcast in this type of event, notifying the public to listen for and seek out emergency response advice from their local authorities.

In a land inundation event, evacuation of low-lying coastal areas is likely to occur. Evacuation advice would vary across the individual warnings for each state and territory as pre-determined by emergency management organisations.

For more information on planning for an evacuation, consult the Evacuation Planning Handbook at www.knowledge.aidr.org.au/evacuation-planning-handbook.

For more information on tailoring and constructing warning messages, consult the Public Information and Warnings Handbook at www.knowledge.aidr.org.au/warnings-handbook; and the companion Guideline 1: Warning message construction: Choosing your words at www.knowledge.aidr.org.au/media/5978/guideline-warning-message-construction.pdf (PDF 433KB).

Table 4: Key public safety advice messages

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

Marine Threat	Land Inundation Threat
Evacuations from communities are not 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 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 State Emergency Services has ordered the evacuation of 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 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. Take care in other coastal areas where low-level effects may be observed.	

Chapter 4: Tsunami detection methods

Key points

- A seismometer measures the vibrations of the earth at a single location over time.
- A network of seismometers can be used to determine earthquake magnitude and location within approximately 10 minutes of an initial earthquake rupture.
- Deep ocean tsunami detection sensors (also known as tsunami buoys or tsunameters) can detect tsunami wave passage in the open ocean with up to one-millimetre accuracy.
- Coastal sea level stations (also known as tide gauges) consist of sensors of acoustic, radar and/or water pressure to measure variation in the water level near the coast.
- The Australian Sea Level Monitoring Network operated by the Bureau of Meteorology has two key components: an Australian deep ocean sea level network and an Australian coastal sea level network.
- The Australian deep ocean sea level network consists of six tsunameters, paired for redundancy, in the Indian Ocean, the Coral Sea, and the Tasman Sea.
- The Australian coastal sea level network includes approximately 40 coastal sea level stations around Australia's coastlines and its offshore islands, as well as in 14 Southwest Pacific countries.
- New tsunami detection techniques are emerging to take advantage of commercial undersea cables and Global Navigation Satellite Systems (GNSS).

Introduction

When the 2004 Indian Ocean tsunami occurred, real-time, deep ocean observing systems were virtually non-existent in the Indian Ocean; tsunami sources could only be estimated through seismic parameters. Since then, significant progress has been made in understanding tsunami mechanisms, and an advanced network of tsunami observing systems has been deployed.

Types of detection methods

Seismometers

A seismometer measures the vibrations of the earth 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 both 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 three 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 eight 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

Deep ocean tsunami detection sensors (also known as 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 of the tsunameters currently deployed are DART™ (Deep ocean Assessment and Reporting of Tsunami) buoys, developed initially in the United States by the Pacific Marine Environmental Laboratory of the National Oceanic and Atmospheric Administration (NOAA).

Each tsunameter consists of a sea-bed bottom pressure recorder (or BPR) and a surface buoy. The BPR measures the weight of the water column above it. When placed on the sea-bed approximately five kilometres deep, the BPR is insensitive to wind-driven waves and swells, due to the extremely small proportion of weight that ocean surface occupies in the entire water column.[5]

The BPR is, however, 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 rather than merely disturbing the shallow ocean surface. 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 Joint Australian Tsunami Warning Centre (JATWC).

The tsunami detection system has two 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 six 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 in the sea floor. In event mode, the device reports the sea level data of one-minute intervals, at five- to seven-minute intervals to the satellite, for the following three hours. This supports rapid verification of a possible tsunami. For distant sources, tsunameters can be manually switched to event mode by an operator.

5 This proportion can be explained as ten metres over five kilometres; one over 500, or 0.2 per cent.

Placement of tsunameters

Tsunameters should be 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. Ideally, tsunami bottom pressure sensors should be placed at a depth of 3000-5000 metres to prevent contamination of the signal by other types of waves. International maritime boundaries should also be considered when deploying tsunameter systems.

The life cycle of a tsunameter (bottom pressure sensor and surface communications buoy) is approximately two to four years. The Bureau's maintenance program involves the replacement of the surface buoy and the sea-floor pressure sensor every one to two years.

To offset the effects of the harsh ocean environment, each tsunameter station has in-built communication redundancy. In addition, two tsunameters are deployed near each other in each ocean area, mitigating the risk of losing vital information should one tsunameter fail. Six tsunameters are currently deployed: two in the Indian Ocean, two in the Coral Sea, and two in the Tasman Sea. They form the Australian deep ocean sea level network – one component of the broader Australian Supported Sea Level Monitoring Network, operated by the Bureau of Meteorology (the 'Bureau'; see Figure 13).

Australia also accesses data from other countries participating in the Indian Ocean Tsunami Warning and Mitigation System (IOTWMS) and the Pacific Tsunami Warning and Mitigation System (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, using the World Meteorological Organisation's dedicated Global Telecommunication System (WMO GTS). Figure 14 provides a snapshot of the global DART network at July 2018.

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. These are installed at practical locations, such as on piers near the coast. Some require higher specifications for climate monitoring purposes; all require real-time sea level reporting capabilities for effective tsunami monitoring.

Approximately 40 tide gauges are deployed along Australian coastlines in Australia and 14 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 (see Figure 13).

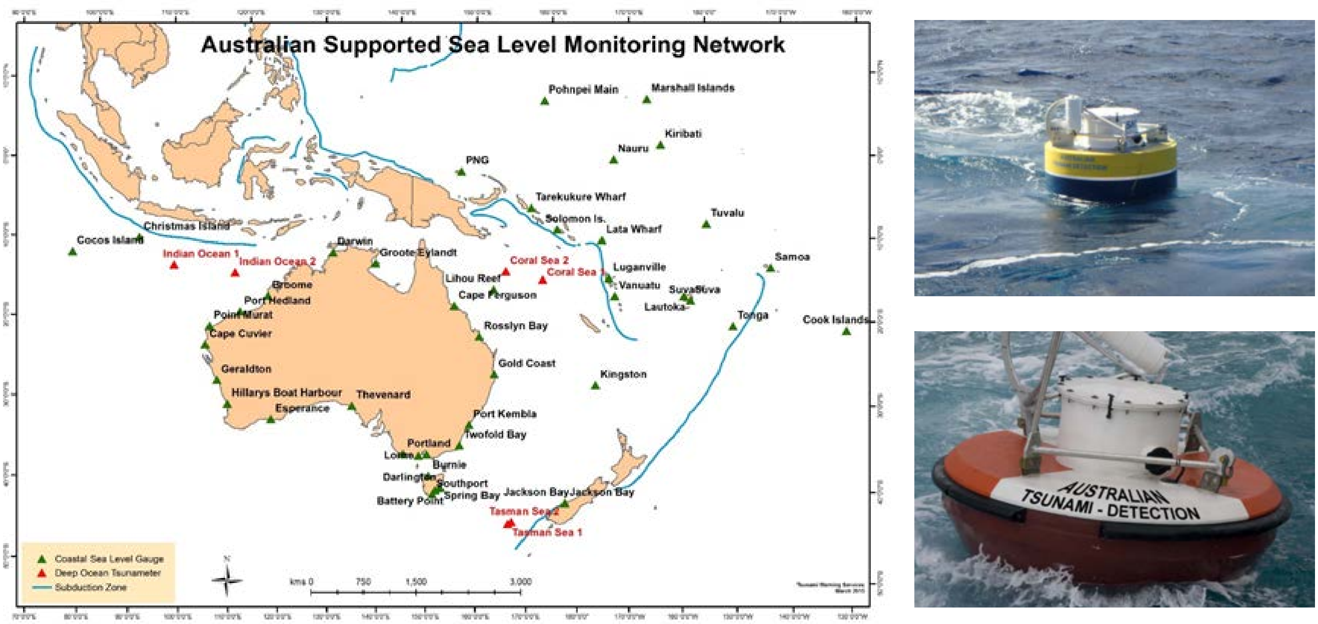


Figure 13 Australian Supported Sea Level Monitoring Network operated by the Bureau; examples of a tide gauges and a DART™ buoy. Source: Images courtesy of Bureau of Meteorology.

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

Observations from sea level gauges verify the existence and local effects of a tsunami and provide information to help determine when a tsunami threat has passed.

Emerging detection techniques

While earthquake and tsunami detection capabilities have improved in Australia and around the world, 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 like commercial fibre-optic cables.
- Coastal radars and infra-sound sensors can help detect tsunamis located significantly offshore; 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 15 provides a schematic illustration of what future, enhanced ocean observation capabilities in tsunami detection might look like.

Ionospheric disturbances

Tsunamis can produce gravity waves that propagate up to the ionosphere – a region of the Earth's atmosphere where there is a high concentration of ions and electrons that can affect the spread of radio waves. These ionospheric disturbances can be studied in detail using ionospheric total electron content (TEC) measurements, collected by continuously operating ground-based receivers (such as GPS) from the Global Navigation Satellite Systems (GNSS).

Further information is available from the United States NOAA at www.pmel.noaa.gov/news-story/detecting-tsunami-disturbances-earths-atmosphere.

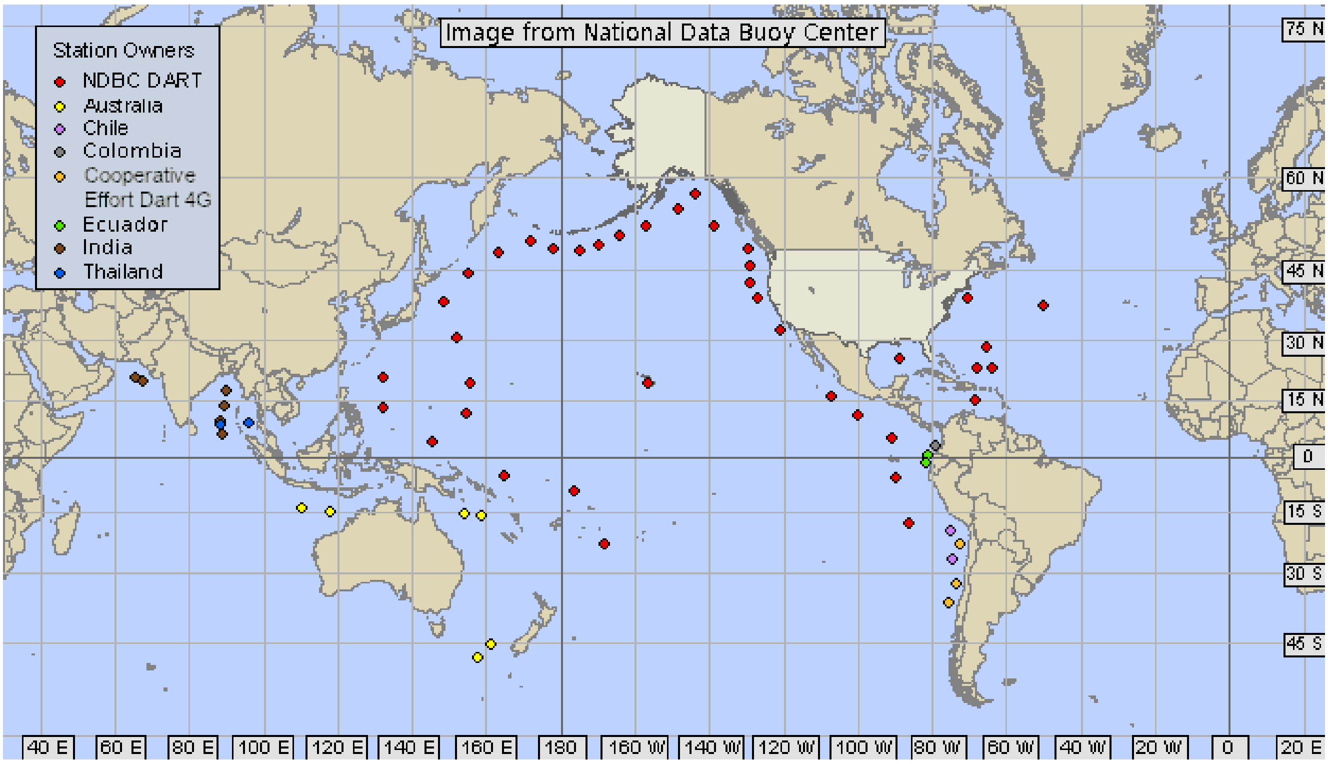


Figure 14 Global DART Tsunameter Network including six Bureau-operated DARTs at July 2018. Source: National Oceanic and Atmospheric Administration (NOAA) National Data Buoy Center, United states, available at www.ndbc.noaa.gov/dart.shtml.

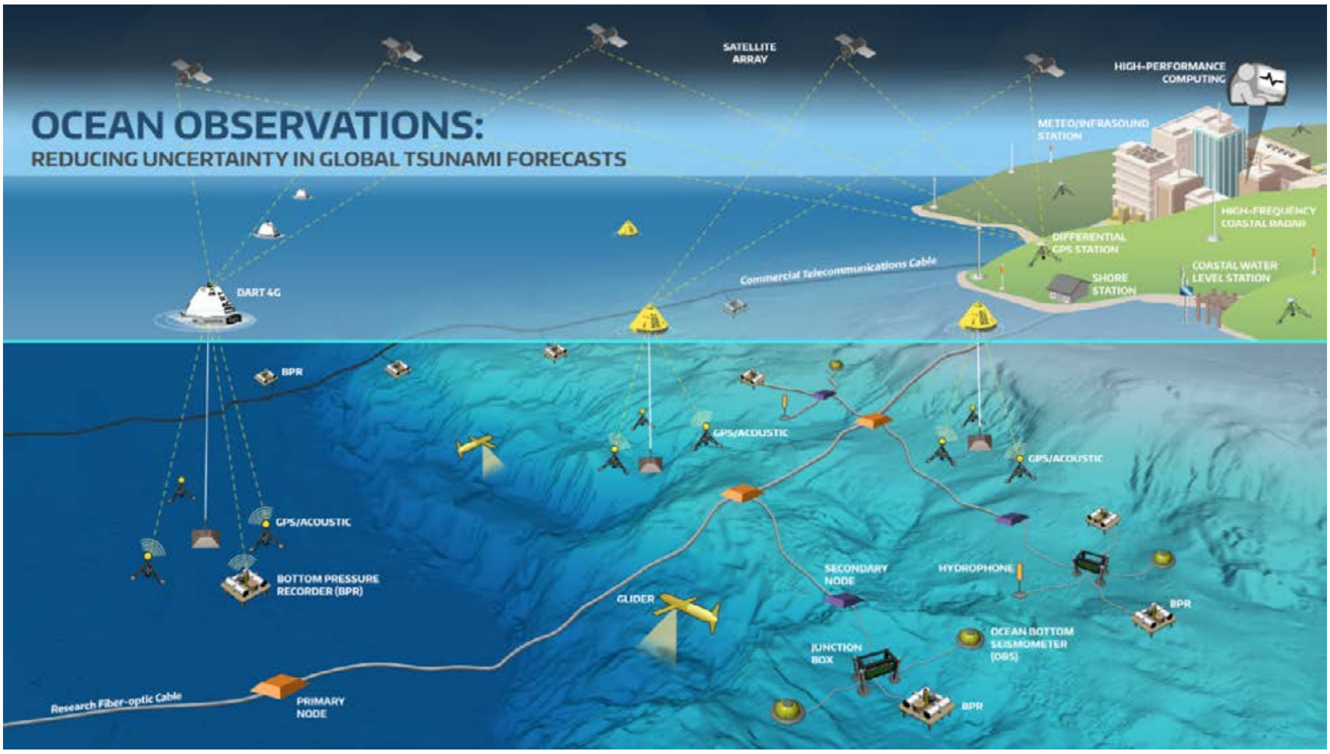


Figure 15 A schematic illustration of possible future global ocean observations to reduce uncertainties in tsunami forecasts. Source: The Pacific Marine Environmental Laboratory of the United States NOAA.

Chapter 5: Emergency preparedness for tsunami

Key points

- Emergency preparedness for tsunami encompasses emergency planning, capability development, response, recovery, exercising and community engagement.
- Tsunami emergency plans should be developed where an identified tsunami hazard is likely to pose a risk to life or property.
- Planners should develop an accurate understanding of available tsunami risk information when developing the plan.
- Strategies and arrangements detailed within tsunami emergency plans should link with established warning systems.
- Emergency managers involved in managing responses to tsunami should have an understanding of tsunami science, tsunami risk, warning systems and tsunami emergency plans.
- Tsunami plans should be developed with community involvement and ownership, with an understanding that community members have a responsibility in keeping themselves safe.
- Evacuation planning is a critical component of plans.
- Plans should be regularly exercised with learning incorporated into emergency procedures.
- Maps and visualisation tools should be an essential component of the community understanding its risks.

Introduction

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 build community preparedness through emergency planning, emergency management capability development, establishment of warning systems, exercising and community education.

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 tsunami.

There is a recognised need to improve the capability of emergency services and functional areas to manage emergency responses to tsunami. Plans are now available at various levels to assist with preparedness. It is essential that emergency managers involved in managing responses to tsunami have an understanding of tsunami science, tsunami risk, warning systems and tsunami emergency plans.

For further information, refer to the state tsunami plans in each jurisdiction, as well as the Plans and Procedures for Tsunami Warning and Emergency Management (2016) at www.ioc-tsunami.org/index.php?option=com_content&view=article&id=356:sop-manual&catid=20&lang=en&Itemid=68, developed by the Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO).

Tsunami emergency planning

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 or special event differ from the general coordination arrangements set out in the main or supporting plans for the area.

Tsunami emergency plans should be holistic in scope; encompassing arrangements for all necessary activities, for all magnitudes of tsunami. The development of plans should involve all agencies likely to play some part during tsunami emergencies. People who are 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 tsunami enables a proactive response to tsunami emergencies, by developing an understanding of 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 16 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 systems, to ensure guidance is given as to how to respond to different types of tsunami warning products. Tsunami emergency plans 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 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 agency in an operational context. Plans may be written in advance and subsequently modified before their release during tsunami response operations.

Developing tsunami emergency plans

Global tsunami preparedness is maturing; from the establishment and operation of robust warning systems like the Australian Tsunami Warning System (ATWS), to building community resilience through mitigation and prevention. Building community resilience involves community engagement, knowledge sharing and capability development.

The ATWS is operated under the international guidelines of the IOC-UNESCO . Australian state emergency services have been part of the ATWS development since its inception in 2005. These agencies play a vital role in informing the public of potential tsunami impacts – the 'last mile' of a tsunami warning system.

A tsunami emergency plan should follow the comprehensive Prevention-Preparedness-Response-Recovery (PPRR) approach to emergency management.

Consider the following in planning for tsunami:

- Prepare and maintain tsunami plans, including through reviews and exercises.
- Train emergency management personnel and operations centre and field staff.
- Develop response protocols for multi-agency effort, under the overall control of a designated lead agency for tsunami incidents.
- Ensure appropriate agencies, 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.
- Develop and maintain tsunami intelligence systems that complement emergency plans.
- Develop arrangements for fire and hazardous material incident planning, structural collapse and landslide incident planning in the context of tsunami.
- Develop emergency management strategies for waterways including marinas, boat ramps and ports.

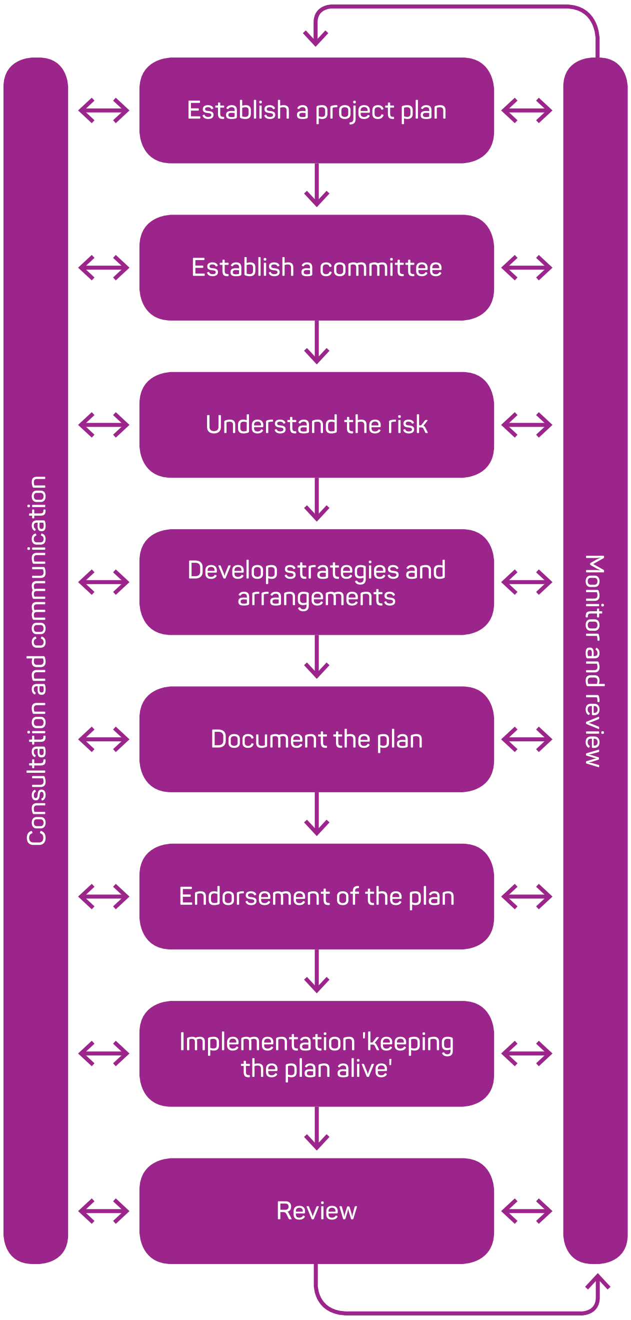


Figure 16 Continuous emergency planning process. Source: Australian Institute for Disaster Resilience.

> For further information on Australia's Total Warning System, consult the Public Information and Warnings Handbook at www.knowledge.aidr.org.au/warnings-handbook.

- Conduct exercises to test arrangements.
- Work with communities to plan and prepare for, respond to and recover from tsunami in their area, including through community engagement strategies and awareness campaigns.
- 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 the 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
  - key components of the emergency plan.
- Use maps to mark at-risk areas as well as evacuation relief centres and assembly areas.
- Plan for evacuation centre and welfare management, including relief and recovery arrangements.

Intergovernmental Coordination Group

To assist countries to build tsunami resilience, the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWMS) developed the Indian Ocean Tsunami Ready (IOTR) Program and National Recognition Guidelines. The guidelines are available at http://www.ioc-tsunami.org/components/com_oe/oe.php?task=download&id=36302&version=1.0&lang=1&format=1; Table 5 shows the key steps/indicators.

Table 5: Indian Ocean Tsunami Ready Indicators

10 Tsunami ready indicators		
Mitigation (MIT)	**Preparedness (PREP)**	**Response (RESP)**
MIT 1: Have Community Tsunami Risk Reduction Plan	PREP 1: Produce easily understood tsunami evacuation maps as determined to be appropriate by local authorities in collaboration with communities	RESP 1: Address tsunami hazards in the community's Emergency Operations Plan (EOP)
MIT 2: Have designed and mapped tsunami hazard – inundation zones	PREP 2: Develop and distribute outreach and public education materials	RESP 2: Commit to supporting the Emergency Operations Centre (EOP) during a tsunami incident, if an EOC is open and activated
MIT 3: Have a public display of tsunami information	PREP 3: Hold at least three outreach and public educational materials	RESP 3: Have redundant and reliable means for a 24-hour warning point (and EOC if activated) to receive official tsunami threats
	PREP 4: Conduct an annual tsunami community exercise	RESP 4: Have redundant and reliable means for a 24-hour warning point and/or EOC to disseminate official tsunami alerts to the public

Source: Guidelines for Indian Ocean Tsunami Ready Programme, published online by IOC-UNESCO Tsunami Programme at http://www.ioc-tsunami.org/index.php?option=com_oe&task=viewDocumentRecord&docID=20236

- Incorporate evacuation route maps into plans, and arrangements for pre-deployment of resources to staging areas outside the impact area.
- Develop arrangements for the redeployment of resources to staging areas outside the impact area.
- Build the search and rescue capability of emergency service agencies.
- Monitor potentially affected areas and undertake rapid impact assessments. Restrict access to and maintain security of evacuated areas.

Key considerations for tsunami emergency planning

Planning for marine- and land-based assets and users

A tsunami plan should consider both marine- and land-based assets and users who may be vulnerable to tsunami (see Table 6).

Tsunami emergency management of waterways

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).

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 ships 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.

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.

For further information, refer to the Guidelines and Best Practices for Tsunami Hazard Analysis, Planning, and Preparedness for Maritime Communities at http://itic.ioc-unesco.org/index.php?option=com_oe&task=viewDocumentRecord&docID=18495, developed by the United States National Tsunami Hazard Mitigation Programme.

Tsunami 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
- monitoring and evaluating implemented strategies.

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

Marine-based assets and users	Land-based assets and users
• Boats and their crew in shallow water • Beach users, including swimmers, surfers, sunbathers, and fishers • Divers and snorkelers • Aquaculture industries • Submarine power, telecommunications, fuel and water supply lines • People and facilities in ports, harbours and marinas • Sewerage outfalls	• People and property in caravan parks and camping areas in low-lying coastal areas or on floodplains in tidal river areas • Coastal infrastructure including roads, bridges, power, water, gas, sewerage and telecommunications • Residential, commercial and industrial buildings and their occupants in low-lying coastal areas or on floodplains in tidal river 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 • Walkers in coastal parks and reserves

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

Capability development is achieved through organisation, efficient use of skilled human resources, effective networks of similar organisations, and government support. Conducting training and education is particularly important for capacity building with regards to tsunami.

Community engagement for tsunami

Community engagement is a crucial aspect of building community resilience to any hazard type. Community engagement refers to working with communities to improve preparedness, prevention, response and recovery; in this context, in relation to tsunami. Community engagement programs aim to empower people using training, tools and knowledge; promoting the sharing of responsibility for building a more resilient community.

Consider the following aspects of community engagement:

- Develop an informed understanding of tsunami 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.
- Consult 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 the Preparedness-Planning-Response-Recovery (PPRR) cycle.
- Build a culture where community engagement and operational response are seen as equally important, complementary strategies for emergency management.

Emergency planners should build internal and external capacity to engage the communities they serve. The breadth of engagement programs delivered for tsunami should be tailored to meet the needs of diverse community segments, particularly those most at risk.

> Examples for working in community plans or engagement materials are provided in Case study 3.
>
> For more information on community engagement and the linkages with national programs, consult the National Strategy for Disaster Resilience: Community Engagement Framework Handbook at www.knowledge.aidr.org.au/community-engagement-framework-handbook.

Case study 3: Typical responsibilities for members of the community

Source: adapted from New South Wales State Tsunami Plan (2015)

Prepare now – know how to respond appropriately and recover effectively to help your community become more resilient.

Preparedness

- **Know your risk**
  Understand the potential risks and impact of tsunami at home, work and places you visit. Know where to go in case you are affected.
- **Plan for what you will do**
  Develop home emergency plans to identify who to contact, what to do, and where to go and when. Share plans and practice them with family, friends, pets and neighbours.
- **Businesses: develop continuity plans**
  Develop continuity plans to prepare, minimise losses and maintain essential services during or soon after a tsunami.
- **Be informed**
  Know where to find risk information and understand warnings, triggers and the safest actions to take in a tsunami.
- **Be involved**
  Work with local emergency services, local leaders, councils and other stakeholders to anticipate and manage emergencies that could affect your community.

Response

- **Be aware**
  Monitor emergency warnings and broadcasts and follow the advice of emergency services.
- **Look out for each other**
  Share information with family, friends and neighbours and help those that may need assistance.
- **Leave early**
  Leave potential tsunami affected areas early if you are at risk of tsunami or are advised by emergency services to evacuate.
- **Do not go to the coast to watch the tsunami**
  Do not go to the coast to watch the tsunami – there is the possibility of dangerous, localised land inundation of the immediate foreshore.

Recovery

- **Stay clear of tsunami affected areas**
  Stay clear of tsunami affected areas until you are advised by emergency services that it is safe to enter.
- **Ensure your home is safe before entering**
  Check for structural damage and potential risk of electrocution.
- **Manage ongoing health, safety and hygiene**
  Ensure personal items, food and water in contact with water from the tsunami are not consumed. Wear protective clothing while cleaning.
- **Understand where and how to get support**
  Understand where and how to get support and assistance with your recovery.

Tsunami response operations

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

- rare occurrence – few operational staff will have the opportunity to develop experience in response
- potential to cause widescale damage along an entire coastline
- potential to generate global media interest.

It is essential emergency managers affirm the protection of life and the minimisation of disruption to functioning communities as operational objectives. These objectives should be supported by workable operational strategies.

Emergency managers should develop an understanding of the key phases, tasks and potential levels of impact associated with tsunami.

Typical tsunami operational strategies

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

- Protect and preserve life.
- Establish and operate flood warning systems.
- Issue community information and warnings.
- Coordinate the evacuation of affected communities with consideration to their welfare.
- Protect critical infrastructure and assets essential to community survival during an emergency incident.
- 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-agency effort under the control of a designated lead agency or emergency incident controller. Agencies with different skills and resources can be matched with tasks best suited to their capabilities.

Tsunami response operations can be separated into three key phases:

- pre-impact (warning)
- impact
- post-impact.

Table 7 provides examples of typical actions for each phase.

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 Threat and Land Inundation Threat; these warnings are issued through the ATWS .

For more information on warnings, refer to Chapter 3: Tsunami warning systems.

Marine Threat

A Marine 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 other emergency services as well as organisations such as Surf Life Saving Clubs, Port Authorities and Volunteer Marine Rescue groups.

The safety of people on boats 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 provided weather and sea conditions remain favourable.

People on boats in harbours, estuaries or in shallow coastal water should return to shore, secure their boats 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 Joint Australian Tsunami Warning Centre (JATWC) for a Land Inundation Threat will, with the approval of individual jurisdictions, include additional advice to the public regarding evacuation. Commonly, 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 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 agencies may need to prepare more detailed, localised evacuation warnings or orders for communities. Locally specific information will allow community members to relate more easily to the advice given and take necessary action. Such evacuation orders can be written in advance and then 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 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 may become trapped by a tsunami. These people should be encouraged to shelter in the upper storey of a sturdy brick or concrete multi-storey building.

Evacuation orders 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
- 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 lifesaving clubs and marine rescue agencies that will need to move trailer-able equipment to higher ground. Staging areas for the movement of emergency equipment should be defined in plans.

For further information about evacuation planning, consult the Evacuation Planning Handbook at www.knowledge.aidr.org.au/evacuation-planning-handbook.

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 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 welfare 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. • 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 • welfare 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 welfare 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. • Search and rescue activities for people from the sea and estuaries.
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 • welfare provision • disaster victim identification • response to fire and hazmat incidents • disease control • provision of advice to the community.
	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. • 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.

Tsunami All Clear and Safe Return

Jurisdictional response agencies 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 agency 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 All Clear notification.

A number of considerations will determine whether residents and business 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 prior to 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 agencies.

Tsunami After-Action Reviews

Following each tsunami event or exercise debrief, an After-Action Review should be undertaken, involving all stakeholders, to consider the effectiveness of prevention and preparedness activities and response and recovery operations. Findings from significant events should be broadly shared and incorporated into improved tsunami disaster resilience planning.

Tsunami recovery operations

Recovery encompasses the process of returning affected communities to their proper level of functioning after a tsunami. There will often be a need for emergency services to assist in the recovery phase of a tsunami operation. Preparation for recovery should begin during the pre-impact phase; recovery operations will begin concurrently with impact period response operations.

For further information on initiating and conducting recovery operations, refer to the Community Recovery Handbook at www.knowledge.aidr.org.au/community-recovery-handbook.

Tsunami exercising

Exercises provide an opportunity to ensure plans are workable and effective. They also help to educate emergency services, functional areas, supporting agencies, local government and the community about emergency management arrangements for tsunami. 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 no single test can adequately simulate all aspects of response. All agencies need to be involved in the exercising process, and all parts of the plan should be exercised regularly.

Learnings from exercises help to inform capability in other response capabilities and in building a culture of high-performing teams and productive working relationships (see Case study 4).

For information on managing and conducting exercises in Australia, refer to the Managing Exercises Handbook at www.knowledge.aidr.org.au/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 and/or provincial level.

For past international tsunami exercises, visit the International Tsunami Information Center at http://itic.ioc-unesco.org and click on Tsunami Exercises in the left-hand panel.

Case study 4: Key lessons identified from previous tsunami exercises

Adapted from key lessons identified from New South Wales tsunami exercises. Source: New South Wales State Emergency Service.

- It may be difficult to populate Combat Agency Incident Management Teams.
- It may be difficult to adequately staff and rely on external agency support and coordination.
- How will incident management teams distribute capability in a (possibly) autonomous decision-making capacity? What assets are response teams prepared to lose? When can teams actually go in?
- Up-to-date maintenance and administration of equipment lists, hardcopy instructions and detailed knowledge of areas outside the footprint is essential to coordinating resources in a timely fashion.
- What will agencies at various levels do in the event of loss of communications at impact?
- Emergency managers want to be able to measure your engagement strategy and success.
- Marry exercising with community engagement activities.
- There is a need to consider recovery in preparedness.
- Conduct surveys before and after exercising and community engagement activities.
- Local stories and anecdotes are very powerful.
- Use media platforms to your advantage – this can significantly increase the audience for your awareness campaign.
- Use online tools and sources, such as sentiment analysis on social media.
- Determine how to release spatially enabled intelligence data in the future.
- We should share data freely as most agencies will have obligations under the various governments' Open Data Policies.
- Communities love maps, so use visualisation tools and augmented reality – they are being used more often.
- Visualisation tools should be fit for purpose, simple, easy to understand, shared and appropriate for the broader community.
- Maps are fantastic for community engagement and stakeholder education. However, GIS professionals, emergency service organisations and community leaders and representatives should simplify specialist knowledge for broad audiences.
- The public will have to make their own decisions to evacuate because there simply won't be enough time to warn. They will be making life and death decisions on the data agencies supply (or in the future, supply/don't supply).
- Warning and evacuation products should be consistent, easily understood, and standardised.

New South Wales State Emergency Service conducting Exercise Puysegur Surge on the inaugural World Tsunami Awareness Day, Manly, Sydney, 2016. Source: New South Wales State Emergency Service

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