Tsunami Guide for QUEENSLAND

Australian Government
Geoscience Australia

Queensland Government

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- Front and back covers – Source: Adobe Images
- Inside back cover – Indonesia 10 years after devastating Indian Ocean tsunami. Source: Getty Images

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Thank you

The Tsunami Guide for Queensland was a collaborative effort, bringing together the expertise of multiple stakeholders. QFES would like to thank all the organisations and individuals who assisted us in developing this document. Particular thanks to Geoscience Australia, the Queensland Department of Environment and Science and the University of Newcastle.

Foreword

Hon. Craig Crawford MP
Minister for Fire and Emergency Services

Mike Wassing AFSM
A/Commissioner, Queensland Fire and Emergency Services

Disaster events affect the lives of all Queenslanders and have a significant impact on the economy and our environment. Whether of natural or human origin, disasters are becoming increasingly extreme and complex, exacerbated by our globally interlinked economies.

We realise, since a hazard such as a Tsunami has not impacted Queensland in recent memory, that this does not mean that it cannot happen. Tsunami is a rare but ever-present risk to communities across coastal Queensland, the consequences of which would be felt State-wide.

Following the release of the State Natural Hazard Risk Assessment in 2017, and through consultation with stakeholders at all levels of Queensland's Disaster Management Arrangements (QDMA), the need for detailed and consistent information regarding Queensland's risk from potential tsunami impact was identified.

Our collective ability to assess and more deeply understand disaster risk is the first step towards the development of resilience. This approach is also reflective of the international focus on understanding disaster risk as priority one of the Sendai Framework for Disaster Risk Reduction 2015–2030.

Queensland is exposed to a range of natural hazards which can lead to significant consequences for our communities. Within the last decade we have experienced natural disasters of a size and scale that are almost unprecedented in our Nation's modern history. These events reinforce the need to communicate appropriate risk information across the three tiers of QDMA: Local, District and State.

Starting at the local level, the communication of consistent risk information between each tier of QDMA can support communities and government, emergency services and all emergency management partners in making informed decisions.

The information contained within this hazard guide can be used by stakeholders across government and practitioners throughout the emergency management sector. It represents a maturing capability for informing the development of risk-based plans across QDMA. Risk-based planning is one of the cornerstone enablers for the Queensland community to be better able to prevent, be prepared for, respond to and recover from natural disasters.

As the Minister for Fire and Emergency Services, and the Commissioner of Queensland Fire and Emergency Services, we thank all stakeholders for their contribution to this assessment and the continued commitment towards creating safer and more resilient communities. We would also like to specifically thank Geoscience Australia and the Queensland Department of Environment and Science for partnering with QFES on this initiative, the University of Newcastle for their support and local governments for their ongoing cooperation.

We encourage all Queenslanders affected by disaster risk to consider the information and strategies within this valuable guide and use it to inform the management of risks applicable to their interests and responsibilities.

Introduction

In 2017, Queensland Fire and Emergency Services (QFES) completed the State Natural Hazard Risk Assessment which evaluated the risks presented to Queensland by seven in-scope natural hazards. This publication can be found at www.disaster.qld.gov.au.

The risks presented by tsunami were not evaluated as part of this assessment as there were State and Commonwealth projects underway at the time that would better inform the understanding of the hazard. These have since been completed and now underpin this guide.

Accordingly, this Tsunami Guide for Queensland was developed, with support from Geoscience Australia and the Department of Environment and Science's Coastal Impacts Unit (CIU), through a consultative process which also helped contextualise the findings of Geoscience Australia's Probabilistic Tsunami Hazard Assessment 2018 (PTHA18) for Queensland.

Consultation with the CIU provided the 'Queensland Context', capitalising on the history of tsunami research and study undertaken by the Department of Environment and Science. The provision of a robust scientific basis enhances this guide and seeks to enable the emergency management sector to readily understand the hazard.

As a companion piece to the State Earthquake Risk Assessment, this guide is designed to support Local and District Disaster Management Groups in the completion of their risk-based disaster management plans through the provision of consistent, scientifically based information on tsunami which may impact Queensland communities.

Due to the complexities involved in deriving an understanding of the onshore impacts, requiring near-shore and inundation modelling, it is not currently possible to provide a consolidated risk assessment for use across all coastal local government areas within Queensland.

Information on how Local and District Disaster Management Groups can utilise this guide within the Queensland Emergency Risk Management Framework (QERMF) Risk Assessment Process and/or seek further advice in evaluating tsunami risk, through accessing relevant expertise, can be found on page 15.

Tsunami

Definition

Tsunami (pronounced 'soo-nar-me') is a Japanese word comprising 'tsu' meaning harbour and 'nami' meaning wave.

Tsunami are waves caused by the sudden movement of the ocean surface due to earthquakes, sea floor (or 'submarine'), landslides, land slumping into the ocean, large volcanic eruptions or meteorite impacts in the ocean.

Until recently, tsunami were often called tidal waves. This term is now generally discouraged because tsunami generation has nothing to do with tides, which are driven by the gravity of the earth, moon and sun. Although some tsunami may appear like a rapidly rising or falling tide at the coast, in other situations they can also feature one or more turbulent breaking waves.[1]

Australian context

Dozens of tsunami have been observed historically in Australia and have generated marine hazards and locally significant inundation. However, hazard studies suggest the potential for larger events, with much greater impacts, to occur.

Australia's historical tsunami record is not a reliable guide to our tsunami hazard because written history is short compared with the estimated frequency of damaging tsunami. The geological records suggest energetic marine inundations have occurred at some sites in the last few thousand years but it is very difficult to determine with any certainty whether these deposits represent tsunami or storm surges.

The average return intervals (frequency and likelihood) of large tsunami are very uncertain, due to constraints of observational data and limitations in our understanding of key tsunami sources, such as earthquakes and landslides. As a result, modelled tsunami average return intervals in hazard studies should generally be interpreted as 'nominal' or 'indicative', rather than an accurate measure.

Probabilistic Tsunami Hazard Assessment

In 2018, Geoscience Australia released an updated Probabilistic Tsunami Hazard Assessment - the PTHA18. PTHA18 models the frequency with which tsunami of any given size occur around the entire Australian coast due to subduction earthquakes in the Indian and Pacific Oceans. The PTHA also provides modelled tsunami data for hundreds of thousands of earthquake-tsunami scenarios around Australia.

The PTHA provides vital information to emergency managers for planning and reducing the risk of tsunami on the Australian coast, and for the insurance industry to understand the tsunami risk as an input to pricing insurance premiums. More specifically, the PTHA18 was significantly updated to include advances in our understanding of earthquakes and the resulting tsunami, and to provide hazard information for all Australian offshore territories.

Compared with the previous iterations of the PTHA, the PTHA18 includes more comprehensive treatment of the natural variability of earthquake size and slip. This has an important impact on the predicted tsunami wave heights and hazard.

[1] Adapted from Geoscience Australia's definition (www.ga.gov.au/scientific-topics/hazards/tsunami)

National consistency

The PTHA also provides a nationally consistent basis for understanding tsunami inundation hazards in Australia. Importantly, the PTHA does not define the onshore tsunami impacts, or the effect of tsunami on communities.

However, understanding the frequency of tsunami offshore, as provided by the PTHA, is a valuable input for developing local tsunami inundation models, in conjunction with additional high-resolution bathymetry (equivalent to topography on land) and elevation data. This in turn allows the derivation of evidence-based evacuation plans to improve community safety. Further, high risk areas can be identified and prioritised for further analysis or to conduct scenarios to improve risk mitigation and community safety at a local, regional and national level.

Currently the PTHA does not include non-earthquake sources that can cause a tsunami such as landslides, volcanic activity, asteroids and meteorological events. Methods for assessing tsunami hazards for these sources are much less well established than for earthquakes both internationally as well as in Australia. Further research is required to underpin a nationally consistent treatment for these tsunami sources.

The Australian Tsunami Warning System

The Australian Tsunami Warning System (ATWS) is an end-to-end tsunami warning and emergency response system. The ATWS involves key national, state and territory partners and agencies in earthquake detection, tsunami assessment and warning, and emergency response and recovery. The ATWS includes:

- The Joint Australian Tsunami Warning Centre, operated by Geoscience Australia and the Bureau of Meteorology (BoM), which provides emergency managers and the Australian public with at least 90 minutes warning.
- The Australian Tsunami Advisory Group (ATAG), which provides national leadership in the coordination of programs and projects relating to tsunami capability development, promoting research, information, knowledge management and education in Australia. ATAG is an expert advisory group for the Australia-New Zealand Emergency Management Committee (ANZEMC) and its sub-committees. ATAG members are drawn from each Australian state and territory, including offshore territories, Surf Life Saving Australia, New Zealand and the Australian Government. For more information about ATAG visit the Australia Institute for Disaster Resilience website.[2] Additional national resources are provided at the end of this guide.

The Queensland context

What is the history of tsunami in Queensland?

Tsunami are rare, highly directional events. Because our historical records are short, and damaging tsunami are relatively rare in this region, there are large uncertainties in how often they might occur in Queensland. Further, scientists still do not have a good understanding of the frequency of key tsunami generating processes such as large earthquakes and volcanic eruptions.

Since the 2004 Indian Ocean tsunami, the CIU has upgraded the state-wide storm tide monitoring network to measure water levels at one-minute intervals, capturing multiple tsunami events within Queensland, including those from the Solomon Islands 2007, South America, and Japan 2011, some of which are demonstrated in Figure 1.

To date, the largest tsunami wave captured by the CIU storm tide monitoring network was a 0.5 metre wave detected at Clump Point, Mission Beach during the 2007 Solomon Islands earthquake, as shown in Figure 4b.

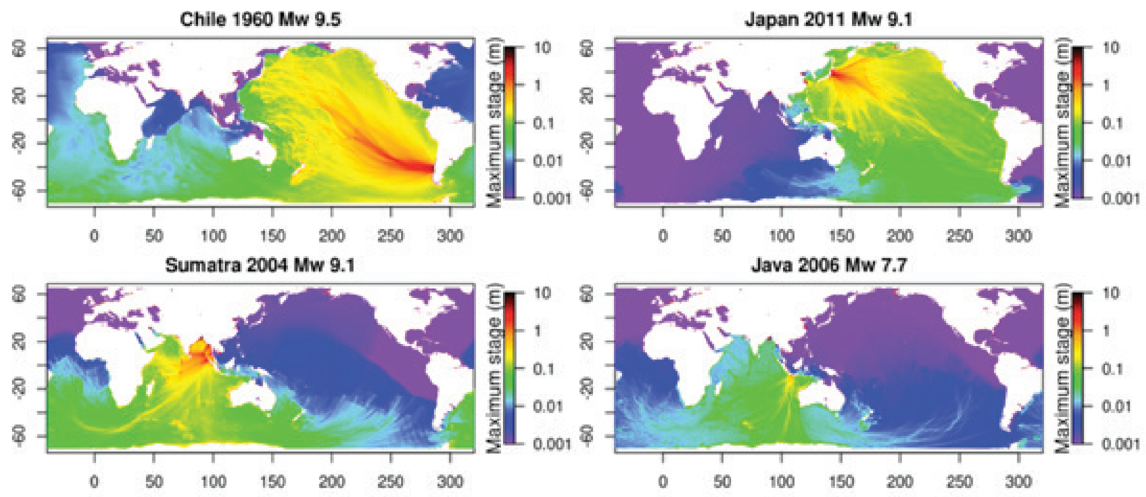


Figure 1: Demonstrated tsunami directionality from historical events. Source: Geoscience Australia

[2] https://knowledge.aidr.org.au/resources/australian-tsunami-advisory-group/

What is the history of tsunami from submarine landslides?

While earthquakes on subduction zones, where the earth's tectonic plates meet, are the leading cause of tsunami-based risk, the risk posed from submarine landslides cannot be ignored.

Historic submarine landslides are evident off the Queensland coast and research groups have identified areas where future landslides may be possible (as shown in Figure 2).[3] A recent report from the University of Newcastle suggested estimates of return intervals for submarine landslide generated tsunami are between 1,500 to 15,000 years.[4]

It is likely that such an event would be triggered from a large undersea earthquake. However, the chance of such a large earthquake occurring within Queensland is very small. For example, there is around a 0.06 per cent chance per year of a magnitude 6.0 earthquake occurring within any 100 x 100km area near the Fraser Coast region.

Elsewhere in the world, submarine landslides have caused tsunami that have led to the destruction of property and loss of life, including our neighbouring Papua New Guinea. Earthquakes are the most probable trigger for submarine landslides as they destabilise sediment, causing slopes to collapse. However, the generation of a large tsunami from these events depends on multiple key factors including:

- the size of the slide
- the depth of the slide
- the unstable sediment moving as one solid mass
- a significant slip rate of the landslide
- friction from the underlying seafloor not acting to reduce the slip rate.

While we can identify likely submarine landslide sites, they could also occur at any location along the coastline.

Mathematical modelling shows that a submarine landslide along the east coast of Australia has the potential to cause a destructive tsunami as illustrated overleaf in Figure 3. Additional information on submarine-landslide tsunami is also available at Geoscience Australia's YouTube channel.[5]

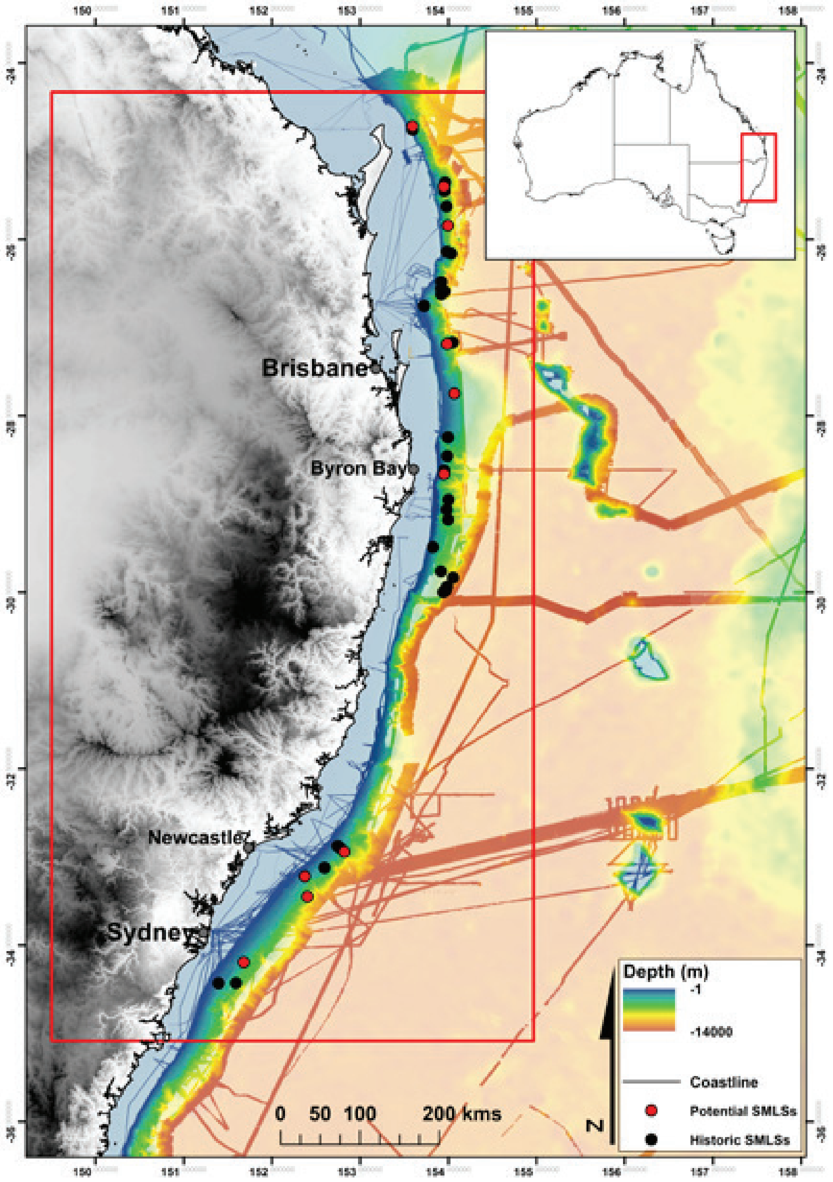


Figure 2: This illustration shows the location of historic submarine landslides with tsunamigenic potential (black dots) and potential future submarine landslides sites (red dots) identified by Clarke (2014) along the east Australian continental margin. The red box outlines the region containing submarine landslides with tsunamigenic potential. Slides with tsunamigenic potential were defined as those with dimensions of 50-250m thick, 1km to >10km wide and in depths of 500-2500m. Source: Clarke et al. (2018)

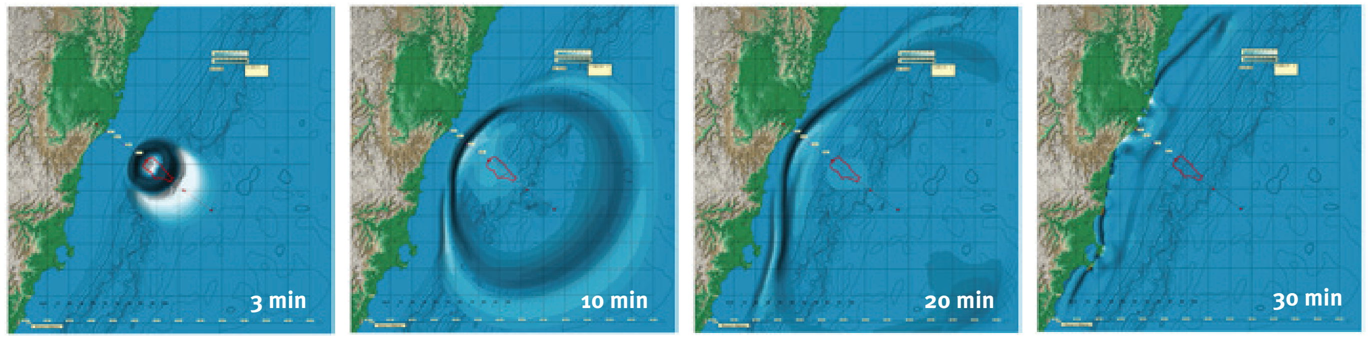
[3] Wai Chik Yu 2017: Submarine landslides, canyons, and morphological evolution of the East Australian Continental Margin. University of Sydney

[4] Power, H. E., Wilson, K. M., Helfensdorfer, A. M., Mollison, K. C., Clarke, S. L., and Hubble, T. C. T. (2018), *Understanding the Submarine Landslide Hazard to NSW*, Report for New South Wales Office of Emergency Management State Emergency Management Project 2016-2018, 151 pp

[5] https://www.youtube.com/watch?v=feXCIfatJYo

Figure 2 references:
Clarke, S.L. (2014) Submarine landslides of the eastern Australian upper continental margin. PhD. Thesis, The University of Sydney, 217 pp

Clarke, S.L., T. Hubble, G. Miao, D. Airey, and S. Ward (2018). Eastern Australia's submarine landslides: implications for tsunami hazard between Jervis Bay and Fraser Island. Landslides, [under revision]



The tsunami is generated from a point source (like dropping a pebble in a pond) and the wave radiates outwards.

When the wave encounters the continental shelf, a bow-shaped wave forms and continues to travel towards the coastline. The initial wave is the largest but subsequent waves follow.

Figure 3: A submarine landslide generated tsunami along the Queensland coast would be expected to follow the pattern shown in the illustrations above, which models the Bulli slide near Wollongong, New South Wales. Source: Dr Hannah Power, University of Newcastle

Understanding the hazard

How does a tsunami occur?

Tsunami are generated by the displacement of a water column over a large area, typically in the ocean. A range of geophysical mechanisms can achieve this including earthquakes, landslides, volcanic activity, asteroids and meteorological processes. For more information, refer to Tsunami: The Ultimate Guide, or animations available at the Geoscience Australia website.[6]

The main source of tsunami are those generated by submarine earthquakes along the subduction zones within the circum-Pacific seismic belt, also known as the Ring of Fire. This belt is a collection of oceanic trenches, volcanoes and plate movements along the rim of the Pacific Ocean and is responsible for about 70 per cent of the world's tsunami. The main subduction zones that generate tsunami along the Queensland Coast are the Kermadec-Tonga, New Hebrides, Solomon and South America trenches, shown in Figure 4a.

Figure 4a: Trench locations corresponding to tectonic plates which generate tsunami along the Queensland coastline. Source: USGS

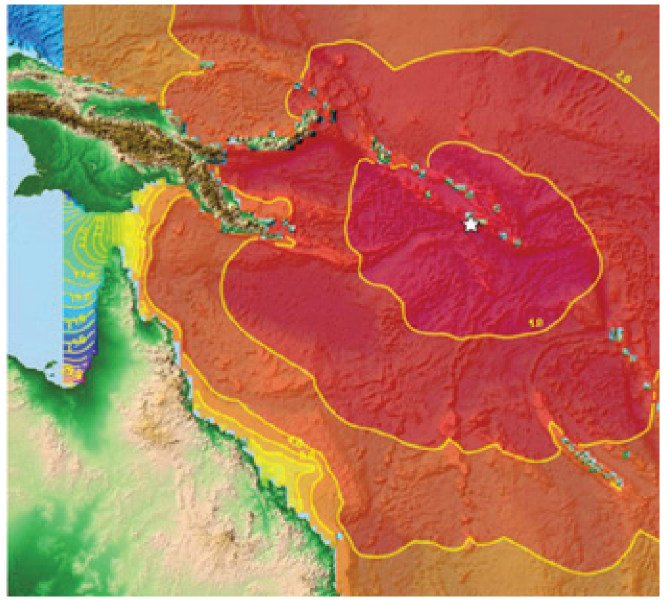


Figure 4b: Tsunami model showing the movement of waves generated from the 2007 Solomon Islands earthquake. Source: Yushiro Fujii, International Institute of Seismology and Earthquake Engineering (IISEE)

[6] http://www.ga.gov.au/scientific-topics/hazards/tsunami

A simple example to demonstrate how tsunami act is by dropping a pebble into a pond: the pebble generates a deformation of the water surface which in turn creates a wave or series of waves that radiate from the source of disruption in concentric circles of increasing size, as shown in Figures 3 and 4b.

However, tsunami generated by submarine earthquakes do not emanate from a single point but rather a complex pattern of earth bed movements.

Accordingly, the specific characteristics of the earthquake generation process can have a significant impact on tsunami magnitude and characteristics.

The most probable cause of tsunami remains earthquakes that are generated on subduction zones, as shown in Figure 5.

If I felt an earthquake near the Queensland coast, would there be a tsunami?

An earthquake does not necessarily generate a tsunami. However, if you experience strong shaking for more than 30 seconds and are on or near the beach, it is prudent to move away. If the strong shaking lasts longer than 60 seconds, go to higher ground.

The New Zealand Ministry for Civil Defence and Emergency Management has adopted the communication message of 'Long or Strong: Get Gone" which provides an excellent overview for personal protection. More information is available at New Zealand's Ministry of Civil Defence and Emergency Management website.[7]

Further, Surf Lifesaving Australia also developed a straightforward guide on how the community should act upon receiving a tsunami warning. This guide can be found as Appendix A, on page 17.

How do tsunami behave?

The exact nature of the waves is affected by how the earthquake occurred. An earthquake rupture is very complex spatially (with lengths from less than 100 kilometres to more than 1000 kilometres) and may last for minutes. As the tsunami travels across the deep ocean, it will be directed, scattered, and reflected by the shape of the seafloor and any land masses in its way.

Why is there more than one wave?

Even if you make disturbance in your bathtub, you will see that a series of waves is generated. This is a fundamental property of

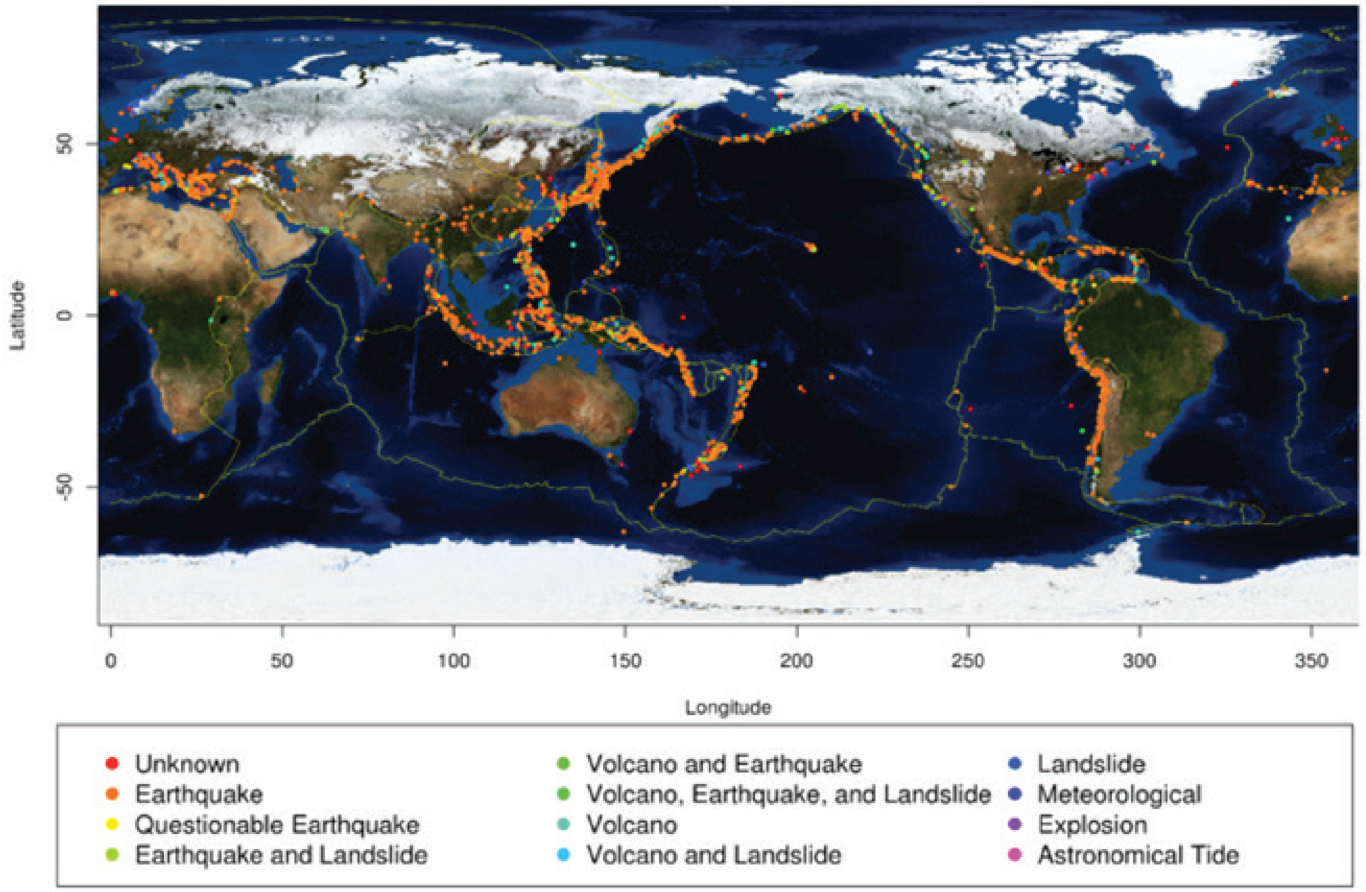


Figure 5: Record of event-driven tsunami across earth. Source: National Geophysical Data Centre

[7] https://www.civildefence.govt.nz/get-ready/get-tsunami-ready/

water waves. Because of gravity, water will be accelerated away from uplifted areas (and towards low areas). Once the waves are initiated, they will keep propagating around the ocean until they slowly dissipate due to friction.

A tsunami comprises a series of very long waves and each wave generally lasts between five and 40 minutes. The first wave may not be the largest and the tsunami may still be evident up to 24 to 48 hours after the first wave. Even if a tsunami does not impact land, dangerous rips and currents can result. Therefore, water activities should cease until the hazard advisory is lifted (refer to ATWS section on Page 5).

How fast do tsunami travel?

Tsunami speed is directly related to the water depth:

$$\sqrt{(Gravity\ x\ Depth)}$$

This means a tsunami will travel fast in deep water and will slow down as the water depth becomes shallower.

Tsunami can travel as fast as an aircraft, around 600 kilometres to 800 kilometres per hour, in very deep water.

Will the water from the coastline recede before the arrival of a tsunami?

The nature of subduction zones and how an earthquake was generated would indicate whether water will recede from a beach. At subduction zones, one tectonic plate slides underneath another, and for the most common kind of large earthquakes (known as 'thrust'), the tsunami will have a leading peak on the 'sinking plate side' (often called the oceanic plate) and a leading trough on the 'overlying plate site' (often called the continental plate).

Communities will experience a leading peak or trough, depending on which side of the subduction zone they are on.

Queensland is located on the oceanic plate side of some subduction zones and the continental plate side of others so could have either a leading peak or trough.

How long does a tsunami last?

This will vary widely depending on the event and the characteristics of the nearshore environment. A tsunami may be evident for just a few hours to several days after initial impact.

How are tsunami different from wind waves?

Both waves are influenced by similar processes of refraction, diffraction, reflection and trapping, but tsunami waves occur at a much larger scale than wind waves (Figure 9). Tsunami do not tend to dissipate over significant distances, whereas wind waves will.

Wind waves will tend to break and dissipate on the beach, whereas tsunami typically do not break (as illustrated in Figure 6). The momentum of a tsunami can push water further inland than wind waves, with the current too strong for a person to stand or remain stable (Figure 7).

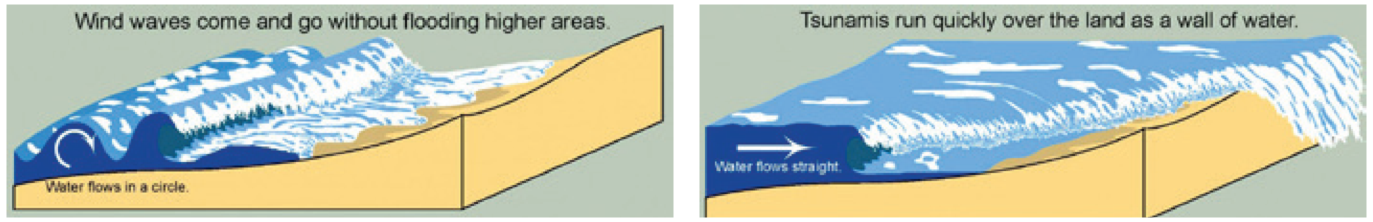


Figure 6: Differences between wind waves and tsunami at the coast. Source: AIDR Tsunami Emergency Planning in Australia Handbook

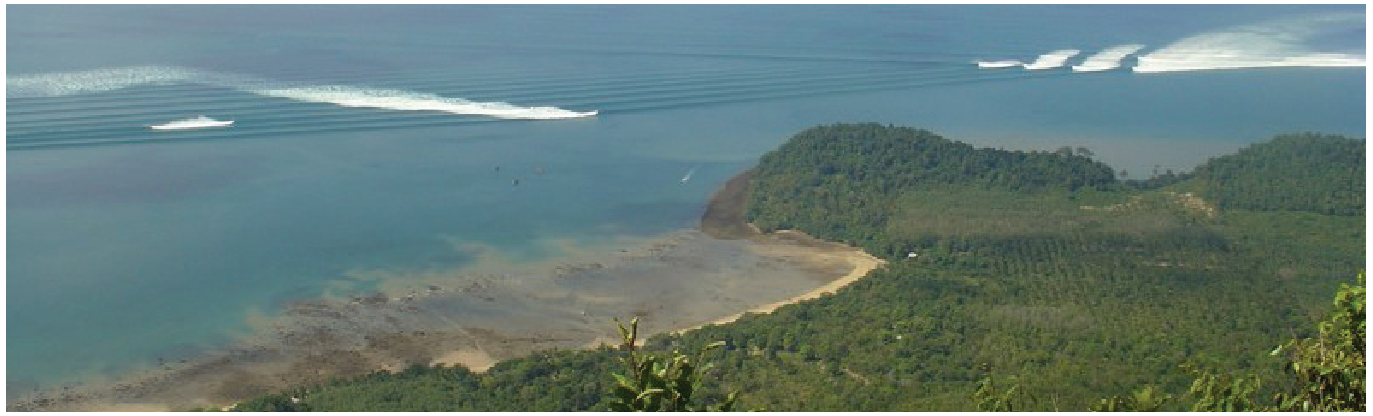
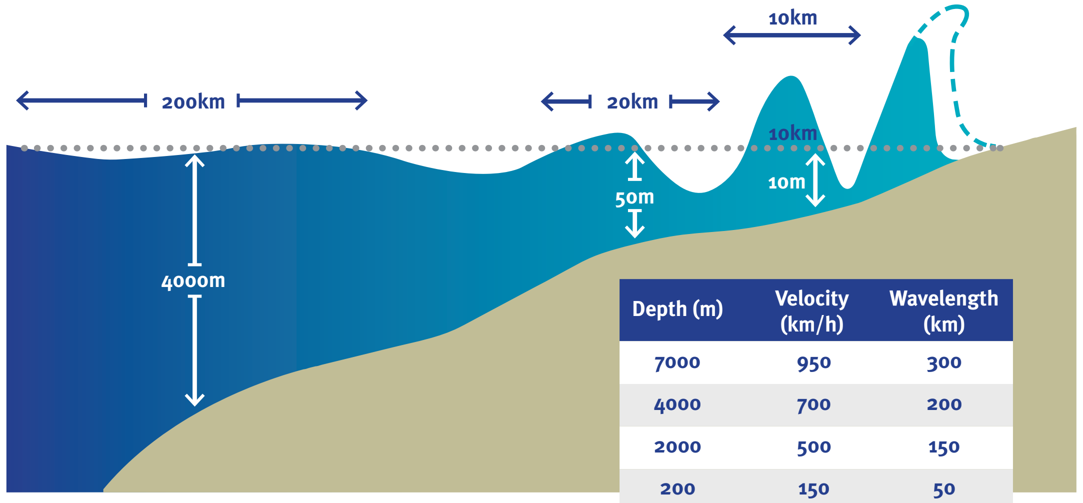


Figure 7: The 26 December 2004 Indian Ocean tsunami approaching the North Beach of the island Koh Jum, off the coast of Thailand. The waves present in the photo, taken from the top of Mount Pu, are actually shorter period waves riding on top of the tsunami, which is not obvious with the naked eye. Source and copyright: Anders Grawin, reproduced with permission

How does the coastline affect tsunami?

The shape of the sea floor plays a major role in how much the tsunami will grow in height (shoaling) or lose height. This is illustrated in Figure 8. Tsunami slow down and increase in size (shoal) as they travel over the continental shelf. Low-lying areas are likely to be more vulnerable but this is also highly dependent on where the tsunami was generated.



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

Figure 8: Wave characteristics in the open ocean and near shore. Sourced and adapted from: AIDR Tsunami Emergency Planning in Australia Handbook

Further, as the tsunami approaches the coastline, it is influenced by coastal features and nearshore bathymetry in the following ways:

- refraction can focus energy on particular features, such as prominent headlands
- complex bathymetry may cause crossing of waves, generating localised amplification
- the tsunami can also be reflected off the coastline, generating a longer and more complicated wave train.

Tsunami will therefore differ along the coast, as illustrated in Figure 9.

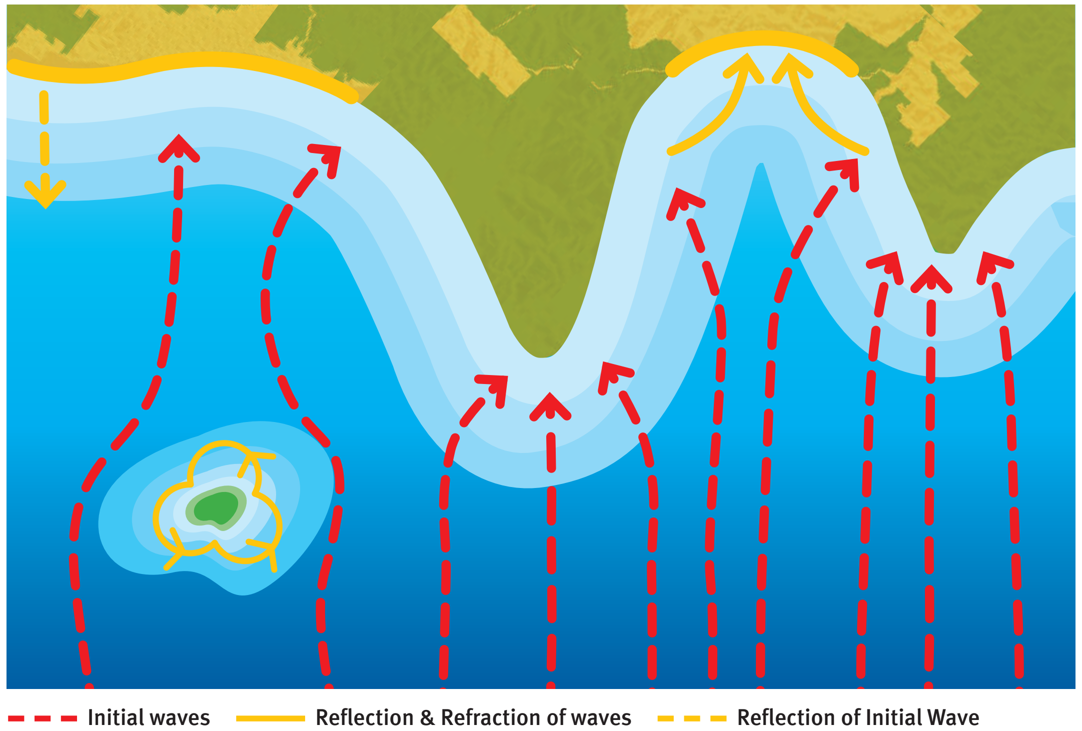


Figure 9: Refraction and reflection of tsunami waves. Source: CIU

Geoscience Australia has created several video guides about tsunami behaviour which are useful for disaster management and community education and can be found at Geoscience Australia's YouTube channel.[8]

Queensland's exposure to tsunami

What areas of Queensland are more exposed?

The PTHA18 provides the projected offshore tsunami wave heights for a range of different annual exceedance probabilities (the chances of the event occurring once in a year, expressed as a percentage) from earthquake sources only. It identifies parts of the coastline which may be more vulnerable than others but does not address the potential impacts on the land. The PTHA18 can provide scenarios for input into further inundation studies.

The CIU examined the nearshore hazard along the east Queensland coast by using the original PTHA document to determine amplification factors from 100 metres depth to 10 metres depth. The results suggested the hazard is greatest for South East Queensland as well as for some areas within the Great Barrier Reef lagoon. However, a full assessment of the hazard would require detailed inundation modelling as further shoaling would occur landwards of the 10 metre depth contour.

Figure 2 highlights several areas where current research indicates submarine landslides may generate a localised tsunami. However, without further study, it is not possible to currently state which Queensland coastal locations have a higher level of exposure from this hazard than others.

If an earthquake-tsunami were to occur, where in Queensland might it be observed?

The PTHA18 shows us that the entire Queensland coast (including within the Gulf of Carpentaria) could experience a tsunami, with the southern parts of Queensland having a higher level of hazard (i.e. wave height) than other parts of the coastline because of the narrower and gradual sloping continental shelf and the location of the predominant source zones.

The most likely source for tsunami for the Queensland coast are the Kermadec-Tonga trench (north of New Zealand), the New Hebrides trench (near Vanuatu and New Caledonia) and the Solomon trench (near the Solomon Islands and eastern Papua New Guinea). Tsunami generated from earthquakes on the west coast of South America could also impact the Queensland Coast.

Further, the Gulf of Carpentaria could experience a tsunami from earthquakes generated in the Banda Sea but this region is relatively sheltered compared with the east coast.

How long would it take for a tsunami to reach the Queensland coast?

The time for a tsunami to travel from source to shore depends on the depth of the ocean, the nearshore environment and the travel distance. More specifically:

- The nearest subduction zone to Queensland is the New Hebrides and Solomon Islands with travel times of three to four hours. The Kermadec-Tonga Trench travel times are between four and six hours with tsunami from Chile taking over 18 hours.
- Tsunami generated from submarine landslides will have much shorter arrival times due to their close proximity to the coast. As an example, if a submarine landslide-tsunami had been generated by the August 2016 magnitude 5.8 earthquake about 60 kilometres off the Bowen coastline, it would have taken around 30 minutes to impact the shoreline.
- Figures 10 and 11 illustrate the difference in travel time from a regional earthquake-tsunami and a local submarine landslide-tsunami.

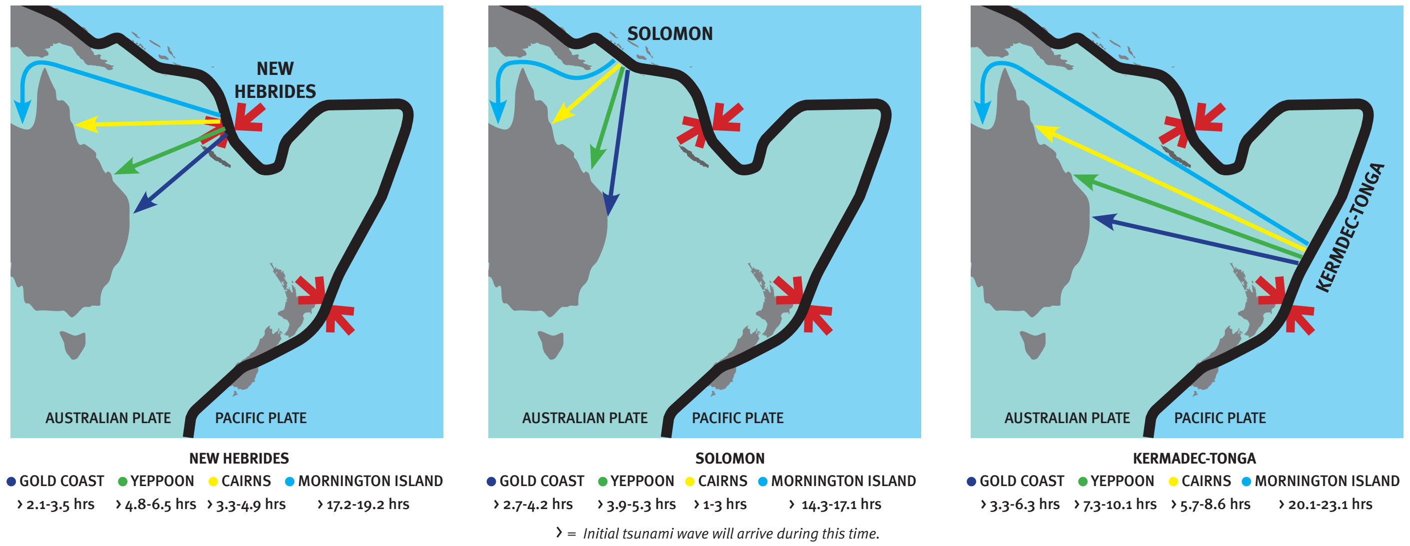


Figure 10: Travel times for regional earthquake-tsunami from the Solomon, New Hebrides and Kermadec-Tonga trenches. **Note:** These travel times are derived from models and are based on the initial tsunami arrival offshore. They do not consider the time required for the tsunami to propagate close to shore, or the fact that the tsunami may consist of multiple waves lasting for hours or days. Therefore, these travel times are not suitable for determining when the largest waves will arrive, or when the tsunami risk has passed. In the event of an actual tsunami, the Joint Australian Tsunami Warning Centre will include travel times in their warning products. These should be considered the definitive source in the event of a tsunami. Source: produced by QFES with assistance from Geoscience Australia

[8] https://www.youtube.com/watch?v=ILlyfwDwJVs&feature=youtu.be

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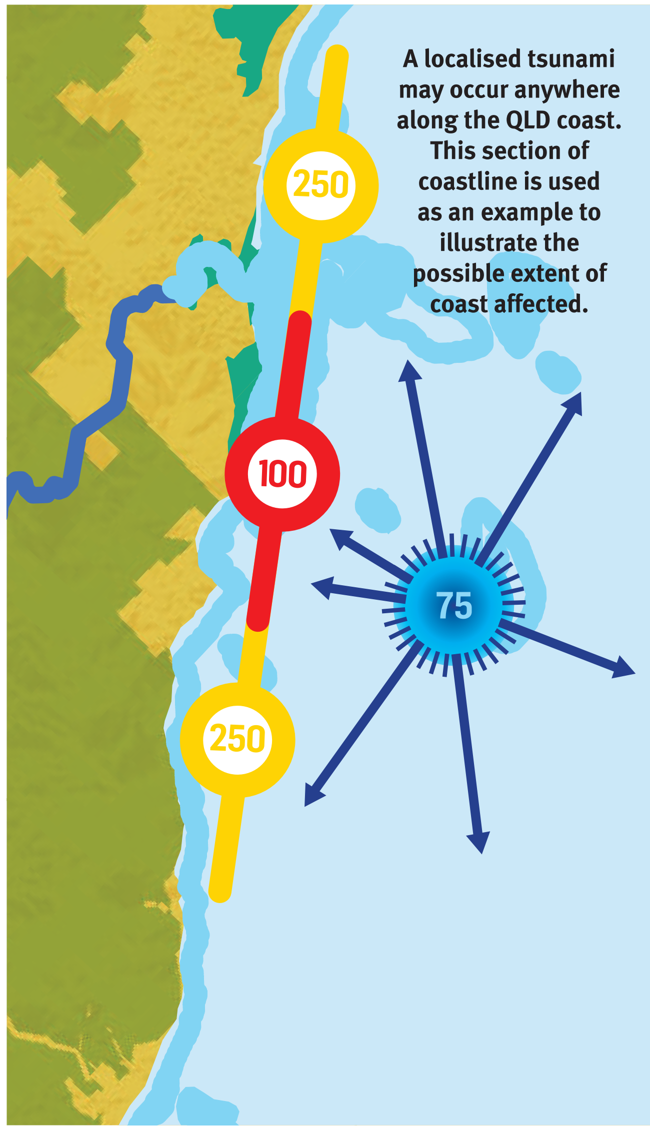


A localised tsunami may inundate the coastline within **18-60 minutes** of landslide collapse that would vary with distance from the slide

Up to 100km of the coastline may experience current speeds in excess of **4-10m/s** and wave amplitudes of in excess of **4-10m**

250+ km of coastline may experience currents speeds greater than **2m/s** and wave amplitudes of over **1m**

Inundation and high current speeds could occur in low-lying areas

An area of ocean, centred on the continental slope above the tsunami source with a radius in excess of **75km** would be extremely hazardous for vessels

A leading negative amplitude wave may cause ocean drawback, providing a 4-5min warning before inundation. Some areas may have a leading positive wave with no prior ocean drawback

Figure 11: Indicative diagram representing the travel times and possible impacts from a localised tsunami event on the Queensland Coast. Produced with assistance from Dr Hannah Power, University of Newcastle

Can tsunami affect Moreton Bay or Hervey Bay?

Modelling by CIU suggests that tsunami can propagate into these bays. The tsunami hazard is greater on the ocean side of the islands and the northern regions of the bays, with low lying areas vulnerable to tsunami. More information can be found at the Coastal assessment studies page of the Queensland Government website.[9]

Can tsunami affect the Gulf of Carpentaria?

Tsunami generated outside the Gulf of Carpentaria can propagate into the Gulf, just as they can propagate throughout the ocean. However, the recent PTHA18 suggests that the Gulf has low exposure to earthquake generated tsunami compared with the rest of Australia. Broadly speaking, the shallow bathymetry around northern Australia makes it harder for tsunami energy to reach the Gulf coast.

Does the Great Barrier Reef protect Queensland from tsunami?

Modelling suggests that small amplitude tsunami, such as that recorded by the Queensland Department of Environment and Science storm tide monitoring network during the 2007 Solomon Island event, can propagate over the reef with little dissipation.

For larger amplitude events, some dissipation over the reef can occur but the tsunami can regain this energy through shoaling as it approaches the beach. The complex geometry and gaps between the many reefs within the Great Barrier Reef can also focus energy on particular stretches of coastline. Further information can be found at the Coastal assessment studies page of the Queensland Government website.[10]

[9] https://www.qld.gov.au/environment/coasts-waterways/beach/studies
[10] https://www.qld.gov.au/environment/coasts-waterways/beach/studies

How do islands and breakwaters affect tsunami?

While areas in the lee of islands and breakwaters can be sheltered from ocean wind waves, this is not the case for tsunami. The wavelength of tsunami are tens of kilometres, even in relatively shallow water, whereas small islands and breakwaters are around hundreds of metres in size. Documented cases in other parts of the world show tsunami have wrapped around an island and even amplified in the lee.

Figures 12a and 12b show the effect of the offshore breakwater at Redcliffe for a hypothetical tsunami by modelling with and without the structure. Although a slight reduction in amplitudes occurs with the structure in place, current speeds around the structure significantly increase.

Advice to the public should always be to heed warnings and move to higher ground. Structures or features that provide shelter from wind waves should never be assumed to provide the same protection from tsunami.

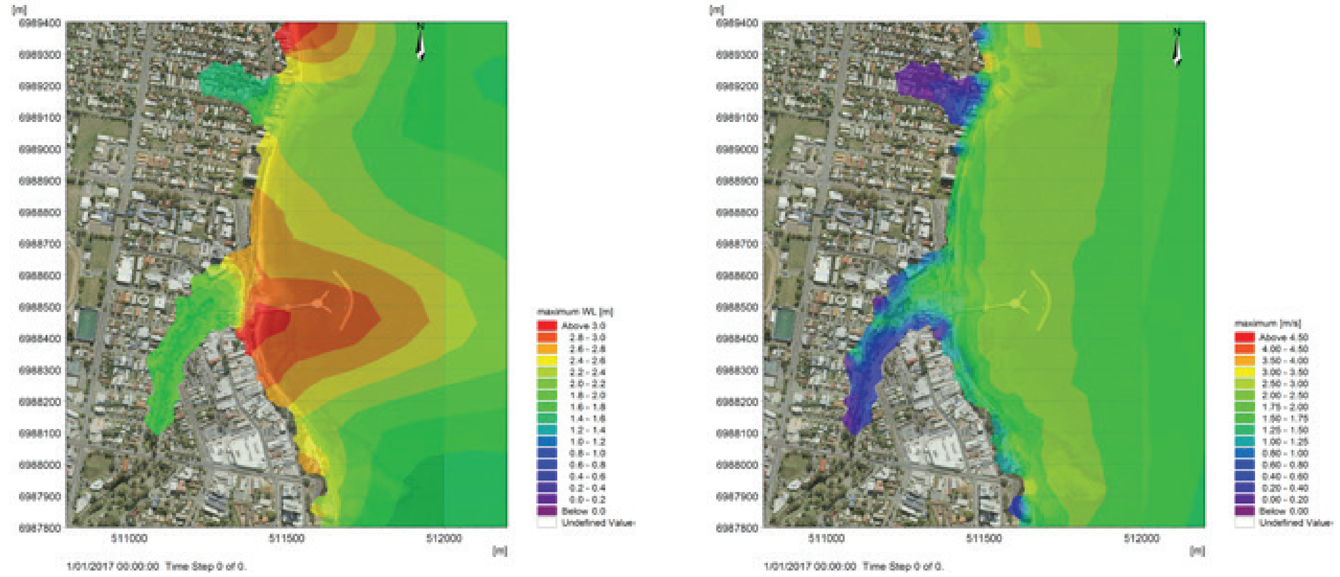


Figure 12a: Maximum water level (left) and maximum current speed (right) for modelled tsunami scenario with Redcliffe breakwater omitted. Source: CIU

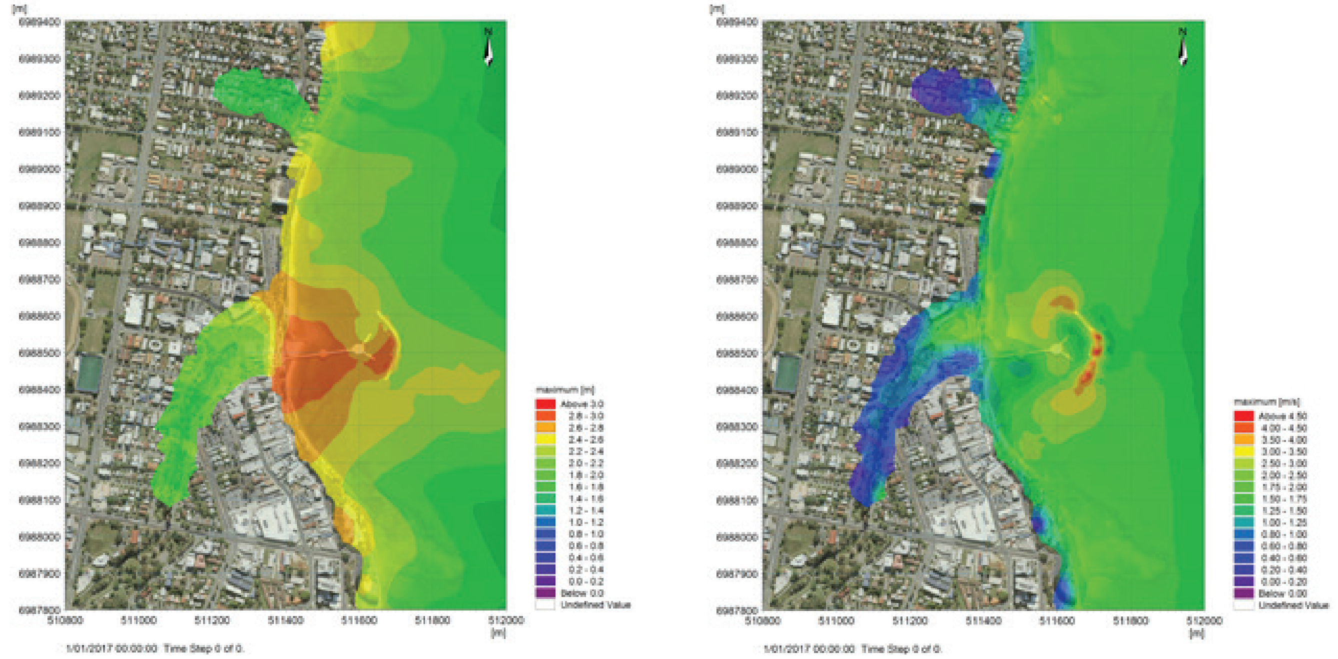


Figure 12b: Maximum water level (left) and maximum current speed (right) for modelled tsunami scenario with Redcliffe breakwater included. Source: CIU

Tsunami risk considerations

What is the annual risk to Queensland's coastline from a tsunami?

Any estimate about the annual risk to Queensland will be very uncertain, mainly because scientists do not have a precise understanding of how often large earthquakes, or other source events, occur in key locations of relevance to Queensland. Fundamentally, these difficulties stem from the fact that large tsunami are rare on most coastlines, compared with the length of reliable historical records and instrumental measurements.

The assessment of the risk requires the development of tsunami inundation models to calculate vulnerability to the hazard. The hazard exposure will vary along the coast due to nearshore and coastline characteristics. Tsunami inundation modelling has been undertaken for the Sunshine Coast, Moreton Bay and Hervey Bay by the Department of Environment and Science with the reports available at the Coastal assessment studies page of the Queensland Government website.[11]

However, these studies do not answer the question of what annual exceedance probability will result in a land risk as this will vary along the coast, depending on the nearshore characteristics that have transformed the waves, and the topographic features that restrict wave run-up. There is also uncertainty associated with the offshore probabilistic hazard assessments undertaken by Geoscience Australia. The stage of the daily and yearly can also complicate the matter further. Instead, the reports consider various scenarios at mean sea level and high tide to give an indication of areas that may be potentially impacted.

Appendix B provides most likely and credible worst-case scenarios for several locations at the 100 metre depth contour along the Queensland coast.

Could Queensland experience a tsunami of the scale of the 2004 Indian Ocean tsunami?

Tsunami are most often very damaging near the earthquake source. The 2004 Indian Ocean tsunami was so devastating in the Aceh province in northern Sumatra because this area is very close to a major subduction zone in southern Indonesia. However, tsunami also can be very damaging at intermediate and far distances from the source, depending on tsunami directionality.

For example, during the 2004 event, the tsunami still reached heights of around five to 10 metres in Somalia (about 5000 kilometres from the earthquake source), which led to around 300 deaths. Despite its distance from the source, the tsunami was well suited to direct energy to this region.

Historically there are multiple instances where tsunami directionality has led to large impacts far from the earthquake source. For example, Hawaii has repeatedly suffered damaging tsunami due to earthquakes in South America and the Aleutian Islands in the northern Pacific.

Although Queensland is not located very close to major earthquake sources (the nearest being around 1500 kilometres away), it may still be vulnerable to a 'well directed' tsunami. Tsunami modelling undertaken by CIU showed maximum water levels of up to 10 metres could occur on the ocean side of Moreton and North Stradbroke Islands during very extreme events (10,000 year ARI).

We have not seen in modern times an event in the south west Pacific of a similar magnitude, but it may be possible.

We do not know what the impacts would be until further studies are undertaken.

Are ports and marinas vulnerable to tsunami?

Coastal infrastructure, such as ports, harbours and marinas, may be affected during a tsunami. Strong currents can develop within ports and harbours, even if there is no land risk, damaging vessels, facilities and causing substantial erosion.

As an example, the 1960 Chile event generated a tsunami that impacted parts of the New South Wales coastline. The tsunami was observed at the Fort Denison tide gauge within Sydney Harbour, with damage to leisure craft in the Sydney area and evidence of erosion within the harbour.

Impacts were observed in Geraldton Harbour, Western Australia following the 2004 Indian Ocean tsunami and there is evidence large container ships in the Oman port – some 6000 kilometres from the earthquake event itself – were impacted. Further, the 2011 Great East Japan tsunami caused damage to vessels and port facilities within California.

How much warning time will there be?

The Joint Australian Tsunami Warning Centre, or JAWTC, is jointly operated by Geoscience Australia and the BoM. Geoscience Australia detects earthquakes, determines the potential for these earthquakes to generate tsunami and then advises BoM within 10 minutes of the earthquake occurring. BoM then uses its network of sea level monitoring equipment to confirm the existence of a tsunami and uses tsunami models to estimate the risk level at the Australian coast. BoM issues the relevant tsunami warnings and bulletins to emergency management agencies and the public, giving at least 90 minutes' notice to move away from the coast and travel to higher ground.

What can state and local governments do?

Understanding the local tsunami hazard is an important first step in managing tsunami. As noted previously, the PTHA18 provides an indication of what the offshore wave height might be for a range of different annual exceedance probabilities and this information can be used as input into detailed studies to understand the tsunami hazard onshore.

High quality onshore and nearshore elevation data is required to model tsunami inundation and nearshore behaviour with accuracy. Lower resolution global datasets are generally only

[11] https://www.qld.gov.au/environment/coasts-waterways/beach/studies

suitable for modelling oceanic scale tsunami propagation. If good quality elevation data is unavailable, then advanced tsunami models may be of little benefit compared with crude geometric models such as the bathtub, or attenuation rules of thumb.

If local governments wish to pursue modelling within their area, the Department of Environment and Science's Coastal Impacts Unit can provide technical advice as they do for other coastal hazards, such as storm tide. Local governments also should refer to the Tsunami Hazard Modelling Guidelines.[12]

What can the public do?

Public messaging regarding tsunami and storm surge risk often reflects the following advice:

- Understand the hazard and understand the local environment.
- Check with local libraries and local councils for information and plans.
- Check with local councils about local warning systems, evacuation process and nominated evacuation routes.
- If living in a flood-prone area or evacuation zone, consider making arrangements to stay with friends on higher ground in the event of a tsunami.
- Ask about emergency and evacuation plans at workplaces, schools and childcare providers. Check if they need details of individual household emergency contacts.
- Develop personal evacuation plans, and discuss emergency plans with family and friends, especially those with vulnerabilities (for example, accessibility, age, physical or mental health, language skills).
- If the water is receding from the beach, move immediately to higher ground.
- Heed all warnings and do not return to an area until told to do so.

In addition to Surf Life Saving Australia's Tsunami in Australia factsheet (provided as Appendix A), Queensland Government provides key, consistent messaging on how to prepare for and respond to tsunami. This information can be found on the Queensland Government's 'Preparing for Disasters' website.[13]

How to use this guide within the QERMF Risk Assessment Process

Although widespread destruction due to tsunami (as observed in subduction zones such as Indonesia) is highly unlikely within Queensland, the consequences of these events can be devastating and have significant and prolonged impacts on the community. Advice for the implementation of this guide at a Local or District level is to distill the information contained within this document by applying a scenario-based approach to evaluate and understand:

1. The probability of occurrence of a earthquake tsunami of the magnitude required to deliver potentially destructive waves against the location under assessment. This can be derived from the information provided in Appendix B and the PTHA18.
2. The vulnerability of the location under assessment through analysis of local near-shore ground conditions and bathymetry (underwater equivalent to topography).

   Note: Steps 2 requires location specific, in-depth inundation modelling such as that undertaken by the Coastal Impacts Unit, Department of Environment and Science
3. The elements of the community which may be exposed in the location under assessment (against the six QERMF categories of exposed elements) and the vulnerability of these exposed elements, noting that some elements may be exposed through broader social or economic impacts from an tsunami event occurring outside of the region.
4. The existing controls to manage or mitigate this type of event at the respective level of Queensland's Disaster Management Arrangements (QDMA) (such as building codes, community warning strategies and specific agency disruption or continuity plans).
5. The existing capabilities at the respective level of QDMA to respond to this type of event.
6. The capacity of the identified capabilities.
7. The identified gaps in capability or issues of concern (residual risk) and how the management of these will be implemented through the passage of residual risk through QDMA.

Once steps 1 through 7 have been completed, this assessment can then be tabled for acceptance by a disaster management group for incorporation in to their respective disaster management plan.

Next steps

If further research, analysis or assessment is required after using this guide to understand the tsunami hazard for a particular area, a collaborative approach with the stakeholders listed below is recommended, particularly to inform further in-depth or area specific studies. A collaborative approach with these agencies will ensure consistency in evaluating the hazard in line with State and national assessments.

Key agencies:

- Queensland Fire and Emergency Services (Hazard and Risk Unit)
- Coastal Impacts Unit, Department of Environment and Science
- Coastal Science Research Group (Dr Hannah Power), School of Environmental and Life Sciences, University of Newcastle (regarding submarine-landslide tsunami)
- Geoscience Australia.

[12] https://knowledge.aidr.org.au/media/5640/tsunami-planning-guidelines.pdf
[13] https://www.qld.gov.au/emergency/dealing-disasters/prepare-for-disasters/evacuation-kit

References and sources of additional information

Much of the information supplied in this tsunami guide comes from Geoscience Australia and tsunami modelling reports prepared by the Queensland Department of Environment and Science, available from:

- https://www.qld.gov.au/environment/coasts-waterways/beach/studies-tsunami

State and National Resources

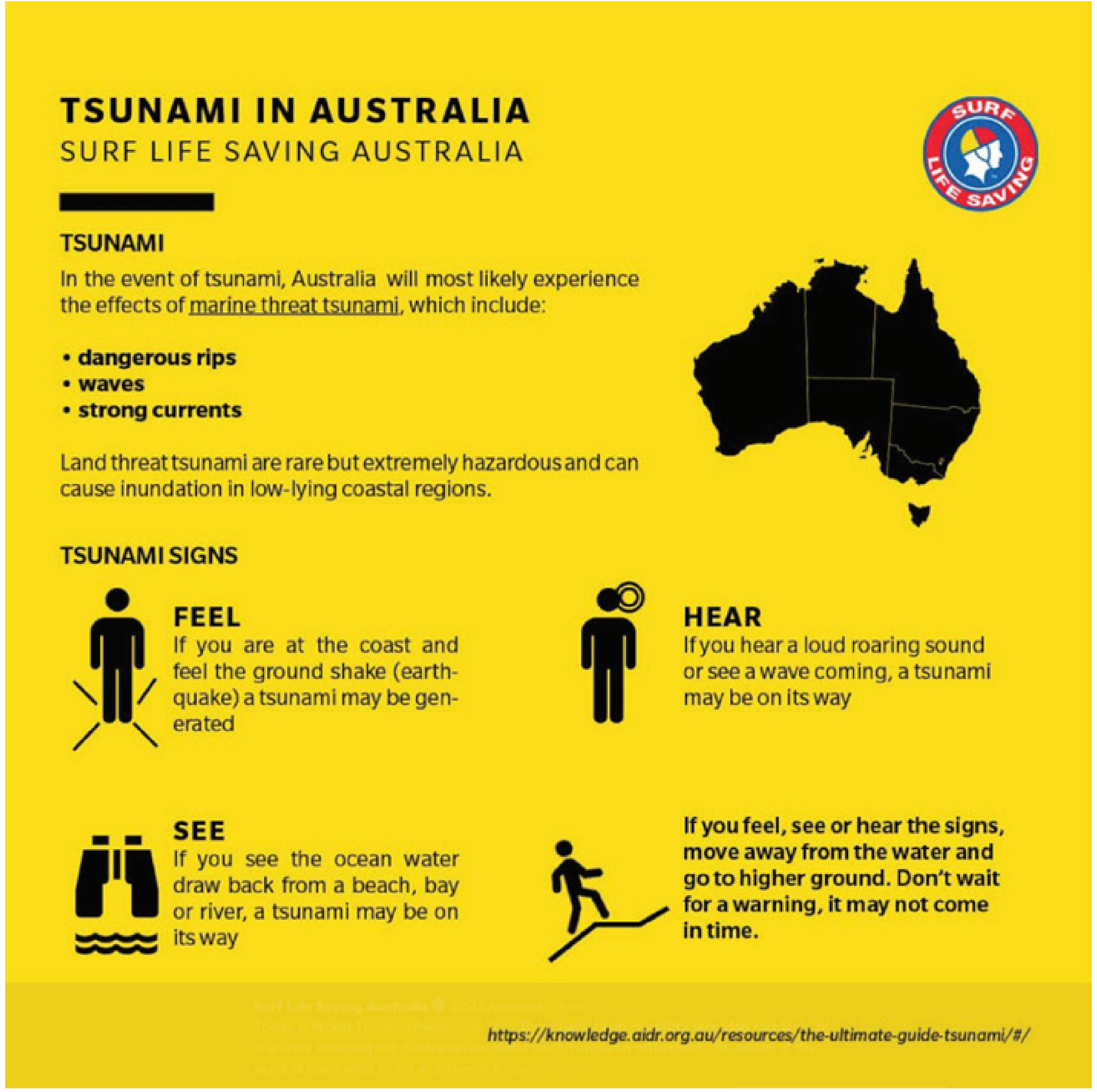
- Tsunami: Get Ready Queensland - https://getready.qld.gov.au/natural-disasters/tsunami/
- Queensland Tsunami Notification Manual - https://www.disaster.qld.gov.au/dmg/st/Documents/M1183-Queensland-Tsunami-Manual.pdf
- AIDR Tsunami Emergency Planning in Australia Handbook and companion document – https://knowledge.aidr.org.au/resources/tsunami-planning-handbook
- Tsunami: The Ultimate Guide – https://knowledge.aidr.org.au/tsunami-the-ultimate-guide
- Tsunami Hazard Modelling Guidelines – https://knowledge.aidr.org.au/resources/tsunami-planning-handbook
- Australian Tsunami Advisory Group (ATAG) – https://knowledge.aidr.org.au/resources/australian-tsunami-advisory-group
- The 2018 Probabilistic Tsunami Hazard Assessment – www.ga.gov.au/ptha
- Geoscience Australia tsunami page – http://www.ga.gov.au/scientific-topics/hazards/tsunami
- Geoscience Australia tsunami videos – https://www.youtube.com/watch?v=ILlyfwDwJVs&feature=youtu.be
- Bureau of Meteorology tsunami page – http://www.bom.gov.au/tsunami

International resources

- UNISDR World Tsunami Awareness Day 5 Nov – https://www.unisdr.org/tsunamiday
- UNISDR International Day for Disaster Risk Reduction 13 October – https://www.unisdr.org/we/campaign/iddr
- NOAA National Centre for Environmental Information – Tsunami Data and Information – https://www.ngdc.noaa.gov/hazard/tsu.shtml
- IOC Tsunami Programme IOC – http://www.ioc-tsunami.org/index.php
- Tsunami: The Tsunami Story – https://www.tsunami.noaa.gov/tsunami_story.html
- International Tsunami Information Center – http://itic.ioc-unesco.org/index.php
- Tsunami: Produced by the COMET Program – http://www.torbenespersen.dk/Publish/tsunami/index.htm

Appendices

Appendix A: Surf Life Saving Australia's Tsunami in Australia factsheet



TSUNAMI IN AUSTRALIA
SURF LIFE SAVING AUSTRALIA

TSUNAMI

In the event of tsunami, Australia will most likely experience the effects of marine threat tsunami, which include:

- **dangerous rips**
- **waves**
- **strong currents**

Land threat tsunami are rare but extremely hazardous and can cause inundation in low-lying coastal regions.

TSUNAMI SIGNS

FEEL
If you are at the coast and feel the ground shake (earthquake) a tsunami may be generated

HEAR
If you hear a loud roaring sound or see a wave coming, a tsunami may be on its way

SEE
If you see the ocean water draw back from a beach, bay or river, a tsunami may be on its way

If you feel, see or hear the signs, move away from the water and go to higher ground. Don't wait for a warning, it may not come in time.

https://knowledge.aidr.org.au/resources/the-ultimate-guide-tsunami/#/

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Appendix B: Hazard Deaggregation Plots (PTHA18 Geoscience Australia)

How to understand and interpret the plots:

1) These plots depict the subduction zones most likely to generate an earthquake-tsunami affecting the given locations in Queensland.

2) These deaggregation maps (depicting a most likely and credible worst-case scenario for each location) reflect a combination of two factors:

a) How likely a large earthquake is to occur on each source-zone; and

b) How well placed that source-zone is to direct tsunami waves to the site of interest.

3) We cannot directly go from information in these plots to an understanding of the onshore impact without undertaking nearshore and inundation modelling such as that undertaken by the Coastal Impacts Unit, Department of Environment and Science. Although there will be some correlation between the 'maximum-stage' and the onshore impacts, it is far from precise because other aspects of the wave train also affect inundation.

4) In general, the exposure of Queensland to offshore tsunami is "moderate" by Australian standards, at least for these distant earthquake sources. On the east coast of Queensland, as one heads north there is a general decrease in the offshore wave heights for fixed return period and depth.

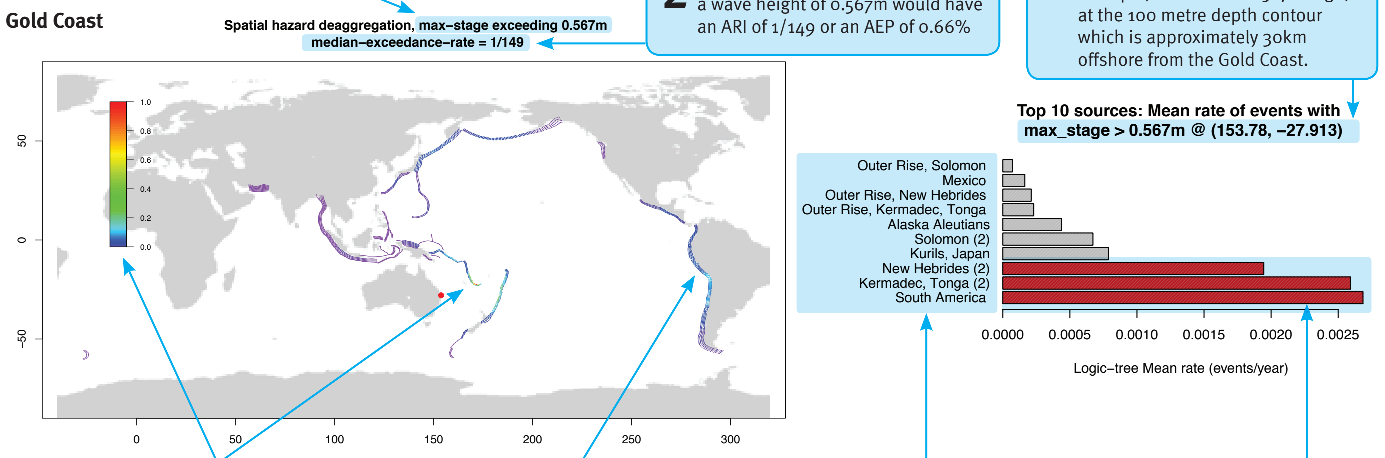
How to read the Hazard Deaggregation Plots

1 "max-stage" indicates the height of the wave at a given location (refer to box 5).

2 This plot indicates that an event with a wave height of 0.567m would have an ARI of 1/149 or an AEP of 0.66%

5 Indicates the offshore location at which this wave height reaches the 100 metre depth contour along the Queensland Coast. Point 3 above is important to note here. In this example, the wave is 0.567m high, at the 100 metre depth contour which is approximately 30km offshore from the Gold Coast.

Gold Coast



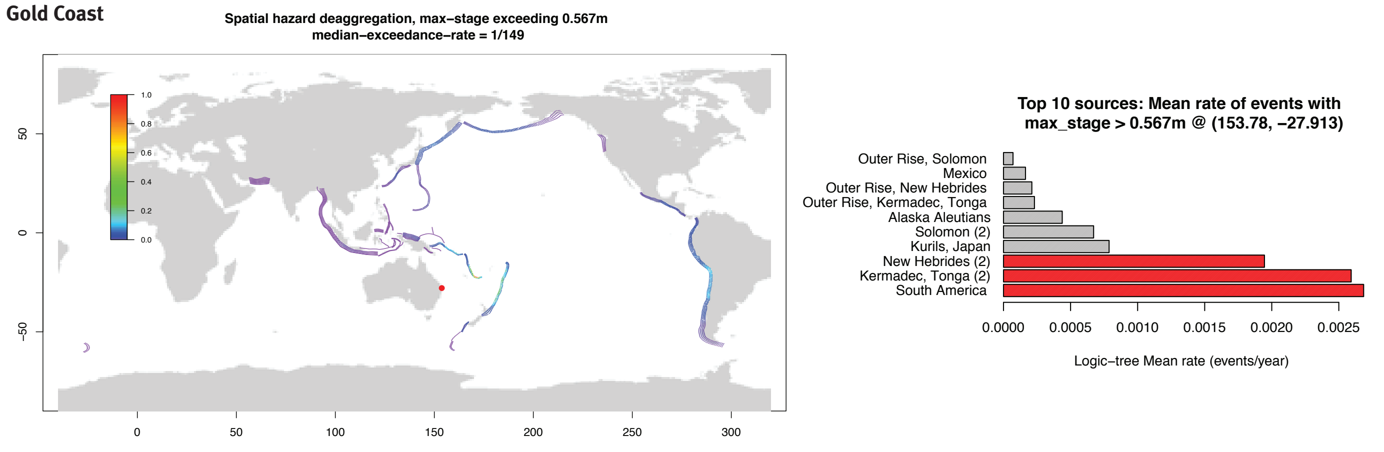
3 Visual representation of how likely an earthquake tsunami of this wave height is to occur on each of the source zones. **For example:** A zone highlighted in red would be more likely to generate a tsunami at this wave height than a similarly-sized zone in green or blue.

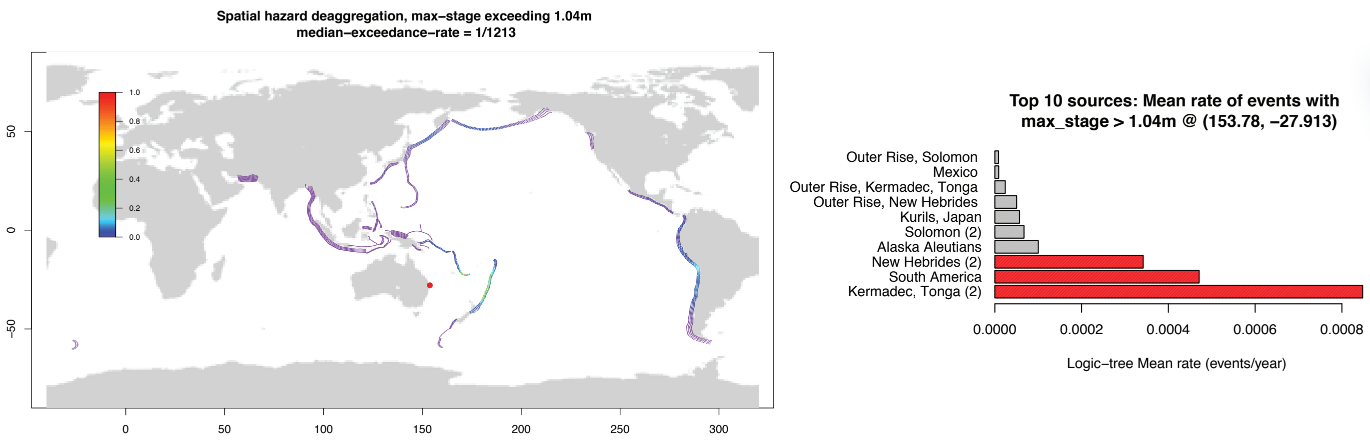
4 Demonstrates that tsunami are a global and localised risk as the size of a source zone is also important. **For example:** A large zone with green or blue may add up to give a greater contribution than a small zone in red. Box 7 shows that the larger South American source zone is more likely to generate this wave then the smaller New Hebrides source zone.

6 Indicates those source zones capable of generating an earthquake tsunami that will impact the location under assessment (refer to Figure 4a).

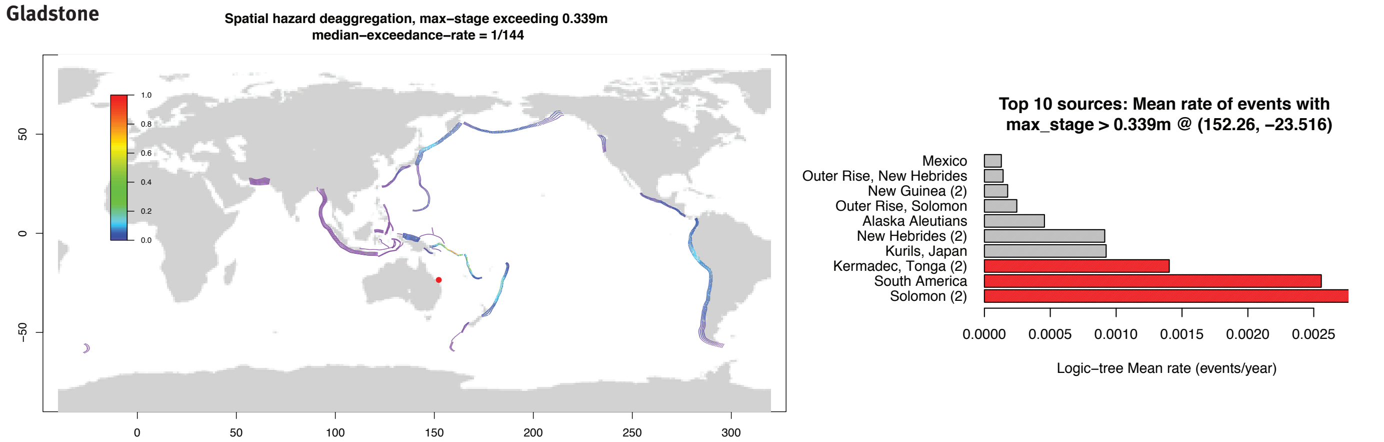
7 Indicates that these source zones have the highest likelihood of generating an earthquake tsunami that will impact the location under assessment.

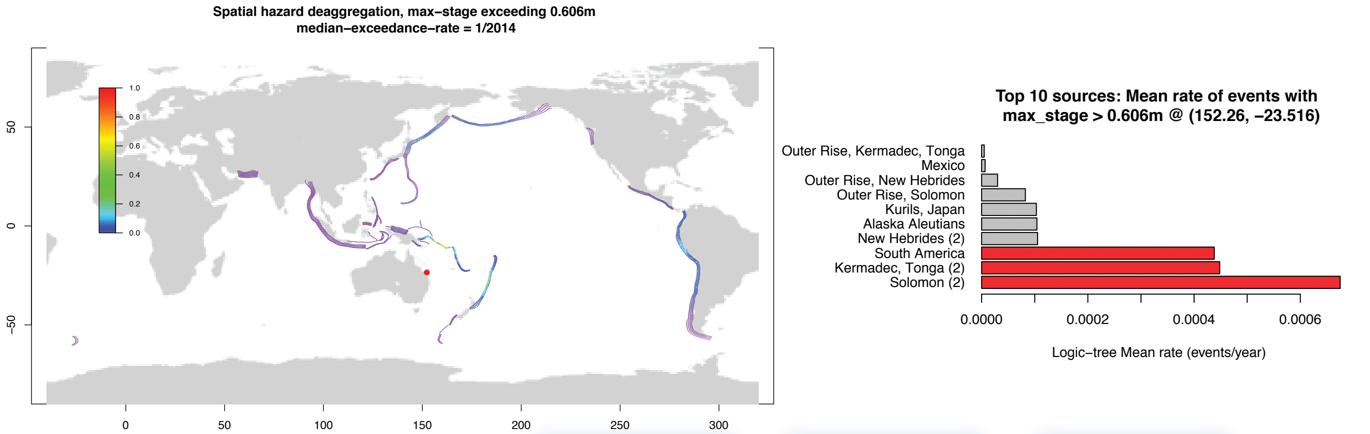
Gold Coast



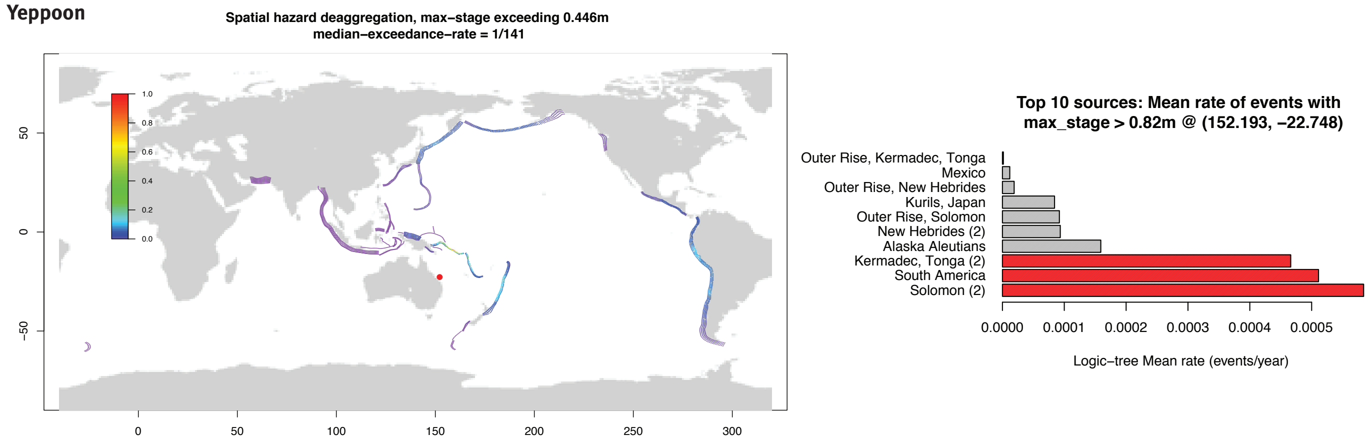


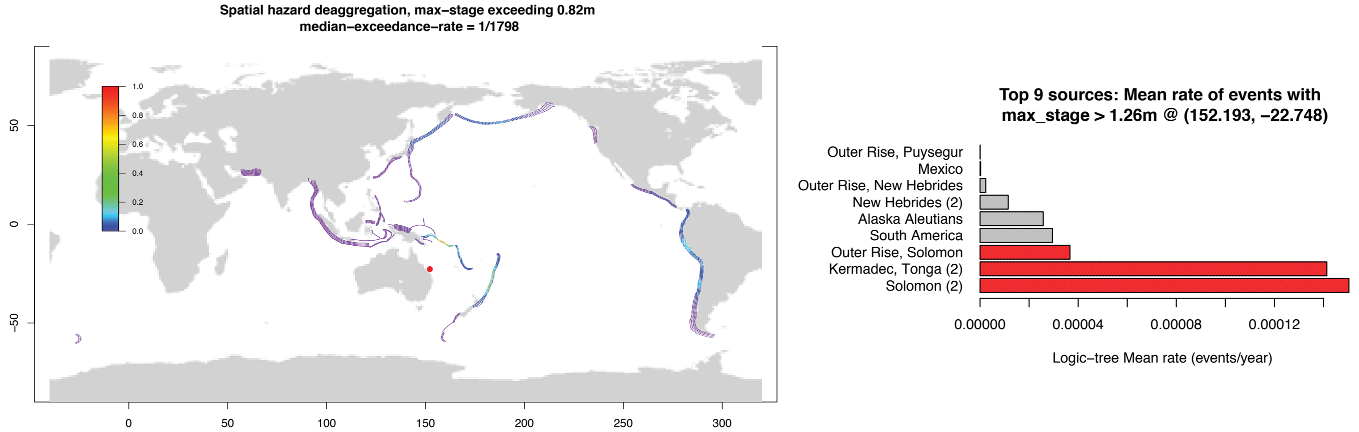
Gladstone



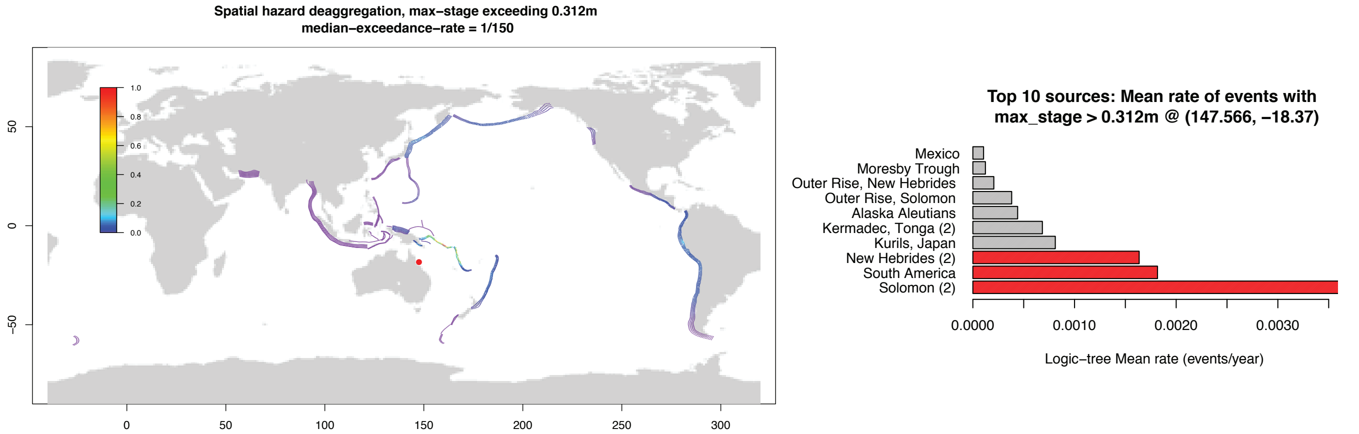


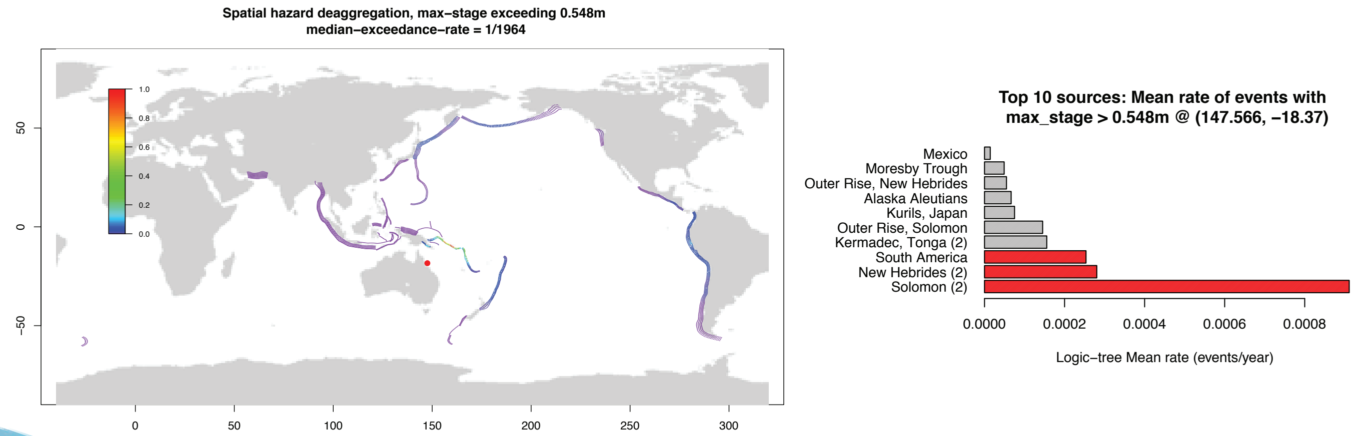
Yeppoon



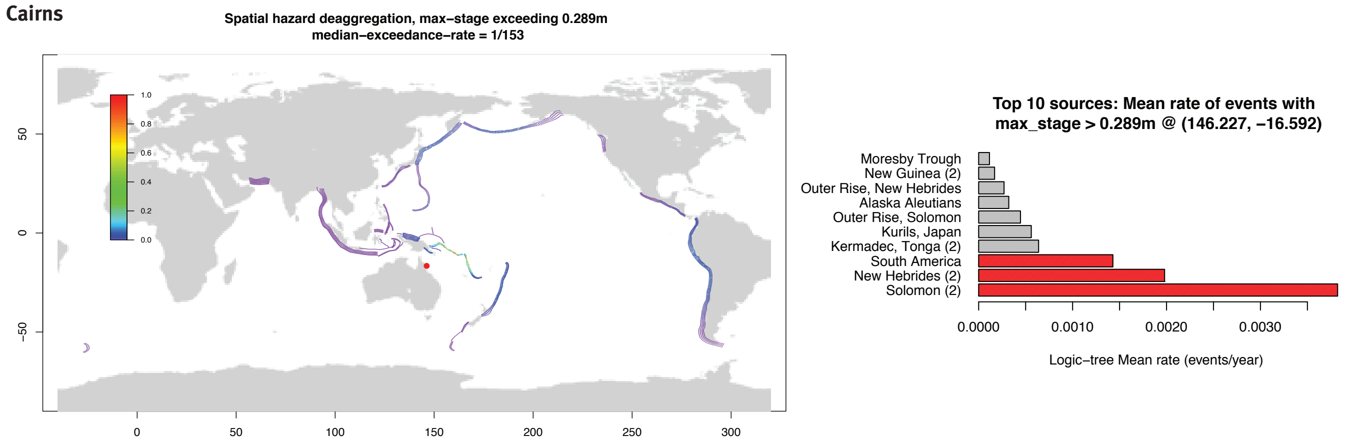


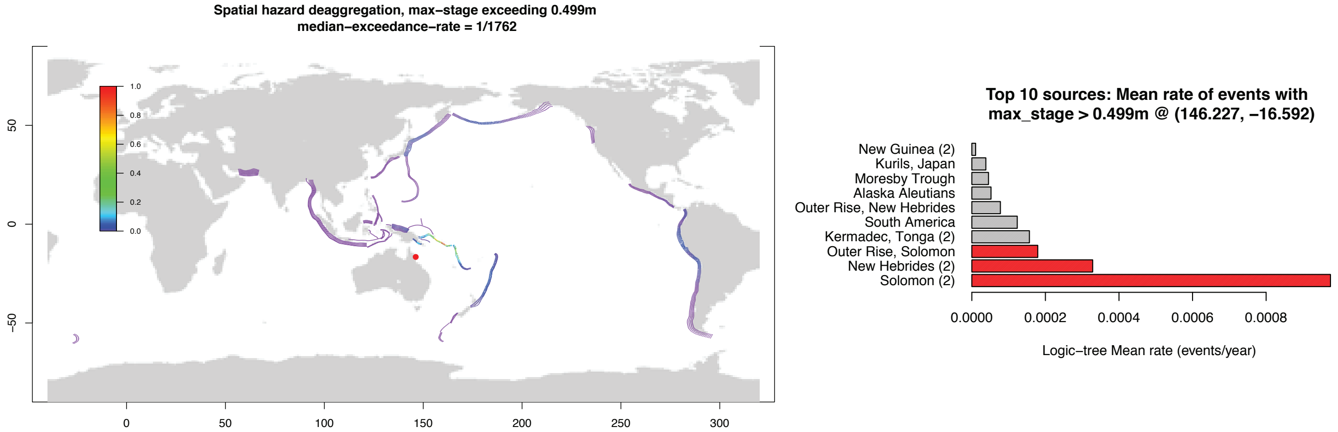
Townsville



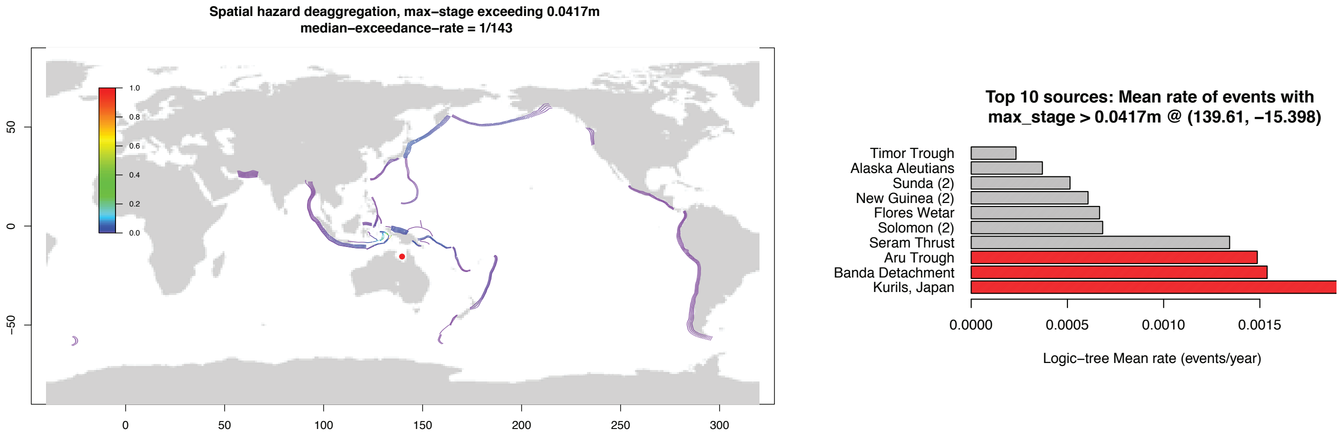


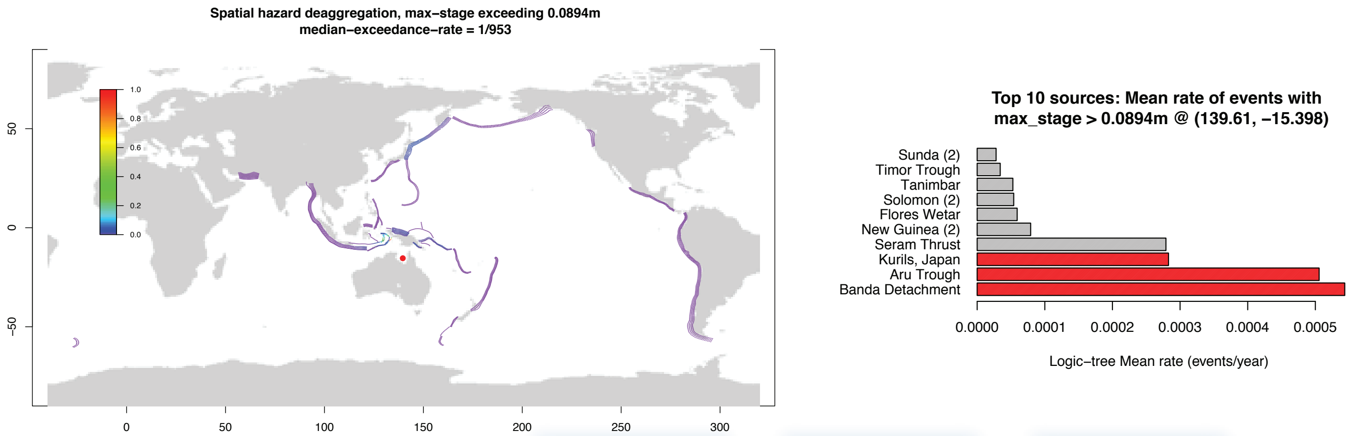
Cairns





Karumba and Mornington Island



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Geoscience Australia
Queensland
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