



Tsunami Hazards in the Port of Hobart: Maritime Advice

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Quality Information

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Executive Summary

1. The primary objective of the project is to provide advice on possible hazards to shipping (commercial, scientific research, and other agreed significant vessels) from modelled tsunami scenarios in the Derwent Estuary, Tasmania, for the principal Hobart port area (including Constitution Dock and Macquarie Point); Selfs Point Wharf; Risdon Wharf; Prince of Wales Bay wharf and dock facilities; the principal navigational channels and established anchorage areas from Iron Pot to Risdon Wharf; and the navigational channel specifically in the vicinity of the Tasman Bridge. The project was conducted as a desktop study and, whilst comprehensive in approach, the findings should be viewed as preliminary in nature. Further research is needed to test the reliability and validity of the findings to improve/ensure their accuracy.

2. A literature review was undertaken to assess and summarise the types of advice being provided to similar organisations, particularly port authorities, in other jurisdictions in Australia and internationally. The literature has three common themes, namely the provision of timely warning systems and procedures; evacuation of personnel; and advice to shipping and small craft. Although advice to shipping exists, it does not figure prominently in the emergency management/response literature. However, conventional wisdom (good seamanship practice), supported by general and academic literature is that the safest place to be for shipping is at sea in deep water. Information on what actions should be taken by a ship in port which is unable to get to deep water appears relatively limited, but that which does exist is based primarily on the Japanese experience. The literature also provides general advice to small craft, such as, if weather and time-permit move the vessel to deep water (over 45 metres) if it is able to handle the conditions. If it cannot handle the conditions, then it may be safer to leave the boat tied up and physically move personnel to higher ground.

3. The South East Tasmania Tsunami Inundation Model, developed for this project, indicates:

- Tsunami waves adhere to the general rules of wave behaviour in shallow water i.e. As the wave approaches shore (with water becoming shallower), the wave height increases, wavelength decreases and velocity decreases
- Wave heights are generally lower in the outer shipping channel, becoming higher in the port and dock areas
- A funnelling of the wave is observed as the channel narrows to the north of the Tasman Bridge and the maximum wave height is higher. This may also be exacerbated by reflection of waves from the steep bathymetry on the eastern shore
- Because of the long wavelengths, the tsunami waves arrive as a rise in water level that occurs over a period of 10-20 minutes (from starting level to peak wave height). The water level then decreases to a minimum value across the following 10-20 minutes
- In addition to the tsunami waves themselves, significant seiching and wave reflections are evident and may also generate significant water disturbance

4. The *2016 Tasmanian State Natural Disaster Risk Assessment: All Hazard Summary* indicates the likelihood of a disastrous tsunami is assessed as EXTREMELY RARE, with its overall consequence being MAJOR, and its overall risk rating being MEDIUM.

5. Based on the modelled tsunami scenarios, possible hazards to shipping and related maritime infrastructure were developed by considering the possible worst case consequences for Property (Vessel, Small craft, and Infrastructure); Life (Vessel, Small craft, and Vicinity); and Environment (Land, and Water). The potential consequences are detailed in the table

series 6-7, 9-12. From this a number of potential mitigating scenarios and actions were developed.

6. For shipping, appropriate mitigating actions are:

- If there is enough time before the arrival of the tsunami ships should evacuate outside the port
- If there is not enough time before the tsunami arrives ships should aim to remain in the deepest water in the port area. (This is considered feasible when the expected wave height is not excessive as is the case in the Principal Shipping Channel off White Rock Point)
- If evacuation is not possible the mooring system should be reinforced by increasing the number of mooring ropes, and regulating the mooring ropes so the ship cannot 'hang' on the ropes. It is noted that the mooring forces are usually smaller when the tsunami current is parallel to the ship. (This is the case for ships moored at Selfs Point Wharf and Nyrstar Wharf)

7. Based on the speculative evacuation times in Tables 15-18 and provided that a 1 hour warning is received it is probable that:

- A Handymax bulk carrier originally berthed at Risdon (Nyrstar) Wharf would meet the incoming tsunami wave to the south of the Tasman Bridge in the Principal Shipping Channel but still to the north of the deeper water off White Rock Point
- A Handymax oil tanker originally berthed at Selfs Point Wharf would meet the incoming tsunami wave a little to the south of the Tasman Bridge in the Principal Shipping Channel.
- The *Aurora Australis* originally berthed at Princes Wharf would meet the incoming tsunami wave in the vicinity of the deepest water off White Rock Point in the Principal Shipping Channel.
- A cruise ship similar to the *Sapphire Princess* and originally berthed at Macquarie Wharf would meet the incoming tsunami wave in the vicinity of the deepest water off White Rock Point in the Principal Shipping Channel.

8. Because most of the commercial shipping using the berths in the Port of Hobart have drafts greater than the inundation water levels above the berth deck, there is limited likelihood of these vessels being bodily lifted by the tsunami wave on to the berth. However, smaller vessels/craft with shallower drafts, e.g. less than 1.2 metres at the CSIRO Wharf, are at risk of being lifted on to the berth deck.

For shipping alongside that cannot, or decides not to, evacuate to deeper water the main risk is breaking adrift. Consequences of breaking adrift include major damage to the drifting ship, and other vessels and infrastructure struck by the drifting ship.

As the tsunami wave approaches, a ship alongside is lifted and may heel against the berth or break adrift if mooring lines are not tended to deal with the rising water. Mooring lines will slack off as the water recedes which may cause the ship to range away from the berth or break adrift if mooring lines are not tended to deal with the receding water. Extra mooring lines should be utilised if possible and crew should be stationed to slack off/tighten mooring lines as necessary.

For smaller vessels with shallower drafts it may be more prudent to put out extra moorings and then evacuate the crew to a safe, higher location ashore.

9. For small craft, appropriate mitigating actions are:

- Small craft underway

Small craft constructed for use in offshore waters which have sufficient warning may be safer in deeper water. If it is not feasible to reach deeper water then the small craft should attempt to land, be secured, and the crew evacuated to a safe location.

Small craft constructed for use in sheltered waters are less likely to be able to ride out a tsunami wave or be able to evacuate to deeper water. For small craft of sufficient engine power, it may be feasible to reach deep water, but only if it is considered safe to do so. Consequently, the most appropriate course of action may be to land, secure the craft, and evacuate the crew to a safe location.

- Small craft at designated anchorages, marinas and alongside a berth

There is evidence of turbulence (e.g. breaking waves) at all Marinas and all Designated Small Craft Anchorages. Consequently, the most appropriate course of action may be to secure the craft, and evacuate the crew to a safe location. If sufficient time is available, small craft of sufficient engine power may be able to reach deep water, but only if it is considered safe to do so. Some of the larger craft alongside at a berth (e.g. fishing boats, ocean cruising yachts, ferries) may be able to let go and reach deep water, if sufficient time is available. If this is not feasible then the craft should be secured, and the crew evacuated to a safe location.

10. In summary, this preliminary report indicates the possible hazards to shipping from a worst case scenario tsunami in the Port of Hobart. The report is a high level review and potentially forms the basis for further more detailed consideration and research. In order to improve the accuracy and validity of the hazards and effects of a tsunami on vessels using the Port of Hobart more detailed research is needed. This could include:

- Improved data on vessels using the Port of Hobart e.g. types, size, speed
- Improved data on the alongside status of vessels using the Port of Hobart e.g. time taken for a vessel to let go and clear a berth including availability of crew and engines, mooring lines and gangways, manoeuvring issues, meteorological conditions
- Simulating ship evacuation scenarios on the Australian Maritime College simulators
- Reviewing potential hazards, damage criteria, mitigating actions including evacuation scenarios
- Consideration of the effects of 'smaller' tsunamis and different states of the tide
- Possibly testing the effects of a tsunami on vessels alongside a berth in the Australian Maritime College Model Test Basin

Outcomes from this research could be used to develop/refine/improve the advice to vessels and small craft in the Port of Hobart in the event of a tsunami warning being received.

1. Introduction

1.1. Background

The Department of State Growth commissioned AMC Search Ltd to provide advice on possible hazards to shipping based on modelled tsunami scenarios in the Derwent Estuary, Tasmania. Details of the full scope of the project are at Appendix 1.

AMC Search Ltd (AMCS) is the commercial arm of the [Australian Maritime College](#) and is a wholly owned subsidiary of the [University of Tasmania](#). It is a company that provides solutions to maritime and maritime related organisations through its well-regarded consultancy services. With the backing of its parent institution, the Australian Maritime College, AMCS has provided training and consultancy services since 1985, using the internationally-renowned resources of the College.

1.2. Project Objective

The primary objective of the project is to provide advice on possible hazards to shipping (commercial, scientific research, and other agreed significant vessels) from modelled tsunami scenarios in the Derwent Estuary, Tasmania, for the following specific areas:

- a) The principal Hobart port area (including Constitution Dock and Macquarie Point);
- b) Selfs Point Wharf;
- c) Risdon Wharf;
- d) Prince of Wales Bay wharf and dock facilities;
- e) The principal navigational channels and established anchorage areas from Iron Pot to Risdon Wharf; and
- f) The navigational channel specifically in the vicinity of the Tasman Bridge.

1.3. Project Methodology

To achieve the objectives of the project a five stage approach was adopted, namely:

- Advice on the design of the tsunami computer model was provided to ensure that the model outputs provided the necessary information for shipping hazards to be adequately assessed
- A literature review was undertaken to assess and summarise the types of advice being provided to similar organisations, particularly port authorities, in other jurisdictions in Australia and internationally
- The tsunami computer model (South East Tasmania Tsunami Inundation Model) outputs were analysed to assess the implications for shipping at specified locations
- Some mitigating action scenarios were developed to further illustrate the implications for shipping
- A draft report summarising the findings, identifying any potential constraints and recommendations for further work and actions was prepared and presented at a workshop for stakeholders
- A final report incorporating comments from stakeholders and feedback from the workshop was prepared and delivered to the Department of State Growth

1.4. Tasmanian Emergency Plans - Tsunamis

Tasmanian emergency plans are well developed and the plans of direct relevance to this project are:

- Tasmanian Emergency Management Plan (TEMP)
- TasPorts Emergency Management Plan

The Tasmanian Emergency Management Plan (TEMP), Issue 8 [1] is the overarching plan for the management of emergencies in Tasmania. TEMP Table 4 lists the State Emergency Management Committee's Advisory Agencies and Management Authorities for Hazards; for tsunamis the State Emergency Service is responsible for "*Prevention and Mitigation*" whilst the Department of Police and Emergency Management is responsible for "*Preparedness*" and "*Response*". TEMP Section 3.1.17 lists tsunamis as a research and risk assessment theme currently being considered.

The Tasmanian Ports Corporation (TasPorts) Emergency Management Plan, Version 1.5 [2] includes tsunamis under its Severe Weather Warning Procedure; it states:

"In preparation for a storm, Port Control is to initiate safety precautions and actively monitor weather conditions. Severe Weather/Thunderstorm Warnings are issued by the Bureau of Meteorology for any of the following conditions:

- *wind gusts 90kph/49kts or more*
- *average wind speeds across land of 63kph/34kts or more*
- *heavy rainfall that is conducive to flash flooding or a reported flash flood*
- *abnormal high tides caused by winds (expected to exceed highest astronomical tide), and*
- *Tsunami warning"*

Details of the procedure to be followed are at Appendix 2.

The Tasmania State Emergency Services website [3] contains resources aimed at improving knowledge and awareness of tsunamis; it indicates that tsunamis have been experienced in Tasmania:

"There are two types of tsunami threat – land inundation threat and marine environment threat. A marine threat is the most likely type to occur but is more difficult to identify than the land threat. As opposed to wind driven waves, a tsunami is more like a wall of water. It usually appears as a series of waves, with the time between each wave ranging from ten minutes to two hours. At the beach, a tsunami wave does not break like normal beach waves, but continues to push ashore and may be seen as a rapidly rising tide. While Tasmania has not been significantly impacted by a tsunami in recent history, its proximity to the subduction zones that stretch from Papua New Guinea to New Zealand give rise to the potential for tsunami activity, particularly along the east coast. Geoscience Australia has identified the greatest tsunami risk to Tasmania is likely to be from the Puysegur Trench area off the south coast of New Zealand, an active region for earthquakes. If a tsunami is generated from this location it will approach Tasmania across the Tasman Sea. Research into tsunami activity in Tasmania indicates that unusual wave activity has been detected around the coastline on at least 16 occasions since 1852, and that this activity was likely to have been associated with a tsunami event."

2. South East Tasmania Tsunami Inundation Computer Model

To ensure that outputs from the tsunami computer model provided the necessary information for hazards to shipping to be adequately assessed, advice on the design of the model was provided by AMC Search Ltd to the Department of State Growth on 15 August 2015. The full scope of the advice requested is contained at Appendix 3.

The following indicative wave data was requested for 69 specific locations:

- Wave height (Amplitude peak to trough, in metres)
- Wave length (Peak to peak or trough to trough, in metres and duration e.g. minutes/seconds)
- Wave velocity (Preferably in knots; or metres per second)
- Wave form (Profile and descriptor e.g. slow water level rise, rapid water level rise; a 'wall of water', breaking wave)
- Time of arrival at each location relative to location 1 i.e. location 1 is time zero
- Time taken for the Tsunami wave to arrive at locations

Meetings were held in Hobart on 10 May 2016 to review the progress of the development of the tsunami model and in Launceston on 28 July 2016 to review the outputs from the model to ensure they provided the necessary information for shipping hazards to be adequately assessed.

The South East Tasmania Tsunami Inundation Model results provided data for the 69 requested locations in the form of:

- A spreadsheet containing the requested wave data (see Appendix 4)
- Six data maps namely:
 - Marine Hazard Map1 (PSC 8-30)
 - Marine Hazard Map2 (PSC 5-8, ANC 1-4)
 - Marine Hazard Map3 (PSC 1-3, ANC 4)
 - Constitution Dock (HP 2-19) (see Appendix 5)
 - Risdon Wharf (RW 1-4) (see Appendix 6)
 - Prince of Wales Bay (POW 1-8) (see Appendix 7)
- Four videos showing the depth of the tsunami, and four videos showing the momentum of the tsunami as it progresses up the Derwent, namely:
 - Channel and Docks
 - Hobart
 - Selfs Point
 - Prince of Wales Bay

These data were used to identify the possible hazards to shipping in the Port of Hobart.

3. Literature Review - Tsunami Advice in Other Jurisdictions

3.1. Introduction

A literature review was undertaken to assess and summarise the types of advice being provided to similar organisations, particularly port authorities, in other jurisdictions in Australia and internationally. The review focused on literature associated with Tsunami high risk zones as illustrated in Diagram 1 [4]. The diagram denotes every location where a tsunami run-up has been recorded in historical time and this includes the south of Tasmania.

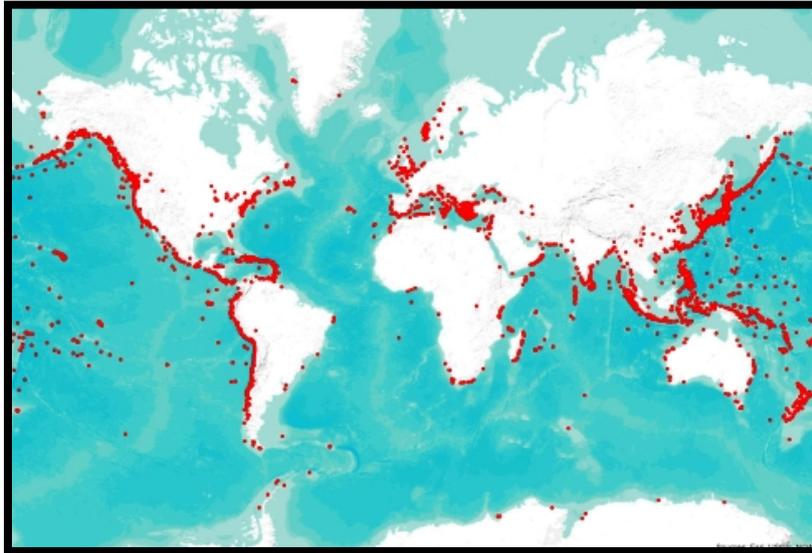


Diagram 1: World Tsunami Zones

(Source: Generated from the data in the NGDC global tsunami database [4])

It is noted that there are many descriptions of tsunamis in the literature and Anderson [5] provides a generic description of tsunamis:

"In deep, open-ocean water, these waves are often less than a metre high and can travel at speeds up to 1,000 kilometres per hour. However, as they reach shallow water and approach shorelines the leading edge of the waves begin to slow down, and the wave begins to "pile up" behind causing the wave to grow in height. The crests of these waves can be many metres high by the time they reach the shoreline. Sometimes, however, the crest of the wave isn't the first to arrive, the trough is. In this case, instead of very high water levels, the first sign of a tsunami is what appears to be a very, very low tide exposing unusually wide or unprecedented stretches of the seabed. It is important to note that the largest of the tsunami waves is often the third or fourth wave and there can be anywhere from a few tens of minutes, to more than an hour between wave crests."

However, in the case of the Port of Hobart it is the wave crest which arrives first.

The tsunami related documents which were reviewed are contained in the lists of References and Additional Tsunami Related Documents Reviewed. In addition to the literature search a number of videos of tsunami effects were sourced from YouTube and are listed following the list of references.

3.2. Summary of Advice

The literature has three common themes, namely:

- Provision of timely warning systems and procedures
- Evacuation of personnel
- Advice to shipping and small craft

Warning systems and procedures are almost exclusively aimed at notifying emergency response organisations and those likely to be directly affected by the tsunami. There is limited evidence of shipping being mentioned in response plans. Persons liable to be affected by a tsunami, including port workers, are generally advised to move to higher ground away from the coast or congregate on top of structures that will remain above the water.

Although general advice to shipping exists, it does not figure prominently in the emergency management/response literature. However, conventional wisdom (good seamanship practice), supported by general and academic literature is that the safest place to be for shipping is at sea in deep water. Information on what actions should be taken by a ship in port which is unable to get to deep water appears relatively limited, but that which does exist is based primarily on the Japanese experience. Port specific information on the detailed actions to be taken by a ship in port is also relatively limited. The literature also provides general advice to small craft, such as, if weather and time-permit move the vessel to deep water if it is able to handle the conditions. If it cannot handle the conditions, then it may be safer to leave the boat tied up and physically move to higher ground.

3.3. Literature Extracts

The following extracts from the literature indicate the relevant scope of advice for shipping and small craft:

With respect to warnings the *Tasmanian State Tsunami Emergency Response Plan* [6] indicates the following:

“3.2.3 Warnings and Public Information - National

The official tsunami warning centre for Australia is the Joint Australian Tsunami Warning Centre (JATWC) that is operated by the BoM and GA. Based in Melbourne and Canberra, the JATWC has been established so that Australia has an independent capability to detect, monitor, verify and warn the community of the existence of tsunami in the region and possible threats to Australian coastal locations and offshore islands.

The BoM Tasmanian Regional Forecasting Centre maintains distribution lists for Tsunami Bulletins, Watches and Warnings. The distribution lists contain contacts for TasPol, SES, TasALERT, Marine and Safety Tasmania (MAST), Tasmanian Ports Corporation and the media. The bulletin and warning messages are also automatically uploaded to the BoM website and are available on local radio and TV announcements or via a phone information line (1300 tsunami or 1300 878 626).”

“3.3.6 Warnings and Public Information - Tasmania

Tsunami warnings may not always be possible for all tsunamis e.g. those caused by sources other than earthquakes. For tsunamis originating from the Puysegur Trench (south of NZ) there may be as little as 60 minutes until the tsunami arrives at the Tasmanian coastline. It is therefore critical that warnings reach affected communities quickly and efficiently and by all appropriate means.

As detailed in Section 3.2.3 and Appendix 3 of this plan, Tsunami Warnings are initially issued by the BoM and are distributed to media outlets and emergency management agencies.

TasPol RDS will coordinate the dissemination of Tsunami Watches, Warnings and Bulletins issued by the JATWC through the BoM, to commercial and recreational vessels, ports and marinas via marine radio distress and calling frequencies.”

“5.3 Appendix 3 - Tsunami Warnings and the Australian Tsunami Warning System (ATWS)

Effective warning time, and therefore warning arrangements, will vary depending on the proximity of tsunami generation, for example:

- *A distant tsunami (e.g. Chile, California or Alaska) may arrive over 12 hours after it has been generated*

- An earthquake along the Puysegur Trench in New Zealand may arrive approximately 2 hours after impact
- A local tsunami possibly caused by a submarine landslide may arrive at the initial point of impact along the Tasmanian coast within minutes. Under these circumstances, limited warning time may be available to adjacent coastal communities outside the initial impact area. (BoM may not be able to provide a Tsunami Warning under this circumstance)
- Meteorological tsunami – caused by high winds.”

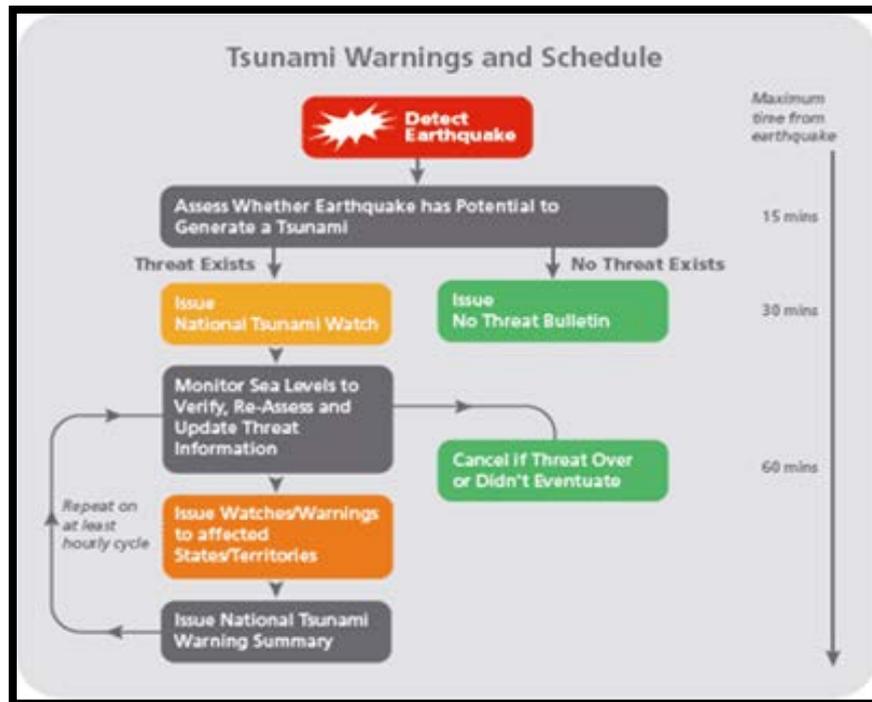


Diagram 2: Tsunami Warnings and Schedule (Source: Figure 2 *Tasmanian State Tsunami Emergency Response Plan* [6])

With respect to advice to shipping and small craft the *Tasmanian State Tsunami Emergency Response Plan* [6] indicates the following:

“3.3.7.2 Management of Waterways

People on boats or ships will be encouraged to:

- *If in shallow water, get out of the water and move away from the immediate water’s edge of harbours, coastal estuaries, rock platforms and beaches*
- *When sufficient warning time is available, return any boats in harbours, estuaries and in shallow coastal water to shore, then secure the boat and move away from the waterfront*
- *Move vessels already at sea to deep water well offshore and remain there until further advised.*
- *When sufficient warning time is available, ocean capable ships currently in port or at anchorage may be instructed to move to deep water offshore to a depth greater than 30 metres. Vessels instructed to move from ports or harbours to deep water offshore will be prioritised in terms of risk posed to the nearby port facilities and population and their potential to provide assistance during rescue and recovery phases. It may be difficult for smaller vessels to move to deep water if there is a concurrent severe weather event occurring or predicted. Tasmanian Ports Corporation (Tasports) will coordinate the movement of ships within the port limits.”*

Mikami et al in their *Field Survey of the 2011 Tohoku Earthquake and Tsunami in Miyagi and Fukushima Prefectures* state the following:

"Essentially when there is a tsunami alert all ships are ordered to go to the sea, as otherwise they risk floating over defences and exacerbate the damage (many examples of ships were left stranded inland during the Tohoku and Chile tsunamis). I am not sure whether any document actually indicates this, but it is "common knowledge" in areas frequently hit by tsunamis, such as Japan." [7]

The Hong Kong Weather Service advice is:

"... the impact of tsunamis to vessels at deep sea would be minimal. Hence, the general guidelines for countermeasures to be taken for vessels in case of tsunamis are:

- those at port, harbour or in shallow water should evacuate to an area with deep water (sea depth of 50 m or more for tsunamis at coast smaller than 3 m, but deeper for more significant tsunamis, according to the Ministry of Agriculture, Forestry and Fisheries of Japan) if there is enough time to do so before tsunami arrival, or*
- secure the vessels and evacuate the crew away from the waterfront if the time is not enough for the ships to evacuate to the deep sea or if evacuation is difficult. Furthermore, vessels which are already in or have evacuated to deep sea areas should take control to avoid being upset by or caught in the flow of the current." [8]*

The United States Department of Commerce, National Oceanic and Atmospheric Administration's / National Weather Service, National Tsunami Warning Center suggests:

"If you are on a boat or ship, weather and time-permitting, move your vessel to deeper water (at least 150 feet). If it is the case that there is concurrent severe weather, it may safer to leave the boat at the pier and physically move to higher ground. Damaging wave activity and unpredictable currents can affect harbor conditions for a period of time after the tsunami's initial impact. Be sure conditions are safe before you return your boat or ship to the harbor." [9]

Queensland Government advice is:

"On a boat or ship

- if in a harbour, estuary or shallow water close to shore, and there is enough time, return to land, secure your vessel and move to higher ground*
- if at sea, move to deep water (open ocean) well off-shore and stay there until further advised." [10]*

The International Tsunami Information Center *What to do? Tsunami safety for boaters* brochure indicates:

"1 ... do not return to port if you are at sea and a tsunami warning has been issued. Port facilities may become damaged and hazardous with debris. Listen to mariner radio reports when it is safe to return to port.

2 ... rapid changes in water level and unpredictable dangerous currents are magnified in ports and harbors. Damaging wave activity can continue for many hours following initial tsunami impact. Contact the harbor authority or listen to mariner radio reports. Make sure that conditions in the harbor are safe for navigation and berthing.

3 Boats are safer from tsunami damage while in the deep ocean (> 100 m) rather than moored in a harbor. But, do not risk your life and attempt to motor your boat into deep water if it is too close to wave arrival time.

4 For a locally-generated tsunami, there will be no time to motor a boat into deep water because waves can come ashore within minutes. Leave your boat at the pier and physically move to higher ground.

5 For a tele-tsunami generated far away, there will be more time (one or more hours) to deploy a boat. Listen for official tsunami wave arrival time estimates and plan accordingly.

6 Most large harbors and ports are under the control of a harbor authority and/or a vessel traffic system. These authorities direct operations during periods of increased readiness, including the forced movement of vessels if deemed necessary. Keep in contact with authorities when tsunami warnings are issued." [11]

The Bureau of Meteorology (2016), *Tsunami Frequently Asked Questions* states:

"If your boat is in deep water and offshore, maintain your position. If your boat is berthed or in shallow water, secure your vessel and move inland or to higher ground." [12]

Wiśniewski and Wolski [13] in their journal article, *The safety of the shipping and ports in the aspect of the tsunami events*, develop actions for shipping in port in the event of a tsunami warning. Table 1 illustrates:

Table 1: Standard recommendations for the operations of the ship before the tsunami					
Tsunami forecast	magnitude	Time until tsunami arrival	Moored ship in port	Anchored and moored ships	Ships underway in the port and roads
Tsunami Warning	Strong tsunami (3-10m+)	Short (under 0.5h)	Halt cargo handling. The recommended evacuation of the crew to land	Use engine	The recommended offshore evacuation
		Medium (0.5-1.5h)	Halt cargo handling. The recommended offshore evacuation of the ship. Possible evacuation of the crew to land	Use engine or possible offshore evacuation	
		Long (over 1.5h)	Halt cargo handling. Offshore evacuation	Offshore evacuation	
	Average tsunami (1-3m)	Short (under 0.5h)	Halt cargo handling. Strengthen mooring. Possible evacuation of the crew to land	Use engine	Offshore evacuation
		Medium (0.5-1.5h)	Halt cargo handling. Strengthen mooring. Offshore evacuation or evacuation of the crew to land	Use engine or possible offshore evacuation	
		Long (over 1.5h)	Halt cargo handling. Strengthen mooring Offshore evacuation or evacuation at designated places of refuge in the port	Offshore evacuation	
Tsunami Advisory	Small tsunami (under 1m)		Halt cargo handling. Strengthen mooring. Possible offshore evacuation	Note the conditions (if not worse in the next message). In these cases, use engine or offshore evacuation	Offshore evacuation

Note: Based on Wiśniewski and Wolski, *The safety of the shipping and ports in the aspect of the tsunami events* [13]

The 9th Regional Japan Coast Guard Headquarters brochure, *To secure Life and Ship from Tsunami* [14], states the following:

"When warning and/or advisory are issued, all ships are supposed to suspend loading and work regardless of situations such as alongside, anchorage and the like, and then respond by reference to the table below." Table 2 illustrates:

Table 2: Shipping in Port - Response to Tsunami Warning							
Tsunami Warning Category	Estimated Maximum Tsunami Height		Adequate time before arrival of tsunami	Ships at Berth in Port		Ships Anchored and on a mooring buoy	Navigating Ships
	Quantitative expression	For earthquakes		General Ships	Ships with dangerous cargo		
Major Tsunami Warning	Above 7.5m	Huge	NO	Evacuate mooring or evacuate on shore		Evacuate in port	
	Below 7.5m		YES	Evacuate out of port		Evacuate out of port	
Tsunami Warning	3m	High	NO	Evacuate mooring		Evacuate in port	
			YES	Evacuate out of port or evacuate mooring	Evacuate out of port	Evacuate out of port	
Tsunami Advisory	1m	N/A	N/A	Evacuate out of port or evacuate mooring		Evacuate in port or evacuate out of port	Evacuate out of port

Note 1: Terminology explanation
ADEQUATE TIME BEFORE ARRIVAL OF TSUNAMI:

- YES: After TSUNAMI WARNING issued, there are adequate time to evacuate ships and secure their safety.
- NO: After TSUNAMI WARNING issued, there are little time to evacuate ships and secure their safety.

MOORING EVACUATION: To keep moored against TSUNAMI by reinforcement of mooring along with engine. (Consider evacuating land workers and the like aboard the ship for emergency shelter.)

EVACUATION IN PORT: To remain at waters for emergency evacuation in a port, by using anchor, engine, thruster and the like.

EVACUATION OUT OF PORT: To evacuate offshore from a port to the open sea where the water is deep. (Consider EVACUATION IN PORT when it becomes difficult to sail during EVACUATION OUT OF PORT)

EVACUATION ON SHORE: To evacuate ship crew ashore and then to high ground, after taking all possible measures to secure the safety of dangerous cargo and to prevent a ship from being drift."

Note 2: Based on 9th Regional Japan Coast Guard Headquarters, *To secure Life and Ship from Tsunami* [14]

There is considerable similarity in the advice to shipping in port when a tsunami warning is received and Table 3 is a compilation of the advice to shipping and small craft based on the literature in general and specifically:

- Hong Kong Weather Service, *List of Countermeasures against Tsunami*, [15]
- 9th Regional Japan Coast Guard Headquarters brochure, *To secure Life and Ship from Tsunami* [14]
- Wiśniewski B and Wolski T (2012) article, *The safety of the shipping and ports in the aspect of the tsunami events* [13]

Predicted Tsunami height	Able to get to deep water	Vessels alongside in port			Anchored/ moored v/l's	Vessels underway in port area	
		Large & mid size v/l's		Small craft		Large & mid size v/l's	Small craft
		V/l's with DG	Other v/l's				
Over 3 metres	No	Evacuate to deep water	Evacuate to land	Evacuate to land	Use engine	Evacuate to deep water	Land and evacuate
	Maybe		Evacuate to land, or to deep water	Evacuate to land, or (to deep water if safe to do so)	Use engine, or evacuate to deep water		Evacuate to deep water, or (land and evacuate if safe to do so)
	Yes		Evacuate to deep water		Evacuate to deep water		Evacuate to deep water, or land and evacuate
1 - 3 metres	No		Evacuate to land, or strengthen moorings	Evacuate to land	Use engine		Land and evacuate
	Maybe		Evacuate to deep water, or to land, or strengthen moorings	Evacuate to land, or (to deep water if safe to do so)	Use engine, or evacuate to deep water		Evacuate to deep water, or (land and evacuate if safe to do so)
	Yes		Evacuate to deep water, or strengthen moorings		Evacuate to deep water		Evacuate to deep water, or land and evacuate
0.5 - 1 metre		Evacuate to deep water, or strengthen moorings	Secure craft, or evacuate to deep water	Use engine, or evacuate to deep water		Secure craft, or evacuate to deep water	

Note: Based on Hong Kong Weather Service, *List of Countermeasures against Tsunami* [15]; 9th Regional Japan Coast Guard Headquarters, *To secure Life and Ship from Tsunami*, 9th Regional Japan Coast Guard Headquarters [14]; and Wiśniewski and Wolski, *The safety of the shipping and ports in the aspect of the tsunami events* [13]

It is noteworthy that there is no consistency on precisely what depth constitutes deep water, as the literature variously describes deep water as:

- Offshore 30+ metres {*Tasmanian State Tsunami Emergency Response Plan* [6]}
- Deeper water 150+ feet (45+ metres) {National Oceanic and Atmospheric Administration [9]}
- Sea depth of 50+ metres (Tsunamis under 3 metres; deeper for higher tsunamis) {Hong Kong Weather Service [8]}
- Deep ocean 100+ metres {International Tsunami Information Center [11]}
- Open ocean {Queensland Government [10]}

4. Analysis of Computer Model Outputs

South East Tasmania Tsunami Inundation Model Results

4.1. Model Outputs

- A table of results for gauges across the entire modelling area, including 65 within the Derwent estuary, shipping channel and marina or dock areas. These are identified in the description field of Appendix 4
- A sequence of maps showing the location of the 69 gauges of interest, summarising the key results at each location and showing areas of turbulence (i.e. where the maximum wave is breaking). Appendices 5, 6, and 7 contain the gauge data for Constitution Dock, Risdon Wharf, and Prince of Wales Bay
- Movie animations showing the model results over time. Two copies of each file were produced – one showing the changes in depth over time and the other showing the momentum. Although not strictly showing velocity, the vectors (arrows) on the momentum plots are a useful tool for visualising the direction of the tsunami propagation

4.2. Summary of computer model findings and interpretations

General observations:

- Tsunami waves adhere to the general rules of wave behaviour in shallow water. As the wave approaches shore (with water becoming shallower), the wave height increases, wavelength decreases and velocity decreases. This pattern can be seen in both the gauge data and the animations of the model run. Wave heights are generally lower in the outer shipping channel, becoming higher in the port and dock areas
- A funnelling of the wave is observed as the channel narrows beyond (upstream) the Tasman Bridge. Maximum wave height is higher here, which may also be exacerbated by reflection of waves from the steep bathymetry on the eastern shore
- With such long wavelengths, the tsunami waves arrive as a rise in water level that occurs over a period of 10-20 minutes (from starting level to peak wave height). The water level then decreases to a minimum value across the following 10-20 minutes
- In addition to the tsunami waves themselves, significant seiching and wave reflections are evident in the time series data. In some cases, this results in maximum water levels that are out of sync with the tsunami wave timing, and may also generate significant water disturbance

Shipping channel:

- Tsunami arrival times vary between 2.5 and 3.25 hours after the earthquake, with a difference of 36 minutes between PSC1 (off Iron Pot) and PSC30 (entering Prince of Wales Bay)
- End times show disturbance that persists for 13-15 hours at most locations
- Maximum wave heights vary from a minimum of 2.4 m at PSC6 (off Blinking Billy Point), to a maximum of 5.1 m at PSC21 (off New Town Bay). Many values fall between 3.5 and 4.5 m
- Wavelengths for the largest wave in each sequence are generally between 3 and 5 km. This is within the expected range for tsunami waves as they enter shallow water

- Most of the tsunami-induced velocity fluctuations relate to wave speed, with maximum values falling between 15.5 knots (mid channel at the entrance to Prince of Wales Bay) and 32.7 knots (at PSC3, off Blinking Billy Point). Maximum induced current speeds are in the order of 2 to 7 knots
- No evidence of turbulence was observed in the shipping channel, as the water depth is large relative to the wave height
- Data reliability for these gauges is satisfactory, as they are all located offshore and in suitably deep water

Port area and wharves:

- Arrival times of the first wave range from 3 hours at HP2 (east of Battery Point) to 3 hours 12 minutes at POW8 (Pauline Point)
- Maximum wave heights range from 2.7 m at POW4 (INCAT jetty) to over 5 m at Selfs Point, PSC21 and Geilston Bay Marina
- Wavelengths for the first wave vary significantly, depending on the water depth and thus the degree of shoaling the wave has experienced. In shallower areas next to the shore, wavelengths are in the order of 100 to 500 m, while in deeper locations wavelengths remain at several kilometres
- Maximum wave speeds vary between 4.8 knots at POW2 (INCAT slipway) and 30.9 knots off Macquarie Point (HP19). In general, wave speeds are less than 10 knots within the dock areas and next to the shore. Higher velocities occur further out in the channel
- Turbulence is observed at 13 of the 35 gauges in the port and dock areas. Prince of Wales Bay is particularly affected, as is Macquarie Wharf and Princes Wharf 1
- A backup of water level is observed in some locations, most notably in the centre of Constitution Dock. Following inundation by the first wave, the water does not fully drain before the arrival of the second wave and the water level remains at least 1.5 m higher than the starting level for the duration of the model run. However, at no point does the water height exceed that of the first wave peak level
- The reliability of gauges in the port and dock areas is variable. There were some concerns regarding the reliability of gauges located close to the shoreline, particularly in areas with steep relief such as around the docks and cliffs. A reliability index was constructed to indicate the level of confidence in the data at each gauge location. Gauges located offshore are rated as satisfactory, but those situated at or near the shoreline boundary are generally rated marginal. Only four are deemed unreliable. These gauges were not removed from the final output, but new gauges were added a short distance away to provide extra information that is more reliable.

4.3. Definitions

- **Max wave height** – The distance from peak to trough of the wave that generated the highest water level in the time series
- **Max stage** - The maximum water level above Highest Astronomical Tide (HAT) reached during the tsunami event.
- **Wave length** – An approximate value calculated from the velocity and 2 x the time period between the maximum peak and its associated trough

- **Max current** – The maximum current velocity, provided in both ms-1 and knots. This value represents the absolute particle movement throughout time (i.e. a persistent induced current)
- **Turbulence** –An approximation of the areas likely to be affected by turbulence associated with shoaling and tsunami wave breaking (e.g. generating a bore) was calculated using the ratio of wave height (h) to water depth (d). Areas were designated ‘turbulent’ where $h/d \geq 0.72$. (Note: Modelling is based on 2D shallow water wave equations and as such, cannot resolve vertical movement. Consequently, the model cannot simulate 3D turbulence or breaking waves).
- **Wave speed** – The maximum celerity (wave speed), provided in both ms-1 and knots, derived from the water depth by the formula $c = \sqrt{gd}$. This is the instantaneous speed encountered as the wave passes a point. The effect of tsunami wave speed on marine craft is difficult to quantify and will depend on the length and draw of the boat (as with normal wind-waves).

5. Possible Hazards to Shipping Based on Modelled Tsunami Scenarios In The Derwent Estuary

Implications for Shipping

5.1. Tsunami Waves: General Effects

Research into tsunami activity in Tasmania indicates that unusual wave activity has been detected around the coastline on at least sixteen occasions since 1852, and that this activity is likely to have been associated with a tsunami event. Geoscience Australia has identified the greatest tsunami risk to Tasmania is likely to be from the Puysegur Trench area off the south coast of New Zealand, an active region for earthquakes. The likelihood of a disastrous tsunami is assessed as EXTREMELY RARE, with its overall consequence being MAJOR, and its overall risk rating being MEDIUM [16].

Of specific note is that a Tsunami initiated by an earthquake in the Puysegur Trench could reach Tasmania in 2 hours, the JATWC aims to issue a National Tsunami Watch within 30min of the earthquake and issue specific Watches and Warnings within 60mins of the earthquake. These would then be followed by additional warnings issued by Tasmania Police. This in effect means that the public in Hobart could realistically expect 1hrs warning. [6]

"The risk of tsunami to people was increased from 'Medium' in 2012 to 'High' in 2016 due to an increase in consequence from 'Major' to 'Catastrophic', despite a decrease in likelihood to 'Extremely Rare'. Experts believed that the rapid onset of this event (less than 3 hours warning in best-case conditions) limited the capacity of the emergency services to inform all vulnerable areas or people and as such it seemed realistic to expect more than 50 deaths or serious injuries. As the region of greatest vulnerability includes the Hobart waterfront, a busy place at regular times throughout the week and year, the evacuation during a large event was also considered." [16] The assessed levels of risk posed by a tsunami are contained in Table 4.

Risks to:	Likelihood	Consequence	Risk level
People – Deaths	Extremely rare	Catastrophic	High
People – Injury	Extremely rare	Catastrophic	High
Economic – General	Extremely rare	Catastrophic	High
Economic – Industry	Extremely rare	Major	Medium
Environment – Species	Extremely rare	Major	Medium
Environment – Value	Extremely rare	Moderate	Medium
Public Administration	Extremely rare	Major	Medium
Social Setting – Community Wellbeing	Extremely rare	Moderate	Low
Social Setting – Cultural Significance	Extremely rare	Major	Medium

Note: Extracted from 2016 Tasmanian State Natural Disaster Risk Assessment: *All Hazard Summary* [16]

The South East Tasmania Tsunami Inundation Model shows that the tsunami waves follow the basic rules of wave behaviour in shallow water i.e. as the wave approaches the shore, where the water becomes shallower, the wave height increases, the wavelength decreases and wave velocity also decreases. In broad terms wave heights are generally lower in the outer reaches of the shipping channel and tend to increase in the port/dock areas.

Because the tsunami waves have very long wavelengths the effect is a rise in water level, from starting level to peak wave height, over a period of 10 – 20 minutes. The water level then decreases to a lower level over the following 10 – 20 minutes.

Wave heights reduce to 1 metre after about 10 -12 hours and disturbance of the water due to the tsunami persists for 13 – 15 hours at most locations.

"A tsunami poses a significant risk only to those ships in shallow waters and in port areas. Ships in port are not required to maintain watch on the GMDSS communications equipment; consequently, a separate system for promulgating warning messages needs to be established within each port. Tsunami warnings need to be rapidly sent to those ships most at risk." [17]

" One of the major hazards due to tsunamis, even of small amplitudes, are the very strong currents that can be generated, that can rip the tie lines and moorings of vessels and cause serious damage to piers and docks" [18]

Wiśniewski and Wolski [13] conducted an analysis of the effects of the Japanese tsunami of 11 March 2011 on shipping in port. Whilst recognising Japanese tsunami waves were of greater magnitude than the modelled waves for the Derwent and the Port of Hobart, their findings are illustrative of the consequences for shipping caught in port and are contained in Table 5a. From their analysis they produced a more generalised description of the effects of a tsunami on ships in port which are contained in Table 5b.

Ran aground or ashore			Broke moorings and drifted in harbour		
Number	Ship type	DWT	Number	Ship type	DWT
4	Bulk	175000-3200	2	Tanker	75000-9500
4	Freighter	6900-530	1	Bulk	51000
3	Fishing	380-220	1	Container	44500
			1	Research	27000
			2	General cargo	24000

Table 5b: Effects of Tsunamis on Ships in Port		
Tsunami Magnitude	Ship Size	Damage Pattern
Small (Tsunami height: more than 2 or 3 m)	Small Ship	<ul style="list-style-type: none"> – Drifting – Collision with quay wall – Overturning / Sinking – Being cast ashore
Large (Tsunami height: more than 5 or 6 m)	Small Ship	<ul style="list-style-type: none"> – Being cast ashore – Collision with buildings
	Large Ship	<ul style="list-style-type: none"> – Drifting – Collision with quay wall – Being cast ashore – Collision with buildings

Source: Wiśniewski B and Wolski T, *The safety of the shipping and ports in the aspect of the tsunami events* [13]

5.2. Tsunami Effects and Potential Consequences

The following explains the various heights referred to in the rest of the report; Diagram 3 illustrates, using the data for the CSIRO Wharf as an example.

- **Inundation height**
Height of wave crest above berth deck
- **Stage height**
The level of the water surface above the highest astronomical tide (MS on maps)
- **Maximum Wave height**
Height of the wave from crest to trough
- **Berth height**
Height of the berth deck above Chart Datum
- **Mean Higher High Water (MHHW)**
The mean of the higher of the two daily high waters over a long period of time. When only one high water occurs on a day, this is taken as the higher high water
- **Highest Astronomical Tide (HAT)**
This is the highest level which can be predicted to occur under average meteorological conditions and any combination of astronomical conditions. This level will not be reached every year. HAT is not the extreme level which can be reached, as storm surges may cause considerably higher levels to occur
- **Lowest Astronomical Tide (LAT)**
This is the lowest level which can be predicted to occur under average meteorological conditions and any combination of astronomical conditions. This level will not be reached every year. LAT is not the extreme level which can be reached, as storm surges may cause considerably lower levels to occur
- **Chart Datum**
LAT has been used as port and chart datum since 1994
- **Charted depth**
Depth of water below Chart Datum (LAT)

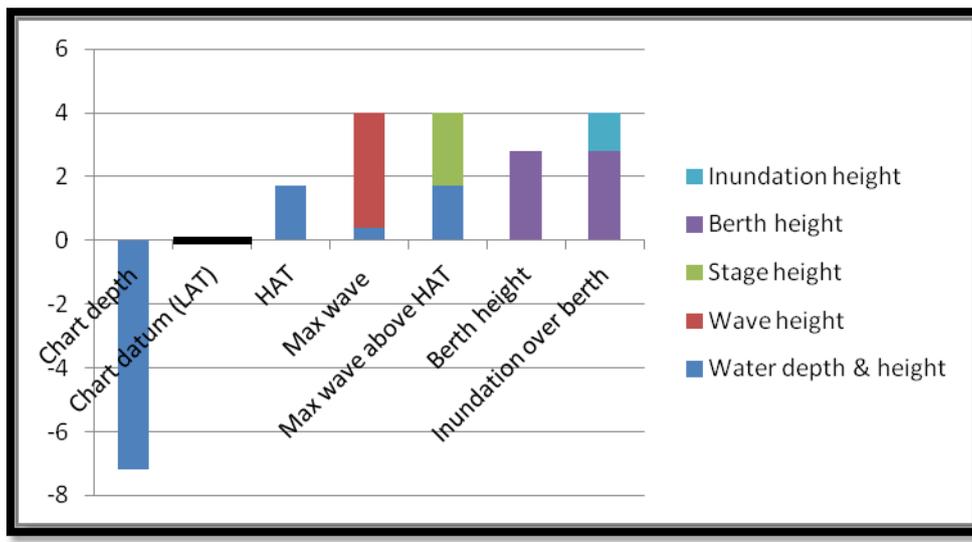


Diagram 3: Tsunami Wave - Depths and Heights (Example CSIRO Wharf)

The following terminology applies for the sections and tables listing the effects and potential consequences of a worst case tsunami:

- Vessel (commercial vessels including bulk carriers, oil tankers and cruise ships; scientific research vessels including *Aurora Australis*, *L'Astrolabe* and *Investigator*)
- Small craft (fishing vessels; river ferries and tourist craft; tug boats; leisure craft including cabin cruisers, power boats and yachts)
- Infrastructure (wharves and docks; navigation and mooring buoys; marina pontoons and associated infrastructure)
- Property damage-vessel
 - Minor (loose objects move; minor dents and scrapes)
 - Moderate (secured objects break loose; dents requiring repair; equipment damage)
 - Major (loss of watertight integrity of hull, sinking; collisions; grounding)
- Property damage-small craft
 - Moderate (damage to fittings, superstructure, masts, equipment)
 - Major (capsize; loss of watertight integrity of hull, sinking; foundering; collisions; grounding)
- Property damage-infrastructure
 - Damage caused by wave, uncontrollable vessels and small craft, and floating wreckage; loss of navigaids; damage to bridge piers;
- Life-vessel (Note: These descriptors are consistent with the *National Emergency Risk Assessment Guidelines* [19])
 - Minor - Injuries requiring basic medical aid that could be administered by paraprofessionals, which would require bandages or observation. Examples include a sprain, a severe cut requiring stitches, a minor burn (partial thickness on a small part of the body) or a bump on the head without loss of consciousness
 - Serious - Injuries requiring a greater degree of medical care and use of medical technology such as X-rays or surgery, but not expected to progress to life-threatening status. Examples include full thickness burns across a large part of the body or partial thickness burns to most of the body, loss of consciousness, fractured bones, dehydration or exposure

- Fatal/Critical - Mortally injured, is certain to lead to death regardless of available treatments. Injuries that pose an immediate life-threatening condition if not treated adequately and expeditiously. Examples include uncontrolled bleeding, a punctured organ, other internal injuries, spinal column injuries or crush syndrome
- Life-small craft
 - Minor/Serious
 - Fatal/Critical
- Life-vicinity
 - Fatal/Critical

5.3. Tsunami Effects and Potential Consequences: Principal Shipping Channel Iron Pot to Prince of Wales Bay (and specifically in the vicinity of the Tasman Bridge)



Bulk Carrier *Mount Baker* transiting Tasman Bridge
 L 177 B 29.4 DWT 32040
<http://www.mast.tas.gov.au/>

The tsunami waves create a rise in water level, from starting level to peak wave height, over a period of 10 – 20 minutes and because of this there is no evidence of turbulence (e.g. breaking waves) in the principal shipping channel. Wave heights are generally lower in the outer reaches of the shipping channel and tend to increase in the port/dock areas. As the waves pass to the north of the Tasman Bridge, where the channel narrows, a funnelling effect occurs. This causes the wave height and current to increase in this region. Within the principal shipping channel wave heights are reduced to approximately 1 metre after 10 – 12 hours.

The minimum depth at the entrance to the River Derwent is 14.1m at the Iron Pot Bar. The maximum size vessel allowed to transit the Tasman Bridge is 185 metres in length. The Centre Line of the Main Navigation Span of the Tasman Bridge is 44 metres above Mean High High Water (MHHW is 1.5 metres above chart datum) [20] and the Main Navigational Channel is approximately 100 metres wide [21].

The following Table 6 illustrates the potential consequences of a worst case scenario tsunami wave in the Principal Shipping Channel at the highest astronomical tide (HAT). For ease of analysis the potential consequences were considered for the five sections of the channel from Iron Pot to the entrance to Prince of Wales Bay. Potential consequences were considered for maritime property (commercial shipping, small craft and related maritime infrastructure) and

the potential consequences damage to maritime property may have for life and the environment.

Table 6: Principal Shipping Channel - Summary of Tsunami Wave (worst case scenario) Model Data (see note below) and Summary of Tsunami Potential Consequences					
Location	Maximum wave heights (m)	Wave lengths (m)	Currents (knots)	Turbulence (breaking waves)	Wave speed (knots)
PSC1 - 4	3.6 - 4.7	1871 - 2412	2.2 - 3.5	No	25 - 35
Site ID PSC1 mid channel off Iron Pot: to Site ID PSC4 slightly East of mid channel off White Rock Point					
Consequences					
Property					
Vessel	Minor damage				
Small craft	Moderate/major damage				
Infrastructure	Loss of nav aids caused by wave				
Life					
Vessel	Minor injury				
Small craft	Minor/serious injury				
Vicinity	Serious/critical injury				
Environment					
Land	Coast/beach wreckage, oil pollution				
Water	Drifting wreckage, oil pollution				
Location	Maximum wave heights (m)	Wave lengths (m)	Currents (knots)	Turbulence (breaking waves)	Wave speed (knots)
PSC 4 - 8	2.4 - 3.8	1940 - 6715	2.1 - 2.7	No	29 - 35
Site ID PSC4 slightly East of mid channel off White Rock Point: to Site ID PSC 8 mid channel off Sullivans Cove, due South of Rosny Point					
Consequences					
Property					
Vessel	Minor damage				
Small craft	Moderate/major damage				
Infrastructure	Loss of nav aids caused by wave				
Life					
Vessel	Minor injury				
Small craft	Minor/serious injury				
Vicinity	Serious/critical injury				
Environment					
Land	Coast/beach wreckage, oil pollution				
Water	Drifting wreckage, oil pollution				

Location	Maximum wave heights (m)	Wave lengths (m)	Currents (knots)	Turbulence (breaking waves)	Wave speed (knots)
PSC 8 - 15	3.1 - 4.5	1080 - 3060	2.2 - 4.8	No	21 - 37
Site ID PSC 8 mid channel off Sullivans Cove, due South of Rosny Point: to Site ID PSC 15 in Tasman Bridge approach channel on 353° leads off Lindisfarne Bay					
Note:	Site ID PSC 11 is the south end of the Tasman Bridge Main Navigational Channel Site ID PSC 12 is mid channel immediately under the Tasman Bridge Site ID PSC 13 is the north end of the Tasman Bridge Main Navigational Channel (see Chart Aus172 Port of Hobart for details)				
Consequences					
Property					
Vessel	Major damage (Steering difficulty-hits Tasman Bridge)				
Small craft	Major damage (Steering difficulty-hits Tasman Bridge)				
Infrastructure	Loss of nav aids caused by wave; Damage to Tasman Bridge caused by vessel striking piers				
Life					
Vessel	Serious/critical injury (if vessel strikes Tasman Bridge)				
Small craft	Minor/serious injury				
Vicinity	Serious/critical injury				
Environment					
Land	Coast/beach wreckage, oil pollution				
Water	Drifting wreckage, oil pollution				
Location	Maximum wave heights (m)	Wave lengths (m)	Currents (knots)	Turbulence (breaking waves)	Wave speed (knots)
PSC 15 - 21	4.5 - 5.1	1980 - 3468	2.9 - 4.7	No	13 - 29
Site ID PSC 15 in Tasman Bridge Channel on 353° leads off Lindisfarne Bay: to Site ID PSC 21 mid channel off New Town Bay					
Consequences					
Property					
Vessel	Moderate damage				
Small craft	Major damage				
Infrastructure	Loss of nav aids caused by wave				
Life					
Vessel	Serious injury				
Small craft	Serious/critical injury				
Vicinity	Serious/critical injury				
Environment					
Land	Coast/beach wreckage, oil pollution				
Water	Drifting wreckage, oil pollution				

Location	Maximum wave heights (m)	Wave lengths (m)	Currents (knots)	Turbulence (breaking waves)	Wave speed (knots)
PSC 21 - 27	3.7 - 5.1	2448 - 4200	3.5 - 6.3	No	25 - 29
Site ID PSC 21 mid channel off New Town Bay: to Site ID PSC 27 mid channel between Dowsings Point and Store Point on 308° leads					
Consequences					
Property					
Vessel	Major damage (Steering difficulty- vessel grounds)				
Small craft	Major damage				
Infrastructure	Loss of nav aids caused by wave				
Life					
Vessel	Serious/critical injury				
Small craft	Serious/critical injury				
Vicinity	Serious/critical injury				
Environment					
Land	Coast/beach wreckage, oil pollution				
Water	Drifting wreckage, oil pollution				
Note: The figures in this table are derived from the SE Tasmania Tsunami Modelling results and are indicative. For precise data see the results from the SE Tasmania Tsunami Model.					

5.4. Tsunami Effects and Potential Consequences: Designated Shipping Anchorages



Anchorage

<http://timspace.blogspot.com.au/2012/04/sapphire-princess-2008-post-1.html>

The tsunami waves create a rise in water level, from starting level to peak wave height, over a period of 10 – 20 minutes and because of this there is no evidence of turbulence (e.g. breaking waves) at the designated shipping anchorages. Wave heights are generally lower in the outer reaches of the shipping channel and tend to increase in the port/dock areas. The following Table 7 illustrates the potential consequences of a worst case scenario tsunami wave at the Designated Shipping Anchorages at the highest astronomical tide (HAT).

Table 7: Designated Shipping Anchorages - Summary of Tsunami Wave (worst case scenario) Model Data (see note below) and Summary of Tsunami Potential Consequences					
Location	Maximum wave heights (m)	Wave lengths (m)	Currents (knots)	Turbulence (breaking waves)	Wave speed (knots)
ANC1 - 4	2.8 - 3.1	1080 - 1512	2.2 - 2.6	No	31 - 33
Site ID ANC 1-4 Vessel anchorages 1-4 (East of Principal Shipping Channel site ID PSC 4-6)					
Consequences					
Property					
Vessel	Major damage (Drags anchor-vessel grounds)				
Small craft	Moderate/major damage				
Infrastructure	Loss of nav aids caused by wave				
Life					
Vessel	Serious injury				
Small craft	Serious/critical injury				
Vicinity	Serious/critical injury				
Environment					
Land	Coast/beach wreckage, oil pollution				
Water	Drifting wreckage; oil pollution				
Note: The figures in this table are derived from the SE Tasmania Tsunami Modelling results and are indicative. For precise data see the results from the SE Tasmania Tsunami Model.					

5.5. Tsunami Effects and Potential Consequences: Principal Hobart Port Area Constitution Dock and Macquarie Wharf



Sullivans Cove (Macquarie Wharf, Victoria Dock, Constitution Dock, Kings Pier Marina, Elizabeth Street Pier, Princes Wharf, CSIRO Wharf)

<http://www.tasmania.australiaforeveryone.com.au/sullivans-cove.htm>

Tides at Hobart are irregular, the maximum rise and fall being 1.37 metres. [20]

Chart Aus172 Port of Hobart notes the Highest Astronomical Tide (HAT) is 1.7 metres above chart datum. Chart datum is the level of water that charted depths displayed on a nautical chart are measured from. The Australian Hydrographic Service use the Lowest Astronomical Tide (LAT) to define chart datums. LAT is the height of the water, under average meteorological conditions, at the lowest possible theoretical tide. [22]

This means that at the Highest Astronomical Tide (HAT) the height of a berth above the HAT can be as much as 1.7 metres less than the height above chart datum listed in Table 8.

Table 8: Hobart Port Information					
Berth	Declared depth (metres)	depth	Height of berth above chart datum (metres)	Number of bollards	Usage
Princes 1	7.3		3.31	13	Antarctic Supply, Small
Princes Inter	7.6		3.34	6	
Princes 2	8.0		3.34	4	Cruise, Naval
Princes 3	9.0		3.25	8	Cruise, Naval
Princes 4	7.2		2.79		CSIRO
Elizabeth South	8.1		3.11	9	
Elizabeth North				9	
Macquarie 1	4.1		3.1 to 4.01		Small Fishing, Fish Unloading Facility
Macquarie 2	9.1		4.01	10	Larger Fishing, Caustic Acid
Macquarie 3	9.9		4.01	12	Car Carriers, Bulk Products, Cruise, Antarctic
Macquarie 4	13.0		4.01 to 2.79	15	Container Traffic, Break Bulk, Cruise, Antarctic
Macquarie 5	13.0		2.79	10	Container Traffic, Break Bulk, Cruise, Antarctic
Macquarie 6	11.4		2.79 to 3.2	13	Lay-up berth
Self's Point	14.4		3.71	10 on wharf; 4 on dolphins	Fuel Terminal, Bunkering Facility
Risdon (Nyrstar)	10.2		3.33	19	Concentrates, Acid, Fertiliser

Source: Tasports, *Port Information Port of Hobart Berth Data* [20]

The CSIRO wharf is used by the research vessel *Investigator*. It is 94 metres in length, with a beam of 18 metres, a draft of 8.5 metres and a DWT of 4,000.



National Research Facility vessel *Investigator* off CSIRO Wharf
<http://www.marinetraffic.com/se/ais/details/ships/shipid:697740/imo:9616888/mmsi:503791000/vessel:INVESTIGATOR>

Princes Wharf is used by the Antarctic Resupply vessel *Aurora Australis*. It is 95 metres in length, with a beam of 20.35 metres, a draft of 7.85 metres and a deadweight tonnage (DWT) of 3910.



Aurora Australis at Princes Wharf 2 and *L'Astrolabe* at Princes Wharf 1
[https://en.wikipedia.org/wiki/Aurora_Australis_\(icebreaker\)](https://en.wikipedia.org/wiki/Aurora_Australis_(icebreaker))

Macquarie Wharf 3 is used by Car Carriers, Bulk Products, Cruise and Antarctic vessels. The cruise ship *Sapphire Princess* which has used the wharf is 290 metres in length, with a beam of 37.75 metres, a draft of 8.2 metres and a DWT of 14,600.



Sapphire Princess at Macquarie Wharf 2

<http://timspages.blogspot.com.au/2012/04/sapphire-princess-2008-post-1.html>

Wave heights are generally lower in the outer reaches of the shipping channel and tend to increase in the port/dock areas. There is evidence of turbulence (e.g. breaking waves) at Constitution Dock, Victoria Dock and Macquarie Wharf 1-3.

The following Table 9 illustrates the potential consequences of a worst case scenario tsunami wave in the Principal Hobart Area at Constitution Dock and Macquarie Wharf at the highest astronomical tide (HAT).

Table 9: Principal Hobart Port Area Constitution Dock and Macquarie Wharf - Summary of Tsunami Wave (worst case scenario) Model Data (see note below) and Summary of Tsunami Potential Consequences						
Location	Maximum wave heights (m)	Wave lengths (m)	Currents (knots)	Turbulence (breaking waves)	Wave speed (knots)	
HP1 - 3	3.9 - 4.1	500 - 800	1.1 - 1.8	No	26 - 29	
Site ID HP1-3 Approaches to Sullivans Cove						
Consequences						
Property						
Vessel	Moderate damage					
Small craft	Major damage					
Infrastructure	Loss of nav aids caused by wave					
Life						
Vessel	Serious injury					
Small craft	Serious/critical injury					
Vicinity	Serious/critical injury					
Environment						
Land	Coast/beach wreckage, oil pollution					
Water	Drifting wreckage, oil pollution					

Location	Maximum wave heights (m)	Wave lengths (m)	Currents (knots)	Turbulence (breaking waves)	Wave speed (knots)
HP4	3.6	600	1.2	No	16
HP5	3.1	300	1.0	No	14
HP6	3.4	300	0.6	No	13
Site ID HP4 CSIRO Wharf (Research v/l) 1.1m above HAT					
Site ID HP5 Princes Wharf 2&3 (Cruise & Naval v/l)s 1.6m above HAT					
Site ID HP6 Princes Wharf 1 (Antarctic Supply & Small v/l)s 1.6m above HAT					
Consequences					
Property					
Vessel	Major damage (Vessel lifted & heeled; breaks adrift)				
Small craft	Major damage (Craft lifted on to wharf; breaks adrift)				
Infrastructure	Major damage to wharves caused by wave and floating wreckage				
Life					
Vessel	Serious injury				
Small craft	Serious/critical injury				
Vicinity	Serious/critical injury				
Environment					
Land	Inundation; Wharf area wreckage, oil pollution				
Water	Drifting wreckage, oil pollution				
Location	Maximum wave heights (m)	Wave lengths (m)	Currents (knots)	Turbulence (breaking waves)	Wave speed (knots)
HP7	4.4	200	0.5	No	15
HP8	4.0	150	0.4	No	15
Site ID HP7 Between Brooke Street Pier and Ferry Pier					
Site ID HP8 Elizabeth Street Pier, south side					
Consequences					
Property					
Vessel	N/A				
Small craft	Major damage (Craft lifted on to pier; breaks adrift)				
Infrastructure	Major damage to piers caused by wave and floating wreckage				
Life					
Vessel	N/A				
Small craft	Serious/critical injury				
Vicinity	Serious/critical injury				
Environment					
Land	Inundation; Wharf area wreckage, oil pollution				
Water	Drifting wreckage, oil pollution				

Location	Maximum wave heights (m)	Wave lengths (m)	Currents (knots)	Turbulence (breaking waves)	Wave speed (knots)
HP9	4.4	200	0.6	No	21
HP10	4.0	950	0.8	Yes	6
HP11	3.3	900	1.3	Yes	8
Site ID HP9 Kings Pier Marina entrance Site ID HP10 Constitution Dock (Small craft) Site ID HP11 Victoria Dock (Small craft)					
Consequences					
Property					
Vessel	N/A				
Small craft	Major damage (Craft lifted on to dock; breaks adrift)				
Infrastructure	Major damage (Inundation; Destruction of marina; Loss of nav aids)				
Life					
Vessel	N/A				
Small craft	Serious/critical injury				
Vicinity	Serious/critical injury				
Environment					
Land	Inundation; Waterfront wreckage, oil pollution				
Water	Drifting wreckage, oil pollution				
Location	Maximum wave heights (m)	Wave lengths (m)	Currents (knots)	Turbulence (breaking waves)	Wave speed (knots)
HP12	3.1	300	0.8	Yes	10
HP13	3.8	480	1.1	Yes	14
HP14	3.5	600	1.4	Yes	13
Site ID HP12 Macquarie Wharf 1 (Small Fishing v/l) 1.4m above HAT Site ID HP13 Macquarie Wharf 2 (Large fishing and Caustic Acid v/l/s) 2.3m above HAT Site ID HP14 Macquarie Wharf 3 (Car Carriers, Bulk Products, Cruise & Antarctic v/l/s) 2.3m above HAT					
Consequences					
Property					
Vessel	Major damage (Vessel lifted & heeled; breaks adrift)				
Small craft	Major damage (Craft lifted on to wharf; breaks adrift)				
Infrastructure	Major damage caused by wave and floating wreckage				
Life					
Vessel	Serious injury				
Small craft	Serious/critical injury				
Vicinity	Serious/critical injury				
Environment					
Land	Inundation; Wharf area wreckage, oil pollution				
Water	Drifting wreckage, oil pollution				

Location	Maximum wave heights (m)	Wave lengths (m)	Currents (knots)	Turbulence (breaking waves)	Wave speed (knots)
HP15	3.8	660	2.3	No	30
HP19	3.3	2500	3.8	No	30
Site ID HP15 200m east of end of Macquarie Wharf 3/4					
Site ID HP19 200m east of Macquarie Point					
Property					
Vessel	Moderate damage				
Small craft	Major damage				
Infrastructure	Loss of navaid's caused by wave				
Life					
Vessel	Serious injury				
Small craft	Serious/critical injury				
Vicinity	Serious/critical injury				
Environment					
Land	Coast/beach wreckage, oil pollution				
Water	Drifting wreckage, oil pollution				
Location					
	Maximum wave heights (m)	Wave lengths (m)	Currents (knots)	Turbulence (breaking waves)	Wave speed (knots)
HP16	3.2	730	1.6	No	17
HP17	3.1	660	1.4	No	17
HP18	3.3	1200	2.0	No	18
Site ID HP16 Macquarie Wharf 4 (Container, Break Bulk, Cruise & Antarctic v/ls) 1.1m above HAT					
Site ID HP17 Macquarie Wharf 5 (Container, Break Bulk, Cruise & Antarctic v/ls) 1.1m above HAT					
Site ID HP18 Macquarie Wharf 6 (Lay-up berth) 1.1m above HAT					
Consequences					
Property					
Vessel	Major damage (Vessel lifted & heeled; breaks adrift)				
Small craft	Major damage (Craft lifted on to wharf; breaks adrift)				
Infrastructure	Major damage caused by wave and floating wreckage				
Life					
Vessel	Serious injury				
Small craft	Serious/critical injury				
Vicinity	Serious/critical injury				
Environment					
Land	Inundation; Wharf area wreckage, oil pollution				
Water	Drifting wreckage, oil pollution				
Note: The figures in this table are derived from the SE Tasmania Tsunami Modelling results and are indicative. For precise data see the results from the SE Tasmania Tsunami Model.					

5.6. Tsunami Effects and Potential Consequences: Selfs Point Wharf



British Fidelity at Selfs Point Wharf

https://www.marinetraffic.com/en/photos/by/%20-%20forward/page:3/photo_keywords:hobart

Selfs Point Wharf is an oil terminal and is used by Handymax oil tankers which are typically 150-200 metres in length, with a beam of 28 metres, a draft of 12 metres and 35,000 - 45,000 DWT. The tanker *British Fidelity* which has used the wharf is 183 metres in length, with a beam of 32 metres and a DWT of 46,800.

The tsunami waves create a rise in water level, from starting level to peak wave height, over a period of 10 – 20 minutes and because of this there is no evidence of turbulence (e.g. breaking waves) at Selfs Point Wharf. Wave heights are generally lower in the outer reaches of the shipping channel and tend to increase in the port/dock areas.

The following Table 10 illustrates the potential consequences of a worst case scenario tsunami wave at Selfs Point Wharf at the highest astronomical tide (HAT).

Table 10: Selfs Point Wharf - Summary of Tsunami Wave (worst case scenario) Model Data (see note below) and Summary of Tsunami Potential Consequences					
Location	Maximum wave heights (m)	Wave lengths (m)	Currents (knots)	Turbulence (breaking waves)	Wave speed (knots)
SPW1	4.9	2528	4.0	No	26
SPW3	5.1	2332	3.5	No	24
Site ID SPW1 100 m to the South of Selfs Point Wharf Site ID SPW3 100m to the North of Selfs Point Wharf					
Consequences					
Property					
Vessel	Moderate damage				
Small craft	Major damage				
Infrastructure	Loss of nav aids caused by wave				
Life					
Vessel	Serious injury				
Small craft	Serious/critical injury				
Vicinity	Serious/critical injury				
Environment					
Land	Coast/beach wreckage, oil pollution				
Water	Drifting wreckage, oil pollution				
Location					
Maximum wave heights (m)					
Wave lengths (m)					
Currents (knots)					
Turbulence (breaking waves)					
Wave speed (knots)					
SPW2	5.0	2246	4.7	No	25
Site ID SPW2 Selfs Point Wharf (Oil Tanker) 2.0m above HAT					
Consequences					
Property					
Vessel	Major damage (Vessel lifted & heeled; breaks adrift)				
Small craft	Major damage (Craft lifted on to wharf; breaks adrift)				
Infrastructure	Major damage caused by wave and floating wreckage				
Life					
Vessel	Serious injury				
Small craft	Serious/critical injury				
Vicinity	Serious/critical injury				
Environment					
Land	Inundation; Wharf area wreckage, oil pollution				
Water	Drifting wreckage, oil pollution				

Location	Maximum wave heights (m)	Wave lengths (m)	Currents (knots)	Turbulence (breaking waves)	Wave speed (knots)
SPW4	4.9	2281	4.3	No	16
Site ID SPW4 Selfs Point Jetty					
Consequences					
Property					
Vessel	N/A				
Small craft	N/A				
Infrastructure	Major damage caused by wave and floating wreckage				
Life					
Vessel	N/A				
Small craft	N/A				
Vicinity	Serious/critical injury				
Environment					
Land	Inundation; Wharf area wreckage, oil pollution				
Water	Drifting wreckage, oil pollution				
Note: The figures in this table are derived from the SE Tasmania Tsunami Modelling results and are indicative. For precise data see the results from the SE Tasmania Tsunami Model.					

5.7. Tsunami Effects and Potential Consequences: Risdon (Nyrstar) Wharf



IVS Raffles at Risdon (Nyrstar) Wharf

https://www.marinetraffic.com/en/photos/by/%20-%20forward/page:3/photo_keywords:hobart

Risdon (Nyrstar) Wharf is used by Handymax bulk carriers which are typically 150-200 metres in length, with a beam of 25 metres, a draft of 12 metres and 52,000-58,000 DWT with five cargo holds and four cranes. The bulk carrier *IVS Raffles* which has used the wharf is 180 metres in length, a draft of 10.6 metres, with a beam of 28.4 metres and a DWT of 32,050.

The tsunami waves create a rise in water level, from starting level to peak wave height, over a period of 10 – 20 minutes and because of this there is no evidence of turbulence (e.g. breaking waves) at Risdon (Nyrstar) Wharf. Wave heights are generally lower in the outer reaches of the shipping channel and tend to increase in the port/dock areas.

The following Table 11 illustrates the potential consequences of a worst case scenario tsunami wave at Risdon (Nyrstar Wharf) at the highest astronomical tide (HAT).

Table 11: Risdon (Nyrstar) Wharf - Summary of Tsunami Wave (worst case scenario) Model Data (see note below) and Summary of Tsunami Potential Consequences						
Location	Maximum wave heights (m)	Wave lengths (m)	Currents (knots)	Turbulence (breaking waves)	Wave speed (knots)	
RW1	4.5	3400	5.1	No	21	
RW4	3.8	3000	5.2	No	17	
Site ID RW1 100m to the South East of Nyrstar Wharf 2						
Site ID RW4 100m to the North West of Nyrstar Wharf facilities						
Consequences						
Property						
Vessel	Moderate damage					
Small craft	Major damage					
Infrastructure	Loss of nav aids caused by wave					
Life						
Vessel	Serious injury					
Small craft	Serious/critical injury					
Vicinity	Serious/critical injury					
Environment						
Land	Coast/beach wreckage, oil pollution					
Water	Drifting wreckage, oil pollution					
Location	Maximum wave heights (m)	Wave lengths (m)	Currents (knots)	Turbulence (breaking waves)	Wave speed (knots)	
RW2	3.3	3000	5.2	No	17	
Site ID RW2 Nyrstar Wharf 2 (Bulk Carrier- Concentrates, Acid, Fertiliser) 1.6m above HAT						
Consequences						
Property						
Vessel	Major damage (Vessel lifted & heeled; breaks adrift)					
Small craft	Major damage (Craft lifted on to wharf; breaks adrift)					
Infrastructure	Major damage caused by wave and floating wreckage					
Life						
Vessel	Serious injury					
Small craft	Serious/critical injury					
Vicinity	Serious/critical injury					
Environment						
Land	Inundation; Wharf area wreckage, oil pollution					
Water	Drifting wreckage, oil pollution					
Location	Maximum wave heights (m)	Wave lengths (m)	Currents (knots)	Turbulence (breaking waves)	Wave speed (knots)	
RW3	2.7	4000	5.4	No	14	
Site ID RW3 Nyrstar Wharf 1 (Bulk Carrier- Concentrates, Acid, Fertiliser) 1.6m above HAT						
Consequences						
Property						
Vessel	Major damage (Vessel lifted & heeled; breaks adrift)					
Small craft	Major damage (Craft lifted on to wharf; breaks adrift)					
Infrastructure	Major damage caused by wave and floating wreckage					
Life						
Vessel	Serious injury					
Small craft	Serious/critical injury					
Vicinity	Serious/critical injury					
Environment						
Land	Inundation; Wharf area wreckage, oil pollution					
Water	Drifting wreckage, oil pollution					
Note: The figures in this table are derived from the SE Tasmania Tsunami Modelling results and are indicative. For precise data see the results from the SE Tasmania Tsunami Model.						

5.8. Tsunami Effects and Potential Consequences: Prince of Wales Bay Wharf and Dock facilities



Kilimanjaro VI at Richardson Devine yards, Prince of Wales Bay

Incat fitting out wharves, Prince of Wales Bay

https://www.marinetraffic.com/en/photos/by/%20-%20forward/photo_keywords:prince%20of%20wales%20bay

https://www.marinetraffic.com/en/photos/by/%20-%20forward/photo_keywords:incat

Wave heights are generally lower in the outer reaches of the shipping channel and tend to increase in the port/dock areas. There is evidence of turbulence (e.g. breaking waves) at INCAT Jetty and Slip, Prince of Wales Bay Marine P/L Dock facilities and Derwent Marine Dock facilities.

The following Table 12 illustrates the potential consequences of a worst case scenario tsunami wave in Prince of Wales Bay at the highest astronomical tide (HAT).

Table 12: Prince of Wales Bay Wharf and Dock facilities - Summary of Tsunami Wave (worst case scenario) Model Data (see note below) and Summary of Tsunami Potential Consequences					
Location	Maximum wave heights (m)	Wave lengths (m)	Currents (knots)	Turbulence (breaking waves)	Wave speed (knots)
PSC28	3.7	2686	6.9	No	17
PSC29	3.8	1800	4.9	No	17
PSC30	4.0	2100	4.0	No	16
Site ID PSC28 Off Dowsings Point					
Site ID PSC29/30 Entering Prince of Wales Bay					
Consequences					
Property					
Small vessel	Moderate damage				
Small craft	Major damage				
Infrastructure	Loss of nav aids caused by wave				
Life					
Vessel	Serious injury				
Small craft	Serious/critical injury				
Vicinity	Serious/critical injury				
Environment					
Land	Coast/beach wreckage, oil pollution				
Water	Drifting wreckage, oil pollution				

Location	Maximum wave heights (m)	Wave lengths (m)	Currents (knots)	Turbulence (breaking waves)	Wave speed (knots)
POW1	3.8	2232	3.5	No	17
POW3	3.7	2080	4.0	Yes	13
Site ID POW1 100m East of north end of INCAT Slip					
Site ID POW3 100m East of INCAT Jetty					
Consequences					
Property					
Small vessel	Moderate damage				
Small craft	Major damage				
Infrastructure	Loss of nav aids caused by wave				
Life					
Vessel	Serious/critical injury				
Small craft	Serious/critical injury				
Vicinity	Serious/critical injury				
Environment					
Land	Coast/beach wreckage, oil pollution				
Water	Drifting wreckage, oil pollution				
Location	Maximum wave heights (m)	Wave lengths (m)	Currents (knots)	Turbulence (breaking waves)	Wave speed (knots)
POW2	2.7	2200	1.7	Yes	5
Site ID POW 2 INCAT Slip					
Consequences					
Property					
Vessel [High speed catamaran]	Major damage (Lifted on to shore; breaks adrift)				
Small craft	Major damage (Lifted on to shore; breaks adrift)				
Infrastructure	Major damage caused by wave and floating wreckage				
Life					
Vessel	Serious injury				
Small craft	Serious/critical injury				
Vicinity	Serious/critical injury				
Environment					
Land	Inundation; Slip area wreckage, oil pollution				
Water	Drifting wreckage, oil pollution				
Location	Maximum wave heights (m)	Wave lengths (m)	Currents (knots)	Turbulence (breaking waves)	Wave speed (knots)
POW4	2.8	1250	2.7	Yes	8
Site ID POW4 INCAT Jetty					
Consequences					
Property					
Vessel [High speed catamaran]	Major damage (Lifted on to jetty/shore; breaks adrift)				
Small craft	Major damage (Lifted on to jetty/shore; breaks adrift)				
Infrastructure	Major damage caused by wave and floating wreckage				
Life					
Vessel	Serious injury				
Small craft	Serious/critical injury				
Vicinity	Serious/critical injury				
Environment					
Land	Inundation; Jetty area wreckage, oil pollution				
Water	Drifting wreckage, oil pollution				

Location	Maximum wave heights (m)	Wave lengths (m)	Currents (knots)	Turbulence (breaking waves)	Wave speed (knots)
POW6	2.8	Turbulence	5.0	Yes	7
Site ID POW6 Prince of Wales Bay Marine P/L Dock facilities					
Consequences					
Property					
Vessel	N/A				
Small craft	Major damage (Lifted on to dock/shore; breaks adrift)				
Infrastructure	Major damage caused by wave and floating wreckage				
Life					
Vessel	N/A				
Small craft	Serious/critical injury				
Vicinity	Serious/critical injury				
Environment					
Land	Inundation; Dock area wreckage, oil pollution				
Water	Drifting wreckage, oil pollution				
Location					
Maximum wave heights (m)					
Wave lengths (m)					
Currents (knots)					
Turbulence (breaking waves)					
Wave speed (knots)					
POW7	3.1	Turbulence	3.1	Yes	6
Site ID POW7 Derwent Marine Dock facilities					
Consequences					
Property					
Vessel	N/A				
Small craft	Major damage (Lifted on to dock/shore; breaks adrift)				
Infrastructure	Major damage				
Life					
Vessel	N/A				
Small craft	Serious/critical injury				
Vicinity	Serious/critical injury				
Environment					
Land	Inundation; Dock area wreckage, oil pollution				
Water	Drifting wreckage, oil pollution				
Note: The figures in this table are derived from the SE Tasmania Tsunami Modelling results and are indicative. For precise data see the results from the SE Tasmania Tsunami Model.					

6. Discussion-Shipping

Some Specific Implications for Shipping in the Port of Hobart

6.1. Introduction

UNESCO [23] makes the following recommendations:

"When a tsunami warning is issued, the harbour authority will issue warnings, orders and restrictions for offshore evacuation. Port authorities, ship and boat owners and fishing cooperatives should meet and agree on pre-planned safety measures. The following points should be organized based on the tsunami's estimated time of arrival:

- *Medium and large vessels will be evacuated outside the port*
- *Vessels that cannot be evacuated will be safely moored*
- *Medium and large vessels will be withheld from entering the port*

Fishing boats:

- *Three main objectives relating to boat safety measures are the protection of life, the protection of property (the boat itself) and the prevention of secondary damage caused by a drifting vessel.*
- *During a tsunami, the evacuation of fishing boats endangers those involved and this fact makes it impossible to draw up general guidelines for their evacuation.*

- *Pay close attention to the advisory issued by the National Tsunami Warning Centre regarding the tsunami's estimated time of arrival.*
- *If there is enough time, fishing boats preferably should evacuate to deeper waters (around 100 metres depth); if not, it will be extremely dangerous to evacuate to offshore waters.*
- *Instead, a combination of loose mooring and loose anchorage can reduce the risk of boats drifting onto land. Keeping the mooring and anchor cables loose is widely believed effective in preventing them from being severed by the collision of the first wave or strain from buoyancy."*

A further important consideration is:

"Tsunami harbor effects include geometric amplification, resonance, and large eddy creation. Even when tsunami is 'small' (~1 m), generated currents can be strong enough to breaking lines." [18]

Wiśniewski and Wolski [13] summarise the ways to prevent damage to shipping in port from a tsunami as follows:

- If there is enough time before the arrival of the tsunami the best way to prevent damage to the ship by a tsunami is evacuation outside the port.
- If there is not enough time before the tsunami arrives ships should aim to remain in the deepest water in the port area. This is considered feasible when the expected wave height is not excessive.
- If evacuation is not possible the mooring system should be reinforced. Countermeasures for mooring during the tsunami should be increasing the number of mooring ropes and automatic regulation of mooring ropes so the ship cannot 'hang' on the ropes. It is noted that the mooring forces are usually small when the tsunami current is parallel to the ship.

6.2. Deeper Water

For shipping in the Principal Shipping Channel, at the Designated Shipping Anchorages, and alongside in the Port of Hobart, and it may be necessary/safer to evacuate to deep water. There is no agreement on what constitutes deep water as deep water depths noted from the literature review vary between at least 30 metres, at least 45 metres, 50 metres or more, and over 100 metres. Water depths in the principal shipping channel range between 15 metres off Iron Pot, 21 metres off Sullivans Cove and a maximum of 33 metres off White Rock Point. Depths of 45 metres are not reached until Storm Bay, about 10 nautical miles (18.5km) to the south east of Iron Pot.

The approximate distances from the three main berthing locations and the shipping anchorages to deeper water are shown in Table 13.

Distance from: -	Distance to: -			
Risdon (Nyrstar) Wharf	Tasman Bridge	Off White Rock Point-PSC Deepest (33m depth)	Off Iron Pot	Storm Bay (45m depth)
0	2.5	9.5	15	24.5
Selfs Point Wharf				
0	1.5	8.5	14	23.5
Princes/Macquarie Wharf				
0	n/a	6.5	12	21.5
Anchorage 1 - 4				
0	n/a	4 - 1.5	9.5 - 7	19 - 16.5

Note: Distances are approximate as there will be variations depending on the actual courses followed
Source: Australian Hydrographic Office, *Port of Hobart, Chart Aus172* corrected to 2015 # 782 [21]

6.3. Warning Times

Experts believed that the rapid onset of this event (less than 3 hours warning in best-case conditions) limited the capacity of the emergency services to inform all vulnerable areas or people and as such it seemed realistic to expect more than 50 deaths or serious injuries [16]

A Tsunami initiated by an earthquake in the Puysegur Trench could reach Tasmania in 2 hours, the JATWC aims to issue a National Tsunami Watch within 30 minutes of the earthquake and issue specific Watches and Warnings within 60 minutes of the earthquake. These would then be followed by additional warnings issued by Tasmania Police. This in effect means that the public in Hobart could realistically expect 1 hour warning. [6]

Based on the results of the South East Tasmania Tsunami Inundation Model, tsunami arrival times vary between 2.5 and 3.25 hours after the earthquake, with a difference of 36 minutes between PSC1 (off Iron Pot) and PSC30 (entering Prince of Wales Bay). Warnings and the arrival of the tsunami wave are summarised in Table 14.

Event	Elapsed time
Earthquake occurrence	0
National Tsunami watch alert	30 min
Specific watches and warnings issued	1 hr
Tasmania Police issue additional warnings	
Realistic notification of Hobart public	2 hr
Wave reaches Tasmania	2 hr
Wave reaches Iron Pot	2 hr 35 min
Wave reaches Sullivans Cove	3 hr
Wave reaches Selfs Point	3 hr 05 min
Wave reaches Risdon (Nyrstar)	3 hr 08 min
Wave reaches Prince of Wales Bay	3 hr 10 min

Source: *Tasmanian State Tsunami Emergency Response Plan*, extracts [6]
South East Tasmania Tsunami Inundation Model Results

6.4. Shipping in the Principal Shipping Channel

Any shipping underway in the Principal Shipping Channel, which is in communications with Hobart Port control when a tsunami warning of at least 1 hour is received, should be able to reach deeper water at either White Rock Point or Storm Bay before the tsunami wave arrives. The rationale for this is:

- Shipping underway should be able to make sufficient speed to reach deeper water

For shipping in the Principal Shipping Channel south of the Tasman Bridge when the tsunami wave arrives it is postulated that they may well be able to successfully ride waves of this nature. The rationale for this is:

- Modelled maximum wave height in the Principal Shipping Channel south of the Tasman Bridge is 4.7 metres off Iron Pot. North of Iron Pot to off Sullivans Cove the wave height varies between 2.4-3.8 metres
- Because the tsunami waves have very long wavelengths the effect is a rise in water level, from starting level to peak wave height, over a period of 10 – 20 minutes which most shipping should be able to successfully navigate

For shipping in the Principal Shipping Channel north of the Tasman Bridge when the tsunami wave arrives it is postulated that they may well have difficulty in manoeuvring in these conditions and attempting to pass under the Tasman Bridge should be avoided. The rationale for this is:

- Modelled maximum wave height in the principal shipping channel, north of the Tasman Bridge, varies between 3.7-5.1 metres
- The channel is narrower north of the Tasman Bridge with stronger currents of up to 6.3 knots predicted by the model
- Because of the strong current and the higher wave heights most shipping is likely to experience some difficulty in manoeuvring in these conditions in this more confined area

6.5. Shipping at the Designated Shipping Anchorages

Shipping anchored at the Designated Shipping Anchorages, which is in communications with Hobart Port control when a tsunami warning of at least 1 hour is received, should be able to evacuate and reach deeper water off White Rock Point before the tsunami wave arrives. The rationale for this is:

- Shipping at anchor will have engines ready.
- Weighing anchor should take no more than 15 minutes.

6.6. Shipping Alongside-Letting Go and Clearing the Berth

Mercado-Irizarry and Liu [24] suggest that within an hour most modern vessels can easily move out of port (clear the berth?). The one hour can be reduced depending on the state of readiness of the engines and crew, and the ease by which a vessel can manoeuvre clear of its berth.

For shipping alongside at Constitution Dock and Macquarie Wharf in the Principal Hobart Port Area, Selfs Wharf, and Risdon (Nyrstar) Wharf it may be feasible to reach a relatively safe location south of the Tasman Bridge within the principal shipping channel or in deeper water off White Rock Point. However, the feasibility of achieving this depends on a number of factors which include the amount of notice given of an impending tsunami, the time taken for a vessel to let go and clear a berth, the distance from a berth to a safer location, and the speed of the ship in question.

The time taken for a vessel to let go and clear a berth depends on a number of factors including:

Cargo Issues

- Ceasing cargo operations
- Clearing away cargo handling equipment (e.g. oil lines, shore based loading/discharging equipment)

Availability of Crew

- Capability and capacity of crew actually aboard as some may be ashore or the vessel may be 'laid up' with only a skeleton care crew

Availability of Engines

- Availability depends on whether the vessel is 'laid up', alongside with engines shut down or with engines on 'stand by'

Mooring Issues

- Letting go mooring lines depends on the availability of linesmen at the berth, capability to let go from on board, and the type of mooring line arrangements (e.g. automatic berthing/mooring system, self-tensioning winches, ropes/wire and bollards)
- Gangways are commonly a part of the ship's equipment but may be provided from ashore for vessels such as cruise ships and tankers. Consequently, the safe removal of a gangway depends on the availability of crew or shore based personnel.

Manoeuvring Issues

- Need for and availability of a pilot
- Need for and availability of tugs
- Capability of Master/officers to manoeuvre the vessel
- Difficulty of manoeuvres to clear the berth

Meteorological conditions

- Wind direction and speed
- Current direction and speed

6.7. Shipping Alongside-Tentative Evacuation Scenarios

Different ship types have different characteristics which affect their manoeuvrability and, hence, the time taken to clear a berth and reach full speed. The following speculative scenarios are 'best case' scenarios and were calculated using tentative estimates. The scenarios illustrate the potential time differences for ships alongside in evacuating to deep water. Further, more detailed research is needed to determine more reliable outcomes.

-Risdon (Nyrstar) Wharf is used by Handymax bulk carriers which are typically 52,000-58,000 DWT, 150-200 metres in length, with a beam of 25 metres, a draft of 12 metres and a service speed of 13-15 knots.

Assumptions:

- Vessels tend to berth starboard side to with the bow facing down river
- Single propeller
- Crew and engines available
- Crew able to remove gangway and let go mooring lines
- Pilot and tugs unavailable
- After clearing the berth, the vessel can head direct to the Principal Shipping Channel
- The vessel can pass safely under the Tasman Bridge

Table 15: Evacuation Estimates - Risdon (Nyrstar) Wharf - Handymax Bulk Carrier			
From	To	Estimated Time	Running Time
Risdon (Nyrstar) Wharf	Letting go/clearing berth	30 min	30 min
Clearing berth	Tasman Bridge	15 min	45 min
Tasman Bridge	Increasing to Full speed by PSC deepest	35 min	1 hr 20 min
PSC deepest	Iron Pot	25 min	1 hr 45 min
Iron Pot	Storm Bay 45metres depth	50 min	2 hr 35 min
Total		2 hr 35 min	2 hr 35 min

-Selfs Point Wharf is an oil terminal and is used by Handymax oil tankers which are typically 35,000 - 45,000 DWT, 150-200 metres in length, with a beam of 28 metres, a draft of 12 metres and a service speed of around 15 knots.

Assumptions:

- Vessels tend to berth port side to with the bow facing up river

- Single propeller
- Crew and engines available
- Crew able to remove gangway and let go mooring lines
- Pilot and tugs unavailable
- After clearing the berth, the vessel needs to turn short round (180°) to head to the Principal Shipping Channel
- The vessel can pass safely under the Tasman Bridge

From	To	Estimated Time	Running Time
Sells Point Wharf	Letting go/clearing berth	45 min	45 min
Clearing berth	Tasman Bridge	10 min	55 min
Tasman Bridge	Increasing to Full speed by PSC deepest	30 min	1 hr 25 min
PSC deepest	Iron Pot	20 min	1 hr 45 min
Iron Pot	Storm Bay 45metres depth	40 min	2 hr 25 min
Total		2 hr 25 min	2 hr 25 min

-**Princes Wharf** is used by the Antarctic Resupply vessel *Aurora Australis* which has a DWT of 3910, is 95 metres in length, with a beam of 20.35 metres, a draft of 7.85 metres and a service speed of 16.5 knots. The *Aurora Australis* is fitted with 3 thrusters.

Assumptions:

- *Aurora Australis* tends to berth port side to
- Single propeller, one thruster forward and two thrusters aft
- Crew and engines available
- Crew able to remove gangway and let go mooring lines
- Pilot unavailable and tugs not required because of thrusters
- After clearing the berth, the vessel needs to turn to starboard to head to the Principal Shipping Channel

From	To	Estimated Time	Running Time
Princes Wharf	Letting go/clearing berth	30 min	30 min
Clearing berth	Increasing to Full speed by PSC deepest	25 min	55 min
PSC deepest	Iron Pot	20 min	1 hr 15 min
Iron Pot	Storm Bay 45metres depth	35 min	1 hr 50 min
Total		1 hr 50 min	1 hr 50 min

-**Macquarie Wharf 3** has been used by the cruise ship *Sapphire Princess* which has a DWT of 14,600, is 290 metres in length, with a beam of 37.75 metres, a draft of 8.2 metres and a service speed of 20-24 knots. The *Sapphire Princess* is fitted with 6 thrusters.

Assumptions:

- Cruise ships tend to berth starboard side to
- Two propellers, three thrusters forward and three thrusters aft
- Crew and engines available
- Crew able to remove gangway and let go mooring lines
- Pilot unavailable and tugs not required because of thrusters
- After clearing Macquarie 2 the vessel needs to turn to starboard, and from Macquarie 3 needs to turn short round to head to the Principal Shipping Channel

From	To	Estimated Time	Running Time
Macquarie Wharf	Letting go/clearing berth	30 min	30 min
Clearing berth	Increasing to Full speed by PSC deepest	20 min	50 min
PSC deepest	Iron Pot	15 min	1 hr 5 min
Iron Pot	Storm Bay 45metres depth	30 min	1 hr 35 min
Total		1 hour 35 min	1 hr 35 min

As previously stated, the Tasmanian State Emergency Service expects to provide an approximate warning time for an impending tsunami for the Principal Hobart Port Area of approximately 1 hour. This means that the tsunami wave would reach Iron Pot approximately 35 minutes after the warning was received. Table 19 illustrates.

Location	Wave Travel time from PSC1	Wave Arrival time after earthquake
From: PSC1 Mid channel off Iron Pot	0 minutes	2 hr 35 min
To:		
ANC1 Vessel anchorage 1	19 minutes	2 hr 54 min
HP3 Approaches to Sullivans Cove (200m to the East of Battery Point)	25 minutes	3 hr 00 min
SPW2 Selfs Point Wharf	30 minutes	3 hr 05 min
RW2/3 Risdon (Nyrstar Wharf)	33 minutes	3 hr 08 min
POW1 Prince of Wales Bay (100m East of north end of INCAT Slip)	35 minutes	3 hr 10 min

Source: South East Tasmania Tsunami Inundation Model Results

Based on the speculative evacuation times in Tables 15-18 above and provided that a 1 hour warning is received it is probable that:

- A Handymax bulk carrier originally berthed at Risdon (Nyrstar) Wharf would meet the incoming tsunami wave to the south of the Tasman Bridge in the Principal Shipping Channel but still to the north of the deeper water off White Rock Point
- A Handymax oil tanker originally berthed at Selfs Point Wharf would meet the incoming tsunami wave a little to the south of the Tasman Bridge in the Principal Shipping Channel.
- The *Aurora Australis* originally berthed at Princes Wharf would meet the incoming tsunami wave in the vicinity of the deepest water off White Rock Point in the Principal Shipping Channel.
- A cruise ship similar to the *Sapphire Princess* and originally berthed at Macquarie Wharf would meet the incoming tsunami wave in the vicinity of the deepest water off White Rock Point in the Principal Shipping Channel.

Recognising that the evacuation time estimates are speculative and the conditions described by the assumptions will not occur in all circumstances, it is recommended that further research is undertaken to develop more reliable outcomes and for a wider range of conditions. This would enable better decisions to be made on whether a ship should evacuate or stay.

6.8. Shipping Alongside- Berth Inundation

The following Table 20 illustrates approximate inundation water levels above the wharf deck height at maximum wave height and highest astronomical tide (HAT).

Location	Berth Height above Chart Datum	Height of HAT above Chart Datum	Berth Height above HAT	Stage Height above HAT	Inundation Height above Berth Deck
CSIRO Wharf	2.8	1.7	1.1	2.3	1.2
Princes Wharf 2-3	3.3	1.7	1.6	2.3	0.7
Macquarie Wharf 1-4	4.0	1.7	2.3	2.3	0
Macquarie Wharf 5-6	2.8	1.7	1.1	2.1	1.0
Selfs Point Wharf	3.7	1.7	2.0	2.5	0.5
Risdon (Nyrstar) Wharf	3.3	1.7	1.6	1.7	0.1

Source: Tasports, *Port Information Port of Hobart Berth Data* [20]
 Australian Hydrographic Office (2005), *Port of Hobart*, Chart Aus172 corrected to 2015 # 782 [21]
 South East Tasmania Tsunami Inundation Model results

Because most of the commercial shipping using the berths in the Port of Hobart have drafts considerably greater than the inundation water levels above the berth deck, there is almost no likelihood of these vessels being bodily lifted by the tsunami wave on to the berth. However, smaller vessels/craft with shallower drafts, e.g. less than 1.2 metres at the CSIRO Wharf, are at risk of being lifted on to the berth deck.

For shipping alongside that cannot, or decides not to, evacuate to deeper water the main risk is breaking adrift. Consequences of breaking adrift include major damage to the drifting ship and other vessels, and infrastructure struck by the drifting ship.

As the tsunami wave approaches, a ship alongside is lifted and may heel against the berth or break adrift if mooring lines are not tended to deal with the rising water. Mooring lines will slack off as the water recedes which may cause the ship to range away from the berth or break adrift if mooring lines are not tended to deal with the receding water. Extra mooring lines should be utilised if possible and crew should be stationed to slack off/tighten mooring lines as necessary.

For smaller vessels with shallower drafts it may be more prudent to put out extra moorings then evacuate the crew to a safe, higher location ashore.

7. Possible Hazards to Small Craft Based On Modelled Tsunami Scenarios In The Derwent Estuary

Implications for Small Craft

7.1. Tsunami Waves: General Effects

Wave heights are generally lower in the outer reaches of the shipping channel and tend to increase in the port/dock areas. There is evidence of turbulence (e.g. breaking waves) at all Marinas and all Designated Small Craft Anchorages. Because of their construction, inundation of marina infrastructure is almost inevitable.

Most small craft marinas are built in sheltered, shallow waters and, as such, are likely to be subject to seiches. Seiches are oscillations of enclosed and semi-enclosed bodies of water, such as bays, lakes or reservoirs, due to strong ground motion from seismic events, wind stress, volcanic eruptions, large landslides and local basin reflection of tsunamis. [25]

Wiśniewski and Wolski [13] report on the numbers of small craft in Brookings Harbor, Oregon and Crescent City Harbor, California which were damaged or sunk as a result of the Japanese 2011 tsunami. These small craft harbours are approximately 4320 nautical miles (8000 km) from the Japanese port of Sendai, which was devastated during the tsunami, and arrived about 10 hours after the earthquake. In Brookings Harbor 6 small craft between 34 - 92 feet (10 - 28m) in length were sunk (3) or damaged (3), and in Crescent City Harbor 16 small craft between 29 - 68 feet (9 - 21m) in length were sunk (12) or damaged (4).

Precisely what constitutes a small craft is ill defined. However, in Brookings Harbor and Crescent City Harbor of the vessels sunk, one was 92 feet (28m) and another was 68 feet (21m) in length; whilst one of the damaged vessels was 68 feet (21m) in length and weighed 220 tons. The 220 ton vessel is a common size for an American offshore fishing vessel.

7.2. Tsunami Effects and Potential Consequences: Designated Small Craft Anchorages and Marinas



Geilston Bay Boat Club anchorage
 Motor Yacht Club Tasmania Marina, Lindisfarne Bay
<https://www.flickr.com/photos/witnesskingtides/8276720056>
<https://au.pinterest.com/pin/36802921928885333/>



Bellerive Yacht Club Marina, Kangaroo Bay
 Royal Yacht Club of Tasmania Marina, Sandy Bay
http://burburyconsulting.com.au/portfolio_category/maritime/
<http://www.fsc.com.au/about/reciprocal-yacht-clubs/>

The following Table 21 illustrates the potential consequences of a worst case scenario tsunami wave at Designated Small Craft Anchorages and Marinas at the highest astronomical tide (HAT).

Table 21: Designated Small Craft Anchorages and Marinas - Summary of Tsunami Wave (worst case scenario) Model Data (see note below) and Summary of Tsunami Potential Consequences					
Location	Maximum wave heights (m)	Wave lengths (m)	Currents (knots)	Turbulence (breaking waves)	Wave speed (knots)
G1	5.2	624	2.3	Yes	11
G2	4.3	Turbulence	3.8	Yes	10
G3	4.1	Turbulence	3.2	Yes	6
G5	4.0	Turbulence	1.9	Yes	5
G6	3.5	Turbulence	2.0	Yes	5
POW5	3.2	Turbulence	7.2	Yes	9
POW8	3.9	Turbulence	5.0	Yes	10
Site ID G1 Geilston Bay: Geilston Bay Boat Club marina and anchorage Site ID G2 Lindisfarne Bay: Motor Yacht Club Tasmania marina and anchorage Site ID G3 Kangaroo Bay: Bellerive Yacht Club marina and anchorage Site ID G5 Sandy Bay: Royal Yacht Club of Tasmania marina and anchorage Site ID G6 Sandy Bay: Derwent Sailing Squadron marina and anchorage Site ID POW5 Prince of Wales Bay: Prince of Wales Bay Marina Wharf Site ID POW8 Prince of Wales Bay: Pauline Point Marina Domain Slipyard small craft anchorage Cornelian Bay small craft anchorage New Town Bay small craft anchorage Koomela Bay small craft anchorage Montagu Bay small craft anchorage					
Consequences					
Property					
Small craft	Major damage caused by wave; Capsize/sinking caused by wave; breaking adrift from anchorage				
Infrastructure	Inundation; Destruction of marina; Loss of nav aids caused by wave				
Life					
Small craft	Serious/critical				
Vicinity	Serious/critical				
Environment					
Land	Inundation; Coast/beach wreckage, oil pollution				
Water	Drifting wreckage, oil pollution				
Note: The figures in this table are derived from the SE Tasmania Tsunami Modelling results and are indicative. For precise data see the results from the SE Tasmania Tsunami Model.					



Marina, Prince of Wales Bay
<https://www.youtube.com/watch?v=Zov-d8PwJUJ>

8. Discussion-Small Craft

Some Specific Implications for Small Craft in the Port of Hobart

8.1. Introduction

There is no clear definition of a small craft. However, in the context of tsunamis it is useful to consider small craft in two categories, namely small craft constructed for use in:

- Offshore waters (e.g. fishing boats, ocean cruising yachts)

- Sheltered waters (e.g. ferries, leisure craft including cabin cruisers, yachts, dinghies)
- A further consideration is whether the small craft is powered by an engine and, if it is, is the engine sufficiently powerful to deal with a tsunami wave and associated currents.

Table 22 is a summary of the advice to small craft based on the literature in general and specifically:

- List of Countermeasures against Tsunami, Hong Kong Weather Service, March 2012 [15]
- 9th Regional Japan Coast Guard Headquarters, *To secure Life and Ship from Tsunami* [14]
- Wiśniewski B and Wolski T (2012), " *The safety of the shipping and ports in the aspect of the tsunami events* ", Scientific Journals, Maritime University of Szczecin 2012, Vol.30 (102) pp 150–157 [13]

Predicted Tsunami height	Able to get to deep water	Small craft alongside in port	Small craft underway in port area
Over 3 metres	No	Evacuate to land	Land and evacuate
	Maybe	Evacuate to land, or (to deep water if safe to do so)	Evacuate to deep water, or (land and evacuate if safe to do so)
	Yes		Evacuate to deep water, or land and evacuate
1 - 3 metres	No	Evacuate to land	Land and evacuate
	Maybe	Evacuate to land, or (to deep water if safe to do so)	Evacuate to deep water, or (land and evacuate if safe to do so)
	Yes		Evacuate to deep water, or land and evacuate
0.5 - 1 metre		Secure craft, or evacuate to deep water	Secure craft, or evacuate to deep water

Note: Based on Hong Kong Weather Service, *List of Countermeasures against Tsunami* [15]; 9th Regional Japan Coast Guard Headquarters, *To secure Life and Ship from Tsunami* [14]; and Wiśniewski and Wolski, *The safety of the shipping and ports in the aspect of the tsunami events* [13]

8.2. Small craft underway

Small craft constructed for use in offshore waters which have sufficient warning may be safer in deeper water. If it is not feasible to reach deeper water then the small craft should attempt to land, be secured, and the crew evacuated to a safe location.

Small craft constructed for use in sheltered waters are less likely to be able to ride out a tsunami wave or be able to evacuate to deeper water. For small craft of sufficient engine power, it may be feasible to reach deep water, but only if it is considered safe to do so. Consequently, the best course of action may be to land, secure the craft, and evacuate the crew to a safe location.

8.3. Small craft at designated anchorages, marinas and alongside a berth

There is evidence of turbulence (e.g. breaking waves) at all Marinas and all Designated Small Craft Anchorages. Consequently, the best course of action may be to secure the craft, and evacuate the crew to a safe location. If sufficient time is available, small craft of sufficient engine power may be able to reach deep water, but only if it is considered safe to do so.

Some of the larger craft alongside at a berth (e.g. fishing boats, ocean cruising vessels, and ferries) may be able to let go and reach deep water, if sufficient time is available. If this is not feasible then the craft should be secured, and the crew evacuated to a safe location.

9. Further Research

The project was conducted as a desktop study and, whilst comprehensive in approach, the findings should be viewed as preliminary in nature. Further research is needed to test the reliability and validity of the findings to improve/ensure their accuracy.

In summary, this preliminary report indicates the possible hazards to shipping from a worst case scenario tsunami in the Port of Hobart. The report is a high level review and forms the basis for further more detailed consideration and research. In order to improve the accuracy and validity of the hazards and effects of a tsunami on vessels using the Port of Hobart more detailed research is needed. This could include:

- Improved data on vessels using the Port of Hobart e.g. types, size, speed
- Improved data on the alongside status of vessels using the Port of Hobart e.g. time taken for a vessel to let go and clear a berth including availability of crew and engines, mooring lines and gangways, manoeuvring issues, meteorological conditions
- Possibly simulating ship evacuation scenarios on the Australian Maritime College simulators
- Reviewing potential hazards, damage criteria, mitigating actions including evacuation scenarios
- Consideration of the effects of 'smaller' tsunamis and different states of the tide
- Possibly testing the effects of a tsunami on vessels in port in the Australian Maritime College Model Test Basin

Outcomes from this research could be used to develop/refine/improve the advice to vessels and small craft in the Port of Hobart in the event of a tsunami warning being received.

Additionally, recognising that the evacuation time estimates are speculative and the conditions described by the assumptions will not occur in all circumstances, it is recommended that further research is undertaken to develop more reliable outcomes and for a wider range of conditions and scenarios. This would enable better decisions to be made on whether a ship should evacuate or stay.

10. References

(Note: Websites accessed between 1/4/16 and 5/10/16)

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10.1. Videos

Japanese Coastguard ship in deep water in 2011 tsunami waves

<https://www.youtube.com/watch?v=nWPR1HavsCE>

Japanese fishing vessels in port waters in 2011 tsunami waves

<https://www.youtube.com/watch?v=cC8wuj31MWs>

Tsunami 2011 effect on ship Asia Symphony-lifted on to deck of berth

<https://www.youtube.com/watch?v=2yinEJ2nbD0>

Inundation of small Japanese port by 2011 tsunami waves

<https://www.youtube.com/watch?v=181EBnSsliY>

Small craft off Crescent City, USA in 2011 tsunami waves

<https://www.youtube.com/watch?v=c2luqXyx2NU>

Effect of tsunami on fishing vessels in Coquimbo Port, Chile

<https://www.youtube.com/watch?v=t9M4MOUjNGs>

Small craft harbour damage from 2011 tsunami waves in Santa Cruz, California, USA

<https://www.youtube.com/watch?v=iltleWB1XH8>

Tsunami 2011 effect on small craft in Crescent City Harbor, California, USA

<https://www.youtube.com/watch?v=8ltLkvZYnxQ>

Tsunami Surge Depoe Bay, Oregon, Aboard C/V Morning Star

<https://www.youtube.com/watch?v=bXeZqMAe3-Y>

Tsunami 2011 effect on small craft in Brookings Harbor, Oregon, USA

<https://www.youtube.com/watch?v=VG08lsGzoP4>

10.2. Additional Tsunami Related Documents Reviewed

The following additional tsunami related documents were reviewed:

- International (High Risk Zones), *PIANC (2010), PIANC Report No. 212 Mitigation of Tsunami Disasters in Ports*, PIANC, Brussels, Belgium
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- North America:
 - Canada
 - British Columbia Tsunami Notification Plan
<http://www2.gov.bc.ca/assets/gov/public-safety-and-emergency-services/emergency-preparedness-response-recovery/provincial-emergency-planning/tsunami-notification-process-plan.pdf>
 - Port McNeill, B.C. Emergency Plan
<http://static1.squarespace.com/static/55ca2350e4b08d9e4143db86/t/571aa9f9555986bfe84e495e/1461365251817/1+-+PM+EMERGENCY+PLAN+-+Updated+April+2016.pdf>
 - Port Hardy, B.C. Earthquake and Tsunami Poster
http://www.porthardy.ca/sites/default/files/port_hardy_tsunami_preparedness_poster.pdf
 - USA
 - Hawaii Tsunami Emergency Plan
<http://files.hawaii.gov/dlnr/dobor/contacts/Plan-TSUNAMI.pdf>
 - The Seattle Globalist describes some evacuation procedures for Tacoma
<http://www.seattleglobalist.com/2015/03/18/northwest-detention-center-tsunami-disaster-evacuation-tacoma/34981>
- Central and South America
 - Caribbean
 - Communication Plan for the Interim Tsunami Advisory Information Service to the Caribbean Sea and Adjacent Regions
http://www.ioc-unesco.org/index.php?option=com_oe&task=viewDocumentRecord&docID=6354
- East Asia: Japan/Korea
 - Japan
 - Assessment of tsunami hazards in ports and their impact on marine vessels derived from tsunami models and the observed damage data (Academic Paper) <http://link.springer.com/article/10.1007/s11069-015-1772-0>
 - Safety of vessels against tsunamis (Academic Paper) http://www.hko.gov.hk/wservice/tsheet/pms/images/tsunami_marine_safety_2.pdf

- Yokohama and Kawasaki (Action Plan for Ships against Tsunamis)
<http://www6.kaiho.mlit.go.jp/03kanku/yokohama/info/information/tunamien.pdf>
- Analysis of Ship Refuge Action in Tsunami Using AIS Data: Case of the 2011 East Japan Earthquake and Tsunami (Academic Paper)
<http://www.davidpublishing.com/davidpublishing/Upfile/3/4/2014/2014030481780921.pdf>
- Some recommendations to the ship master in order to evacuate a cruise ship due to tsunami arrival by Trika Pitana, Eiichi Kobayashi Kobe University Kobe, Japan (Academic Paper)
<http://iamu-edu.org/wp-content/uploads/2014/07/Some-recommendations-to-the-ship-master-in-order-to-evacuate-%D0%B0-cruise-ship-due-to-tsunami-arrival.pdf>
- Korea
 - Tsunami response system for ports in Korea (Academic paper)
<http://www.nat-hazards-earth-syst-sci.net/15/1999/2015/nhess-15-1999-2015.pdf>

Australia and New Zealand (Moderate Risk Zones)

- Australia
 - Australia
 - Tsunami Emergency Planning in Australia
<https://www.aidr.org.au/media/1461/manual-46-tsunami-emergency-planning-in-australia.pdf>
 - Earthquake and Tsunami Awareness for Australians
<http://www.tsunamisafe.com.au/uploads/36/brochure-tsunami-awareness-brochure-pdf-spread-final.pdf>
 - Western Australia
 - State Emergency Management Plan for Tsunami
<https://extranet.fesa.wa.gov.au/sites/emwa/Lists/StateEmergencyManagementDocumentLibrary/State%20EM%20Plans/Hazard%20Plans/Westplan%20Tsunami.pdf>
 - Victoria
 - State Tsunami Emergency Plan
<http://www.ses.vic.gov.au/em-sector/em-planning/em-partners-resources/state-tsunami-emergency-plan>
 - NSW
 - State Tsunami Plan
https://www.emergency.nsw.gov.au/media/admin/765/_/I99n5kyvkb1zc4kcg/SubPlan_Tsunami_20150301.pdf
 - Lord Howe Island Tsunami Emergency Sub Plan
<http://www.tsunamisafe.com.au/uploads/43/plan-lhi-plan.pdf>
 - Queensland
 - Brisbane City Council Disaster Management Plan 2015 Tsunami Management Sub-Plan
<https://www.brisbane.qld.gov.au/community/community-safety/disasters-emergencies/disaster-management-plans>

- Bundaberg (Regional Council Tsunami Response Plan)
<http://www.bundaberg.qld.gov.au/files/bundaberg-tsunami-response-plan.pdf>
- Mourilyan (MSQ Port Procedures and Information for Shipping)
<http://www.msq.qld.gov.au/search-results.aspx?query=tsunami>
- Brisbane (MSQ Port Procedures and Information for Shipping)
<http://www.msq.qld.gov.au/search-results.aspx?query=tsunami>
- New Zealand
 - New Zealand
 - GeoNet New Zealand, Tsunami
<http://info.geonet.org.nz/display/tsunami/Tsunami>
 - Tsunami Research Co. NZ, Hazards from far-field tsunamis in New Zealand ports and harbours
<http://tsunamiresearch.co.nz/projects/tsunamis-in-new-zealand-ports/introduction/>
 - Government Tsunami advice
<http://www.getthru.govt.nz/disasters/tsunami/>
 - Lyttelton, South American Tsunamis in Lyttelton Harbour (Academic paper) <http://link.springer.com/article/10.1007%2Fs00024-014-1026-1#page-1>
 - Marsden Point, Tauranga, Taranaki and Lyttelton, Far-Field Tsunami Hazard in New Zealand Ports (Academic Paper)
<http://link.springer.com/article/10.1007%2Fs00024-014-0987-4#page-1>
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Appendices

Appendix 1: Project Scope

1. Provide advice on possible hazards to shipping (commercial, scientific research, and other agreed significant vessels) from modelled tsunami scenarios in the Derwent Estuary, Tasmania;
2. Provide advice on the design of the computer model being developed by MRT to ensure that outputs provide the necessary information for shipping hazards to be adequately assessed;
3. Undertake a literature assessment and summarise the types of advice being provided to similar organisations, particularly port authorities, in other jurisdictions in Australia and internationally;
4. Analyse the tsunami computer model outputs and assess the implications for shipping at the locations specified below;
5. The following specific areas at a minimum are to be considered for hazards to shipping:
 - a. the principal Hobart port area (including Constitution Dock and Macquarie Point);
 - b. Selfs Point Wharf;
 - c. Risdon Wharf;
 - d. Prince of Wales Bay wharf and dock facilities;
 - e. the principal navigational channels and established anchorage areas from Iron Pot to Risdon Wharf; and
 - f. the navigational channel specifically in the vicinity of the Tasman Bridge.
6. Prepare and submit to the Department's Representative a draft report addressing the above tasks, summarising the Consultant's findings, identifying any potential constraints and any recommendations for further work and actions;
7. Present the draft Report to stakeholders at a workshop in Hobart;
8. Provide to the Department's Representative a final Report incorporating any comments from stakeholders or feedback from the workshop attendees;
9. Comply with any reasonable requests of the Department's Representative in relation to the provision of any aspect of the Service (including any Departmental policies or requirements that need to be adhered to); and
10. Provide such ad hoc or further information as the Department's Representative may reasonably require.

Appendix 2: Tasports Tsunami Warning Procedure

RESPONSIBILITIES

Daily Procedure

- Port Control to monitor TasPorts wind instruments approximately hourly
- Bureau of Meteorology emails checked promptly

Immediate Actions

- Port Control to notify the Duty Pilot/s
- Port Control to notify the Marine Manager
- Security Centre to notify Port Operations Supervisor/s, Operations Manager and the Site Coordinator/s to secure loose items, floating plant and cease cargo operations as required
- Port Control (Radio Room) to notify the Manager of Devonport Airport (if the warning includes Devonport)
- Security Centre to notify the Event Manager of any specific public 'event' occurring in the Port
- Port Control to monitor wind speeds and sea states every 30 minutes
- Port Operations to dispatch Patrolman/Wharf Officers to check moorings of all vessels (small boats and ships)
- Port Control to notify Kings Pier small vessels owners via landline and/or text message to mobile phones in the event of strong easterlies 'Severe storm imminent, please attend to your vessel'
- Port Control to notify vessels in port as directed by Duty Pilot
- Port Control to advise port users via a VHF Channel 16 broadcast
- Port Control and Security Centre to monitor small boats via CCTV and patrols in case they come adrift Port Control to liaise with the Marine Manager on whether the Port is to be closed or vessel movements restricted

Post-Incident

- Stand down when Severe Weather Warning is cancelled by the Bureau of Meteorology
- Contribute to debrief by compiling a detailed incident report

(Source:

http://www.tasports.com.au/pdf/Safety/201504_Emergency_Management_Plan.pdf)

Appendix 3: Wave Data for shipping hazards to be adequately assessed

Wave data incorporated into the design of the computer model to ensure that outputs provide the necessary information for shipping hazards to be adequately assessed

This is the request made to the Department of State Growth for the following to be incorporated into the tsunami computer model.

1. WAVE DATA

The following indicative wave data is required for the listed locations:

- Wave height (Amplitude peak to trough, in metres)
- Wave length (Peak to peak or trough to trough, in metres and duration e.g. minutes/seconds)
- Wave velocity (Preferably in knots; or metres per second)
- Wave form (Profile and descriptor e.g. slow water level rise, rapid water level rise; a 'wall of water', breaking wave)
- Time of arrival at each location relative to location 1 i.e. location 1 is time zero
- Time taken for the Tsunami wave to arrive at location 1

2. LOCATION DATA

Wave data locations were chosen to ensure the 'form' of the wave is understood at the following locations:

- Principal shipping channel from Iron Pot to Prince of Wales Bay (including in the vicinity of the Tasman Bridge)
- The four designated anchorages
- Principal Hobart port area (including Constitution Dock and Macquarie Point)
- Selfs Point Wharf
- Risdon (Nyrstar) Wharf
- Prince of Wales Bay wharf and dock facilities

Location co-ordinates used for the generation of wave data were derived from Google Maps. Each location is described in terms of its latitude and longitude. For ease of analysis the wave data for each location is numbered with a location number.

Each location also has a descriptor e.g. Off Iron Pot-mid channel; 200m to the East of Battery Point etc. However, these are not accurate positions and were not used as locations to generate wave data.

3. LOCATION CO-ORDINATES

PRINCIPAL SHIPPING CHANNEL; IRON POT TO PRINCE OF WALES BAY (INCLUDING IN THE VICINITY OF THE TASMAN BRIDGE) (Latitude and longitude data from Google Maps)	
1. Off Iron Pot; mid channel 43°04'02.1"S 147°23'42.4"E -43.067257, 147.395121	2. Off John's Point; slightly East of mid channel 43°02'32.0"S 147°22'45.4"E -43.042224, 147.379269
3. Off Flowerpot Point; slightly East of mid channel 43°00'34.3"S 147°22'28.1"E -43.009533, 147.374462	4. Off White Rock Point; slightly East of mid channel 42°58'36.6"S 147°22'14.5"E -42.976825, 147.370685
5. Off Trywork Point; slightly West of mid channel 42°56'24.7"S 147°22'40.4"E -42.940204, 147.377895	6. Off Blinking Billy Point; West of Mid channel 42°54'50.3"S 147°22'27.8"E -42.913981, 147.374376
7. Off RYCT; South of Kangaroo Bluff 42°53'54.8"S 147°21'39.9"E -42.898543, 147.361083	8. Off Sullivans Cove; due South of Rosny Point 42°53'03.0"S 147°21'09.6"E -42.884164, 147.352672
9. Off Macquarie Point; on 353° leads (Tasman Bridge Channel) 42°52'35.0"S 147°20'50.9"E -42.876385, 147.347458	10. Off Ross Bay; on 353° leads (Tasman Bridge Channel) 42°52'14.8"S 147°20'43.5"E -42.870791, 147.345430
11. Off Montagu Bay; on 353° leads (Tasman Bridge Channel) 42°52'03.6"S 147°20'43.2"E -42.867673, 147.345333	12. Under Tasman Bridge; on 353° leads (Tasman Bridge Channel) 42°51'54.1"S 147°20'43.0"E -42.865027, 147.345269
13. Off Pavilion Point; on 353° leads (Tasman Bridge Channel) 42°51'41.9"S 147°20'42.1"E -42.861642, 147.345038	14. Off Rose Bay; on 353° leads (Tasman Bridge Channel) 42°51'25.4"S 147°20'42.1"E -42.857057, 147.345017
15. Off Lindisfarne Bay; on 353° leads (Tasman Bridge Channel) 42°51'11.9"S 147°20'41.0"E -42.853301, 147.344727	16. Off Beltana Point; on 135° leads 42°51'04.1"S 147°20'29.7"E -42.851142, 147.341594
17. Off Koomela Bay; on 135° leads 42°50'56.9"S 147°20'19.4"E -42.849140, 147.338729	18. Off Limekiln Point; on 135° leads 42°50'50.9"S 147°20'10.0"E -42.847461, 147.336122
19. Off Selfs Point Wharf South end; slightly East of mid channel 42°50'42.4"S 147°20'03.3"E -42.845113, 147.334255	20. Off Selfs Point Wharf North end; mid channel 42°50'32.8"S 147°19'56.6"E -42.842435, 147.332388
21. Off New Town Bay; mid channel 42°50'22.5"S 147°19'50.0"E -42.839583, 147.330564	22. Off Shag Bay; mid channel 42°50'12.3"S 147°19'44.3"E -42.836751, 147.328966
23. Off Stanhope Point; mid channel 42°50'00.4"S 147°19'35.4"E -42.833435, 147.326488	24. Off Nyrstar Wharf South end; mid channel 42°49'49.9"S 147°19'24.9"E -42.830528, 147.323580
25. Off Nystar Wharf North end; mid channel 42°49'41.1"S 147°19'11.9"E -42.828093, 147.319964	26. Off Store Point; mid channel 42°49'32.5"S 147°18'56.9"E -42.825705, 147.315807
27. Off INCAT slip; on 308° leads 42°49'25.3"S 147°18'44.0"E -42.823683, 147.312234	28. Off Dowsings Point; midway between Dowsings Point and INCAT jetty 42°49'27.4"S 147°18'25.6"E -42.824279, 147.307116
29. Entering Prince of Wales Bay; mid channel 42°49'29.4"S 147°18'16.7"E -42.824834, 147.304627	30. Entering Prince of Wales Bay; mid channel 42°49'32.8"S 147°18'09.5"E -42.825782, 147.302631

DESIGNATED ANCHORAGES (Latitude and longitude data from Google Maps)	
40. Anchorage 1 42°55'17.7"S 147°23'17.6"E -42.921576, 147.388207	41. Anchorage 2 42°56'06.0"S 147°23'18.0"E -42.935000, 147.388333
42. Anchorage 3 42°56'54.0"S 147°23'06.0"E -42.948333, 147.385000	43. Anchorage 4 42°57'42.0"S 147°22'54.0"E -42.961667, 147.381667

PRINCIPAL HOBART PORT AREA; INCLUDING CONSTITUTION DOCK AND MACQUARIE POINT**(Latitude and longitude data from Google Maps)**

50. Off Secheron Point; 500m to the East 42°53'27.0"S 147°20'45.8"E -42.890836, 147.346042	51. 200m to the East of Battery Point 42°53'12.1"S 147°20'34.9"E -42.886689, 147.343038
52. 250 m to the North of Battery Point 42°53'04.1"S 147°20'21.5"E -42.884484, 147.339304	53. CSIRO Wharf; mid length 42°53'10.8"S 147°20'19.1"E -42.886327, 147.338650
54. Princes Wharf 2 & 3; mid length 42°53'09.1"S 147°20'09.8"E -42.885873, 147.336070	55. Princes Wharf 1; mid length 42°53'08.6"S 147°20'00.7"E -42.885722, 147.333533
56. Between Brooke Street Pier and Ferry Pier 42°53'04.8"S 147°19'58.1"E -42.884663, 147.332809	57. Elizabeth Street Pier; South side, mid length 42°53'03.5"S 147°20'00.9"E -42.884303, 147.333581
58. King Pier Marina entrance 42°53'02.5"S 147°20'06.6"E -42.884022, 147.335158	59. Centre of Constitution Dock 42°52'57.4"S 147°19'59.2"E -42.882621, 147.333120
60. Centre of Victoria Dock 42°52'54.6"S 147°20'03.9"E -42.881837, 147.334402	61. Macquarie Wharf 1; mid length 42°52'56.6"S 147°20'09.9"E -42.882387, 147.336076
62. Macquarie Wharf 2; mid length 42°52'57.7"S 147°20'19.8"E -42.882696, 147.338844	63. Macquarie Wharf 3; mid length 42°52'56.9"S 147°20'25.5"E -42.882462, 147.340416
64. 200 m to the East of end of Macquarie Wharf 3 & 4 42°52'55.8"S 147°20'41.3"E -42.882177, 147.344799	65. Macquarie Wharf 4; mid length 42°52'50.4"S 147°20'28.7"E -42.880655, 147.341296
66. Macquarie Wharf 5; mid length 42°52'46.3"S 147°20'27.9"E -42.879519, 147.341084	67. Macquarie Wharf 6; mid length 42°52'40.1"S 147°20'28.2"E -42.877799, 147.341181
68. 200m to the East of Macquarie Point 42°52'35.8"S 147°20'38.6"E -42.876610, 147.344067	

SELFS POINT WHARF**(Latitude and longitude data from Google Maps)**

80. 100 m to the South of Selfs Point Wharf 42°50'47.8"S 147°19'51.5"E -42.846596, 147.330985	81. Selfs Point Wharf; mid length 42°50'41.0"S 147°19'50.2"E -42.844720, 147.330599
82. 100m to the North of Selfs point Wharf 42°50'34.3"S 147°19'48.4"E -42.842860, 147.330105	83. Selfs Point Jetty; mid length 42°50'43.0"S 147°19'44.7"E -42.845271, 147.329086

RISDON (NYRSTAR) WHARF**(Latitude and longitude data from Google Maps)**

90. 100m South East of Nyrstar Wharf 2; South end 42°49'55.0"S 147°19'21.1"E -42.831943, 147.322530	91. Nyrstar Wharf 2; mid length 42°49'51.4"S 147°19'14.0"E -42.830956, 147.320545
92. Nyrstar Wharf 1; mid length 42°49'48.4"S 147°19'08.8"E -42.830110, 147.319107	93. 100m North West of Nyrstar Wharf facilities; North end 42°49'43.5"S 147°19'00.1"E -42.828761, 147.316704

PRINCE OF WALES BAY WHARF AND DOCK FACILITIES
(Latitude and longitude data from Google Maps)

100. 100m East of North end of INCAT slip 42°49'35.9"S 147°18'43.3"E -42.826640, 147.312026	101. INCAT slip 42°49'35.7"S 147°18'34.3"E -42.826581, 147.309537
102. 100m East of INCAT jetty; North end 42°49'32.1"S 147°18'29.1"E -42.825593, 147.308089	103. INCAT Jetty; mid length 42°49'33.7"S 147°18'23.1"E -42.826022, 147.306426
104. Prince of Wales Bay Marina wharf; mid length 42°49'41.0"S 147°18'10.4"E -42.828048, 147.302896	105. Prince of Wales Marine P/L dock facilities 42°49'38.8"S 147°18'03.7"E -42.827430, 147.301040
106. Derwent Marine dock facilities 42°49'30.9"S 147°17'58.1"E -42.825262, 147.299474	107. Pauline Point marina facilities 42°49'49.0"S 147°18'05.8"E -42.830286, 147.301609

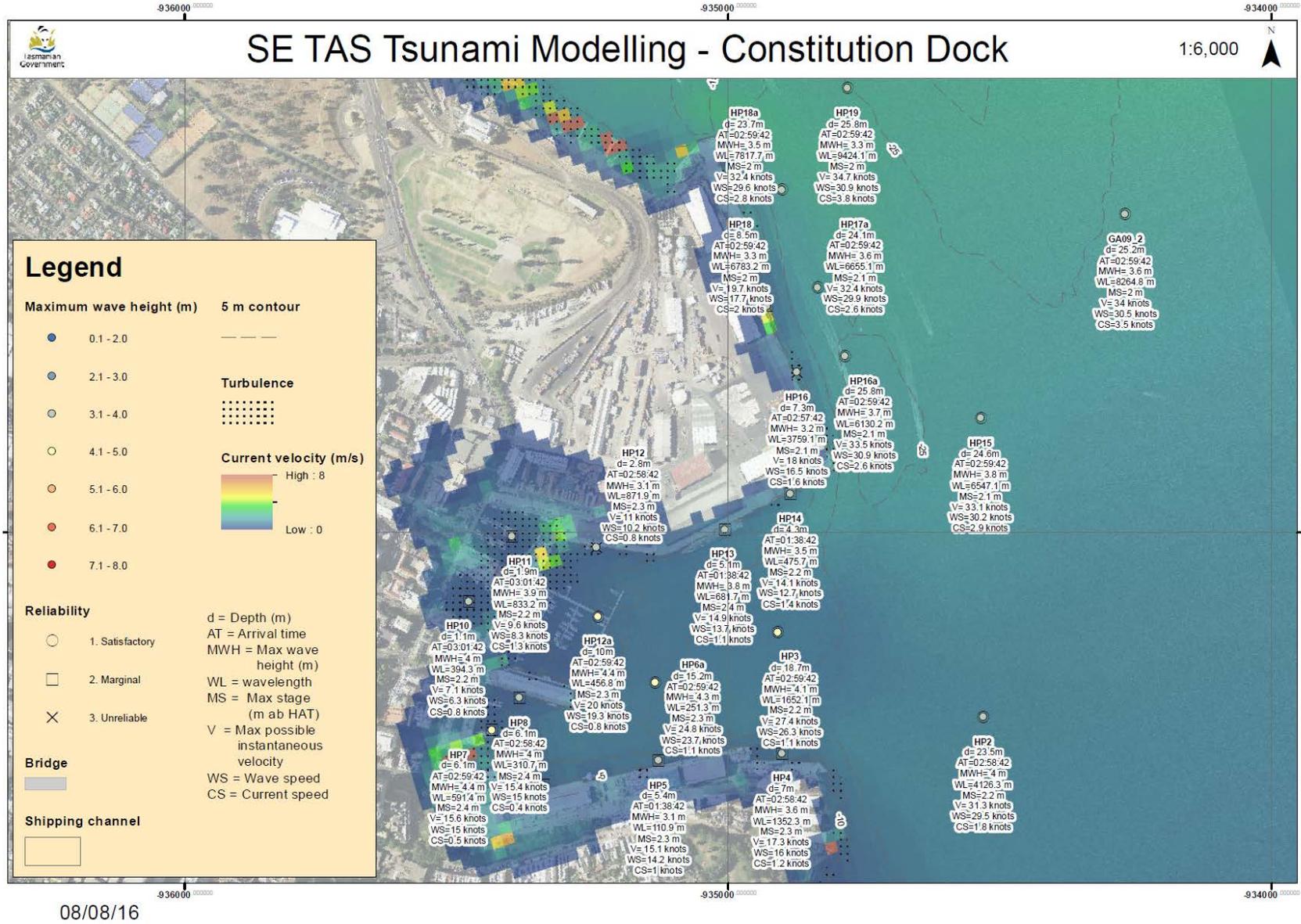
Appendix 4: SE Tasmania Tsunami Model Results

ID	SiteID	SiteName	Description	Type	Eastings	Northing	DistAlongChannel (km)	Depth (m, hat)	Arrival time	End time	Max h (m)	MWH time	Max stage (ab Hat)	Wavelength first wave (m)	Time max current	Max current (m/s)	Max current (knots)	Wave speed (m/s)	Wave speed (knots)	Upper velocity (m/s)	Upper velocity (knots)	Turbulence	Reliability
31	ANC1	Anchorage 1		DESIGNATED ANCHORAGES	531682.3433	5247820.903 NA		25.7	2:53:42 AM	11:01:42 AM	2.8	2:56:42 AM	1.6	1080.0	2:56:42 AM	1.1	2.2	15.9	30.8	17.0	33.0 N		1
32	ANC2	Anchorage 2		DESIGNATED ANCHORAGES	531685.745	5246390.159 NA		25.8	2:51:42 AM	1:08:42 PM	2.9	2:55:42 AM	1.7	1254.0	3:08:42 AM	1.2	2.4	15.9	30.9	17.1	33.3 N		1
33	ANC3	Anchorage 3		DESIGNATED ANCHORAGES	531407.0132	5244850.815 NA		27.5	2:49:42 AM	1:08:42 PM	2.8	2:53:42 AM	1.7	1440.0	3:07:42 AM	1.3	2.6	16.4	31.9	17.7	34.5 N		1
34	ANC4	Anchorage 4		DESIGNATED ANCHORAGES	531128.3966	5243371.346 NA		28.7	2:47:42 AM	1:31:42 PM	3.1	2:52:42 AM	1.6	1512.0	3:25:42 AM	1.3	2.4	16.8	32.6	18.0	35.1 N		1
70	G1	Geillston Bay Boat Club		Marina	528116.4703	5257121.736 NA		3.0	3:06:42 AM	3:35:42 PM	5.2	3:10:42 AM	2.9	624.0	6:06:42 AM	1.2	2.3	5.4	10.5	6.6	12.8 Y		2
79	G10	Bruny Island Jetty		Jetty or wharf	523322.3045	5223273.594 NA		7.9	1:38:42 AM	3:38:42 PM	4.9	2:52:42 AM	0.5	1.9 NC	3:21:42 AM	0.3	0.8	8.8	17.1	9.0	17.6 N		4
79	G10a				523073	5223630 gauge_G10a		23.4	2:51:42 AM	2:43:42 PM	1.8	2:52:42 AM	0.5	NC	3:21:42 AM	0.4	0.8	15.2	29.5	15.6	30.3 N		2
80	G11	Lymington Yacht Club		Marina	506721.7838	5219678.958 NA		1.1	3:02:42 AM	3:01:42 PM	2.6	3:11:42 AM	1.9	1.4 NC	3:19:42 AM	1.9	3.7	6.5	12.5	6.5	10.2 Y		3
81	G12	Franklin Wharf		Jetty or wharf	501213.5888	5229647.111 NA		1.2	3:42:00 AM	NA	1.8	3:43:42 AM	0.3	NC	3:38:42 AM	0.4	0.8	3.4	6.7	3.8	7.5 Y		3
82	G13	Huonville Boat Ramp		Miscellaneous	504126.3595	5235243.357 NA		0.7	4:15:00 AM	NA	0.1	4:15:42 PM	0.2	NC	6:29:42 AM	0.0	0.0	2.7	5.2	2.7	5.2 N?		3
83	G14	Port Huon		Jetty or wharf	498116.4693	5221372.151 NA		8.9	3:07:42 AM	12:11:42 PM	2.0	3:12:42 AM	1.1	NC	4:22:42 AM	0.4	0.8	9.3	18.1	9.8	19.0 N		2
84	G15	Dover Wharf		Jetty or wharf	501854.7079	5203743.126 NA		6.9	2:41:42 AM	12:58:42 PM	2.7	2:44:42 AM	1.5	NC	2:44:42 AM	0.7	1.4	8.2	16.0	8.9	17.4 N		1
84	G15a				501973	5203433 gauge_G15a		19.7	2:41:42 AM	11:42:42 AM	2.6	2:44:42 AM	1.5	NC	2:52:42 AM	0.5	1.1	13.9	27.0	14.4	28.1 N		1
85	G16	Southport Wharf		Jetty or wharf	497981.1014	5191075.585 NA		2.4	2:32:42 AM	2:55:42 PM	7.2	3:40:42 AM	4.8	NC	3:38:42 AM	3.3	6.3	4.9	9.5	6.3	15.8 Y		2
86	G17	Port Arthur		Jetty or wharf	569349.0245	5222459.614 NA		4.2	2:13:42 AM	2:22:42 PM	7.7	2:19:42 AM	3.7	NC	2:26:42 AM	1.9	3.8	6.4	12.5	6.2	16.3 Y		1
86	G17a				569698	5222367 gauge_G17a		16.2	2:12:42 AM	2:22:42 PM	7.8	2:19:42 AM	3.3	NC	2:35:42 AM	4.4	8.5	12.6	24.5	17.0	33.0 N		1
87	G18	Pirates Bay Jetty		Jetty or wharf	577039.4522	5234953.727 NA		2.0	2:08:42 AM	2:46:42 PM	12.9	3:22:42 AM	11.4	NC	2:24:42 AM	5.1	9.9	4.4	8.6	9.5	18.5 Y		2
87	G18a				576624	5235734 gauge_G18a		15.2	2:07:42 AM	2:45:42 PM	19.7	2:10:42 AM	8.7	NC	2:20:42 AM	9.4	18.3	12.2	23.7	21.6	42.0 Y		1
88	G19	Dunalley Wharf		Jetty or wharf	565533.1971	5250757.225 NA		0.5	3:08:42 AM	3:18:42 PM	4.3	7:03:42 AM	2.9	NC	7:12:42 AM	1.5	2.9	2.2	4.3	3.7	7.3 Y		3
88	G19a				565353	5250555 gauge_G19a		1.7	3:09:42 AM	3:17:42 PM	4.3	7:03:42 AM	2.8	NC	6:55:42 AM	2.8	5.5	4.1	8.0	6.9	13.5 Y		1
70	G1a				527994	5257073 gauge_G1a		3.6	3:06:42 AM	3:34:42 PM	5.8	3:10:42 AM	2.8	1500.0	6:06:42 AM	3.7	7.3	5.9	11.5	9.7	18.8 Y		1
70	G1b				527481	5256641 gauge_G1b		7.8	3:05:42 AM	3:24:42 PM	5.1	3:10:42 AM	2.7	NC	6:06:42 AM	1.6	3.1	8.8	17.0	10.4	20.1 N		1
71	G2	Motor Yacht Club Tasmania		Marina	528824.4968	5255554.87 NA		2.5	3:03:42 AM	3:31:42 PM	4.3	3:08:42 AM	2.5	NC	5:48:42 AM	1.9	3.8	4.9	9.6	6.9	13.3 Y		2
89	G20	Maria Island Jetty		Jetty or wharf	587222.2112	5285481.716 NA		1.8	2:14:42 AM	2:19:42 PM	5.6	2:31:42 AM	3.9	NC	2:29:42 AM	4.5	8.7	4.2	8.2	8.7	16.9 Y		2
90	G21	Spring Bay Wharf		Jetty or wharf	575892.9947	5290436.048 NA		2.9	2:26:42 AM	2:23:42 PM	2.9	3:44:42 AM	1.6	NC	2:41:42 AM	2.9	5.6	5.3	10.4	8.2	16.0 Y		1
91	G22	Triabunna Wharf		Jetty or wharf	575179.6634	5293171.153 NA		0.9	2:34:42 AM	3:38:42 PM	3.9	2:40:42 AM	2.4	NC	2:37:42 AM	2.9	5.7	3.0	5.9	5.9	11.5 Y		3
1	G22a				574952	5292740 gauge_G22a		1.3	2:32:42 AM	3:38:42 PM	3.7	3:40:42 AM	2.6	3018.1	4:20:42 AM	3.2	6.3	6.9	6.9	6.8	13.1 Y		1
92	G23	Louville Jetty		Jetty or wharf	575093.4973	5289642.045 NA		1.4	2:24:42 AM	3:22:42 PM	2.9	3:32:42 AM	2.0	NC	3:29:42 AM	1.0	1.9	7.2	14.7	9.2	9.2 Y		3
92	G23a				575461	5289603 gauge_G23a		15.5	2:25:42 AM	2:24:42 PM	3.5	3:32:42 AM	1.7	NC	2:41:42 AM	2.2	4.0	2.0	4.0	28.2 N	28.2 N		1
93	G24	Prosser River Jetties		Jetty or wharf	571680.3125	5287860.417 NA		1.8	2:32:42 AM	3:36:42 PM	4.7	2:36:42 AM	3.0	NC	2:33:42 AM	3.9	6.2	4.2	8.1	6.2	12.0 Y		1
94	G25	Swansea Jetty		Jetty or wharf	589080.5707	5336035.935 NA		1.2	2:43:42 AM	3:28:42 PM	2.6	4:35:42 AM	1.4	NC	11:58:42 AM	3.1	6.0	3.4	6.7	6.5	12.7 Y		1
95	G26	Coles Bay Jetty		Jetty or wharf	606555.8056	5335139.191 NA		2.4	2:41:42 AM	3:00:42 PM	4.3	3:40:42 AM	2.3	NC	4:07:42 AM	2.8	5.4	4.8	9.4	7.6	14.9 Y		2
95	G26a				606465	5334799 gauge_G26a		11.5	2:41:42 AM	3:00:42 PM	4.2	3:41:42 AM	2.0	NC	3:38:42 AM	1.5	3.0	10.6	20.7	12.2	23.7 N		1
96	G27	Wine Glass Bay		Miscellaneous	607913.419	5330585.133 NA		5.4	2:09:42 AM	2:44:42 PM	7.5	2:12:42 AM	5.4	NC	2:34:42 AM	4.6	9.0	7.3	14.1	11.9	24.1 Y		1
97	G28	Triabunna		Map Sheet Hydrograph	574895.8073	5292426.482 NA		1.0	2:31:42 AM	3:35:42 PM	3.4	2:37:42 AM	2.4	NC	4:17:42 AM	3.1	6.0	3.2	6.2	6.3	12.2 Y		1
98	G29	Cygnat		Map Sheet Hydrograph	507073.5892	5219424.467 NA		3.2	3:01:42 AM	3:44:42 AM	2.1	3:10:42 AM	1.1	NC	3:20:42 AM	4.1	8.0	5.6	10.9	9.7	18.9 N		1
71	G2a				528851	5255408 gauge_G2a		8.5	3:03:42 AM	3:30:42 PM	4.9	3:08:42 AM	2.4	1080.0	5:53:42 AM	1.6	3.1	9.1	17.7	10.7	20.8 N		1
72	G3	Bellerive Yacht Club		Marina	529993.1637	5253143.453 NA		1.3	3:00:42 AM	3:15:42 PM	4.1	3:04:42 AM	2.8	NC	3:51:42 AM	3.2	3.6	6.9	5.2	10.2 Y		2	
99	G30	Dover West		Map Sheet Hydrograph	501302.0433	5202970.165 NA		22.9	2:41:42 AM	12:59:42 PM	2.8	2:45:42 AM	1.6	NC	2:52:42 AM	0.5	0.9	15.0	29.1	15.5	30.1 N		1
100	G31	Dover East		Map Sheet Hydrograph	503405.485	5203930.605 NA		12.2	2:40:42 AM	12:57:42 PM	2.7	2:43:42 AM	1.6	NC	2:41:42 AM	0.6	1.2	11.0	21.3	11.6	22.5 N		1
101	G32	Bruny Island Neck North		Map Sheet Hydrograph	530027.5622	5209579.301 NA		16.3	2:23:42 AM	2:11:42 PM	10.9	2:26:42 AM	5.6	NC	2:31:42 AM	2.3	4.5	12.6	24.5	15.0	29.1 N		1
102	G33	Bruny Island Neck South		Map Sheet Hydrograph	526815.5141	5205457.085 NA		14.1	2:23:42 AM	2:56:42 PM	10.4	2:57:42 AM	6.0	NC	2:24:42 AM	4.1	11.7	22.8	13.8	25.9 Y	26.9 Y		1
103	G34	Dunkels Beach		Map Sheet Hydrograph	526864.4622	5200534.502 NA		17.4	2:23:42 AM	3:33:42 PM	10.5	2:25:42 AM	4.1	NC	2:57:42 AM	2.1	4.2	13.1	25.4	15.2	29.5 N		1
104	G35	Granton - Bridgewater		Map Sheet Hydrograph	518849.6479	5267328.336 NA		1.7	3:45:42 AM	7:01:42 AM	2.1	3:49:42 AM	0.7	NC	3:52:42 AM	0.7	1.4	4.1	7.9	4.8	9.3 Y		1
105	G36	Bridgewater - Gagebrook		Map Sheet Hydrograph	521294.1697	5266105.297 NA		7.4	3:38:42 AM	6:53:42 AM	2.0	3:42:42 AM	0.6	NC	6:48:42 AM	0.5	0.9	8.5	16.5	9.0	17.5 N		1
106	G37	Austins Ferry - Old Beach		Map Sheet Hydrograph	521190.0496	5264771.086 NA		3.8	3:34:42 AM	10:22:42 AM	2.1	3:38:42 AM	0.8	NC	3:41:42 AM	1.8	3.5	6.1	11.9	7.9	15.4 N		1
107	G38	Dowsing Point - Ottago Bay		Map Sheet Hydrograph	523929.2927	5259788.225 NA		4.8	3:13:42 AM	1:01:42 PM	2.5	3:17:42 AM	1.2	NC	3:37:42 AM	3.9	7.7	6.9	13.4	10.8	21.0 N		1
108	G39	Claremont		Map Sheet Hydrograph	522018.8733	5263010.425 NA		4.2	3:27:42 AM	11:38:42 AM	2.1	3:34:42 AM	1.0	NC	3:34:42 AM	1.6	3.2	6.4	12.4	8.0	15.6 N		1
72	G3a				529939	5253235 gauge_G3a		3.5	3:00:42 AM	3:15:42 PM	5.1	3:04:42 AM	2.8	1200.0	3:52:42 AM	2.4	5.8	11.3	8.2	16.0 Y			

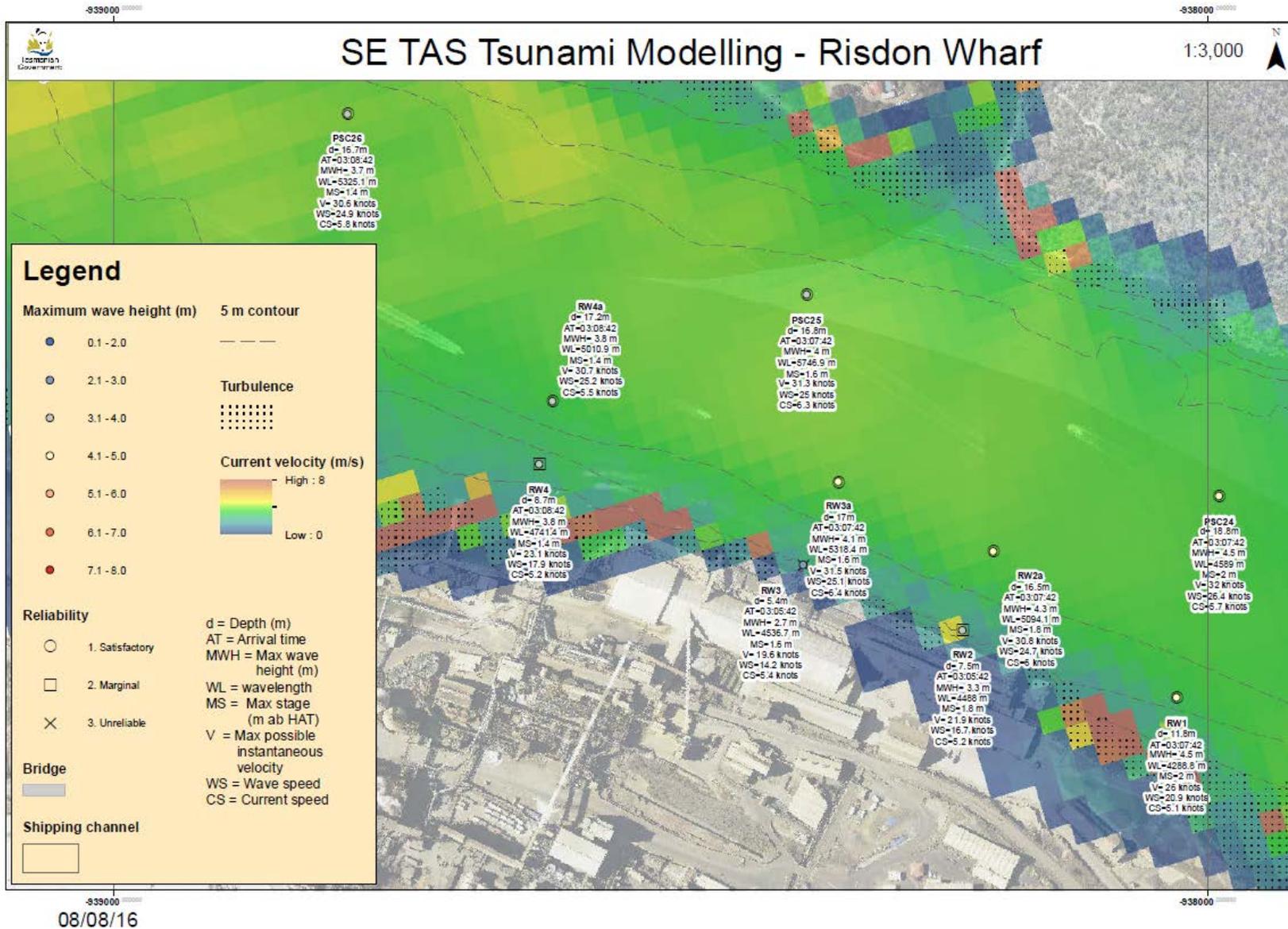
Tsunami Hazards in the Port of Hobart: Maritime Advice

ID	SiteID	SiteName	Description	Type	Eastings	Northings	DistAlongChannel (km)	Depth (m, hat)	Arrival time	End time	Max h (m)	MWH time	Max stage (ab HAT)	Wavelength first wave (m)	Time max current	Max current (m/s)	Max current (knots)	Wave speed (m/s)	Wave speed (knots)	Upper velocity (m/s)	Upper velocity (knots)	Turbulence	Reliability
199	GA09_12			97 GA2009 Gauge	582516.1998	5210452.273	NA	104.6	1:58:42 AM	1:35:42 PM	8.9	2:00:42 AM	6.3	NC	2:00:42 AM	1.3	2.4	NA	NA	NA	NA	N	1
200	GA09_13			98 GA2009 Gauge	578681.0747	5235970.606	NA	49.3	2:05:42 AM	1:55:42 PM	12.9	2:06:42 AM	5.8	NC	2:14:42 AM	2.9	5.7	NA	NA	NA	NA	N	1
201	GA09_14			99 GA2009 Gauge	565405.6416	5210599.778	NA	62.4	2:05:42 AM	1:41:42 PM	7.5	2:07:42 AM	3.9	NC	2:19:42 AM	1.6	3.1	NA	NA	NA	NA	N	1
202	GA09_15			100 GA2009 Gauge	543905.8152	5254961.85	NA	9.0	2:55:42 AM	3:53:42 PM	1.1	6:20:42 AM	1.1	1.1	2.1	2.1	2.1	9.4	18.0	10.5	20.3	N	1
203	GA09_16			101 GA2009 Gauge	553642.1328	5250315.449	NA	13.0	2:49:42 AM	3:35:42 PM	2.3	2:53:42 AM	1.3	NC	6:37:42 AM	0.9	1.8	11.3	21.9	12.2	23.7	N	1
204	GA09_17	Clifton Beach		102 GA2009 Gauge	543321.0757	5239857.303	NA	8.8	2:36:42 AM	3:33:42 PM	8.5	2:38:42 AM	4.7	NC	6:11:42 AM	2.0	3.8	9.3	18.1	11.3	21.9	N	1
205	GA09_18			103 GA2009 Gauge	543920.3754	5243955.799	NA	6.4	2:42:42 AM	3:23:42 PM	4.0	4:15:42 AM	2.4	NC	2:42:42 AM	1.7	3.4	7.9	15.4	9.6	18.8	N	1
206	GA09_19			104 GA2009 Gauge	541193.0128	5249282.177	NA	5.3	2:51:42 AM	3:29:42 PM	3.7	3:12:42 AM	2.0	NC	3:09:42 AM	2.2	4.3	7.2	14.0	9.4	18.3	N	1
189	GA09_2			83 GA2009 Gauge	528504.4876	5252477.667	NA	25.2	2:59:42 AM	1:20:42 PM	3.6	3:04:42 AM	2.0	NC	3:17:42 AM	1.8	3.5	15.7	30.5	17.5	34.0	N	1
207	GA09_20			105 GA2009 Gauge	551134.0305	5252735.864	NA	12.3	2:50:42 AM	3:09:42 PM	2.9	2:53:42 AM	1.6	NC	8:32:42 AM	0.9	1.7	11.0	21.4	11.9	23.0	N	1
208	GA09_21			106 GA2009 Gauge	557450.2327	5226725.285	NA	20.1	2:23:42 AM	2:37:42 PM	4.4	6:08:42 AM	2.2	NC	3:03:42 AM	3.0	5.9	14.0	27.3	17.1	33.2	N	1
209	GA09_22			107 GA2009 Gauge	567971.7265	5236543.466	NA	15.3	3:24:42 AM	9:01:42 AM	1.8	7:08:42 AM	0.6	NC	7:26:42 AM	0.8	1.3	12.3	23.8	12.7	24.6	N	1
210	GA09_23			108 GA2009 Gauge	564507.6681	5248678.042	NA	7.7	3:46:42 AM	3:15:42 PM	2.1	7:02:42 AM	1.1	NC	6:54:42 AM	1.9	3.6	8.7	16.9	10.6	20.5	N	1
211	GA09_24			109 GA2009 Gauge	573389.8274	5257105.154	NA	18.4	2:15:42 AM	2:30:42 PM	9.4	2:17:42 AM	5.0	NC	2:41:42 AM	3.7	7.2	13.4	26.1	17.1	33.3	N	1
212	GA09_25			110 GA2009 Gauge	527862.8416	5199448.959	NA	19.2	2:23:42 AM	3:34:42 PM	10.6	2:52:42 AM	4.8	NC	2:48:42 AM	3.4	6.6	13.7	26.7	17.1	33.2	N	1
213	GA09_26			111 GA2009 Gauge	528072.8631	5207709.804	NA	13.0	2:23:42 AM	2:15:42 PM	12.8	2:23:42 AM	6.0	NC	2:36:42 AM	2.7	5.3	11.3	21.9	14.0	27.3	Y	1
214	GA09_27			112 GA2009 Gauge	536281.2754	5237704.994	NA	3.2	3:07:42 AM	7:03:42 AM	1.8	3:29:42 AM	0.8	NC	3:24:42 AM	1.3	2.5	5.6	10.9	6.9	13.4	N	1
215	GA09_28			113 GA2009 Gauge	536871.2947	5248030.331	NA	6.3	2:59:42 AM	11:11:42 AM	2.6	3:05:42 AM	1.4	NC	3:17:42 AM	1.9	3.7	7.8	15.2	9.9	18.9	N	1
216	GA09_29			114 GA2009 Gauge	570429.6509	5227243.968	NA	16.6	2:11:42 AM	1:43:42 PM	8.1	2:18:42 AM	2.8	NC	2:29:42 AM	8.6	16.6	12.7	24.8	21.3	41.4	N	1
190	GA09_3			84 GA2009 Gauge	531595.5245	5248800.591	NA	25.6	2:54:42 AM	10:25:42 AM	2.4	2:57:42 AM	1.5	NC	2:57:42 AM	1.1	2.1	15.8	30.8	16.9	33.1	N	1
191	GA09_4			85 GA2009 Gauge	531662.3021	5243902.583	NA	26.3	2:48:42 AM	12:08:42 PM	2.8	2:53:42 AM	1.6	NC	3:06:42 AM	1.1	2.2	16.1	31.2	17.4	33.8	N	1
192	GA09_5			86 GA2009 Gauge	529700.5304	5239787.546	NA	24.2	2:43:42 AM	1:03:42 PM	3.8	2:47:42 AM	1.8	NC	2:47:42 AM	1.3	2.6	15.4	29.9	16.7	32.5	N	1
193	GA09_6			87 GA2009 Gauge	530018.7453	5234913.089	NA	21.5	2:38:42 AM	2:24:42 PM	3.6	2:40:42 AM	1.8	NC	2:54:42 AM	1.6	3.1	14.5	28.2	16.1	31.3	N	1
194	GA09_7			88 GA2009 Gauge	532136.7232	5230645.958	NA	18.8	2:33:42 AM	2:31:42 PM	5.3	3:26:42 AM	3.1	NC	2:36:42 AM	1.8	3.5	13.6	26.4	15.4	29.9	N	1
195	GA09_8			89 GA2009 Gauge	535471.6778	5226925.359	NA	30.6	2:28:42 AM	2:11:42 PM	5.4	2:29:42 AM	2.5	NC	2:40:42 AM	1.6	3.1	NA	NA	NA	NA	N	1
196	GA09_9			90 GA2009 Gauge	538130.0366	5222843.153	NA	39.3	2:24:42 AM	2:13:42 PM	4.8	2:25:42 AM	2.6	NC	2:35:42 AM	1.5	2.9	NA	NA	NA	NA	N	1
35	HP1	Off Secheron Point	500m to the East	PRINCIPAL HOBART PORT AREA	528255.2066	5251249.492	NA	23.3	2:58:42 AM	1:43:42 PM	3.9	3:04:42 AM	2.2	NC	3:13:42 AM	1.4	2.2	15.1	29.4	15.8	30.7	N	1
44	HP10	Centre of Constitution Dock		PRINCIPAL HOBART PORT AREA	527203.7012	5252165.993	NA	1.1	3:01:42 AM	3:38:42 PM	4.0	3:05:42 AM	2.2	NC	3:01:42 AM	0.4	0.8	3.2	6.3	3.7	7.1	Y	2
45	HP11	Centre of Victoria Dock		PRINCIPAL HOBART PORT AREA	527308.7395	5252252.638	NA	1.9	3:01:42 AM	3:25:42 PM	3.9	3:05:42 AM	2.2	NC	3:01:42 AM	0.4	0.8	4.3	8.3	4.9	9.6	Y	2
46	HP12	Macquarie Wharf 1	mid length	PRINCIPAL HOBART PORT AREA	527445.202	5252191.018	NA	2.8	2:58:42 AM	3:28:42 PM	3.1	3:05:42 AM	2.3	NC	3:08:42 AM	0.4	0.8	5.2	10.2	5.6	11.0	Y	3
46	HP12a				527414	5252075	gauge_HP12a	10.0	2:59:42 AM	2:10:42 PM	4.4	3:05:42 AM	2.3	NC	5:42:42 AM	0.4	0.8	9.9	19.3	10.3	20.0	N	3
47	HP13	Macquarie Wharf 2	mid length	PRINCIPAL HOBART PORT AREA	527671.1092	5252155.799	NA	5.1	1:38:42 AM	3:38:42 PM	3.8	3:04:42 AM	2.4	NC	3:27:42 AM	0.6	1.1	7.1	13.7	7.7	14.9	Y	2
47	HP13a				527669	5252058	gauge_HP13a	16.7	2:59:42 AM	2:10:42 PM	4.2	3:04:42 AM	2.2	NC	5:42:42 AM	0.6	1.1	12.8	24.8	13.4	26.0	N	2
48	HP14	Macquarie Wharf 3	mid length	PRINCIPAL HOBART PORT AREA	527799.589	5252181.266	NA	4.3	1:38:42 AM	3:38:42 PM	3.5	3:04:42 AM	2.2	NC	3:27:42 AM	0.7	1.4	6.5	12.7	7.3	14.1	Y	2
48	HP14a				527804	5252090	gauge_HP14a	18.7	2:59:42 AM	2:10:42 PM	4.1	3:04:42 AM	2.2	NC	3:27:42 AM	0.9	1.7	13.5	28.0	14.4	28.0	N	2
49	HP15	200 m to the East of end of Macquarie Wharf 3 & 4		PRINCIPAL HOBART PORT AREA	528157.6504	5252211.458	NA	24.6	2:59:42 AM	1:43:42 PM	3.8	3:04:42 AM	2.1	NC	3:17:42 AM	1.5	2.9	15.5	30.2	17.0	33.1	N	2
50	HP16	Macquarie Wharf 4	mid length	PRINCIPAL HOBART PORT AREA	527872.2664	5252381.635	NA	7.3	2:57:42 AM	3:29:42 PM	3.2	3:04:42 AM	2.1	NC	3:13:42 AM	0.8	1.6	8.5	16.5	9.3	18.0	N	3
50	HP16a				527961	5252384	gauge_HP16a	25.8	2:59:42 AM	2:10:42 PM	3.7	3:04:42 AM	2.1	NC	3:13:42 AM	1.3	2.6	15.9	30.9	17.2	33.5	N	3
51	HP17	Macquarie Wharf 5	mid length	PRINCIPAL HOBART PORT AREA	527855.4642	5252507.854	NA	8.0	2:59:42 AM	3:15:42 PM	3.1	3:04:42 AM	2.1	NC	3:13:42 AM	0.7	1.4	8.9	17.3	9.6	18.6	N	2
51	HP17a				527949	5252512	gauge_HP17a	24.1	2:59:42 AM	2:10:42 PM	3.6	3:04:42 AM	2.1	NC	3:14:42 AM	1.3	2.6	15.4	29.9	16.7	32.4	N	2
52	HP18	Macquarie Wharf 6	mid length	PRINCIPAL HOBART PORT AREA	527864.1599	5252698.821	NA	8.5	2:59:42 AM	3:14:42 PM	3.3	3:04:42 AM	2.0	NC	3:05:42 AM	1.0	2.0	9.1	17.7	10.1	19.7	N	2
52	HP18a				527939	5252693	gauge_HP18a	23.7	2:59:42 AM	2:10:42 PM	3.5	3:04:42 AM	2.0	NC	3:17:42 AM	1.4	2.8	15.2	29.6	16.7	32.4	N	1
53	HP19	200m to the East of Macquarie Point		PRINCIPAL HOBART PORT AREA	528100.3985	5252829.896	NA	25.8	2:59:42 AM	2:10:42 PM	3.3	3:04:42 AM	2.0	NC	3:17:42 AM	1.9	3.8	15.9	30.9	17.8	34.7	N	1
36	HP2	200m to the East of Battery Point		PRINCIPAL HOBART PORT AREA	528011.7986	5251711.005	NA	23.5	2:58:42 AM	1:43:42 PM	4.0	3:04:42 AM	2.2	NC	3:14:42 AM	0.9	1.8	15.2	29.5	16.1	31.3	N	1
37	HP3	250 m to the North of Battery Point		PRINCIPAL HOBART PORT AREA	527707.8742	5251957.097	NA	18.7	2:59:42 AM	2:10:42 PM	4.1	3:04:42 AM	2.2	NC	5:00:42 AM	0.6	1.1	13.5	26.3	14.1	27.4	N	1
38	HP4	CSIRO Wharf	mid length	PRINCIPAL HOBART PORT AREA	527653.6447	5251752.654	NA	7.0	2:58:42 AM	3:26:42 PM	3.6	3:04:42 AM	2.3	NC	3:50:42 AM	0.6	1.2	8.3	16.0	8.9	17.3	N	2
38	HP4a				527694	5251883	gauge_HP4a	19.9	2:59:42 AM	2:10:42 PM	4.1	3:04:42 AM	2.2	NC	3:50:42 AM	0.6	1.2	14.0	27.2	14.6	28.4	N	1
39	HP5	Princes Wharf 2 & 3	mid length	PRINCIPAL HOBART PORT AREA	527443.1669	5251803.913	NA	5.4	1:38:42 AM	3:30:42 PM	3.1	3:05:42 AM	2.3										

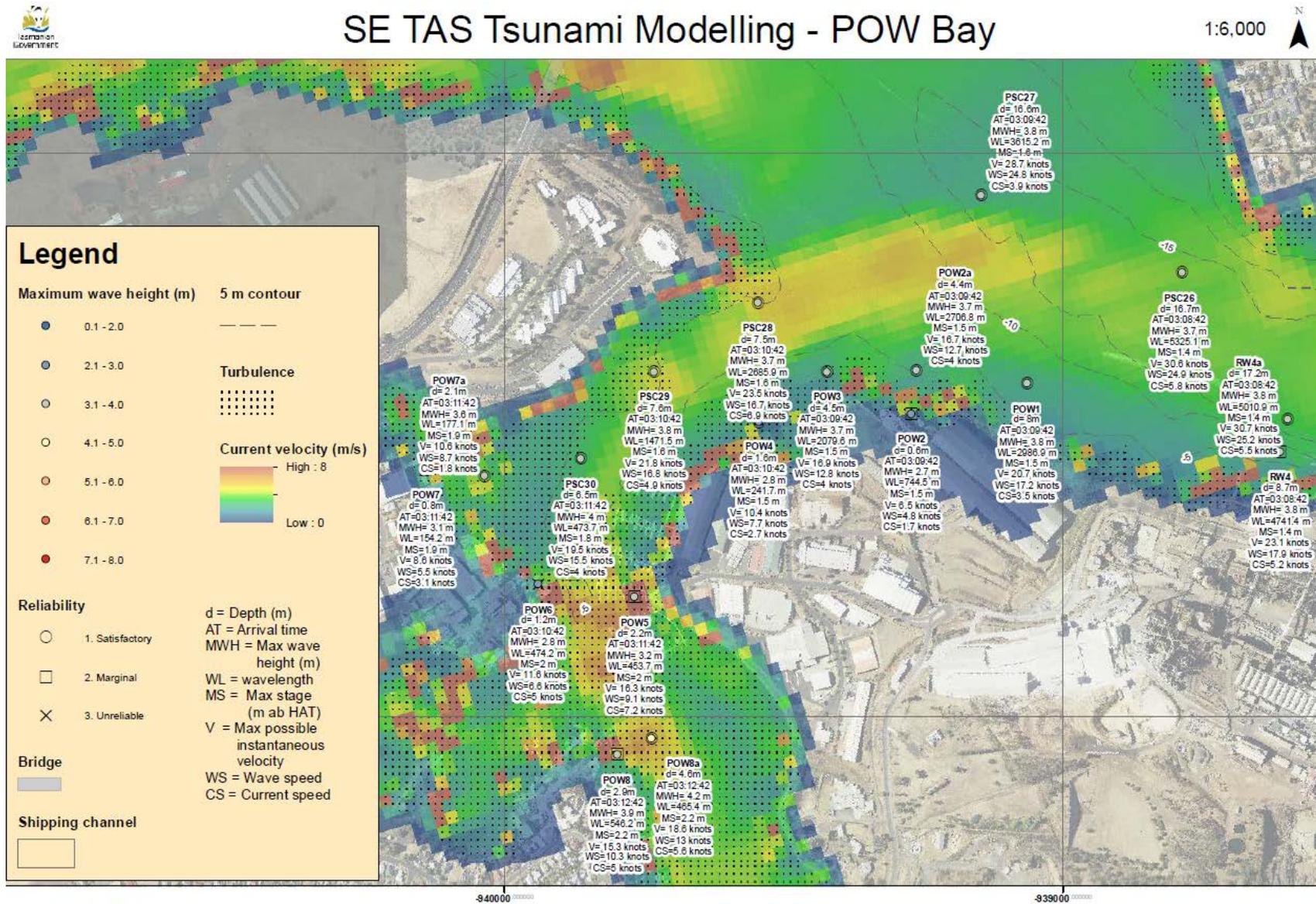
Appendix 5: Data Map Constitution Dock (HP 2-19)



Appendix 6: Data Map Risdon Wharf (RW 1-4)



Appendix 7: Data Map Prince of Wales Bay (POW 1-8)



08/08/16