Coastal Inundation Mapping for Tasmania - Stage 3

For the Department of Premier and Cabinet

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Blue Wren Group

Purpose: *"To drive continuous improvement in the provision of high quality environmental data and information that is understandable and directly relevant to management purposes."*

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Summary

This report was prepared for the project “Coastal Inundation Stage 3” for the Tasmanian Department of Premier and Cabinet and accompanies a set of GIS datasets produced in that project. The project was concerned with mapping of a set of sea level rise scenarios around the Tasmanian coast and a representation of a set of those scenarios as inundation hazard bands. This report is primarily intended to document the methods used in the project. The sea level rise allowances used in this project have been supplied by the Tasmanian Government to create coastal inundation area maps to support the development of a coastal policy, and a coastal inundation planning code. The sea level rise allowances were based on a regional sea-level projections and the A1FI emission scenario.

Outputs include:

1. Coastal inundation extent maps
   - Revised polygon shapefile map showing the extent of expected permanent inundation associated with 0, 0.2 and 0.8 metre sea level rise (coinciding with sea level rise scenarios above 2010 levels for years 2050, and 2100). The maps identify areas that are contiguous[1] or non-contiguous with the mean high tide line.
   - Revised maps of the extent of storm tide inundation associated with 1% Annual Exceedance Probabilities (AEPs) for each of the years 2010, 2050 and 2100, with one polygon dataset per specified year. The maps identify areas that are contiguous or non-contiguous with the mean high tide line.

2. Coastal inundation hazard maps

2.1. Revised maps of the extent of permanent and storm tide inundation associated with the high, medium, low and coastal inundation investigation bands of likelihood, using the recently acquired LiDAR DEM for those coastal areas for which it is now available.
   - High (Currently vulnerable to coastal erosion with future inundation hazard): Area vulnerable to highest astronomical tide now; and 0.2-metre sea level rise from the mean high tide by 2050 + rounding up to the nearest 100 mm.
   - Medium (Vulnerable to Coastal inundation and erosion by 2050): area vulnerable to a 1% AEP storm event in 2050 + rounding up to the nearest 100mm + 300 mm for freeboard .
   - Low (Vulnerable to Coastal inundation and erosion by 2100): Area vulnerable to a 1% AEP storm event in 2100 + rounding up to the nearest 100mm + 300 mm for freeboard.
   - Coastal Inundation investigation band is the area below the 10 metre contour in the non-LiDAR mapped areas, but outside of the identified high, medium or low hazard bands.

3. Report and analysis of coastal inundation hazard bands

3.1. The following indicators at State level and for each Local Government Area (LGA):
   - The area (hectares) of land in each band.
   - The number of vacant cadastral parcels in each band.
   - The number of residential dwellings.

3.2. This report

[1] where 'contiguous' means the inundated area of water is directly connected to the coast and 'non-contiguous' means the inundated area is separated from the coast as an isolated pool.

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Definitions

A1FI	The IPCC's "high emission" scenario
ACE CRC	Antarctic Climate & Ecosystems Cooperative Research Centre
AEP	Annual Exceedance Probability
AHD	Australian Height Datum is the current official standard Australian height reference (ICSM, 2006). For Tasmania it is based on mean sea level at Burnie and Hobart tide gauges in 1972. For a number of reasons including suboptimal location of some tide gauges, limited period of the reference sea level determination and non-inclusion of sea level topography AHD is an approximation of mean sea level only.
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEM	Digital elevation model, a surface representing the surface heights of the land
DPaC	Department of Premier and Cabinet
GIS	Geographic Information System
ILS	Information & Land Services Division of the Department of Primary Industries, Parks, Water and Environment, Tasmania
IPCC	Intergovernmental Panel on Climate Change
ISHW	Indian springs high water. Defined as Mean Sea Level plus the amplitudes of the tidal constituents: M2 + S2 + O1 + K1.
ISLW	Indian springs low water. Defined as Mean Sea Level minus the amplitudes of the tidal constituents: M2 + S2 + O1 + K1.
LiDAR	Light detection and ranging (like "radar", or radio detection and ranging, but using laser light pulses instead of radio pulses)
LGA	Local Government Area
MHW	The average of all high waters over a period of time (ICSM, 2007). For inundation modelling, the high water used was the "NTC High Water" (see below).
MSL	Mean Sea Level For a tidal station Mean Sea Level is the mean over a period of time of the hourly heights at that station (ICSM, 2007).
NTC	National Tidal Centre, Bureau of Meteorology
NTC High Water	The tidal range grid modelled by the National Tidal Centre (NTC) used to model the approximate high water mark, which in most cases also represents the historically mapped coastline well. The NTC tidal range is the height in metres between Mean Sea Level and Indian Spring Low Water multiplied by two to give an estimate of the complete tidal range. It is twice the sum of the amplitudes of the four main tidal constituents, M2, S2, O1 and K1. For Part a) inundation modelling, the high water used was the NTC modelled high water, which is at a height of half the NTC tide range above Mean Sea Level.
SLR	Sea level rise
Storm Tide	A combination of the tidal component plus any raised sea level due to wind set up or reduced air pressure. It is what is measured at tide gauges during a storm event.
UTAS	University of Tasmania

Introduction

This report was prepared for the project “Coastal Inundation Stage 3” for the Tasmanian Department of Premier and Cabinet (DPaC) and accompanies a set of GIS datasets produced in that project. The project was concerned with mapping of a set of sea level rise scenarios around the Tasmanian coast and a representation of a set of those scenarios as inundation hazard bands. This report is primarily intended to document the methods used in the project. The sea level rise allowances used in this project have been supplied by the Tasmanian Government to create coastal inundation area maps to support the development of a coastal policy, and a coastal inundation planning code. The sea level rise allowances were based on regional sea-level projections and the A1FI emission scenario.

Project aim and purpose

This project follows on from the Coastal Inundation Stages 1 and 2 projects, also known as the Tasmanian Coastal Inundation Mapping Project, (Mount *et al.*, 2010, Mount *et al.*, 2011 and Lacey *et al.*, 2012). Recently acquired LiDAR DEM mapping has largely replaced the Climate Futures DEM and also extends to cover all major coastal communities. This project provides new inundation mapping of the LiDAR DEM areas and inundation mapping based on the Tasmanian 25 metre DEM in all other coastal areas.

This stage of the project has three components; coastal inundation extent maps, coastal inundation hazard maps, and statistical analysis of the impact of coastal hazards and reporting which are further specified as follows:

1. Coastal inundation extent maps
   - Revised polygon shapefile map showing the extent of expected permanent inundation associated with 0, 0.2 and 0.8 metre sea level rise (coinciding with sea level rise scenarios for years 2050, and 2100 above the 2010 (base) level). The maps identify areas that are contiguous or non-contiguous with the mean high tide line.
   - Revised maps of the extent of storm tide inundation associated with 1% Annual Exceedance Probabilities (AEPs) for each of the years 2010, 2050 and 2100, with one polygon dataset per specified year. The maps identify areas that are contiguous or non-contiguous with the mean high tide line.

2. Coastal inundation hazard maps

2.1 Revised maps of the extent of permanent and storm tide inundation associated with the high, medium, low and coastal inundation investigation bands of likelihood, using the recently acquired LiDAR DEM for those coastal areas for which it is now available.
   - High (Currently vulnerable to coastal erosion and to future inundation hazard): Area vulnerable to highest astronomical tide now; and 0.2-metre sea level rise from the mean high tide by 2050 rounded up to the nearest 100 mm.
   - Medium (Vulnerable to Coastal inundation and erosion by 2050): area vulnerable to a 1% AEP storm event in 2050 rounded up to the nearest 100mm plus 300 mm added for freeboard .
   - Low (Vulnerable to Coastal inundation and erosion by 2100): Area vulnerable to a 1% AEP storm event in 2100 rounded up to the nearest 100mm plus 300 mm added for freeboard.
   - Coastal Inundation investigation band is the area below the 10 metre contour in the non-LiDAR mapped areas, but outside of the identified high, medium or low hazard bands.

3. Report and analysis of coastal inundation hazard bands

3.1. The following indicators will be provided both at State level and for each Local Government Area (LGA):

- The area (hectares) of land in each band.
- The number of vacant cadastral parcels in each band.
- The number of residential dwellings. The residential dwellings data is taken from LIST data services and is correct at the time publication for each 1:25 000 topographic maps.

3.2. This report

Input Datasets

Following is a brief description of the input datasets used in the mapping.

LiDAR DEM

The LiDAR dataset was supplied by the Information & Land Services Division (ILS) of the Department of Primary Industries, Parks, Water and Environment (DPIPWE). This dataset has been assembled from data provided from four sources and covers all main coastal urban areas. The DEM was provided as a gridded dataset with the individual grid cells 1 m x 1 m. Vertical accuracy was specified as within ±0.30m at 95% confidence interval.

Thick vegetation that obscures the ground surface can produce false LiDAR heights with an upward bias from the true ground surface. The height difference produced may be small but has the potential to be sufficient to have an effect on inundation modelling outcomes in some areas.

Tasmanian 25m DEM

The Tasmanian 2nd Edition 25 metre DEM (Information & Land Services Division, DPIPWE) was used in areas not covered by the LiDAR DEM. The 25 metre DEM has a floating point dataset and has been produced from 1:25,000 Series maps, primarily by interpolation between 10 metre contours. This interpolation method lends itself to errors in areas where contours are widely spaced such as low lying coastal areas. This DEM is, however, currently the best available alternative to the LiDAR DEM over coastal areas and can at least provide an indication of areas potentially subject to inundation due to sea level rise.

Tidal range data

Over the majority of the mapped area, the National Tidal Centre (NTC) modelled tidal range grid was used to determine the approximate high water mark. This was supplemented by additional published tidal height data for the Tamar Valley and Macquarie Harbour (Mount *et al* 2011).

The NTC tidal range data was obtained from the National Tidal Centre in the form of a five minute resolution grid of points including coverage of Tasmanian coastal waters.
The NTC tidal range is the height in metres between Mean Sea Level and Indian Springs Low Water multiplied by two to give an estimate of the complete tidal range. It includes the four main tidal constituents, M2, S2, O1 and K1, and was calculated as:

Tidal range = (M2 + S2 + O1 + K1) amplitude * 2

For inundation mapping purposes it was assumed that the midpoint in the NTC tidal range represents mean sea level (MSL) and that this height is also at zero metres AHD. Regional variations in tidal dynamics may mean that the midpoint in the range is not always MSL. Also MSL, although intended as the base datum of AHD, is only approximate due to errors in methods used to derive AHD. Sea level rise in the time since AHD was derived (1983) has also added an amount to MSL which will vary by region.

For the purposes of the current mapping, half the NTC tidal range was considered to represent an approximation of the difference between MSL and high tidal height, and when added to MSL the total height should approximate, though tend to be higher than, the height of the mapped coastal high water mark. In this report this height is referred to as “NTC High Water”.

The Average Recurrence Interval (ARI; same as return period) for Burnie, George Town and Hobart for both tidal predictions (i.e. tide only) and observations (tide + surge) for a level equal to "Indian Springs High Water" (ISHW, defined as Mean Sea Level plus the amplitudes of the tidal constituents: M2 + S2 + O1 + K1) were extracted and are presented in Table 1 below. The results are based on periods of approximately 30 years.

There is a lot of variation in the ARI, even around Tasmania and the inclusion of surges (i.e. within the observational data) has a significant effect. The main difference between the north (Burnie and George Town) and the south (Hobart) is that the main semidiurnal tide is much larger in the north, which reduces the influence of the other tidal constituents (including those not contributing to ISHW). Therefore, in the north, the ISHW is a better measure of the maximum possible tide whereas in the south, all the other constituents (not included in the definition of ISHW) make the highest tide significantly larger than ISHW. In the north, therefore, ISHW is exceeded much less often than in the south.

Table 1: Average Recurrence Intervals (ARI) for three Tasmanian port tide gauges – observed and predicted are for periods of approximately 30 years (Source: John Hunter, pers. comm.)

Port	ISHW (m, AHD)	Average Recurrence Interval (days)	
		Predictions (Tide only)	Observations (Tide plus surge)
Burnie	1.514	322	61
George Town	1.521	843	47
Hobart	0.658	39	21

However, when you include the effects of surges, the difference between north and south becomes less apparent. What this means is that it is appropriate to define the level chosen to be the base to which the sea level is added (i.e. labelled as the NTC modelled high water in this report) as “the sea level that is exceeded about every 1-2 months”. This base sea level is the combined effect of the tides and all other factors affecting the level of the sea such as the wind and air pressure. In colloquial terms, it could be thought of as the height found at the “back of the beach” or at the “height of the higher high tides”.

Note that tide ranges are complex phenomena and the modelling approach used by the NTC is not designed to precisely model tide ranges in estuaries and more enclosed embayments. Typically, though not always, tide ranges are reduced where the tidal wave passes through constrictions, such as estuary entrances, or over shallow water. In these circumstances, the inundation modelling will tend to overestimate the sea level as the tide range may not actually be as high as the NTC estimate.

Storm Tide AEP data

Modelled storm tide AEP predictions for the whole Tasmanian coast from the CSIRO (McInnes *et al.* 2009, McInnes *et al.* 2012) were used as the source dataset in the AEP calculations. In the Stage 2 project heights for AEPs of 0.005%, 0.05%, 0.5%, 1%, 2% and 5% were extracted from the modelled exceedance probability curves. These were then adjusted upwards by 0.07 metres in order to best fit the observed AEP heights in 2000 at tidal gauges of Hobart and Burnie. A further upwards adjustment of 0.03 metres was then added to allow for the estimated sea-level rise from 2000 to 2010, yielding AEP heights relevant to the base year of the Tasmanian sea-level rise allowances (2010).

In the Stage 3 project only the 1% AEP datasets were used. References to inundation heights for the other AEP percentages are retained in the Coastal Inundation Height References dataset.

Tasmanian Sea-Level Rise Allowances

The Tasmanian sea-level rise allowances for 2050, 2075 and 2100, relative to 2010 are 0.2, 0.4 and 0.8 metres, respectively. These are based on the technique of Hunter (2012), observations of storm tides from the tide gauges at Hobart and Burnie, and regional projections of sea-level rise based on the IPCC A1FI emission scenario (Hunter et al., 2012). These allowances were added to the AEPs for 2010, to derive AEPs appropriate to 2050, 2075 and 2100. It has been assumed that the change in AEPs over this time period is dominated by the effect of sea-level rise on mean sea level; future change in the variability of sea-level around the mean (e.g. due to an increase in storminess) is believed to be small and has been neglected (Hunter, 2012).

In the Stage 3 project only inundation heights for the years 2010, 2050 and 2100 were mapped. References to inundation heights for 2075 are retained in the Coastal Inundation Height References dataset.

Cadastral Parcels and Buildings

GIS datasets were provided which identified the positions of Tasmanian cadastral parcels and buildings, as of February 2012, in areas that may be at risk of flooding due to coastal inundation and sea level rise. This data was provided by DPaC in ESRI geodatabase format.

Local Government Areas

GIS datasets which identified the extent of Tasmanian Local Government Areas were ‘HSA_V2_1.gdb’ (from DPaC) and ‘munylwm.shp’ (originally sourced from ILS).

Coastal Inundation Extent Maps

Two mapping approaches were followed for the coastal inundation extent maps; these being an additive approach based on tidal heights and an approach based on storm tide annual exceedance probabilities. The two mapping approaches are discussed below separately under the headings "**Permanent Inundation and SLR**" and "**Storm Tide Event plus SLR**". The Coastal Inundation extent maps followed the format used in Stage 2a of the Coastal Inundation Mapping for Tasmania and differ from Stage 2 mapping in that inundation heights are rounded up to the nearest ten centimetres in LiDAR areas.

Permanent Inundation and SLR

The "**Permanent Inundation and SLR**" component of this mapping, used the "bathtub" inundation method (Eastman, 1993). The "bathtub" or "still water" method is essentially a simplified representation of reality generated with electronic mapping systems (GIS). The method assumes a calm still sea surface. The sea level components (including sea level rise levels and the tidal range) were combined with a digital elevation model (DEM) to calculate a spatial grid over the area of interest showing the locations likely to be inundated given the model settings and constraints. The positions of possible future, or "indicative", shorelines were extracted from the grid model. Given that the mapped coastline is usually at the high water mark and that most human activities are landwards of the high water mark, this was considered a useful base height to which to add the sea level rise estimates. The resultant "indicative" shorelines can be considered as new positions for the "back of the beach" in the simple virtual reality of the model.

Previous mapping presented in Stage 1 (Mount *et al*., 2011) followed a probability based approach in which error probability levels were also calculated based on the error probabilities propagated from the input datasets. This approach produced output datasets representing 5%, 50% and 95% likelihoods that a new shore position was at or above the mapped height based on error inputs. Algorithms used in this mapping approach have been documented in Mount *et al*. (2011). Mapping for Stages 2 and 3 was required at the 50% probability level only, meaning that a much simpler additive mapping approach could be applied. Consequently reference to the 50% probability level has been omitted and is assumed.

Inputs to this mapping can be summarised as follows:

- The LiDAR DEM or where that was not available the Tasmanian 25 metre DEM was substituted,
- The Mean Sea Level (MSL) is assumed to equal 0 m Australian Height Datum (AHD),
- Tide estimates (in metres AHD), based on the NTC High Water Mark (see Definitions section) for the majority of the mapped area or published tidal data for Tamar River and Macquarie Harbour, and
- A series of sea level rise heights, these being 0.0, 0.2 and 0.8 metres for the Stage 3 project.

The primary outputs were a series polygon datasets representing the most likely position of the shoreline with 0.0, 0.2 or 0.8 metre sea level rise allowance relative to 2010. Datasets were combined into a single polygon shapefile.

Geoprocessing implementation – "Permanent Inundation and SLR"

Polygon datasets were prepared separately for LiDAR and non-LiDAR areas and then combined into the final dataset. Geoprocessing was conducted using ArcGIS 10.2 with the majority of processing being scripted using Python 2.7. Methods are detailed below. For LiDAR areas the combined tidal inundation and sea level rise was rounded-up to the nearest ten centimetres. For the 25 metre DEM areas it was rounded-up to the nearest whole metre.

Modelled tidal range data was available as points around the whole Tasmanian coast. The modelled points were all on the seaward side of the coastline and usually did not extend to the coast, especially in the vicinity of bays and estuaries. A spline interpolation with barriers was used to create the tidal range surface extending across the land. In Macquarie Harbour the tidal height as published by Koehnken (1996) was used. For the Tamar region, mean high tide (MHT) heights were used as published by Foster *et al*. (1986) and interpolated using the spline with barriers method.

Sea level rise increments to the specified heights were added to the tidal heights to produce a series of inundation height surfaces. The inundation surfaces had a grid spacing of 1000 metres. Inundation surfaces were subtracted from the DEM and cells of the resultant inundated DEM surface with a value less than zero were designated as inundated. Outputs were converted to polygon shapefiles which showed areas expected to be inundated under the modelled scenarios. The polygon shapefiles were clipped to a polygon version of the coastline. LiDAR based and non-LiDAR based datasets were combined into a single state-wide dataset. A polygon mask, identifying location of LiDAR areas, was used to erase the same areas from the 25 metre DEM based outputs. LiDAR and 25 m DEM based datasets were then merged to produce the combined shapefile. Some minor editing was required to add in some of the Launceston flood levees (Fullard, 2013) which were too narrow to show up on the LiDAR DEM.

Output Dataset – "Permanent Inundation and SLR"

The output is a single combined polygon dataset representing the areas of permanent (tidal) inundation that can be expected for the years 2010, 2050 and 2100. Concentric polygon areas represent regions expected to be inundated by sea level rise of 0.0, 0.2 and 0.8 metre respectively above 2010 levels. The LiDAR DEM has been used as the height reference where it was available. The Tasmanian 25 metre DEM was used in all other areas. The sea level reference was the NTC modelled high water except is the Tamar Valley and Macquarie Harbour where alternative published mean high tide heights were used. Figure 1 shows an example of the Permanent Inundation zones.

The output dataset name is "**TidalInundationModel_RU_V4"** and is provided in file geodatabase (.gdb) format with the dataset having the same name as the geodatabase in which it is enclosed. The dataset is projected in GDA 94 MGA Zone 55. Attributes are listed in Table 2. Attribution has been included to allow selection of inundation polygons associated with each of the target years and also to distinguish between polygons that are contiguous or non-contiguous with the coast. Table 3 lists queries in ArcGIS that can be used to select contiguous or non-contiguous inundation polygon extents.

Table 2: Attribute fields for TidalInundationModel_RU_V4

Field Name	Data type	Details
TR2010	Text	"0.0 m" indicates inundation level in 2010.
TR2050	Text	"0.2 m" indicates projected inundation level in 2050.
TR2100	Text	"0.8 m" indicates projected inundation level in 2100.
IC2010	Integer	(1 = contiguous with coast; 0 = not contiguous with coast) at 0.0 m inundation.
IC2050	Integer	(1 = contiguous with coast; 0 = not contiguous with coast) at 0.2 m inundation.
IC2100	Integer	(1 = contiguous with coast; 0 = not contiguous with coast) at 0.8 m inundation.
SL_Ref	Text	NTC_HW (= NTC modelled high water), MHT (= Mean high tide in Tamar area), MHT Mac Hb (= mean high tide Macquarie Harbour)
SLR_Lev_RU	Text	Sea level rise level (in metres) in which the polygon appears "inundated".
DEM_Ref	Text	L2 (= LiDAR DEM), DEM25 (= State 25 m DEM) **Note: Inundation heights in the LiDAR areas are rounded up to the nearest whole ten centimetres and in 25 m DEM areas have been rounded up to the nearest whole metre.**
Shape_Length	Floating point	Polygon perimeter in metres.
Shape_Area	Floating point	Polygon area in square metres.

Table 3: ArcGIS queries for selection of inundation extents that are contiguous or not contiguous with the coast from the tidal inundation dataset

To select	Query
Polygons contiguous with the coast that are expected to be inundated in 2010.	"TR2010_RU" = '0 cm' AND "IC2010_RU " = 1
Polygons not contiguous but potentially inundation in 2010 under some circumstances.	"TR2010_RU " = '0 cm' AND "IC2010_RU " = 0
Polygons contiguous with the coast that are expected to be inundated in 2050.	"TR2050_RU " = '20 cm' AND "IC2050_RU " = 1
Polygons not contiguous but potentially inundation in 2050 under some circumstances.	"TR2050_RU " = '20 cm' AND "IC2050_RU " = 0
Polygons contiguous with the coast that are expected to be inundated in 2100.	"TR2100_RU " = '80 cm' AND "IC2100_RU " = 1
Polygons not contiguous but potentially inundation in 2100 under some circumstances.	"TR2100_RU " = '80 cm' AND "IC2100_RU " = 0

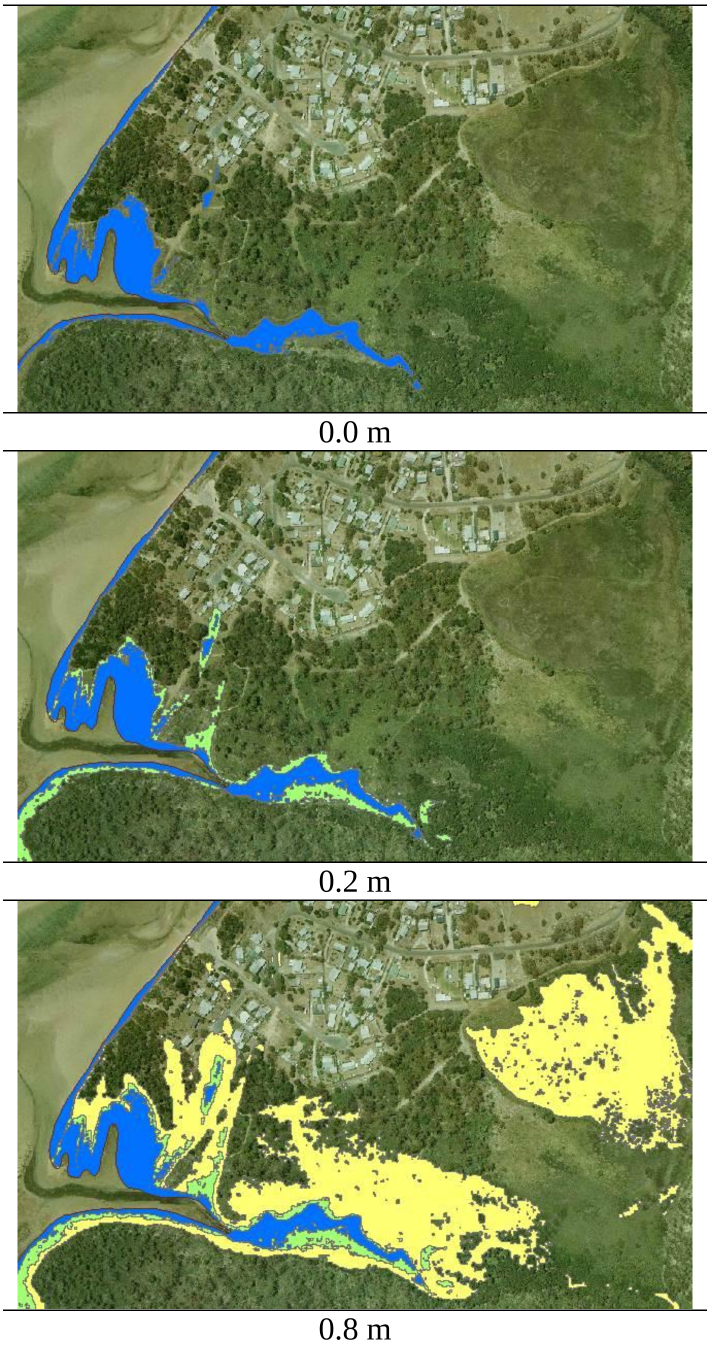


Figure 1. Example of sea level rise permanent inundation zones shown as a series of inundation “footprints” on a base map. The sea level heights shown are 0.0, 0.2 and 0.8 metres corresponding with tidal inundation heights rise for the years 2010, 2050 and 2100 shown as blue, green and yellow respectively. The inner, landward edge of each band is where the specified inundation height applies and any land seaward of that line has a higher probability of flooding. The 0.0 metre band can be counted as having already been inundated prior to inundation of the 0.2 metre band. The 0.2 metre band can be counted as having already been inundated prior to inundation of the 0.8 metre band. Inundation heights have been rounded-up to the nearest 10 cm. Note that some areas shown as inundated are not connected (non-contiguous) with the coast and therefore may not be directly inundated but may be affected by impaired drainage. The base map consists of an aerial photo. The mapped area is at Bellingham and is approximately 900 m across and north is up.

Discussion – "Permanent Inundation and SLR"

It should be noted that not all variables relevant to the accurate modelling and prediction of new shoreline positions are currently available for all the locations of interest around the coast, that is, there are limitations on the available data inputs at the Tasmanian scale. For example,

- The LiDAR DEM currently only covers the more highly populated coastlines.
- The lower resolution 25 metre DEM may give an indication only of potential coastline positions with sea level rise.
- The tide range data for Tasmania is limited to either direct observations at the main tide gauges or, for other locations along the shore, to modelled estimates from the National Tidal Centre, Bureau of Meteorology. The tides in more enclosed bays and estuaries or around islands can be substantially different to those shown in the available data.
- Also, there is no consideration of the complex interactions between erosion, coastal recession and inundation. The "bathtub" or "still water" method is essentially a passive model and assumes a calm sea surface. It is useful because it is a simple, fast method that indicates locations with the potential for inundation and can, if used judiciously and with other lines of evidence, assist with prioritising further activity.
- The IPCC projections of sea-level rise used in these calculations involve considerable uncertainty, arising from imperfect understanding both of the science and of the world's future emissions.

A recent study of tidal datasets for the Tamar region by Kidd *et al*., (2014) has highlighted some inconsistencies in published tidal data for that region and indicate that the mean high tide heights published by Foster *et al*. (1986) may be underestimated. Tidal heights for the Tamar region may need to be reviewed.

The Launceston flood levee has recently been upgraded to withstand flood heights of greater than 5 metres (Fullard, 2013).

Storm Tide Event plus SLR

In the absence of sea-level rise, future flooding events from the sea depend on the tides, storm surges and waves. While the tides are predictable, future storm surges and waves may only be described in a statistical sense. For example, the time and height of high water at a given location is known at any future time from our knowledge of past tides and of the motions of the Sun and the Moon. However, future storm surges are generally quantified by the average time between events when a certain level is exceeded (the "return period" or "average recurrence interval"), or by the probability that a certain level is exceeded once or more during a given period (e.g. the "Annual exceedance probability" or AEP). Similar statistics may be applied to the occurrence of waves, although the effects of waves are not specifically included in the projections provided here. For the present work, tides and storm surges ("storm tides") around the Tasmanian coastline were derived from numerical modelling by Kathleen McInnes of CSIRO. From these results were derived heights for AEPs of 0.005%, 0.05%, 0.5%, 1%, 2% and 5%. As described in the Section "Storm Tide AEP Data", the modelled AEP heights were adjusted to best fit observations from Hobart and Burnie, and to relate to the year 2010, the base year for the Tasmanian sea-level rise allowances.

Under climate change, flooding events from the sea will become more frequent, mainly due to the effect of sea-level rise. Future sea level has been estimated by numerous modelling groups around the world and is regularly collated and summarised by the Intergovernmental Panel on Climate Change (IPCC) in their Assessment Reports. These estimates are, however, accompanied by significant uncertainty (both due to uncertainty in the science and uncertainty in future emissions of greenhouse gases). The sea-level rise allowances used in this project have been supplied by the Tasmanian Government to create coastal inundation area maps to support the development of a coastal policy, and a coastal inundation planning code. These allowances are based on the technique of Hunter (2012), observations of storm tides from the tide gauges at Hobart and Burnie, and regional projections of sea-level rise based on the IPCC A1FI emission scenario (Hunter *et a*l., 2012).

The Tasmanian sea-level rise allowances (0.2, 0.4 and 0.8 metres for 2050, 2075 and 2100, relative to 2010, respectively) were then added to the modelled heights for 2010 for AEPs of 0.005%, 0.05%, 0.5%, 1%, 2% and 5%, to yield the 24 data sets of heights used for the inundation mapping in Stage 2 of the Coastal Inundation Mapping project. Only the 1% AEPs for the years 2010, 2050 and 2100 have been mapped in the Stage 3 project, however references to inundation heights for all of the above listed AEPs and years are retained in the Coastal Inundation Height References dataset.

Geoprocessing implementation – "Storm Tide Event plus SLR"

Three "Storm Tide Event plus SLR" height datasets representing the heights for 1% AEP each of the years (2010, 2050 and 2100) were geographically mapped. Each of the AEP height datasets represented calculated storm tide plus sea level rise exceedance heights for sea level rise scenarios as specified by the Tasmanian Government to create coastal inundation area maps to support the development of a coastal policy, and a coastal inundation planning code.

GIS processing was conducted using ArcGIS 10.2 with the majority of processing being scripted using Python 2.7. The main geoprocessing steps are summarised as follows.

A spline with barriers interpolation method was used to calculate a series of height surfaces, from a set of AEP datasets for the year 2000. Sea level rise heights of 0.03, 0.23 and 0.83 metre were added to the height surfaces to calculate AEP height surfaces for the years 2010, 2050 and 2100 respectively. These AEP height surfaces were used to create inundation surfaces with rounded-up inundation heights at a grid spacing of 1000 metres. For LiDAR areas the combined AEP inundation and sea level rise was rounded-up to the nearest 10 cm and in the 25 metre DEM areas it was rounded-up to the nearest whole metre. Inundation surfaces were subtracted from the LiDAR and 25m DEM surfaces and cells of the resultant surface with a value less than zero were designated as inundated. Outputs were converted to polygon shapefiles which showed areas expected to be inundated under the modelled scenarios. This polygonisation step used the "no_simplify" option. The polygon layers were then clipped to a polygon version of the coastline. LiDAR mapped regions were merged into a combined shapefile for each target year. A polygon mask, identifying location of LiDAR areas, was used to erase the same areas from the 25 metre DEM based outputs. LiDAR and 25 m DEM datasets were then merged to produce combined state-wide polygon shapefiles for each target year. Datasets were converted to geodatabase format to reduce file size and to speed up screen refresh times. Some minor editing was required to add in some of the Launceston flood levees which were too narrow to show up on the LiDAR DEM.

Output Datasets – "Storm Tide Annual Exceedance probabilities"

AEP datasets are listed in Table 4 and are provided in file geodatabase format with the dataset having the same name as the geodatabase in which it is enclosed. All of the datasets are projected in GDA 94 MGA Zone 55. Attributes of the datasets are listed in Table 5. An example of the Storm Tide AEP bands is shown in Figure 2.

Table 4: Storm Tide AEP RU V4 Datasets

Dataset Name	File geodatabase	Target Year	Projected sea level rise (m)
StormTide_AEP_RU_2010_V4	Storm_Tide_AEP_RU_2010_V4.gdb	2010	0
StormTide_AEP_RU_2050_V4	Storm_Tide_AEP_RU_2050_V4.gdb	2050	0.2
StormTide_AEP_RU_2100_V4	Storm_Tide_AEP_RU_2100_V4.gdb	2100	0.8

Table 5: Attributes of the Storm Tide AEP RU V4 Datasets

Field Name	Data type	Details
AEP1pct_RU	Text	"1%" indicates inundation at 1% AEP level.
IC1pct_RU	Integer	(1 = contiguous with coast; 0 = not contiguous with coast) at 1% AEP level.
AEP_Level	Text	First AEP level in which the polygon appears "inundated".
SLR	Text	Sea level rise for target year (2010, 0.0 m; 2050, 0.2 m; 2100, 0.8 m).
DEM_Ref	Text	L2 (= LiDAR DEM) DEM25 (= State 25 m DEM) **Note: Inundation heights in the LiDAR areas are rounded up to the nearest whole ten centimetres and in 25 m DEM areas have been rounded up to the nearest whole metre.**
Shape_Length	Floating point	Polygon perimeter in metres.
Shape_Area	Floating point	Polygon area in square metres.

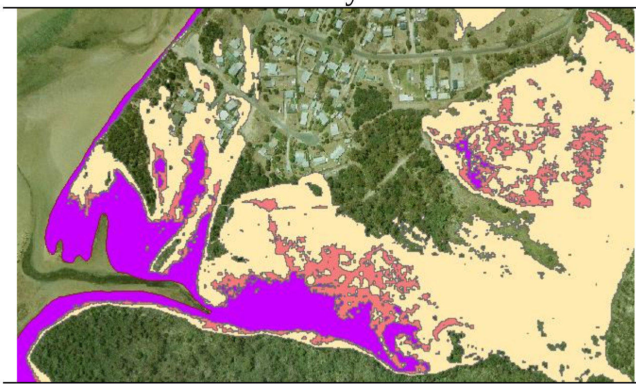
Attribution has been included to allow selection of inundation polygons associated with each of the target years and also to distinguish between polygons that are contiguous or non-contiguous with the coast. Table 6 lists queries in ArcGIS that can be used to select contiguous or non-contiguous inundation polygon extents for the AEP datasets.

Table 6: ArcGIS queries for selection of inundation extents that are contiguous or not contiguous with the coast from the AEP datasets

To select	Query
Polygons contiguous with the coast that are expected to be inundated at 1% AEP level.	"AEP1pct_RU" = '1%' AND "IC1pct_RU" = 1
Polygons not contiguous but potentially inundation at 1% AEP level under some circumstances.	"AEP1pct_RU" = '1%' AND "IC1pct_RU" = 0

1% AEP for year 2010

1% AEP for year 2050



1% AEP for year 2100

Figure 2. Example of storm tide inundation zones shown as a series of inundation “footprints” on a base map. The sea level heights shown corresponding with 1% AEP storm tide inundation heights for the years 2010, 2050 and 2100 mapped as purple, orange and pale orange respectively. The inner, landward edge of each band is where the respective exceedance probability applies and any land seaward of that line has a higher probability of flooding. Inundation heights have been rounded-up to the nearest 10 cm. Note that some areas shown as inundated are not connected (non-contiguous) with the coast and therefore would not be directly inundated but may be affected by impaired drainage. The base map consists of an aerial photo. The mapped area is at Bellingham and is approximately 900 m across and north is up.

Discussion – "Storm Tide Event plus SLR"

Note that the precise *landward extent* (i.e. edge or boundary) of the polygon represents the specified AEP for the prescribed year and the area within the remainder of the polygon has a higher exceedance probability.

For example, for a polygon with "AEP_Level" of 1% in the dataset StormTide_AEP_2100_V4_RU:

- Anything lying at ground level at the landward edge (or boundary) of the polygon ("flood plain") has an AEP of 1% of being flooded by a storm tide once or more during 2100,
- Any land *seaward* of this line (i.e. lying inside this flooding zone) has a *higher* probability of being flooded, and
- Any land *landward* of this line (i.e. lying outside this flooding zone) has a *lower* probability of being flooded.

A number of caveats accompany these results:

- These storm-tide coastal flooding zones include the effects of tides, storm surges and sea-level rise only. They do not include the effects of wave set-up or wave run-up. Additional allowances (known as "freeboard") may therefore need to be made for effects associated with waves.
- The IPCC projections of sea-level rise used in these calculations involve considerable uncertainty, arising from an imperfect understanding both of the science and of the world's future emissions.
- These results relate to the increase in the probability of extreme events caused by a rise in mean sea level; they do not include any projections based on changes in storm tides.

Coastal Inundation Hazard Maps

Maps showing High, Medium, Low and Investigation bands of coastal inundation likelihood were prepared using a protocol specified by DPaC. In LiDAR mapped areas the High, Medium and Low bands were based on the extent the following permanent and storm tide inundation scenarios.

- **High** (Currently vulnerable to coastal erosion and to future inundation hazard): Area vulnerable to highest astronomical tide now; and 0.2-metre sea level rise from the mean high tide by 2050 rounded up to the nearest 100 mm.

- **Medium** (Vulnerable to Coastal inundation and erosion by 2050): area vulnerable to a 1% AEP storm event in 2050 rounded up to the nearest 100mm plus 300 mm added for freeboard.

- **Low** (Vulnerable to Coastal inundation and erosion by 2100) Area vulnerable to a 1% AEP storm event in 2100 rounded up to the nearest 100mm plus 300 mm added for freeboard.

In addition, in those coastal areas outside of the LiDAR mapped areas a band defined as the **Coastal Inundation Investigation** band is the area extending to the coast below the 10 metre contour. Within this band no level of likelihood was assigned.

Geoprocessing implementation – "Coastal Inundation Hazard Maps"

Geoprocessing was conducted using ArcGIS 10.2. Inputs for the High, Medium and Low bands were prepared from Coastal Inundation Extent datasets or equivalently prepared data. The "Permanent Inundation" dataset for 2050 was the input dataset for the High scenario. Inputs with a 300 mm freeboard allowance (Medium and Low) were prepared in the same way as the corresponding Storm Tide Event plus SLR datasets except that an additional 300 mm was added to the combined AEP inundation and sea level rise heights before this was subtracted from the DEM height surfaces.

Inundation polygons which were not-contiguous with the coast were removed from the LiDAR sourced 'high', 'medium' and 'low' datasets before these datasets were spatially unioned (combined). Small polygons, with an area less than 5 square metres, were removed by converting them to the same band category as the surrounding polygons. The dataset was then simplified using the ArcGIS Simplify Polygon tool with the bend simplify option, 2.4 metre minimum curve length and topology correction. The resulting hazard map for LiDAR areas was then combined with a polygon representation of a band extending between the 10 metre contour and the coast using a combination of erase and merge steps. The Identity tool was used to extract attributes from the 'Tasmania_Coastal_Heights_Ref_V3_4' dataset. Additional attribute fields were added and calculated.

Output Dataset – Coastal Inundation Hazard V2_1

The dataset **"Coastal_Inundation_Hazard_V2_1"** is provided in ESRI file geodatabase **"Coastal_Inundation_Hazard_V2_1.gdb"**. Attributes are listed in Table 7. The dataset is projected in GDA 94 MGA Zone 55 and heights are in metres AHD. An example of the Coastal Inundation Hazard bands is shown in Figure 3. As mapped, the bands do not overlap and the area within each band is counted at the hazard level in which it is first inundated.

Table 7: Attribute of Coastal_Inundation_Hazard_V2_1

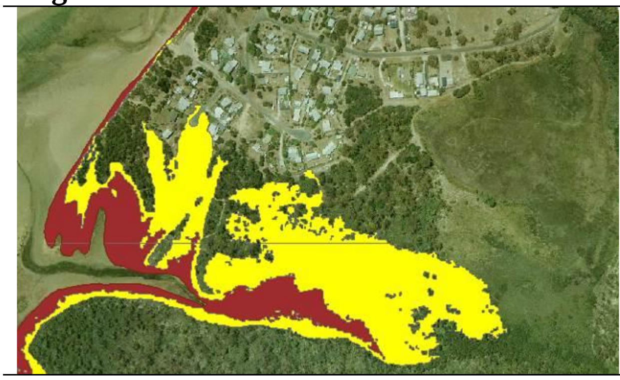
Field Name	Details
Disclaimer_Part_1	"Hazard Planning Maps produced by the Department of Premier and Cabinet (this map being such a map) are produced and released for the purpose of informing actions taken and decisions made by local or state government under relevant provisions of the"
Disclaimer_Part_2	"Land Use Planning and Approvals Act 1993 and Building Act 2000. Whilst every care has been taken to prepare this map, the Government of Tasmania makes no representations or warranties about its accuracy, reliability, completeness or suitability for"
Disclaimer_Part_3	"any particular purpose other than its intended purpose. Hazard bands as depicted in this map may not accurately represent the existence or otherwise of hazards in the mapped area."
Disclaimer_Part_4	"Independent expert advice should be sought if action is to be taken that may be impacted by the existence or otherwise of hazards in the mapped area."
Hazard_Band	"High", "Medium", "Low" or "Investigation"
Hazard_Exposure	If "Hazard_Band"="High", "This area is vulnerable to the highest astronomical tide now, and to a 0.2 metre sea level rise from the mean high tide by 2050." If "Hazard_Band"="Medium", "This area is vulnerable to a 1% AEP storm event in 2050 and a 0.8m sea level rise by 2100." If "Hazard_Band"="Low", "This area is vulnerable to a 1% AEP storm event in 2100." If "Hazard_Band"="Investigation", "This area is outside the LiDAR-mapped area and as it is below the mapped 10 m contour may be partly vulnerable to sea level rise but data used for this analysis were not sufficient to further determine potential inundated areas."
Height_High	Inundation height in metres for the "High" scenario. Calculated as = INT((TR_20SLR +0.1)*10)/10
Height_Medium	Inundation height in metres for the "Medium" scenario. Calculated as =(INT((AEP1pct_2050 +0.1)*10)/10)+0.3
Height_Low	Inundation height in metres for the "Low" scenario. Calculated as =(INT((AEP1pct_2100 +0.1)*10)/10)+0.3
LL_Pos_EN	Tile lower left eastings and northings in kilometres, (eg. e473_n5448).
Easting	Tile centre easting in metres (MGA zone 55)
Northing	Tile centre northing in metres (MGA zone 55)
Base_Ht	Interpolated reference high water mark height at the centre of tile. In most cases this will be based on NTC tide range. See note 1.
Base_Ht_Ref	Source of height reference used in tile (NTC TR, NTC tide range; MHT Mac Hb, mean high tide for Macquarie Harbour; MHT Tamar, mean high tide Tamar).
TR_0SLR	Modelled inundation height for tile with 0 sea level rise at 50% probability level.
TR_10SLR	Modelled inundation height for tile with 10 cm sea level rise at 50% probability level.
TR_20SLR	Modelled inundation height for tile with 20 cm sea level rise at 50% probability level.
TR_30SLR	Modelled inundation height for tile with 30 cm sea level rise at 50% probability level.
TR_40SLR	Modelled inundation height for tile with 40 cm sea level rise at 50% probability level.
TR_50SLR	Modelled inundation height for tile with 50 cm sea level rise at 50% probability level.
TR_60SLR	Modelled inundation height for tile with 60 cm sea level rise at 50% probability level.
TR_70SLR	Modelled inundation height for tile with 70 cm sea level rise at 50% probability level.
TR_80SLR	Modelled inundation height for tile with 80 cm sea level rise at 50% probability level.
TR_90SLR	Modelled inundation height for tile with 90 cm sea level rise at 50% probability level.
TR_100SLR	Modelled inundation height for tile with 100 cm sea level rise at 50% probability level.
TR_110SLR	Modelled inundation height for tile with 110 cm sea level rise at 50% probability level.
TR_120SLR	Modelled inundation height for tile with 120 cm sea level rise at 50% probability level.
HAT	Modelled Highest Astronomic Tide from NTC. This data is included for reference and has not been used in tide height calculations. "-999" = No data. See Note 2.
Local_Storm_Surge	Local storm surge if known.
Wave_Setup	Wave setup if known.
Wave_Runup	Wave runup if known.
AEP_005pct2010	Modelled 0.005% Annual Exceedance Probability height for 2010.
AEP_05pct2010	Modelled 0.05% Annual Exceedance Probability height for 2010.
AEP_5pct2010	Modelled 0.5% Annual Exceedance Probability height for 2010.

AEP1pct2010	Modelled 1% Annual Exceedance Probability height for 2010.
AEP2pct2010	Modelled 2% Annual Exceedance Probability height for 2010.
AEP5pct2010	Modelled 5% Annual Exceedance Probability height for 2010.
AEP_005pct2050	Modelled 0.005% Annual Exceedance Probability height for 2050.
AEP_05pct2050	Modelled 0.05% Annual Exceedance Probability height for 2050.
AEP_5pct2050	Modelled 0.5% Annual Exceedance Probability height for 2050.
AEP1pct2050	Modelled 1% Annual Exceedance Probability height for 2050.
AEP2pct2050	Modelled 2% Annual Exceedance Probability height for 2050.
AEP5pct2050	Modelled 5% Annual Exceedance Probability height for 2050.
AEP_005pct2075	Modelled 0.005% Annual Exceedance Probability height for 2075.
AEP_05pct2075	Modelled 0.05% Annual Exceedance Probability height for 2075.
AEP_5pct2075	Modelled 0.5% Annual Exceedance Probability height for 2075.
AEP1pct2075	Modelled 1% Annual Exceedance Probability height for 2075.
AEP2pct2075	Modelled 2% Annual Exceedance Probability height for 2075.
AEP5pct2075	Modelled 5% Annual Exceedance Probability height for 2075.
AEP_005pct2100	Modelled 0.005% Annual Exceedance Probability height for 2100.
AEP_05pct2100	Modelled 0.05% Annual Exceedance Probability height for 2100.
AEP_5pct2100	Modelled 0.5% Annual Exceedance Probability height for 2100.
AEP1pct2100	Modelled 1% Annual Exceedance Probability height for 2100.
AEP2pct2100	Modelled 2% Annual Exceedance Probability height for 2100.
AEP5pct2100	Modelled 5% Annual Exceedance Probability height for 2100.
Shape_Length	Tile perimeter length in metres
Shape_Area	Tile area in square metres

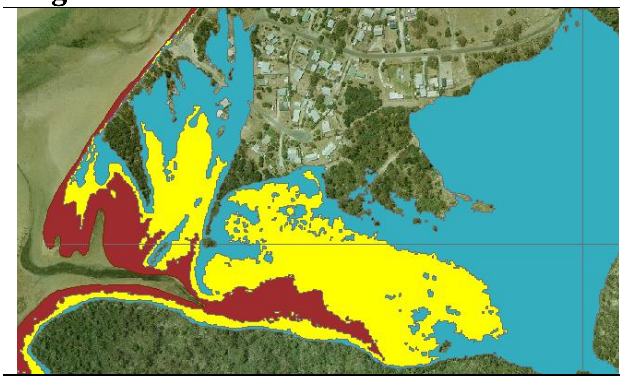
Note 1
In most cases the reference height if from the National Tidal Centre modelled tidal range grid (i.e. "NTC High Water"). For the Tamar region, mean high tide (MHT) heights were used as published by Foster *et al*. (1986). Base height in Macquarie Harbour is from Koehnken (1996). Figures are a best estimate based on the input data but may not reflect actual conditions, particularly in rivers and estuaries, and require verification.

Note 2
Modelled HAT (Highest Astronomic Tide) has been included for reference and has not been used in tide height calculations. Interpolated values for rivers and estuaries are approximate and should only be used in those areas with caution. Values for locations inland from the open coast have been designated "no_data" and have been given a value of "-999".

High band



High and Medium bands



High, Medium and Low bands

Figure 3. Example of coastal inundation hazard bands shown as a series of inundation “footprints” on a base map. High, Medium and Low bands are shown as red, yellow and blue respectively. The inner, landward edge of each band is where the specified inundation probability applies and any land seaward of that line has a higher probability of flooding. The High band can be counted as having already been inundated prior to inundation of the Medium band. The Medium band can be counted as having already been inundated prior to inundation of the Low band. Inundation heights have been rounded-up to the nearest 10 cm. Not shown is the Investigation band which is used in non-LiDAR areas only. The base map consists of an aerial photo. The mapped area is at Bellingham and is approximately 900 m across and north is up.

Analysis of the Coastal Inundation Hazard Bands

Numbers of residential buildings, numbers of vacant private cadastral parcels and areas of all cadastral parcels within the Coastal Inundation Hazard bands were determined for the State and for each LGA.

Cadastral and LGA datasets were combined with the Coastal Inundation Hazard Map using a series of spatial union and identity steps to bring together the attributes of the input datasets. Attribute tables were then exported and opened in Microsoft Access. A series of database queries were used to select the required data which are presented in Tables 8 to 10.

Data tables with a larger selection of attributes have also been prepared in Excel format for DPaC to conduct further analysis. These were first processed in Access then exported to Excel format.

Table 8: The area (hectares) of land in each Hazard Band, listed by LGA

LGA Name	Hazard Band				Total for High, Medium and Low bands	Overall Total
	High	Medium[1]	Low[2]	Investigation		
King Island	1	2	3	5957	6	5963
Hobart	1	13	32	0	46	46
Burnie	8	16	24	0	48	48
Glenorchy	6	21	27	0	54	53
West Coast	19	42	38	15502	99	15602
Waratah-Wynyard	28	33	46	235	107	342
Devonport	72	39	32	0	143	143
Brighton	45	131	21	0	197	197
Flinders	37	124	37	59983	198	60182
Derwent Valley	47	154	33	0	234	234
George Town	76	88	77	633	241	874
Dorset	161	77	80	15200	318	15518
Central Coast	222	127	140	0	489	489
Sorell	298	223	120	178	641	820
Kingborough	91	430	172	1432	693	2126
Break O'Day	180	346	241	3667	767	4434
Tasman	176	444	175	904	795	1700
Latrobe	420	241	175	1	836	838
Launceston	366	433	98	0	897	897
Huon Valley	638	322	150	11399	1110	12509
West Tamar	442	625	272	0	1339	1339
Clarence	367	628	568	4	1563	1567
Glamorgan-Spring Bay	1800	827	612	5343	3239	8582
Circular Head	970	2029	1503	14395	4502	18897
State Total	**6475**	**7415**	**4677**	**134834**	**18562**	**153402**

[1] Excluding areas already counted for the High band.
[2] Excluding areas already counted for the High and Medium bands.

Table 9: Numbers of vacant private cadastral parcels with an area less than 2000 square metres and with more than 10% of their area within the hazard bands, listed by LGA [1]

LGA Name	Hazard Band				Total for High, Medium and Low bands	Overall Total
	High	Medium[2]	Low[3]	Investigation		
Glenorchy	0	0	0	0	0	0
King Island	0	0	0	42	0	42
Circular Head	0	0	1	1	1	2
Derwent Valley	1	0	0	0	1	1
Dorset	0	0	1	1	1	2
Flinders	0	0	1	5	1	6
Launceston	0	0	1	0	1	1
Brighton	0	1	1	0	2	2
Burnie	0	0	2	0	2	2
Devonport	0	0	3	0	3	3
Waratah-Wynyard	0	0	3	0	3	3
Hobart	0	0	6	0	6	6
George Town	5	0	3	0	8	8
Break O'Day	2	0	7	14	9	23
Tasman	0	0	10	0	10	10
West Tamar	1	5	7	0	13	13
Glamorgan-Spring Bay	0	0	18	14	18	32
Kingborough	1	1	16	6	18	24
Sorell	3	3	13	0	19	19
West Coast	2	4	15	4	21	25
Central Coast	1	0	25	0	26	26
Huon Valley	5	4	18	0	27	27
Clarence	3	15	14	0	32	32
Latrobe	1	11	26	0	38	38
State Total	**25**	**44**	**191**	**87**	**260**	**347**

[1] Where the parcel intersected more than one band, the band with the greatest intersecting area is counted.
[2] Does not include parcels already counted for the High band.
[3] Does not include parcels already counted for the High and Medium bands.

Table 10: Number of individual buildings with 'BUILD_TYPE' = 'Residential', listed by LGA.

LGA Name	Hazard Band				Total for High, Medium and Low bands	Overall Total
	High	Medium[1]	Low[2]	Investigation		
King Island	0	0	0	34	0	34
Launceston	0	0	0	0	0	0
Dorset	0	0	2	0	2	2
Burnie	0	1	3	0	4	4
Derwent Valley	0	5	3	0	8	8
Flinders	0	5	11	104	16	120
Tasman	0	7	12	3	19	22
Glenorchy	0	2	19	0	21	21
Waratah-Wynyard	0	5	20	0	25	25
Brighton	0	2	27	0	29	29
Circular Head	0	8	22	1	30	31
Devonport	0	0	43	0	43	43
George Town	1	14	34	0	49	49
Break O'Day	0	29	22	22	51	73
Sorell	0	27	25	0	52	52
Hobart	0	12	42	0	54	54
Glamorgan-Spring Bay	0	29	85	34	114	148
Kingborough	0	38	81	46	119	165
West Coast	0	50	81	22	131	153
West Tamar	0	53	80	0	133	133
Huon Valley	0	81	87	72	168	240
Latrobe	0	88	184	0	272	272
Central Coast	0	62	249	0	311	311
Clarence	0	273	206	3	479	482
State Total	**1**	**791**	**1338**	**341**	**2130**	**2471**

[1] Does not include buildings already counted for the High band.
[2] Does not include buildings already counted for the High and Medium bands.

Coastal Inundation Height Reference Dataset Version 3.4

Version 3.4 corrects an error in the "Base_Ht" attribute for the Tamar region where it incorrectly differed from the "TR_0SLR" attribute in Version 3.3. In all other respects the dataset remains the same as Version 3.3.

The approach for this dataset was to utilise all the input calculations to the SLR mapping presented in the Stage 2 mapping and instead of mapping those on a DEM, the results were stored in the form of 1 kilometre square grid tiles implemented as a GIS polygon vector layer. The "**Tasmania_Coastal_Heights_Ref_V3_4**" tiles consist of square polygons covering the whole of the Tasmanian shoreline inland from the coast to at least the 10 m contour. See the example in Figure 4 below.

The "**permanent sea level rise**" inundation heights are based on the tide range calculations plus added sea level rise in steps of 0.1 metre up to 1.2 metre. The calculated reference inundation heights are relative to the Australian Height Datum (AHD) at the centre of individual 1 km tiles.
In most cases the reference height if from the National Tidal Centre modelled tidal range grid (i.e. "NTC High Water"). For the Tamar region, mean high water (MHW) heights were used as published by Foster *et al*. (1986). Base height in Macquarie Harbour is from Koehnken (1996). Figures are a best estimate based on the input data but may not reflect actual conditions, particularly in rivers and estuaries, and require verification. Attributes of this geodatabase are listed in Table 11 below.

The "**storm tide AEP plus sea level rise**" heights are for AEP heights for AEP percentages of 0.005%, 0.05%, 0.5%, 1%, 2% and 5% for the years 2010, 2050, 2075 and 2100 as listed in Table 11 below. Heights are relative to AHD.

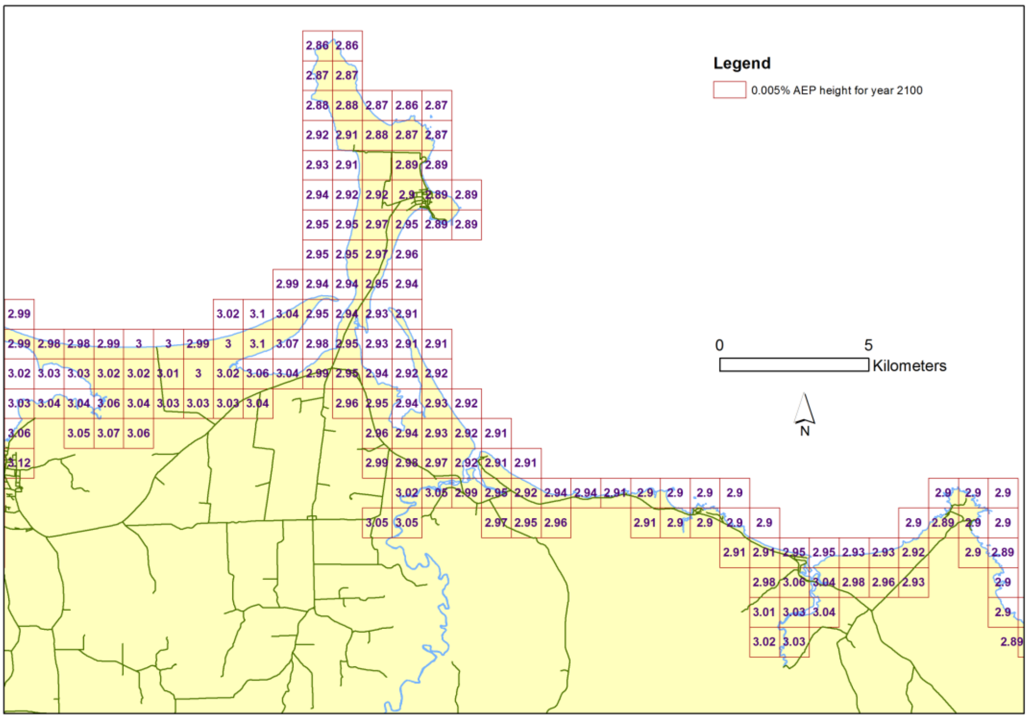


Figure 4. Example of the 1 km tiles showing the calculated 0.005% AEP height in metres for the year 2100. Note the change in the heights across the area is generally small between adjacent tiles but is more significant across larger distances.

The Coastal Inundation Height Reference dataset also includes the following attributes:

HAT (Highest Astronomical Tide). This is the highest tide that may be expected under normal meteorological conditions. Data was obtained from NTC in the form of a 5 minute grid of points. A spline-with-barriers interpolation was used to interpolate this data to the Tasmanian coast. This data was not interpolated into estuaries or rivers or otherwise inland of the coast and has been provided as an additional reference to tidal heights.

Local Storm Surge, Wave Setup and Wave Runup. Attributes have been included for these factors. The concept of "local" storm surge depends on scale and is somewhat arbitrary. The storm-tide modelling of McInnes *et al*. (2012) (used to estimate the heights for each AEP) had a resolution of about 100 metres; all surges of a scale larger than this are therefore included in the AEP heights and only surges of scale around 100 metres or less are not included (we have no information on such small-scale surges). Also, wave setup and wave runup was not included in the storm tide modelling. Therefore, no data was available on these factors and they have been designated "unknown".

Output Dataset – Coastal Inundation Height Reference

The dataset **"TasHeightsRefV3_4"** is provided in ESRI geodatabase **"Tasmania_Coastal_Heights_Ref_V3_4.mdb"**. Attributes are listed in Table 11. The dataset is projected in GDA 94 MGA Zone 55 and heights are in metres AHD.

Table 11: Attribute of Height Reference layer V3.4

Field Name	**Details**
LL_Pos_EN	Tile lower left eastings and northings in kilometres, (eg. e473_n5448).
Easting	Tile centre easting in metres (MGA zone 55)
Northing	Tile centre northing in metres (MGA zone 55)
Base_Ht	Interpolated reference high water mark height at the centre of tile. In most cases this will be based on NTC tide range. See note 1.
Base_Ht_Ref	Source of height reference used in tile (NTC TR, NTC tide range; MHT Mac Hb, mean high tide for Macquarie Harbour; MHT Tamar, mean high tide Tamar).
TR_0SLR	Modelled inundation height for tile with 0 sea level rise at 50% probability level.
TR_10SLR	Modelled inundation height for tile with 10 cm sea level rise at 50% probability level.
TR_20SLR	Modelled inundation height for tile with 20 cm sea level rise at 50% probability level.
TR_30SLR	Modelled inundation height for tile with 30 cm sea level rise at 50% probability level.
TR_40SLR	Modelled inundation height for tile with 40 cm sea level rise at 50% probability level.
TR_50SLR	Modelled inundation height for tile with 50 cm sea level rise at 50% probability level.
TR_60SLR	Modelled inundation height for tile with 60 cm sea level rise at 50% probability level.
TR_70SLR	Modelled inundation height for tile with 70 cm sea level rise at 50% probability level.
TR_80SLR	Modelled inundation height for tile with 80 cm sea level rise at 50% probability level.
TR_90SLR	Modelled inundation height for tile with 90 cm sea level rise at 50% probability level.
TR_100SLR	Modelled inundation height for tile with 100 cm sea level rise at 50% probability level.
TR_110SLR	Modelled inundation height for tile with 110 cm sea level rise at 50% probability level.
TR_120SLR	Modelled inundation height for tile with 120 cm sea level rise at 50% probability level.
HAT	Modelled Highest Astronomic Tide from NTC. This data is included for reference and has not been used in tide height calculations. "-999" = No data. See Note 2.
Local_Storm_Surge	Local storm surge if known.
Wave_Setup	Wave setup if known.
Wave_Runup	Wave runup if known.
AEP_005pct2010	Modelled 0.005% Annual Exceedance Probability height for 2010.
AEP_05pct2010	Modelled 0.05% Annual Exceedance Probability height for 2010.
AEP_5pct2010	Modelled 0.5% Annual Exceedance Probability height for 2010.
AEP1pct2010	Modelled 1% Annual Exceedance Probability height for 2010.
AEP2pct2010	Modelled 2% Annual Exceedance Probability height for 2010.
AEP5pct2010	Modelled 5% Annual Exceedance Probability height for 2010.
AEP_005pct2050	Modelled 0.005% Annual Exceedance Probability height for 2050.
AEP_05pct2050	Modelled 0.05% Annual Exceedance Probability height for 2050.
AEP_5pct2050	Modelled 0.5% Annual Exceedance Probability height for 2050.

AEP1pct2050	Modelled 1% Annual Exceedance Probability height for 2050.
AEP2pct2050	Modelled 2% Annual Exceedance Probability height for 2050.
AEP5pct2050	Modelled 5% Annual Exceedance Probability height for 2050.
AEP_005pct2075	Modelled 0.005% Annual Exceedance Probability height for 2075.
AEP_05pct2075	Modelled 0.05% Annual Exceedance Probability height for 2075.
AEP_5pct2075	Modelled 0.5% Annual Exceedance Probability height for 2075.
AEP1pct2075	Modelled 1% Annual Exceedance Probability height for 2075.
AEP2pct2075	Modelled 2% Annual Exceedance Probability height for 2075.
AEP5pct2075	Modelled 5% Annual Exceedance Probability height for 2075.
AEP_005pct2100	Modelled 0.005% Annual Exceedance Probability height for 2100.
AEP_05pct2100	Modelled 0.05% Annual Exceedance Probability height for 2100.
AEP_5pct2100	Modelled 0.5% Annual Exceedance Probability height for 2100.
AEP1pct2100	Modelled 1% Annual Exceedance Probability height for 2100.
AEP2pct2100	Modelled 2% Annual Exceedance Probability height for 2100.
AEP5pct2100	Modelled 5% Annual Exceedance Probability height for 2100.
Shape_Length	Tile perimeter length in metres
Shape_Area	Tile area in square metres

Note 1
In most cases the reference height if from the National Tidal Centre modelled tidal range grid (i.e. “NTC High Water”). For the Tamar region, mean high tide (MHT) heights were used as published by Foster *et al*. (1986). Base height in Macquarie Harbour is from Koehnken (1996). Figures are a best estimate based on the input data but may not reflect actual conditions, particularly in rivers and estuaries, and require verification.

Note 2
Modelled HAT (Highest Astronomic Tide) has been included for reference and has not been used in tide height calculations. Interpolated values for rivers and estuaries are approximate and should only be used in those areas with caution. Values for locations inland from the open coast have been designated “no_data” and have been given a value of “-999”.

Discussion – Coastal Inundation Height Reference

The “**Coastal Inundation Height Reference**” tiles can be used to identify the heights of the water surfaces calculated for the listed inundation and AEP scenarios. Heights were calculated without rounding-up.

The data set is intended as a way of looking up threshold or trigger heights for parcels of land that fall either partly or entirely with any particular tile. For example,

- if a parcel of land does fall partly or entirely within the boundaries of a particular tile
    - AND
- if a particular height was designated by an appropriate authority to require (i.e. trigger) further action,
    - AND
- the parcel of land was found to be entirely or partially below that reference height
    - THEN
- the required action would be triggered.

Important note: As these reference heights have NOT been mapped onto the ground, this data set does NOT show mapped areas of land that are likely to be subject to inundation.

The Coastal Inundation Height Reference”, has some limitations that should be acknowledged:

- The tide range data for Tasmania is limited to either direct observations at the main tide gauges or, for other locations along the shore, to modelled estimates from the National Tidal Centre, Bureau of Meteorology. The tides in more enclosed bays and estuaries or around islands can be substantially different to those shown in the available data. The Height Reference tiles may cover places with tidal ranges different to those used to calculate the tile heights. If this is the case, then the calculated heights may not reflect actual heights experienced at the shore.

- A single Height Reference tile may cover places with different tidal ranges and the calculated heights may not reflect actual heights experienced at the shore in one or more of those places.
- The IPCC projections of sea-level rise used in these calculations involve considerable uncertainty, arising from imperfect understanding both of the science and of the world's future emissions.
- These results relate to the increase in the probability of extreme events caused by a rise in mean sea level; they do not include any projections based on changes in storm tides.

References

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Hunter, J.R., Church, J.A., White, N.J. and Zhang, X,, (2013). Towards a global regionally-varying allowance for sea-level rise , Ocean Engineering, 71 (1) 17-27.

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McInnes, K.L., O'Grady, J.G., Hemer, M., Macadam, I., Abbs, D.J., White, C.J., Bennett, J.C., Corney, S.P., Holz, G.K., Grose, M.R., Gaynor, S.M. and Bindoff, N.L. (2012), Climate Futures for Tasmania: extreme tide and sea level events technical report, Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart, Tasmania.

Mount, R.E., Lacey, M.J. and Hunter, J.R. (2010) Tasmanian Coastal Inundation Mapping Project Report Version 1.2, prepared for Tasmanian Planning Commission.

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Appendix 1. Draft Metadata

Coastal High Water plus Sea Level Rise Inundation Modelling metadata – Tasmania, Version 4

Draft metadata prepared by Dr Michael Lacey, University of Tasmania 12th January 2015.

General Properties	
File Identifier	
Hierarchy Level	series
Hierarchy Level Name	series
Standard Name	ANZLIC Metadata Profile: An Australian/New Zealand Profile of AS/NZS ISO 19115:2005, Geographic information - Metadata
Standard Version	1.1
Date Stamp	2015-01-12
Resource Title	Coastal High Water plus Sea Level Rise Inundation Model – Tas., Version 4
Other Resource Details	M.J. Lacey, J.R. Hunter and R.E. Mount (2015) Coastal Inundation Mapping for Tasmania – Stage 3. Report to the Department of Premier and Cabinet by the University of Tasmania and the Antarctic Climate and Ecosystems Cooperative Research Centre
Key Dates and Languages	
Date of creation	2015-01
Date of publication	2015-01
Metadata Language	eng
Metadata Character Set	utf8
Dataset Languages	eng
Dataset Character Set	utf8
Abstract	A digital dataset that represents modelled potential inundation effects of a set of combined sea level rise and high tide scenarios for coastal areas of Tasmania and adjoining land regions within the extent of a coastal LiDAR DEM or alternatively the Tasmanian 25 metre DEM where the LiDAR DEM was not available. Sea level rise scenarios include 0.0, 0.2 and 0.8 metres above 2010 level. At each sea level rise scenario high water modelling is based on modelled tide range data provided by the National Tidal Centre. Some extrapolation of input data was required to extend tide data into the Tamar Estuary. Inundation heights have been rounded-up to the nearest 0.01 metre in LiDAR areas and nearest metre in non-LiDAR areas.
Purpose	This dataset was prepared to assist in the identification of regions that may be subject to the effects of sea level rise such as coastal flooding.
Metadata Contact Information	
Name of Individual	Name withheld
Organisation Name	
Position Name	
Role	author
Voice	
Facsimile	
Email Address	
Address	 Australia
Resource Contacts	
Name of Individual	

Organisation Name	
Position Name	
Role	pointOfContact
Voice	
Facsimile	
Email Address	
Address	 Australia
Lineage Statement	Inputs: Digital Elevation Models LIDAR information as supplied via the Information & Land Services Division (ILS) of the Department of Primary Industries, Parks, Water and Environment (DPIPWE) or the Land Information System Tasmania (LIST), November 2014. Tasmanian 25 metre DEM (second edition) as supplied via the Information & Land Services Division (ILS) of the Department of Primary Industries, Parks, Water and Environment (DPIPWE) or the Land Information System Tasmania (LIST) SLR The sea level rise allowances are based on regional sea-level projections and the A1FI emission scenario. The allowances used in this dataset have been supplied by the Tasmanian Government to create coastal inundation area maps to support the development of a coastal policy, and a coastal inundation planning code. Tidal Range Tidal range modelled data was obtained from the National Tidal Centre (NTC) in the form of a five minute resolution grid of points extending from longitude 111º to 116º East and from latitude 9º to 45º South. This model represents tidal amplitudes in metres between Mean Sea Level and Indian Spring Low Water multiplied by two to give an estimate of the complete tidal range. It includes the four main tidal constituents, M2, S2, O1 and K1, and was calculated as: Tidal amplitude = (M2 + S2 + O1 + K1) amplitudes * 2 The NTC tide range grid needed to be extrapolated to extend into Boullanger Bay and Robbins Passage. This extrapolation incorporated tidal heights for Welcome Inlet and Robbins Passage as published by Donaldson *et al*. (2012). Mean High Water was used for the Tamar Estuary south of 5446000 metres MGA Zone 55 as sourced from Foster *et al*. (1986). A height surface was generated using a spline with barriers interpolation from heights at nine locations along the estuary. For Macquarie Harbour MHW height was used as published by Koehnken (1996). Mapping Treatments This version is based on modelled heights used in Version 2, with heights rounded up to the nearest 10 cm before mapping. Inundation Modelling Method: Inundation modelling used the “bathtub” inundation method (Eastman, 1993). Three coastal high water plus-SLR height datasets representing the specified tidal and sea level rise heights with specified rounding adjustments were geographically mapped. GIS processing was conducted using ESRI ArcGIS 10.2 with the majority of processing being scripted using Python 2.7. The main geoprocessing steps are summarised as follows. A spline with barriers interpolation method was used to calculate a series of height surfaces from the tidal datasets Sea level rise heights of 0.00, 0.20 and 0.80 metre were added to the height surfaces to calculate tidal height surfaces for the years 2010, 2050 and 2100 respectively. For LiDAR areas

the combined tidal inundation and sea level rise was rounded-up to the nearest ten centimetres and in 25 metre DEM areas rounded-up to the nearest whole metre. The inundation surfaces had a grid spacing of 1000 metre. Inundation height surfaces were subtracted from the LiDAR and 25m DEM surfaces and cells of the resultant surface with a value less than zero were designated as inundated. Outputs were converted to polygon shapefiles which showed areas expected to be inundated under the modelled scenarios. This polygonisation step used the "no_simplify" option. The polygon layers were then clipped to a polygon version of the coastline. LiDAR based and non-LiDAR based datasets were combined into a single state-wide dataset. A polygon mask, identifying location of LiDAR areas, was used to erase the same areas from the 25 metre DEM based outputs. LiDAR and 25 m DEM based datasets were then merged to produce the combined shapefile. Some minor editing was required to add in some of the Launceston flood levees which were too narrow to show up on the LiDAR DEM.

The output is a single combined polygon dataset representing the areas of permanent (tidal) inundation that can be expected for the years 2010, 2050 and 2100. Concentric polygon areas represent regions expected to be inundated by sea level rise of 0.0, 0.2 and 0.8 metre respectively above 2010 levels. The dataset name is "TidalInundationModel_RU_V4" and is provided in file geodatabase (.gdb) format with the dataset having the same name as the geodatabase in which it is enclosed.

Attributes of the TidalInundationModel RU V4 Dataset:

Attribute	Details
TR2010_RU	"0.0 m" indicates projected inundation level in 2010, with heights rounded up to the nearest 10 cm before mapping.
TR2050_RU	"0.2 m" indicates projected inundation level in 2050, with heights rounded up to the nearest 10 cm before mapping.
TR2100_RU	"0.8 m" indicates projected inundation level in 2100, with heights rounded up to the nearest 10 cm before mapping.
IC2010_RU	Polygons as mapped: 1 = contiguous with coast or; 0 = not contiguous with coast at 0.0 m inundation.
IC2050_RU	Polygons as mapped: 1 = contiguous with coast or; 0 = not contiguous with coast at 0.2 m inundation.
IC2100_RU	Polygons as mapped: 1 = contiguous with coast or; 0 = not contiguous with coast at 0.8 m inundation.
SL_Ref	NTC_HW (= NTC modelled high water) MHT Tamar (= Mean high tide in Launceston area) MHT Mac Hb (= mean high tide Macquarie Harbour)
TR_Lev_RU	Sea level rise level (in metres) in which the polygon first appears "inundated".
DEM_Ref	L2 (= LiDAR) DEM25 (= State 25 m DEM) **Note: Inundation heights in the 25 m DEM areas have been further rounded up to the nearest whole metre.**
Shape_Length	Polygon perimeter in metres.
Shape_Area	Polygon area in square metres.

Inundated areas contiguous or non-contiguous with the coast in each year can be selected using a combination of two attributes. For example query "TR2050_RU" = '0.2 m' AND "IC2050_RU" = 1 will select polygons contiguous with the coast that are expected to be inundated in 2050.

References:

Donaldson, P., Sharples, C., Anders, R.J., (2012) The tidal characteristics and shallow-marine seagrass sedimentology of Robbins Passage and Boullanger Bay, far northwest Tasmania. A technical report to Cradle Coast Natural Resource Management. Blue Wren Group, School of Geography and Environmental Studies, University of Tasmania, Hobart.

Eastman, J.R., Kyem, P.A.K., Toledano, J., Jin, W. (1993) GIS and decision making. Explorations in Geographic Information Systems Technology, Vol. 4. Geneva, United Nations Institute for Training and Research (UNITAR).

DCC (2009) Climate Change Risks to Australia's Coast: A First Pass National Assessment. Canberra, Department of Climate Change.

Foster, D.N., Nittim, R., Walker, J. (1986) Tamar River Siltation Study; WRL

	Technical Report No. 85/07.
	Koehnken L. (1996) Macquarie Harbour – King River Study. Technical Report, DELM
Jurisdictions	
	Tasmania
Search Words	
	CLIMATE-AND-WEATHER-Climate-change
	CLIMATE-AND-WEATHER-Extreme-weather-events
	HAZARDS-Flood
	HAZARDS-Severe-local-storms
	MARINE
Themes and Categories	
Topic Category	elevation
Topic Category	geoscientificInformation
Topic Category	environment
Status and Maintenance	
Status	completed
Maintenance and Update Frequency	notPlanned
Date of Next Update	
Reference system	
Reference System	GDA94
Spatial Representation Type	
Spatial Representation Type	vector
Metadata Security Restrictions	
Classification	
Authority	
Use Limitations	
Dataset Security Restrictions	
Classification	
Authority	
Use Limitations	
Extent - Geographic Bounding Box	
North Bounding Latitude	-40
South Bounding Latitude	-44
West Bounding Longitude	144
East Bounding Longitude	149
Additional Extents - Geographic	
Identifier	TAS
Distribution Information	
Distributor 1	
Distributor 1 Contact	
Name of Individual	Name withheld
Organisation Name	
Position Name	
Role	distributor
Voice	
Facsimile	
Email Address	
Address	
	Australia

Storm Tide plus Sea Level Rise Inundation Modelling metadata – Tasmania, Version 4

Draft metadata prepared by Dr Michael Lacey, University of Tasmania 12th January 2015.

General Properties	
File Identifier	
Hierarchy Level	series
Hierarchy Level Name	series
Standard Name	ANZLIC Metadata Profile: An Australian/New Zealand Profile of AS/NZS ISO 19115:2005, Geographic information - Metadata
Standard Version	1.1
Date Stamp	2015-01-12
Resource Title	Storm Tide plus Sea Level Rise Inundation Model – Tas., Version 4
Other Resource Details	M.J. Lacey, J.R. Hunter and R.E. Mount (2015) Coastal Inundation Mapping for Tasmania – Stage 3. Report to the Department of Premier and Cabinet by the University of Tasmania and the Antarctic Climate and Ecosystems Cooperative Research Centre
Key Dates and Languages	
Date of creation	2015-01
Date of publication	2015-01
Metadata Language	eng
Metadata Character Set	utf8
Dataset Languages	eng
Dataset Character Set	utf8
Abstract	A series of digital datasets that represent modelled potential inundation effects of combined sea level rise and storm tide scenarios for coastal areas of Tasmania and adjoining land regions covered by coastal LiDAR DEM or alternatively the Tasmanian 25 metre DEM where the LiDAR DEM was not available. The boundaries of these flooding zones indicate specific annual exceedance probabilities (AEP) of 1% for years 2010, 2050 or 2100 with sea level rise allowances based on the technique of Hunter (2012), observations of storm tides from the tide gauges at Hobart and Burnie, and regional projections of sea-level rise based on the IPCC A1FI emission scenario (Hunter et al., 2012). The allowances used in this dataset have been supplied by the Tasmanian Government to create coastal inundation area maps to support the development of a coastal policy, and a coastal inundation planning code. This version is based on modelled heights used in Version 2, but with inundation heights rounded up to the nearest 10 cm before mapping
Purpose	This dataset was prepared to assist in the identification of regions that may be subject to the effects of sea level rise such as coastal flooding.
Metadata Contact Information	
Name of Individual	Name withheld
Organisation Name	
Position Name	
Role	author
Voice	
Facsimile	
Email Address	
Address	

	Australia
Resource Contacts	
Name of Individual	
Organisation Name	
Position Name	
Role	pointOfContact
Voice	
Facsimile	
Email Address	
Address	 Australia
Lineage Statement	Inputs: Digital Elevation Model LIDAR information as supplied via the Information & Land Services Division (ILS) of the Department of Primary Industries, Parks, Water and Environment (DPIPWE) or the Land Information System Tasmania (LIST), November 2014. Tasmanian 25 metre DEM (second edition) as supplied via the Information & Land Services Division (ILS) of the Department of Primary Industries, Parks, Water and Environment (DPIPWE) or the Land Information System Tasmania (LIST) “Storm Tide plus SLR” height datasets Data prepared by John Hunter, ACE CRC, UTAS with the assistance of information on tides and storm surges ("storm tides") around the Tasmanian coastline derived from numerical modelling by Kathleen McInnes of CSIRO. The boundaries of these flooding zones indicate specific annual exceedance probabilities (AEP) of 1% for years 2010, 2050 or 2100 with sea-level rise allowances based on the technique of Hunter (2012), observations of storm tides from the tide gauges at Hobart and Burnie, and regional projections of sea-level rise based on the IPCC A1FI emission scenario (Hunter et al., 2012). Three Storm-Tide plus-SLR height datasets representing 1% AEPs for the specified time periods were geographically mapped. GIS processing was conducted using ESRI ArcGIS 10.2 with the majority of processing being scripted using Python 2.7. The main geoprocessing steps are summarised as follows. This version is based on modelled heights used in Version 2 except that heights have been rounded up to the nearest 10 cm before mapping. A spline with barriers interpolation method was used to calculate a series of height surfaces, from a set of AEP datasets for the year 2000. Sea level rise heights of 0.03, 0.23 and 0.83 metre were added to the height surfaces to calculate AEP height surfaces for the years 2010, 2050 and 2100 respectively. For LiDAR areas the combined AEP inundation and sea level rise was rounded-up to the nearest ten centimetres and in 25 metre DEM areas rounded-up to the nearest whole metre. The inundation surfaces had a grid spacing of 1000 metre. Inundation height surfaces were subtracted from the LiDAR and 25m DEM surfaces and cells of the resultant surface with a value less than zero were designated as inundated. Outputs were converted to polygon shapefiles which showed areas expected to be inundated under the modelled scenarios. This polygonisation step used the “no_simplify” option. The polygon layers were then clipped to a polygon version of the coastline. LiDAR based and non-LiDAR based datasets were combined into a single state-wide dataset. A polygon mask, identifying location of LiDAR areas, was used to erase the same areas from the 25 metre DEM based outputs. LiDAR and 25 m DEM based datasets were then merged to produce the combined shapefile. Some minor editing was required to add in some of the Launceston flood levees which were too narrow to show up on the LiDAR DEM. AEP datasets are listed in Table 1 and are provided in file geodatabase (.gdb) format with the dataset having the same name as the geodatabase in which it is

	enclosed. All of the datasets are projected in GDA 94 MGA Zone 55. Attributes of the datasets are listed in Table 2.

Table 1: Storm Tide AEP Datasets

Dataset Name	Target Year	Projected sea level rise (m)
StormTide_AEP_RU_2010_V4	2010	0
StormTide_AEP_RU_2050_V4	2050	0.2
StormTide_AEP_RU_2100_V4	2100	0.8

Table 2: Attributes of the Storm Tide AEP Datasets

Field Name	Details
AEP1pct_RU	“1%” indicates inundation at 1% AEP level.
IC1pct_RU	(1 = contiguous with coast; 0 = not contiguous with coast) at 1% AEP level.
AEP_Level	AEP level (=1%)
SLR	Sea level rise for target year (2010, 0.0 m; 2050, 0.2 m;; 2100, 0.8 m).
DEM_Ref	L2 (=LiDAR) DEM25 (= State 25 m DEM) **Note: Inundation heights in the 25 m DEM areas have been rounded up to the nearest whole metre.**
Shape_Length	Polygon perimeter in metres.
Shape_Area	Polygon area in square metres.

Inundated areas contiguous or non-contiguous with the coast in each year can be selected using a combination of two attributes. For example query "AEP1pct_RU" = '1%' AND "IC1pct_RU" = 1 will select polygons contiguous with the coast that are expected to be inundated at 1% AEP level.

References:

Hunter, J., 2012. A simple technique for estimating an allowance for uncertain sea-level rise, Climatic Change, 113, 239-252, DOI: 10.1007/s10584-011-0332-1. (http://staff.acecrc.org.au/~johunter/hunter_2012_author_created_version_merged.pdf)

Hunter, J.R., Church, J.A., White, N.J. and Zhang, X., 2013. Towards a global regionally-varying allowance for sea-level rise , Ocean Engineering, 71 (1) 17-27.

Jurisdictions	
	Tasmania
Search Words	
	CLIMATE-AND-WEATHER-Climate-change
	CLIMATE-AND-WEATHER-Extreme-weather-events
	HAZARDS-Flood
	HAZARDS-Severe-local-storms
	MARINE
Themes and Categories	
Topic Category	elevation
Topic Category	geoscientificInformation
Topic Category	environment
Status and Maintenance	
Status	completed
Maintenance and Update Frequency	notPlanned
Date of Next Update	
Reference system	
Reference System	GDA94

Spatial Representation Type	
Spatial Representation Type	vector
Metadata Security Restrictions	
Classification	
Authority	
Use Limitations	
Dataset Security Restrictions	
Classification	
Authority	
Use Limitations	
Extent - Geographic Bounding Box	
North Bounding Latitude	-40
South Bounding Latitude	-44
West Bounding Longitude	144
East Bounding Longitude	149
Additional Extents - Geographic	
Identifier	TAS
Distribution Information	
Distributor 1	
Distributor 1 Contact	
Name of Individual	Name withheld
Organisation Name	
Position Name	
Role	distributor
Voice	
Facsimile	
Email Address	
Address	
	Australia

Coastal Inundation Height Reference metadata – Tasmania Version 3.4

Draft metadata prepared by Dr Michael Lacey, University of Tasmania 12th January 2015.

General Properties	
File Identifier	
Hierarchy Level	series
Hierarchy Level Name	series
Standard Name	ANZLIC Metadata Profile: An Australian/New Zealand Profile of AS/NZS ISO 19115:2005, Geographic information - Metadata
Standard Version	1.1
Date Stamp	2015-01-12
Resource Title	Coastal Inundation Height Reference (Tas), Version 3.4
Other Resource Details	M.J. Lacey, J.R. Hunter and R.E. Mount (2015) Coastal Inundation Mapping for Tasmania – Stage 3. Report to the Department of Premier and Cabinet by University of Tasmania and the Antarctic Climate and Ecosystems Cooperative Research Centre
Key Dates and Languages	
Date of creation	2015-01
Date of publication	2015-01
Metadata Language	eng
Metadata Character Set	utf8
Dataset Languages	eng
Dataset Character Set	utf8
Abstract	A digital dataset representing 1 km square polygon tiles covering the entire Tasmanian shoreline (up to the 10 metre contour) where each tile is attributed with modelled potential inundation heights for a number of tidal, combined sea level rise and high tide or storm tide scenarios. The purpose of the data set is to provide a reference for “looking up” potential inundation heights around the Tasmanian coast. The reason the heights vary around the coast is that the height of the high water mark varies with the tidal range around the coast from approximately 1 to 3+ metres. The sea level rise reference heights include modelled high tide in 0.1metre increments to 1.2 metre. At each sea level rise scenario high calculated water heights are based on modelled tide range data provided by the National Tidal Centre except for the Tamar Valley and Macquarie Harbour where published mean high water (MHW) heights were used. Data also includes modelled storm tide inundation heights associated with specific annual exceedance probabilities (AEP) of 0.005%, 0.05%, 0.5%, 1%, 2% or 5% for years 2010, 2050, 2075 or 2100 with sea level rise allowances based on regional sea-level projections and the A1FI emission scenario. Note that the calculated heights are the most likely based on the calculation inputs, though this is NOT necessarily the most likely position of the sea level in the future. Some extrapolation was required to extend tide data into areas inland from the open coast including estuarine areas.
Purpose	This dataset was prepared to assist in the identification of regions that may be subject to the effects of sea level rise such as coastal flooding by providing a reference for “looking up” potential inundation heights around the Tasmanian coast.
Metadata Contact Information	
Name of Individual	Name withheld
Organisation Name	
Position Name	

Role	author
Voice	
Facsimile	
Email Address	
Address	
	Australia
Resource Contacts	
Name of Individual	
Organisation Name	
Position Name	
Role	pointOfContact
Voice	
Facsimile	
Email Address	
Address	
	Australia
Lineage Statement	Inputs: SLR The sea level rise allowances are based on regional sea-level projections and the A1FI emission scenario. The allowances used in this dataset have been supplied by the Tasmanian Government to create coastal inundation area maps to support the development of a coastal policy, and a coastal inundation planning code. Tidal Range Tidal range modelled data was obtained from the National Tidal Centre (NTC) in the form of a five minute resolution grid of points extending from longitude 111º to 116º East and from latitude 9º to 45º South. This model represents tidal amplitudes in metres between Mean Sea Level and Indian Spring Low Water multiplied by two to give an estimate of the complete tidal range. It includes the four main tidal constituents, M2, S2, O1 and K1, and was calculated as: Tidal amplitude = (M2 + S2 + O1 + K1) amplitudes * 2 Tidal heights were interpolated across the Tasmanian land surface using the spline with barriers method. For the Tamar region, mean high water (MHW) heights were used instead of NTC high water and were based on MHW heights for nine locations along the Tamar sourced from Foster *et al*. (1986) and were extrapolated across the region. The tide range grid was also extrapolated into Macquarie harbour using the base heights reported in Koehnken (1996). A spline with barriers interpolation method was used to calculate a series of height surfaces, from a set of AEP datasets for the year 2000. Sea level rise heights of 0.03, 0.23, 0.43 and 0.83 metre were added to the height surfaces to calculate AEP height surfaces for the years 2010, 2050, 2075 and 2100 respectively. In most cases heights were extracted from the inundation surfaces at the tile centre points. AEP heights in tiles that intersect the coast are the average of input data points at 100 metre spacing along the coast that fall within that tile. The dataset **“TasHeightsRefV3_4**” is provided in ESRI personal geodatabase **“Tasmania_Coastal_Heights_Ref_V3_4.mdb”**. Attributes are listed in Table 1. The dataset is projected in GDA 94 MGA Zone 55 and heights are in metres AHD.

Table 1: Attributes of TasHeightsRefV4

Attribute	Details
LL_Pos_EN	Tile lower left eastings and northings in kilometres, (eg. e473_n5448).
Easting	Tile centre easting in metres (MGA zone 55)
Northing	Tile centre northing in metres (MGA zone 55)
Base_Ht	Interpolated reference high water mark height at the centre of tile. In most cases this will be based on NTC tide range except where otherwise stated in this metadata.
Base_Ht_Ref	Source of height reference used in tile (NTC TR, NTC tide range; MHT Mac Hb, mean high tide for Macquarie Harbour; MHT Tamar, mean high tide Tamar).
TR_0SLR	Modelled inundation height for tile with 0 sea level rise at 50% probability level.
TR_10SLR	Modelled inundation height for tile with 10 cm sea level rise at 50% probability level.
TR_20SLR	Modelled inundation height for tile with 20 cm sea level rise at 50% probability level.
TR_30SLR	Modelled inundation height for tile with 30 cm sea level rise at 50% probability level.
TR_40SLR	Modelled inundation height for tile with 40 cm sea level rise at 50% probability level.
TR_50SLR	Modelled inundation height for tile with 50 cm sea level rise at 50% probability level.
TR_60SLR	Modelled inundation height for tile with 60 cm sea level rise at 50% probability level.
TR_70SLR	Modelled inundation height for tile with 70 cm sea level rise at 50% probability level.
TR_80SLR	Modelled inundation height for tile with 80 cm sea level rise at 50% probability level.
TR_90SLR	Modelled inundation height for tile with 90 cm sea level rise at 50% probability level.
TR_100SLR	Modelled inundation height for tile with 100 cm sea level rise at 50% probability level.
TR_110SLR	Modelled inundation height for tile with 110 cm sea level rise at 50% probability level.
TR_120SLR	Modelled inundation height for tile with 120 cm sea level rise at 50% probability level.
HAT	Modelled Highest Astronomic Tide from NTC. Interpolated values for rivers and estuaries are approximate and should only be used in those areas with caution. Values for locations inland from the open coast have been designated "no_data" and have been given a value of "-999".
Local_Storm_Surge	Local storm surge if known.
Wave_Setup	Wave setup if known.
Wave_Runup	Wave runup if known.
AEP_005pct2010	Modelled 0.005% Annual Exceedance Probability height for 2010.
AEP_05pct2010	Modelled 0.05% Annual Exceedance Probability height for 2010.
AEP_5pct2010	Modelled 0.5% Annual Exceedance Probability height for 2010.
AEP1pct2010	Modelled 1% Annual Exceedance Probability height for 2010.
AEP2pct2010	Modelled 2% Annual Exceedance Probability height for 2010.
AEP5pct2010	Modelled 5% Annual Exceedance Probability height for 2010.
AEP_005pct2050	Modelled 0.005% Annual Exceedance Probability height for 2050.
AEP_05pct2050	Modelled 0.05% Annual Exceedance Probability height for 2050.
AEP_5pct2050	Modelled 0.5% Annual Exceedance Probability height for 2050.
AEP1pct2050	Modelled 1% Annual Exceedance Probability height for 2050.
AEP2pct2050	Modelled 2% Annual Exceedance Probability height for 2050.
AEP_005pct2075	Modelled 0.005% Annual Exceedance Probability height for 2075.
AEP_05pct2075	Modelled 0.05% Annual Exceedance Probability height for 2075.
AEP_5pct2075	Modelled 0.5% Annual Exceedance Probability height for 2075.
AEP1pct2075	Modelled 1% Annual Exceedance Probability height for 2075.
AEP2pct2075	Modelled 2% Annual Exceedance Probability height for 2075.
AEP5pct2075	Modelled 5% Annual Exceedance Probability height for 2075.
AEP_005pct2100	Modelled 0.005% Annual Exceedance Probability height for 2100.
AEP_05pct2100	Modelled 0.05% Annual Exceedance Probability height for 2100.
AEP_5pct2100	Modelled 0.5% Annual Exceedance Probability height for 2100.
AEP1pct2100	Modelled 1% Annual Exceedance Probability height for 2100.
AEP2pct2100	Modelled 2% Annual Exceedance Probability height for 2100.
AEP5pct2100	Modelled 5% Annual Exceedance Probability height for 2100.
Shape_Length	Tile perimeter length in metres
Shape_Area	Tile area in square metres

References:

Eastman, J. R., P. A. K. Kyem, J. Toledano and W. Jin (1993). GIS and decision making. Explorations in Geographic Information Systems Technology, Vol. 4. Geneva, United Nations Institute for Training and Research (UNITAR).

Foster, D.N., R., Nittim and J. Walker, (1986). Tamar River Siltation Study; WRL Technical Report No. 85/07.

Koehnken L. (1996) Macquarie Harbour – King River Study. Technical Report, DELM

Jurisdictions

	Tasmania
Search Words	
	CLIMATE-AND-WEATHER-Climate-change
	CLIMATE-AND-WEATHER-Extreme-weather-events
	HAZARDS-Flood
	HAZARDS-Severe-local-storms
	MARINE
Themes and Categories	
Topic Category	elevation
Topic Category	geoscientificInformation
Topic Category	environment
Status and Maintenance	
Status	completed
Maintenance and Update Frequency	notPlanned
Date of Next Update	
Reference system	
Reference System	GDA94 MGA Zone 55
Spatial Representation Type	
Spatial Representation Type	vector
Metadata Security Restrictions	
Classification	
Authority	
Use Limitations	
Dataset Security Restrictions	
Classification	
Authority	
Use Limitations	
Extent - Geographic Bounding Box	
North Bounding Latitude	-40
South Bounding Latitude	-44
West Bounding Longitude	144
East Bounding Longitude	149
Additional Extents - Geographic	
Identifier	TAS
Distribution Information	
Distributor 1	
Distributor 1 Contact	
Name of Individual	Name withheld
Organisation Name	
Position Name	
Role	distributor
Voice	
Facsimile	
Email Address	
Address	
	Australia

Coastal Inundation Hazard Maps metadata – Tasmania Version 2.1

Draft metadata prepared by Dr Michael Lacey, University of Tasmania 21st January 2015.

General Properties	
File Identifier	
Hierarchy Level	series
Hierarchy Level Name	series
Standard Name	ANZLIC Metadata Profile: An Australian/New Zealand Profile of AS/NZS ISO 19115:2005, Geographic information - Metadata
Standard Version	1.1
Date Stamp	2015-01-21
Resource Title	Coastal Inundation Hazard Maps, Version 2
Other Resource Details	M.J. Lacey, J.R. Hunter and R.E. Mount (2015) Coastal Inundation Mapping for Tasmania – Stage 3. Report to the Department of Premier and Cabinet by University of Tasmania and the Antarctic Climate and Ecosystems Cooperative Research Centre
Key Dates and Languages	
Date of creation	2015-01
Date of publication	2015-01
Metadata Language	eng
Metadata Character Set	utf8
Dataset Languages	eng
Dataset Character Set	utf8
Abstract	Maps showing High, Medium, Low and Investigation bands of coastal inundation likelihood. In LiDAR mapped areas the High, Medium and Low bands were based on the extent the following permanent and storm tide inundation scenarios. - High (Currently vulnerable to coastal erosion with future inundation hazard): Area vulnerable to highest astronomical tide now; and 0.2-metre sea level rise from the mean high tide by 2050 + rounding up to the nearest 100 mm. - Medium (Vulnerable to Coastal inundation and erosion by 2050): area vulnerable to a 1% AEP storm event in 2050 + rounding up to the nearest 100mm + 300 mm for freeboard . - Low (Vulnerable to Coastal inundation and erosion by 2100): Area vulnerable to a 1% AEP storm event in 2100 + rounding up to the nearest 100mm + 300 mm for freeboard. In addition, in those coastal areas outside of the LiDAR mapped areas a band defined as the Coastal Inundation Investigation band is the area extending to the coast below the 10 metre contour. Within this band no level of likelihood was assigned. This dataset combines elements from the following datasets (please also refer to metadata from those datasets): Coastal High Water plus Sea Level Rise Inundation Model – Tas., Version 4 Storm Tide plus Sea Level Rise Inundation Model – Tas., Version 4 Coastal Inundation Height Reference (Tas), Version 3.4
Purpose	This dataset was prepared to assist in the identification of regions that may be subject to the effects of sea level rise such as coastal flooding.
Metadata Contact Information	
Name of Individual	Name withheld
Organisation Name	
Position Name	

Role	author
Voice	
Facsimile	
Email Address	
Address	
	Australia
Resource Contacts	
Name of Individual	
Organisation Name	
Position Name	
Role	pointOfContact
Voice	
Facsimile	
Email Address	
Address	
	Australia
Lineage Statement	Inputs: Inputs for the High, Medium and Low bands were prepared from Coastal Inundation Extent datasets or equivalently prepared data. The 'Coastal High Water plus Sea Level Rise Inundation Model – Tas., Version 2' dataset for 2050 was the input dataset for the High scenario. Inputs with a 300 mm freeboard allowance (Medium and Low) were prepared in the same way as the corresponding 'Storm Tide plus Sea Level Rise Inundation Model – Tas., Version 4' datasets except that an additional 300 mm was added to the combined AEP inundation and sea level rise heights before this was subtracted from the DEM height surfaces. Inundation polygons which were not-contiguous with the coast were removed from the LiDAR sourced 'high', 'medium' and 'low' datasets before these datasets were spatially unioned. Small polygons, with an area less than 5 square metres, were removed by converting them to the same band category as the surrounding polygons. The dataset was then simplified using the ArcGIS Simplify Polygon tool with the bend simplify option, 2.4 metre minimum curve length and topology correction. The resulting hazard map for LiDAR areas was then combined with a polygon representation of a band extending between the 10 metre contour and the coast using a combination of erase and merge steps. The Identity tool was used to extract attributes from the 'Tasmania_Coastal_Heights_Ref_V3_4' dataset. Additional attribute fields were added and calculated. The dataset **"Coastal_Inundation_Hazard_V2"** is provided in an ESRI file geodatabase with the same name. Attributes are listed in Table 1. The dataset is projected in GDA 94 MGA Zone 55 and heights are in metres AHD.

Table 1: Attribute of Coastal_Inundation_Hazard_V2

Field Name	Details
Disclaimer_Part_1	"Hazard Planning Maps produced by the Department of Premier and Cabinet (this map being such a map) are produced and released for the purpose of informing actions taken and decisions made by local or state government under relevant provisions of the"
Disclaimer_Part_2	"Land Use Planning and Approvals Act 1993 and Building Act 2000. Whilst every care has been taken to prepare this map, the Government of Tasmania makes no representations or warranties about its accuracy, reliability, completeness or suitability for"
Disclaimer_Part_3	"any particular purpose other than its intended purpose. Hazard bands as depicted in this map may not accurately represent the existence or otherwise of hazards in the mapped area."
Disclaimer_Part_4	"Independent expert advice should be sought if action is to be taken that may be impacted by the existence or otherwise of hazards in the mapped area."
Hazard_Band	"High", "Medium", "Low" or "Investigation"

Hazard_Exposure	If "Hazard_Band"="High", "This area is vulnerable to the highest astronomical tide now, and to a 0.2 metre sea level rise from the mean high tide by 2050." If "Hazard_Band"="Medium", "This area is vulnerable to a 1% AEP storm event in 2050 and a 0.8m sea level rise by 2100." If "Hazard_Band"="Low", "This area is vulnerable to a 1% AEP storm event in 2100." If "Hazard_Band"="Investigation", "This area is outside the LiDAR-mapped area and as it is below the mapped 10 m contour may be partly vulnerable to sea level rise but data used for this analysis were not sufficient to further determine potential inundated areas"
Height_High	Inundation height in metres for the "High" scenario. Calculated as = INT((TR_20SLR+0.1)*10)/10
Height_Medium	Inundation height in metres for the "Medium" scenario. Calculated as =(INT((AEP1pct_2050+0.1)*10)/10)+0.3
Height_Low	Inundation height in metres for the "Low" scenario. Calculated as =(INT((AEP1pct_2100+0.1)*10)/10)+0.3
LL_Pos_EN	Tile lower left eastings and northings in kilometres, (eg. e473_n5448).
Easting	Tile centre easting in metres (MGA zone 55)
Northing	Tile centre northing in metres (MGA zone 55)
Base_Ht	Interpolated reference high water mark height at the centre of tile. In most cases this will be based on NTC tide range. See note 1.
Base_Ht_Ref	Source of height reference used in tile (NTC TR, NTC tide range; MHT Mac Hb, mean high tide for Macquarie Harbour; MHT Tamar, mean high tide Tamar).
TR_0SLR	Modelled inundation height for tile with 0 sea level rise at 50% probability level.
TR_10SLR	Modelled inundation height for tile with 10 cm sea level rise at 50% probability level.
TR_20SLR	Modelled inundation height for tile with 20 cm sea level rise at 50% probability level.
TR_30SLR	Modelled inundation height for tile with 30 cm sea level rise at 50% probability level.
TR_40SLR	Modelled inundation height for tile with 40 cm sea level rise at 50% probability level.
TR_50SLR	Modelled inundation height for tile with 50 cm sea level rise at 50% probability level.
TR_60SLR	Modelled inundation height for tile with 60 cm sea level rise at 50% probability level.
TR_70SLR	Modelled inundation height for tile with 70 cm sea level rise at 50% probability level.
TR_80SLR	Modelled inundation height for tile with 80 cm sea level rise at 50% probability level.
TR_90SLR	Modelled inundation height for tile with 90 cm sea level rise at 50% probability level.
TR_100SLR	Modelled inundation height for tile with 100 cm sea level rise at 50% probability level.
TR_110SLR	Modelled inundation height for tile with 110 cm sea level rise at 50% probability level.
TR_120SLR	Modelled inundation height for tile with 120 cm sea level rise at 50% probability level.
HAT	Modelled Highest Astronomic Tide from NTC. This data is included for reference and has not been used in tide height calculations. "-999" = No data. See Note 2.
Local_Storm_Surge	Local storm surge if known.
Wave_Setup	Wave setup if known.
Wave_Runup	Wave runup if known.
AEP_005pct2010	Modelled 0.005% Annual Exceedance Probability height for 2010.
AEP_05pct2010	Modelled 0.05% Annual Exceedance Probability height for 2010.
AEP_5pct2010	Modelled 0.5% Annual Exceedance Probability height for 2010.
AEP1pct2010	Modelled 1% Annual Exceedance Probability height for 2010.
AEP2pct2010	Modelled 2% Annual Exceedance Probability height for 2010.
AEP5pct2010	Modelled 5% Annual Exceedance Probability height for 2010.
AEP_005pct2050	Modelled 0.005% Annual Exceedance Probability height for 2050.
AEP_05pct2050	Modelled 0.05% Annual Exceedance Probability height for

	2050.
AEP_5pct2050	Modelled 0.5% Annual Exceedance Probability height for 2050.
AEP1pct2050	Modelled 1% Annual Exceedance Probability height for 2050.
AEP2pct2050	Modelled 2% Annual Exceedance Probability height for 2050.
AEP5pct2050	Modelled 5% Annual Exceedance Probability height for 2050.
AEP_005pct2075	Modelled 0.005% Annual Exceedance Probability height for 2075.
AEP_05pct2075	Modelled 0.05% Annual Exceedance Probability height for 2075.
AEP_5pct2075	Modelled 0.5% Annual Exceedance Probability height for 2075.
AEP1pct2075	Modelled 1% Annual Exceedance Probability height for 2075.
AEP2pct2075	Modelled 2% Annual Exceedance Probability height for 2075.
AEP5pct2075	Modelled 5% Annual Exceedance Probability height for 2075.
AEP_005pct2100	Modelled 0.005% Annual Exceedance Probability height for 2100.
AEP_05pct2100	Modelled 0.05% Annual Exceedance Probability height for 2100.
AEP_5pct2100	Modelled 0.5% Annual Exceedance Probability height for 2100.
AEP1pct2100	Modelled 1% Annual Exceedance Probability height for 2100.
AEP2pct2100	Modelled 2% Annual Exceedance Probability height for 2100.
AEP5pct2100	Modelled 5% Annual Exceedance Probability height for 2100.
Shape_Length	Tile perimeter length in metres
Shape_Area	Tile area in square metres

Jurisdictions

Tasmania

Search Words

CLIMATE-AND-WEATHER-Climate-change
CLIMATE-AND-WEATHER-Extreme-weather-events
HAZARDS-Flood
HAZARDS-Severe-local-storms
MARINE

Themes and Categories

Topic Category	elevation
Topic Category	geoscientificInformation
Topic Category	environment

Status and Maintenance

Status	completed
Maintenance and Update Frequency	notPlanned
Date of Next Update	

Reference system

Reference System	GDA94 MGA Zone 55

Spatial Representation Type

Spatial Representation Type	vector

Metadata Security Restrictions

Classification

Authority

Use Limitations	
Dataset Security Restrictions	
Classification	
Authority	
Use Limitations	
Extent - Geographic Bounding Box	
North Bounding Latitude	-40
South Bounding Latitude	-44
West Bounding Longitude	144
East Bounding Longitude	149
Additional Extents - Geographic	
Identifier	TAS
Distribution Information	
Distributor 1	
Distributor 1 Contact	
Name of Individual	Name withheld
Organisation Name	
Position Name	
Role	distributor
Voice	
Facsimile	
Email Address	
Address	
	Australia