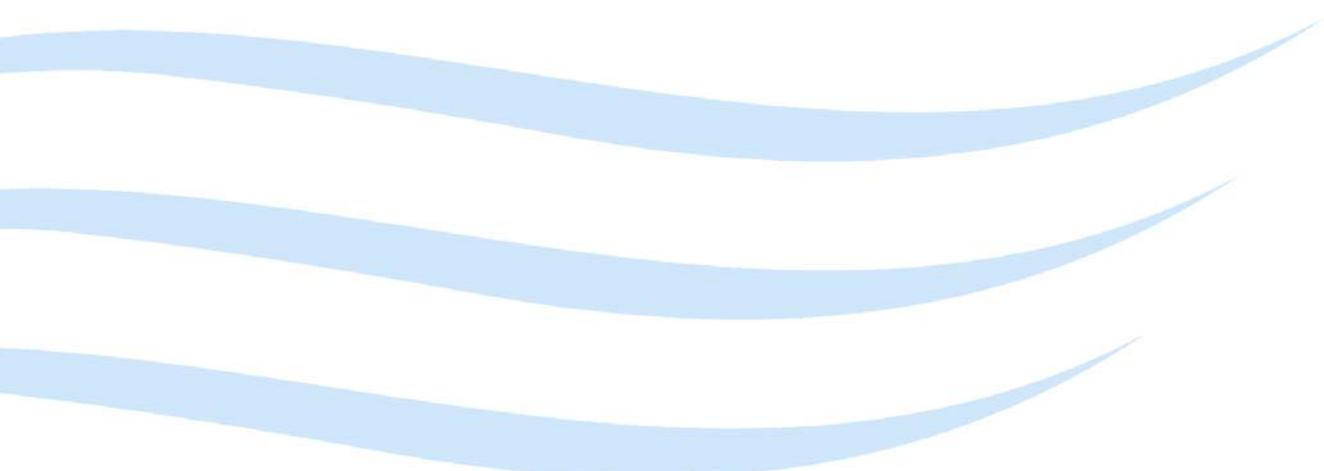


# Sea-Level Extremes In Tasmania

Summary and Practical Guide for  
Planners and Managers



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Planners and Managers

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This document forms a companion to Hunter, J. 2008 *Historical and Projected Sea-Level Extremes for Hobart and Burnie, Tasmania*, Technical Report prepared by the Antarctic and Climate and Ecosystems Cooperative Research Centre – December 2007. Published by the Department of Primary Industries and Water, Tasmania.

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## Introduction

The coastal zone is vulnerable to the impacts of natural hazards such as erosion and flooding from storm surges. Climate change and sea-level rise will exacerbate the impacts of these hazards, causing progressive flooding and erosion of shorelines. Information on historical and projected sea-level extremes is critical to the development of planning, mitigation and management responses that are appropriate, and based on sound risk management techniques.

The project 'Climate Change and Coastal Risk Management' was established to improve the information available on extreme sea-levels in Tasmania. The Project has been coordinated by the Department of Primary Industries and Water in collaboration with the Antarctic Climate and Ecosystems Cooperative Research Centre and is supported by the Tasmanian Risk Mitigation Programme.

The data on which analyses of historical extreme sea-level events may be based is limited. In Tasmania, the two tide gauge records most suitable for this type of analysis are Hobart and Burnie. The George Town tide gauge has a similar record to Burnie, however this was not used in the analysis because it is considered to be in effect the same as Burnie's.

Australian and international planning and management regimes use a number of different exceedance statistics. In Tasmania, planning schemes and other similar regulatory instruments most commonly use the 1% annual exceedance probability. This refers to high sea-level events which have a 1% chance of occurring once or more in any one year.

This method however, does not always provide a realistic understanding of the chance of an event occurring over longer time periods. For example, for a development with an expected life span of around 100 years, it may be more important to know the chance of a particular height of sea-level being exceeded once or more during that whole 100 year span, rather than the chance of it occurring in any one of the years during that time.

The Technical Report (Hunter 2008) that forms a companion to this Guide provides the ability to calculate different statistics depending on the requirements of a particular situation. This Guide covers some of the more common situations likely to be faced by strategic planners and managers in Tasmania, especially in local-level planning and management authorities.

Hypothetical examples of situations where a planner or manager may use sea-level exceedance statistics are provided in the Appendix at the end of this Guide.

The impact of waves is also important for assessing the vulnerability of areas to flooding and erosion. Detailed local analyses are required to determine the magnitude of this impact. Hence, this issue is not covered by the following Statewide analysis in this Guide which primarily considers 'still-water' conditions. Background information relating to the issue of the impact of waves is available in Sharples (2006).

## Definitions

Full definitions are provided in the Technical Report that forms a companion to this Guide. The following is an extract and summary of some of the key terms.

AHD	Australian Height Datum, which for Tasmania was proclaimed in 1983 and is based on the annual mean sea level for 1972 at Hobart and Burnie.
Annual exceedance probability (AEP)	The chance of an event exceeding a certain magnitude in any one year.
Asset life	The expected serviceable lifetime of an asset, such as a building or other infrastructure.
Exceedance probability	The chance of an event exceeding a certain magnitude.
IPCC	Intergovernmental Panel on Climate Change.
Return Period	Usually the average time between exceedance events. Sometimes also referred to as the average recurrence interval or ARI. Note that there can be differences in the way return period is calculated, so caution may be required if the method of calculation is not clear.

## Storm-surge and sea-level rise

Storm-surges are a natural hazard of the coastal zone, and low-lying coastal areas are vulnerable to storm-surge flooding.

Storm-surges are extremely high sea levels, which occur when a number of factors combine, including: low atmospheric pressure, on-shore winds, and high tides. Significant rainfall can also inject a greater volume of water into the coastal zone from river systems.

Atmospheric pressure is important, as a 1 hectopascal drop in pressure approximately equates to a 1cm rise in sea-level. The contribution from on-shore winds is also significant, as it effectively pushes the water against the coast. If this occurs in areas with extensive shallows and/or bays and estuaries that funnel the effect, then the impact can be amplified even further.

Sea-level rise will exacerbate the impacts of storm-surge flooding, with the extent of areas at risk increasing. Sharples (2006) mapped the indicative areas at risk from extreme storm surges at 2004 sea-levels, as well as the potential indicative increase in area associated with two different projections for sea-level rise. Sharples noted that as well as an increase in the area at risk, sea-level rise will result in the areas susceptible to flooding at the current sea-level will be flooded to deeper levels in the future.

In 2001, the Intergovernmental Panel on Climate Change (IPCC) released its Third Assessment Report, which projected a global sea-level rise from 1990 to 2100 of between 9 and 88cm. The Fourth Assessment Report was subsequently released in 2007 and projected a sea-level rise from 1990 to 2095 of between 18 and 59cm. However, the Fourth Assessment Report also suggested that an additional 10 to 20cm should be added to the upper ranges of these projections in order to account for effects related to the melting of land ice in Greenland and Antarctica. Once the differences between the Third and Fourth Assessment Report projections are considered, the upper limits of the projections are in close agreement. The Fourth Assessment Report also added the caveat that "larger values cannot be excluded, but understanding of these effects is too limited to assess their likelihood or provide a best estimate or an upper bound for sea level rise" (IPCC 2007).

Recent analysis (eg Rahmstorf et al. 2007) of observed sea-level change since 1990 indicates that sea levels are currently rising along the uppermost trajectory of the IPCC Third Assessment Report projections.

The projections for extreme high sea-levels provided by Hunter (2008) incorporate sea-level rise, using IPCC Third Assessment Report data because data from the Fourth Assessment Report were not available at the time. In addition, the Fourth Assessment Report only provided projections of sea level at 2095 and not throughout the 21st century. Hunter also provides information on the lower, mid, and upper end of sea-level rise scenarios. Full descriptions are provided by Hunter (2007).

## Exceedance statistics

Exceedance statistics are used to express the chance that an event will occur during a certain period of time (or the likelihood of a specific event occurring). Exceedance statistics are commonly used in planning and management to define a level of acceptable risk, where the likelihood of occurrence is balanced against the costs of mitigating the risk.

There are a number of ways of expressing the chance of an event occurring. Return period and exceedance probabilities are commonly used. A detailed description of the different statistical methodologies is provided in Hunter (2008).

A review of the use of exceedance statistics demonstrates that there are a number of different statistical methodologies being used in planning and management. The result is that there is sometimes a lack of clarity about exactly what is being referred to. For example, it is not always clear what is being referred to by the commonly used phrase “1 in 100 year flood”. This is sometimes used to refer to an exceedance event which, on average, happens once every 100 years, and sometimes to an event that has a 1 in 100 chance of occurring in any one year (ie the 1% annual exceedance probability). These two statements are only approximately equivalent for longer timeframes (eg for around 100 years or longer). For shorter time frames, the probability statistics mean that, for example, for an event which on average happens once every year, the probability that it will happen during any one year is only 63% and not 100%. Further details are provided in section 2 ‘Definitions and Explanations’ of Hunter (2008), while the Bureau of Meteorology provides some short definitions at [http://www.bom.gov.au/hydro/has/ari\\_aep.shtml](http://www.bom.gov.au/hydro/has/ari_aep.shtml).

A short paper reviewing the use of exceedance statistics is provided in the following document, which is available for download at [www.dpiw.tas.gov.au/climatechange](http://www.dpiw.tas.gov.au/climatechange):

Department of Primary Industries and Water 2008 *Background report: Coastal flooding – Review of the use of Exceedance Statistics in Tasmania*, Department of Primary Industries and Water, Tasmania.

In Tasmania, the exceedance statistic most commonly used, especially for planning and management, is the 1% annual exceedance probability. The following sections provide a summary of this statistic for Tasmania based on the Technical Report of Hunter (2008).

There are also other ways of representing the risk a coastal development faces from storm-surge flooding and sea-level rise, and these are outlined in Hunter (2008). Some hypothetical examples based on common situations are included at the end of this Guide for illustrative purposes (see Appendix – Hypothetical examples of the use of exceedance statistics). The aim of these examples is to outline the risks faced by developments in the coastal zone over their entire life span, and not just the risk faced in any one year.

This Guide primarily focuses on still-water conditions. It should be noted that a ‘freeboard’ is sometimes used in addition to such exceedance levels to allow for the impact of waves. In situations where there is exposure to large ocean swell, or there is a significant distance across the water allowing large wind-waves to be generated, the set-up and run-up of the waves against the shore can result in water reaching levels well above those suggested by storm surge flooding levels. Specific site analyses are required to determine the level of impact this may result in.

## Exceedance probabilities for Tasmania

### Hobart and Burnie

There are two tide gauge stations in Tasmania with a sufficiently long record and the appropriate geographical separation for use in projecting the probabilities of extreme sea-levels in Tasmania for this century. Hunter (2008) analysed these records, and incorporated projected sea-level rise, to determine a range of exceedance probabilities and effective return periods.

The statistical information of most relevance to planners and managers in the coastal zone have been extracted from Hunter (2008) and are provided below (Table 1). These figures will be most commonly used for identifying areas of hazard for strategic planning, where the broad use of an area is defined (such as residential). They also provide the commonly used level of risk as a basis for risk management activities.

The statistical information provided by Hunter (2008) includes the projections for sea-level rise, as well as the uncertainties in the various elements of the calculation, including uncertainties in the projections for sea-level rise, and for projecting historical tide gauge datasets beyond the length of their record.

The sea-level rise projections used in the following analyses are for the IPCC's upper emission scenario, known as "A1FI". Actual measurements of currently rising sea-levels have been shown to be tracking along the upper limit of the IPCC projections (Rahmstorf et al. 2007). Together with current global emissions being above those used in the A1FI scenario, using the upper scenario represents a precautionary approach.

The primary statistic presently used for strategic planning in Tasmania is the 1% annual exceedance probability. This describes extreme high sea levels that have a 1% chance of occurring once or more in a single year. It does not represent the risk that an event will occur during a longer period of time. To determine the chance of an event occurring during the whole asset life, other important considerations are needed, especially the expected life span of the asset, and the level of risk that is acceptable.

Some common examples of the use of exceedance statistics are provided in the Appendix – Hypothetical examples of the use of exceedance statistics. These examples show how the information in Hunter (2008) can be used to determine the probabilities of risk for individual situations.

In addition to the 1% annual exceedance probabilities, the exceedance probabilities for sea levels during longer time frames are also given in Table 1.

In the coastal zone, development is possible where the risks have been identified and can either be accepted or addressed by suitable adaptation measures. An example of this is ensuring that the habitable floor levels are above a certain flood hazard height. Protecting essential service lines such as water, power and sewage that occur at a height lower than an expected storm surge height is another example.

Exceedance probabilities for an asset life of 100 years are provided in Table 1 for the current regime of sea-levels (year 2000). They are also provided for the years 2040 and 2100 to provide information on the increasing level of risk due to sea-level rise. For example, based on the Hobart data, over a 100 year time period, there is a 70% chance of the height 1.49m above Australian Height Datum (AHD) being exceeded at year 2000 sea-levels. By the year 2040, the same level of chance of exceedance over the same 100 years rises to 1.59m above AHD. By the end of the century, the height has risen to 1.92m above AHD.

The exceedance probability threshold levels of 90%, 80%, 70% and 60% are given for an asset life of 100 years for each of the current, 2040 and 2100 year timeframes.

**Table 1 Exceedance probabilities for Hobart and Burnie**

- Notes: 1. Numbers refer to meters above Australian Height Datum (AHD)  
 2. "Figure" refers to the Figure number in Hunter (2008) from which the data was derived.  
 3. The numbers in the Table do not include the impact of waves.

Statistic	Hobart				Burnie			
	Figure <sup>2</sup>	Min	Mean	Max	Figure <sup>2</sup>	Min	Mean	Max
<b>Annual exceedance probability (AEP)</b>								
1% AEP – yr 2000	22	1.41	1.5	1.65	F 172	1.905	1.92	1.94
1% AEP – yr 2040	52	1.54	1.6	1.74	F 202	2.06	2.07	2.08
1% AEP – yr 2100	142	2.09	2.15	2.2	F 292	2.7	2.75	2.8
<b>Exceedance Probability (Asset life 100yrs)</b>								
90% EP (100yrs) – yr 2000	30	1.36	1.4	1.46	F 180	1.9	1.91	1.92
90% EP (100yrs) – yr 2040	60	1.45	1.5	1.55	F 210	1.95	1.97	2.0
90% EP (100yrs) – yr 2100	150	1.63	1.72	1.81	F 300	2.11	2.15	2.18
80% EP (100yrs) – yr 2000	30	1.39	1.45	1.54	F 180	1.91	1.92	1.94
80% EP (100yrs) – yr 2040	60	1.48	1.55	1.63	F 210	1.97	2.0	2.025
80% EP (100yrs) – yr 2100	150	1.71	1.83	1.96	F 300	2.19	2.23	2.27
70% EP (100yrs) – yr 2000	30	1.41	1.49	1.61	F 180	1.91	1.925	1.951
70% EP (100yrs) – yr 2040	60	1.51	1.59	1.7	F 210	1.985	2.02	2.05
70% EP (100yrs) – yr 2100	150	1.79	1.92	2.06	F 300	2.28	2.3	2.34
60% EP (100yrs) – yr 2000	30	1.43	1.53	1.69	F 180	not	plotted	1.97
60% EP (100yrs) – yr 2040	60	1.53	1.63	1.77	F 210	2.01	2.03	2.075
60% EP (100yrs) – yr 2100	150	1.86	2.0	2.15	F 300	2.33	2.37	2.41

### Statewide figures

Most Tasmanian tide gauge stations do not have a record of sufficient length for the type of analysis used by Hunter (2008).

Therefore, an extrapolation method is required in order to apply the Hobart and Burnie information to the rest of the State.

Data from the National Tidal Centre (Figure 1) provides information on the tidal regime around Tasmania. Sharples (2006) also provides relevant information with an analysis of storm-surge flood levels (see section 4.3, pages 78–88, and in particular, Figure 18, page 84).

Figure 1 indicates that Tasmania can be broadly divided into three tidal zones: Bass Strait; a transitional zone for the northern half of the east coast; and the rest of the State. Such divisions are largely confirmed by the analysis in Sharples, with the exception of the west coast. The Sharples analysis indicates that the northern half of the west coast should also be considered as a transitional zone. For the transitional zone, it is possible to use the mean of the tidal data from the

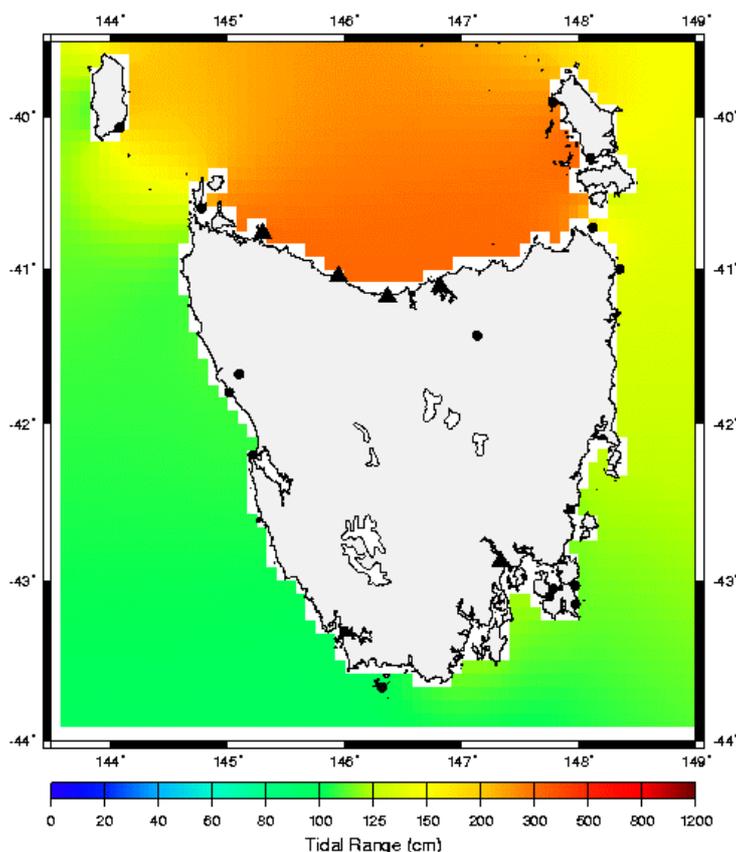
Hobart and Burnie tide gauges (see the Appendix – Selected exceedance probabilities for Tasmania).

This means that for the purposes of determining probabilities for extreme high sea-level events:

- the Hobart figures can be used for the south of the State from approximately Macquarie Harbour to Freycinet Peninsula;
- the transitional zone can be considered for between approximately Freycinet and Cape Naturaliste, and approximately Macquarie Harbour to Cape Grim; and
- the Burnie figures are generally representative of the zone through Bass Strait.

For the Furneaux Group, Burnie figures can be used for the western shorelines, while the transitional zone figures can be used for the eastern shorelines. For King Island, Hobart figures can be used for the western shorelines, Burnie figures for the eastern shorelines, and the transitional figures for the northern and southern end of the island.

Figures for the transitional zone are provided in the Appendix – Selected exceedance probabilities for Tasmania.



**Figure 1 Tidal range around Tasmania**

Source: National Tidal Centre, Bureau of Meteorology, 2007 Tide Predictions for Tasmania  
[http://www.bom.gov.au/oceanography/tides/MAPS/tas\\_range.shtml](http://www.bom.gov.au/oceanography/tides/MAPS/tas_range.shtml), accessed 4 June 2008.

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## Appendix – Selected exceedance probabilities for Tasmania

- Notes:
- Numbers refer to meters above Australian Height Datum (AHD).
  - The numbers in the Table are for 'still-water' conditions and do not include the impact of waves.
1. Transitional numbers are based on the mean of the Hobart and Burnie numbers.
  2. "Figure" refers to the Figure number in Hunter (2008) from which the data was derived.

Statistic	Hobart				Transitional <sup>1</sup>			Burnie			
	Figure <sup>2</sup>	Min	Mean	Max	Min	Mean	Max	Figure <sup>2</sup>	Min	Mean	Max
Annual exceedance probability (AEP)											
1% AEP – yr 2000	22	1.41	1.5	1.65	1.66	1.71	1.80	F 172	1.905	1.92	1.94
1% AEP – yr 2040	52	1.54	1.6	1.74	1.80	1.84	1.91	F 202	2.06	2.07	2.08
1% AEP – yr 2100	142	2.09	2.15	2.2	2.40	2.45	2.50	F 292	2.7	2.75	2.8
Exceedance Probability (Asset life 100yrs)											
90% EP (100yrs) – yr 2000	30	1.36	1.4	1.46	1.63	1.66	1.69	F 180	1.9	1.91	1.92
90% EP (100yrs) – yr 2040	60	1.45	1.5	1.55	1.70	1.74	1.78	F 210	1.95	1.97	2.0
90% EP (100yrs) – yr 2100	150	1.63	1.72	1.81	1.87	1.94	2.00	F 300	2.11	2.15	2.18
80% EP (100yrs) – yr 2000	30	1.39	1.45	1.54	1.65	1.69	1.74	F 180	1.91	1.92	1.94
80% EP (100yrs) – yr 2040	60	1.48	1.55	1.63	1.73	1.78	1.83	F 210	1.97	2.0	2.025
80% EP (100yrs) – yr 2100	150	1.71	1.83	1.96	1.95	2.03	2.12	F 300	2.19	2.23	2.27
70% EP (100yrs) – yr 2000	30	1.41	1.49	1.61	1.66	1.71	1.78	F 180	1.91	1.925	1.951
70% EP (100yrs) – yr 2040	60	1.51	1.59	1.7	1.75	1.81	1.88	F 210	1.985	2.02	2.05
70% EP (100yrs) – yr 2100	150	1.79	1.92	2.06	2.04	2.11	2.20	F 300	2.28	2.3	2.34
60% EP (100yrs) – yr 2000	30	1.43	1.53	1.69			1.83	F 180	not plotted		1.97
60% EP (100yrs) – yr 2040	60	1.53	1.63	1.77	1.77	1.83	1.92	F 210	2.01	2.03	2.075
60% EP (100yrs) – yr 2100	150	1.86	2.0	2.15	2.10	2.19	2.28	F 300	2.33	2.37	2.41

## **Appendix – Hypothetical examples of the use of exceedance statistics**

The following hypothetical examples highlight the possible application of exceedance probability and effective return period information to risk management and planning in the coastal zone. All tables and graphs referred to are from Hunter (2008), and his numbering system has been maintained.

Hunter (2008) also provides a worked example in section 9 of his Technical Report.

Most Tasmanian regulatory standards to which developments must be assessed against are defined in terms of the *annual* exceedance probability, that is, the probability as calculated for *any one year*. The worked examples in this Guide use this method of assessing probabilities and heights.

In addition, an alternative methodology is provided, based on the expected lifespan of a development. This method of considering exceedance statistics generates slightly different numbers, and can be used to communicate the level of risk an asset or development may face over its *whole* lifespan. The information can be used to give the probability that a given level will be exceeded once or more during the life of the asset. Some people may find this a more meaningful expression of the potential risk than using annual exceedance levels, which describe the chance of a particular event occurring in any one year.

The worked examples provide a brief outline of both methods of risk expression to show the alternate views of the risk faced by areas and developments.

Note that the impact of waves can be highly locally specific, and would need to be considered with respect to the particular conditions at each location.

## **Situation**

A development is proposed in south-east Tasmania on a gently sloping undeveloped waterfront block ranging from 1.4m to 2.0m above AHD. The development is expected to be in place for at least 100 years.

## **Requirements**

This situation requires the use of:

- Assessing risks as they are now, and in the year 2100;
- Risk standards used in regulation of 1% annual exceedance probability.

The relevant charts from Hunter (2008) are for Hobart, Table 79 and Figures 142 and 143.

## **Interpretation**

There are a number of different ways of interpreting the above information.

### Elevation

- In 2000, the annual exceedance level for 1.4m AHD is approximately 2% (figure 142) (range 1.4–3%, table 79). The return period is just over 40 years (figure 143) (range 32.9–73.5 years, table 79).
- By 2100, the annual exceedance level for 1.4m increases to around 67% (figure 142) (range 65.3–68.1%, table 79) with an effective return period of 0.9 years (table 79).
- This means for the lower side of the block that the chance of flooding in a single year has risen significantly from very low (2%), to a 67% chance by the end of the century.
- For the upper side of the block (2m), the chance of flooding in the year 2000 has not been calculated because it is so low.
- By 2100, the annual chance of flooding at the top of the block is around 3% (figure 142) (range 2.3–3.9%, table 79). The effective return period for such events is around 35 years (figure 143) (range 25.1–43.9 years, table 79).

### Flooding risk

- In 2000, the 1% annual exceedance probability corresponds to an elevation of nearly 1.5m AHD (range 1.4–1.6m) (figure 142).
- By 2100, the 1% annual exceedance probability corresponds to a height of around 2.15m AHD (figure 142).

### Risk during whole asset life

The above information defines the risk in terms of *annual* exceedance probability. The following identifies the risks associated with the chances of flooding during the whole lifespan of the development. The following uses table 83 and figures 150 and 151 of Hunter (2008).

- In 2000, at the lower side of the block (1.4m), the probability of water reaching this level is around 90% (figure 150) (range 74.4–95.2%, table 83). The return period for such events is around 43 years (figure 151) (range 32.9–73.5 years, table 83).
- By 2100, the same chance of flooding (90%) and the same effective return period (43 years) corresponds to a height of just above 1.7m AHD (range 1.62–1.81m) (figure 150 and 151).
- By 2100, the chance of water reaching the lower part of the block (1.4m) is almost certain (exceedance probability of 100%) (figure 150). The effective return period for such events can not be extrapolated from the available data, but is probably reasonably short (between 10 and 20 years, figure 151).
- At the upper side of the block (2m), in 2000, the exceedance probability and return periods can not be projected, but the graph (figure 150) suggests that the chance of flooding is very low.

- By 2100, the upper side of the block at 2m has a chance of flooding of around 60% (range up to 75%) (figure 150). The effective return period for such events is extrapolated as just over 100 years (range down to nearly 70 years) (figure 151).

### **Discussion**

While the area would seem to be relatively 'safe' from flooding in the context of the year 2000, sea-level rise will cause the chance of flooding of at least some parts of the block to increase substantially. With the development expected to be in place for at least 100 years, the changing 'hazard' conditions need to be considered.

For the regulator of the development who needs to apply a standard level of flooding risk acceptance, the level at which the development is set will be considerably different if current or projected future conditions are used. For example, the 1% annual exceedance probability is, for the year 2000, nearly 1.5m. However, the same hazard exposure in 2100 corresponds to a height of 2.15m AHD.

This means that critical floor levels that need to be kept above this level of risk of flooding will need to be set substantially higher than would otherwise be set if this information was not considered. It should also be noted that some regulatory instruments, such as the *Building Act 2000*, also include an additional 'freeboard' to assist with addressing the impact that local waves may have.

Such information also does not provide any direct evidence of what erosion may occur as a result of the impact of increased flooding. It would be expected though that soft sediments would be subject to increased erosion. Therefore, foundations would need to be constructed in such a way as to cope with the possible removal of the surrounding substrate.

## **Situation**

An existing car park on the north-west coast at 2.0m above AHD. Its use as a car park is still expected in 2040.

## **Requirements**

This situation requires the use of:

- Assessing risks as they are now, and in the year 2040;
- Risk standards used in regulation of 1% annual exceedance probability.

The relevant charts from Hunter (2008) are for Burnie, Table 109 and Figures 202 and 203.

## **Interpretation**

There are a number of different ways of interpreting the above information.

### Elevation

- In 2000, the elevation 2.0m AHD was unlikely to be inundated by historically recorded storm surges (figure 202).
- By 2040, the annual chance of flooding for the elevation of 2.0m will rise to approximately 9% (figure 202) (range 8.2–9.5%, table 109), with an effective return period for such events of just over 10 years (figure 203) (range 10.1–11.9 years, table 109).

### Flooding risk

- In 2000 the 1% annual exceedance probability corresponds to an elevation of about 1.92m AHD (range 1.91–1.95m) (figure 202).
- By 2040, the 1% annual exceedance probability corresponds to an elevation of 2.07m AHD (range 2.06–2.08m, figure 202).

### Risk during whole asset life

The above information defines the risk in terms of *annual* exceedance probability. The following identifies the risks associated with the chances of flooding during the whole lifespan of the development. The following uses table 112 and figures 208 and 209, which takes a precautionary approach and is based on a 50 year asset life, as tables for 40 years are not available in Hunter (2007):

- In 2000, the chance of storm surges exceeding the 2.0m elevation (ie flooding of the area) is very unlikely (figure 208).
- By 2040, the chance of the area having been inundated at least once during the life of the asset rises to around 70% (figure 208) with a possible range 56.5–78.8% (table 112). The effective return period for such flooding events reduces to just over 40 years (figure 209) (range 32.3–60.2 years, table 112).
- To maintain a whole-of-life exceedance probability the same as in 2000 (ie, unlikely), by 2040 the elevation of the area would have to be increased from 2.0m to over 2.1m.
- To maintain a whole-of-life return period the same as in 2000, by 2040 the elevation of the area would have to be increased from 2.0m to just over 2.1m (figure 209).

## **Discussion**

In this hypothetical example, the annual chance of the area being inundated increases from 'unlikely' in the year 2000 to around 9% in the year 2040. The likely effective return period also becomes just over every 10 years by the year 2040. In terms of commonly used design standards (1% annual exceedance), the 2.0m elevation is adequate in the year 2000, but by 2040 an extra 15cm (ie from 1.92 to 2.07m) is required.

The 'Risk during whole asset life' indicates that by 2040, there is about a 70% chance of the area being inundated at some stage. This could further increase if the area was subject to wave impacts.

The increase in risk by 2040 may not be a major issue for a car park that has little in the way of important infrastructure on it. There would probably be a degree of inconvenience for the period it was inundated, and perhaps some damage to materials from the salt in the water. However, such flooding could be of concern where, for example, electrical services to lights or parking meters may be damaged.

## **Situation**

A south-eastern Tasmanian planner wants to manage development this century by identifying a 'coastal hazard zone' which indicates the different levels of risk that correspond to annual exceedance probabilities (AEP) of 1 in 10 (ie 10%), 1 in 20 (ie 5%), 1 in 50 (ie 2%) and 1 in 100 (ie 1%).

## **Requirements**

This situation requires the use of:

- Assessing risks as they are now, and in the year 2100;
- Risk standards used in regulation of 1% annual exceedance probability.

The relevant charts from the Technical Report are Table 79 and Figures 142 and 143 (Hunter 2008).

## **Interpretation**

This hypothetical situation requires the identification of heights that correspond to particular exceedance levels.

### Flooding risk

In the year 2000, figure 142 shows the elevations corresponding to the relevant annual flooding risk levels are:

- 10% AEP corresponds to an elevation of about 1.18m AHD
- 5% AEP corresponds to an elevation of about 1.3m AHD (range approx 1.28–1.32m)
- 2% AEP corresponds to an elevation of about 1.42m AHD (range approx 1.37–1.5m)
- 1% AEP corresponds to an elevation of about 1.56m AHD (range approx 1.42–1.72m)

By the year 2100, figure 142 shows the elevations corresponding to the relevant annual flooding risk levels are:

- 10% AEP corresponds to an elevation of about 1.84m AHD
- 5% AEP corresponds to an elevation of about 1.95m AHD (range approx 1.91–1.98m)
- 2% AEP corresponds to an elevation of about 2.08m AHD (range approx 2.02–2.14m)
- 1% AEP corresponds to an elevation of about 2.2m AHD (range approx 2.1–2.3m)

## **Discussion**

Different types of development can accommodate different levels of risk of flooding. For example, the decking of a jetty can be inundated regularly, and it generally only causes an inconvenience at the time. Likewise, it is possible for the risk of flooding to be reasonably high for an area used as a car park. It is an inconvenience at the time, but there may be little long-term damage caused. However, other infrastructure, such as hospitals, are of such importance and potentially vulnerable to damage that they should not be exposed to even low levels of risk.

Using the degree of flooding risk identified above, the types of development that are acceptable for each zone can be better understood. It should be noted that depending on the local conditions, an additional amount may need to be added to allow for the impact of waves.

The changing environmental conditions projected for this century highlight that the risks associated with a zone determined by current conditions will increase significantly by the end of the century.

In this example, the planner could set a range of development zones based on the levels projected for 2100 and thereby ensure that the level of risk does not exceed design standards this century. Alternatively, the planner could take an approach of moving hazard zones, where it is recognised that for any particular area, the risks will gradually increase through time, and mitigation activities

will be taken when this occurs to accommodate the increased level of risk. This could take the form of a development being modified as soon as the area is assessed as having a higher level of risk. Another option would be for any redevelopment occurring in the future to be done in accordance with the newly assessed level of risk, and perhaps also require that existing structures are also modified to reflect the higher level of risk.

