BACKGROUND REPORT

Coastal flooding

Review of the use of Exceedance Statistics in Tasmania

Department of Primary Industries and Water

Tasmania
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Introduction

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

There are a number of ways of expressing exceedance statistics. A review of usage was prompted during initial stakeholder consultation on a Technical Report by Dr John Hunter. It became clear that there was an element of confusion about what exceedance statistics actually meant, which one should be applied in certain circumstances, and what was actually being referred to in a number of current Tasmanian land use planing and building standards.

Examples from a number of regulatory instruments, directives and guidance material in Tasmania and from other jurisdictions, highlight that that there are a number of ways exceedance statistics can be used, and that there are some examples of unclear use. The review highlights that for the purposes of the Climate Change and Coastal Risk Management Project, clarity and consistency in the use of exceedance statistics is important, and will aid communication of the actual level of 'risk' in risk management planning.

The purpose of the review was to obtain a clearer understanding of the use of relevant statistics, and to help guide further development of extreme sea-level statistics for use in risk management planning.

The review has indicated that the most appropriate exceedance statistic to be used in Tasmania, and in the Climate Change and Coastal Risk Management Project, is annual exceedance probability.

Background

The need for a review was recognised while undertaking an analysis of historical and projected sea-level extremes for Hobart as part of the Climate Change and Coastal Risk Management Project coordinated by the Department of Primary Industries and Water. In particular, recognising that the lifespan of an asset – or 'asset life' – influenced the level of risk that development faced due to coastal inundation and sea-level rise. The longer an asset exists at a location, the greater the chance a significant flooding event will impact on the asset. Discussions with key stakeholders also indicated there was doubt as to what was being referred to when the common usage phrase of "1 in 100 year flood" was used.

The need for a clearer understanding lies in the following question about the phrase "1 in 100 year flood": Was this the 1 in 100 chance an event would occur at some time during the life of the asset, or was it the 1 in 100 chance that an event would occur in one year?

Exceedance Statistics

There are a number of ways that the chance of an event occurring can be expressed. These are called exceedance statistics, and 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.

Return period and exceedance probability are commonly used. Return period usually refers to the average time between events of a certain magnitude, while exceedance probability indicates the chance an event of a particular magnitude will occur in a certain period of time. A detailed description of the different statistics is provided by Hunter (2008) *Historical and projected sea-level*

extremes for Hobart and Burnie, Tasmania, A Technical Report by the Antarctic and Climate and Ecosystems Cooperative Research Centre, commissioned by the Department of Primary Industries and Water, Tasmania. There is also a number of other reference documents that provide such information – some are listed in the section of the Appendix titled 'Other jurisdictions'. The Bureau of Meteorology also provides a useful summary at http://www.bom.gov.au/hydro/has/ari_aep.shtml.

In addition, Hunter (2008) also explains the importance of the asset life. The longer the time frame being considered, the greater the chance of an event of a particular magnitude being experienced at some stage during that time frame. For example, while there is a chance of a major event occurring this year, it is reasonably small. However, if the next 100 years is considered, then it is much more likely that such a major event will occur at least once during that time. There is also the complication that while some statistics can be considered the inverse of one another over longer time frames, the clear relationship is not appropriate for short time scales (especially less than 20 years).

Current use of Exceedance Statistics

A review was conducted during January to March 2007. It examined a range of Tasmanian regulatory instruments, and selected national and international documents, for their use of exceedance statistics. Not all were specific to coastal issues; some deal with riverine flooding, but have been included as the issues and statistics are closely related.

The range of Tasmanian, national and international examples of use of exceedance statistics are outlined in the Appendix – Examples of use.

The range of examples given highlight that there is a general trend for standards to be expressed as either *annual exceedance probability* or in terms of *average recurrence interval*. There are a number of Tasmanian examples that are not so specific about the statistic being referred to. General usage and common understanding would probably suffice on most occasions, especially as the resulting mapping is generally provided by consultants who are experienced in the area and are therefore correctly applying the relevant statistic.

The Technical report by Hunter (2008) highlights the impact that the length of time the statistic is considered over can have on the resulting flooding 'height'. Clear expression of the statistic being referred to is therefore important to ensure that the appropriate level is being used.

Across the range of national and international documents reviewed, the 1% annual exceedance probability, or the 100 year average recurrence interval (ARI), are the main standards used. Some areas also consider the 200 year ARI and the 50 year ARI. In Tasmania, the expression of risk in planning and building terms is generally as the *annual exceedance probability* rather than *average recurrence interval*.

Conclusion

It is important though for planning and management activities to recognise that there are particular criteria applied to the calculation and mapping of hazard zones, and that it is necessary to correctly refer to hazard statistics to ensure that there is no confusion as to what is being referred to.

For the purposes of a clearer understanding of exceedance statistics within the Tasmanian context, it is recommended that it is generally appropriate to refer to '1% annual exceedance probability', which is also expressed in terms of a 1 in 100 chance that an event will occur in any one year.

Appendix – Examples of use

The following are a list of examples of where exceedance statistics are currently being used in Tasmania, and in selected national and international documents. The review was conducted during January to March 2007.

Note: Abbreviations used in this Appendix include:
- Annual Exceedance Probability (AEP)
- Average Recurrence Interval (ARI)

Tasmania

Building Regulations

The Building Regulations 2004 define a floodplain area for a number of major watercourses based on annual exceedance levels.

> *s12. For the purposes of section 159 of the Act, the following is the designated flood level:*
> *(b) the level which has a 1% probability of being exceeded in any year for the following watercourse floodplains: …*

Flood plain mapping (riverine)

Flood plain mapping done for the then DPIF, and undertaken by the HEC) in the 1990s have used the following with the addition of a note:

> *…subject to inundation by a flood of 1:100 (AEP) severity, and for smaller floods having AEP's of 1:50 and 1:20 years….*
> *…*
> *Note : The AEP of 1 : 100 is the probability, on the average that a given flood height will be equalled or exceeded in any year. The 1 : 100 AEP flood height has a 1% chance of being exceeded in any one year.*

Annual Exceedance Probability	*Probability of the Design Flow Being Equalled or Exceeded at Least Once In a…….*	
	20 Year Period	*50 Year Period*
1:100	*18%*	*39%*
1:50	*33%*	*64%*
1:20	*64%*	*92%*

Similar work by Hobart Water (undertaken by Hydro Tasmania in ~2002–4) has used:

> *One in 100 year ARI*

In Launceston, hazard mapping has been done for several Average Recurrence Intervals:

> *200 Year ARI, 100 Year ARI, 50 Year ARI, 20 Year ARI*

Other related datasets for Launceston provide for the same time intervals, but describe the mapping slightly differently, for example:

> *expected area affected in a 1:100 year flood inundation event*

Planning Schemes

Draft Central Coast Planning Scheme 2005 includes a Coastal and Riparian Schedule (S6) that uses annual exceedance levels[1]:

> *flood prone land means:*
> *(a) land identified in the Lower Forth Flood Evacuation Plan with a 1 in 200 Annual Exceedance Probability; and*

[1] S6.3.1, p111

(b) land known, or likely, to be subject to flooding in a 1 in 100 Annual Exceedance probability.

The West Tamar Planning Scheme (9 August 2005) uses:

S4.4 Excavation and Filling
Excavation or filling does not:
c) increase run-off characteristics for storm events up to at least the 1 in 5 year design storm;

The Kingborough Planning Scheme 2000 includes a natural hazards principle in the Environmental Management Schedule, with the Acceptable Solution[2]:

Principle - Areas of natural hazard will be avoided or suitable strategies to minimise risk applied.
1.2.2.1 Avoidance of hazard: All applications for use or development is to
(e) be located outside the 1 in 100 year flood limit of the local drainage catchment.

Kingborough also deal with Road and Access Construction in Schedule 5 Waterways, Wetlands and the Coastal Area[3]:

5.2.3.3 Bridges and crossing design for flood: Permanent bridges and crossings are to be designed to withstand the 1 in 50 year flood level and not obstruct fish passage.

The Brighton Planning Scheme 2000 includes two important sections in the 7.3 Waterway Overlay[4]:

7.3.7 A permit must only be issued for development located within the Waterway Overlay between the 1 in 20 year and the 1 in 100 year flood levels where:-
(a) building densities do not exceed one habitable building per hectare below the 1 in 100 year flood level;
(b) habitable buildings are erected as high on the block as practical, given title boundaries, access and service infrastructure;
(c) the lowest habitable floor level is not below the 1 in 100 year flood level; and
(d) there is an emergency access route for vehicles from any habitable building to a public road that is at no point more than 30 cms below the 1 in 100 year flood level.
7.3.8 All development within the Waterway Overlay below the 1 in 20 year flood level is Prohibited, except for necessary minor buildings and structures including open fences, stockyards, open sided barns and pump houses.

Brighton also includes in the Environmental Management Standards[5]:

Issue 3: Natural Hazards *Areas subjected to hazard will be managed to minimise the need for remedial or engineering works to protect property or human life.*	
A3 Use and development must:- *(a) Not have a floor area less than 300mm above the 1 in 100 year flood level;* *(b) be located further than 30m measured horizontally from the furthest land-bound extent of the wetland to minimise the risk of disturbance and shoreline* *recession; and* *(c) be located further than 10m from the outer limit of a waterway to avoid erosion.*	*P3 A use or development within an area of flooding, erosion, landslip, wetlands, coastal inundation or other similar hazard must provide a site plan in accordance with Part 3 of the Scheme that demonstrates measures to:-* *(a) Minimise the effects of these hazards;* *(b) Avoid damage to or loss of buildings, structures, access roads, or other works;* *(c) Prevent the effects of any hazard being increased; and* *(d) The need for future engineering or remediation works is minimised.*

Brighton have the following specifications in Schedule 5 Coastal And River Foreshore Development[6]:

S5.1. The purpose of the Coastal and River Foreshore Development Schedule is to control development that may cause environmental harm to foreshore areas and the waters of the Jordan or Derwent Rivers.
S5.3. An application for development or use which is proposed within 30 metres of the High Water Mark of the tidal reaches of either river shall be accompanied by a report demonstrating that the proposal will satisfy

[2] p95
[3] p128
[4] p81
[5] Schedule 4 p122–123
[6] p127

the State Coastal Policy and that any building will not be subject to inundation from the 1 in 100 year estimated flood levels (ie. 3 metres AHD).

In the West Coast Planning Scheme 2002, there is a Wetlands and Waterways Code that deals with the issue of Road and Private Roadways Construction[7]:

5.6 Permanent bridges and crossings are to be designed to withstand the 1 in 50 year flood level.

The draft Standards developed for the review of the State Coastal Policy in 2005 included development standards for flooding, and the Acceptable Solution[8]:

Buildings and works (including depositing fill) are located outside land mapped as within a 1 in 100 year flood area.

In the Waratah-Wynyard Planning Scheme 2000

Table 12.1 Issue 4.0:- Flood, Storm, Surge and Landslip Hazards
Objective: To ensure use or development mitigates risk from flooding, storm surge and landslip.
4.1 No development is to be undertaken on any part of the site which has the following characteristics:
(a) located on an active floodway or within the 1-in-100 year flood risk area; or

and

Table 16.1 Issue 4.0:- Roads and Private Roadways Construction
Objective: To ensure that roads and private roadway tracks do not result in erosion, siltation or affect water quality of wetlands and waterways.
4.6 Permanent bridges and crossings are to be designed to withstand the 1 in 50 year flood level.

Other jurisdictions

Other Australian jurisdictions

The following are samples of the use of exceedance terminology used in other Australian jurisdictions.

NSW Coastline Management Manual[9]
New South Wales Government, September 1990.

Excerpt from Appendix B: Coastline Processes: Appendix B3 - Storms

8 THE DESIGN STORM EVENT

Typically, coastline hazard is assessed in terms of the likely impact of a design storm event. The selection of an appropriate design event is governed by many factors, including safety aspects, likely damage and social disruption, all of which depend upon the type and nature of the development. It should be noted that longer term coastal changes, such as shoreline recession and sea level rise, also affect the damage potential of the design storm event. Recession exposes additional development to storm hazard; elevated sea levels allow larger storm waves to attack the coast.
Typically, a design storm event is specified in terms of its "Annual Exceedance Probability" (AEP), e.g. the 5% storm event. There is a 5% chance of such a storm occurring in any year. On average five such storms would be expected to occur in a period of 100 years, i.e. the average recurrence interval of a storm of this severity is 20 years.
The coast can experience the design storm event at any time. Long periods of relative calm, as experienced in the past decade, can give a false sense of security

Excerpt from Appendix B: Coastline Processes: Appendix B5 - Waves

4 STATISTICAL REPRESENTATION

Wave behaviour in the ocean is far more complex than depicted in Figure B5.1. The area of interest may be subject to swell waves arriving from a number of different fetches and to locally generated wind waves. Waves arriving from different directions can generate a very confused sea surface which takes on a "choppy" appearance.
Observed wave behaviour is the result of interactions between all wave trains arriving at a location, as shown in Figure B5.2. Thus, wave behaviour is inevitably characterised by a range or "spectrum" of wave heights, periods, lengths and directions of travel. Consequently, it is appropriate to treat wave parameters in a statistical fashion.

[7] p181
[8] p9
[9] http://www.environment.gov.au/coasts/publications/nswmanual/index.html

It is often extreme events that are of interest, although periods of calm or average conditions are also important for coastal processes. A common means of presentation of wave climate is in terms of an exceedance plot whereby wave height (or some other parameter) is shown as a function of Annual Exceedance Probability (AEP - see Appendix B3).

Department of Sustainability and Environment (State of Victoria)[10]

Floodplain Management

What is a Floodplain?

A floodplain is the low lying land bordering a creek, river, lake, sea coast or artificial channel. In Victoria floods are usually caused by heavy prolonged rainfall.

This produces surface runoff which flows overland into rivers and streams. When there is a large amount of runoff, water overflows the river banks onto the adjacent floodplain causing land to flood.

Built up urban land can be affected by overland flows that occur during severe storms when the capacity of drainage systems is exceeded.

For planning purpose the 1% probability (one in a hundred year) flood is used to identify land which is liable to flooding. This is determined from data obtained from previous floods and from flood studies.

Gippsland Lakes Flood Level Declaration 2005[11]:

' What are flood level guidelines?

Flood levels provide an estimate, based on historic data and other available data, of how high flood waters are likely to rise. A 'one in 100 year' level is an indication of the highest level likely to occur at least once every 100 years. Similarly, a one in 50 year level is that expected once every 50 years, and so on. In Victoria, planning requirements are based on one in 100 years levels.'

Gold Coast City Council[12]:

'What is a "100 year ARI"?

ARI = Average Recurrence Interval. When talking about floods, this is an indication of how frequently a flood of a particular size is likely to occur on average. Therefore, a flood the size of a 100 year ARI flood is likely to occur once in 100 years on average, but it has a 1% chance of occurring in any one year. A flood the size of a 10 year ARI is likely to occur once in 10 years on average, and it has a 10% chance of occurring in any one year.

Will a flood with a "100 year ARI " occur only once in 100 years?

As this is often referred to as the "100 year flood", it is tempting to think that it will only happen once in 100 years.

A "1 in 100 year ARI" refers to the magnitude or size of a flood. It means that a flood of that size or larger is likely to occur only once in 100 years, but it has 1 chance in 100 (1%) of occurring in any year. However, the rainfall events which cause floods are random and there is no guarantee when such a flood will occur, nor that it won't be much larger.

In fact, floods of that size have been known to occur more frequently than once in 100 years. Kempsey in northern NSW experienced two floods of this size in eight months in 1949 and 1950. During the 1890s the Brisbane River experienced three 100 year ARI floods over a period of five years. (Floodplain Management in Australia: Best Practice Principles and Guidelines, CSIRO, 2000)

Floods will happen. There is approximately a 50% chance of experiencing a 1 in 100 year ARI flood at least once in a 70 year lifespan. (Floodplain Management in Australia: Best Practice Principles and Guidelines, CSIRO, 2000) '

Water Facts, Government of Western Australia[13]:

[10] http://www.dse.vic.gov.au/DSE/wcmn202.nsf/LinkView/0CC261CDFFD0F000CA2572450007EBF6E2435AAD7CBD0079CA256FEB001C70C6

[11] http://www.wgcma.vic.gov.au/mediaLibrary/files/Floodplain_Drainage/FloodLevelsQA.pdf

[12] http://www.goldcoast.qld.gov.au/t_standard.aspx?pid=334#5

[13] portal.environment.wa.gov.au/pls/portal/url/ITEM/DC6A0B38F76C856BE03010AC6E051BDF

'Average recurrence interval (ARI) - A statistical estimate of the average period in years between the occurrence of a flood of a given size or larger. The ARI of a flood event gives no indication of when a flood of that size will occur again.

100 year ARI flood - A flood having an average recurrence interval (ARI) of 100 years. This flood has a 1% chance of occurring in any one year and has a 50% chance of being experienced at least once in a person's life time. The 100 year ARI flood has been generally adopted in Australia and overseas as the basis for floodplain management planning.

NSW Planning Reform: 31 January 2007 - New guideline to the Floodplain Development Manual[14]:

' The Guideline confirms that, unless there are exceptional circumstances, councils should adopt the 100-year flood as the Flood Planning Level (FLP) for residential development. In proposing a case for exceptional circumstances, a council would need to demonstrate that a different FPL was required for the management of residential development due to local flood behaviour, flood history, associated flood hazards or a particular historic flood.'

International

New Zealand

The Hawke's Bay Regional Council defines risk in terms of annual exceedance[15]:

Inundation Risk Areas

Land covered by the Extreme Inundation Risk Zone (EIRZ) means that those areas are at risk of damage from coastal inundation from a storm event with a 1 in 50 chance of occurring each year. That land is also at risk from wave damage or flooding due to waves travelling up the beach and overtopping the beach berm.

Land covered by the Moderate Inundation Risk Zone (MIRZ) means that those areas are at risk of damage from coastal inundation from a storm event with a 1 in 50 chance of occurring each year.

[14] http://www.planning.nsw.gov.au/planning_reforms/index.asp
[15] http://www.hbrc.govt.nz/Coast/CoastalHazards/tabid/143/Default.aspx