DEVELOPING HAZARD LINES IN RESPONSE TO FLOODING AND SEA LEVEL RISE

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Introduction:

2011 was deemed 'year of the flood' after the summer months bought flooding to much of Southern and Eastern Australia. Within the coastal zone, floodwaters caused extensive damage to property and lives and caused lengthy disruption to services and livelihoods.

Coastal flooding can be caused by either storm surge (a temporary rise in ocean levels), extreme rainfall in the coastal catchments or a combination of both. The risks of coastal flooding are significant due to high likelihood of floods occurring (the coastal zone generally experiences more extreme rainfall than inland areas), the high vulnerability (coastal areas are generally low lying) and large consequences (the majority of Australia's population and infrastructure are located within the coastal zone).

In addition, the risk of coastal flooding may be magnified because of human induced climate change. That is, as ocean and atmospheric temperatures warm, sea levels will rise and the frequency, magnitude, and location of extreme weather events may change leading to an enhanced risk of coastal flooding. In an attempt to address this, in 2009 the NSW State Government's 'Sea Level Rise Policy' set benchmarks of a 0.4m increase by 2050 (compared with 1990 levels) and 0.9m increase by 2100 (compared with 1990 levels) (DECC 2009). These benchmarks for the first time fixed climate change risk into policy and created a new flood level for planning authorities to meet.

Despite the NSW Government (2009) benchmarks, long-term management of flood has been left largely to local planning authorities. One response from councils has been to develop "hazard lines." Hazard lines are used in coastal planning to identify where hazard areas exist under current and projected future climate conditions. The hazard areas are then used to inform management, adaptation, and planning strategies.

Identifying hazard areas is complex – they are associated with numerous uncertainties and assumptions. And their implications are significant - setting the hazard area too low could leave councils at risk of future liability if property and/or livelihoods are damaged, and too high will negatively affect property values and economic. Planning restrictions on the grounds of flooding are also becoming increasingly challenged in court. As such, the formation of hazard lines must be be transparent and strive towards accuracy.

This paper outlines the steps, assumptions and key complexities that arise when developing and applying hazard line benchmarks, and provides a case study of the approach followed by one NSW Local Council (Lake Macquarie City). The paper also summarises the uncertainties associated with issues such as setting baseline conditions, co-incidence of storm surge and catchment flooding, shoreline erosion, applying freeboard and how to deal with a moving level of risk. The paper provides discussion into why these factors are significant, as well as providing an approach that could be adopted by other estuary councils to help create consistency in coastal hazard line development.

What is a hazard line?

A hazard line is an arbitrary line that can be drawn on a map to indicate where a hazard may occur. Specific to flooding, a hazard line is a vertical measurement that can indicate the projected flood for an accepted level of risk.

Under current flood risk planning, hazard lines have generally been based on the 1:100 year Average Recurrence Interval (ARI) flood level. The 100-year ARI (equivalent to the 1% Annual Exceedance Probability) has been adopted by many authorities throughout Australia as an almost uniform standard for flood-related planning controls. The 100-year ARI flood has also been used to define the 'floodplain' or the 'limit of flooding' in many cases. The consequences of flooding above this level have, in the past, been largely overlooked (Bewsher et al. 2003).

Why develop hazard lines?

Australians love the coast – over 85% of Australians live within the coastal zone and it is an area of significant economic and environmental value (DCC 2009). Growth in coastal regions across Australia is also increasing. Hazard lines have the ability to balance growth against potential risk.

The definition of risk management in the NSW state Floodplain Management Manual is *"ensuring optimal use of the floodplain whilst controlling flood losses to an acceptable level"* (DIPNR 2005). Hazard lines are developed to allow us to continue maximising the benefits of the coastal zone while minimizing flood risk.

Stemming from this reason, there are now several legal requirements that have lead to the development of hazard lines by local councils:

Integrating Climate Change into Flood Plain Management Plans

Councils have a responsibility under the Local Government Act 1993 (section 733) to manage flood liable land, and are guided in this through the Floodplain Development Manual (DIPNR 2005).

As a result of growing awareness on climate change and the impacts of rising sea levels, the manual has been updated by the *Floodplain Risk Management Guideline: Practical Consideration of Climate Change (DECC 2007)* and more recently *the Flood risk management guide – incorporating sea level rise benchmarks into flood risk assessments* (DECCW 2010a). As such, it is now mandatory when reviewing Local Government flood manuals to incorporate sea level rise when identifying flood risk.

Exempt and complying development

The NSW State Government has a State Environmental Planning Policy (SEPP) for Exempt and Complying Development Code 2008. This code is designed to 'remove red tape for low risk and low impact development' by allowing some developments to no longer require a Development Application. The code was updated in February 2011 to widen the scope of development that could be considered under the code. As a result, developments on lots that are within a flood control were then potentially eligible to use the code (DoP 2011).

The Code will apply to a development unless a property is classified:

(d) a high hazard area

(e) a high risk area

A problem with this code in light of sea level rise is that properties that are currently not classified as high hazard from flood may be so in the future as a result of rising sea levels. Therefore, in order to apply development controls, these properties need to be 'tagged' as unable to comply with the code.

Developing hazard lines within the local Flood Plan can ensure these properties require a DA through council.

Legal liability:

Local Government has a clear responsibility to address the issue of climate change in a range of legislative, policy and guideline documents managed by the State and Federal Governments (WSC 2011). The Chief Judge of the Land and Environment Court of NSW suggested:

"*The possibility that Local Government will be held liable for losses arising from climate change, if they are unwilling to take its impacts into account at decision-making stages and integrate their planning decisions*"

Councils have an obligation to develop accurate and robust hazard areas and then apply them within their planning framework.

Development of hazard lines:

So far, there has been no national standard on developing hazard lines. The most significant contribution from the Commonwealth Government has been to publish the *Risks to Australia's coast* report (DCC 2009) and it's supplement *Climate Change Risks to Coastal Buildings and Infrastructure* (DCCEE 2011) which used a sea level rise projection of increase of 1.1m by 2100 as their benchmark.

At a state level, the NSW State Government has taken significant steps in developing a policy on managing sea-level rise. A key document in developing hazard lines was the *Sea Level Rise Policy NSW*, which adopts the benchmarks of 0.4m by 2050 (on 1990 levels) and 0.9m by 2100. (DECC 2009)

Consequentially, the *NSW Coastal Planning Guideline: Adapting to sea level rise* was released (DOP 2010). This guideline provided guidance on how sea level rise should be considered in land use planning and development assessment in coastal and estuarine areas. The guideline provides a basic diagram for how to incorporate the sea level rise benchmarks into hazard areas for both coastal flooding (including estuaries and coastal lakes) and coastal erosion (Figure 1).

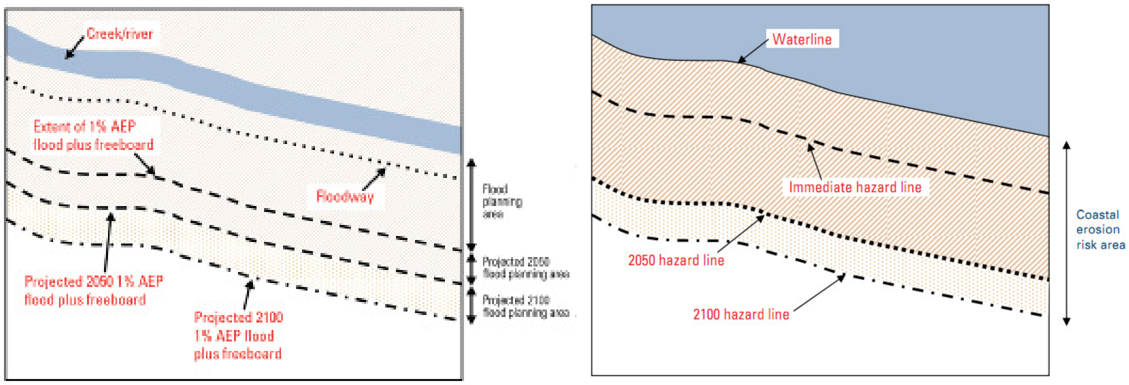

Figure 1: Coastal Flood Risk Areas and Coastal Erosion Risk Areas (DOP 2010)

Generally, the guideline recommends that flood hazard mapping continue to use the 1% AEP however to then model the impact of sea level rise on top of this level.

Following on from this guideline, the State Government released two management guides, for ocean and estuary areas. There is a significant difference in the way sea level rise will affect open oceanic shorelines to other enclosed estuary shorelines, and therefore both require different management guides.

The *Coastal risk management guide- incorporating sea level rise benchmarks into coastal risk assessments* (DECCW 2010b) updates the sea level rise information in the *NSW Coastline Management Manual* (DIPNR 2005). The guide is targeted to open coastal shores and includes details about sea level rise as well as setting erosion hazard areas, largely based on the Bruun Rule.

The *Flood risk management guide – incorporating sea level rise benchmarks into flood risk assessments* (DECCW 2010a) updates the sea level rise information in the *NSW Floodplain Development Manual* (DIPNR 2005) and should be read in conjunction with the Manual. The guide also updates the sea level rise section of the *Floodplain Risk Management Guideline: Practical Consideration of Climate Change* (DECC 2007).

This guide includes an appendix with advice for setting and modelling ocean boundary conditions for hydraulic flood modelling in tidal waterways. It also provides advice on setting flood risk for estuaries – it states 'for planning purposes on estuarine foreshores, in the absence of better information, it is recommended that estimations of recession due to sea level rise use the same *'Bruun Rule'* approach with relevant average foreshore slopes inferred or estimated from survey information'.

Application of the 'hazard line' approach – a case study from Lake Macquarie City Council

Lake Macquarie City Council (LMCC) is located around the coastal Lake Macquarie, a large estuary with over 175 km of foreshore, located just south of Newcastle, NSW. In 2011, they undertook a review of their Floodplain Management manual to incorporate climate change and as a result developed a series of hazard lines.

LMCC has close to 4000 hectares, and over 10,000 properties located below 3m AHD, adjacent to the Lake foreshore (WMAwater 2011). It has relatively few open ocean coastal properties at risk. LMCC was one of the first Australian Councils to adopt a Sea Level Rise

Adaptation and Preparedness Policy in 2008 whereby setting a projected rise in sea levels of 0.91m by 2011 on 1990 levels (LMCC 2008).

To review their Floodplain management study, LMCC engaged consultants WMAwater to develop two key documents:

1: Lake Macquarie waterway Flood Study
2: Lake Macquarie waterway Flood Risk Study and Management Plan

The Flood Study included the hydrological modelling to identify flood levels while the Management Plan identified areas within the local government area at risk from flooding and basic adaptation response options.

Outcomes of their hazard lines:

In light of the Flood Study and in discussion with internal and external stakeholders, the following flood levels were developed (Table 2). A diagram showing how these flood levels translate into hazard areas is shown in Table 3.

Table 1: Hazard levels for Lake Macquarie City Council

Hazard Area	**Level (m AHD)**	**Measure**	**Comments**
High lake hazard	0.10	Year 2011 lake mean still water level	In an estuary such as Lake Macquarie, water levels may be higher than ocean sea levels because of a narrow channel limiting water from escaping. This is referred to as 'pumping'. The Lake is currently 'pumped' up by 0.1m above mean ocean levels. The measure is the mean still water level – this is the tidal average, rather than using the Highest Astronomical tide, that is, the highest tidal height that can occur.
	< 1.00	Below 2100 lake mean still water level	Lake Macquarie City Council has adopted a 0.91m increase in sea levels by 2100 on 1990 levels. This hazard zone captures permanent inundation by 2100.
High flood hazard	1.00	Year 2100 lake mean still water level	
	1.23	Year 2011 1:20 year flood	
	< 1.50	Below Year 2011 1:100 year flood	This hazard zone is the current (2011) 1:100 ARI flood level*
Low flood hazard	1.50	Year 2011 1:100 year flood	
	1.61	Year 2050 1:20 year flood level	
	1.50 – 2.32	Between high hazard flood level and Year 2100 1:100 year flood level	
	1.86	Year 2050 1:100 year flood level	Lake Macquarie City Council has applied a linear increase of sea level rise to reach 0.91m 2100. As such, there is a projection of 0.4m AHD by 2050. This

			hazard zone also includes a 1:100 year flood level.
	2.10	Year 2100 1:20 year flood level	
	2.32	Year 2100 1:100 year flood level	

* The 1:100 year flood event includes a 1:5 storm surge to catchment event and 1:5 catchment to storm surge event.

** Future flood levels do not include any increase in the frequency or intensity of rainfall.

Table 2: Flood levels for Lake Macquarie City Council

Planning Area	**Level (m AHD)**	**Measure**	**Comments**
Flood planning level: Low density residential and commercial developments	2.36	Year 2050 Flood Planning Level	The NSW Floodplain Development Manual includes a 0.5m ‘freeboard’ in the flood floor heights for general residential development. This freeboard is to provide a factor of safety to ensure that the risk exposure selected is accommodated. LMCC has added a 0.5m freeboard to hazard areas that include periodic flooding however; it does not apply to the hazard areas that relate solely to permanent flooding. This is because for permanent flooding, an increase in floor heights is not an adequate solution for reducing sea-level rise risk.
	2.45	Year 2011 PMF	Current Probable maximum flood
	2.81	Year 2050 PMF	Year 2050 Probable maximum flood (current flood plus 0.4m)
Flood planning level: Medium density residential and mixed use developments	2.82	Year 2100 Flood Planning Level	Combination of: - 0.9m sea level rise, 1:100 year flood event and 0.5m freeboard.
	<3.00	Year 2100 Flood Planning Level “rounded up”	
	3.27 m	Year 2100 PMF	

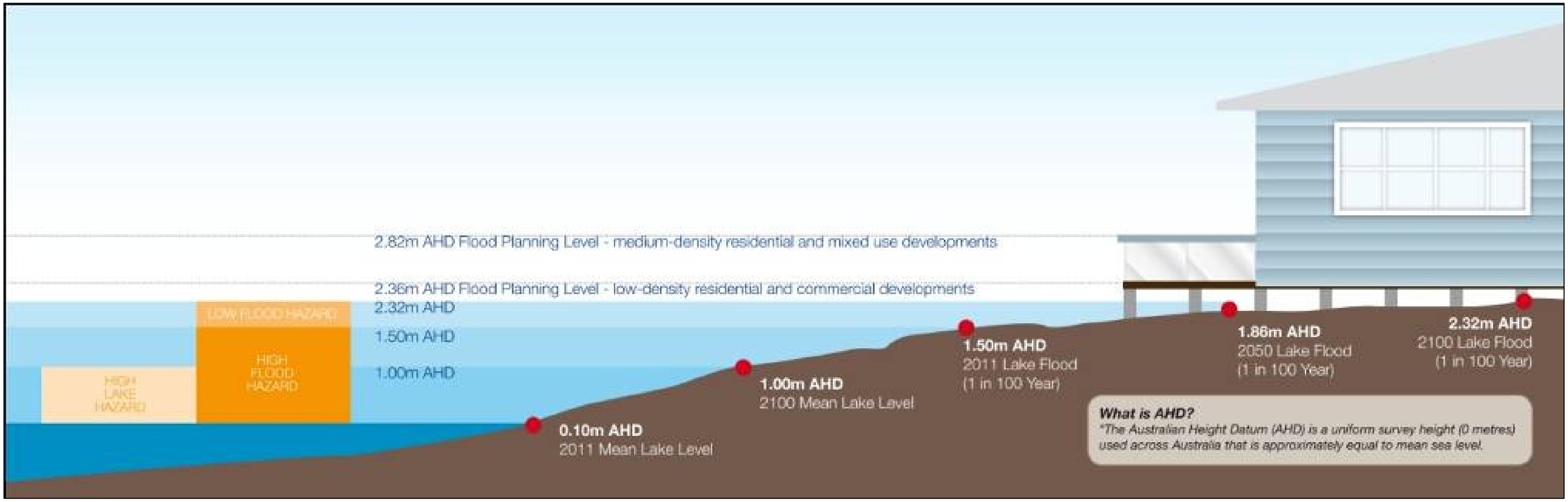

Figure 2: Schematic representation of flood hazard areas and planning floor levels.

Discussion: Uncertainties and assumptions of the 'hazard line' approach

Through the process of developing these hazard lines, both the council and the consultant managed several assumptions and uncertainties which are discussed in the following section.

Identification of baseline risk:

Before modelling future flooding, it's essential to have a good understanding of the current flood risk. This section looks at the uncertainties and assumptions in calculating the current flood climate.

Mean sea level or Highest Astronomical Tide?

There are two key options for selecting a base sea level – either the mean sea level or the Highest Astronomical tide.

Mean sea level is the average value of sea level over a period of years, to decades. Sea level varies with a wide range of time scales, including twice-daily and daily tides, meteorological fluctuations over days to weeks, and seasonal, interannual, decadal and multi-decadal variations. It is generally accepted that between 50 and 80 years of data are necessary for the estimation of the trend in mean sea level at a single site (Douglas et al. 2001)

The benefits of applying to mean sea level is that it is a good median point of the tide and does not add extra height to flood levels. Statistically, it is less likely that a severe storm surge will occur during a 'spring' 'king' high tide. However the downside is that if a storm does occur during a HAT, the flood planning levels will be insufficient.

Highest Astronomical Tide (HAT) is the highest level of water, which can be predicted to occur under any combination of astronomical conditions. Tide predictions do not include weather conditions, so technically a HAT can occur once ever 18 years the longest astronomical cycle) (OzCoasts 2011). For LMCC, the tidal fluctuations are generally ±0.05.

The benefits of applying the HAT is that if a flood event occurs during the HAT, the flood levels will accommodate for this event. However, it can also significantly add to flood planning levels - for estuaries where the tidal range is high such as Port Stephens, it can add an additional 1m.

The flaws of the stationary climate assumption

When dealing with flood risk, planners generally use exceedance statistics such as the 100 year ARI. Exceedance statistics help define a level of acceptable risk, where the balance between likely occurrence and costs of mitigating the risk are balanced (DPIW 2008).

A flaw with using exceedance statistics is that they rely on the assumption that the climate is stationarity. That is, the assumed chance of an extreme event occurring is the same from one time period (season, year, decade) to another and that probabilities estimated from historical values will be applicable in the future. However, recent research has shown that Australia's climate is inherently non-stationary and therefore that the ARI of hydroclimatic variables such as rainfall, streamflow, droughts and floods may be significantly under or over estimated depending on the climate state.

Australia's climate is driven by short and long-term meteorological mechanisms such as the El Niño – Southern Oscillation (ENSO) and the Interdecadal Pacific Oscillation (IPO). These cycles have been shown an impact on climatic conditions such as rainfall and streamflow (Verdon-Kidd et al. 2004b), forest fires (Verdon-Kidd et al. 2004a), drought (Kiem et al. 2004) and floods (Kiem et al. 2003). For example, in Kiem et al (2003) it was found that a flood equal in magnitude to the traditionally estimated (i.e. assuming stationarity) 100 year ARI flood actually occurred with an ARI of 15 during the negative (wet) phase of the Interdecadal Pacific Oscillation (IPO). In another study it was found that floods occurring during an IPO negative phase were on average 1.8 times larger than floods with the same ARI during an IPO positive phase (Micevski et al. 2006).

The implications of this for the hazard line approach is that the 100 year ARI used in identifying flood risk may be higher or lower than the actual flood risk, dependant on the period of time that the 100 year flood level was calculated.

Rainfall vs. coincidence of storm surge

The damaging effects of flooding come from two main causes – rainfed catchment flooding, and storm surge. By themselves, both can cause flooding, but when combined they exacerbate flood levels.

In the past, an approach used as been to assume 100 year ARI rainfall and 100-year ARI ocean levels are coincident, that is, a 100-year flood height from both catchment and storm surge will occur at the same time. There is validity in the assumption as the same low pressure systems that cause the catchment flood are often the cause of storm surge. However, today the assumption that a 1:100 year storm surge event would coincide with a 1:100 year catchment flood has been considered overly conservative.

In the *Flood Risk Management Guide; Incorporating sea level rise benchmarks in flood risk assessments,* under 'Envelop scenarios for determining flood planning levels and areas, the scenarios are supplied:

- Estimated 1% AEP ocean flooding with 5% AEP catchment flooding with coincident peaks
- Estimated 5% AEP ocean flooding with 1% AEP catchment flooding with coincident peaks
- Neap tide cycle with 1% AEP catchment flooding with coincident peaks

The implications of modelling the coincidence of less extreme events are that the resulting flood levels may be lower than actual flood levels. However, by assuming that a 100 year ARI or the Probable Maximum Flood (PMF) will occur simultaneously will significantly raise the flood level and create a more challenging planning response.

Future level of risk:

Once the current flood risk has been identified, the added impacts of a changing climate, specifically rising sea levels needs to be considered.

Picking a sea level rise projection:

Although sea level rise is one of the most certain implications of climate change, the amount sea levels may rise, the rate of the rise and the regionally specific consequences of sea level rise are hard to determine. As a result, several benchmarks can be used:

- NSW Government sea level rise policy states "the best national and international projections of sea level rise along the NSW coast are for a rise relative to 1990 mean sea levels of 40cm by 2050 and 90cm by 2100 (DECC 2009).
- For the year 2100, the Commonwealth Government adopted a sea level rise Figure of 1.1m in its recently complete First Pass National Assessment – climate change risks to the Australian Coast.
- IPCC projections and local conditions - The IPCC base their Figures on future greenhouse gas emission scenarios and provide a range of sea level rise projections for each scenario. In the 2007 report, the IPCC projections ranged from 0.18 to 0.59 m across all the emissions scenarios by 2090–2099 – these projections however do not take into consideration the melt of ice sheets, nor regional variation. This regional variation is the reason that the updated state benchmarks can differ slightly. The increases in sea level will not occur uniformly across the globe, with some regions experiencing higher levels of sea level rise than others. Such variations are due to variations in the thermal expansion of the ocean (CSIRO et al. 2007).

Having multiple options for sea level rise benchmarks may see neighbouring councils adopt different levels, which would create inconsistencies in planning responses. However simply adopting a Federal or even State Government estimate does not allow for the regionally specific impacts of sea level rise.

LMCC originally adopted a benchmark of 0.91m by 2100 based on IPCC and CSIRO projections (LMCC 2008). When in 2009 the NSW State Government released their level at only 0.01m less, LMCC adopted 0.9m.

Assuming a linear increase:

The NSW and Commonwealth benchmarks equates to an increase of around 1cm per year between 2010 and 2100 levels. However, the increase is not likely to be linear, and in fact speed up towards the end of the century (DECCW 2009). Another reason the rise is not a linear increase is that shoreline erosion occurs during a storm event – therefore there is a lag time between sea levels rising and the flow on erosion.

However, it is very difficult to identify the rate and extent of the rise and as such; it is commonly set as a linear increase between 1990 levels and the 2100 level. This means that at any point in time, the projected increase will be either higher or lower than the actual sea levels.

Setting the base year (and future year) for mean sea level.

Sea levels are not static, and have been rising for several thousand of years. However, because of climate change, this rate is increasing. From 1961-2003, the rate of sea level rise was 1.8m per year, with a rise of 3 mm between 1993-2003 (Church et al. 2006).

Because of this rise, the 'base' year in which the benchmarks are applied to can make a significant difference. For example, the benchmarks set by the NSW State government are an increase on 1990 mean water levels. However the Commonwealth levels are an 'increase of 1.1m over this century', which would refer to the years 2000 to 2100. Some of the Lake Macquarie City Council sea level rise guidelines refer to 'current sea levels' which would imply the year it was written.

There is over 20 year's difference between the NSW State Government benchmarks and 'current sea levels'. If sea levels have risen approx 3.4mm / year since 1993 (OzCoasts 2011) it would equate to a change in ocean levels of 0.068m. This is 17% of the 2050 benchmark! It is very hard to identify such a small change – sea levels are constantly varying because of astronomical (lunar) tides as well as storm surge, flooding and atmospheric pressure.

A second reason it is necessary to identify a base year is for mapping hazard lines. Most councils, including LMCC, use LiDAR topographic data to map their local region. However, as sea levels rise, updates to LiDAR will continue to show the waterline at 0m. Therefore, it is important that site-specific surveys use AHD (Australian Height Datum), which is a base geodetic level that will not be compromised because of sea level rise.

Changes to storm frequency and intensity

In a report done by HCCREMS (Blackmore et al. 2010) it was found that for the Newcastle region, there was a projected 4% increase in the formation of east coast lows during autumn and winter as a result of climate change. Unfortunately the current climate models are not sophisticated enough to provide information on the probability of changes in the magnitude nor frequency of these extreme maritime storms (CSIRO and BOM 2007). Therefore, although we may see an increase in the number of storms, we do not know how often or how devastating they will be.

The Floodplain Risk Management guideline plans for an increase in storm activity by recommending and increase in peak rainfall and storm volume of:

Low level rainfall increase = 10%
Medium level rainfall increase = 20%
High level rainfall increase = 30%

The guideline states that: *A high level rainfall increase of up to 30% is recommended for consideration, due to the uncertainties associated with this aspect of climate change and to apply the 'precautionary principle'.(DECCW 2010).*

The guideline does not provide an indication of when this increase would occur. However in the 'Practical Considerations of Climate Change' , the Lake Macquarie Region and a projected change in the extreme rainfall (40 year 1 day rainfall total) of -10% to +12% by 2030 and -7% to +10% by 2070. (DECC 2007)

During the LMCC Flood Study, the consultant ran a sensitivity analysis on the increase of rainfall and found that the rainfall increase varied depending on the size of the event. For example, for a 5 year ARI, a 10% increase in rainfall would see an additional 50mm in peak water levels. However, a 100 year ARI, which is 20 times less likely to occur, increased water levels by approximately 120mm.This additional flood level were considered overly conservative.

The DECC guideline is currently the only reference in providing guidelines for rainfall increases due to climate change (WMAwater 2011). There is also evidence that precipitation may decrease – a study by the CSIRO and Bureau of Meteorology found that projections on annual precipitation were a decrease over nearly all of Australia. This however varied between locations and did not specifically relate to storm activity (CSIRO and BOM 2007).

Due to the uncertainty of the Figures and the significant raise in flood levels it would cause, LMCC decided that no additional rainfall increase would be added to the flood modelling and resulting peak water levels.

A compensation to potentially underestimating flood risk is to accommodate this in the Freeboard. Freeboard is an additional amount above the 1%ARI level to allow for a margin for modelling uncertainty and local risk. The NSW Floodplain Management Manual recommends a freeboard of 0.5m, which can cover uncertainty in flood estimates and climate change. (DIPNR 2005)

Sea level rise and erosion:

An increase in sea levels can also cause shorelines recession, where sediment is eroded away by floodwaters and wave energy. Recession occurs when wave energy dislodges and removes sediment from a shoreline. When the outgoing sediment from a shoreline is greater than the incoming sediment, a shoreline will shift landward (Stevens 2010).

The rate of shoreline recession is hard to predict as, generally, it does not proceed evenly as sea levels rise, but occurs periodically during major storm events, when energetic waves can reach the backshore to cause erosion. Therefore, there is a lag between the sea level rise and the corresponding degree of erosion. The lag will depend on the frequency and intensity of storms affecting the shoreline (Stevens 2010).

Erosion will occur very differently on an open ocean coast to an estuary shoreline. The wave energy and sediment types are different and as such, the same rule cannot be applied.

Open coastal shores:

For the open ocean coast, a commonly applied indicator of shoreline erosion has been the 'Bruun Rule', where for every 1m vertical rise, the shoreline has a potential to recede by 50-100m (Figure 4). This rule has been contested, however in lieu of a better alternative, is still regularly applied in coastal zone hazard plans.

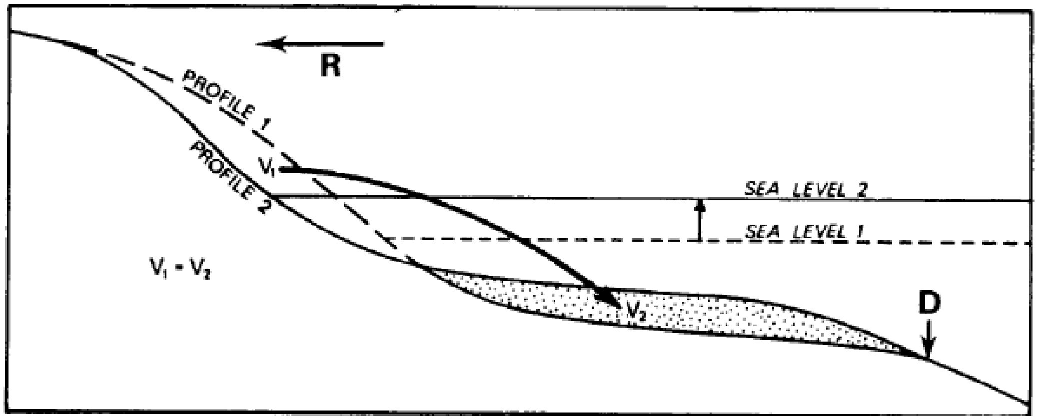

Figure 3: The standard Bruun Rule (Bird 1993)

Estuarine shores:

The Bruun rule is not easily applied to estuaries for several key reasons:

- The Bruun rule is applied largely to open ocean shores made of sandy material. It does not necessarily provide a good model of the response of bedrock, coarse sediment or very fine sediment shorelines (as found in estuaries) to sea level rise (Cooper et al. 2004).

- Within an estuary, eroded material is often not re-deposited offshore but is lost to the basin (Lee and Mehta 1997; Kirby 2000, in(Rossington 2008). Once a severe weather event has passed, the wave energy in an estuary is not sufficient to move sediment back to its place in the profile.

- Equilibrium relationships, such as the Bruun Rule have not been systematically tested for estuarine shores and the wide range of morphological types they have (Rossington 2008).

Despite these factors, the Flood Risk Management Guide states that ' *For planning purposes on estuarine foreshores, in the absence of better information, it is recommended that estimations of recession due to sea level rise use the same 'Bruun Rule' approach with relevant average foreshore slopes inferred or estimated from survey information.*

Currently the hazard lines developed by LMCC do not include any consideration of shoreline erosion. This is because it is location dependant and cannot be applied through LGA wide hazard lines. Although LMCC have developed an online tool for estimating the response of estuarine shores to sea level rise (Stevens 2010), it is not easily able to be translated into planning policy.

A Government initiative to help identify shorelines at risk from erosion is Smartline a national geomorphic map of the Australian coastline. A map of the entire coastline of Australia has been developed, however most estuaries have not yet been included.
Gesture

Conclusions:

Developing hazard lines is an important step in identifying regions that are a risk from current and future coastal flooding. The implications of these hazard lines are significant –

they will form the basis for planning restrictions and responses and if they are too high or too low may leave property, residents, and infrastructure at risk. Councils have the predominate role in developing these hazard lines and due to the lack of a national framework, are responsible for making decisions on how these hazard lines are developed.

A range of uncertainties and assumptions become apparent when developing hazard lines. The first is in identifying the base flood risk such as identifying the mean sea level and the flaws in using exceedance statistics in a non-stationary climate. The second area of uncertainty is how to then add the implications of climate change including the amount of sea level rise, the rate of which it will rise and potential changes to extreme weather events.

Exploring the methods of developing hazard lines can create a transparency in how and why Figures have been selected, and provide opportunity for planners to create improved hazard lines. The inconsistencies that can occur when individual local governments apply hazard lines may also highlight the importance of a state or national framework for creating hazard lines.

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