

IMPACTS OF CLIMATE CHANGE ON NATURAL HAZARDS PROFILE

STATEWIDE OVERVIEW

December 2010



**Environment,
Climate Change
& Water**

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This profile was developed by the NSW Department of Environment, Climate Change and Water (DECCW) in collaboration with:

- Bureau of Meteorology (BoM)
- University of Wollongong (UoW).

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- Only some meteorological and climatological hazards are covered. Other natural hazards such as landslide and earthquake are not covered.
- This profile is not a comprehensive description of the current state of natural hazards.
- Some projections currently involve a considerable degree of uncertainty.

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Published by:

Department of Environment, Climate Change and Water NSW
59–61 Goulburn Street, Sydney
PO Box A290
Sydney South NSW 1232
Ph: (02) 9995 5000 (switchboard)
Ph: 131 555 (information & publications requests)
Fax: (02) 9995 5999
TTY: (02) 9211 4723
Email: info@environment.nsw.gov.au
Website: www.environment.nsw.gov.au

For further information contact:

Department of Environment, Climate Change and Water
59–61 Goulburn Street, Sydney
PO Box A290
Sydney South NSW 1232
Phone: 1300 361 967 or (02) 9995 5000

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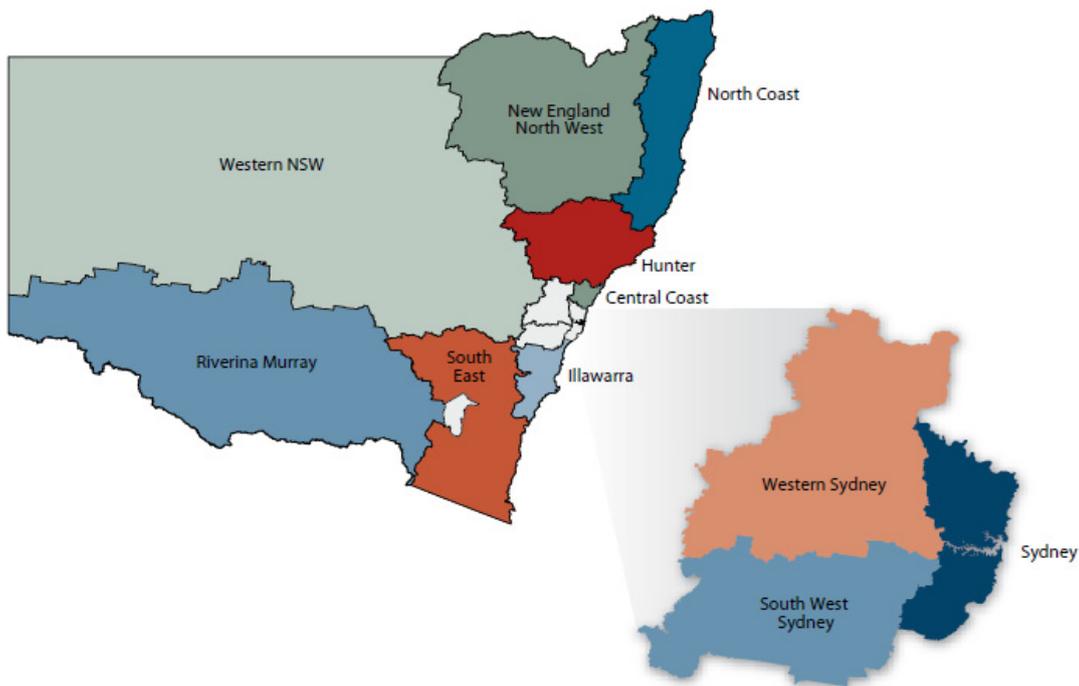
1 Introduction

The state of New South Wales experiences recurring, costly and significant natural hazards potentially impacting upon public safety, private property, infrastructure integrity and the insurance sector. This profile provides emergency management agencies with information on:

- the following natural hazards to which New South Wales is exposed:
 1. Fire
 2. Wind
 3. Hail
 4. Lightning
 5. Flash flooding
 6. Riverine flooding
 7. Heatwaves
 8. Coastal erosion and inundation
- projections of how these natural hazards may change into the future due to climate change.

An Impacts of Climate Change on Natural Hazards Profile has been prepared for each of the following State Plan regions: North Coast; Hunter; Illawarra; South East; Riverina Murray; Western; and New England/North West, as shown in Figure 1. The Sydney, Western Sydney, South West Sydney and the Central Coast State Plan regions have been incorporated into one regional profile: Sydney/Central Coast.

Figure 1: Map of the NSW State Plan regions



2 Current climate and natural hazards of NSW

2.1 Current climate

The climate of New South Wales ranges from hot and semi-arid about parts of the west and north-west, through sub-tropical in areas of the North Coast region, to cool temperate in the South East region. There are some variations within the regions, with the North Coast region ranging from sub-tropical about the coast, through sub-humid on the slopes, and temperate on the western inland; and the New England/North West region ranging from hot and semi-arid in the far north west to temperate about the tablelands. Coastal regions range from sub-tropical north from the Hunter region; warm temperate in the Sydney/Central Coast region; to cool temperate south from the Illawarra region.

Rainfall is generally heaviest along the seaboard and about the near coastal mountains, with averages ranging from 1200 mm/year in the North Coast region to 730 mm/year in the South East region. It is mostly summer–autumn dominant in coastal regions, with runoff highest in spring–summer in the north, and highest in autumn–winter in the south. Inland regions are more varied, with average rainfall in the Riverina Murray region ranging from 1050 mm/year at the edge of the Snowy Mountains to 240 mm/year in the north west of the region; the Western region ranging from an average 180–200 mm/year in the dry west to 1000 mm/year around the Central Tablelands; and the New England/North West region ranging from less than 600 mm/year in the west to 1200 mm/year about the Tablelands.

Runoff is summer dominant in the New England/North West and the Western regions, but winter–spring dominant in the Riverina Murray region and about the mountains of the South East region. Runoff is highest in winter in the south, but in summer in the north, and is split through the Western region between winter dominant in eastern parts and summer dominant in the drier west.

2.2 Natural hazards

New South Wales is periodically affected by the eight natural hazards considered in this assessment. Some examples of recent significant natural events experienced in New South Wales are shown in Table 1.

Table 1: Recent significant natural events in NSW

Event	Date	Estimated damage/cost*
Severe storm	8 June 2007	\$1350 million (cost)
South-east hailstorm	14 April 1999	\$1700 million (cost)
Bushfires in Sydney (also Canberra, Wollongong and Dubbo)	21 December 2001 – 15 January 2002	650,000 hectares burned, 121 houses destroyed and 340 more damaged \$68.79 million (cost)
Inland floods	April 1990	\$50 million (cost; Nyngan alone)

* Emergency Management Australia estimates (EMA 2009) – cost is original dollar values.

It should be noted that in most cases the above phenomena were not unprecedented and were less intense than the highest magnitude events possible under present climatic conditions.

In New South Wales flash flooding, riverine flooding, hail, wind and coastal erosion due to very rough seas, are often associated with low-pressure systems off the eastern coast of Australia, as was the case with the severe storm on 8 June 2007. Known as East Coast Lows (ECLs), these systems occur on average 10 times each year. The severe storm on 8 June 2007 resulted from an intense ECL – the first of five over the Tasman Sea for that month alone – and ultimately led to more than 20,000 calls to the NSW State Emergency Service (SES) over the following 17 days. The Australian Bureau of Meteorology (BoM) described this sequence of five ECLs as ‘rare but not unprecedented’.

The June 2007 storm saw large areas of the Hunter region subject to Natural Disaster Declarations with widespread flooding. Wind gusts reached 124 km/h at Nobbys Head, contributing to the 76,000 tonne bulk carrier *Pasha Bulker* running aground on Nobbys Beach, Newcastle. Rainfalls of 200–300 mm were common, leading to major flooding of the Hunter, Paterson and Williams rivers and the biggest floods since 1971 at Singleton and Maitland. Thousands of people were evacuated from Central Maitland, South Maitland and Lorn alone, and infrastructure was severely impaired with roads closed, rail lines damaged, gas supplies disrupted, and power cut to 200,000 users.

Significant damage and cost also resulted from a localised hailstorm in parts of Sydney on 14 April 1999, when a ‘supercell’ thunderstorm developed about 115 km south-west of Sydney and to the north of Nowra. It produced some of Sydney’s largest recorded hail (approximately 8 cm in diameter). The storm hit a total of 85 suburbs, with damage heaviest in the highly developed and heavily populated south-eastern Sydney area. It damaged 20,000 properties, 40,000 vehicles, 25 aircraft at Sydney Airport and resulted in 20,000 requests for SES assistance.

Bushfires from December 2001 to January 2002 constituted the longest continuous period of bushfire emergency in New South Wales up to that time,

as a run of high summer temperatures coincided with the peak of an El Niño drought event. Damage extended across a broad area of the state, covering parts of the Sydney/Central Coast, Illawarra and Western regions. Helensburgh and the Shoalhaven in the Illawarra region were among the worst affected areas. A total of 121 houses were destroyed, along with 15 business premises and 255 other structures. Approximately half of the 10,000 evacuations were from around Sussex Inlet in the Jervis Bay area amid a total of about 100 fires, most of which were found to have been started by either lightning or arsonists.

Parts of the Western region were hit by severe floods in April 1990. Floodwaters extended over an estimated one million square kilometres from south-west Queensland through a broad area of inland New South Wales to northern Victoria, but were worst at Nyngan where record rainfall (exact total unknown because of flooding) took the Bogan River to a new peak level.

3 Projected changes to climate and natural hazards in NSW

The following section details projected changes to climate and the frequency and intensity of natural hazards in New South Wales out to 2050. Projections for significant fire, coastal erosion and weather-related hazards are based on those developed for the *NSW Climate Impact Profile: the impacts of climate change on the biophysical environment of New South Wales* (DECCW 2010). The *NSW Climate Impact Profile* projections were developed using current global climate model data provided by the Climate Change Research Centre at the University of New South Wales. Further research will be needed to improve the accuracy of these projections.

3.1 Projected changes to climate

Average daily temperatures in New South Wales are projected to rise by up to 3°C by 2050, with the greatest increases in maximum temperatures likely to occur in the north and west. Australia's annual mean temperatures have increased by about 0.9°C since 1910, with significant regional variations (CSIRO 2007). The climate of the 21st century is considered virtually certain to be warmer than at present (IPCC 2007). Higher temperatures are expected to be accompanied by significantly increased evaporation levels across much of New South Wales by 2050. The projections also indicate that significant events such as heatwaves are likely to become more frequent, and that sea levels will continue to rise.

Rainfall variations are dominated by projections of a slight increase in the north-east of the state during summer, but this will be accompanied by a significant decrease in winter rainfall over the south-western regions. Many areas are also expected to experience a shift from winter dominant to summer dominant rainfall. Projected increases in evaporation are considered likely to counteract the expected increases in summer rainfall.

Changes to rainfall and evaporation patterns in northern New South Wales appear to be within recorded levels of variability. However, the drying of the autumn, winter and spring seasons in the south – and particularly the south-west – is expected to be outside variability observed in historical records.

Patterns of the El Niño–Southern Oscillation (ENSO) cycle and other climatic influences may be modified by global warming and this is an active area of research. Although large uncertainties exist regarding the future interactions of ENSO and other climatic influences, El Niño years experienced in New South Wales are likely to continue to result in an increased probability of lower than average rainfall and become hotter. La Niña years experienced in the state are likely to continue to result in an increased probability of higher than average rainfall and become warmer, with storms producing heavy downpours likely to become more frequent.

Sea levels are projected to rise by up to 40 cm above 1990 mean sea level by 2050. Sea level rise and storms are virtually certain to increase coastal inundation and erosion, causing sandy shorelines along the coast to recede, typically by 20–40 m over the same period. This will also increase the risk of coastal flooding.

3.2 Projected changes to natural hazards

The current resolution of global climate models means that relatively large damaging weather events such as ECLs) are currently not captured. The Department of Environment, Climate Change and Water (DECCW) is leading a multi-institutional research initiative called the Eastern Seaboard Climate Change Initiative (ESCCI) to address specific research gaps. The first priority of ESCCI is to establish an ECL project to improve future projections.

In addition, little information is available for small scale, short-lived damaging weather events such as severe thunderstorms which are not adequately captured in the resolution of climate models so that a low level of confidence is associated with any projections of extreme winds. Further research is required to improve projections for changes to flood-producing rainfall events. Studies of triggering events such as severe thunderstorms, ex-tropical cyclones and troughs, and broad scale weather systems resulting in flooding currently do not provide enough certainty for projections of frequency and intensity. The impacts of flooding at specific locations may have been assessed in flood investigations; however, many of the impacts of climate change on flood behaviour are yet to be investigated in detail. The exposure of individual locations to flooding and the associated impacts on flooding due to climate change are quite specific and need to be addressed by flood investigations in particular catchments and locations.

More detailed high resolution (spatial and temporal) information on future climate is required to improve certainty of projections of extreme fire hazards. Understanding future changes to El Niño frequency and intensity is also a key research need, as is research on ignitions (lightning and human), and changes in moisture and elevated carbon dioxide levels on vegetation, as the degree to which vegetation fuel characteristics will change and affect fire regimes is unknown.

Factors affecting local shoreline positions such as sediment supply, near shore currents, and wave characteristics (height, period and direction) may change, and modelling at present is extremely coarse and relatively uncertain. Projections for global sea level rise are subject to ongoing refinement by the international scientific community.

Further research on all climate variables is ongoing and will be reviewed by the Intergovernmental Panel on Climate Change (IPCC) in the development of its Fifth Assessment Report (due for finalisation in 2014). This material will be reviewed following its release.

3.2.1 Fire

Increases in the number and intensity of days of high temperature, low humidity and higher evaporation levels will influence both fire frequency and fire intensity, with the frequency of occurrence of days of very high to extreme fire-risk possibly increasing by 10–50% in all regions. The fire season is likely to be extended in most regions, but research towards a much better understanding of future changes to the frequency and intensity of El Niño, ignition rates and fuel accumulation is needed to project the extent of the increase both for New South Wales overall and for individual State Plan regions. Also, further research is needed to resolve the effects of future

changes in moisture and elevated carbon dioxide levels on the frequency and intensity of fires.

While fire frequency is likely to increase across most regions, the fire return period is projected to remain within present ranges. Less certainty surrounds changes to fire frequency in the Riverina Murray and Western regions, and the western parts of the New England/North West region. In these regions, decreased fire is possible due to lower availability of herbaceous fuels, and changes in farming practices may further reduce fire in cropping lands.

Potential days for prescribed burning are projected to increase in all regions except the Riverina Murray and Western regions, where they will likely decline. This projection is based on the number of days where the Forest Fire Danger Index is potentially appropriate. Actual suitable days will also depend on fuel moisture, forecasts of unfavourable weather and other safety considerations.

3.2.2 Wind

East Coast Lows

Significant wind speeds along the NSW coast have frequently been associated with ECLs. The severe storm on 8 June 2007 produced gusts of up to 124 km/h at Nobbys Head, 135 km/h at Norah Head, and 106 km/h at Fort Denison on Sydney Harbour. The overall incidence of ECLs affecting New South Wales is currently around 10 per year, with 3–5 of those systems producing severe coastal impacts with gale force winds and flooding rains. They generally occur from autumn through to spring, and are winter dominant. Projected changes in these systems are largely unknown at this point; however, the proposed ECL project is designed to address at least some aspects of this research gap.

Severe thunderstorms

Thunderstorms with severe winds affect all regions of the state each year with frequencies varying from an average of 1 per year in the Illawarra region; 4 per year in the South East and Riverina Murray regions; 5 per year in the Sydney/Central Coast region; 8 per year in the Hunter and North Coast regions; and 11 per year in the New England/North West and Western regions. Damaging wind gusts during thunderstorms can exceed 90 km/h, with most storms occurring from late spring through to autumn with a summer peak. Projected changes in these systems are also largely unknown.

Tropical and ex-tropical cyclones

Severe winds can result from ex-tropical cyclone systems, but their incidence is virtually nil for most regions of New South Wales. The North Coast region has been the most likely to be affected by ex-tropical cyclones moving through south-eastern parts of Queensland, but the incidence to date has been low.

Some modelling studies have projected an increase in categories 3 to 5 systems due to climate change, but tropical cyclone frequency is likely to be highly dependant on the level of greenhouse gas emissions, and both

frequency and intensity is likely to depend on changes in the magnitude of sea surface temperatures (SST), and upper atmosphere circulation changes.

Gales and frontal systems

Wind hazards derived from gales and frontal systems have a current incidence grading from moderate in the South East region; through low to moderate in the Riverina Murray, Illawarra, Sydney/Central Coast and Hunter regions; to low in the North Coast, New England/North West and Western regions. There is a low level of confidence for future projections, but several models indicate a likely decline in the frequency of westerly gales as the winter westerly belt moves further south.

3.2.3 Hail

Hail is currently more prevalent over the northern half of the state, with the average frequency of hail-producing thunderstorms reaching 13 per year in the North Coast region; 11 per year in the New England/North West region; 10 per year in the Sydney/Central Coast region; 8 per year in the Hunter and Western regions; 3 per year in the Illawarra region; 4 per year in the South East region; and 2–3 per year in the Riverina Murray region.

The average frequency of hail events in which hail stones exceed 5 cm in diameter is currently 3 per year in the North Coast region; 2 per year in the Sydney/Central Coast region and 1 per year in the Hunter region, but falls of that size are rare in the other regions. Sparse populations in the Western and Riverina Murray regions may lead to under-reporting of incidence.

The hail season generally extends from August to March, and is summer dominant in most regions except the North Coast region, where October is the peak month with an average of four hail events. Future work to improve climate models is required to incorporate projections for the frequency and intensity of hailstorms.

3.2.4 Lightning

The average number of days in which lightning occurs is highest about the north-east of New South Wales, with the North Coast reaching 30–40 days per year; the New England/North West region 25–30 days per year; and the Hunter region 20–30 days per year. The Sydney/Central Coast, Illawarra and South East regions average 20–25 days per year; the Western region 15–25 days per year; and the Riverina Murray region 10–20 days per year.

Lightning is summer dominant but can occur at any time of the year, and the incidence within coastal regions tends to be highest slightly inland and near the ranges. Lightning strikes tend to be around 2–3 per km² per year for most regions, peaking along the coast and particularly in the tablelands and mountains. Lightning strikes in the North Coast region occur on average 2–3 per km² per year in the north, but only 1–2 per km² per year in the south, despite the average number of days in which lightning occurs peaking at a state high of 40–50 per year in the south of that region.

Lightning frequencies drop to 1–2 per km² per year in the Riverina/Murray region and parts of the Hunter region, and 0–2 per km² per year in the Western region, particularly along the western border where frequencies

reach as low as 0.5 per km² per year. However, sparse populations in these areas may lead to under-reporting of incidence.

Current research of lightning in Australia is insufficient to project the change in frequency and intensity of lightning due to climate change, but some international studies have suggested a change in global lightning frequency of 5–6% for every 1°C of temperature change (Price and Rind 1992). Studies from the United States also indicate that there may be an increase in high based (dry) thunderstorms.

3.2.5 Flash flooding

Flash flooding occurs within all regions of New South Wales from all types of relatively short duration storms and other meteorological events, including severe thunderstorms, and where they occur, ECLs and ex-tropical cyclones.

Cut-off lows occur year round but are dominant during autumn and winter. They primarily affect the south of the state, specifically parts of the Riverina Murray region and the south of the Western region. Cut-off lows are responsible for 80% of the winter days that receive rainfall greater than 25 mm in the southern areas of the Murray–Darling Basin.

The vulnerability and exposure of people and property to flash flooding through all regions of New South Wales is significant and widespread. It is generally expected to increase along with the increasing development density in growth areas and changing community profiles; however, the vulnerability of individual locations to flooding depends on specific factors and needs to be addressed by flood investigations in specific catchments and locations.

There are areas within the state, such as east of the Illawarra escarpment in the Illawarra region, that are particularly vulnerable to flash flooding. In low-lying coastal areas such as around coastal lake systems, a combination of raised ocean levels and catchment flooding can be the controlling flood mechanism. Further assessment of climate change impacts on flood-producing rainfall events will be needed for specific projections to be made for individual locations, due to the significant variation in flood behaviour and impacts.

3.2.6 Riverine flooding

The meteorological drivers of riverine flooding are usually the same as those for flash flooding: relatively short duration storms, severe thunderstorms, and ECLs and ex-tropical cyclones where these occur. However, systems such as troughs and north-west cloud bands can also contribute to riverine flooding.

Trough systems can occur at any time of the year in all regions, but are most prevalent in the period October to March with summer dominance. Their current frequency and intensity and the likely changes due to climate change are largely unknown.

North-west cloud bands can occur over inland areas of New South Wales, and although they rarely directly produce flooding rain, they are responsible for wetting catchments and providing a soil moisture profile that is more conducive to flooding. North-west cloud bands are most prevalent in the March to October period, particularly between April and September, and are

related to warm temperatures in the Indian Ocean. They are responsible for a large proportion of rain events over western New South Wales, but their frequency and intensity is unknown and no research is available on future trends for these systems.

The vulnerability and exposure of people and property to riverine flooding through all regions of the state is significant and widespread. It is generally expected to increase along with the increasing development density in growth areas and changing community profiles; however, the vulnerability of individual locations to flooding depends on specific factors and needs to be addressed by flood investigations in specific catchments and locations.

3.2.7 Heatwave

These profiles have used a definition for heatwaves of three consecutive days with maximum temperatures above the 90th percentile for the month, and temperature statistics collated on that basis indicate that central and western parts of New South Wales are regarded as having the highest incidence of heatwaves. Over the period 1979–2008, the number of heatwaves for both spring and summer exceeded 30 at Tamworth, Moree and Armidale in the New England/North West region; and Dubbo and Bathurst in the Western region. Heatwaves were exceptionally frequent in March (autumn) at Grafton and Port Macquarie in the North Coast region; and at Scone in the Hunter region.

Sea breezes curtail heatwaves at centres in coastal regions (Sydney/Central Coast, Hunter, Illawarra, South East and North Coast), but temperatures are generally much higher to the west, away from the eastern seaboard. However, heatwaves are slightly more frequent in the eastern parts of both the Riverina Murray and Western regions.

Current projections for temperature suggest increases in mean maximum temperature of 1–3°C by 2050, almost certainly increasing the severity of heatwaves. Their frequency is also likely to increase.

3.2.8 Coastal erosion and inundation

Sea levels along the NSW coast are projected to rise at an accelerated rate reaching 40 cm above 1990 mean sea levels by 2050. Projections are being continually refined by the international scientific community and the IPCC will release its next update on global sea level rise in its Fifth Assessment Report in 2014.

Factors such as astronomical tides and variations in storm intensity, winds and local barometric pressure all affect still water levels in all coastal regions. The impacts of climate change on these factors are not adequately known, but research suggests a 1% increase in storm surge is possible, in addition to projected sea level rise.

Coastal regions of New South Wales experience an average wave climate of 1–2 m from the south-east, and an 8% increase in the maximum storm wave height and period is projected out to 2050 for waves arriving from the southerly, easterly and south-easterly directions. In the north of the state, the frequency of swell waves is projected to increase, while in the south their

frequency is likely to decrease, but major research such as the proposed ECL project is needed to improve projections.

A combination of underlying factors including wave characteristics (particularly wave direction), beach orientation, presence of control features (such as bedrock, headlands and entrance breakwater structures) and sediment transport processes currently contribute to shoreline recession. The rate of shoreline recession due to these factors currently varies between 0–1.0 m per year in the North Coast and Hunter regions; and between 0–0.3 m per year in the Sydney/Central Coast, Illawarra and South East regions. Future rates of shoreline recession may vary as a result of climate change, but the nature and extent of that change out to 2050 is not currently known. In addition, embedded within current measured rates of shoreline recession is a component attributable to historical sea level rise. Further research is needed to de-couple the sea level rise component from measured recession.

Historical sea level rise is estimated to contribute to sandy shoreline recession by 0.15–0.3 m per year based on a rate of global average sea level rise of approximately 3 mm per year. A projected rise in sea level of up to 40 cm out to 2050 is likely to result in a recession of sandy parts of the coastline of up to 20–40 m. These changes in shoreline position are based on a general rule of thumb (the ‘Bruun rule’), and detailed study at individual locations is required for more accurate projections.

Ocean tsunamis are not driven by meteorological processes; however their impacts are directly influenced by the proximity of people and property to coastal water level. The entire coast of New South Wales is known to be exposed to tsunamis. The effect of a tsunami reaching the coast can range from so slight as to be unnoticed, to an event large enough to overtop coastal dunes and waterfronts to inundate low-lying coastal land. The actual risk of tsunami inundation is currently under investigation for the SES. As of August 2009 the extent of inundation and indicative probability of tsunami events was not established with any confidence for any locations. However, it can be reasonably inferred that any low-lying coastal location which has a vulnerability to coastal inundation due to estuarine flooding or storm surge, or any area identified as a coastal erosion hot spot, will have a vulnerability to tsunami inundation.

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