Case Study

Storm tides, coastal erosion and inundation

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Synthesis and Integrative Research Program

Historical Case Studies of Extreme Events

Storm tides, coastal erosion and inundation

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The role of NCCARF is to lead the research community in a national interdisciplinary effort to generate the information needed by decision makers in government, business and in vulnerable sectors and communities to manage the risk of climate change impacts.

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Preface

The National Climate Change Research Facility (NCCARF) is undertaking a program of Synthesis and Integrative Research to synthesise existing and emerging national and international research on climate change impacts and adaptation. The purpose of this program is to provide decision-makers with the information they need to manage the risks of climate change.

This report on storm tides along East Coast Australia forms part of a series of studies/reports commissioned by NCCARF that look at historical extreme weather events, their impacts and subsequent adaptations. These studies examine particular events – primarily extremes – and seek to explore prior vulnerabilities and resilience, the character and management of the event, subsequent adaptation and the effects on present-day vulnerability. The reports should inform thinking about adapting to climate change – capacity to adapt, barriers to adaptation and translating capacity into action. While it is recognised that the comparison is not and never can be exact, the over-arching goal is to better understand the requirements of successful adaptation to future climate change.

This report compares the adaptive response to storm tides of coastal communities along East Coast Australia. Australia's coastal communities are vulnerable to coastal erosion and inundation as a result of major storm surges and storm tides. Throughout the 1950s until the mid-1970s, Australia's East Coast experienced a particularly stormy period. One of the worst years was 1967, when five Tropical Cyclones (TC) and three East Coast Lows (ECL) caused extensive damage during the first half of the year. Many coastal communities experienced severe erosion and flooding. Since the mid-1970s, calmer weather has prevailed, and the knowledge of how to prepare and respond to storm tide impacts is in danger of being forgotten as the memory of past events fades. This case study focuses on the adaptive response of three coastal communities – the Gold Coast, Byron Bay and the Collaroy-Narrabeen region – to the stormy period from the 1950s to the mid-1970s.

Other reports in the series are:

- *East Coast Lows and the Newcastle-Central Coast* Pasha Bulker *Storm*
- *The 2008 Floods in Queensland: Charleville and Mackay*
- *Adaptation Lessons from Cyclone Tracy*
- *Heatwaves: The Southern Australian Experience of 2009*
- *Drought and the Future of Rural Communities: Drought Impacts and Adaptation in Regional Victoria, Australia*
- *Drought and Water Security: Kalgoorlie and Broken Hill*

To highlight common learnings from all the case studies, a Synthesis Report has been produced, which is a summary of responses and lessons learned.

All reports are available from the website at www.nccarf.edu.au.

Erratum [added 3rd April 2013]

In the original version of this report, Figure 4 (page 16) contained a footnote that read:

> When Suffolk Park was subdivided in 1922, the distance 'A' was set at 5 chains [100m] between the property boundary and mean high water (MHW). In 1996, 'A' was 60 m. This reduction is supported by anecdotal accounts from residents who described the loss of the original foredunes and swales in storms between the 1950s and 1970s. In 2010, 'A' is around 20 m.

This footnote has been found to contain inaccurate data and has been removed. This does not affect the main arguments of the Report.

Note that minor typographic errors have been corrected at the same time.

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Executive summary

The majority of Australia's population and major cities are located on the coast. Since the 1950s, many coastal settlements have changed from 'family' beach holiday villages to permanent settlements, and in some cases growing urban areas. The Gold Coast is now the sixth largest urban area in Australia, and Noosa has highly priced CBD real estate. Many of the people who have moved to rapidly growing coastal areas have not experienced the physical or economic impacts of major coastal storms, and are unaware of the risks from sea level rise and intense tropical cyclones.

This study reviews the vulnerability of Australian coastal communities to storm tides by analysing historical storm surges and more recent storm events along Australia's East Coast. Narrabeen, Byron Bay and the Gold Coast are used as case studies to conduct a detailed analysis of the vulnerabilities, impacts and responses to past events in these communities. The report identifies lessons learnt from past events, and looks at current challenges and priorities that should be considered when developing appropriate adaptation responses in Australian coastal communities.

This report focuses on the period of storminess that occurred between the late 1960s and early 1970s, when each of the case study areas was severely impacted. It is shown that since that time there has been a period of relative calm, during which much of the development on the coast has occurred and various adaptation strategies have been implemented. Extreme coastal storms are widely variable over recorded history, but many link to the climate indices, the Southern Oscillation Index (SOI) and more importantly the Inter-decadal Pacific Oscillation (IPO), which explain the decadal time scale of storminess periods. It is noted that there have been no comparable extreme events since 1974 in the case study areas.

The impact of past extremes is exemplified by the 1967 sequence of storms that resulted in houses being lost, complete erosion of beaches and extensive damage to public infrastructure on the Gold Coast. By comparison, the 2009 events had significantly less impact (a one-in-ten year event versus the 1967 one-in-100+ year event), but caused considerable concern due to the level of current development and higher sea levels. The characteristics of past storm erosion and inundation events that made them particularly severe and damaging were the sequence and duration of storms and, in the case of tropical cyclones, their path. It is noted that if Tropical Cyclone Hamish had crossed the coast anywhere from Hervey Bay to the Gold Coast there would likely have been a similar impact to that which occurred in 1967.

At the time of the earlier events, the Gold Coast and Byron Bay case study areas were relatively undeveloped, but with beachfront and low-lying properties at risk. Because of this low-key development, there was an adequate coastal reserve to allow natural coastal process recovery. The communities also tended to comprise long-term residents who had experienced earlier storminess back in the 1950s. With rapid development from the 1970s onwards, the vulnerability of growing coastal urban areas increased rapidly as community resilience decreased due to the loss of 'corporate' memory of storm events and high population turnover. This period has been characterised by a 'calm weather planning' mentality at all levels of government and the community.

Initially, adaptation responses were set in place at different times, namely:

- **Gold Coast – from 1968**
  - Erosion studies (formation of Beach Protection Authority (BPA), *Coastal Management Act*).
  - Gradual implementation of management plan – seawalls, groynes, entrance training, nourishment.

- **Byron Bay – from 1970s**
  - Erosion studies, (coastal management guidelines, setback lines incorporated into Local Environmental Plans (LEP) in 1988).
  - Temporary protection works, legal action.
- **Narrabeen/Collaroy from 1970s**
  - Seawall proposed – community protest.
  - Nourishment proposed.
  - Council buy-back scheme implemented – 2003.

However, the responses are limited in their effectiveness for future adaptation under climate change. A key barrier to adaptation has been individual attitudes to extreme events, such as the view expressed after the 1974 Gold Coast storms that this was a one-in-100 year event, and would therefore never happen again in a lifetime.

The immediate response to extreme storms was similar at each location. Individuals took action in terms of protecting their property by using concrete blocks, old tyres, car bodies and sand bags. Mobilisation of the army and other higher level responses also occurred. By comparison, the response in 2009 was limited to some sandbagging and beach scraping. However, emergency management systems that had been developed since the 1970s saw evacuations planned for some events.

The recent events in 2009, and the scientific view that a return to a period of storminess and higher sea level is likely, has seen some renewed action taken to address climate change risk, particularly with regard to upgrading of coastal hazard guidelines and policies in each state. Communities are, however, left with the legacy of over three decades of reduced funding, loss of technical expertise in responsible authorities, and ‘calm weather planning and policy’.

Present-day communities in the case study areas have a high level of vulnerability to future extreme events, due to:

- the impact of rising sea levels
- a general denial of risk, and a belief that sea level rise will be gradual and will happen some distance into the future, especially as major impacts have not been experienced for 30 years
- concerns of local government over liability, and
- adaptive capacity being limited in larger urban areas due to the integration of tourism/lifestyle economies with service industries.

As for future development of adaptation strategies, the case studies have demonstrated the following:

- Past adaptive strategies have yet to be tested.
- Adaptive strategies (e.g. setbacks) lack effective legal and political frameworks.
- There is a need to act quickly after events to change policy, etc. as the community loses its collective memory within a short period.
- Strategies need to be consistent along a section of coastline:
  - The 1960s ad-hoc protection exacerbated problems elsewhere.
  - Buy-back is ineffective unless all properties are included at a set price (not market price).

- Setback (retreat) needs a parallel legal and social framework to cover the transition to future retreat.

The sea level around Australia has risen some 130 mm since 1820, with 70 mm of that rise occurring since 1950. Rising sea levels will result in greater impacts from storm tides – a major natural hazard for coastal communities. Severe storms and cyclones account for one-third of the total damage cost to the Australian community from natural hazards, which was estimated at $40 billion between 1967 and 1999 (calculated in 1999 dollars).

Ensuring resilience to anticipated future climate change impacts is crucial. Early key actions should focus on building both national awareness of climate change and adaptive capacity. Climate change planning and action have tended to be left to environmental divisions within councils. The complexity of cross-cutting climate change risks in the coastal zone requires an effective collaborative inter-jurisdictional reform effort. Australia needs an over-arching national coastal policy that clarifies the roles and responsibilities of all levels of government when addressing the impacts of climate change. Priorities for collaborative action need to be identified as a first step in coordinating a national reform agenda.

Adaptation to climate change as a means of maximising gains and minimising losses has remained relatively unexplored at the location-specific level. Preparing for adaptation to climate change is justified; costs for preparing now are small in comparison with the costs of likely future impacts. Plans should identify where the existing buffer is of sufficient width to accommodate future impacts, where immediate protection or retreat is required, and how actions can be undertaken. The precautionary principle should be applied, as future events may exceed those experienced over the last two centuries.

1. Introduction

Disaster risk reduction efforts aim to reduce socioeconomic vulnerabilities by addressing the underlying causes of vulnerability and by strengthening the resilience and adaptive capacity of societies and communities at risk. Adaptation to climate change is influenced by financial, social and environmental factors such as the capital available to address the problem, relevant technologies, social values and governance structures. The coastal system is particularly vulnerable where the stresses on natural systems coincide with high exposure and low human adaptive capacity. Coastal adaptive capacity is defined as the coastal system's ability to adapt in order to accommodate climatic changes or to increase the range of variability with which the system can cope (Nicholls et al. 2007). The concept of adaptive capacity has assumed greater prominence partly as it enables researchers and policymakers to account for the multiple stressors in which climate adaptation measures must be implemented. In the coastal zone, enhancing both resilience and adaptive capacity is crucial for increasing disaster preparedness and prevention, disaster recovery and coastal adaptation to climate change (Klein, Nicholls & Thomalla 2003).

1.1 Study aims

The aim of this study is to examine the physical, social and economic vulnerabilities of coastal communities to major storm surges that result in storm tide inundation and coastal erosion. The study considers how past adaptation responses to extreme coastal storm events were dealt with and provides guidelines for improved responses.

The study focuses on the East Coast of Australia from South-East Queensland to the Central Coast of New South Wales, where a significant proportion of Australia's population lives relatively close to the coast. Three sites along the coast were selected to demonstrate the range of adaptation strategies that have been developed to address storm erosion and inundation. Using three case studies – Narrabeen, Byron Bay and the Gold Coast – the study:

- identifies current physical, social and economic vulnerabilities of coastal communities and coastal ecosystems to climate and storm hazards
- reviews past technical, policy, planning and regulatory responses to extreme storm tide and coastal erosion events, and
- assesses the lessons of past responses, establishes priorities for future events under climate change and identifies alternative or additional strategies that can improve community preparedness.

2. Vulnerability of coastal settlements to coastal erosion and inundation

Vulnerability is defined by the IPCC (2007b) as

> the degree to which a system is susceptible to and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.

In the context of Australian coasts, vulnerability has been defined as 'a nation's ability to cope with the consequences of an acceleration in sea level rise and other coastal impacts of global climate change including physical impacts and impacts on socio-economic and ecological systems' (Harvey & Woodroffe 2008: 68). Australia's coasts are highly vulnerable to extreme events, such as storms and tropical cyclones, which impose substantial costs on coastal societies (Voice, Harvey & Walsh 2006).

2.1 Storm tide

Severe storms produce a temporary increase in sea surface height as a result of wind set-up, inverse barometer, current set-up, wave set-up and wave run-up (AGO 2007; Hennessy 2004). A *storm surge* is an increase in coastal water levels well above the normal high tide. Storm surge is combined with daily tidal variation, the combined water level is known as the *storm tide*. While wind and pressure are responsible for generating sea level extremes, factors such as coastal geometry and the width of the continental shelf play a role in determining the relative contribution by waves and storm surge. Wide, shallow continental shelves produce large storm surges, while a narrow continental shelf like that off the Central East Coast of Australia will produce large waves.

Few studies have considered the effect of climate change on storm surges. McInnes, Walsh and Pittock (2000) and McInnes et al. (2003) estimate the height of storm tides in Cairns for the present climate and for the year 2050. The present one-in-100-year storm tide height of about 2.3 m increased to about 2.6 m by 2050 due to increased cyclone intensity (10hPa drop in central pressure) and increased to 3 m with sea level rise.

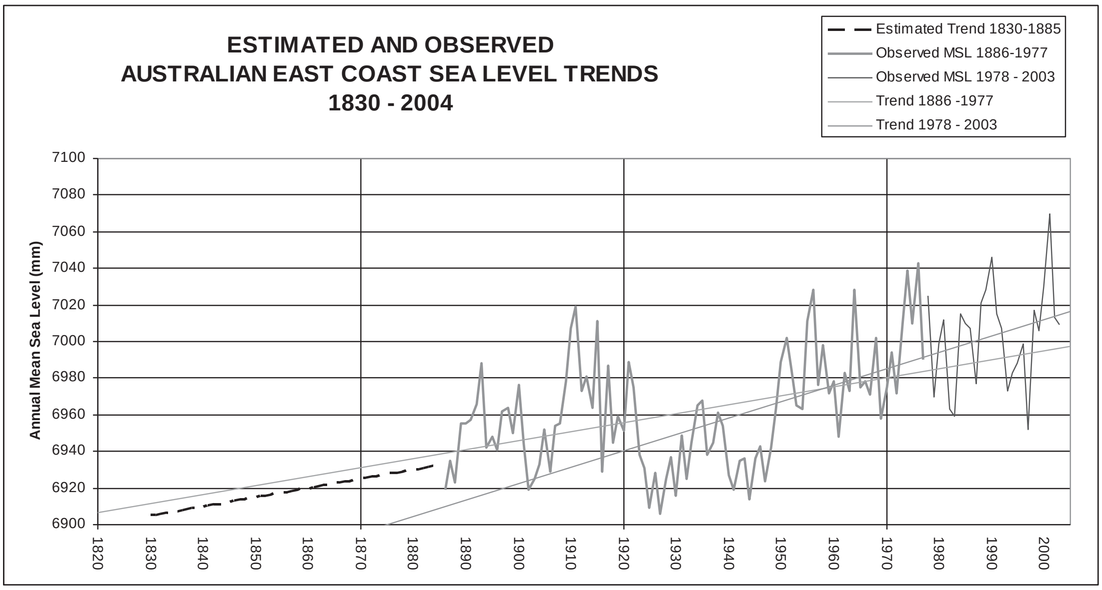
2.2 Sea level rise

Coastal Australia is vulnerable to many impacts from climate change that are likely to challenge most sectors of society, the economy and the environment (Coasts and Climate Change Council 2010). Low-lying areas, beaches and extensive coastal plains associated with estuaries and deltas are especially at risk (Aboudha & Woodroffe 2006). Coastal environments are closely linked to sea level. The coastal zone is increasingly expected to be impacted by sea level rise and its interactions with tidal and storm-surge variability (Preston et al. 2008; Preston 2007). Extreme weather events could become more frequent and intense, resulting in larger and more damaging storm surges (DCC 2009a).

The underlying influence on coastal change is sea level change (Helman & Tomlinson 2008). There is a high degree of certainty in the projection of sea level rise (IPCC 2007a), and the impacts are first observed as coastal erosion and inundation during severe storm periods (Helman & Tomlinson 2010). Australian tide gauge records follow global trends which recently have shown the rise to be higher than predicted (Figure 1) (Rahmstorf et al. 2007).

One of the consequences of global warming is that oceans expand as they heat. Due to the time lag for heating of the deep ocean, sea level will continue to rise for centuries beyond the stabilisation of atmospheric CO_2 (IPPC 2007a).

The sea level on the Australian East Coast has risen some 0.13m since 1820, with 0.7m of that rise since 1950 (Helman & Tomlinson, 2008). In Sydney, the frequency of extreme sea level events exceeding normal high tide has increased significantly since 1950 (Hennessy et al., 2004). In 2007, the IPCC projected sea level rise of between 0.1 to 0.8m by 2100 (IPCC, 2007a). Recent studies show that global sea level has been rising at the upper limit of IPCC projections (Figure 1) suggesting that climate change could occur more rapidly than previously thought, with Australia experiencing a rise of one metre or more by 2100 (DCC, 2010a; DCC, 2009a). These potential changes to the coast have serious implications for the natural and built environment's capacity to withstand and recover from impacts.



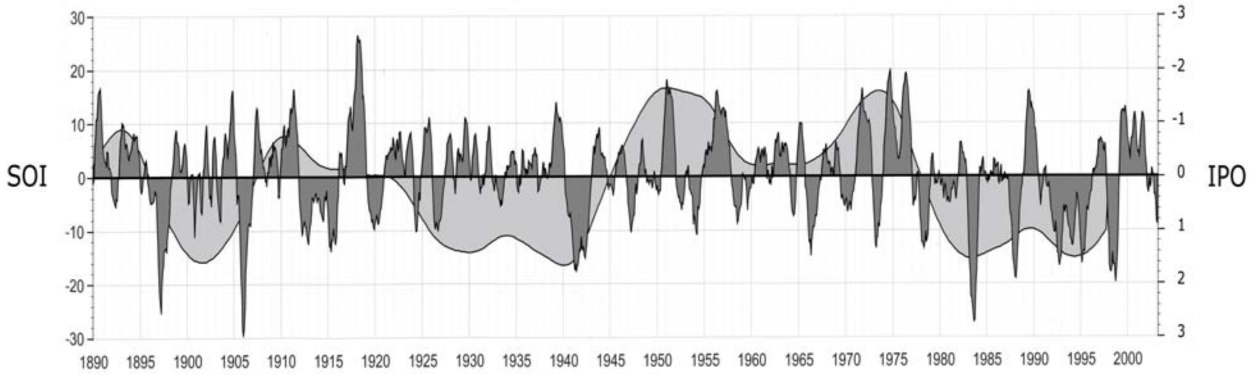
Source: 1830–86 trend back-projected from observed record (1886–1976) and in broad agreement with the estimation from the 1840s records at Hobart. 1886–2004 observed records. Data from PSMSL. Projected from IPCC (2007a).

Figure 1: Estimated and observed sea level trends 1840–2004

2.3 Storm cycles, erosion and inundation

Erosion is rarely gradual, but generally occurs when increased wave energy is provided by major storms. Storm occurrence is extremely variable – for example, in the first six months of 1967 the Gold Coast experienced more severe storms than it had during the previous two decades. A combination of a lack of public awareness due to minimal storm activity during recent decades and sea level rise suggests that a severe storm is likely to have a dramatic impact on unprepared coastal communities.

Tomlinson (2001) suggests that long-term coastal cycles of storm energy and coastal erosion might be related to oscillations of the Pacific Ocean. Recent research (Helman & Tomlinson 2008; Ryan, Kench & Hart 2008) confirms that coastal erosion episodes, storm inundations and major floods in coastal rivers generally occur during negative IPO phases (Figure 2). During the 1990s, a multi-decadal oscillation of the Pacific Ocean was described as Interdecadal Pacific Oscillation. The positive and negative phases of IPO have been linked to climatic, geomorphic and ecological processes over multi-decadal time scales. In Australia, IPO phases have been related to: rangeland droughts and degradation (McKeon et al. 2000; McKeon et al. 2004); central and southern Murray Darling Basin (MDB) rainfall and streamflow (Verdon & Franks 2006; Verdon 2007; McGowan et al. 2009) and coastal storms and droughts (Helman 2007). Helman and Tomlinson (2008) note that periods of severe storms not related to negative IPO also occur – for example, the severe tropical cyclones in the mid-1930s.



Source: Queensland Centre for Climate Change Excellence.

Figure 2: SOI (dark grey) and inverse IPO (light grey) plotted for a century

The annual to multi-decadal oscillations of the sandy sections of the coast would not be a problem if the sea level were stable. The coastline would move inland during storm phases and accrete seaward during calm periods. However, during times of rising sea level, storms provide energy that expresses sea level rise as erosion. Predicted sea level rise over coming centuries is likely to occur as a series of dramatic inundation and erosion events along sandy sections of the coast, which will move the beach inland (Helman & Tomlinson 2010).

2.4 Vulnerable coastal settlements

Historical settlement patterns have resulted in the majority of Australia's population and major cities being located on the coast. Since the 1950s, many coastal settlements have changed from 'family' beach holiday villages to permanent settlements, and in places growing urban areas. Australia has become a society where most people live, work and enjoy recreation at the coast. All Australian state and territory capital cities are located within the coastal zone. Also, much of the nation's commercial activity occurs in coastal areas where the coastal population continues to grow (DCC 2009a; Coasts and Climate Change Council 2010). The Gold Coast is now the sixth largest urban area in Australia, and Noosa has highly priced CBD real estate. Many of the people who have moved to these rapidly growing coastal areas have not experienced the physical or economic impacts of major coastal storms.

Rapid economic and population growth along Australia's coasts – particularly in subtropical and tropical areas – is leading to increasing exposure to sea level rise and intense tropical cyclones. Approximately 85 per cent of Australia's population now lives within 50 km of the coast (Palutikof 2010; DCC 2009a). Storm tides are a major natural hazard for coastal communities. Severe storms and cyclones account for one-third of the total damage cost from natural hazards to the Australian community, which was estimated at $40 billion between 1967 and 1999 (calculated in 1999 dollars) (Geoscience Australia). The Department of Climate Change report *Climate Change Risks to the Australia's Coast* (DCC 2009a) identifies up to 247 000 residential buildings across all states, with a value of $63 billion, at risk of being inundated or eroded during this century. Over the next 30 years, the coastal population is expected to increase by 26 per cent, reaching 7.2 million people by 2036. This translates to the number of coastal dwellings increasing from the current figure of approximately 2.76 million to 3.9 million by 2036 (Begonia & Gates nd).

2.5 Storm surge inundation

Flooding by sea water in low lying coastal regions for periods of several hours and more, along as much as 100 km of coastline, can occur. This places property and lives at risk, and affects both business activity and the financial security of a region. Evacuation of low-lying areas prior to a storm landfall is required in some circumstances to help prevent loss of life through drowning. Wave action, elevated water levels and surge run-up also damage dunes and near-shore structures. Impacts of sea level rise and storm surges on ocean-front land, coastal rivers and canal development include:

- water damage to building contents (interior linings, furnishings, appliances, equipment and plant)
- possible contamination of building interior from sewage, soil and mud
- undermining and/or destruction of foundations, potentially leading to structural collapse
- salt spray on coastal buildings, affecting most materials' durability, and
- coastal erosion (in some areas likely to be severe), resulting in loss or damage to property (AGO 2007).

State authorities – especially local governments – have limited resources and need to prioritise their response to natural hazards. By defining the relative vulnerability of the level of exposure to a natural hazard across a region, it is possible to derive a rating of the overall risk posed by the hazard. The resulting index can be used to produce a 'risk surface' map. Areas with the greatest level of exposure to storm tide inundation tend to be those that are perceived as the most desirable locations, close to the water.

3. Extreme storm events

3.1 Past extreme storm surge events

The climate history of the East Coast shows identifiable storm periods that, combined with a slowly rising sea level, have resulted in permanent changes to coastal features such as beaches, spits and entrances (Helman & Tomlinson 2008). From the position of beaches shown on survey plans, dating to the 1870s, many East Coast beaches have moved inland between 100 and 200 m, and Tomlinson (pers. comm. 2010) estimates that, at current coastal land prices, the value of coastal land already lost since European settlement would run to trillions of dollars.

However, this has not, as many suggest, been a slow process of annual change. Permanent changes to the coast only occur during periods of storm energy. Periods of storm energy since the mid-1800s are shown in Table 1.

Table 2 lists past recorded extreme storm surge events in North and South-East Queensland to Northern New South Wales (Callaghan & Helman 2008). The most severe storms recorded on the East Coast have been in North Queensland, with the 1899 Mahina Cyclone on Cape York reaching an estimated storm surge height of 14 m.

The record of storm descriptions and surges indicate that over the last 150 years there has been no very severe storm (Tropical Cyclone 3 or above) recorded in South-East Queensland. The highest surge recorded, of 1.5 m (Harper & Grainger 2001), is well below the probable maximum surge. A very extreme storm in South-East Queensland may have a surge of around 3 m in coastal lakes and with wave run-up on the ocean coast, of up to 5 m (WBM 2000) for the Byron coast. Long-term coastal records and modelling of the tracks of 3000 years of synthetic tropical cyclones suggest that it is possible for such an event to occur. These cyclone tracks extend over the whole Coral Sea and much of the northern Tasman

Sea, with possible landfalls from North Queensland to the Central Coast of New South Wales (Hardy, Mason & Astorquia 2004).

Since the late 1970s, the IPO has been positive and there have been a low number of storms; this is considered by Helman (2007) to be the calmest period over the last 200 years. In addition, the expected accretion that occurred during past calm periods has not occurred. Observations along the coast show foredune accretion until a cutback in 1987, then further accretion until the May 1996 storm. Accretion and foredune recovery since 1996 have been minimal, with the dune face slowly retreating, which is attributed to faster rates of sea level rise along the coast (Helman 2007). As the rate of sea level rise increases, storms of relatively low intensity are leading to increasing erosion, as predicted by Walsh (2004): 'Those places on the coast that are currently eroding will erode faster and those places that are not yet eroding will start to erode.'

Table 1: Erosion periods and Pacific Ocean climate indices, annual Southern Oscillation Index (SOI) and long-term Inter-decadal Pacific Oscillation (IPO)

Years	Climate phase	Coastal changes
1864–93	IPO predominantly negative	Severe erosion and erosion faces cut along coast, wide beaches reduced, inundation of low-lying coastal land, creek entrances changes
1920	IPO neutral SOI strongly positive	Some erosion
1933–36	IPO neutral SOI tending neutral	Very severe erosion on South-East Queensland coast
1945–74	IPO strongly negative in 1950s and 1970s, Predominance of positive SOI years	Most inland erosion escarpment on the East Coast (1974) at the end of this period. 1967 most extreme storm year not related to climate indices

3.2 Recent coastal erosion events

No significant storm surge has been recorded in recent decades. Inundation was observed during 19-year high tides in 2009. Recent storms, although not severe enough to cause significant surge, did cause minor erosion in some vulnerable places on the coast (Helman & Callaghan 2008).

3.2.1 Severe Tropical Cyclone Hamish, 4–11 March 2009

A tropical low formed in the Coral Sea east of Lockhart River on 4 March 2009. The low drifted to the south-west and intensified to become Tropical Cyclone Hamish on 5 March. It continued in a south to south-west direction and intensified over the next 24 hours, before taking a south-easterly track parallel to the coast. Severe Tropical Cyclone Hamish reached category 3 intensity on 6 March.

Under favourable conditions for further development, Hamish intensified offshore to category 5 on 7 March, north-east of Mackay. Hamish remained category 5 for almost 24 hours with Central Pressure (CP) 925hPa, maximum sustained wind speed of 215 km/h and maximum wind gusts of 295 km/h (category 5 over 280 km/h). It continued its track south-east, parallel to the coast, and maintained category 4 during 8 March.

Eventually, it moved into a region of increasing wind shear, and by 10 March the system became sheared with the upper circulation captured by strong upper winds. The low level circulation then meandered back to the north and north-west while weakening to a tropical depression over the following 24 hours.

Table 2: Past storm surge records in South-East and North Queensland and Northern New South Wales

DATE/ EVENT	LOCATION	STORM SURGE (m)	NOTES
August 1864	Cape Byron		Dunes breached; Belongil and other wetlands deeply inundated
10 March 1891	Broadwater		Highest known tide at Southport
17 January 1893	Ballina		Deepest submersion for years
18 February 1894	Moreton Bay	0.6	
25 July 1897	Gold Coast		Storm surge on coast
1899 Mahina Cyclone	Cape York	c14	300 crew and 70 vessels lost
25 February 1908	Gold Coast		Southport seawall overtopped
9 February 1914	Brisbane	0.6	
1918 Mackay Cyclone	Mackay	5.5	Cyclone, central pressure 933hPa
1918 Innisfail Cyclone	Innisfail	3	Most severe storm to cross a populated area on the Queensland coast, central pressure 928hPa
5 February 1931	Brisbane	1.1	
1 February 1934	Brisbane	1.2	Highest surge recorded, Moreton Bay, up to 1934
21 February 1954	Brisbane	0.7	
17 February 1957 TC Clara	Brisbane	>0.5	
1 January 1963 TC Annie	Brisbane	0.8	
29 January 1967 TC Dinah	Broadwater Moreton Bay, with wave influence	c1.5	Most severe storm year Highest storm surge in South-East Queensland.
11 February 1972 TC Daisy	Fraser Island Bribie Island	c0.8 c0.6	Around 3 m on ocean coast
7 February 1974 TC Pam	Brisbane	0.7	
12 March 1974 TC Zoe	Brisbane	0.7	
19 January 1976 TC David	Moreton Bay Yeppoon	0.8 1.2	Significant impact on South-East Queensland, even with the centre over 600 km north
14 February 1981 TC Cliff	Gold Coast	0.7	
2 May 1996	Beachmere	0.7	
17 March 1993 TC Roger	Gold Coast Seaway	0.7	

A fishing trawler capsized in the Swains Reef area as Hamish passed nearby. One of the three crew was rescued, but two were lost. Dangerous surf conditions affected South-East Queensland beaches. Very severe erosion occurred on the northern end of Fraser Island, with Sandy Cape closed to vehicles for a prolonged period of time due to coffee rock exposed on the beach.

On Wednesday, 13 March 2009, MV *Pacific Adventurer*, a bulk carrier, was caught in cyclonic seas 15 km east of Moreton Island. In the large waves, the ship lost 31 containers of ammonium nitrate fertilizer. A lost container ruptured the ship’s fuel tank, leaving an oil slick on South-East Queensland beaches for 75 km from the Sunshine Coast to Bribie and Moreton Islands. A massive clean-up effort was organised by state agencies. The federal government called in navy mine hunter HMAS *Yarra* to find the containers of ammonium nitrate, which were located on the continental shelf.

3.2.2 East Coast Low, May 2009

The storm event between 19 and 24 May 2009 was significant in that it caused large seas over a wide area of East Coast Australia, and caused similar coastal erosion to the East Coast Low (ECL) in May 1996. Wave rider buoys recorded significant wave heights of over 5 m between the Sunshine Coast and Sydney. Disastrous flooding and damaging winds also occurred in South-East Queensland on the North Coast of New South Wales. The Bureau of Meteorology issued timely warnings that undoubtedly saved many lives. However, two lives were unfortunately lost: one person was killed by flying debris on the Gold Coast and another drowned in floods in Northern New South Wales.

There has been recent media coverage of erosion events occurring between Fraser Island (Queensland) and Sydney. Media accounts describe the loss of beach and the resulting income loss by dependent communities and coastal tourist operators. Examples include:

- loss to beach tourism operations when beaches where closed prior to a severe storm at Fraser Island at Christmas 2007
- beach loss on the Sunshine Coast and erosion on Gold Coast beaches during the May 2009 storm, and
- erosion of beaches adjacent to private property at many places on the New South Wales coast from a series of East Coast Lows over recent years.

4. Case studies

4.1 Gold Coast

In South-East Queensland, rapidly expanding coastal developments are occurring both north and south of Brisbane. Beach erosion problems on the Gold Coast have occurred because many developments, initially holiday cottages that became multi-storey buildings, were built close to the ocean without adequate buffers.

During 1967, five tropical cyclones were estimated to remove 8 million cubic metres of sand from Gold Coast beaches. Although the Gold Coast has not experienced excessive extreme events over the past 30 years, the potential for a tropical cyclone to generate storm waves and surges, causing widespread damage to the local community, is high. Castelle et al. (2007) and Castelle, Le Corre and Tomlinson (2008) suggest Gold Coast beaches would not be able to withstand the impact of an increased frequency of extreme events similar in scale to those of 1967.

4.1.1 Storm/erosion history

Southport Spit extended north until the 1860s, when decades of severe storms widened the entrance and moved the bar south. By the 1880s, the Southport bar had moved 800 m south of its 1840 position, and remained there until 1901 (Connah 1946). The entrance was east of Nerang Street, Southport and 1 km wide, with a recurved spit and flood tide silting in

Broadwater. Ocean waves from the wide mouth caused erosion of the western shore of the Broadwater at Southport, and seawall construction commenced. In 1898, following two tropical cyclones, mountainous seas and strong south-easterly gales from the Maitland Gale completed the breach through Stradbroke Island that began as washovers in 1895 and 1896. After 1901, the spit migrated north again, and the southern end of South Stradbroke Island moved north by over 3.5 km (Brooks 1953).

Severe erosion of Gold Coast beaches occurred following a succession of tropical cyclones between 1933 and 1936. Maximum storm surge during this period was estimated at 1.2 m. Southport Spit was breached near the Southport Surf Life Saving Club (SLSC) and protective timber walls were constructed to help protect the beaches from erosion at Coolangatta, Kirra, Narrowneck and Currumbin.

After further erosion in the 1950s, Gold Coast beaches experienced very severe erosion in 1967 when five cyclones and multiple ECLs hit the Gold Coast in one year, removing most of the sand from the Gold Coast's beaches (Smith 1994). The wide, sandy beaches of previous decades 'vanished' from the visible beach, with Tropical Cyclone Dinah (category 4) causing severe erosion. The impact was dramatised in the press and exaggerated on television. The media message was that the Gold Coast was ruined. As a result, tourists stayed away and it took three years to get out of the economic depression. Natural recovery of the beaches from the 1967 erosion took until 1971. The economic impact was assessed by Maitra and Walker (1972) and, based on the storm record and translated into today's economy, a one-in-25 year event would cost the Gold Coast 13 per cent of tourism dollars, or $305 million (in 2001 dollars). A minor event of, say, a one-in-five years Average Recurrence Interval (ARI) is estimated to cost $47 million.

The community response in 1967 was to take piecemeal action to protect property, using car tiers, rocks, concrete blocks and old car bodies, amongst other things. The local authority had no coordinated approach to coastal emergency response. Since the late 1950s, the Queensland government had been undertaking coastal process studies culminating in the commissioning of the Delft Hydraulics Laboratory in the early 1960s to examine the whole of the Gold Coast. Their report was in draft form when the storms of 1967 struck, and provided detailed information to back up a suite of recommendations for coastal protection. On the basis of the Delft Report (as it is now known), which was finalised in 1970, the Queensland government passed the *Beach Protection Act* (July 1968), which set up the Beach Protection Authority (BPA). The Delft Report outlined a series of works for Gold Coast beaches that included a whole-of-coastline seawall, groynes and other coastal control structures, the training of the Nerang River Entrance and extensive beach nourishment. This adaptation strategy was enshrined in the *Coastal Management Act 1973*, and has been the basis for coastal protection works implemented by the Gold Coast City Council and the Queensland government since.

During the last three decades of relatively calm conditions, many of the Delft Report recommendations have been implemented. In general, the protective actions taken (summarised below) have been accepted by the community. However, in 2004 the Palm Beach Protection Strategy was challenged and the Gold Coast City Council abandoned its policy of gradual implementation of the Delft Report recommendations, and commissioned a review of past activities and the development of a Shoreline Management Plan that addressed physical, economic, ecological and community issues. It is noteworthy that, even after the devastation of the 1967 events, there has been no consideration of a retreat strategy for adapting to extreme events.

4.1.2 Protection strategies

Wall building and nourishment

The Gold Coast Seawall, 16 m across and 6 m high with a steep front slope, is constructed along urban sections of the coastline and cost around $3000 per metre to construct in 2006. The seawall alignment (A Line) was selected to pick up as many of the older seawalls as possible. The seawall consists of three layers, armour boulders up to four tonnes, secondary armour around 360 kg and a clay shale foundation layer. The seawall was tested in a wave tank to withstand attack from a one-in-100 year cyclone wave. The Gold Coast Planning Scheme requires beachfront property owners to pay for seawall construction at their properties before making any further development. The council constructs sections of seawall that protect public land.

Sand replenishment

In Australia, beach protection works are generally the responsibility of local authority under the overall direction of state governments. In the mid-1970s, the Gold Coast City Council began beach replenishment, taking sand from estuarine sources for both the Surfers Paradise and Kirra beachfronts following continuing erosion due to storms in the early 1970s. This was not always successful due to insufficient sand, so offshore sources were sought. During the late 1980s, and throughout the 1990s, southern Gold Coast beaches were partly replenished by large-scale offshore dredging and sand pumping. This was part of a broader southern Gold Coast Beaches Protection Strategy, which culminated in the Tweed River Entrance Sand Bypassing Scheme. The strategy’s primary objective was to replace the deficit of sand on the Gold Coast beaches due to the trapping of sand on the beaches south of the Tweed River as a result of the extension of the Tweed training walls in 1962. Offshore sources were the only economically viable source of this sand. The objective of the bypassing scheme was then to maintain a normal supply of sand to nourish Gold Coast beaches.

Tweed River Entrance sand bypass

In the early 1900s, the New South Wales government constructed training walls at the mouth of the Tweed River. These walls were extended in 1962, and have an inevitable effect on the beaches downdrift on the southern Gold Coast. In 2001, a sand bypassing system started operating to deliver sand across the Tweed River bar so that it could be pumped to southern Gold Coast beaches. There was an accumulation of sand at some beaches and surf breaks, which led surfers to lobby for improved surf at Snapper Rocks by moving the sand outlet. At Kirra Point, a popular surfing site, surfers are concerned that sand is altering the quality of surf, but there is debate about the objectivity of impact perception. Given time, the excess sand currently creating concern at Kirra will dissipate and the bypassing system will be required as a permanent component of the Gold Coast’s beach-protection strategy. The return of wide sandy beaches at Kirra has seen a resurgence of property development in that area. It would appear, however, that little has been learnt by the community about the hazards of extreme events and persistent coastal erosion.

Gold Coast Seaway and sand bypass

The Delft Report recommended the stabilisation of the Southport bar with the construction of the Gold Coast Seaway and a sand bypass system to pump sand to South Stradbroke Island under the navigation channel. Some sand is also used for beach nourishment of Surfers Paradise beaches.

Kirra Point Groyne

Public and political pressure for action on coastal erosion in the early 1970s demanded the construction of physical structures such as groynes, despite engineering advice that such structures alone could not solve the Gold Coast’s erosion problems. Anticipated downdrift effects were experienced, and triggered further construction of localised protection works.

Northern Gold Coast Protection Strategy

The Delft Report recommended the construction of a groyne at Narrowneck to provide for wider beaches south to Surfers Paradise. Instead, in the late 1990s, the council implemented a strategy that included a submerged groyne (Narrowneck reef), beach nourishment and dune rehabilitation. So far, the reef has worked well as a coastal control point, but has been disappointing in its secondary objective of improving surfing. A surprising benefit of the Narrowneck Reef has been its ability to attract marine growth and reef fish, making it a popular diving and fishing location.

Palm Beach Protection Strategy

In 2004, Gold Coast City Council proposed a new beach protection scheme for Palm Beach that included three reefs and beach nourishment. Members of the community were opposed to the plan and organised a 'no reef' protest campaign that prevented its full implementation.

4.1.3 Conclusions

The implementation of the Delft Report recommendations, and in particular the construction of terminal walls under the dunes, has worked well for Gold Coast beaches during the period from the 1970s to the 2000s – an unusually long calm period during which accretion of beaches was expected. Until recently. residents have generally been opposed to the construction of a buried wall, rock groynes and major sand nourishment schemes, as they are seen as unnecessary and in the case of the Tweed Sand Bypassing Scheme to negatively impact on recreational amenity. However, with sea level continuing to rise, it has been observed that less-intense storms such as those in 2009 caused erosion and exposure of the walls. Unlike the lack of engagement by beachfront property owners during the consultation process surrounding the Palm Beach Protection Strategy in 2004, there now appears to be an increasing level of awareness and concern over beach protection.

4.2 Byron Bay

The coast of Byron Bay is internationally known for its beaches and Cape Byron – the prominent headland and easternmost point of Australia. A combination of surfing and alternative culture developed during the 1970s and 1980s, with Byron Bay now internationally known as a surf hotspot with many local surfers competing at an international level. Debates over coastal management have occurred since the 1970s. A number of residences have been threatened by the advancing sea, prompting coastal planned retreat, including implementing setbacks and constraints on new development (Byron Shire Council 2003). Byron Shire is the only local government in Australia to have a statutory coastal setback plan.

4.2.1 Storm/erosion history

The first chart of Byron Bay was made by Lieutenant Johns, master of HMS *Rainbow* under Captain Rous in 1828. While this chart cannot be compared directly with modern maps, it shows extensive inshore sand especially north of Cape Byron. The first survey of the beaches between Brunswick River and Broken Head was made by Surveyor John Barling in 1872. The coastal features shown can directly be compared with a survey of Cape Byron Bay by Francis Howard in 1883. The posts in the sand dunes placed at each mile by Barling had already eroded, and are not shown by Howard. Changes to coastline features since the first accurate surveys include continuing erosion and loss of spits – for example, the reduction (since 1883) in the size of Belongil Spit and the creek mouth moving southward by around 1.5 km.

There have been a number of severe erosion and inundation storm surge events. The earliest described was in August 1864, when a severe storm eroded the beach dunes with washovers and inundation of the coastal wetlands (Callaghan & Helman 2008). Ainsworth described the area behind the dunes as being 'like an extension of the sea' (cited in Callaghan & Helman 2008). Later erosion events are associated with severe storms in 1849, during the 1860s and 1880s. In 1883, Howard described a fresh erosion face in the dunes, and noted that the beach had been swept over (cited in Callaghan & Helman 2008). Beach mining leases, surveyed on the beaches from 1888 to the 1940s, and aerial photos from the 1940s document continuing erosion during storm periods, especially after World War II. In February 1954, the outer portion of the new jetty was destroyed by a cyclone with flooding and storm surge inundation of the Belongil swamp. During Cyclone Pam in 1974, the front of the existing carpark and the surf club were destroyed. The surf club was moved to its present location and the carpark wall rebuilt further inland at its present position.

East Coast Low (ECL), late May 2009

The intensity of the May 2009 storm event at Byron Bay was assessed at the lower limit of storms that cause coastline erosion. While the storm of May 2009 was less intense than an event in May 1996, in erosion terms it was still more severe due to sea level rise (Helman & Tomlinson 2008). For example, on Tallow Beach the 1996 erosion face was 30 to 50 m further seawards when compared with 2009, where the erosion face is generally at the foot of the slumped 1974 face. At Belongil, rock protection walls remained intact but a section of geotextile bags placed at Manfred Street in 2002 were washed over, with erosion of the dune above. The beach in front of the walls was lost to the outer bar and considerable erosion occurred down drift of last wall, as shown in Figure 3.

Source: Belongil Progress Association.

Figure 3: Aerial view of Belongil Spit after May 2009 storm

4.2.2 Coastline erosion response

Following the period of severe erosion during the 1950s and 1970s, when many coastline properties were lost, an extensive study of coastal processes was conducted and completed in 1978 by the state government Public Works Department (PWD) Coastal Branch. The PWD study showed long-term coastal recession, which is supported by more recent studies (WBM), with recession rates of between 0.6 m and 1.6 m per year. The extensive New South Wales Department of Public Works studies (Skene 1986; PWD 1978) identified long-term erosion in the area, and in response a setback policy (Part J) was developed. ‘Erosion lines’ were defined on Public Works maps (Skene 1986) and in 1988 a Local Environmental Plan (LEP) was prepared under the *Environmental Planning and Assessment Act 1979*. The LEP contained Development Control Plan (DCP) No. 1, Part J: Coastal Erosion Lands.

The policy in Part J of the DCP applies to all coastal erosion lands identified on the Public Works maps. The objectives of the policy are:

- to make provision for the orderly and economic development of land within the coastal erosion zones
- to ensure that such development is carried out in a manner that does not adversely affect coastal processes and will not be adversely affected by coastal processes, and
- to provide guidelines to determine the merits of development on coastal lands as required by section 90(1)(g) of the *Environmental Planning and Assessment Act 1979*.

Three erosion lines (Figure 4), with planning precincts between, are defined in the DCP as:

- immediate impact line
- 50-year erosion line, and
- 100 year erosion line.

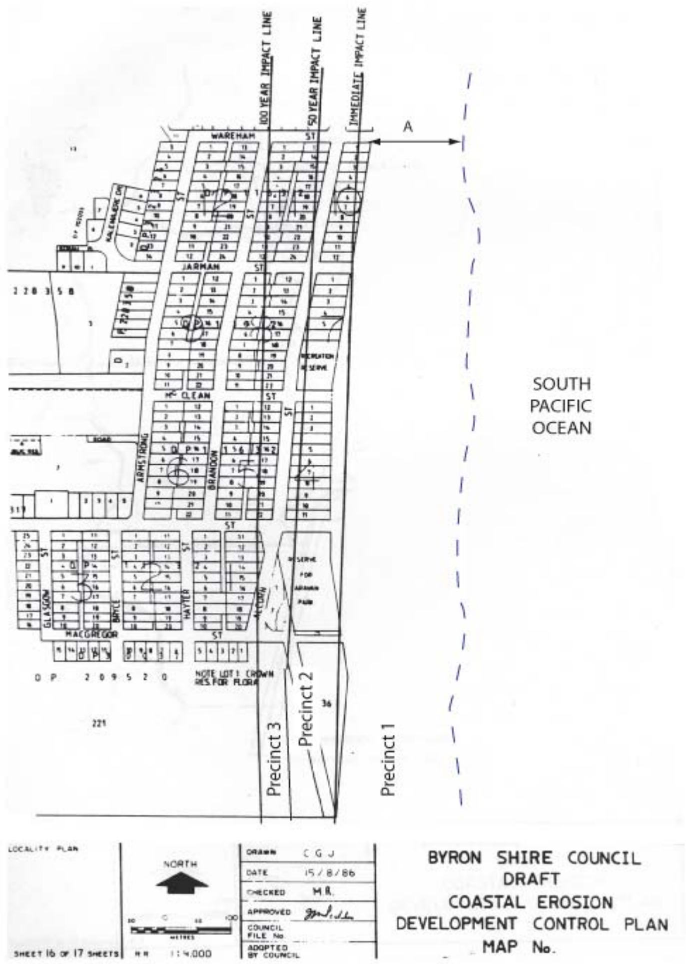


Figure 4: Statutory planning set-back lines and precincts under DCP1, LEP 1988, at Suffolk Park, Byron Shire

Planning precincts and development policy

Precinct 1 is between the beach escarpment (storm face) and the immediate impact line (Figure 4). Generally no new buildings or works, unless related to use of the beachfront, and any building is easily removable and does not require service mains. Precinct 2 is between the immediate and 50-year lines. Development of houses that are relocatable will be considered on the understanding that any consent granted will be subject to a restriction under section 88E of the *Conveyancing Act 1919* that, ‘in the event that the erosion escarpment … comes within [specified distance, usually between 20 and 50 m] of any building’, the development consent will cease and the owner will be responsible for any removal. Precinct 3 is between the 50- and 100-year erosion lines, with similar conditions to Precinct 2. Restrictions also apply on extensions to buildings that existed before the policy was introduced. Houses ‘shall be designed and constructed … [for easy] … removal from the site by road vehicle’. Work by individual property owners to protect land from erosion will require the consent of council, and ‘will have no effect on any adjoining properties or on any coastal process’.

Byron Shire Planned Retreat Policy

Planned retreat is a coastal management approach that acknowledges coastal processes and long-term recession as a dominant factor in planning for the use of coastal areas. On an eroding coastline, this requires the retreat of development and infrastructure as the erosion escarpment (most landward limit of erosion) moves inland.

Planned retreat allows the temporary use and occupation of coastal lands until the erosion escarpment encroaches within a specified distance from a development (depending on the type of development), which will be required to be relocated. Planned retreat is a precautionary approach to managing coastal development, comprising actions aimed at maintaining a buffer along the coastline. This is designed to accommodate natural coastal processes, and reduces the level of risk associated with storm erosion and inundation.

The objective of planned retreat in Byron Shire is to address the following issues facing the coastline in relation to development and infrastructure:

- management of coastline erosion and inundation
- retention of public access to the beach
- protect beach amenity, and
- environmental sustainability.

The original setback lines were developed for the Byron Shire by the New South Wales Department of Public Works, and were based on extensive studies of coastal processes. The implementation of the retreat policy is made difficult by inadequate legislation for both council and community. The New South Wales sea level rise policy is in draft form, and provides guidance to local government through state legislation.

4.2.3 Conclusions

While over the last two decades Byron Shire’s setback planning has been more or less successful in preventing over-development of vulnerable coastal land, it has not solved the ethical, moral, legal, policy and management issues of relocating beachfront residents. In theory, the Byron Shire policy has many appropriate provisions and many elements of a ‘managed relocation’ strategy:

- use of a 100-year planning horizon
- space for long-term erosion over the next century
- recognition that within this zone there will be immediate impacts from storms
- approval for limited development in this zone being conditional on future coastline movement
- approval ceasing if the erosion face moves within a specified distance, and
- responsibility of the owner for relocation or removal.

However, the policy has not been successful in preventing development of these coastal lands with buildings that technically may comply (could be disconnected from their footings) but could not easily be moved if threatened by a storm event. For example, multi-level houses recently have been constructed in the vulnerable erosion zones that, due to height and width, are ‘relocatable structure[s] but are not … easily removed … by road vehicle’ (Byron Shire Council LEP). One reason why this policy has not successfully been implemented has been the multi-decadal nature of coastal behaviour. The policy was introduced after the severe erosion events prior to the mid-1970s but with no major erosion events during the last three decades, many current property owners have not experienced severe storms. This long interval between severe events, which also spans several elected councils and considerable staff turnover, has led to a false sense of security, resulting in a gradual easing of policy restrictions in response to continual pressure for development. The long period of three decades between major storm events, combined with fading knowledge of these events, encourages various degrees of complacency and scepticism.

While this is implied, the scheme does not explicitly protect the beach – the asset on which the Byron Shire depends to attract almost two million visitors a year. Nor does it protect the natural functioning of the surf zone, the biodiversity corridors or the public reserve that provides access to the beach. Coastline planning in Byron Shire is recognised for its state and national importance. Yet, despite decades of studies and reports, a clearly agreed scientific description of the Byron coast and its processes has not been produced. A firm scientific understanding is an essential starting point for the shire's coastal sustainable planning. Community support for the council's approach will depend on an agreed understanding of how the Byron coast was formed, how it has changed with past sea level rise, how it will change with projected future sea level rise and the role of the Memorial Baths protection works in the process.

In recent court proceedings,[1] Commissioner GT Brown of the New South Wales Land and Environment Court noted that, despite the significance of 'the range of planning instruments that apply to the site' and to which council has responded appropriately, council should seek 'a coordinated and planned approach to coastal hazard assessment and management'. In response to Commissioner Brown's recommendation, it is proposed that an 'agreed position' will be produced by coastal scientists who have studied the Byron Coast. The position will become the foundation upon which council's future coastal policy and planning is based. The process will take a similar approach to the multi-reviewed and agreed position of the world's climate scientists in IPCC reports that inform international and government policy.

Current legal, policy and management models are not yet developed to deal with inland coastal movement. Options for future management of climate change on the coast need to be explored and implemented to ensure that the beaches of Byron Shire are retained. The beaches and surf breaks of the Byron coast are an essential component of the sustainable future of the shire. Economic and social values of the Byron coast need to be established firmly, and recognised by the community. How these values interact with changes to the coast due to rising sea levels must be stated clearly and widely appreciated.

4.3 Collaroy/Narrabeen

Collaroy and Narrabeen are two of Sydney's iconic northern beaches, stretching 3.5 km north from Long Reef. In places, the beachfront is highly developed with high-rise buildings, four surf clubs and very high levels of visitation. The area is part of the Sydney Coastal Councils Group study on vulnerability and adaptive capacity in a metropolis area (Preston et al. 2008). Subdivision of the area first took place in the early 1900s, predominantly for holiday homes. After World War II, residential housing and home units grew rapidly. The 1960s boom led to the construction of high-rise buildings very close to the beach, *Flight Deck* and *Marcassa*. The footings of these buildings have been eroded and now have protection works.

According to the DCC (2010b) there are a total of 1432 residences and 262 commercial properties at risk from flooding in the Narrabeen Lagoon, the largest coastal lagoon in the Sydney region. Historical flood events at Narrabeen Lagoon depict rainfall runoff and elevated

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1 *John Van Haandel v Byron Shire Council* [NSWLEC 394] (21 June 2006, updated: 14 July 2006) (Finding 25).

ocean levels as being the main flooding mechanism, with the last major event occurring in 1986. The DCC (2010b) states that the Narrabeen catchment is likely to experience an increased frequency and intensity of storms and rainfall over the coming century.

4.3.1 Storm/erosion history

There is a well-documented history of erosion along Collaroy and Narrabeen beaches from the 1920s. During the 1940s, there was further erosion and loss of beachfront lots at the southern end of Collaroy. Severe erosion in 1967 was exceeded by 1974, and rubble was dumped at the dune face from late 1960s, continuing into the 1970s. During a storm in 1998, the SES dropped anything it could find on the dune face.

4.3.2 Coastline planning response

The problems facing Collaroy and Narrabeen beaches in northern Sydney provide an example of coastal management with the following issues:

- There is a long history of ongoing erosion.
- A range of nourishment schemes exists.
- The value of potentially affected property is estimated at $0.5 billion, in addition to the very high recreational and amenity values of the beach.
- There is considerable denial of the problem of long-term erosion.
- There has been minimal take-up of the council’s offer to purchase erosion-prone properties.

Following the erosion caused by the 1970s severe storm period, Warringah Shire Council introduced building setbacks of 15 m and 23 m. During the 1980s, numerous studies were undertaken by the New South Wales state government and council to understand the issues. These studies provided the basis for hazard lines (immediate impact and 50-year) and draft building guidelines.

Warringah Shire Coastal Management Committee was established in 1995, and from its inception the committee favoured a management planning approach that included voluntary purchase of threatened ocean-front properties. The purchase was to be at full market value, where council had to bid or make offers in the marketplace, competing with other buyers. The Collaroy/Narrabeen Coastline Management Plan was finalised in 1997, and council considered that a seawall was the best option.

Seawall proposal

The committee opposed the construction of a seawall; council ignored this advice and included an option for a seawall. The seawall option was rejected by resident action in the ‘Line in the Sand’ demonstration in November 2003, when around 3000 residents linked hands on the beach along the line of the proposed seawall. This event made national news. As a result, the council altered its position and removed the seawall option.

Recent actions

Since 2003, the management plan has included:

- buy back (proposed for single-dwelling properties only, no apartments or high-rise buildings)
- minor sand nourishment (from the lagoon entrance and building sites)
- major sand nourishment (this element of the plan is yet to be acted upon by the state government)
- no private seawalls permitted, and
- no council-funded continuous seawall.

All apartments and high-rise buildings have some type of seawall protection (made from a range of materials), as do many of the houses. However, A Short (pers. comm.) considers that many of these structures could be vulnerable to failure in a major event.

Since 2003, beach nourishment has been provided by the dredging of the lagoon entrance (every three years) and excavated sand from building sites. Only five beachfront properties have been purchased, the last in 2007 at a cost of $2.7 million. These purchases have been funded from council's development fund (levied on all new developments to enhance public amenity in the area) and some from New South Wales government funds. On purchased properties, the buildings have been demolished and the areas used as a beachside park, parking or other facilities. However, despite development restrictions in the management plan, several developments have been approved directly by the Planning Minister, or have challenged council in the Land and Environment Court.

4.3.3 Conclusions

Since the management plan, council has carried out a number of the recommended actions aimed at preserving and protecting the beach as a national asset for public recreation and amenity. In particular, the management plan has ensured that building and development along Collaroy-Narrabeen Beach has regard to the current and future hazards of wave impact and coastal erosion. The key issue with the overall strategy is the reliance on property buy-back which, if it continues in a piecemeal fashion, will not ensure a continuous buffer at the right time in the future. It is also of concern that the community may believe that the strategy will provide protection against extreme events. The community's dislike of a seawall option may also be an outcome of its general misunderstanding of the effectiveness of the strategy; to be an effective adaptation strategy, complete buyout of beach front properties would be required.

5. Responses to past events

5.1 Long-term adaptation

The last period of severe storms ended in the mid-1970s, with severe erosion along the coast. From the case studies presented in Section 4, there is evidence that adaptation at a policy and management level was actioned as shown in the following summary.

Specialist coastal study units were established in Queensland (Beach Protection Authority) and in New South Wales (Public Works Coastal Branch). Many studies were initiated – for example, on the Gold Coast (Delft 1970) and in Byron Bay (PWD 1978). These studies provided practical understanding of the coastal process, and led to the beginnings of coastal adaptation measures.

In response to these earlier erosion events, the New South Wales government developed coastal management planning guidelines that set out methodologies for assessing coastal hazard and responses. The Queensland government established the Beach Protection Authority in 1968 and passed the *Coastal Management Act* in 1973. However, the last few decades of calm weather have seen these specialist units dissolved and the importance of the coastal studies neglected.

Over recent years, there has been a resurgence of response at the state government level, with both states introducing draft sea level rise policies to guide coastline planning. New South Wales and Queensland have adopted slightly different sea level rise planning guidelines for the next century, of 0.9 m and 0.8 m respectively. While such differences may not currently be significant, they do allow sceptics to suggest that sea level at Point Danger will be 0.1 m different on each side of the border, and illustrates that policy consistency should exist within and across jurisdictions.

On the Gold Coast, there has been a progressive implementation of the Delft Report recommendations, including protective seawalls along the property line, groynes and other coastal control structures, nourishment with sand from a range of sources as part of regular creek entrance management and large-scale capital programs. Despite extensive development, there is generally a sufficient sand buffer available to accommodate natural variability due to storms – although with some cases, such as Palm Beach, that buffer is minimal.

At Byron Bay and Narrabeen, the question of property protection is becoming a major community issue. In Byron Bay, the PWD coastal study resulted in the incorporation of planning setbacks into the local environmental plan. In Collaroy/Narrabeen, proposed protective works were the subject of a massive public backlash, resulting in Warringah Shire Council adopting a buyout scheme to purchase properties vulnerable to erosion at Narrabeen beach. Although there has been sand nourishment of Narrabeen Lagoon, there has been very little take-up of the buyback scheme due to the high value of oceanfront land.

5.2 Community attitudes

The response of coastal property owners to the extreme events of the 1960s and 1970s has had little detailed documentation in the case study areas. On the Gold Coast, the council's Coastal Engineer, Sam Smith, did document a range of local residents' perceptions with regard to their experiences (Smith 1994). In summary:

- When interviewed during a period of calm weather, over 90 per cent of beachfront residents believed that they wouldn't be affected by erosion.
- The public thinks that a typical significant storm (which in reality may have a one-in-six or so year return period) is a very rare event and is soon forgotten.
- There is a 70 per cent turnover of beachfront population every decade.
- The visible beach represents the whole beach.
- A variation in width of the visible beach to 10 m per day is acceptable, but more is an erosion event (this level of variation is just noise on the overall profile changes).
- Only 5 per cent accept that the active beach goes out to a water depth of 15 m.
- The public at large does not accept the reality that 30–40 m recession can occur.
- There is a general belief that the dune will prevent erosion. (The dune may be only 5 per cent of the total volume of sand that can be activated in a storm.)
- The wave breaking closest to residential property is the one doing the damage; therefore the storm waves breaking offshore are not moving sand (the waves are only breaking out to sea because sand has been moved offshore).
- Seawalls will protect (they do, but they also require maintenance).
- Property owners believe that a hard surface or structure is the best protection.
- There will never be an event bigger than the last one.
- The amount of erosion didn't depend on the state of the beach beforehand.
- A one-in-100 year event will not occur for 100 years.

Other observations made by Smith were:

- Visible erosion is not necessarily a function of the biggest waves.
- The media will sensationalise.

- Locals are likely to understand what is happening and act – tourists will pack up and leave.
- The perception of new residents on the coast with regard to erosion hazard is similar to that of tourists.

It is reasonable to assume that all coastal communities will have similar responses.

5.3 Emergency response

At the level of immediate response to past extreme events, there have been changes in the way human safety and property protection are controlled and actioned. In particular, in the areas of evacuation planning, the role of community and government agencies – including the SES and police – has changed significantly over the last three decades. Many of the emergency response processes have been tested for floods, cyclones in northern Australia and bushfires. For example, during its south-east movement parallel to the coast in early 2009, Cyclone Hamish threatened to track towards a number of offshore islands, with expected damaging winds, large waves and storm surge. Evacuations of the Whitsunday group, as well as Heron, Lady Elliott and Fraser Islands were organised prior to the cyclone's arrival.

These processes will not be discussed here; however, it is fair to say that they have yet to be tested for major coastal erosion and inundation events in our case study areas.

The other concern with immediate response is the area of property protection. Similar examples of emergency protection were found for each of the case study areas for the extreme events of the 1960s and 1970s. The following description of the Gold Coast is taken from Jackson, Corbett and Tomlinson (2007).

Emergency protection works aimed at reducing the erosion of the dunes were varied in both their type and effectiveness. Measures taken included:

- boulders
- car bodies
- concrete rubble
- concrete slabs (including collapsed swimming pools)
- drums filled with concrete
- gravel
- masonry bricks and blocks as rubble
- plastic sheeting
- prayers
- sand
- sand bags, and
- timber walls and groynes.

The most successful were well-constructed boulder walls. However, poor-quality or overtopped boulder walls failed quickly. Areas where adequate boulder walls had been constructed over a long length during earlier severe erosion events were the most successful. While the beach was lost, the extent of erosion was curtailed. Erosion occurred unabated up- and downdrift without any significant increase in the extent. Recovery of the beach occurred after the storms in all areas. One problem was that with the cyclonic rains, access to quarries for suitable rock was limited. Other measures that had some success were:

- rubble, where at a flat angle and thick enough, and

- sandbags, where well interlocked and well filled.

The army was dispatched to deal with the disaster. It brought in a familiar tool, hessian sandbags (Figure 5). Larger plastic fertiliser bags were also used by council and residents, but proved less effective due to their low coefficient of friction. Gold Coast City Council distributed sandbags to owners, who filled them using readily available sand from their yards.

Figure 5: Erosion in 1967 at Surfers Paradise – army personnel laying sandbags

The behaviour of residents under stress was not always uplifting. Pilfering of sandbag stores by residents, and diverting council trucks loaded with rock to protect roads, was commonplace. Pressure on politicians by influential beachfront owners was widespread. Commitments to pay for council rock were often avoided after the event. Even short-term erosion can have severe economic and social impacts. However, emergency protection works can be done quickly, effectively and efficiently with the right materials and techniques without adverse impacts. Timing is critical, and works generally need to be able to be done at low tides for safety and to achieve the best results. The observation of the behaviour of various protection works has led to better wall designs that are easy to install and can cope with very severe events. To minimise the economic impacts to the tourist economy and need for emergency, Gold Coast City Council maintained a large stock of bags for emergencies for many years, and may still have them. Beachfront parks were seen, at least by the coastal engineers, as an emergency supply of sand for filling sand bags. They also established a boulder wall line and required all new works (then over $25 000) to be protected by a well-designed and constructed wall to be covered by a dune. These walls lie buried ready for the next severe erosion. Long-term works to widen the beaches have further reduced the risks to the economy and properties.

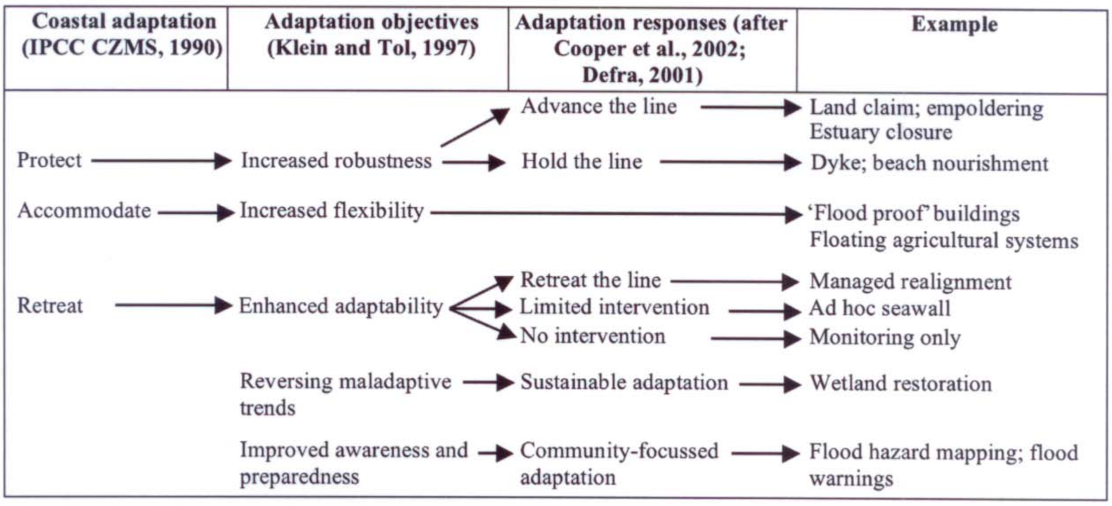
6. Coastal adaptation strategies

IPCC (2007b) defines adaptation as an 'adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities'. IPCC further distinguishes between different types of adaptation, namely anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation. Pittock (2003) argues that, in Australia, adaptation to climate change as a means of maximising gains and minimising losses has been relatively little explored at the location-specific level, and in a cost-benefit framework. The costs of adaptation to climate change, however, are much lower than damage costs would be without adaptation, even if only property losses and fatalities were considered. According to Nicholls et al. (2007), an absence of adaptation measures for cases of extreme sea level rise and other changes such as increased storm intensity would likely render some low-lying areas unviable by 2100. Therefore, effective adaptation is paramount.

Klein et al. (2001, cited in Nicholls et al. 2007) describe three trends in coastal adaptation options (see Figure 6):

1. a growing recognition of the benefits of 'soft' protection and of 'retreat and accommodate' strategies
2. an increasing reliance on technologies to develop and manage information, and
3. an enhanced awareness of the need for coastal adaptation to reflect local, natural and socioeconomic conditions.

Although there are various adaptation options available, Nicholls et al. (2007) outline the level of present knowledge as a major constraint for future adaptation measures: 'While knowledge is not adequate in any aspect, uncertainty increases as we move from the natural sub-system to the human sub-system, with the largest uncertainties concerning their interaction.' According to Nicholls et al. (2007), the decision about which adaptation option is chosen is likely to be largely influenced by local socioeconomic considerations.



Source: Nicholls et al. (2007).

Figure 6: Planned adaptation practices

Attitudes to beach protection vary considerably. Some lobby for coastal protection and elaborate on the consequences of not doing so; others, as observed at Byron Bay, identify the role of protection structures in overall beach erosion and argue for no further hardening of the shoreline. In particular, there are many perceptions about the role of seawalls, the benefits of nourishment and the need for long-term strategies.

6.1 Protective structures

What seems to be lost on many commentators is that the seawall has been placed there after properties have been threatened by erosion, not before. As is the case on the Gold Coast, the seawall is a last line of defence.

6.2 Beach nourishment

Similar confusion exists about beach nourishment – adding sand to the beach from external sources. The classic comments from eminent environmental commentators on TV programs include criticism of beach nourishment because a storm came and removed it. What is not discussed is what would have happened had there been no nourishment. Nourishment can be resoundingly successful, as demonstrated by the work done at Surfers Paradise during 1974 where nourishment was required to circumvent the natural recovery processes following an extended period of storm events. In too many cases, discussions of beach erosion fail to address one of the most sensible alternatives to beach protection: relocation from the shoreline. Beachfront land ownership is a complex legal, social, economic and political issue that needs to be discussed openly and addressed in the context of sea level rise.

6.3 Retreat strategies

Strategies aimed at moving development back from eroding coastline and limit the possibility of storms inundation, can be achieved by planning schemes but attempts to move coastline residents before the coast is eroded has proved to be very difficult to achieve.

6.4 Identifying at-risk/vulnerable areas

Risk surface maps are invaluable to emergency services in their development of disaster prevention, awareness, preparedness and response plans. Risk surface maps can also be used by insurance companies, local government, developers, and utilities to reduce disruptions to lifelines and the general public (Geoscience Australia website).

7. Lessons learnt

Recent 2009 storm events are not extreme when compared with those experienced in the past. It is generally considered that Gold Coast events had about a one-in-ten year ARI. The 1967 sequence of storms and the major storms of 1974 rated more like a one-in-100 year+ event, and would be considered a truly extreme event. As noted elsewhere, coastal storminess is linked to decadal cycles, and the responses to these events must be seen in light of the 30-year period of relative calm since the mid-1970s.

On the Gold Coast, there was a substantial response from governments to the extreme events, with the implementation of coastal protection works, state legislation and state-based technical teams under the guidance of the Beach Protection Authority (BPA). However, over time many of the actions taken have been reversed, and lessons learnt seem to have been forgotten. This movement away from a more proactive stance by governments has paralleled the decadal shift in storminess to the calm period since 1977. These three decades have been characterised by a ‘calm weather planning’ mentality, which has seen many new developments approved in highly vulnerable areas. This is not unique to the Gold Coast, as it has occurred in all case study areas. The implication for future coastal inundation is obvious.

The adaptation strategy for coastal erosion on the Gold Coast has been one of management and protection. This has been effective to date, but many of the elements of this strategy have yet to be tested under extreme conditions, and will potentially be limited over future decades under the projected sea level rise scenarios. As a strategy, it has also been shown to lack broad support in the community (with reference to community objections to the Palm Beach Protection Strategy in 2004) if action is proposed during a calm weather period.

The most significant lesson learnt from the Gold Coast experience – and indeed all case study areas – is that periods of extreme events demand a robust technical response. The capacity to provide this was developed in both the Beach Protection Authority (BPA) in Queensland and the New South Wales Public Works Department, but over the last decade or so, as the calm period has continued, this capacity has gradually been removed. Even the BPA has recently been disbanded.

The adaptation strategy for Byron Bay was one of 'Planned Retreat' – or, more correctly, application of a set-back policy. While this seems to be the preferred strategy worldwide for coastal climate change adaptation, the difficulties involved in enforcing such a policy have increasingly been highlighted since it was introduced in 1988. Although the set-back scheme is unique to Byron Bay, such a policy is difficult to implement due to the lack of legal clarity over property rights. This has highlighted the importance of the need for all levels of government to be of one accord in terms of statutory processes, legal framework and community engagement. Recent coastal management policy and guidelines being proposed for New South Wales may also conflict the basic tenet of planned retreat that there should be no exceptions.

At Narrabeen/Collaroy, the adaptation strategy has been that of property buy-back, thereby creating a buffer or set-back. Although this has only been in place since 2003, it is clear that it has been limited in both the formulation of the policy (with certain types of properties being exempt) and in the capacity for the local and state governments to purchase property on the open market. Arguably, unless all beachfront properties have been acquired, a continuous buffer against erosion and inundation will not be achieved.

Both New South Wales case studies provide a model for long-term future response to climate change, and would only be effective if climate change occurred as a slow linear-type increase in sea level and other environmental impacts, such as increases in wave energy. The social, legal and political change needed to address the loss of property rights and community relocation has a chance under these circumstances. Neither case study accommodates the reality that coastal impacts are primarily due to extremes of climate variability underlain with these long-term changes.

In terms of the individual exposed to an extreme event scenario, it would appear that the lessons learnt are short-lived, as demonstrated not only by the information provided by Smith (1994), which suggest that the threat is forgotten within days, but by what appears to be a 'she'll-be-right' attitude. Smith noted that if an event was reported as a 1-in-100 year event, say, then people who lived through it felt that the worst was over and they would never be impacted again in their life time. Similar sentiments have been expressed at community meeting and forums recently, where old time residents claim that their beach hasn't changed in years. Overall it would appear that unlike residents in north Queensland, who regularly face major flooding and adapt, coastal residents in the case study areas expect their coastal beach or waterway foreshore to remain constant.

In terms of the immediate emergency response to threats to property, a similar situation exists to that of the broader long-term planning and resourcing mentioned above. In many cases, there is a lack of technical expertise or experience in dealing with such emergencies. This includes both emergency planning and the stockpiling of materials such as sandbags. All coastal areas will suffer again from erosion 'disasters', and the political expectations and demands by residents on all levels of government for temporary protection works will be very high, regardless of any overall coastal management plan.

8. Priorities for the future

The Australian government regards ‘preparing Australia for the unavoidable impacts of climate change’ as imperative (DCC 2009b: 1). The Australian State of Environment Report (2006: 49) states that ‘planning for adaptation to climate variability should be a priority’. However, to date there has been limited incorporation of climate change considerations in current planning policy and legislation, both in the context of mitigation and adaptation (Garnaut 2008; NSW Environmental Defender’s Office 2008; Planning Institute of Australia 2007). Further, the New South Wales Environmental Defender’s Office (2008) demonstrates that where there is mention of climate change in legislation, none imposes mandatory duties on local councils: ‘Councils are merely required to take climate change into account, but are not required to make “climate friendly” decisions.’ (2008: 36) According to NCCARF (2009), it appears that professional planners, engineers and scientists working for government, industry and community agencies have not been well informed about climate change and adaptation issues. Other challenges that both hinder and inhibit coastal climate change adaptation include: the complexity of institutional and inter-jurisdictional arrangements; lack of a national mechanism for collaboration; and short-term thinking, where the future risks of climate change are not considered by decision-makers (DCC 2009a).

8.1 Government roles and responsibilities for coastal adaptation

From the work presented here, it is suggested that the most effective action government can take is to adopt the recommendations of the House of Representatives (2009) report into the coastal zone. Key recommendations include:

- further research on storm surge impacts
- further coastal zone adaptation research planning
- the review and reassessment of natural disaster mitigation programmes
- a national assessment of coastal infrastructure vulnerable to sea level rise and extreme events, and clarification of the associated legal and liability issues
- awareness of legal and socioeconomic issues associated with vulnerability to sea level rise
- consideration of the establishment of a funding program for infrastructure enhancement, and
- undertaking an awareness campaign ‘to alert coastal communities to the key challenges’.

The House of Representatives (2009) report has captured succinctly the issues facing the coastal zone, and calls for a nationally consistent approach to dealing with climate change issues. Of course, the levels of government have different roles and responsibilities with regard to climate change adaptation. The Australian government has limited power in coastal planning and management, resulting in state, territory and local governments having a greater role in direct coastal adaptation action. Each state government has delegated some of its powers, under legislation, to local councils. In addition, various non-government sectors, such as water utilities, port authorities and insurers, all have roles that relate to the management of coastal areas and facilities (DCC 2010a).

In all states, local governments are responsible for day-to-day administration, yet there is currently little mention of climate change in Australian legislation for local government. The ‘discretionary’ nature of the legislative framework has meant there has not been a strong push for local governments, or other levels of government, to fill the knowledge gap (DCC 2009b;

NSW Environmental Defender's Office 2008). Various barriers to effective integration of climate change within local policy and planning schemes include: access to reliable data on potential climate risks (Voice, Harvey & Walsh 2006); lack of resources and adequate monitoring of policy implementation and review (Hunt et al. 2007); and the need for advice on the best way to reflect these matters in a planning scheme (Gurran, Hamin & Norman 2008). In addition, local governments have a range of competing priorities and generally lack decision-making frameworks that value the avoidance of future risks.

According to DCC (2009a), national and state inquiries into coastal zone management have recognised inconsistent and uncoordinated approaches as a barrier to integrated decision-making. In a number of areas, local governments lack the capacity to assess and reduce climate risk (DCC 2009a). According to the New South Wales Environmental Defender's Office (2008), local governments are at the forefront of local adaptation action, yet a lack of data, tools and capacity has left many local councils unsure about how to reduce damage from inundation and extreme events. This disparity between local governments has left some lacking the resources to identify and implement cost-effective adaptation. While other councils may be well equipped, reduced technical capacity across local government agencies responsible for coastal management directly impedes the mainstreaming of cost-effective adaptation approaches (DCC 2009a).

8.2 Current challenges for climate change adaptation in coastal areas

There is currently a great deal of uncertainty across all levels of government and all sectors of the community about how best to respond to coastal climate change risks. There is also little comprehension across society about the magnitude of risk that confronts Australia in the coastal zone. Thus it is imperative to create an informed Australia (Coasts and Climate Change Council 2010). However, to implement an effective adaptation agenda, various challenges need to be addressed, including the following:

8.2.1 Challenge 1

A lack of national action in regards to coastal climate change adaptation.

Recommendations:

a. Improve understanding of response options

Ensuring resilience to anticipated future climate change impacts is crucial. Early key actions should focus on building both national awareness of climate change and adaptive capacity. This includes providing risk knowledge information. Several guidance documents have been produced to build understanding with regard to the costing of climate change impacts and the application of risk-management approaches to reduce potential adverse consequences (e.g. Garnaut 2008; SGS Economics and Planning 2009). Other guidance documents have been targeted specifically at local government actors, with the aim of assisting them through a range of tools to identify and implement climate change adaptation options (e.g. DCC 2009a, 2009b, 2010a; AGO 2006). Several regional climate change assessments funded by NCCAP have also been undertaken to improve risk knowledge, including in Sydney (Smith et al. 2007; Withycombe et al. 2008; Smith et al. 2008; Preston et al. 2008); Clarence City Council, Tasmania (SGS Economics and Planning 2009); the Gold Coast; Western Port, Victoria; and the Australian Capital Territory. For example, using vulnerability mapping as a risk-communication tool and stakeholder engagement, the Sydney region climate change project included assessments of biophysical changes and local adaptive capacities, as well as an analysis of the barriers for adaptation at multiple levels of governance (Smith et al. 2007; Withycombe et al. 2008; Smith et al. 2008; Preston et al. 2008). Likewise, Gurran, Hamin & Norman (2008) undertook a targeted review of local planning practices relating to climate change mitigation and adaptation, and developed a planning guide for the National Sea Change Taskforce.

Based on their review, Gurran, Hamin & Norman (2008) called for new approaches to coastal planning and governance. There needs to be clear guidance on public and private obligations and options in responding to and preparing for climate change, both in terms of managing changes with existing developments and for new investments. The Garnaut Report (2008) contends that current socioeconomic and environmental trends will need to be accompanied by a conscious process of planning to reduce vulnerability to climate change. Coastal communities experiencing rapid population growth, for example, need to factor climate change considerations into planning and assessment frameworks (Gurran, Hamin & Norman 2008). Similarly, building codes and engineering specifications for infrastructure in high-risk areas in the coastal zone need to be upgraded. The building code currently includes 'no provisions to minimise the risk of inundation from sea level rise' (DCC 2009a: 150). Also, as the building code sets minimum standards, it is difficult for local governments to justify setting more stringent requirements (DCC 2009b).

b. Identify appropriate adaptation actions

Climate change has tended to be accepted as an issue for infrastructure, planning and communities, and left to the environmental divisions within councils for planning and action. Adaptation to climate change as a means of maximising gains and minimising losses has been relatively little explored at the location-specific level, and in a cost-benefit framework (Pittock 2003). However, there are clearly circumstances where preparing now for adaptation to climate change is justified, particularly when the costs for preparing now are small compared with the costs of likely future impacts (DCC 2009a). For 'at-risk' areas, strategies need to be developed that identify the on-ground action needed to manage those risks. Plans should identify where climate change risks can be accommodated, where protection is required and how planned retreat can be undertaken.

For each approach, the costs and benefits need to be identified and evaluated (DCC 2009a). The recent report *Coastal Inundation at Narrabeen Lagoon – Optimising Adaptation Investment* (DCC 2010b), for example, discusses adaptation options and analyses the costs and benefits over time in response to risks of flood inundation. The report recommends the immediate construction of a 3 m high levee on Lake Park Road. The proposed levee is considered a viable proposition, as it would generate net economic benefits of around $0.9 million. A flood awareness system is also recommended. This would provide residents and businesses with early warning of floods, would be relatively inexpensive to implement and would deliver net benefits of around $12 million (DCC 2010b). In some cases, specific planning and management actions have already been implemented in response to past disasters. Several states have coastal setback and minimum elevation policies, including those to accommodate potential sea level rise and storm surge (McLean et al. 2001). In South Australia, setbacks take into account the 100-year erosion trend plus the effect of a 0.3 m sea level rise to 2050. Building sites are required to be above storm-surge flood level for the one-in-100 year return interval (McLean et al. 2001). Byron Bay has implemented setbacks and constraints on new development, having already had a number of properties threatened by the advancing seafront (<http:www.smh.com.au>). Collaroy/Narrabeen has introduced the property buy-back scheme, while the Gold Coast's principal strategy for managing its high-risk capitalised shorelines has involved the construction of coastal protection infrastructure to be able to maintain coastal assets in their current location.

8.2.2 Challenge 2

A lack of clarity of governance roles and responsibilities is a barrier to an effective national response.

Recommendations:

a. Improve inter-jurisdictional cooperation

Australia currently lacks an over-arching national coastal policy. The complexity of cross-cutting climate change risks in the coastal zone requires an effective collaborative inter-jurisdictional reform effort. Clarity about the roles and responsibilities of all levels of government for adapting to the impacts of climate change and identifying priorities for collaborative action is needed as a first step in coordinating a national reform agenda (DCC

2010a, 2009a). Gurran, Hamin & Norman (2008: 60) recommend that 'an intergovernmental agreement involving all three levels of government be developed to clearly state the commitments and responsibilities of Federal, State and Local government in planning for climate change'. A positive step in this direction is the Commonwealth government's proposal to work through the Council of Australian Governments (COAG) to develop a national adaptation agenda. The objectives of the National Coastal Risk Assessment, endorsed by COAG, include providing an assessment of climate change implications for Australia's coastal regions, with a particular focus on coastal settlements and ecosystems; identifying key barriers to developing effective coastal adaptation responses; and identifying national priorities for adaptation to reduce climate change risk in the coastal zone (DCC 2009a).

b. Enhance consistency in coastal planning across governments

Few municipal planning schemes include specific provisions for climate change adaptation (Gurran, Hamin & Norman 2008). There is an urgent need to reduce uncertainty and enhance consistency in coastal planning and decision-making. At the same time, it is necessary to address the different degrees of exposure that will occur at different places around the coast. Different extreme events such as storm surges and cyclones have regional characteristics; therefore, the form of development will need to differ between places (DCC 2009a).

c. Mainstream adaptation into integrated coastal zone management

Nicholls et al. (2008) call for more integrated assessments of climate change in coastal areas to better support climate and coastal management policy development, and to improve analysis of impacts, key vulnerabilities and adaptation options. A key conclusion in IPCC assessments (IPCC 2007b, 2001; McLean et al. 2001; Bijlsma et al. 1996) is that integrated coastal zone management (ICZM) responses are more effective than stand-alone efforts to reduce climate-related risks to coastal systems, thus making ICZM an appropriate method to deal with climate change, sea level rise and other coastal challenges.

d. Strengthen government capabilities

States, territories, local government, industry and communities all play important roles in designing, implementing and monitoring on-the-ground coastal adaptation responses. To address the discretionary nature of councils' activities, the state government guidelines need to be developed to assist councils to set benchmarks for strategic planning in relation to coastal hazards. In addition, guidelines need to provide guidance on when and how to conduct adaptive activities that address climate change risks in the coastal zone (DCC 2009a; Garnaut 2008). Local government is responsible for key planning and land-use decisions that are critically affected by climate change risks, yet in many cases they do not have the capacity in terms of resources and skills to do this effectively. There is a need to build the capacity of those charged with management in the coastal zone to ensure that they have the knowledge, tools and skills to manage risk. According to Gurran, Hamin & Norman (2008), many local councils in Australia already have the basis for incorporating climate change considerations within their legislative decision-making and development-assessment framework; however, that work needs to be revised in relation to specific climate change scenarios.

8.2.3 Challenge 3

A need to provide updated policy relevant information on coastal vulnerability.

Recommendations:

a. Provide information and tools essential for decision-making

Decision-makers currently lack the information and tools needed to address climate change in many decisions (Hinkel & Klein 2009; Voice, Harvey & Walsh 2006). There remains an urgent need for robust information to be generated and communicated effectively for use by communities all around Australia. However, providing updated policy relevant information on coastal vulnerability involves major challenges. Information needed by decision-makers includes the scale and extent of combined sea level rise, storm surge and coastal recession and the spatial areas at risk from these changes (Coasts and Climate Change Council 2010a). Coastal vulnerability assessments have so far mainly focused on physical vulnerabilities and impacts, with little attention given to other dimensions, in particular socioeconomic perspectives or the human dimensions of climate change (Hennessy et al. 2004). This is a major oversight, as significant interactions of climate change with other non-climate drivers are overlooked. Knowledge also needs to be integrated in a much more comprehensive way, and the integrated knowledge must be made available in a form that allows a diverse community of end-users and policy-makers to answer the specific questions with which they are confronted (Hinkel & Klein 2009). There has also been limited research to date on how to integrate climate change considerations – particularly relating to adaptation – within statutory planning frameworks within Australian local planning practice (Nicholls et al. 2008; Planning Institute of Australia 2007). Integrated studies are needed that cross sectoral boundaries, involve stakeholders, consider other stresses on community infrastructure and management systems, and examine costs and benefits.

b. Engage all stakeholders

Climate-adaptation strategies will require the support of the broader community. The engagement of all stakeholders – governments, individuals and the private sector – is essential in order to develop and implement a comprehensive and well-considered national coastal adaptation agenda (DCC 2009a). The success of that engagement is linked to sharing information on risks, risk allocation, adaptation options and responsibilities.

9. Conclusions

This study supports the findings of other recent publications (House of Representatives 2009; DCC 2009a) that a considerable proportion of infrastructure and development along Australia's coast is vulnerable to coastal hazards that are expected to increase with climate change. Policy-makers and stakeholders need to be aware of the issues and to be provided with tools to help them assess risk and make appropriate decisions. We need to bridge the gap between adaptive theory and practicalities in terms of planning and development on an eroding coast. If left unresolved, future storms causing unacceptable damage will force governments and communities to face up to the issue – but by then the options might be more limited.

In recent decades, because significant storm surges have not occurred in the three study sites, vulnerable areas have become increasingly populated. Many recently developed low-lying coastal areas are vulnerable to inundation from significant storm surges. The absence of severe storms has lured beachfront residents into a false sense of security, and lessons learnt in the 1960s and 1970s will have to be learnt again.

While each of the case studies is facing the same problems of ongoing erosion from rising sea levels, three decades of very low storminess has only lightly stressed the coast. Future storms, like those that have occurred in the past, will cause unprecedented damage. In general, emergency management is well placed to prevent loss of life, and experience of past major storms shows that there is little that can be done during the event.

In all three case studies, beach nourishment was employed to lessen erosion damage. But it is evident that in times of relative calm communities have been unwilling to accept seawalls or groynes across the beach. The reasons for this include a misunderstanding that seawalls cause erosion (they are usually built in response to erosion), and concern over a loss of beach and surfing amenity. Proposed groynes at all three of the case studies were rejected by the communities, and therefore not built. Seawalls to control erosion have also been rejected, with the exception of the Gold Coast where the wall is buried under the dunes at the back of the beach. Storms in recent years have not been severe enough to seriously stress beach systems. It is certainly clear that surfers as one beach user group are not pleased by schemes that either provide too much or too little sand as beach nourishment. The return of severe storm energy will change the engineering and economics of nourishment. In many cases, relocation will be the only option, and it is unlikely that it will happen in a planned and orderly fashion as envisaged in the Byron Planned Retreat policy.

Governments have an important role to play in enabling coastal adaptation, particularly as climate change impacts in the coastal zone have cross-cutting social, economic and environmental consequences. There are considerable problems involved in building adaptive capacity into coastal planning schemes due to a lack of cooperation and consistency across government. What must be addressed now is how the nation can best define these roles within the constraints of current governance arrangements, and still provide effective adaptation. Leadership, clearer roles and responsibilities, investment in national capability to enable decision-makers to take an informed approach, and enhanced local capacity to manage on-ground impacts are all crucial (DCC 2009a). Building adaptive capacity in coastal urban areas can be achieved by addressing key issues, including vulnerabilities and appropriate adaptation responses, stakeholder perceptions about risks, the role of social culture, and the building of institutions and policies that foster resilience to shocks and surprises.

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