NCCARF Synthesis and Integrative Research Program

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Case studies of extreme events

East Coast Lows and the Newcastle/Central Coast Pasha Bulker Storm

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Historical Case Studies of Extreme Events

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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 information they need to manage the risks of climate change.

This report on East Coast Lows and the Newcastle-Central Coast Pasha Bulker storm 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, i.e. 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 overarching goal is to better understand the requirements of successful adaptation to future climate change.

This report highlights the Pasha Bulker storm in 2007. A total of five east coast lows (ECLs) affected coastal regions between Illawarra and the Hunter during June 2007, which is a rare but not unprecedented event. Of these five, the first (June 8-9) was the most serious (in terms of impact) and resulted in widespread flooding and wind damage, coastal erosion, the grounding of the Pasha Bulker (a 40,000 tonne bulk carrier ship) on Nobbys Beach, Newcastle and the loss of nine lives. The 'Pasha Bulker Storm', as it has become known, was one of the most significant meteorological events in Australia's history, with large economic losses and social disruption due to the loss of critical infrastructure. Approximately 300,000 people were without mains electricity for four days (some for up to a month), the coal export chain halted for two weeks and communications were interrupted for days.

Other reports in the series are:

- Cyclone Tracy
- The 2008 Floods in Queensland: Charleville and Mackay
- Storm tides along east-coast Australia
- 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.

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1 Executive Summary

This report has been produced for the National Climate Change Adaptation Research Facility (NCCARF) as part of a series of historical case studies, which are aimed at increasing our understanding of adaptive capacity to extreme events in Australia. The 'extreme event' studied in this report is the Newcastle/Central Coast Pasha Bulker Storm of June 2007, where the Newcastle and Central Coast regions of New South Wales experienced severe weather and subsequent flooding, along with various secondary impacts.

A total of five East Coast Lows (ECLs) affected coastal regions between Illawarra and the Hunter during June 2007, which is a rare but not unprecedented event. Of these five, the first (June 8-9) was the most serious (in terms of impact) and resulted in widespread flooding and wind damage, coastal erosion, the grounding of the Pasha Bulker (a 40,000 tonne bulk carrier ship) on Nobbys Beach, Newcastle and the loss of nine lives. The 'Pasha Bulker Storm', as it has become known, was one of the most significant meteorological events in Australia's history, with large economic losses and social disruption due to the loss of critical infrastructure. Approximately 300,000 people were without mains electricity for four days (some for up to a month), the coal export chain halted for two weeks and communications were interrupted for days.

This event is one of the most documented extreme weather events in Australia's history as a result of:

- Television news footage, newspaper articles, interviews etc;
- Surveys of residents in Maitland, Newcastle and Lake Macquarie following the event by various authorities;
- The "*Pasha Bulker storm of 8-10 June 2007 and the performance of Newcastle's key infrastructure*" workshop run by the Centre for Climate Impact Management (C2IM) at the University of Newcastle with various industry leaders;
- Aerial and oblique photographs supplied by the public and authorities;
- Data collection (flood levels, rainfall records etc) taken during the event;
- Recent installation of automated water level gauges; and
- Reports and journal articles arising from the experience of the event.

The level of documentation available on this event makes it an excellent case study for which to analyse the adaptive capacity of Australia for severe storms. This report provides background information on the meteorology of East Coast Lows, the impact of the 'Pasha Bulker' storm and a discussion of the 'lessons learned' from the event and subsequent adaptation strategies employed. The report also provides important reflections on the event at both regional and national level and from this recommendations and conclusions on adaptation actions arising from similar storm events.

A number of important policy based recommendations have been drawn from this study, including:

- The experiences gained during the June 2007 event highlights the need to have **a list of pre-established facilities that would be suitable to act as a Disaster Recovery Centres** (DRCs) in such an event.
- State and local governments must continue to invest in ensuring an **adequately skilled environmental health workforce** is available and equipped to respond to disasters and emergency events such as the Pasha Bulker storm.
- **Greater community awareness of insurance cover inclusions** is needed along with a framework to cover aspects of storm damage not included under general home/business insurance (e.g. landslip, fallen trees)
- A consistent **policy for coastal developments** (agreement at federal, state and local levels of government) is needed to deal with existing coastal infrastructure/housing and planning guidelines around new infrastructure/housing.
- **Increased community awareness of emergency procedures and processes** is needed, along with information and education opportunities which strengthen the community's sense of safety and confidence in preparedness for future disaster events.
- **Ongoing communication and education of communities susceptible to flooding** (both flash flooding and river flooding) is required to ensure people respond appropriately to flood warnings in the future.
- Further work needs to be carried out to **evaluate the benefits of flash flood warning systems** in fast response catchments in order to build a strong case for the installation of such systems
- It is recommended that all states and territories would benefit from formal arrangements with the ABC for **provision of emergency health information** during a disaster.

"Vows made in storms are forgotten in calm"

Thomas Fuller

2 Introduction

2.1 Background

A series of East Coast Lows impacted coastal regions between Illawarra and the Hunter during June 2007. The succession of storms from June 7-10, 2007 resulted in widespread flooding and wind damage, coastal erosion, the grounding of the Pasha Bulker (a 40,000 tonne bulk carrier ship) on Nobbys Beach and the loss of nine lives (along with many calls for emergency assistance). The 'Pasha Bulker storm', as it has become known (and will be referred to in this report), was one of the most significant meteorological events in Australia's history. It was the eighth largest general insurance loss (adjusted for both inflation and current levels of development) since systematic insurance records were started in 1968 [Crompton and McAneney, 2008]. The storm consisted of three distinct impacts:

- flash flooding on the night of 8 June in the urban area of Newcastle and as far south as the Central Coast (about 1 in 100 year return period, impacting 800,000 people);
- more general flooding on the Hunter River 3 days later (about 1 in 40 return period, impacting about 100,000 people); and
- high winds and wave heights on the night of 8 June (the worst in the Newcastle-Sydney region since the Sygna storm in 1974. The Sygna storm was also an East Coast Low).

While the media focus was on the grounded Pasha Bulker and the Hunter River floods, most insurance losses resulted from the 8 June flash flooding in the Newcastle, Lake Macquarie and Central Coast region. In fact, the Hunter River floods were successfully managed by the extensive flood mitigation measures installed along the Hunter River as a result of previous floods in this area. Significant economic losses and social disruption occurred due to the loss of critical infrastructure. Approximately 300,000 people were without mains electricity for four days (some for up to a month), the coal export chain halted for two weeks and communications were interrupted just to name a few of the problems encountered.

2.2 Project aims

The aim of this project is to provide a whole-of-government (federal, state and local), business and community perspective on the:

1. context and impact of the Pasha Bulker storm;
2. adaptation measures being put in place as a result of the knowledge gained from the experience from within and immediately after the storm; and
3. adaptation measures being put in place following subsequent reflection on ways of better preparing for such storms.

In addition this report highlights the regional and national implications of such events, highlighting the need for further research into the historical variability, potential future changes in the frequency and/or magnitude and suitable adaptation responses to East Coast Lows for coastal cities in Australia.

3 Geographic profile

The Hunter Region is located 130 km north of Sydney, New South Wales (NSW), and includes 11 local government areas (LGAs). The Hunter region covers approximately 31,000 km^2 and is the sixth largest city in Australia. The region has a wide diversity of landscape, including rivers, lakes, mangroves, coastal sands, alluvial plains, rural hinterland, National Park, State Forest and nature reserves. Land uses include urban development, tourism, agriculture, coal mining, power generation, heavy industry, forestry and aquaculture. As with many coastal cities, the highest density of urban development is located along the coastal fringe.

Figure 1 shows the location of the Hunter Region and the various townships that were affected by the June 2007 Pasha Bulker storm.

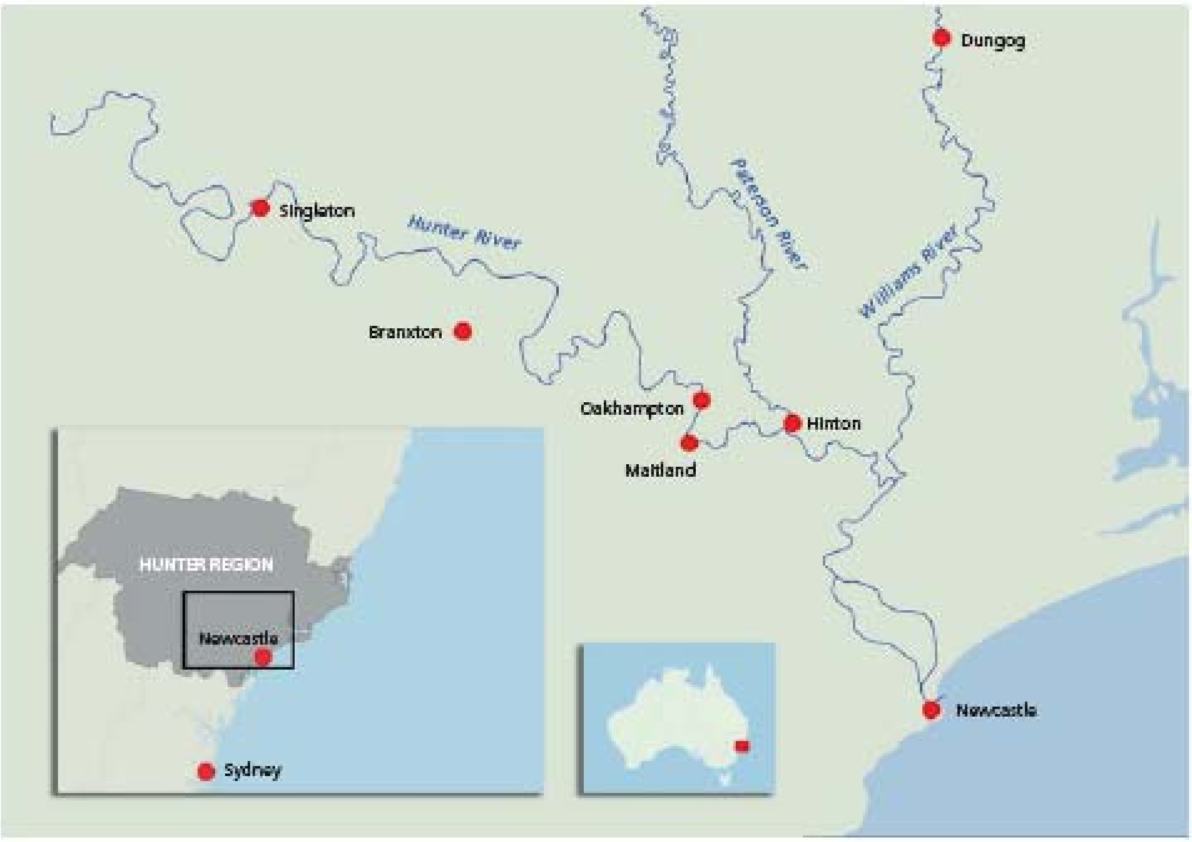


Figure 1 Location of the Hunter Region and areas affected by the June 2007 Pasha Bulker storm highlighted with red circles (source: Carpenter, 2007)

4 Climatological context of the June 2007 Pasha Bulker storm

4.1 The East Coast Low phenomenon

East Coast Lows (ECLs) are intense low pressure systems, which occur several times a year off the east coast of Australia. They tend to form between latitudes 20°S and 40°S, often with some motion parallel to the eastern coastline of Australia. ECLs can occur at any time of the year, but tend to be more common in the Australian autumn and winter [Speer et al., 2009]. These large-scale storms can result in gale force winds along the coast and adjacent waters, heavy rainfall leading to widespread flooding, and rough seas and prolonged heavy swells causing damage to the coast line. ECLs have a high interannual variability, with some years experiencing several ECLs while during other years only a few will develop. ECLs are responsible for approximately 16% of all heavy rainfall events and 7% of major Australian disasters [Hopkins and Holland, 1997].

ECLs can form from a variety of weather situations, however it is most common that they will form offshore within a pre-existing low pressure trough in the upper atmosphere over eastern Australia. The low pressure system develops at sea level near the coast, to the east of the upper level system, which then often rapidly intensifies [Harper and Granger, 2000]. The small low pressure systems may then interact with high pressure to the south (blocking high) resulting in gale conditions which can last from hours to several days. Sea surface temperature gradients offshore also contribute to the development of an ECL since the storm draws energy from a combination of ocean temperature gradients, coastal convergence, uplift and a supply of moist-tropical air at the surface [Harper and Granger, 2000].

4.2 June 2007 – A series of East Coast Lows

A total of five ECLs occurred during June 2007, which is a rare but not unprecedented event (similar years include 1950 and 1974). The five ECLs were the result of favourable conditions in the upper atmosphere and coastal waters off NSW (which were about 1°C above average due to the La Niña event that occurred that year). Three out of the five ECLs formed out of an easterly trough that developed off the NSW coast while the other two developed as secondary systems in the wake of an earlier low pressure system. Of the five ECLs, the first event (June 8-9) was the most serious (in terms of impact) but the third event (June 19-20) was in fact the most intense. Luckily, the full impact of the third event (June 19-20) was not felt over land areas as the low did not venture as close to the coast as the first event.

The ECL responsible for the Pasha Bulker storm on June 8-9, in a pre-existing low pressure trough over the northern Tasman Sea, which was directing a humid northeast to southeast air stream across northeast NSW [BoM, 2007]. A weak low developed off the coast of Coffs Harbour on the morning of the 7 June (Figure 2), but by the late evening of that day the pressure had deepened to 1009 hPa just north of Newcastle. This resulted in gale force south-easterly winds over a period of about 12 hours (resulting in the grounding of the Pasha Bulker on Nobbys Beach). By noon on the 8 June the low had weakened and the winds had eased, however a persistent east-west line of thunderstorms between 3:30pm and 7:30pm delivered heavy rains over Newcastle and northern parts of Lake Macquarie.

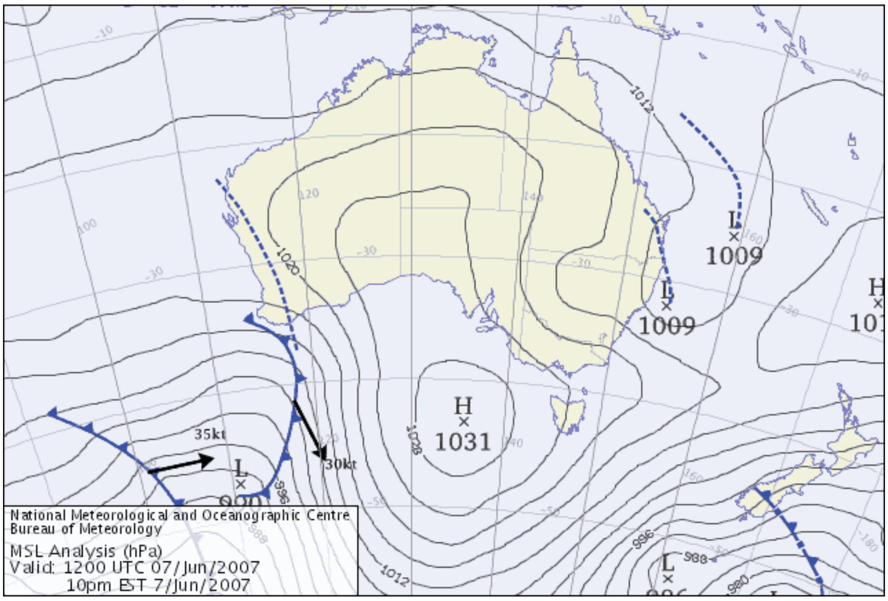
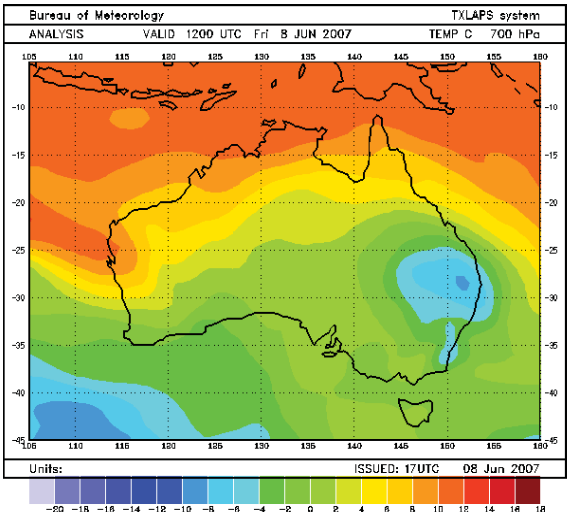
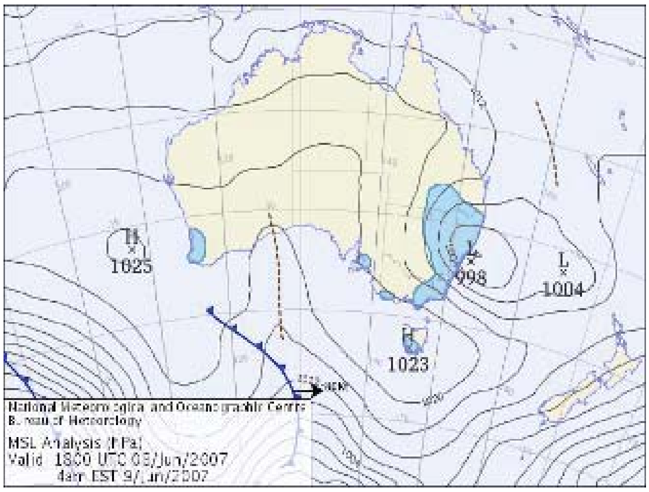


Figure 2 Synoptic map at 10:00pm on 7th June 2007 (Source: Bureau of Meteorology)

From June 8-10 the ECL moved along the NSW coast and into the Tasman Sea. Renewed intensification of the ECL was influenced by a high pressure system that moved through Bass Strait during 8-9 June, deepening the easterly flow over NSW. In addition, an upper cold pool (Figure 3a) and associated north westerly jet stream moved across the north of the state reaching the coast on the 8 June. A second, smaller low formed that evening and crossed Newcastle in the early hours of 9 June (Figure 3b), resulting in the strongest observed wind gust (a maximum of 135 km/hr at Norah Head and 105 km/hr at Nobbys Signal Station).



a)



b)

Figure 3 a) Mid-atmospheric temperature pattern at 10:00pm on 8th June 2007; b) Synoptic map at 4:00 am on the 9th June 2007 (Source: Bureau of Meteorology)

The minimum central pressure of this low was estimated to be 992-994 hPa (Figure 4). Although the low weakened as it moved inland, a line of storms moved south resulting in heavy rainfalls along the Central Coast.

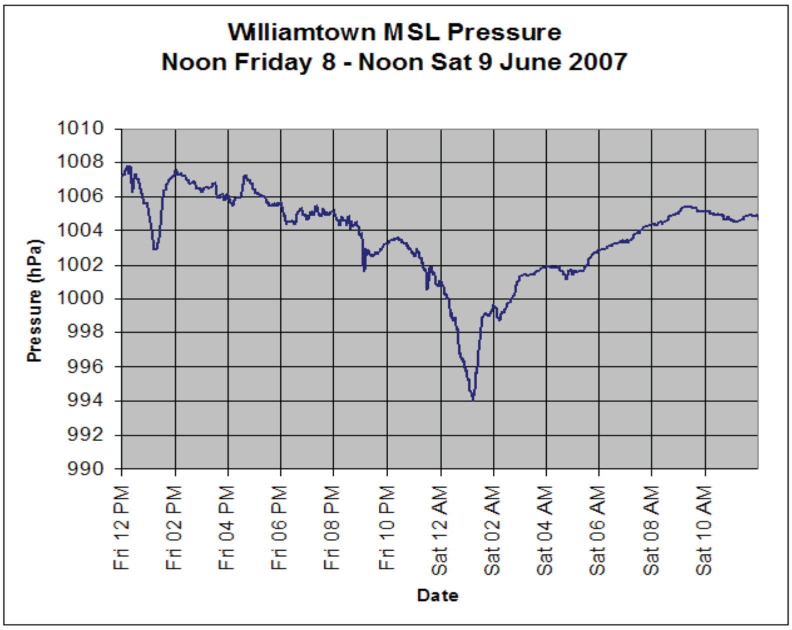


Figure 4 Williamtown mean sea level (MSL) pressure between 8th and 9th June 2007 (Source: Bureau of Meteorology)

4.2.1 Rain

Heavy rainfalls were received between the June 7-10 across the Newcastle, Central Coast and the Hunter regions, with over 400 mm of rainfall received at some locations (more than twice the average monthly totals for June). The peak in rainfall occurred for most regions on the 8th and 9th of June when Newcastle (Nobbys Signal Station) recorded 164.8 mm in 6 hours (Figure 5). Newcastle University and BMT WBM Pty Ltd analysed data from a network of 30 pluviographs throughout the Hunter region to assess the meteorological significance of the event [Haines and Thyer, 2008]. There was a high degree of variability among the pluviographs, however at some locations the measured rainfall for 3, 6, 12 and 24 hour durations had a recurrence interval in excess of 100 years. It is important to note however that these recurrence intervals are estimated using short data sets which may not capture the true rainfall distribution.

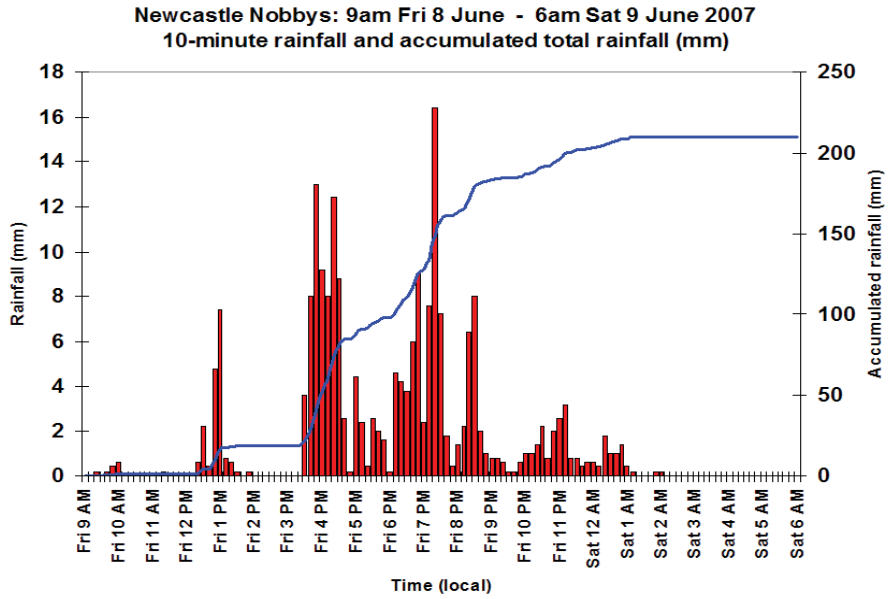


Figure 5 Newcastle 10-minute rainfall on 8th and 9th of June 2007 measured at Nobby's signal station (source: www.bom.gov.au)

4.2.2 Wind

Gale force winds were sustained for approximately 20 hours from 6am on the 8th June through to 2am on the 9th June [Carpenter, 2007]. The maximum windgust speed recorded was 135 km/hr at Norah Head, followed by 125 km/hr at Nobbys Head (Figure 6). While a significant event, wind speed records were not broken during this ECL [Carpenter, 2007].

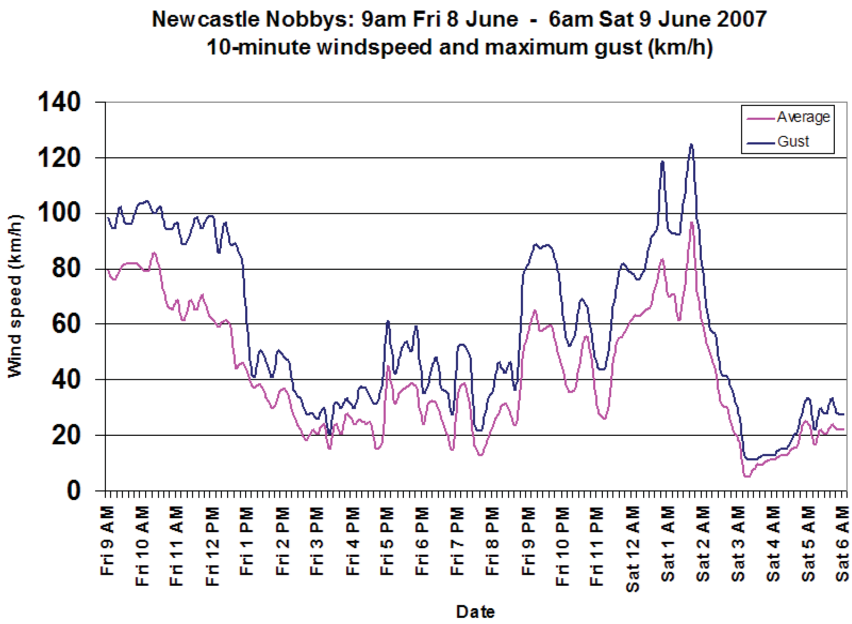


Figure 6 Newcastle 10-minute windspeed 8-9 June 2007 recorded at Nobbys' Signal Station (Source: Bureau of Meteorology)

4.2.3 Waves

The maximum significant wave height recorded by the Sydney directional waverider buoy (the closest waverider buoy to this ECL) was 6.87 m during the early morning of the 9 June and the maximum individual wave height measured was 14.13 m (Figure 7). The wave height recorded at Sydney was found to have a recurrence interval in the order of 4 to 10 years based on storm wave height/duration analysis [Watson *et al.*, 2007]. It is likely that the maximum wave height in Newcastle Harbour was greater, with some reports estimating swells of 17 metres [Calvert *et al.*, 2007].

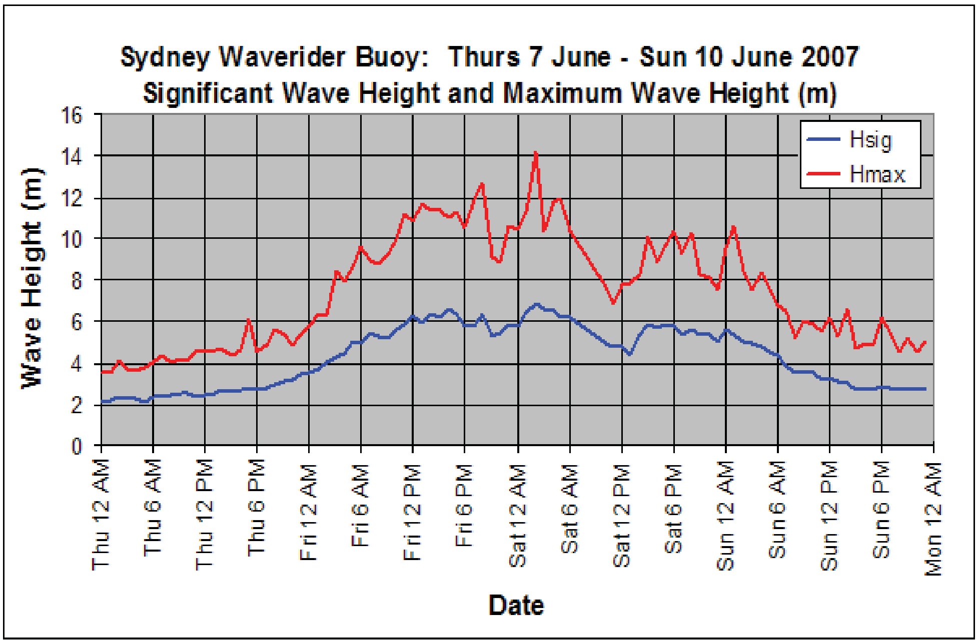


Figure 7 Sydney waverider buoy record from 7-10 June 2007 (Source: Bureau of Meteorology)

The peak ocean water level during the storm was 1.48 m recorded at Middle Head in Sydney Harbour. This represents an increase of 23 cm above the 'normal' ocean tide which is likely due to storm surge (combination of low atmospheric pressure and wind driven set up). This was not considered an unusually high ocean tide, with water levels reaching this height 50 times per year on average [Watson *et al.*, 2007]. The combination of large waves and increased water levels during these few days did, however, result in a depletion of sand from beaches in the Sydney to Central Coast region. In total there were seven events during June 2007 that together caused considerable beach erosion over the course of that month [Watson *et al.*, 2007].

4.3 Historical context of the June 2007 Pasha Bulker storm

The ECL experienced from the 8-9 June 2007 was not a particularly strong or deep low pressure system compared to other ECLs experienced in the past. The significance of this ECL was that it developed so close to shore, with the area of maximum rainfall centred on a highly developed part of the coast [Carpenter, 2007]. An ECL of similar strength to that experienced from the 8-9 June 2007 tends to occur annually (on average), however they often form out to sea, not on land as was the case with this storm [BoM, 2009]. The Australian Bureau of Meteorology (BoM) have a detailed database of historical lows beginning in 1972, which demonstrates that there is no evidence of a long term trend in the frequency of ECLs along the east coast. However, there is some evidence of enhanced intensity during periods of highly positive values of the Southern Oscillation Index (SOI), which is a measure of the El Niño/Southern Oscillation (ENSO) phenomena [Harper and Granger, 2000]. Positive values of the SOI represent La Niña conditions, while negative values indicate El Niño conditions. Periods of transition between El Niño and La Niña have also been linked to increased frequency of ECLs due to an enhanced sea surface temperature gradient offshore [Hopkins and Holland, 1997]. A strong correlation between the Southern Annular Mode (leading mode of variability in the Southern Ocean) and the frequency of ECLs has also been identified [Wiles *et al.*, 2009], highlighting the need for further investigation into the natural variability of ECLs.

The June 2007 storms have often been compared to the May 1974 storms, which also resulted in widespread devastation along the coast of NSW. The May 1974 ECL was concentrated between Illawarra and the Hunter and also claimed a bulk carrier ship (the Sygna) which ran aground on Stockton Bight (Figure 8), just north of Nobby's beach where the Pasha Bulker was grounded. The 'Sygna storm', as it became known, produced much stronger windgusts (170 km/hr) than the Pasha Bulker storm. However, the Sygna storm had a much shorter duration and less rainfall recorded (maximum 24-hour rainfall was 194 mm at Pambula). The storm event was determined to have a corresponding wave height recurrence interval in the order of 20-70 years [Watson *et al.*, 2007] and the Newcastle port reported a swell of over 17 metres at the entrance. The water level encountered during the May 1974 storm was 53cm higher than Pasha Bulker storm (2.37 m) in Sydney Harbour – the highest level since records commenced over 100 years ago [Watson *et al.*, 2007]. The ECLs of May 1974 also had a greater impact on coastal erosion than those ECLs experienced in 2007, due to larger off shore wave heights.

Figure 8 Wreck of the Sygna ship on Stockton Bight as it looks in 2009. Photo: Lee Stone.

5 The impact of the June 2007 Pasha Bulker storm

5.1 Overview

A natural disaster was declared on the 8 June 2007 for 13 local government areas (LGAs) (Liverpool Plains, Upper Hunter, Gloucester, Dungog, Singleton, Muswellbrook, Maitland, Lake Macquarie, Wyong, Port Stephens, Newcastle, Gosford and Cessnock) and extended on the 14 June to include a further six LGAs (Great Lakes, Greater Taree, Hawkesbury, Mid-western Regional, Warrumbungle and Gilandra) [Carpenter, 2007]. Estimates of insured losses stand at around AUD1.35 billion with the bulk of the losses arising from the excessive rainfall and subsequent flooding, rather than the wind damage. The event ranks as the eighth most costly natural disaster to affect Australia, when adjusted for inflation and current development levels, or the fourth largest adjusted for inflation alone as at 2008 [Crompton and McAneney, 2008].

The following sections providing detailed information on the impacts of the storm in terms of flooding, damages to utilities and infrastructure, and effects on community and health.

5.2 Flooding

5.2.1 The impact of the storm on Newcastle and Lake Macquarie LGA

The ECL that created the Pasha Bulker storm generated significant rainfall across the central and mid-north coast regions of NSW. Rainfall for the 24 hour period exceeded 300mm at a number of stations in the local area. The highest intensity rainfall occurred from 3:00pm to 8:00pm, and was concentrated in the southern Newcastle/northern Lake Macquarie area. Croudace Bay on the edge of Lake Macquarie recorded 155 mm between 4:00pm and 6:00pm. Rainfall intensities exceeded 1 in 100 year probability at a number of sites across the region, some by up to 63% [Haines and Thyer, 2008]. Rainfall intensities typically reduced with distance inland, which correlates with the westward tracking of the storm from offshore.

The intensity of the rain combined with the steep topography of the local catchments resulted in flash flooding throughout many areas of Newcastle and Lake Macquarie, with the most severe flooding occurring downstream of the areas that received the greatest rainfall. Comparison of actual flood information with existing probabilistic flood models suggest that in some areas, such as Throsby/Styx and Cottage Creeks, the resulting flood had an indicative recurrence probability of 1 in 100 years, while for Ironbark Creek at Wallsend, the flooding was about 1 in 40 years [BMT WBM, 2009].

Lake Macquarie rose 1 m above its normal level on the 9th June with a level of 1.1 m AHD (Australian Height Datum), equating to a 1 in 35 year average recurrence interval (ARI) probability flood event. The levels observed on 9 June 2007 were only 100 mm below the highest observed Lake level of 1.2 m AHD recorded in June 1949 [Jones, 2007]. Low lying areas were affected for up to 24 hours by the high Lake levels which were exacerbated by the elevated level of the Pacific

Ocean at Swansea Heads as a result of the extreme low pressure system. Catchments that drain to Lake Macquarie recorded near-record or above record flood levels, in fact five catchments experienced in excess of a 1 in 100 year flood event [Jones, 2007].

Cardiff Central Business District (CBD) (Lake Macquarie LGA) was greatly affected by the flooding, with an estimated AUD2 million damage losses to business [Jones, 2007]. Commercial areas of Wallsend and Newcastle West (both Newcastle LGA) were also particularly hard hit. Ironbark Creek through the Wallsend CBD is notorious for its susceptibility to flash flooding. Some shops on Tyrell Street (Wallsend) were inundated by up to 1.6m of floodwater. Evacuations of many properties, including Wallsend Plaza, were required at the peak of the event, increasing the level of personal risk. Flooding in Newcastle West was significantly worsened through blockage of culverts by shipping containers, which had been dislodged from nearby building sites.

Other suburbs notably affected by floodwaters included: Hamilton, Merewether, Hamilton North, Cooks Hill, Hamilton South, Broadmeadow and New Lambton in the Newcastle LGA; and, Warners Bay and Belmont in the Lake Macquarie LGA.

For most areas, flooding came quickly and lasted less than an hour. Flood depths and velocities across overland flowpaths were high, and caused considerable traffic chaos as the event coincided with a Friday afternoon peak hour. In many areas, streets turned into rivers, quickly overwhelming cars, and forcing them to be abandoned in the floodwaters.

Flood velocities were reported to be particularly high within the concrete-lined open channels – even the smaller drains in the upper catchments (e.g. through Adamstown). In comparison, velocities were generally slower across overland flow paths. Floodwaters had sufficient force to dislodge a number of large concrete panels from within stormwater channels. Where floodwaters departed or re-entered a formal channel, the velocities were sufficient to mobilise footpath slabs and damage footings of some houses.

While floodwaters receded quickly in most areas, some suburbs experienced more prolonged inundation, such as Newcastle West (due to the blockage in drainage culverts) and harbourside areas of Carrington, Wickham, Maryville and Islington, where local drainage was likely to have been inhibited due to elevated waters in Throsby Creek, and also increasing tides. The peak rainfall in the late afternoon of 8th June fortunately coincided with a low tide in Newcastle harbour, during a neap stage (i.e. small tides) of the tidal cycle.

Data collected from the Newcastle Pilot Station shows that water levels in Newcastle Harbour peaked at 1:39am on Saturday 9th June at a level of 1.07 m AHD, and approximately coincided with the timing of when the centre of the low pressure system crossed the coast over Newcastle (at a pressure of 990 hPa) [BMT WBM, 2009].

In total, almost 20,000 calls for help were made to the State Emergency Service (SES), with more than 2,500 of these requesting assistance from flooding [Watson *et al*., 2007]. More than 5,000 cars were written off, while more than 90,000 claims have been filed with insurance companies [Carpenter, 2007]. An estimated 10,000 properties were inundated across the Newcastle LGA, which typically included yards, garages, and outside buildings (Figure 9 a&b). Of these, some 1000 to 2000 properties experienced over-floor flooding. The commercial district of Wallsend had flooding of up to 1.5 m over the floors, while many residential areas (e.g. Hamilton North) had over-floor flooding of greater than 0.8 m. Many thousands of properties reported flood waters reaching just below their floors.

a)

b)

Figure 9 Urban flooding during the event a) Westfield car park, Kotara, b) Hunter Street, Newcastle CBD.

There were a number of localised low points in the topography that experienced substantial flood inundation. In some cases, flooding in these areas was exacerbated by flow impediments, for example, the Samdon Road/Donald Street intersection, reached flood depths of 1.8 m as a result of flood waters being impounded by the rail embankment. Flood impacts were also reported to be compounded by a range of other flow impediments including high median strips on major roads, high camber levels on local roads (above gutter level), and solid steel panel (e.g. Colorbond®) fencing built across overland flowpaths.

In addition to the constructed flow impediments, flooding associated with the June long weekend storms was made more severe by debris blockages within the stormwater drainage system. Gale force winds and rain generated considerable debris, while overland flows mobilised this storm debris and many other floatable items, such as garbage/recycling bins, steel panel and other fence panels, shopping trolleys and cars. To complicate matters, sudden failure of steel panel fences was reported to cause local surges in floodwater, contributing to the speed and ingress of flooding into some areas. Many cars became lodged within open drains across Newcastle, most notably in Hamilton and Wallsend.

A notable aspect of the interaction between the debris and the stormwater system in the Cottage Creek catchment was that (1) proceeding downstream there are numerous switches between open channel and narrow (narrower than the open channel) pipe entrances providing numerous points at which debris could block the stormwater system (2) numerous bridges with in-channel piers that reduce the channel opening significantly and these openings are of the size that a steel panel or cyclone-mesh panel can become entangled, and (3) numerous crossings of the open channel with pipes and other infrastructure at levels just above the 1 in 100 year flood level but below the surrounding ground level. All three characteristics provide ample opportunity for debris to block the storm water system. It is notable that current design recommendations (e.g. Australian Rainfall and Runoff, 1987) do not mention the potential role of urban debris in reducing flow cross-sections in stormwater systems (as compared with their recommendations for rural flooding).

The most substantial blockage occurred at the downstream end of Cottage Creek, where shipping containers from nearby construction sites became lodged within culverts. These particular blockages resulted in elevated water levels on the upstream side. The extent of exacerbation of flooding impacts resulting from the blocked drains was investigated using computer flood models [BMT WBM, 2008]. The Cottage Creek blockage was found to generate flood levels of up to one metre higher than normal through the Newcastle West business area, and up to 0.5 m higher through Marketown Shopping Centre. Further, the damming effect caused by the containers meant that inundation persisted for many hours after the peak event, with water unable to drain out of the catchment. The timing of major blockages within the stormwater system is unfortunately not known. This is considered important, as a blockage during a rising hydrograph can have much greater consequences than a blockage on the falling side of a flood.

Following the event, flood marks were identified and captured at almost 2000 locations around Newcastle and Northern Lake Macquarie. Most of these flood marks were subsequently ground surveyed to provide an indicative peak water level surface across the city. GIS has been used to generate a flood level surface from the surveyed data. This flood level surface was then draped over the Digital Terrain Model (DTM) for Newcastle to provide a map of inundation extents and indicative depths for the June 2007 flood (Figure 10). Descriptions of flood behaviour and economic losses were also provided by the community through personal interviews and questionnaires and used in interpreting the flood’s behaviour. Multiple flood marks and debris lines at some locations highlight the multiple peaks in flood response, as rainfall intensified then abated several times during the event.

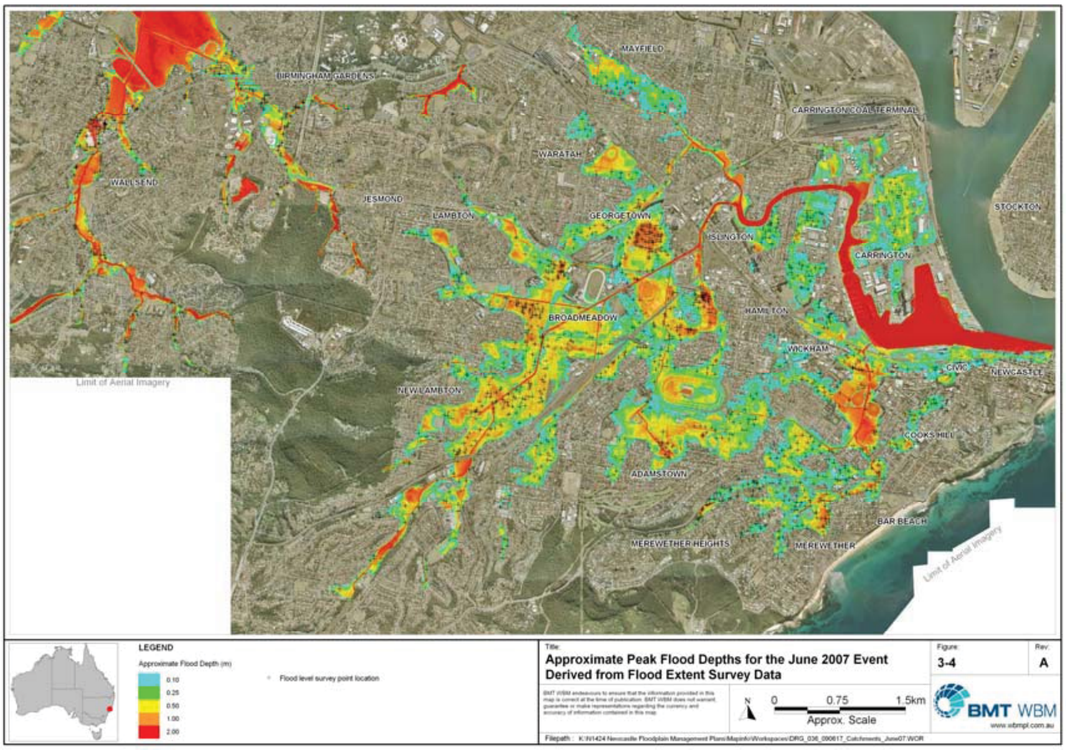


Figure 10 June 2007 peak flood extents and associated depths, interpreted from some 2000 surveyed flood marks (source: BMT WBM, 2009)

Comparisons of the inundation extents and flood depths with the design results from recent flood studies suggest that, with the exception of some areas that received less rainfall (e.g. Mayfield, Carrington, Wallsend), the Pasha Bulker storm generally reached flood levels equivalent to a 1 in 100 year ARI flood event.

5.2.2 Flash flooding in Gosford and Wyong LGAs

The volume and intensity of the rainfall over the Tuggerah and Wyong township areas on the 8 June exceeded the 1 in 100 year ARI for 2 to 6 hours [Santina, 2007]. Flash flooding occurred where street drainage could not manage the runoff generated from the intense storm burst that occurred as a result of the storm. Significant flooding occurred in areas along Ourimbah Creek, Lower Wyong River, including Mardi Creek, Tumbi Umbi Creek, Salt Water Creek, Wallarah Creek and Tuggerah Lake [Santina, 2007].

Overbank flooding occurred along Wyong River, Mardi Creek and along parts of Ourimbah Creek with elevated water levels in Tuggerah Lake resulting in the flooding of a significant number of properties. For Tuggerah Lakes the flood was calculated to be a 1 in 10 to 1 in 15 year ARI flood, while Mardi Creek experienced a 1 in 35 year event. Lower Wyong River and Ourimbah Creek only experienced a 1 in 2 year ARI flood.

The flooding resulted in a considerable amount of damage and disruption, including cut off roads and inundation of numerous private and commercial premises [Molino Stewart Pty Ltd, 2008]. Approximately 400 residents were evacuated from areas surrounding the Tuggerah Lake in the Central Coast [Carpenter, 2007].

Wyong Council, together with consultants, collected flood information immediately after this event, by photographing and identifying the debris marks on fences, posts, building walls and other structural features for survey at a later date. Coal Operations Australia Limited and SES gathered additional flood level information to assist in determining the extents of the flood. The results of the field analysis were then used to generate a model of the flood surface [Molino Stewart Pty Ltd, 2008].

5.2.3 Hunter River flooding

The rainfall from 8-11 June 2007 in the Hunter catchment produced the second highest flood peak event at Belmore Bridge (Figure 11) at Maitland since the devastating February 1955 flood [Webb, 2008]. Approximately 5000 people were evacuated from their homes in Maitland on 11 June, with the SES expecting the nearby Hunter River to break its levee banks and flood populated areas. However the river peaked at 10.7 m, not high enough to break the levee banks and residents were quickly allowed to return home. Section 6.1 provides more details on the flooding of the Hunter River and an analysis of the performance of the Maitland Hunter River Flood Protection System.

Figure 11 The Belmore Bridge at Maitland spanning the flooded Hunter River. Photo taken 2:30pm 11 June 2007 (Source: Image courtesy of SES NSW)

5.3 Utilities and infrastructure

5.3.1 Power outages

The storm caused unprecedented and widespread damage to Energy Australia's power supply network (Figure 12). Wind gusts of more than 120 km/hr uprooted trees, damaging power lines and some power lines were also washed away in the resulting flood waters. Tree throw was higher than expected because of significant rainfall preceding the storm so that soils were already saturated reducing tree root stability. Around 100,000 homes and businesses from the Hunter to the northern suburbs of Sydney were without power on 8 June. By Saturday morning, that number doubled to a peak of 200,000 homes without power. In the Hunter, one in three of Energy Australia's customers was without power in the region. At times Energy Australia's call centre was taking, on average, 1000 calls every half an hour. In the 24 hour period from midnight Friday, 8 June to midnight Saturday, 9 June, more than 93,000 calls were received, the highest number of calls ever received by the call centre.

Figure 12 Damage caused to power lines during the storm. Source: Images courtesy of Energy Australia).

The power restoration process was the biggest undertaken in the Energy Australia's history. Energy Australia's first priority was to make areas safe, repair isolated sections of power lines and restore supply where possible. This required mobilisation of all available Energy Australia staff, with additional resources provided from eight power companies across New South Wales, Queensland, Victoria and the ACT. More than 1500 electricity workers (including 300 from interstate and across NSW) worked to rebuild the electricity network and restore power to customers progressively over seven days. Energy Australia line workers, inspectors and emergency service technicians were called to make up crews to patrol lines, make fallen lines safe where possible, report locations of damaged sections of the network, and switch back on any healthy parts of the network. Support staff also worked continuously as part of the restoration effort.

Hospitals, aged care and health care facilities were identified and prioritised for patrols and restoration. Water and sewer assets were also prioritised in conjunction with Hunter Water and Gosford and Wyong Councils for restoration, or they were given advice to install generators if repairs were likely to take some time. In some areas such as Wollombi in the Hunter, helicopters were used to patrol remote areas where access was hampered by flooding and storm damage. Within three days, Energy Australia had restored power to 90% of affected homes and businesses. As the focus of the power restoration moved from high voltage to low voltage powerlines, the work became slower, longer and more labour intensive. By Friday 15 June, power was restored to all homes and businesses.

5.3.2 Water and wastewater

A total of 207 private and commercial drinking water supplies, 1200 food premises and 2600 waste disposal systems (septic tanks) were affected by the flooding and power outage caused by the Pasha Bulker storm. Two small water utilities in the Hunter Valley introduced water restrictions to conserve safe stored water, while another was left with no other option than to draw water from the Hunter River resulting in high turbidity [Cretikos *et al.*, 2007]. In this case customers were advised to boil water before drinking it in order to meet health standards. Increased turbidity due to heavy rainfall caused problems in Chichester Dam which could have resulted in inadequately disinfected water being introduced to the reticulation system. Luckily a short reprieve during the storm allowed operators access to enable supply to be diverted before it was contaminated [Main *et al.*, 2008]. Some 6,000 to 7,000 Hunter Water customers were without water for periods ranging from a few hours through to several days. Hunter Water's incident response room was set up on Friday 8 June 2007 in order to manage the event and restore water supply to their customers [HW, 2007].

A total of 60 to 70 sewerage pumps failed as a result of (1) the power failure, and/or (2) flooding of pumps and switchboards at dry well wastewater pump stations. These resulted in an overflow of sewage mains and subsequent contamination of flood water across Newcastle and Lake Macquarie. Power outages at Bensville, near Gosford, also caused sewerage infrastructure failures [Calvert *et al.*, 2007]. Where network electrical power could not be reconnected immediately the electricity utility worked with the water utilities to provide connections to temporary portable electrical generators to reinstate supply and sewage services [Main *et al.*, 2008]. Some difficulties were encountered in obtaining a sufficient number of generators and some had to be sourced from interstate (Queensland and Victoria). In addition 14 wastewater tankers were operating around the clock for a number of days to minimise sewer overflows.

By Wednesday the 13th June Hunter Water had managed to stop any further sewage overflows to the environment. The storm and associated floods had a significant impact on Hunter Water's operating costs. Approximately AUD2 million was spent on staff overtime, hire of generators, operation of wastewater tankers and the subsequent clean-up [HW, 2007].

5.3.3 Roads

A section of the Old Pacific Highway near Somersby collapsed at a culvert on 8 June after heavy rain (Figure 13), taking with it a car travelling with five passengers. A subsequent investigation into the collapse has revealed that warnings regarding the deterioration of the road and culvert dated back to 1984. In 2000, the road at the culvert had slumped, and the "mechanisms of collapse" were already in operation (Sydney Morning Herald, 1/7/2008).

Figure 13 Collapse of Pacific Highway, Somersby Central Coast (source: ABC TV)

The overtopping of the New England Highway at Maitland was a notable feature of the Pasha Bulker storm event. The flooding occurred due to a combination of flows from the Hunter River down the Oakhampton Floodway and local runoff within Fisheries Creek [Webb, 2008]. As a result of floodwaters the road was closed between Maitland and Telarah [Webb, 2008]. The Maitland City Link Road was also cut off resulting in traffic being redirected through the centre of Maitland. The NSW Roads and Traffic Authority (RTA) have since carried out preliminary investigations into mitigating flooding of the highway (see Section 6.2.4).

More than 5000 trees were uprooted or partially damaged resulting in the blocking of roads across the Hunter and Central Coast [Calvert *et al.*, 2007]. It is believed that heavy rains saturating the soil preceding the strong winds was a key factor in the large amount of fallen timber (an issue raised at the workshop run by the Centre for Climate Impact Management (C2IM) at the University of Newcastle following the storm).

5.3.4 Rail

The rail network was disrupted with several sections damaged or cut-off by floodwaters or fallen debris (Figure 14). The main north coast rail line was cut at Wondabyne due to storm water discharging through the sandstone quarry causing a landslide [Watson *et al.*, 2007]. A commuter train also became trapped between stations, due to flooding, and all travellers were evacuated to Hornsby. Train services over the Australian Rail Track Corporation (ARTC) Hunter Valley rail network were severely disrupted as a result of the storms. Major problems occurred in the section between Singleton and Whittingham where both tracks were heavily undermined by flood-waters [Australian Rail Track Corporation 2007]. At Minimbah and Belford the structural integrity of the embankments was affected, the flood protection gates at Maitland forced the closure of the track and at Sandgate the switches were affected by flood-waters. ARTC crews worked to reopen affected rail services and were able to begin re-operating in eight days, while full pre-storm track capacity was restored within two weeks. The cost of repairs to Hunter Valley rail network from the storms and flooding was estimated at around AUD4 million.

Figure 14 Damage to the rail lines as a result of the heavy rainfall and subsequent erosion (source: Australian Rail Track Corporation)

Coal exports in the port were also disrupted due to the rail closure. While some coal loading resumed one week after the events, operations were still hampered by the damage sustained to the rail tracks [Carpenter, 2007]. The delay to the export coal supply chain is believed to be the biggest disruption in the Port of Newcastle’s history and was estimated to cause the loss of 2 million tonnes of coal capacity (a conservative estimate of AUD100 million of lost coal output) or the equivalent of more than a week and a half of ship loading. As well as damage to the rail network, coal producers indicated that flooding at some major mines also created significant delays in production [Railway Technical Society of Australasia, 2007].

5.3.5 Water Supply

Not all impacts of the storm were negative, the storm was responsible for a significant increase in water levels in Hunter Water’s reservoirs (mostly in the Grahamstown off-stream storage). Hunter Water reservoirs largely escaped the worst of the drought in the period 2000-2007 due to fortuitous climate conditions. Two clusters of ECLs, one in March-June 2005 and one in September 2006, produced rainfall that fell in a very narrow band over the Hunter Water catchments. Without these two events the capacity of the Hunter Water system at the time of the Pasha Bulker storm would have been about 35% capacity instead of the 82% that it actually was. The Pasha Bulker storm increased the stored water by 15% to 97% capacity.

As evidence of the soil moisture impacts (and thus agricultural impacts) of the storm, soil moisture readings at The University of Newcastle's Scaling And Assimilation of Soil Moisture And Streamflow (SASMAS) field site, 27 instrument sites based around Merriwa nearly 150 km inland, indicated that the soil saturated for the first time since instruments were installed in 2004 (or since for that matter) and that the soil remained saturated for nearly 4 months, in the midst of the worst drought on record. Moreover, some land owners indicated that it was the first time they had seen surface runoff in their tenure on the farms (though surface runoff must have occurred at some stage since the 1950's because of the construction of erosion control banks on some farms in the SASMAS field site).

There is a growing belief that ECLs are responsible for the major reservoir filling events on the east coast. This is based on anecdotal evidence but a major objective of the new East Coast Climate Change Initiative (ESCCI), largely initiated to better understand ECLs as a result of the Pasha Bulker storm, is to provide a historical database of ECLs going as far back as records will allow. This will provide quantitative data with which to better assess the role of ECLs in reservoir filling events, and thus better inform discussions on any changes in ECL occurrence and potential water resources impacts as a result of climate change.

5.4 Community and health

5.4.1 The immediate impact

During the storm two adults and three children were killed when their car was swept away as a portion of the old Pacific Highway collapsed (see Section 5.3.3). A 40 year old male was also drowned when swept into Throsby Creek, and two elderly people lost their lives when their car was swept off the road in flood waters at Clarence Town. Further tragedy involved the loss of a ninth life during the storm when a tree fell on their car at Freeman's Waterhole.

The storm placed additional demands on clinical services that were already stretched by the normal increase in winter related activity, due to such things as colds and influenza [Cretikos *et al.*, 2007]. Over the three day storm, Hunter and Central Coast ambulances responded to over 950 calls for assistance [Calvert *et al.*, 2007]. There were 180 presentations at emergency departments of the Hunter New England Area Health Service that were directly storm related, including hypothermia, fractures, lacerations, and joint and limb pain [Cretikos *et al.*, 2007]. Hunter New England Area hospitals also admitted 29 highly dependent patients whose therapy was interrupted by the storm (e.g. patients on dialysis, dependant on oxygen etc). Over 50 residents at smaller health care facilities were relocated to larger hospitals due to flood damage of the facilities in which they were housed. Further pressures on service arose from damage to buildings, infrastructure and vehicles belonging to health facilities (e.g. see Figure 15). In some cases there were staff shortages due to staff having transport issues attending work (cars were damaged, roads were blocked etc).

Compounding this, electricity interruptions were experienced by 12 hospitals and 50 private nursing homes.

Figure 15 Damage sustained to health facilities during the flash flooding in Newcastle (photo courtesy of NSW Government)

In the proceeding weeks after the storm 143 people sought mental health assistance, mainly through the Disaster Recovery Centres [Cretikos *et al.*, 2007].

The immediate impacts of the storm on aspects of the community were widespread. Some issues reported include:

- Evacuation of schools – many Hunter and Central Coast schools had requested parents collect their children for fear they may be left stranded if left to normal closing time [Calvert *et al.*, 2007]. At St Peters College in Tuggerah 500 school students were in fact left stranded.
- Evacuation of nursing homes affected by the flooding – elderly residents from Wyong Nursing Home were evacuated by the SES flood boat.
- Transport issues – commuters returning home were confronted with fallen trees, road closures due to flooding and electrical wires across roads.
- Access to people in distress – flood waters cut access to the New England Highway, preventing government agencies and welfare providers from discovering 20 families at Aberdare in Cessnock that were isolated by flood waters. Once the situation was discovered support services were immediately contacted to provide assistance including housing, clothing and food.
- Electricity interruptions – which lasted in some cases more than seven days, caused failure of household winter heating and hot water which affected the ability of people to prepare hot food and keep food from spoiling.

- Access to cash withdrawals – during the storm period was impeded by power failures which stopped automatic teller machines (ATMs) from working. Likewise, the closure of shop/bank due to flood damage, limited access to money this way.

The Hunter Valley Research Foundation (HVRF) surveyed regional residents to identify and quantify the effects of the storm and flood in the Hunter Region, either at home, at work, or somewhere else in the region, including travelling between home and work [McDonald and Redford, 2008]. People affected by the event were identified in the HVRF's Wellbeing Watch survey conducted between August and November 2007, and the Household Omnibus survey conducted in August and September 2007. Those who indicated that at least one member of their household had been affected were asked to participate in another survey which would detail the ways in which they had been affected. The results showed that more than 30% of residents were negatively affected by the storm and flooding, 18% were affected at work, while 25% were affected elsewhere. Survey respondents affected at home who indicated they were afraid for themselves or others were mainly worried about:

- the extent and speed of rising waters, with debris and cars being swept away;
- the possibility of injury to themselves or others (especially when friends, family, neighbours etc. could not be contacted);
- the wild weather, including the strength of wind and rain and dangers from falling trees;
- hazards from fallen power lines and electricity;
- the possibility of damage to their property and equipment; and
- power cuts and attendant difficulties, including loss of communication facilities, water supply, heating (especially for children and the aged and frail), and cooking facilities, as well food spoilage.

The HVRF survey also found that people who were delayed getting to places from their home during or after the storm and flood experienced an average delay of 2.3 hours. Where they were unable to get to places, they were cut-off for an average of 4 days. Those who evacuated their homes were unable to gain access for an average of more than 7 days.

A number of Hunter residents actually reported positive impacts of the storm (3.2% of those surveyed, or approximately 18,800 people). The benefits mainly related to having renovations or improvements made to their homes following flood damage and having water supplies replenished for stock and the filling of tanks and dams. Other benefits included community cohesion as families, neighbours and members of the community were brought together in response to the disaster [McDonald and Redford, 2008].

The tourism industry suffered as a result of the storm and subsequent damage. Mass accommodation cancellations had an immediate impact with a 9% decline in occupancy throughout June and a 7.3% decline throughout July [Calvert *et al.*, 2007]. The Australian Reptile Park also suffered considerable loss of business due to lack of tourism and damaged sustained to the property (including the death of ‘Eric the Crocodile’, the park’s main attraction).

5.5 Communication and support services during and immediately after the event

ABC Radio, Newcastle supported the community by suspending normal programming and providing on-going radio coverage of the event and information on how people could access support services. The NSW Police also offered their media officer for all communications and media outlets. A 24-hour hotline was established by Hunter New England Area Health to address community concerns. The experiences of health professionals manning the hotline were also used to develop fact sheets to address common questions which were then distributed to the media, support agencies and DRCs [Main *et al.*, 2008].

By Monday afternoon (10^{th} June) NSW State Emergency Service (SES) had logged 19951 calls for assistance, triggering the second largest response operation in NSW history. It took 18 days to clear the backlog of calls for emergency assistance (SES 2007). Around 60% of the calls reported fallen trees, 24% roof damage and 15% flood [Carpenter, 2007]. The SES undertook a total of 7434 jobs in the Hunter and 5372 in the Central Coast, including repairs to buildings, roofs, erection of tarpaulins and help with subsidence problems, among others [Calvert *et al.*, 2007]. By the 11 June extra SES support (70 teams) were provided from ACT, Victoria and Queensland. A problem faced by the SES in the Newcastle region was a level of unpreparedness for urban flash flooding on such a scale. The SES were reliant on the Army providing high ground clearance vehicles from their Adamstown base; however these vehicles had been relocated to Singleton due to residential development of the Adamstown base. Without access to the Army vehicles SES had to borrow personal four wheel drives, which in some cases proved to be inadequate.

During the height of the Pasha Bulker storm the District Emergency Operations Controller activated the Hunter Central Coast District Emergency Operations Centre (DEOC) to help the operations being conducted by the SES (consistent with the *NSW State Emergency and Rescue Management Act 1989*). Activation of the DEOC brought together the various emergency response agencies (fire, policy, ambulance, SES, community services and health services) which facilitated a well organised and targeted response to the storm. On June 11 the DEOC was deactivated and further recovery efforts were managed by the Disaster Recovery Executive Committees (DRECs), chaired by the NSW Department of Premier and Cabinet (DPC). The DRECs were represented by NSW Police, fire brigades, SES, DoCS, Hunter New England Health, various local Councils, Department of Commerce, RTA, Centrelink and Red Cross. A number of meetings were convened during June 2007 through to August 2007. The process aimed to support the role of DoCS as a primary disaster response agency, while drawing on the expertise of other organisations through a multi-organisational approach and was the first time this approach had been used in NSW [Calvert *et al.*, 2007].

A total of 16 Evacuation Centres were set up by DoCS and their disaster partners in the Newcastle and Central Coast regions. Over 1500 people were provided temporary accommodation, food, transport, clothing and referrals to other services [Calvert *et al.*, 2007]. In addition to the immediate assistance provided at the locally established Evacuation Centres, medium and long term support was available from a number of Disaster Recovery Centres (DRCs), set up by DoCS in Singleton, Wyong, Cessnock and Newcastle. At the DRCs, individuals were able to access financial assistance, outreach services, temporary accommodation needs, household items or structural repairs, clean-up assistance and insurance information. The DRCs closed in each region on different dates depending on the needs of the community. The Newcastle DRC (Figure 16) was open until 26 October 2007. After the closure of the DRCs, DoCS continued to provide assistance from a 'virtual' office for an additional four weeks that was contactable through a dedicated disaster recovery phone number.

It was vital that people affected by flood/sewage damage be able to clean their homes as quickly as possible to avoid the risk of disease. In order to help with this process fact sheets on how to clean were distributed through the DRCs, media and Health Services. All sports events that involved contact with potentially contaminated sports grounds were postponed [Cretikos *et al.*, 2007]. A public emergency operations centre was set up by the Hunter New England Area Health Service to coordinate surveillance of activities, respond to acute public health issues and prevent disease outbreaks [Cretikos *et al.*, 2007]. The public health emergency operations centre coordinated daily briefings with water utilities for four weeks after the storm focusing on water quality and quantity, along with results of microbiological monitoring, sewerage overflows and public complaints. The emergency operations centre also reviewed progress on mitigation of health risks to food premises, private swimming pools, mosquito breeding sites and schools.

Figure 16 Disaster recovery centre (photo courtesy of NSW Government)

There were many people who were unable to manage the clean-up effort without assistance (single women, elderly, sick or disabled/injured). In order to assist these people teams of volunteers were organised coordinated by the DPC. Tasks were assigned to each volunteer and contact was made with the client to arrange an appropriate time to undertake the task required. The volunteers were from a range of organisations including Rotary Clubs, Lion Clubs, Churches etc.

Household items damaged by the storm/flood were placed on the kerb for Council collection. There was a significant amount of rubbish and damaged items discarded on the roadside for collection and therefore Councils prioritised collection based on structured sanitation surveys. This survey included rapid inspection of the presence of any vermin or offensive odours and streets in which food premises were located were prioritised. Council also offered free entry to the waste depot for disposal of flood affected household items [Main *et al.*, 2008].

On 14 June 2007 the NSW State Government and Federal Government each provided funding of AUD500,000 from the Community Recovery Funds for each for each of the Hunter and Central Coast Regions. The Newcastle Permanent Building Society also announced the establishment of a Regional Relief Fund, drawing on unused resources still available from the Newcastle Earthquake Fund along with community donations. A planned approach for use of the funds was taken with strong accountability for the use of the funds. The Community Recovery Fund was used to provide:

- grants to community services;
- tourism and small businesses;
- economic development initiatives; and
- heritage and cultural site activities.

Both Hunter Councils Inc and the Central Coast Regional Organisation of Councils provided administrative support for the distribution of funds and a Disaster Recovery Advisory Committee was formed to indentify, assess and plan the various projects funded under the grant.

Support was also provided to Hunter Tourism to implement a marketing campaign to boost the tourism industry that had been impacted as a result for the storm. The NSW State Government and Federal Government each supplied AUD300,000 to kick start the campaign. As a result there was more than a 10% growth in the August to October 2007 tourism statistics.

6 The Adaptation Response

This Section aims to present lessons learnt from the June 2007 storm and subsequent flooding. Section 6.1 outlines the effectiveness of the Maitland Hunter River Flood Protection System that was put in place after the 1955 flood and subsequently tested during the 2007 event. Section 6.2 discusses changes in perceptions of risk and management of infrastructure within each LGA affected by the event.

6.1 The Maitland Hunter River Flood Protection System

Towns in the Hunter River Catchment have a long history of flooding as witnessed by the 1808, 1893 and 1955 major flood events. In February 1955 a major flood swept down the Hunter River valley, killing 25 people and leaving thousands homeless. The 1955 flood affected the towns of Singleton, Maitland, Raymond Terrace and the western suburbs of Newcastle around the Hexham swamp [Carpenter, 2007]. This flood resulted in the development of the Hunter River Flood Protection System – comprising 170 km of levees and control structures. A schematic of the flood mitigation scheme is shown in Figure 17. The system is designed to divert water around the city of Maitland and across the spillways on each side of the river in order to prevent the reoccurrence of the 1955 disaster. In addition to the Flood Protection System, the Glenbawn Dam was also built on the Hunter River 20 km east of Scone in 1958 (and enlarged in 1987). The dam has an additional reserve capacity of 120,000 ML to hold floodwaters to reduce flooding downstream. During the June 2007 event very little rain fell over the Glenbawn catchment, so in this case the dam did not play a major role in flood protection.

Figure 17 Schematic of the Maitland Flood Mitigation Scheme [Source: Hunter-Central Rivers Catchment Management Authority]

The Hunter River Flood Protection System has been maintained on a regular basis and refurbished in preparation for a flood, however the scheme has not been operated since the 1971 flood [Evans *et al.*, 2007]. The scheme was tested during the June 2007 storm which was much smaller than the 1955 flood, however it was the largest since 1971 (both approximately a 5% Annual Exceedance Probability (AEP)). Given the length of time since the flood system was last in operation, few people had firsthand experience of flooding and there was limited public understanding as to how the flood control structures were designed to function [Evans *et al.*, 2007].

The design of the present Maitland flood mitigation scheme uses natural floodways, Oakhampton on the west of Maitland and Bolwarra on the east of Maitland. Spillways in the levee banks upstream of Maitland operate in a 5% AEP flood and water flows over a series of control structures, designed to reduce scouring velocities on each side of the city. In events where floodwaters rise sufficiently (more than 5% AEP) a ring levee to the south of Maitland (note that the railway floodgates form part of this ring levee) will overtop and low lying residential and business areas will become submerged. When the spillways commence overtopping, local roads are cut and eventually Maitland and Lorne become isolated. In a rapid rise flood this can take as little as 12 hours [Evans *et al.*, 2007].

During the June 2007 flood the initial prediction from the BoM was for a 5% AEP, which would have just brought the Maitland spillways into operation (but not overtopping of the ring levee). This meant the flood should not have significantly impacted on Maitland and Lorne. However, the flood warning was revised (to a 2% AEP) by mid morning on June 10 due to unexpected high river levels upstream of Maitland. A flood of this volume would have had serious impacts on Maitland as the ring levee would have overtopped and the village of Lorne would have been partially flooded. Concerns were high since the flood mitigation structures had never been tested in a flood of this size and uncertainty surrounded the integrity of bridges in the region when exposed to expected high debris load [Evans *et al.*, 2007].

In response to the revised flood warning, shops were boarded up and sand bagging of railway floodgates was carried out on 10 June. In addition, approximately 5000 people were evacuated from their homes in Maitland City and Lorn on 11 June, with the SES expecting the nearby Hunter River to break its banks and flood populated areas. The Maitland mitigation scheme operated as planned (though timing of events was not as predicted) and the spillways successfully came into operation at Oakhampton and Bolwarra. Fortunately, the predicted peak in river height at Maitland was not reached (it was 0.4 m lower than expected) and the ring levee was not overtopped.

If the 2007 flood peak had matched the 1971 flood peak a ‘perfect’ flood prediction may have been achieved, however the magnitude and timing of the flood peaks in this instance were not the same. Dewar [2009] investigated the reasons for the difference between the actual flood peak and the predicted flood peak and highlighted the following issues with flood peak prediction:

- The data records are limited – although there is 190 years of data at Belmore Bridge, the Singleton and Greta data sets are only complete since 1970. The lack of large floods in the last 35 years has meant that this short record is insufficient to determine accurate flood height prediction.
- Vegetation changes – the streambanks are much more heavily vegetated at present compared to 1971 [WMAWater, 2009].
- Anomalies with automatic gauges – in the June 2007 event it was found that the automatic gauges at Belmore Bridge and Bolwarra were in error, recording a lower value than the manual gauges (by 0.2 m). It was later determined that the manual readings were accurate. It is rare for the automated gauges to be in error, however it has raised the issue of reliability of automated gauges where no manual checking is possible.
- Changing flood gradients – the system of levees and spillways are designed for a certain flood gradient from Oakhampton Bridge to downstream Belomore Bridge (based on historical flood levels). However, the June 2007 event produced a different flood gradient and resulted in unexpected inundation of the New England Highway. It is not yet understood why the flood gradient was different than predicted. However this highlights the need to consider changes in flood gradients in flood management planning.
- Lowering of the Oakhampton spillway – there is anecdotal evidence that the Oakhampton No.1 spillway was lowered following the 1971 event [Webb, 2008].

Given that Maitland had not experienced a flood of this size for over 35 years, the June 2007 event highlights the benefits of continued investment in the Maitland flood mitigation scheme. Without the scheme Maitland would have experienced another 1949 disaster (a flood of similar size to 2007 but with far more disastrous effects). It is clear that emergency plans must be maintained for all communities protected by levees and community education should be ongoing to maintain awareness of flooding to reduce complacency between events.

6.2 Changes in perceptions of risk and management of infrastructure

The affects of the Pasha Bulker storm and subsequent flooding in the Newcastle and Lake Macquarie region have caused councils and utility authorities (e.g. water, roads, power) to reflect on perceptions of risk in their regions and management of infrastructure. Some important changes made as a response to the Pasha Bulker storm are highlighted in the following sections.

6.2.1 Newcastle City Council

The Pasha Bulker storm and resulting flooding came as a ‘surprise’ to most of the community, many of whom did not even realize that they lived within a floodplain. Flooding of a similar magnitude occurred in the early 1900s [BMT WBM, 2009], but there was little, if any, awareness of this historical occurrence within the community. Newcastle City Council was, and still is, in the process of developing a Floodplain Risk Management Plan for the city. Flood maps generated by computer flood models of the Throsby and Cottage Creek catchments were delivered, ironically, to Council in the week prior to the Pasha Bulker storm. These maps were, however, able to be used to help focus attention and recovery efforts after the flood passed.

Timely data collection following the event was critical in terms of capturing knowledge on local flood behaviour with further rainfall and general clean-up efforts meaning that flood marks and debris lines disappeared quickly. The 2000 flood marks and associated flood information collected by Council will be used to help better apply the principles of the NSW Flood Policy, in the development of Newcastle’s Floodplain Risk Management Plan. This information will also be valuable for emergency response agencies (such as the SES) in their development of flood emergency response strategies and plans.

Council has also since initiated a flash flood warning system for Newcastle. At this stage the system involves telemetered rainfall and water level gauges at numerous locations across Newcastle, linked to the Bureau of Meteorology. A more detailed and specific flood warning and information dissemination system is now to be pursued in order to maximize benefits from the real-time data feeds.

From a community perspective, the flood heightened awareness of the vulnerability of Newcastle to flood risks. Subsequent storms that served as a “reminder” occurred on 9 December 2007 and again on 28 February 2008 (both involving 30 mm of rainfall within a 30 minute period) prompted a wave of correspondence to Council, with Notices of Motion and enquiries from Councillors, and letters to Members of Parliament [BMT WBM, 2009]. It is expected, however, that awareness of flood risks has reduced since the storms. Community surveys carried out immediately after the flood event confirmed a rise in awareness of flooding, with 94% of respondents in Newcastle believing they were vulnerable to flooding, compared to only 36% prior to the June 2007 event [Gissing *et al.*, 2009]. Moreover, respondents indicated that if the same storm occurred again, they would take more/earlier precautions to protect their property/possessions (60%) and/or would evacuate earlier (32%).

First-hand experience in emergency flood management in Newcastle gained during the 2007 storms has highlighted areas of specific concern that need to be addressed as part of future flood planning. Some of these are not new issues but are ongoing problems faced during such events and therefore are important to highlight for emergency managers. These include:

- Rescue and management efforts are quickly hampered when roads become inundated, leading to stranded vehicles and heavy traffic.
- Vehicles (mostly four-wheel drives) travelling through floodwaters created sizable wake (bow waves) up to 0.5 m high. These waves can propagate into private properties and exacerbated flood damage (in some instances, resulting in above floor inundation that otherwise would not have been affected).
- The lack of knowledge and appreciation of flood behaviour meant that many people placed themselves at unnecessary risk by driving or wading through fast flowing floodwaters. Gissing *et al.* (2007) found that 67% of survey respondents in Newcastle walked or drove through floodwater at some stage – nearly 40% did it to get to safety, 20% to get home, 15% to assist others, and 10% to protect property.
- Virtually everyone consulted claimed the flooding of their property was the result of blocked drains, irrespective of the size of the drain or its likely capacity to carry the extreme volumes of rainfall received. The broader community therefore believed that Council and Hunter Water were to blame for the flooding.
- A number of people experienced depression and anxiety over the flood, particularly over the tenuous nature of whether or not insurance would cover personal damage.
- Many people were forced to evacuate their homes and seek alternative accommodation, some for extended periods of time.
- Some brand new developments (and even some still under construction), built in accordance with Council’s flood requirements, experienced over-floor flooding of, in some cases, up to 300mm.

6.2.2 Lake Macquarie City Council

Similar to Newcastle LGA, the Pasha Bulker storm changed perceptions of the magnitude of flood and wind damage for the Lake Macquarie region (i.e. the level of risk is better understood now than prior to the Pasha Bulker storm). The event also raised awareness of the increased intensity and frequency of storm/flood/wind events that may be expected in the future in association with climate change.

Council's Environmental Security arm of the Lake Macquarie City Council Sustainability Department has strategic priorities in place to deal with the implications of severe storm events. For example, the Council will be launching a community awareness/preparedness campaign entitled "Severe Storm Events in Lake Macquarie City", in June 2010 to coincide with the 3rd anniversary of the Pasha Bulker storm. The campaign will focus on likely severe storm events, focussing on risks identified in the Sustainability Department's first estimate environmental security risk footprint for the City.

With respect to the Sustainability Department (SD), floodplain management studies/plans undertaken (current and future) by Lake Macquarie Council will serve to reduce the impact of flooding/storms themselves and the flooding/storm liability of individual owners and occupiers of flood/storm prone property and to reduce private and public losses resulting from these events. SD has identified priority catchments to undertake studies and plans to address current storm/flooding risk and to consider the implications of climate change. Flood studies, floodplain management studies and plans are constantly being undertaken and reviewed, based on Council's strategic prioritisation list for undertaking flood studies/plans for affected Lake Macquarie catchments. The findings of these studies will be incorporated into policy and planning documents (e.g. Development Control Plan (DCP), Local Environment Plan (LEP)).

It was identified by the Lake Macquarie City Council that there are funding and resource implications with regard to undertaking future flood studies and plans for prioritised catchments. Lack of appropriate funding from all levels of government may be a 'road block' to achieving the above objectives. Council relies on supplementary annual grant funding from the NSW State and Commonwealth Government to undertake flood study/plan projects and if these grants aren't forthcoming, then strategic prioritisation catchment projects may be compromised.

6.2.3 Hunter Water

The availability of contingency plans that Hunter Water had prepared (across some assets) prior to the Pasha Bulker storm aided greatly in management of the crisis and reinforced the need to finish the suite of documents across all critical assets. One of the longer term issues arising out of the storm event was the failure of several dry well wastewater pump stations which were flooded. Hunter Water has approximately 50 dry well pump stations across the network and there is a clear need to give some longer term consideration to identifying those which are at most risk of flooding and consider a program of converting such stations to the more modern submersible variety so that the equipment is not susceptible to flooding scenarios.

Hunter Water have provided dedicated plug-in facilities for generators at a large number of assets over recent years, however this is not yet widespread across the whole network. The need to wire in generators in an emergency required both additional resources and extended times, therefore there is a need to take steps to ensure the use of generators can be facilitated in the most expeditious way.

During the June 2007 event Hunter Water lost both a water main and sewer main at a creek crossing. A review of major creek crossings is currently being undertaken to determine the vulnerability of such assets to extremely high stream flows.

6.2.4 NSW Roads and Traffic Authority

Webb, McKeowen & Associates (now trading as WMAwater) were commissioned by the RTA to study the impact of the event on the road network with a view to possible mitigation strategies to prevent or reduce traffic disruptions in a future flood. They found that the New England Highway would likely have remained open if:

- flood gates were installed on the culvert at Mt Pleasant Street – this will delay the passing of floodwaters under Long Bridge;
- earthen mounds were formed linking high grounds on the railway line to the New England Highway and then to high ground on the northern levee bank of Fishery Creek;
- a reduction in the duration of inundation could be achieved if the bridge under Cessnock Road is widened; and
- hydraulic modelling would be required to determine the range of flood events for which the above measures would be effective, however initial investigation suggest that inundation would be prevented a 5% AEP flood (i.e. the 2007 event) if such measures were put in place.

7 Regional and national Implications

Recently there has been a broader recognition by government (both State and Federal) of the importance of ECLs and the need to better understand their historical variability and potential future changes due to climate change. Also required is an improved understanding of the impacts of ECLs on coastal cities and the most appropriate adaptation response. This is reflected in the Bureau of Meteorology (BoM)/ NSW Department of Environment, Climate Change and Water (DECCW) funded Eastern Seaboard Climate Change Initiative (ESCCI) within which ECLs are a core research topic.

The following sections outline a number of issues of regional and national significance that have arisen upon reflection on the Pasha Bulker storm and associated ECLs.

7.1 ECL scenarios – implications for the Hunter/Central Coast and other coastal cities

The series of ECLs that occurred during June 2007 raised awareness on a regional level about the potential dangers of ECLs. On reflection, it is clear that small changes in the sequencing, timing or location of the ECLs may have actually resulted in quite a different (and more severe) impact. It is therefore prudent to hypothesize a number of 'what if' scenarios with respect to the Pasha Bulker storm and consider what the implications could have been with respect to impacts on the community, and responses by emergency management authorities.

Scenario 1: What if the storm's maximum rainfall intensity occurred over the Throsby / Cottage Creek catchment instead of at Croudace Bay, some 10km south.

Given the rainfall measured at Croudace Bay compared to that measured in the Throsby/Cottage catchment, this scenario would have resulted in between 10 and 50% more rainfall in Newcastle (noting the Merewether station already recorded close to the Croudace Bay rainfall total).

BMT WBM [2009] carried out computer modelling on behalf of Newcastle City Council to investigate implications of rainfall that exceeds the 1 in 100 year probability, including a 1 in 200 year event which has a design rainfall and runoff of approximately 10-40% more than the 1 in 100 year event. The results of the 1 in 200 year modelling indicate that inundation extents would increase by about 70 hectares (or 6% of the total inundated area), and that overall, flood depths would increase by generally less than 5 cm. Indeed just 1% of flood affected areas (about 10 ha) would experience an increase in inundation of more than 20 cm, and these areas are largely confined to areas of deep inundation during the 1 in 100 year event anyway (e.g. St Pius X ovals at Kotara and National Park closer to the centre of Newcastle).

The relatively small impact on flood depths of more rainfall in the catchment is the result of the broad flat topography that characterizes much of Newcastle's floodplains. That is, any increase in flood volume can be accommodated relatively simply by spreading across the vast flood extents. Within the upper catchment, where floods are more restricted to narrow flowpaths, the increase in rainfall results in a small increase in flood depths, as well as an increase in flood velocities.

There were many reports following the event of flood levels ‘almost’ reaching the floor level of houses, along with numerous ‘close calls’ and daring rescues. The 1 in 200 year modelling suggests that with more rainfall, only a relatively small number of additional dwellings would have been inundated. Thus, it is unlikely that the damage bill associated with flooding would have been dramatically higher with more rain (unless of course the rain was extraordinary, i.e. approaching Probable Maximum Precipitation (PMP) levels).

The ‘close calls’ and daring rescues, however, may still have had more tragic outcomes with a larger rainfall event. Closer inspection of the modelling results show that although depth increases were modest, there were also increases in flood velocities, particularly along pseudo-floodways such as roads. The stability of people and vehicles is generally measured using the product of velocity and depth ($v \times d$), with conditions considered hazardous for vehicles when $v \times d$ exceeds about 0.25, and hazardous for adults when $v \times d$ exceeds about 0.5 (reference for these values needed). The results of the modelling indicate that a 10-40% increase in rainfall and runoff would have resulted in an approximately 20% increase in areas experiencing $v \times d > 0.5$, and in areas experiencing $v \times d > 0.25$. This suggests that hazardous conditions would indeed worsen with increasing rainfall, possibly resulting in a greater loss of life, or lives seriously threatened, had the Pasha Bulker storm been centred over the Newcastle catchments.

Scenario 2: What if there were major blockages of culverts within the middle and upper reaches of the catchments?

Blockages did occur within some sections of the stormwater system, most notably at the downstream end of Cottage Creek, where two shipping containers were swept into the waterway and became lodged within culverts. Flood levels were made worse here by the lack of alterative low-level flow paths for the water. At the site of the blockage, commercial buildings form a solid wall between National Park and Steele Streets so that overflows were forced down these streets, which are about 1 m higher than the level of the top of the stormwater drain. This backwater flooded back over King and Parry Streets (major routes into and out of the Newcastle CBD) and National Park. This is further addressed in Section 7.7.

In other areas, smaller culverts were also blocked by vehicles, large rubbish bins, shopping trolleys and other debris, however, in these areas there was generally adjacent overland flow occurring and the impacts of the blockage were localised. This scenario considers blockage in major culverts across the floodplain, including culverts through rail embankments.

As part of Newcastle City Council’s Stage 1 Concept Flood Plan, computer simulations were undertaken to investigate the sensitivity of flood risks to a range of blockages within the system [BMT WBM, 2009]. The investigations found that blockages within culverts under roads resulted in a minor to moderate increase in flood levels immediately upstream, however, blockages within culverts under railways resulted in major increases in flood depths. In general, rail lines across Newcastle have been constructed on elevated embankments. The network of rail embankments effectively forms ‘dam walls’ with drainage provided through a limited number of culverts under the embankments. When these culverts are blocked, floodwaters simply fill the areas upstream of the embankments, akin to the filling of a reservoir. Filling continues until the embankment (‘dam wall’) is breached.

Based on the modelling carried out for Newcastle City Council if the large Styx Channel culvert at the Main Northern Rail Line had become blocked during the Pasha Bulker storm, then the areas upstream, stretching as far as District Park in Broadmeadow and Gregson Park in Hamilton, would have become a ‘lake’ (Figure 18). Flood depths in this area would have been higher than what was experienced in June 2007 – by about a metre or more along Samdon St, the Newcastle Showground and Hamilton North, and up to 2-3 m higher immediately upstream of the blockage on land owned by Shell Australia and AGL Energy (off Chatham Road). This depth of water almost flooded the Australian Broadcasting Corporation (ABC) studios, the major source of public emergency information.

Modelling shows that similar results would occur upstream of other blocked culverts under the rail embankments and/or culverts at Kotara (St Pius X ovals), Georgetown, Mayfield and Newcastle West, potentially resulting in much greater inundation extents than experienced in June 2007 (with the obvious exception of Newcastle West, which was blocked during the event).

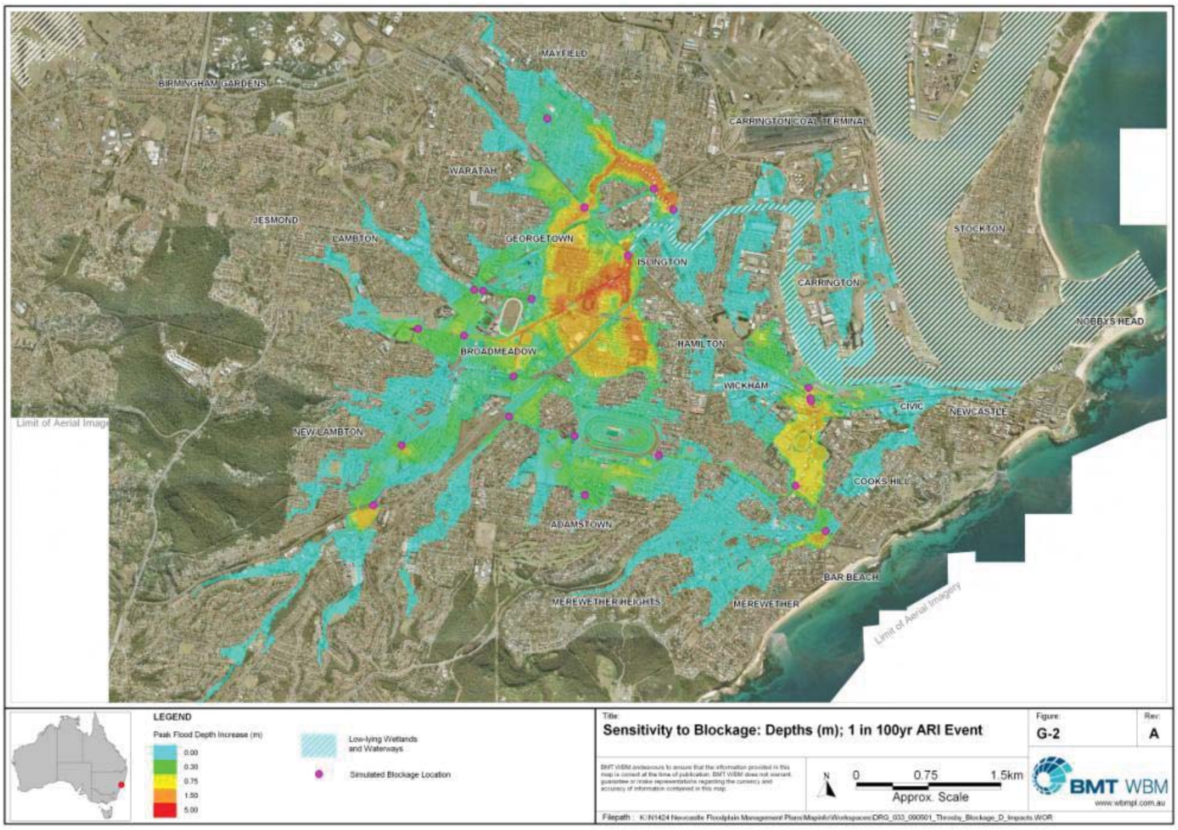


Figure 18 Impact of blockage at selected key culverts within the Throsby/Styx catchment, based on a 1 in 100 year flood (comparable to June 2007 storm) (source: BMT WBM, 2009)

Scenario 3: What if the storm occurred one week later and coincided with king tide conditions?

The Pasha Bulker storm coincided with neap tides, i.e. the smaller tides in the fortnightly spring-neap tide cycle, and at about mid-tide (Figure 19). This scenario considers the impacts on flooding had the storm occurred one week later, during predicted king tides.

Storm surge refers to the elevation of ocean water levels as a result of inverse barometric pressure and wave set-up. The storm surge recorded in Newcastle during the Pasha Bulker storm was over 0.4 m. That is, the predicted water maximum high tide level was to be about 0.6 m, but actually reached about 1.0 metre inside Newcastle Harbour (Figure 19). Storm surge in excess of 0.3 m persisted for several days. Storm surge in Sydney Harbour was about 0.23 metres, giving a maximum high tide level of 0.92 m during the storm (Watson *et al.*, 2007).

The following weekend, predicted high tide levels were to reach 1.04 metres in Newcastle. Had the storm surge coincided with the king tide, then the maximum water level within Newcastle Harbour would have been 1.4 to 1.5 m. Note that the highest level ever recorded in Newcastle Harbour was 1.4 metres during the 'Sygna' storm in May 1974.

An increase in tailwater levels by 0.4 m is unlikely to have had a significant impact on the majority of the floodplain areas across Newcastle, given the relatively steep flood gradients up the catchment. The notable exception to this, however, would be the low-lying suburbs surrounding the Newcastle Harbour, namely Carrington, Maryville, Wickham and Islington, as well as parts of Stockton. During the Pasha Bulker storm, flooding of these suburbs was generally associated with local rainfall not being able to drain to the harbour. If the harbour water levels were high, then these suburbs would also face the dilemma of direct backwater inundation from the harbour. Indeed a substantial proportion of these suburbs would be inundated by a harbour water level of 1.4 m alone (i.e. without any coincident rainfall).

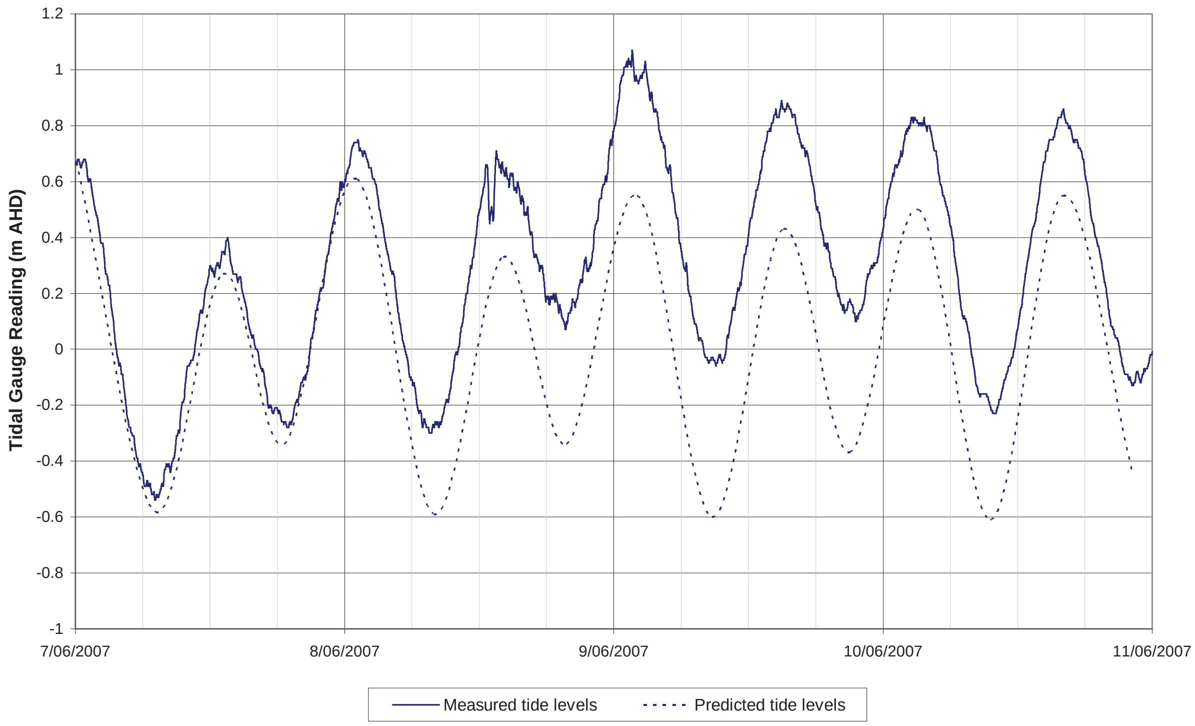


Figure 19 Measured and predicted tides at Newcastle during June 2007 storm, highlighting the degree of storm surge (source: BMT WBM, 2008)

Scenario 4: What if the same ECL had been centred over a different coastal city

The highly localised nature of the rainfall of the Pasha Bulker storm (i.e. the rainfall was quite concentrated along the coast but extended quite some distance inland) means that there is considerable potential for localised damage in a number of cities along the coastline impacted by ECL (roughly southeast Queensland to NSW/Victorian border). There were two main impacts in Newcastle (1) the urban flash flooding driven by localised, high intensity bursts of rainfall, and (2) the Hunter flooding driven by the inland penetration of the rainfall over several days.

The impacts of urban flash flooding were focussed in flat areas with steep headwaters where drains were unable to convey away, either due to insufficient capacity or blockage, sufficient water. In steep areas there was also damage, but it was localised and typically due to overflows of the street drainage system. Using this insight we can start to note areas on the NSW coast that might be at risk of similar damage. For example, in Sydney the Manly region is known for this type of flooding. Some of the flatter industrial areas around Botany Bay are also likely to experience flash flooding, although they lack the steep headwaters contributing runoff. Most of the remaining areas in Sydney are too steep to trigger this mechanism though this is not to say existing flooding trouble spots (e.g. Parramatta, Fairfield and Liverpool) would not have localised problems. On the Central Coast between Sydney and Newcastle the areas between Ourimbah through Wyong to Morriset are highly likely to suffer similar flood inundation problems because of the same combination of steep headwaters and flat developed areas. This area is of particular concern because it is undergoing active residential development by Sydney commuters. To the north of Newcastle there are also a number of smaller towns that share the steep headwaters and flat developed areas, and therefore are at risk of urban flash flood inundation. It is clear that site specific studies of which towns are at risk need to be carried out.

In terms of the longer term river flooding driven by the inland penetration of flood flows, most towns on the east coast between Newcastle and the Queensland border currently suffer problems from this type of storm. The level of preparation for these types of events is variable with Grafton being particularly well prepared, with a scheme similar in scale to that around Maitland. As part of the Eastern Seaboard Climate Change Initiative (ESCCI) it is anticipated there will be studies of the effect of ECLs on this part of the coast to assess impact and adaptation options.

7.2 Provision of environmental health and social services

The June 2007 event highlighted some important issues in establishing suitable locations for the Disaster Recovery Centres (DRCs). It was found that property that suits the requirements of a DRC was not easily available, especially in smaller townships [Calvert *et al.*, 2007]. The locations need to be easily accessible, large enough to have a waiting area for clients, sectional areas for different organisations and good parking options. The lack of suitable accommodation can delay the commencement of operations. In the case of the Pasha Bulker storm Wyong and Newcastle identified locations for the DRC with relative ease, however it was more challenging in the other regions. The experience gained during the June 2007 event highlights the need to have a list of pre-established facilities that would be suitable to act as a DRC in such an event. This finding is universal and is applicable to all states and territories in any emergency event.

The Pasha Bulker storm also stretched the available capacity of health services in the affected regions, highlighting the difficulty health staff in local government would have had in responding to a longer term disaster or secondary event such as an outbreak of food or waterborne disease. Given that a total of five ECLs occurred in June 2007 highlights the possibility of multiple events occurring. If the more severe ECL of the 19-20 June had occurred over land rather than sea, it is likely that the environmental health services would not have been able to cope. Main *et al.* [2008] recommend that state and local governments must continue to invest in ensuring an adequately skilled and available environmental health workforce that is equipped to respond to such disasters and emergency events.

7.3 Insurance cover for natural disasters

According to the Insurance Council of Australia there were 98,000 claims lodged in the Hunter and Central Coast district following the Pasha Bulker storm, the vast majority of which were honoured. Some individuals experienced hardship due to lack of insurance or underinsurance. Estimates based upon applications for government relief (both commonwealth and NSW state) are that 1 in 5 people affected by the storm had no insurance cover at all [Giles, 2007]. This initial assessment of non-insurance in NSW resonates with research commissioned by the Insurance Council of Australia that shows 26% of all NSW households do not have any form of home and contents insurance [Giles, 2007].

Initially some insurance companies treated the event as being a flood event, rather than a storm event meaning that many individuals would not receive compensation. However the Department of Commerce worked with the Insurance Council of Australia to seek clarification and the event was officially classified as storm related ensuring coverage for all those insured [Calvert *et al.*, 2007]. Nonetheless some insurers including the National Roads and Motorists' Association (NRMA) have since added flood cover to their policies for land deemed as flood-prone. This has increased the cost of policies dramatically. According to the NRMA, if there was a repeat of the Pasha Bulker storm, households would still be covered for storm damage but if there was a flooding component, damage would only be covered if the person had flood insurance [Branley, 2009].

A number of issues around what is included in insurance cover were highlighted by the Pasha Bulker storm. For example, although insurance companies cover the cost of repairs to property damage associated with landslip, they do not cover restoration works associated with the landslip itself. This was an issue for the Pasha Bulker storm for a number of families in Rankin Park, Cardiff and Spencer where a major landslip occurred directly behind the properties. In this instance costs of the rectification works were born by Government and the residents involved. The cost of removing a fallen tree from a property is also not covered by insurance unless it has fallen on a fence or other object that is insured. The cost of removal of fallen trees was beyond the reach of many property owners and they did not have the equipment to remove the tree themselves. In one case a property owner on the Central Coast had sixteen 25 m trees fall on her property [Calvert *et al.*, 2007].

The HVRF estimates that the value work-related property loss and damage from the storm and flood totalled approximately AUD458 million, 22% (AUD123 million) of which was not covered by insurance [McDonald and Redford, 2008].

7.4 Coastal developments

During the storm homes located in Cabbage Tree Bay at Noraville on the cliff facing the Ocean experienced escalated erosion rates, with one home sustaining considerable damage. This area has faced years of ongoing erosion on the cliff and has been the focus of an ongoing legal battle between residents and the Council. Since the Pasha Bulker storm Council has ordered residents to remove hard infrastructure from their backyards as a short term adaptation strategy. Council has also sought guidance from NSW Department of Environment, Climate Change and Water (DECCW) regarding the guidelines to be used in the development of the Coastal Management Plan (which is currently being prepared). The issue of coastal development is an ongoing problem for many Councils located along the east coast and requires consideration and appropriate action at all levels of government in order to appropriately address the issue. There is no single solution and future adaptation measures are likely to include retreat, infrastructure (e.g. sea walls), land buyback and changes to planning procedures.

7.5 Household preparedness

Hunter New England Population Health carried out a study to determine the level of household disaster preparedness during the storm, emergency radio network awareness, household information needs and information sources accessed by households during the storm [Cretikos *et al.*, 2008]. The study involved a survey of 320 randomly selected households from Newcastle and Lake Macquarie within two weeks of the storm to examine preparedness and access to information during and after the event. The study found that household preparedness was variable. Basic supplies such as a mobile phone, torch, candles, matches and a three day supply of non-perishable food were available in over 80% of households. However, deficiencies in disaster preparedness were also identified including lack of recommended basic equipment such as battery operated radios, appropriate batteries, first aid kits and emergency contact lists. Less than 50% of households had sufficient drinking water for three days [Cretikos *et al.*, 2008]. Many residents did not consider that their car radio would be a suitable alternative to a household battery operated radio.

The study found that the local radio station (1233 ABC Newcastle) had played an important role in providing public information during the storm [Cretikos *et al.*, 2007], however half of the households surveyed were unaware of the storm warnings on 7 June 2007. Of those that received the storm warning, preparations for the storm were undertaken by approximately 40% of households (such as clearing drains, securing windows and loose objects and cancelling travel). Most households reported that the radio was the most useful source of information during the storm. In particular, the ABC transmitted information that was available on various websites which could not be accessed by many people were affected by the power outage (highlighting the fact that web based emergency systems are not robust). NSW SES and NSW ABC have since signed a memorandum of understanding to facilitate communications with the public during disasters. Such agreements already exist for Victoria, South Australia and Western Australia, however it is recommended that all states and territories would benefit from formal arrangements with the ABC for provision of emergency health information during a disaster [Cretikos *et al.*, 2007]. Moreover, the ABC has put in place procedures for transferring their operations from the Newcastle studios to Sydney in the event that their Newcastle studios become inoperable due to flooding or other damage.

Individuals and communities throughout the region expressed the need for increased awareness of emergency procedures and processes, plus information and education opportunities which strengthen the community's sense of safety and confidence in preparedness for future disaster events. In response a storm preparedness brochure "Stormsafe Hunter" and fridge magnet was mailed to every Hunter household using funds from the Disaster Recovery Fund. Wyong Shire Council and the NSW SES also undertook a review of the June 2007 event; to determine what they did, what worked and what could work better next time. It was clear that community education and communication is a key driver to successfully managing such events. In response the SES produced a website aimed to assist with community education (which can be accessed here http://wyong.ses.nsw.gov.au/Flood_page.html). The website contains useful information on each catchment's flooding characteristics, along with what to do before, during and after a flood. This sort of initiative could be applied on a national scale and such websites should be advertised through schools and community centres in order to increase public awareness.

7.6 Flood preparedness

Maitland has recently undergone strong population growth with the highest population growth rate of any NSW Local Government Area. Many people moving into the city have little or no flood experience (a phenomena also occurring elsewhere in river towns). In 2005 a survey found that the lack of large floods (absent since 1971) and a misconception that the levee banks protect against all large floods had resulted in a lack of flood preparedness in a place that was once known as the 'flooding capital of NSW' [Hunter-Central Rivers CMA, 2006]. In order to overcome this issue the Hunter Central Rivers Catchment Management Authority (CMA) in partnership with the SES and local community developed a flood education strategy. The strategy was launched in February 2007, on the anniversary of the 1955 flood. An information kit, 'Are You FloodSafe' was developed and distributed to 8000 households and businesses containing a DVD with a model of a 100 year flood in Maitland. The model has been showcased at state and national flood conferences and the project was highly commended in the 2007 Australian Safer Communities Award. A survey was conducted to evaluate the project, and found that the level of awareness and preparedness for flooding had increased significantly and the city was declared 'ready to face floods'. The flood of June 2007 was both a test of the mitigation scheme, and the response of the community. Over 4000 residents and business operators were successfully evacuated from the city centre. However, there is some concern that the 'false alarm' that resulted in evacuation of Maitland residents will make residents complacent about flood risk and may reduce response rate during the next flood [Dewar, 2009]. Again this highlights the need for communication and education of the community to ensure people respond appropriately to flood warnings in the future. Since the June 2007 event a variety of additional activities have been implemented by the CMA and SES to promote flood safety and a better understanding of the flood mitigation scheme and its limits.

A survey conducted by Gissing *et al.* [2009] found that before the June 2007 event 60% of people in Maitland thought they could be flooded compared to only 36% in Newcastle. Since the June 2007 event 81% of Maitland and 94% of Newcastle people believe they have a chance of flooding in the future. Interestingly, almost all the respondents in Newcastle did not suspect that they would be flooded until the floodwaters had entered their homes. This demonstrates the need to educate people regarding the natural warning signs that indicate the possibility of flash flooding.

The fundamental differences between the Maitland and Newcastle floods are likely to have contributed to the different responses observed in the respective areas. For example the Maitland flood was associated with long lead times for warnings and active management works (e.g. evacuation). In comparison the Newcastle flood was a flash flood with much shorter lead times on warning which require passive management (systems that do not require intervention during the event such as drains etc).

7.7 Communication during natural disasters

After the Pasha Bulker storm, surveys were undertaken of residents and business owners in Newcastle and Maitland to determine whether official flood warning messages were heard and appropriate action was taken [ADW Johnson Pty Ltd, 2008; Gissing *et al*., 2009]. There are important differences between flood communication in Maitland and Newcastle. Maitland is serviced by the Bureau of Meteorology flood prediction system. Warnings are issued detailing the approximate height and arrival time of flood levels. The SES also has a detailed intelligence system for the Maitland region that provides the community with information on public safety advice and flood consequences. In Maitland, flood warnings for the Hunter River and evacuation notices were issued through Flood Warnings, Flood Watches and Severe Weather Warnings for Flash Flooding. Newcastle is not serviced by a flood prediction system (as it is a flash flooding environment only) and therefore did not receive any evacuation notice (which is triggered under the flood prediction system).

A survey conducted by Gissing *et al.* [2009] found that in Maitland around 59% of people were reported to have heard the Flood Watch on June 7 compared to only 29% in Newcastle [Gissing *et al.*, 2009]. Of those who heard the Flood Watch in Newcastle, only 22% thought it applied to them because many people believed that their area would not flood. Many people claimed to have not heard the warnings as they were at work and did not have access to a radio. The study also found that while radio broadcasts were useful, other means of warning dissemination needs to be improved. Furthermore, it would be beneficial to include as much locally specific information and advice as possible (since residents assumed if their suburb wasn’t mentioned the warning did not apply to them). In addition, further work needs to be carried out to evaluate the benefits of flash flood warning systems in fast response catchments in order to determine the case for the installation of such systems. The study also recommended that flood education should be carried out, particularly in catchments with a high risk of urban flooding.

7.8 Natural Disaster Recovery Relief Arrangements funding

The natural disaster declaration following the Pasha Bulker storm triggered a range of assistance for residents and business owners and ensured both government agencies and Councils were reimbursed through the Natural Disaster Recovery Relief Arrangements (NDRRA) funding for the cost of repairing public infrastructure. At present the period for funding of emergency works as a result of storm flooding is 21 days from the date of declaration of the natural disaster. Funding for waste/rubbish removal under the NDRRA funding is also based on the 21 day timeframe. Due to the continuing rain and subsequent flooding throughout June (due to the series of ECLs) the Councils were unable to complete emergency works and cleanup by the designated timeframe (in this case July 4 2007). An extension period up to 21 August 2007 was granted to Councils through the Department of Commerce. However, this experience has highlighted an important issue about the provision of funding through NDRRA in such situations that requires further consideration. Other impacts resulted in considerable cost to Councils, that were not able to be claimed through NDRRA funding, included:

- An outbreak of Alligator Weed and other aquatic weeds in many LGAs in the Hunter. Councils are still attempting to address this issue without financial support.
- Loss of income from landfill levies (an exception was put in place for storm clean up and flood debris).
- Processing costs incurred by Council owned waste processing and recycling facilities.
- Loss of income from parking meters that were damaged during the event.

It is suggested that the issues highlighted by this event (and possibly others within the NCCARF historical case studies series) be considered during future revisions of NDRRA funding policy.

7.9 Planning Controls in Floodplains

The rural flooding at Maitland and the urban flooding in Newcastle provide an interesting comparative case study in the use of flood mitigations works and floodplain planning controls. These comments should be seen in the context that the rural flooding in the Hunter River at Maitland was relatively less severe (1 in 40 year flood levels) than the flooding in the Newcastle CBDs (1 in 100 year flood levels, and perhaps higher).

The Maitland flood protections works are based on investment in levees and floodway construction and maintenance, and planning controls on floodplain development within the floodways. Moreover the success of the system for low frequency events is predicated on a significant lead time being available for evacuation and some active flood protections works (e.g. closure of flood gates in the levees where the Main Northern Railway crosses the levee system). An assessment of the system's performance in the Pasha Bulker storm is that it worked, to a large extent, as planned.

This success should be compared with those works protecting the central and satellite CBDs of Newcastle. The sole protection in these cases was the stormwater system (designed to a 1 in 100 year flood level, and consisting of a mix of concrete lined channels, pipes and culverts, and a limited number of flood retention basins), with very few planning controls on development in flood prone areas (due to historical development in flood prone areas prior to modern flood protection standards), and in several cases high value businesses adjacent to, or within flood reach, of the drains. Each of the CBDs has unique characteristics, for example:

- Newcastle City CBD: The area around Cottage Creek is a locale of major urban decay and is currently the topic of considerable debate by the community, developers, and local and NSW State Government as part of a revitalisation of the CBD. The cause of the decay is that the major shopping magnets have moved from the CBD to satellite mall developments. The current buildings on Hunter Street around Cottage Creek form a solid barrier between King Street upstream and the Harbour downstream. As part of urban redevelopment there is a unique opportunity to open up alternate overflow paths and reduce the risk of backwater flooding of the suburbs of Cooks Hill and The Junction upstream. Major impediments to capitalising on this opportunity are fragmented land ownership in the area and a lack of political consensus on the way forward for urban renewal. The apparent lack of any single body responsible for flood protection works appears to be an impediment and is addressed in our recommendations.
- Wallsend CBD: This area has been known to have significant flood risk for some time as a result of flood studies dating back at least 10 years. Urban development upstream is likely to make problems worse at this site in the future. The main issue here is the high density of existing development (much of which dates back 100 years) around the creek, the lack of suitable sites for retention ponds immediately upstream and lack of political consensus on financially viable solutions for businesses near the stormwater channel in Nelson Street.
- Cardiff CBD: Here the major issue appeared to be an interaction between the channel system and adjacent developments. Most problems arose here as a result of blockages of bridge openings by cars that floated off car yards adjacent to the channel. This could be easily addressed with barriers between the creek and adjacent business, or by planning controls restricting vulnerable commercial activities adjacent to the channels.

The common attribute of all the CBDs is that the flood risk for each CBD has been known for some time but there has been a lack of funding priority given to addressing the problems. Making it worse, or more likely causing it, is that there is divided responsibility for control of the storm water works. It appears the Newcastle Council has overall control of the channels and has devolved the responsibility for maintenance of the channels to Hunter Water. It was not clear who is responsible for planning controls adjacent to the channels. Of particular note was that nobody we spoke to could answer the question "Who has overall responsibility for controls on infrastructure constructed over the channels (e.g. pipes, conduits, etc which are implicated in many of the stormwater blockages as a result of debris loading)". It was also not clear what roles the NSW Office for Water and Hunter-Central Rivers CMA have to play in Newcastle urban flash flooding protection. One feature of the Maitland flood protection scheme is that it has one coordinating authority, Hunter-Central Rivers CMA, who is responsible for all aspects of the works.

8 Conclusions and recommendations

This report has outlined the climatological context of the June 2007 storm, the subsequent severe weather and flooding, along with various secondary impacts. The report has also discussed the various adaptation strategies put in place (by councils, water authorities etc) based on lessons learned from the event. Further to this the regional and national implications of this event (and other ECLs) have been addressed. Importantly the report has highlighted a number of research and policy based questions. In particular, further research is required to determine:

- What causes periods of enhanced ECL activity?
- How likely is it to get back to back ECLs (e.g. five or more during a month such as what occurred in June 2007)?
- What is the likelihood of similar events occurring elsewhere in Australia?
- What are the climatological/oceanographic conditions that result in ECLs occurring close to the coast (as was the case with this event) rather than out to sea?
- How is climate change likely to alter the frequency and/or magnitude of ECLs in the future (note this will require Global Climate Models (GCMs) or Regional Climate Models first being able to simulate the historical patterns of ECLs)?

Some of these issues may be addressed under ESCCI, however, at the time of writing this report the agenda for ESCCI research over the next three years has not been finalised.

Additional policy based recommendations that have been highlighted in this report are:

- The experiences gained during the Pasha Bulker storm highlights the need to have a list of pre-established facilities that would be suitable to act as a Disaster Recovery Centres (DRCs) in such an event.
- State and local governments must continue to invest in ensuring an adequately skilled environmental health workforce is available and equipped to respond to disasters and emergency events such as the Pasha Bulker storm.
- Greater community awareness of insurance cover inclusions is needed along with a framework to cover aspects of storm damage not included under general home/business insurance (e.g. landslip, fallen trees).
- A consistent policy for coastal developments (agreement at Federal, State and local level of governments) is needed to deal with existing coastal infrastructure/housing and planning guidelines around new infrastructure/housing.
- Increased community awareness of emergency procedures and processes is needed, along with information and education opportunities which strengthen the community’s sense of safety and confidence in preparedness for future disaster events.

- Ongoing communication and education of communities susceptible to flooding (both flash flooding and river flooding) is required to ensure people respond appropriately to flood warnings in the future. Appropriate programs should be established.
- Further work needs to be carried out to evaluate the benefits of flash flood warning systems in fast response catchments in order to build a strong case for the installation of such systems.
- All states and territories should institute formal arrangements with the ABC for provision of emergency (e.g. flood levels, health) information during and after a disaster.
- The Natural Disaster Recovery Relief Arrangements (NDRRA) funding guidelines need more flexibility in situations where cleanup and emergency works are unable to be carried out immediately.
- Clarification is required of the lines of responsibility and regulatory powers of responsible parties for the establishment, maintenance, and enhancement, and planning controls on developments adjacent to and over, the open channel component of the stormwater system. For instance, in the Newcastle CBD it appears that responsibility is divided between a number of parties with no single entity having oversight of, or responsibility for, strategies to reduce flood damage risk.
- A better definition is required for the roles, training, and infrastructure required for emergency services (SES, police, fire, ambulance, etc) tasked with responding to urban flash flooding, and also those who have any interaction with infrastructure holders (e.g. local government, water corporations).

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