Climate change vulnerability in South East Queensland: a spatial and sectoral assessment

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This report, *Climate Change Vulnerability in South East Queensland: A Spatial and Sectoral Assessment*, is part of the South East Queensland Climate Adaptation Research Initiative (SEQ-CARI), a partnership between the Queensland and Australian Governments, the CSIRO Climate Adaptation National Research Flagship, Griffith University, University of the Sunshine Coast and University of Queensland. The Initiative aims to provide scientific knowledge to enable the region to adapt and prepare for the impacts of climate change.

South East Queensland (SEQ) is particularly vulnerable to climate change because of its growing population and coastal location. Human settlements, infrastructure, unique ecosystems, and primary industries all face threats from more extreme weather events, increased temperatures and altered rainfall patterns as a result of increased greenhouse gas emissions. Despite these risks and challenges, climate change may also bring some economic and social opportunities.

SEQ-CARI aims to provide research knowledge to enable the region to adapt and prepare for the impacts of climate change. It will develop practical and cost-effective adaptation strategies to assist decision-makers in government, industry and the community. The initiative is the first comprehensive regional study on climate change adaptation undertaken in Australia and one of only a few worldwide. It is exploring both vulnerabilities and adaptation options in response to climate change so that our prosperous regional economy, environment and lifestyles can be maintained into the future. For more information about this and other projects in the South East Queensland Climate Adaptation Research Initiative (SEQ-CARI) visit: www.csiro.au/partnerships/seqcari.html.

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EXECUTIVE SUMMARY

This report concludes the first phase of the SEQ CARI project and consists of a preliminary regional assessment of the vulnerability of human settlements to climate change at both spatial and sectoral levels. In SEQ, climate change is projected to lead to an increase in average annual temperatures, a change in average rainfall and sea-level rise. In addition, more extreme weather events are projected, with an increase in extreme rainfall events, an increase in the number and frequency of more intense cyclones and an intensification of east coast lows.

The spatial vulnerability assessment has utilised an integrated framework which includes both external (exposure) and internal (sensitivity and adaptive capacity) dimensions of vulnerability, as this is the most common approach currently used in global environmental change and climate change research. Preliminary regional spatial vulnerability assessments have been developed, based on a set of indicators to illustrate the region’s exposure, sensitivity and adaptive capacity to three key climate-related impacts projected to affect the region, namely: extreme heat, extreme rainfall and coastal hazards.

The initial spatial vulnerability assessment for extreme heat indicates that areas associated with the region’s urban footprint (including coastal urban areas) are generally more exposed to heat impacts due largely to heat trapped in the urban canopy as a result of expanded impervious surfaces. This is the case in urbanised coastal areas of the Gold Coast and the Sunshine Coast, plus the bay side areas of Brisbane City and Moreton Bay Regional Council areas, which include a number of localities assessed to be extremely vulnerable to the impacts of extreme heat events. Many of these localities that have been identified as highly vulnerable to extreme heat are also areas with low adaptive capacity. This is particularly noticeable in the south west of Brisbane City and in north east portions of Ipswich City.

The extreme rainfall vulnerability map indicates that most of SEQ has a low vulnerability to extreme rainfall. However, some areas within local government areas of Gold Coast, Brisbane, Logan, Moreton Bay and Sunshine Coast present a medium, high and extremely high vulnerability to extreme rainfall. Of particular concern are a number of areas within the Sunshine Coast and Gold Coast jurisdictions that appear extremely vulnerable to extreme rainfall. Extreme rainfall leading to flooding events affecting these areas could also be potentially intensified if there was a coincidence with coastal hazards, such as storm surges and king tides.

The most vulnerable areas to coastal hazards have been assessed as locations associated with the local government areas of the Sunshine Coast, Gold Coast, Moreton Bay, and Brisbane. Whilst Redland City demonstrates a medium level of exposure and extremely high level of sensitivity to coastal hazards, its high level of adaptive capacity resulted in the area’s overall low vulnerability to coastal hazards.

The sectoral vulnerability assessment focuses on the key sectors comprising the Human Settlement’s component of the project: urban planning and management including coastal management; human health; and emergency management.

For the urban planning and management sector, the report identified that local authorities in the region have made considerable progress in developing policies geared toward climate change strategies in the last few years despite the fact that there was no statutory obligation to do so. On the other hand, the analysis of the current planning schemes illustrates that
adjustments will need to be made in order to improve planning practices. This includes more flexibility in the planning process through adaptive management in order to deal with uncertainties and evolving climate science, better cross-scalar and cross sectoral integration in the policy delivery process, improved governance through better coordination between tiers of government, private sector and public engagement, as well as the establishment of provisions that specifically deal with climate change related hazards. A number of barriers will need to be overcome, especially by local authorities, to implement climate change adaptation strategies in a well-coordinated and holistic manner that integrates multiple sectors.

Key findings for the coastal management sector highlight the vulnerability of SEQ’s coastal areas and the weaknesses of the current coastal planning and management system. A reduction of vulnerability in coastal areas will need to consider the identification of sustainable options to defend, accommodate or retreat communities to safer areas to address the future challenges posed by climate change. Specific initiatives to reduce vulnerability to climate change-related coastal hazards in SEQ should also seek to increase the adaptive capacity of coastal systems. In addition, the management of coastal adaptation in a context of uncertainty and changing climate projections will require more flexible mechanisms to incorporate new sea-level rise and wave climate figures into coastal plans and shoreline erosion management plans. New concepts will need to be integrated into local planning schemes, such as dynamical buffer zones capable of accommodating worst case scenarios with overall lower costs for the society in the long term.

With regards to the health sector, successfully addressing the challenges posed by climate change will require an understanding of the complexity of stressors and external drivers impacting on human health as a result of climate events. Hence, it will be important to understand such complexity will be played out at neighbourhood or community scale in order to differentiate adaptive climate change strategies at this scale from broad regional measures, as there can be no guarantees that the higher order initiatives will successfully translate to the smaller local scale. Local and state level health programs could be better targeted through an improved understanding of how local vulnerabilities are produced and their potential spatial extent across the region. In essence, a better understanding of the vulnerabilities will aid health planners and policy makers to effectively develop appropriate measures across all four phases of prevention, preparedness, response and recovery.

Climate change has received little and only recent attention by the emergency management sector. The majority of emergency management policies and plans at national, state and local levels do not integrate climate change adaptation considerations or even mention climate change as a future threat. Climate change, however, will bring new challenges to the emergency management sector in SEQ. An improvement in disaster risk assessments and in the prevention, preparedness, response and recovery phases of disaster management will be necessary in order to deal with the expanding and changing risks caused by climate change.

In view of the complexity of these vulnerability assessments and their outputs, a cooperative monitoring program needs to be established across the region to collect and update relevant regional and local climate science in order to better inform future vulnerability assessments, which in turn will greatly assist planning and decision making processes. In addition, it is worth while exploring the implications involved in adopting the Precautionary Principle when developing adaptation options for SEQ. Notwithstanding the challenges of this undertaking, this process could result in more effective climate adaptation strategies across the region and across sectors.
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Acronyms

ABS - Australian Bureau of Statistics
ADH - Australian Datum Height
AR-4 - IPCC’s *Fourth Assessment Report*
ARMCANZ - Agriculture and Resource Management Council of Australia and New Zealand
BOM - Australian Bureau of Meteorology
BTE - Bureau of Transport and Economics
CMAR - CSIRO Marine and Atmospheric Research
COAG - Council of Australian Governments
CSIRO - Commonwealth Scientific and Industrial Research Organisation
CZMA - Coastal Zone Management Act
DEM - Digital Elevation Model
DEO - Desired Environmental Outcome
DMA - Disaster Management Act
DRO - Desired Regional Outcome
EMA - Emergency Management Australia
ENSO - El Niño Southern Oscillation
ICM - International Coastal Management
ICZM - Integrated Coastal Zone Management
ISO - International Organization for Standardization
IPCC - International Panel on Climate Change
IPO - Interdecadal Pacific Oscillation
LAPP - Local Adaptation Pathways Program
NCCARF - National Climate Change Adaptation Research Facility
NGO - Non-governmental organisation
NV - Net vulnerability
PPRR - prevention, preparedness, response and recovery
QCCCE - Queensland Climate Change Centre of Excellence
SEQ - South east Queensland
SEQ-CARI - South East Queensland Climate Adaptation Research Initiative
SLR - Sea-level rise
SPP - State Planning Policy
UNCED - United Nations Conference on Environment and Development
UNISDR - United Nations International Strategy for Disaster Reduction
1. Introduction

The Human Settlements component of the SEQ-CARI project, led by Griffith University, consists of a three-year integrated multi-sectoral study of climate change adaptation options for human settlements in South East Queensland (SEQ). The study is examining three interrelated sectors: urban planning and management, including coastal management; human health; and emergency management. Taking a case study approach, the research will develop and enhance adaptation strategies, policies and practices in each sector and across sectors for improved governance and management in response to the impacts of climate change. The project is organised into five phases to be accomplished over the course of three years (2009-2012). The first phase involves a general assessment of the vulnerability of human settlements in SEQ. Phases two, three and four consist of the case study analysis and elaboration, in order to develop and test adaptation options in consultation with stakeholders for a number of specific case study areas within SEQ. The final phase aims to develop adaptation plans and guidelines for each case study area and recommendations for the SEQ region as a whole.

This report concludes the first phase of the project and consists of an initial regional assessment of the vulnerability of human settlements to climate change at both spatial and sectoral levels. Although climatic hazards are an important component of the region’s vulnerability to current and future climatic changes, this assessment adopts a systemic approach which also includes sectoral components of vulnerabilities rather than a purely climate change hazards approach. It is important to highlight that the production of spatial vulnerability assessments depends largely on both the range and the quality of available data. As such, the report acknowledges that the understanding of SEQ’s spatial and sectoral vulnerability to climate change comprises an on-going process in which the evolving climate science plays a key role. In this context, the assessment presented here provides baseline information, rather than a final product, and will guide subsequent phases of the project, particularly the case study elaboration and analysis and the development of adaptation options for the region.

The report is structured in two parts: Spatial Vulnerability Assessment and Sectoral Vulnerability Assessment. The first part is supported by a series of maps, which have been produced to illustrate the current regional spatial vulnerability to selected key climate-related impacts projected to affect the region, namely extreme heat, extreme rainfall and coastal hazards. Although, bushfires and storms are also forecasted to affect SEQ, more robust datasets are required to assess the region’s vulnerability to those hazards due to the complexity involved in the interaction of factors that lead to those events. While this vulnerability assessment does not include analysis for those two hazards, they are the subject of on-going further investigation and future work will incorporate them if more robust datasets become available.

The concept of vulnerability adopted in this assessment is expressed as a function of exposure, sensitivity and adaptive capacity. Hence, first order maps were prepared based on a selection of indicators reflecting the region’s exposure, sensitivity and adaptive capacity to extreme heat, extreme rainfall and coastal hazards. It is important to highlight, however, that there is a variety of methods that can be used to assess vulnerability and each method can produce different results. In addition, the selection of indicators was based on data availability and, similar to other modelling exercises, it is recognised that the assessment
does not cover the full possibilities of indicators that could be incorporated into vulnerability assessments. As such, the assessment constitutes an additional set of information related to climate change vulnerability in SEQ and should be used in combination with other existing and future relevant studies and knowledge available for the region.

The second part of the report comprises the sectoral vulnerability assessment. It starts with an introductory analysis of existing climate change adaptation initiatives currently in place by the federal and state governments. It then presents four separate analyses which describe SEQ’s sectoral vulnerabilities in terms of urban planning and management, coastal management, human health and emergency management. The report concludes with a synthesis of the vulnerability of SEQ human settlements to climate change.
2. Background

2.1 Climate Change in the SEQ Context

The SEQ region encompasses 11 local authorities (see Figure 1), which cover an area of approximately 2.2 million hectares comprising one of the largest planning regions in the world. It also depicts the official Urban Footprint designated under the statutory regional plan for SEQ (Department of Infrastructure and Planning 2009). The region is bounded on its landward side by the Scenic Rim in the south, and by the Western Escarpment and the Conondale Ranges in the north and northwest. With an extending coastline of 240 km from the Queensland-New South Wales border in the south to Noosa in the north and a maximum width of 160 km west towards Toowoomba, SEQ has three main topographic areas: the coastal zone, the Brisbane/Bremer River system and the hinterland foothills and mountains (see Figure 2) (Granger and Leiba 2001).

Over the last 100 years, human settlement in the SEQ region has occurred in the least constrained and easily developed topographical settings, namely the narrow coastal zone and the lower reaches and estuary of the Brisbane River. Hence the majority of the population in SEQ inhabits urban areas with a significant proportion along the urbanised coastal areas extending from the Gold Coast in the south to the Sunshine Coast in the north. Out of the 11 local authorities that comprise the region, the local government areas of Brisbane and the Gold Coast alone currently account for more than 50% of the region’s total population (Roiko et al 2010).

As a result, the coastline has been extensively modified to accommodate a number of urban centres and their major supporting infrastructure, such as the Brisbane Airport. The coastal urban centres include large areas of residential canal estates as well as traditional residential areas ranging from low to high density. Several river courses have been modified to create water storages in the upper reaches with dredging in the lower reaches. Urban development occupies many areas of the floodplains and the region continues to be under pressure from on-going urban development to accommodate current and future population growth (Granger & Leiba 2001). The on-going coastal development and population growth in the region are projected to exacerbate risks from sea-level rise and increases in the severity and frequency of storms and flooding events (Hennessy et al 2007).

In the last two to three decades the region has been subjected to sustained urban growth mostly associated with the metropolitan area dominated by the City of Brisbane as well as its adjacent hinterland (Low Choy et al 2007; Low Choy 2008). SEQ is experiencing one of the highest rates of population growth in Australia and, by 2031, the population projection for the region is estimated to be 4.4 million people (Department of Infrastructure and Planning 2009). Regions across Australia will be differently impacted by climate change. Certain regions and settlements will be exposed to more intense climate impacts than others (Nicholls and Mimura 1998). For instance, the most recent Intergovernmental Panel on Climate Change (IPCC) - Fourth Assessment Report (2007) identifies the SEQ region as one of the ‘hot spots’ in Australia to be affected by climate change. With the strengthening of climate change related information provided by the IPCC in the last decade, a number of climate projections have been made for the whole of Australia and its regions, including SEQ. Despite the uncertainty surrounding current climate science, models have shown that the region will be affected by changes in climatic averages, such as rainfall and temperature, sea-level rise and an increase in extreme weather events (see Figure 3).
Figure 1. SEQ region.
The coastal zone: Moreton Island, North and South Stradbroke Islands, Bribie Island and numerous smaller islands. Narrow mainland shoreline generally no more than 15km with elevations of up to 20m above Australian Height Datum (ADH); low-lying coastal plain broken by rocky promontories or estuaries of major rivers, Coral Sea.

The Brisbane/Bremer River system, including its valley, floodplains and estuaries: the Brisbane/Bremer River system is the major catchment in the region. Other major river systems include: Caboolture River/Burpengary Creek and North and South Pine Rivers in the north; Logan River, Coomera and Nerang Rivers in the south. The Tweed River in the southern boundary of the SEQ region with NSW.

The hinterland foothills and mountains: main ranges trend in a north to south direction including D’Aguilar, Annand, Taylor, Little Liverpool, Dugandan, McPherson and Darlington Ranges and the Larrington Plateau, Scenic Rim, the Conondale Ranges and the Western Escarpment. A number of outlier hills less than 300m above ADH.

Figure 2. SEQ topographic areas.
For instance, in the last decade, there has been an increase of 0.4°C in the average annual temperature and an increase between 0.5 and 1.5°C is projected to occur by 2030 (Suppiah et al 2007; Department of Environment and Resource Management 2009a). The increase in mean temperatures will also increase the number of days over 35°C in the region which could be six times higher in Brisbane, three times higher in Amberley and four times higher in Tewantin by 2070 (Suppiah et al 2007; Department of Environment and Resource Management 2009a). The region’s average rainfall has been changing, particularly in the eastern coastal region where a decline by almost 55mm per decade has been observed since 1950 (Gallant et al 2007). Although rainfall projections carry significant uncertainties it is expected that there will be changes in average rainfall, with an increase in the frequency of dry days and decrease in the frequency of wet days (CSIRO 2007).

On the other hand, by 2070, extreme rainfall events are likely to increase across most of the region, particularly along the stretch from the New South Wales border to the north of Brisbane (Abbs et al 2007). The region could face an increase of up to 25% in the intensity
of 1-in-20 year daily-rainfall event (Hennessy 2004). As SEQ is one of the most flood-prone regions in Australia, an increase in extreme rainfall events could inundate the floodplains of several catchments (Abbs et al 2007). For example, developed floodplains in the Gold Coast region could be inundated due to these extreme rainfall events. This has occurred in January 1974, when a monsoon low triggered five days of torrential rain resulting in the evacuation of more than 2,000 residents from the Gold Coast canal estates (Callaghan and Helman 2008).

Those extreme rainfall events are a consequence of severe storms that affect the region, particularly of tropical and sub-tropical origin. Tropical cyclones can affect SEQ on a small scale, as based on records from the past 100 years, there were about 15 storms classified as cyclones passing within 100km of the Brisbane Central Business District (Harper et al 2001b). East coast lows, however, affect the region more frequently with severe consequences, such as flooding and wind damage, particularly along the coast (Harper & Granger 2001; Abbs et al 2007). In addition, SEQ has moderate thunderstorm activity averaging between 20 to 40 days per year (Hennessy 2004). Those severe thunderstorms can initiate wind gusts and hailstorms causing significant property losses and insurance payouts (Harper et al 2001a).

A number of characteristics presented by human settlements in SEQ can potentially increase the risk and related consequences of bushfires in the region. These include the increasing population inhabiting outer suburban and peri-urban areas which are located in close proximity to bushlands (Granger et al 2001; Low Choy et al 2007). The increase in average mean annual temperature and severe weather events, such as extended periods of drought, due to climate change could also lead to more favourable conditions for the occurrence of bushfires in the region (Hennessy et al 2004).

Storms crossing the coast and weather patterns in the Pacific Ocean, the Coral Sea and the Tasman Sea are major drivers of coastal processes, such as wave propagation, storm surges and coastal erosion. The events driving coastal processes include tropical cyclones, east coast lows and mid-latitude depressions. An increase in the number and frequency of more intense cyclones and southern shifts in their tracks are likely to occur in the future, together with an intensification of east coast lows and consequent increase in the occurrence of extreme events (Department of Climate Change 2009). These changes are likely to affect the overall wave climate of SEQ and their quantification is currently being measured through dynamical downscaling techniques (Hemer et al 2009). While sea-level rise of about 1.3 mm/year, a similar figure to global averages, has been recorded from the early 1990s to 2008 (NTC BOM 2008), projected sea-level rise based on the IPCC scenarios is expected to be approximately 80 cm by 2100 (IPCC 2007). These estimates do not include the contribution of melting ice sheets and higher figures for sea-level rise are plausible by the end of the century, as sea levels will continue to increase after 2100. Thus, in combination with storm surges, a changing wave climate is likely to drive extreme erosion events and the inundation of further inland areas, with consequent damages to private assets and built infrastructure (CSIRO 2007).

Given the issues the region is likely to face due to climate change and the data constraints outlined in Section 1, a preliminary spatial vulnerability assessment was undertaken based on a series of indicators for the exposure, sensitivity and adaptive capacity of SEQ to:

- Extreme heat;
- Extreme rainfall; and
- Coastal hazards.
2.2 Vulnerability: concepts and approaches

The concept of vulnerability can be interpreted from a myriad of perspectives related to many disciplines, including political science, ecology, economics and environmental science. Although there is a large debate surrounding the concept of vulnerability itself, there is growing consensus in terms of the components of vulnerability, i.e. exposure, sensitivity and adaptive capacity (Nelson et al 2010). In this context, this study adopts the definition of vulnerability and its components – exposure, sensitivity and adaptive capacity – proposed by the IPCC’s Fourth Assessment Report (IPCC 2007). Thus, vulnerability is understood here as:

“the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.” (IPCC 2007, p. 883).

Exposure refers to the expected changes to climatic stimuli in a given location. For example, coastal regions are more exposed to sea-level rise than inland communities; and inland regions are more exposed to temperature increases than coastal communities.

Sensitivity is the degree to which a system may directly or indirectly be affected by climate variability or change. For example, the sensitivity of a large city to the impacts of a cyclone crossing over it is greater than for an unpopulated region; and the sensitivity to higher temperatures of crops that require regular winter frosts is greater than tropical crops.

Together, exposure and sensitivity produce the potential impacts of climate change, which can be attenuated by the individual or system’s adaptive capacity.

Adaptive capacity refers to the ability or potential to respond successfully to climate variability and change, including adjustments in behaviour, resources and technologies. It is comprised of a society’s or system’s financial, human, technological, infrastructural, institutional and natural capital.

Associated with the current debate surrounding the concept of vulnerability is the discussion about vulnerability assessment approaches, their outputs and how they contribute to policy development, particularly when those assessments are undertaken to provide information and guide climate adaptation (Nelson et al 2010). A purely hazard-based approach, for example, tends to consider vulnerability assessments as the end-point with strong emphasis on technical solutions to minimise projected climate change impacts (Eriksen & Kelly 2007) rather than as a tool to provide information that may guide the policy and decision making process towards climate adaptation. Alternatively, assessments encompassing coupled human-environmental systems are seen as the starting-point by providing a basis for the analysis of the role of those systems and inherent characteristics in responding to changes (Nelson et al 2010). As a starting-point, vulnerability assessments focused on coupled human-environmental systems assist us in understanding complex issues that involve uncertainties, such as a changing climate.

The science of vulnerability assessments has significantly evolved during the last decade, however, there have been limited contributions to the climate adaptation domain (Ionescu et al 2009). In order to produce assessments that can yield a greater contribution to policy development, particularly related to climate adaptation, there are calls for new types of vulnerability studies to take place (Kelly and Adger 2000; Burton et al 2002). Ultimately, those
studies have to assist in mapping potential hot spots and identifying major drivers to effectively contribute to policy formulation (Eriksen & Kelly 2007). When dealing with complex issues such as climate change, vulnerability assessments should follow an integrated approach to be able to decode the multiple dimensions in which impacts will occur and affect populations both temporally and spatially. As such, those assessments could provide insights for policy makers in terms of identifying the circumstances that put people and places at risk as well as the factors that reduce people's ability to respond to changes. Vulnerability studies should incorporate elements of both natural and social sciences to reflect the dynamic systems in which we live, such as human settlements, as well as the drivers that will affect and change such systems. In this complex dimension, vulnerability assessments not only account for spatial vulnerabilities but also vulnerabilities created or exacerbated by human relations and systems such as the policy arena (Cutter 2003).

Aware of the limitations posited by vulnerability studies in capturing the whole dimension of climate change impacts in terms of the specificities that will occur at particular locations and to particular social groups, the approach to vulnerability assessment adopted by this study follows an integrated framework which includes both external (exposure) and internal (sensitivity and adaptive capacity) dimensions of vulnerability, as this is the most common approach used in global environmental change and climate change research (Füssel 2007; Füssel & Klein 2006).

Following such an approach, this spatial vulnerability assessment should be interpreted as the starting point for discussions involving climate change vulnerabilities in SEQ. As a starting point, it presents preliminary regional spatial vulnerabilities based on a set of indicators identified to illustrate the region's exposure, sensitivity and adaptive capacity to extreme heat, extreme rainfall and coastal hazards (see Section 3 for more details). A series of first order maps have been produced to depict solely the region's susceptibility to climate change related harms, rather than provide a measure of those harms.

The spatial vulnerability assessment is complemented by a sectoral assessment of vulnerabilities related to the current policy domain of key sectors: urban planning and management including coastal management; emergency management; and human health. The assessment investigates current tools, strategies, models and mechanisms adopted by each sector that directly influence sectoral practices in SEQ as well as future climate adaptation options. Hence, the approach adopted to describe the vulnerability of SEQ's human settlements to climate change followed an integrated framework taking into consideration not only natural hazards but also the political, social and economic aspects of the region. The insights provided by this integrated approach resulted in the identification of SEQ's major sectoral challenges to address climate adaptation.
3. Spatial Vulnerability Assessment

The understanding of how a changing climate is affecting and will affect the region in the future is important to determine which strategic measures should be put in place to reduce the region’s vulnerability to climate change impacts. Hence, this initial spatial vulnerability assessment of SEQ aims to illustrate and identify which parts of the region are or will be potentially more susceptible to climate change related impacts such as extreme heat, extreme rainfall and coastal hazards in the future. However, it is important to acknowledge that climate science continues to be improved and developed to provide more accurate information in terms of climate projections for specific regions such as SEQ. As such, the spatial vulnerability assessment presented here is not a static product, rather it is part of an on-going process that will change overtime in order to incorporate more recent scientific information and knowledge as they become available.

3.1 Methodology for Vulnerability Mapping

Climatic datasets used to produce the spatial vulnerability assessment were sourced from the Australian Bureau of Meteorology (BOM) and CSIRO Marine and Atmospheric Research (CMAR). Biophysical data were sourced from SEQCatchments and Geoscience Australia. Socio demographic data were obtained from the 2006 census provided by the Australian Bureau of Statistics (ABS).

In developing a suite of first order vulnerability maps across different climate hazards, several possible methodological approaches were available (Nelson et al 2010). The approach followed in this report was informed by that used by Baum et al (2009) in the Federal Department of Climate Change integrated assessment project on Climate Change, Health Impacts and Urban Adaptability.

3.1.1 Developing exposure, sensitivity and adaptive capacity measures

As explained in Section 2.2, vulnerability is related to exposure, sensitivity and adaptive capacity. The selection of appropriate indicators for each of these components represents one of the key challenges of vulnerability mapping. This selection was informed by the existing literature on vulnerability assessment and mapping, in particular the earlier work undertaken by Preston et al (2008), and the availability of data for disaggregated spatial units in SEQ.

The exposure and sensitivity layers are specific to each hazard and, therefore, the indicators used for these layers vary depending on the hazard considered. The different exposure and sensitivity indicators used for each hazard are detailed in the following sections.

The adaptive capacity layer, on the other hand, is generic for all three hazards. Adaptive capacity is related to a range of factors, including human capital, financial capital, social capital, institutions, infrastructure and access to resources (Watts & Bohle 1993; Adger 1999; Handmer et al 1999; Kelly & Adger 2000; Adger 2003; Wisner et al 2004). While it is not possible to effectively capture all of these dimensions, indicators used in earlier vulnerability assessment and mapping studies, include age, gender, income, unemployment rate, education level, social status, home ownership, ethnicity, household arrangements and assistance requirements (Cutter et al 2000 and 2003; Chakraborty et al 2005; Hebb & Mortsch 2007). The indicators adopted in this study are based on those used in this
earlier vulnerability work and aim to capture the multiple dimensions of adaptive capacity, especially those aspects critical to responding to extreme weather events. In addition to the traditional variables indicating education levels (percentage of population completing year 12), household arrangements (average household size; percentage single parent families) and economic status (percentage of households requiring financial assistance; average household income; labour force participation rate; unemployment rate), other variables were also included, indicating people’s ability to understand and access communication channels (percentage of population that speaks a language other than English; percentage of population with internet access) and to evacuate (percentage of households with no cars; proportion of people who need assistance). Finally, an attempt to capture the social capital dimension of adaptive capacity was made with the following two variables: proportion of people living at the same address as one year ago; and percentage of population doing voluntary work.

The individual measures of exposure, sensitivity and adaptive capacity were constructed using a simple additive process whereby each individual variable was first standardised and then all components were added together. Standardising was done with reference to the following:

\[
\hat{S}_{ji} = \frac{S_{ji} - \text{min}_j}{(\text{max}_j - \text{min}_j)}
\]

Where:
- \(\hat{S}_{ji}\) is the standardised variable \(j\) for suburb \(i\)
- \(S_{ji}\) is the unstandardised variable \(j\) for suburb \(i\)
- \(\text{min}_j\) is the minimum value from the distribution of variable \(j\)
- \(\text{max}_j\) is the maximum value from the distribution of variable \(j\)

Each individual measure of exposure, sensitivity and adaptive capacity was therefore the sum of the relevant standardised variable \(\hat{S}_{ji}\).

As the goal of the vulnerability mapping was to develop individual indicators for different climate events across the SEQ region, the individual components comprising vulnerability had to be combined in a meaningful way.

While the existing literature on vulnerability to extreme weather events provides several examples of both simple and complex index building routines, this study adopted a method of index development first used for understanding the level of relative social deprivation at an intra-urban level in Montreal, Canada (Langlois and Kitchen 2001). Subsequently, Baum (2004 and 2008) has used a similar index to analyse social deprivation in Australian suburbs.

Conceptually Langlois and Kitchen’s index views deprivation as a function of a general indicator of social deprivation plus a range of indicators thought to represent social situations where deprivation is thought or known to occur (i.e. single parent families). Any spatial unit’s level of deprivation depends on the level of general deprivation (a necessary but insufficient condition) and the extent to which particular social situations are present in that area.

A similar argument has been taken to that made by Langlois and Kitchen (2001), suggesting that vulnerability to climate events for a suburb can be measured by taking an indicator of exposure (a necessary but insufficient condition) and having exposure mediated by degrees
of sensitivity and adaptive capacity. Operationally this is expressed by the following:

\[
V_i = \frac{E_i^* (1 + S_i + A_i)}{n}
\]

Where vulnerability in suburb \( i \) \((V_i)\) depends on:
- \( E_i \) the exposure for suburb \( i \);
- \( S_i \) the sensitivity for suburb \( i \);
- \( A_i \) the adaptive capacity for suburb \( i \); and
- \( n \) the total number of components included in the index.

The result is a simple weighted index that accounts for vulnerability across suburbs in SEQ in terms of the three selected climate related hazards of extreme heat, extreme rainfall and coastal hazards.

The existing literature dealing with vulnerability mapping presents a range of possible approaches to classifying outcomes. These range from the use of simple natural breaks in the data through to the use of spatial analysis and spatial weighting regimes. This analysis has utilised the mean and standard deviation as a means of differentiating between levels of outcome. The indices for each of the exposure, sensitivity, and adaptive capacity and vulnerability measures provide a single number for each suburb across the SEQ region. Using this data, the individual suburbs across the region have been ranked into four bands or clusters. Cluster 1 suburbs — those with highest relative exposure, sensitivity vulnerability or lowest adaptive capacity — have a score more than 2 standard deviations above the mean, while cluster 2 suburbs have a score between 1 and 2 standard deviations above the mean. Cluster 3 suburbs have a score between 0 and 1 standard deviations below the mean, while cluster 4 suburbs have scores more than 2 standard deviations below the mean. It should be noted that this method of allocating suburbs to the four groups or clusters is quite arbitrary. For other approaches the cut offs for each cluster would be different and hence a slightly different picture might emerge. However, as part of this study’s aim was to identify the extremes of vulnerability, this approach appears to provide a viable option.

3.2 Extreme Heat

In the last 100 years the Australian average maximum temperature increased by 0.6°C and the minimum temperature increased by 1.2°C (Nicholls & Collins, in Suppiah et al 2007, p. 144). These changes in average temperature can directly impact extreme daily temperatures, such as the ones exceeding 35°C, as well as reduce the number of cold nights (Suppiah et al 2007).

In the SEQ context, the increase in mean temperatures and subsequent increase in the number of days exceeding 35°C is forecasted to occur as a consequence of climate change (Department of Environment and Resource Management 2009a). The number of days exceeding 35°C, based on a mid-range scenario (e.g. A1B scenario - IPCC), varies across the region and some areas are likely to experience a significant increase in the number of hot days by 2070 (see Table 1). For the city of Brisbane, for example, the number of summer days with temperature above 35°C is likely to increase to 1-2.3 days by 2030 and 1.3-6.6 days by 2070, based on a mid-range scenario. However, projections based on a high-range scenario (e.g. A1FI scenario - IPCC) could double the number of hot days projected to affect Brisbane by 2070. In addition, Brisbane is likely to experience an increase in the annual mean minimum temperature from the current 20°C to 20.3-22°C by 2030 and 20.8-26 °C
These changes in mean temperature and number of hot days could lead to extreme thermal events such as heatwaves. Although there is no universally agreed definition of heatwave, as it is context specific in terms of the climatic characteristics of the area under investigation, in general, it can be defined as “a prolonged period of excessive heat.” (Tong et al 2009). In Australia, heatwaves have been identified as one of the major natural hazard that results in death since the early nineteenth century (Guest et al 1999). Heatwave related deaths have similar number of casualties compared to other natural hazards, such as floods and bushfires (Guest et al 1999; Tryhorn & Risbey 2006).

Extreme weather conditions, such as the ones leading to heatwaves, have been experienced in SEQ and represent a significant impact on public health and medical emergencies. For instance, in February 2004, a 20-day period of above average temperatures, or heatwave conditions, resulted in the highest medical emergency on record in SEQ (Australian Bureau of Meteorology 2004; Tong et al 2009). Extreme thermal events are also likely to increase death rates amongst the most susceptible population groups, including the elderly and young children (Tong et al 2009; Auliciems et al 1997).

The fact that a high proportion of Queensland residents (around 63.8%), including SEQ dwellers, use air conditioning indicates that the population might cope well with heat stress and reduced excess mortality rates could be expected (Tong et al 2009). However, the demand for electricity in Queensland is estimated to increase by 1-4% in general and by 1.5-7% during peak demand by 2050 (Walsh et al 2002). The increase in demand on electricity for cooling purposes could result in power failure due to overload with derived socio-economic consequences for human settlements. In addition, extreme heat can also affect the energy infrastructure causing the heating of transmission lines and consequent power cuts. Such effects can be intensified as night temperatures do not cool down and more heat is stored within the urban fabric. The combination of energy demand overload with damage to energy infrastructure could shut down transportation systems as recently observed in Melbourne, in 2009 (Houston & Reilly 2009). This has critical implications for human settlements, particularly for the more economically vulnerable social groups, as

### Table 1. Projected number of days exceeding 35°C for three SEQ locations.

<table>
<thead>
<tr>
<th>Location</th>
<th>Current # of days</th>
<th>Projected # of days above 35°C (based on A1B scenario - IPCC)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2030</td>
<td>2050</td>
</tr>
<tr>
<td>Amberley</td>
<td>13.3</td>
<td>13.5 – 23.1</td>
</tr>
<tr>
<td>Brisbane</td>
<td>1</td>
<td>1 – 2.3</td>
</tr>
<tr>
<td>Tewantin</td>
<td>2.6</td>
<td>3.1 – 5.3</td>
</tr>
</tbody>
</table>

Source: CSIRO n.d.
their ability to access potential shelters could be undermined by the lack of available public transportation systems.

The set of indicators related to exposure, sensitivity and adaptive capacity used to produce first order maps showing SEQ’s vulnerability to extreme heat is provided in Table 2. To determine the region’s exposure to extreme heat, this assessment takes into consideration the land cover characteristics of SEQ, including the percentage of impervious surfaces across suburbs, combined with population density and observed differences in temperature registered through satellite images taken in June and September 2009 depicting thermal profiles. This assessment identifies the region’s sensitivity to extreme heat based on the percentage of people at greater risk of suffering from heat stress, such as the elderly and younger population within the suburbs (see Figure 4).

### Table 2. Vulnerability indicators for extreme heat.

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Adaptive Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Land cover (10 m grid)</td>
<td></td>
<td>1. % population ≥ 65 years of age (suburb)</td>
<td>1. % population completing year 12 (suburb)</td>
</tr>
<tr>
<td>2. Population density (suburb)</td>
<td></td>
<td>2. % population ≥ 65 years of age &amp; living alone (suburb)</td>
<td>2. % population that speaks language other than English (suburb)</td>
</tr>
<tr>
<td>3. Thermal profile (60m grid)</td>
<td></td>
<td>3. % population ≤ 4 years of age (suburb)</td>
<td>3. % households with internet access (suburb)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4. Medium household income (suburb)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5. Labour force participation rate (suburb)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>6. Average household size (suburb)</td>
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<td></td>
<td></td>
<td></td>
<td>7. % of single parent families (suburb)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8. Home ownership (suburb)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>9. % households with no cars (suburb)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10. Unemployment rate (suburb)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>11. Disability stat: proportion of people who need assistance (suburb)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>12. Residential mobility: Proportion of people living at the same address as 1 year ago (suburb)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>13. % population doing voluntary work (suburb)</td>
</tr>
</tbody>
</table>
The three figures on the left depict the vulnerability components: Exposure - top left; Sensitivity - middle left; Adaptive Capacity - bottom left. Main figure depicts integration of the three components into net vulnerability.

Figure 4. SEQ vulnerability to extreme heat.
This initial assessment of SEQ’s exposure to extreme heat shows that areas associated with the urban footprint (see Figure 1) are generally more exposed to heat impacts. Although coastal areas can potentially offset high temperatures through sea breezes, it appears that heat trapped in the urban canopy due to expanded impervious surfaces contribute to an increase in the exposure of those areas to extreme heat. This is particularly noticeable in the urbanised coastal areas within Gold Coast City and the Sunshine Coast Regional Council area, and the bay side areas within the Brisbane City and Moreton Bay Regional Council area. Other areas with relevant exposure include isolated localities in the western corridor (Ipswich and Brisbane Cities) and Logan City.

The assessment indicates that the majority of the region has low to medium sensitivity to extreme heat, with the bulk of medium, high and extremely high sensitivity being located in the western half of the SEQ region, principally in the Lockyer Valley, Scenic Rim and Somerset Regional Council’s area. This is perhaps a reflection of the older demographic that resides in these jurisdictions. This is also likely to be the driving factor toward extreme sensitivity to extreme heat in less populated suburbs.

The bulk of the region presents a high degree of adaptive capacity to extreme heat events. This map also depicts that there are also small and fragmented pockets of low and extremely low adaptive capacity which are located in the local government areas of Brisbane, Redcliffe, Ipswich and Logan. Conversely, while the assessment indicates that areas in the Lockyer Valley, Scenic Rim and Somerset Regional Councils are sensitive to extreme heat events, they also have a medium to high level of adaptive capacity.

The analysis indicates that a number of localities within the local government areas of Brisbane, Ipswich, Logan, Moreton Bay, Gold Coast and Sunshine Coast are extremely vulnerable to the impacts of extreme heat events. The net vulnerability of SEQ to extreme heat was a result of the interaction between its exposure, sensitivity and adaptive capacity. As such many localities identified as being highly vulnerable to extreme heat are also areas with low adaptive capacity. This is particularly noticeable in the south west and north east portions of Brisbane City and Ipswich City respectively. Again, this could be an indication of the heat island effect which is associated with urban development and other impervious surfaces. The assessed low to medium vulnerability to extreme heat for the local government areas of Lockyer Valley, Scenic Rim and Somerset is due to their assessed low exposure, low sensitivity and medium to high level of adaptive capacity.

### 3.3 Extreme Rainfall

Rainfall projections for SEQ carry large uncertainties. Although there has been a decline in total annual rainfall of about 55mm per decade in the last 50 years (Gallant et al 2007), it is expected that the frequency and intensity of extreme rainfall events might increase in the region (Abbs et al 2007). As such, those projections indicate that urbanised areas along floodplains could become particularly more at risk of floods as a result of extreme rainfall events and the high occurrence of impervious surfaces. This has critical implications to human settlements in SEQ as, in Australia, flooding is one of the natural disasters that causes the most damage to urbanised areas (Abbs et al 2007). Every year, it is estimated that flood damages cost the nation more than $300 million (BTE, in Abbs et al 2006, p. ix), with more than $100 million in Queensland alone (ARMCANZ, Smith, in Middelmann et al 2001, p. 9.2).

The SEQ region, like many parts of Australia, inherits a legacy of urbanised areas based on
planning decisions guided by average return intervals of hazards, such as floods (McDonald et al 2010). As a result, many urbanised areas in the region have been developed along floodplains and consequently SEQ is one of the regions most prone to flood damage in Australia (Abbs et al 2007).

The magnitude of damage derived from flood events, however, varies depending on the intensity and duration of extreme rainfall events as well as location. For example, the 1974 floods that affected Brisbane caused damages valued at more than $700 million at that time, however, they were less intense than the previous floods of 1841 and 1893, which resulted in lower impacts due to a smaller population and thus, less infrastructure and development (Middelmann et al 2001).

The experience provided by those earlier extreme flood events resulted in the implementation of flood mitigation and floodplain management strategies across the region. Nevertheless, on-going development pressures to accommodate future growth in SEQ in combination with uncertainties related to rainfall projections for the region and current flood modelling systems create complex challenges for decision-making processes involved in human settlements. This is particularly important in terms of identifying greenfield sites and retrofitting existing developments to minimise flood related risks.

A list of proxies has been identified to enable the development of first order vulnerability maps for extreme rainfall events in SEQ (see Table 3). SEQ’s exposure to extreme rainfall

<table>
<thead>
<tr>
<th>Table 3. Vulnerability indicators for extreme rainfall.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicators</td>
</tr>
<tr>
<td><strong>Exposure</strong></td>
</tr>
<tr>
<td>1. Present average annual rainfall (5 km grid)</td>
</tr>
<tr>
<td>2. Present average 90th percentile annual rainfall (5 km grid)</td>
</tr>
<tr>
<td><strong>Sensitivity</strong></td>
</tr>
<tr>
<td>1. Alluvial plains (25m grid)</td>
</tr>
<tr>
<td>2. Land cover (10 m grid)</td>
</tr>
<tr>
<td>3. Population density (suburb)</td>
</tr>
<tr>
<td><strong>Adaptive Capacity</strong></td>
</tr>
<tr>
<td>1. % population completing year 12 (suburb)</td>
</tr>
<tr>
<td>2. % population that speaks language other than English (suburb)</td>
</tr>
<tr>
<td>3. % households with internet access (suburb)</td>
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<tr>
<td>4. Medium household income (suburb)</td>
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</tr>
<tr>
<td>13. % population doing voluntary work (suburb)</td>
</tr>
</tbody>
</table>
has been determined by the combination of average annual rainfall and the average 90th percentile of annual rainfall in the last 100 years. Existing alluvial plains associated with impervious land cover and high population density comprise the data used to identify the sensitivity of SEQ to extreme rainfalls. Adaptive capacity of SEQ’s population has been assessed based on socio-economic data provided by the 2006 census.

The assessment indicates that areas within the coastal local government areas of Gold Coast, Redland, Moreton Bay, Scenic Rim, and Sunshine Coast can be subjected to either a medium, high or extremely high level of exposure to extreme rainfall (see Figure 5). This is a reflection of high rainfall events which predominately occur in coastal localities. The majority of the western proportion of the region presents a low exposure to extreme rainfall.

By contrast, high to extreme sensitivity to extreme rainfall in the region is dependent on population density and the amount of impervious surfaces. This is represented by, for example, the inner city suburbs of Brisbane City given the amount of waterways running through these built up areas, as well as other large regional catchment areas such as the Nerang River in the Gold Coast and the Maroochydore River in the Sunshine Coast. While the majority of the region has a low sensitivity to extreme rainfall events, the low lying, highly urbanised, and densely populated areas of the Gold Coast, Brisbane, Moreton Bay and Sunshine Coast present a combination of medium, high and extremely high sensitivity to extreme rainfall. In parallel with heat impacts, the dominance of impervious surfaces in these areas, along with low elevations make them sensitive to flooding at times of high rainfall events. Overall, other areas comprised by the region’s urban footprint present a relatively medium sensitivity to extreme rainfall.

The majority of the region has a medium to high level of adaptive capacity to extreme rainfall. It is important to note, however, that the majority of the areas with a medium to high level of adaptive capacity are also the areas which have a low level of exposure and sensitivity to extreme rainfall. Conversely, the analysis indicates that the pockets within the region which have a low and extremely low adaptive capacity are also the areas which present medium, high and extremely high sensitivity to extreme rainfall events. This is most prominent in the Brisbane, Gold Coast and Sunshine Coast areas.

The bulk of the region is considered to have low vulnerability to extreme rainfall events. Based on historic events and the indicators used in this assessment, it is no surprise that the Gold Coast, Brisbane, Logan, Moreton Bay and Sunshine Coast areas present a medium, high and extremely high vulnerability to extreme rainfall and subsequent flooding events. Of particular concern are the extremely vulnerable areas located within the Sunshine and Gold Coast jurisdictions. Again, this is a reflection of the topography, significance of impervious surfaces and relatively high rainfall events. Flooding events derived from extreme rainfall affecting these areas could be potentially intensified if combined coastal hazards such as storm surges and king tide occur at the same time.
Figure 5. SEQ vulnerability to extreme rainfall.

The three figures on the left depict the vulnerability components: **Exposure** - top left; **Sensitivity** - middle left; **Adaptive Capacity** - bottom left. Main figure depicts integration of the three components into net **vulnerability**.
3.4 Coastal Hazards

Coastal hazards to human settlement and infrastructure include sea-level rise (SLR), driven by global warming and by changes in the oceanographic conditions, and all the processes driven by specific weather systems in coastal and oceanic waters, including wave action and storm surges. These are the major causes of coastal erosion and floods, which, combined with higher sea levels, can affect beach systems and nearby coastal properties, infrastructure and communities.

The sea level at any time is the sum of different variables, including: mean sea level, state of the tides, responses to atmospheric pressure and near shore winds, plus the increasing sea level due to near-shore breaking of waves. Global mean sea level has risen at a rate of about 1.7 mm per year in the last two centuries, while in Australia figures are slightly lower as sea level rose about 1.2 mm per year (Church et al 2008). For SEQ, this figure was 1.3 mm during the period 1990-2008 (NTC BOM 2008). The IPCC’s *Fourth Assessment Report* (AR4) estimated global sea-level rise of up to 59 cm by 2100, but more catastrophic figures are predicted if ice melting is included (Alley et al 2005) and sea level continues to rise after 2100. In eastern Australia, including SEQ, the influence of a warming East Australian Current moving further south makes the sea-level rise projections greater than the global level (Department of Climate Change 2009). Current projection figures, combining the results of the IPCC AR4 with regional variations from the global averages (CSIRO 2010), indicate a SLR for SEQ of 80cm by 2080 (Department of Environment and Resource Management 2009b). This figure will be subject to review as a new assessment is undertaken in 2014 based on new scientific information.

Wave climate is a representation of averages and extremes of height, direction and period of ocean waves. Changes in the wave climate can drive severe erosion processes and increased risks of inundation under extreme conditions. In SEQ, the shape of the coast, the net transport of sediments and the frequency of extreme events is driven by different types of storms, namely tropical cyclones and east coast lows. Variability of the wave climate is associated with large-scale climate variability, in particular with oscillations of the El Niño Southern Oscillation (ENSO) operating in a time scale of three to seven years (Allen & Callaghan 2000; Hemer et al 2008) and of the Interdecadal Pacific Oscillation (IPO), operating in a time scale of two to three decades (Helman & Tomlinson 2009). Past studies of changes in tropical cyclone patterns have identified an increase in intensity (Walsh & Ryan 2000), while current research has indicated a possible decrease in the number of events (Abbs 2009). Future projections of wave climate are currently being investigated and preliminary results show a decrease in mean significant wave height, associated with a decrease in the frequency of large southerly wave and an anti-clockwise shift in the mean wave direction, with a dominant north-easterly mean wave direction (Hemer et al 2009).

Two coastal processes can affect the SEQ coast under a changing climate, namely: coastal erosion and coastal inundation. The morphology of the SEQ coastline, mostly characterized by low-lying sandy (high energy) or muddy (low energy) sedimentary coasts, makes coastal erosion and recession a major concern under climate change. Coastal sediments erosion occurs at different paces, either as a chronic process caused by imbalances of sediment budgets over a coastal stretch, or as a consequence of extreme events, when the beach retrofits to cope with energetic seas. Complex hydrodynamic processes associated with a changing sea level can be a major dynamic driver of erosion and realignment of low-energy muddy coast in bays and lagoons.

Climate change is likely to exacerbate both chronic erosion and the beach response to
changing extreme events (Department of Climate Change 2009), resulting in:

1. The natural retrofit of beaches towards new equilibrium profiles as a consequence of sea level rise;
2. Erosion and change to the shape of lower-energy shorelines of bays and lagoons as a consequence of sea-level rise;
3. Changes to the rate of sediment transport as a consequence of changing wave energy reaching the coast;
4. Changes to the direction of the mean energy flux as a result of a new average wave climate, resulting in a new equilibrium platform for the beach; and
5. An exacerbation of the impact on beaches and dune systems as a consequence of changes in the frequency and intensity of occurrence of these extreme coastal events.

Further consideration needs to be given to coastal inundation which can be influenced by rapid changes in water flow across rivers or coastal waters. In SEQ, coastal inundation can be caused by unusual extreme precipitation or by a storm surge associated with a major meteorological event, such as the passage of a tropical cyclone or an east coast low pressure system.

In addressing the hazards related with coastal processes this section has considered a number of related issues which can increase the risk of inundation, including:

1. Sea-level rise will increase the probability of occurrence of an extreme event, by reducing the so-called Average Recurrence Interval. This means that, for example, with a 0.5 m sea-level rise in 2100, an event which occurred on average every 10 years will occur every 10 days (Department of Climate Change 2009);
2. The intensity and frequency of storm surges, induced by strong winds and low pressure over the sea surface, will be mainly provoked by either tropical cyclones or east coast lows;
3. Storms are always accompanied by high waves adding a component to the overall sea level by breaking near the shore – the so-called wave set-up; and
4. Wave run-up, the maximum vertical extent of wave rush over a beach or structure, is proportional to wave characteristics, especially height and length, and this adds an additional component to the overall storm surge risk.

Indicators for coastal hazards related to exposure, sensitivity and adaptive capacity used to identify the vulnerability of SEQ coastlines to coastal climate change processes are set out in Table 4. Ideally, the datasets which could potentially provide the best assessment of coastal vulnerability would include:

- Projections in the regional sea-level rise, based on the best estimates provided by CSIRO for the SEQ region (CSIRO 2009);
- Projected variability in mean wave climate and sediment transport based on the methodology defined by Hemer et al (2009);
- Projected changes in sea level extremes, based on regional modelling for SEQ; and/or
Coastal geomorphology, based on the Smartline Dataset (Sharples et al 2009), which represents the sensitivity to a changing wave climate.

However, the only information available at this stage is regional sea-level rise projections (CSIRO 2010, Department of Environment and Resource Management 2009b) which, combined with the existing information on highest astronomical tide, can be used to identify the most sensitive areas to sea-level rise and floods. The other dataset available is the Smartline Dataset (Sharples et al 2009) providing information on coastal geomorphology and sensitivity of the shoreline. This information was used as the base to calculate two coastal-specific indicators for exposure and sensitivity, which was then combined with adaptive capacity indicators to calculate the overall vulnerability of SEQ coastal areas to coastal hazards. Exposure to extreme sea levels was calculated using the level of the highest astronomical tide combined with up to 3.5m sea-level rise (Wang et al 2010). This was used to simulate a worst case scenario leading to a 3.5m inundation event which could arise from

<table>
<thead>
<tr>
<th>Table 4. Vulnerability indicators for coastal hazards.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Indicators</strong></td>
</tr>
<tr>
<td><strong>Exposure</strong></td>
</tr>
<tr>
<td>1. Future extreme sea level (Digital Elevation Model)</td>
</tr>
<tr>
<td><strong>Sensitivity</strong></td>
</tr>
<tr>
<td>1. Geomorphologic sensitivity (SmartLine)</td>
</tr>
<tr>
<td><strong>Adaptive Capacity</strong></td>
</tr>
<tr>
<td>1. % population completing year 12 (suburb)</td>
</tr>
<tr>
<td>2. % population that speaks language other than English (suburb)</td>
</tr>
<tr>
<td>3. % households with internet access (suburb)</td>
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<tr>
<td>13. % population doing voluntary work (suburb)</td>
</tr>
</tbody>
</table>
a combination of extreme storm surge events with a projected sea-level rise of 0.80m. The sensitivity layer of coastal hazards is based on the geomorphologic sensitivity indicator, particularly the field “exposure” of the Smartline database, representing the sensitivity of the shoreline segment to the oceanic swell and storm wave energies. The combination of the Smartline information with the SEQ suburbs layer provides an average sensitivity of each suburb based on coastal landforms, its topography and lithology (see Figure 6).

As could be expected, all five coastal councils exhibit some level of exposure to coastal hazards. Exposure in the coastal areas ranges from predominately extremely high through to small pockets showing low exposure. The bulk of extremely high exposure to coastal hazards along the coast is within the Gold Coast City Council area, but there are also areas with extremely high exposure along coastal areas of Brisbane, Moreton Bay and Sunshine Coast.

The sensitivity map shows that most of the SEQ coastal suburbs are extremely sensitive sedimentary environments which can be affected by sea-level rise and hydrodynamic changes. With the majority of the population and major infrastructure located within close proximity to the coastline, there is no surprise that the assessment indicates that the entire SEQ coastline is considered to be extremely sensitive to coastal hazards.

Whilst the entire coastline is considered to have extremely high sensitivity to coastal hazards, it is important to note that the five coastal councils have considerable capacity to deal with coastal hazards, with most being of notably medium to high levels of adaptive capacity. There are, however, several coastal suburbs within the coastal councils that have low adaptive capacity.

The overall net vulnerability indicates that the most vulnerable areas to coastal hazards are in the local government areas of the Sunshine Coast, Gold Coast, Moreton Bay, and Brisbane. Despite Redland City demonstrating a extremely high level of sensitivity to coastal hazards, the high level of adaptive capacity determined the area’s overall low vulnerability to coastal hazards.
The three figures on the left depict the vulnerability components: Exposure - top left; Sensitivity - middle left; Adaptive Capacity - bottom left. Main figure depicts integration of the three components into net vulnerability.

Figure 6. SEQ vulnerability to coastal hazards.
3.5 General Considerations

This initial overall spatial vulnerability assessment of SEQ to climate change related impacts, including extreme heat, extreme rainfall and coastal hazards indicates that there are a number of vulnerability hot spots in the region that deserve closer assessment in order to address climate change adaptation (see Figure 7). Several of those localities are spread throughout coastal and inland areas of the region. In interpreting the results presented by this initial assessment, it should be noted that whilst the identified areas with high and extremely high net vulnerabilities are susceptible to harm, this assessment does not provide a measure for such harm such as the financial, social and ecological costs and losses.

To better understand the extent of such harm and the region’s vulnerabilities, further assessments are required, particularly in order to incorporate findings from on-going development of climate science. Despite the limitations inherent to vulnerability assessments, they constitute an important tool to generate discussion with stakeholders to consider the range of adaptation options and to help fine tune desirable adaptation strategies.

In this context, Table 5 has been derived from this initial assessment to present some key observations for the four selected local authorities which will form the basis of future case study analysis that is proposed by the Human Settlements research component. The local government areas which will contain the specific case study areas include: Moreton Bay, Gold Coast City, Ipswich City and Sunshine Coast region. Based on these observations, a number of implications emerge for all sectors under investigation as vulnerabilities result from complex interactions between biophysical and socio-economic systems which can challenge the development and implementation of adaptation options. For instance, areas with high exposure, sensitivity and high adaptive capacity can potentially indicate that the population’s levels of wealth and access to resources could assist in the response process. Nevertheless, climate change related hazards projected to affect those areas could cause significant disruption of people’s livelihood and consequently impacts on economic productivity as well as overload emergency and public health services. In other cases, areas with medium to low exposure and sensitivity and low adaptive capacity can also have severe implications as moderate events could impact a large proportion of the population which is ill prepared to respond and recover.

Given the complexity associated with vulnerability assessments and their outputs, the establishment of a monitoring process should be put in place to assist the region in updating and incorporating climate science into those assessments as well as to better inform the decision making process. Such a monitoring programme would require better cooperation between agencies at all levels including state, local authorities and the non-government sector to access and assess datasets related to climate science. Despite the challenge, this process could result in more effective climate adaptation strategies across the region and across sectors.
Figure 7. Combined SEQ vulnerability to extreme heat, extreme rainfall and coastal hazards.
Table 5. Overview of spatial vulnerability assessment across selected local authorities (case study areas).

<table>
<thead>
<tr>
<th>Local Authorities</th>
<th>Spatial Vulnerability Assessment - Key Remarks</th>
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<tbody>
<tr>
<td></td>
<td>Net Vulnerability (NV)</td>
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</table>
| Moreton Bay Regional Council   | • A number of pockets with extreme NV  
• Significant number of suburbs with medium to high NV | NV is strongly determined by high exposure and sensitivity; there are hot spots with low adaptive capacity; the occurrence of extreme heat events can affect a large amount of people. | • Significant number of suburbs with medium to high NV  
• A couple of hot spots with extreme NV | Although overall NV is medium, a number of coastal suburbs have lower adaptive capacity; and the occurrence of extreme rainfall events can disrupt the livelihood of a large amount of people. | • Hot spots with high and extreme NV |
| Gold Coast City Council        | • Some hot spots with extreme and high NV  
• Some areas with medium NV | NV is strongly determined by high exposure and low adaptive capacity, however, overall, the area has high adaptive capacity facilitating prevention and response. | • Suburbs located nearby shoreline present extreme to high NV | Extreme and high NV are the result of the area high exposure to extreme rainfall, however, overall, the area has high adaptive capacity facilitating recovery. | • A number of pockets with extreme NV |
| Ipswich City Council           | • A number of hot spots with extreme and high NV  
• Significant part of urbanised areas present medium NV | Medium to extreme NV associated with low adaptive capacity indicate areas of concern. | • Significant part of urbanised areas present medium NV | Although overall NV is medium, there are hot spots with extremely low adaptive capacity; and the occurrence of extreme rainfall events can disrupt the livelihood of a large amount of people. | Not directly affected. |
| Sunshine Coast Regional Council | • Some hot spots with extreme and high NV  
• Some areas with medium NV | Overall medium to low NV throughout the area, with few pockets coupled with extreme NV and low adaptive capacity. | • A number of pockets with extreme NV  
• Some areas with medium NV | Extreme and high NV are the result of the area high exposure to extreme rainfall, however, overall, the area has relatively high adaptive capacity facilitating recovery. | • A number of hot spots with extreme high NV  
• Some areas with medium NV |

NV is strongly determined by high exposure and sensitivity; potential disruption of livelihood of a large amount of people; however, overall, the coastal area has no single trend in terms of adaptive capacity compromising response.
4. Sectoral Vulnerability Assessment

This section addresses the sectoral elements of the initial regional vulnerability assessment of human settlements to climate change in SEQ. It examines the individual sectors of urban planning and management; coastal management; human health; and emergency management. These separate analyses of SEQ’s sectoral vulnerabilities have been completed in the context of current climate change adaptation policies and initiatives which exist at federal and state government levels. As previously noted, these analyses were undertaken based on emergent approaches described in the literature, followed by an assessment of current sectoral practices affecting the region in the light of those approaches and the implications for each sector derived from the spatial vulnerability assessment.

4.1 Contemporary Climate Change Adaptation Context

4.1.1 National level support for climate change adaptation

This section reviews and analyses the support provided by the national government for climate change adaptation. Climate change adaptation has only recently risen to the top of national agendas in developed countries throughout the world. This is evident in Australia by the lack of, and only recent, progress and guidance on adaptation at the national level. The three main initiatives reviewed are the National Climate Change Adaptation Program, the National Climate Change Adaptation Framework and the recent Australian Government position paper on ‘Adapting to climate change in Australia’. In addition, this section will also highlight any sectoral implications and/or guidance provided by these initiatives.

Climate Change Adaptation Initiatives

The National Climate Change Adaptation Program, with a budget allocation of $126 million, is an important first step in addressing adaptation to climate change in Australia. The Program seeks to build capacity to support the development of effective and targeted adaptation strategies and aims to integrate adaptation considerations into key policies and programmes across vulnerable sectors. It has funded a number of projects and assessments designed to better understand the potential impacts of climate change and to enhance decision-makers’ ability to respond and address areas of national vulnerability. In addition, this programme is supporting research on adaptation through the establishment of the National Climate Change Adaptation Research Facility (NCCARF). Finally, it has supported the Local Adaptation Pathways Program (LAPP) to help local governments build their capacity to respond to the impacts of climate change.

The National Climate Change Adaptation Framework outlines “the future agenda of collaboration between governments to address key demands from business and the community for targeted information on climate change impacts, and to fill critical knowledge gaps which currently inhibit effective adaptation” (COAG n.d., p.3). A key focus of the Framework is to help decision makers incorporate climate change into their policies and operational decisions at all scales and across all vulnerable sectors. One of the roles of this Framework is to support stakeholders in key sectors – including urban planning and management, coastal management, emergency management and human health – to develop practical strategies to adapt to the impacts of climate change (COAG n.d.). This framework has two priority areas for potential action: building understanding and adaptive capacity; and reducing vulnerability in key sectors and regions, including coastal regions,
health and settlements. The Framework stresses that governments must take a leadership role on adaptation and must develop, implement and review policies and strategies for climate change adaptation. In addition, it states that governments should integrate climate change considerations into existing policies and strategies.

The Australian Government position paper on ‘Adapting to climate change in Australia’, published in 2010, sets out the Australian Government’s vision for climate change adaptation in Australia. It proposes to develop a national adaptation agenda that will clarify roles and responsibilities for adaptation and identify priorities for collaborative action between governments (Commonwealth of Australia 2010, p.1). The paper outlines the roles of the Commonwealth, State, Territory and local governments and identifies initial national priorities for adaptation action. These national priorities are: coastal management; water; infrastructure; natural systems of national significance; prevention, preparedness, response and recovery with regard to natural disasters; and agriculture (Commonwealth of Australia 2010). The paper highlights the dual role of the Commonwealth Government with regards to adaptation, as in some cases it will need to be directly involved in adaptation action (e.g. in the management of some of its important assets, such as Kakadu) and in other cases it will only be indirectly involved by driving and coordinating national reform efforts. The paper emphasises the importance of early action for adaptation (noting that uncertainty is not a reason for inaction) and recognises that adaptation is a shared responsibility and will require the involvement of governments, business and the community to be effective. It recognises that adaptation will also occur at the level of individuals and businesses but that it must provide a policy environment conducive to such adaptation. In addition, the paper highlights the need for cooperation between the Commonwealth and State/Territory governments. The position paper also promotes the notion of embedding or mainstreaming adaptation into existing policy and institutional frameworks and ongoing government operations at all levels of government (i.e. national, state/territory and local). This mainstreaming process should apply not only to the initial national priorities identified but also to all new policy development processes in other sectors, including health, transport and regional development (Commonwealth of Australia 2010).

**Sectoral implications**

The National Climate Change Adaptation Framework provides recommendations and potential areas of action for a variety of sectors, including urban planning, coastal management, emergency management and human health. The position paper on ‘Adapting to climate change in Australia’ identifies sectors that represent initial national priorities for adaptation action and briefly reviews some early adaptation effort within those sectors but does not recommend any specific adaptation strategy or action.

The National Climate Change Adaptation Framework provides some potential areas of action for the key sectors it considers. For settlements, infrastructure and planning the Framework encourages the review of both planning and infrastructure systems (e.g. review the information used to determine vulnerability of settlements land to climate related hazards and develop new or revised risk management guidance to take account of changes arising from climate change). It argues that this should be completed in order to increase the resilience of human settlements to climate change and suggests that planning decisions for development should take account of climate change, especially higher temperatures and changes to rainfall. In addition, it suggests that local governments should be supported in their efforts to adapt to climate change. For coastal management, the Framework suggests undertaking a national assessment of Australia’s coastal vulnerability, which would provide
critical information to coastal managers and decision makers, identifying vulnerable coastal areas and applying appropriate planning policies, where possible, for the migration of coastal ecosystems. Priorities in the health sector include the development and implementation of a national action plan to address climate change and health, development of warning and response systems, and improved research on climate change and health. In the area of emergency management, the Framework suggests that the impacts of climate change need to be incorporated in disaster risk reduction, emergency services planning and recovery management activities. It also highlights the importance of community awareness and a culture of preparedness for effective adaptation response (COAG n.d.). The actions proposed in this Framework complement the recommendations arising from the report for the Council of Australian Governments (COAG) titled: *Natural Disasters in Australia: Reforming mitigation, relief and recovery* (Commonwealth of Australia 2004). These actions include incorporating climate change impacts into planning for natural disaster response management and improving information for emergency services and communities to foster awareness of climate change and adaptation responses (COAG n.d., p.19).

**Summary**

The *National Climate Change Adaptation Framework* and the Position Paper on *Adapting to climate change in Australia* provide useful starting points for national initiatives on climate change adaptation. They include many of the adaptation principles emerging from the literature, especially the key principles of early action, inter-governmental collaboration and mainstreaming. This is important as it provides the right direction and guidance for adaptation in Australia and should enable the state/territory and local governments, industry and the community, as well as the individual sectors, to initiate action on adaptation. However, the National Framework and Position Paper do not have statutory or legal powers and this may limit their actual ability to influence government and non-government sectoral policies and plans. It is also unclear how these initiatives will link with sectoral policies and plans across all tiers of government and thus whether any of the recommendations will be adopted by the sectors. Effective coordination and integration of climate change adaptation policy into sectoral policies represents a key challenge that will need to be addressed to avoid duplication of efforts, gaps and to ensure effective implementation of adaptation measures across all sectors and jurisdictions.

**4.1.2 State level support for climate change adaptation**

This section reviews and analyses the two key climate change and climate change adaptation policies developed by the State of Queensland, namely: *ClimateQ – toward a greener Queensland 2009*; and *ClimateSmart Adaptation 2007-2012*.

**Climate Change Adaptation Initiatives**

*ClimateQ: toward a greener Queensland 2009* is Queensland’s climate change strategy. It consolidates and updates the approaches taken in *ClimateSmart 2050* and *ClimateSmart Adaptation 2007-2012* and outlines the key investments and policies of Queensland’s climate change response. It identifies five key themes that underpin Queensland’s response to climate change, two of which relate to climate change adaptation: protecting significant ecosystems through conservation; and improving resilience and adapting to the impacts of climate change. The strategy also recommends specific policy initiatives for action on climate change. These initiatives are grouped into key sectors, including business, planning and building, community, ecosystems and government. Although adaptation is identified
in the key themes underpinning Queensland’s response to climate change, the majority of initiatives recommended for each sector focus on mitigation activities. Nevertheless, compared with ClimateSmart 2050 there is a strong new focus on dealing with extreme weather events with funding allocated to several new emergency management initiatives (Department of Environment and Resource Management 2009a). Within the planning and building sector, land use planning is recognised as a primary tool for enhancing Queensland’s resilience to climate change.

ClimateSmart Adaptation 2007-2012 is a 5-year plan which aims to provide the foundation for building Queensland’s resilience to the impacts of climate change. It complements the ClimateSmart 2050 strategy launched in 2007 and is aligned with the National Climate Change Adaptation Framework as well as with several national and state sectoral plans. The plan seeks to enhance understanding of climate change risks and vulnerabilities, promote consideration of climate change impacts in decision-making, and generate practical steps to enhance resilience to climate change (Queensland Climate Change Centre of Excellence 2007). It is guided by four key principles: i) adaptation actions contribute to sustainability; ii) adaptation actions do not replace efforts to reduce greenhouse gas emissions; iii) actions consider the emissions they may generate; and iv) working in partnerships is fundamental to success. In addition, it is based around three critical overarching strategies that frame the recommended adaptation actions: i) building and sharing knowledge; ii) including climate change in decisions (this includes using a risk management approach); and iii) reducing vulnerability and increasing resilience to climate change. This Plan identifies 62 adaptation actions that need to be undertaken over the next five years across and within the priority sectors of: water planning and services, agriculture, human settlement, natural environment and landscape, emergency services and human health, tourism, business and industry, and finance and insurance. These actions were developed with the aim of capturing benefits from early adaptation planning, reducing vulnerability in priority sectors and establishing the foundations needed for future adaptation actions.

**Sectoral implications**

ClimateQ outlines Queensland’s response to climate change but focuses mainly on mitigation activities. ClimateQ does not recommend any new climate change adaptation initiatives or investments for the urban planning and management and human health sectors. For coastal management, ClimateQ does highlight Queensland’s investment in developing a Digital Elevation Model (DEM) for the Queensland coast. This DEM will be used to identify areas vulnerable to coastal erosion and areas at increased risk from coastal hazards to inform coastal land use planning. With regards to emergency management, ClimateQ outlines several new initiatives including: focusing on strengthening the response capacity of the State Emergency Service and Rural Fire Service; enhancing preparedness for natural disasters in vulnerable communities; establishing disaster management warehouses in SEQ to store stockpiles of emergency equipment; and bushfire education campaigns (Department of Environment and Resource Management 2009a).

The ClimateSmart Adaptation 5-year plan identifies adaptation actions for human settlements, including the urban planning and management and coastal management sectors, and the emergency services and human health sectors. In relation to the urban planning and management sector, the plan recommends ensuring regional planning activities under the Integrated Planning Act 1997 (IPA 1997), including the 2010 review of the SEQ Regional Plan, draw together state and local government responses to climate change. In addition, it suggests reviewing the effectiveness of existing planning tools in addressing the increased
risks from climate change, including the State Planning Policy 1/03 (Mitigating the Adverse Impacts of Flood, Bushfire and Landslide), the State Coastal Management Plan and local government planning schemes (Queensland Climate Change Centre of Excellence 2007). With regards to coastal management, ClimateSmart Adaptation recommends improving understanding about the risks and impacts of climate change to the coastal zone by continuing storm tide and wave monitoring systems, identifying and mapping areas most at risk from storm tides, improving projections of inundation and flooding due to changes in sea level and extreme events and integrating the information gained into advice and tools. It also suggests reviewing planning guidance given to local government on shoreline erosion management to ensure climate change is integrated into their activities (Queensland Climate Change Centre of Excellence 2007). For the emergency management and human health sector the ClimateSmart Adaptation plan recommends several adaptation actions, including: building the capacity of disadvantaged communities to effectively respond to the potential social and economic impacts of climate change; continuing to provide planning and emergency management advice on storm tides and investigating whether measures are adequate for the next 30 years; ensuring that reviews of local disaster management plans include relevant climate change issues; extending ‘preparedness and awareness’ programmes to communities where the risk of extreme climatic events has increased; and reviewing the Queensland Heatwave Response Strategy to ensure it appropriately considers climate change (Queensland Climate Change Centre of Excellence 2007).

**Summary**

ClimateQ and ClimateSmart Adaptation represent Queensland’s current main climate change and climate change adaptation initiatives. They incorporate many of the key adaptation principles emerging from the literature and from the Australian Government’s National Climate Change Adaptation Framework, including the importance of early action, the need for action at different scales, working in partnerships and mainstreaming adaptation into decision making processes. In addition, ClimateSmart Adaptation provides an action plan for adaptation with a list of 62 adaptation actions, the majority of which are sector-specific. ClimateQ, on the other hand, focuses mainly on mitigation initiatives – with the exception of the new disaster management initiatives – and therefore does not further develop Queensland’s climate change adaptation agenda/policy. Although these initiatives contain sector-specific adaptation recommendations, it is unclear how they will influence sectoral policies and whether these recommendations will be adopted by the relevant state government departments and local government. ClimateQ and ClimateSmart Adaptation both lack statutory power, which constrains their ability to influence relevant state and local government policies as well as the non-government sector. The integration of climate change adaptation into sectoral decision making processes and policies remains a key challenge for Queensland.
4.2 Urban Planning and Management

Contemporary urban and regional planning approaches are underpinned by the traditional rational planning model. Rational planning theory requires a comprehensive body of knowledge to enable planners and policy makers to make informed and logical decisions when assessing potential alternatives (Kay & Alder 2005, p. 58). The comprehensive rational planning model relies on reliable and robust science to inform strategic land use planning and has proved to be an effective way for planners and policy makers to justify decisions in the past (Alexander 1986). For example, planners have traditionally used data from past weather events to minimise exposure of new developments to natural hazards. However, the rational decision-making approach has limitations in the context of managing climate change given the uncertainties surrounding the emergent climate science. In the absence of absolute knowledge and understanding there are ‘inevitably value judgements made which reflect the biases and values of decision makers’ (Kay and Alder 2005, p. 58).

In the past, planners have relied on traditional planning approaches (e.g. zoning, regulation) to manage growth and development pressures on the environment. There is growing awareness however, that a reliance on these more traditional approaches will make it difficult to provide adaptability to changing circumstances such as the challenges posed by climate change. Given these limitations, it is worth while reviewing the current dialogue involving urban and regional planning initiatives to move planning practices beyond incrementalism and adopt a more integrated and holistic approach that will enable effective climate adaptation and deal with the complexity and magnitude of the climate change challenge.

4.2.1 Current and emergent approaches

The current dialogue involving urban and regional planning initiatives focuses on three major inter-related strands, including the governance of the planning process, the networks engaged in the planning system and the scale of planning actions (Neuman 2007). Although this dialogue is heavily focused on issues related to urban form and development, there is growing recognition that climate change challenges should also be included in those discussions (McDonald et al 2010). As such, this assessment presents a brief review of current and emergent approaches in planning initiatives and proposes a set of principles that seek to guide the planning process to address climate adaptation.

The multiple thresholds, diverse stakeholder interests and values that are mobilised under climate change, demand that governance and planning be adaptable to changing circumstances whilst promoting integrated cross-sectoral and cross-scalar responses (Nicholson-Cole & O’Riordan 2009; Lovell et al 2002). Governance is understood here as the social norms and formal rules that govern society and its resource use. It includes the institutional arrangements – legislation, regulations, plans, policies, programs and the organisational structures and processes that implement them. Despite advances in planning and governance frameworks in Australia to facilitate better policy integration across scales, the overarching framework for planning and development continues to be dominated by sectoral policy and decision-making. This creates profound complexities for integrating and coordinating climate policy responses by government and non-government sectors (Norman 2009a; Morrison 2007).

The institutional response to climate change is further compounded by an increasingly dense and complex institutional landscape that offers little confidence in the planning systems’ ability to move beyond a piecemeal approach and deliver effective adaptation across sectors.
and scales (Kok & de Coninck 2007; Adger et al 2005; Urwin & Jordan 2008). This challenge is augmented by the fact that the classical distinction between place and space has been reconfigured by current intensification of connectivity and cross-territorial networks due to globalisation. These changes reflect social organisations that go beyond the ontological concept of territory in which actors/stakeholders now interact and communicate within multiple policy sectors and scales (Amin, in Allmendinger & Haughton 2007, p. 1481). In these circumstances, policy development, including climate adaptation policy, becomes a complex cross-sectoral and cross-scalar process (Allmendinger & Haughton 2007).

There has been a trend in framing climate change as a global issue, albeit with local and regional consequences (Betsill 2001), that generates complex multi-scale governance issues because it meshes ‘the global and local in the presence of the nation-state’ (Bulkeley & Betsill 2005, p. 43). Complexity is compounded by uncertainty about the science, its impacts, and scale of responses required to address the challenge (Brooks et al 2005). As urban planning authority and capability is largely in the hands of state and local governments (Murphy 2007), local governments are critical players in addressing climate change because they are at the forefront of land use planning and development control. This is particularly important given that present and future land use has a major influence on the magnitude of climate change related impacts (Kirshen et al 2008). However, ignoring the interplay between different tiers of governments and other non government agencies can have an adverse effect of allocating solutions and responsibilities only to local authorities (Lindseth 2004). This is challenging on a number of fronts.

Many local governments face difficult and chronic problems with a large proportion lacking the necessary skills and resources to properly manage development pressures, not to mention the inclusion of climate change in the decision-making process (Commonwealth of Australia 1991; Harvey & Caton 2003). As such local governments’ ability to implement adaptation actions is undermined due to: the lack of professional, technical or political support (Allman et al, in Wilson 2006, p. 610); the lack of power or other resources (Wilson 2006); and the dominance of other conventional policy objectives (Bulkeley & Betsill, in Wilson 2006, p. 610). The ability to address climate change impacts at the local scale is further aggravated by the scientific uncertainty and complexity surrounding climate change. Based on the above mentioned, there is great diversity amongst local governments and their ability to respond and manage climate change impacts.

In parallel, there is acknowledgment that centralised approaches don’t always result in improved economic expediency (Singer 2009) – potentially leaving local governments more vulnerable and constrained. Thus, the delimitation of the scale of planning actions needs to be well defined in order to overcome those barriers and buttress the implementation of climate adaptation strategies. In this perspective, when dealing with spatial scales, even when involving official spatial demarcation such as the delimitation of the SEQ region, planning initiatives have to conceive spaces beyond a non-territorial notion as, currently, spaces offer relational settings and are a ‘site of situated practices’ (Amin 2002, p. 391). In this non-territorial context, spaces encompassed by cities, regions or nations have less territorial properties (e.g. ‘localised links, local identity and identification, scalar politics and governance’) and more ‘spatial and temporal exposure and connectivity.’ (Massey, in Amin, p. 391).

This complex myriad of scales (both temporal and spatial) and institutional arrangements involved in the policy process can adversely affect planning practices by overlapping, conflicting, juxtaposing and un-coordinating planning and management responses
While many authors have recognised these failings (Middle 2002; Nicholson-Cole & O’Riordan 2009) as well as the need for better policy integration (Adger et al 2005), methods to achieve improved coordination and policy integration are less evident (Urwin & Jordan 2008). Past research has investigated the efficiency of institutional arrangements by analysing them against both normative (Watson et al 1996) and functionalist criteria (Margerum & Born 2000). Although these assessments provide both meaningful and substantive evaluations, which highlight the deficiencies of institutional arrangements in various contexts, there is less emphasis placed on the necessary changes needed to improve institutional performance.

Adding to the complexity of managing ‘wicked’ or highly contested issues, planning, in more recent years, has become increasingly dialogic - ie with heavy emphasis being placed on consultation, mediation and collaboration (Friedmann 1993). Such planning initiatives could be interpreted as a derivative of the policy-integration imperative that emerged in the 1980s under the sustainability paradigm. There are strong similarities, if not reflecting the same process, between strategies aiming at climate change adaptation and sustainability including the multi-scalar and multi-sectoral perspective which is best described by the integrated/holistic approach involving cross-sectoral integration and engagement of multiple actors/stakeholders (Bulkeley 2000; Jamieson 2006). Increasing stakeholder engagement in the planning process means that it has to address different set of values and interests that often conflict and require mediation. There are many stakeholders that have a vested interest in land use planning and development control. This may well require new alliances between stakeholder groups that both traditional and contemporary planning practices have not needed. However, based on the experience provided by earlier sustainability initiatives, such policy-integration imperative has also a political dimension in which a balance needs to be achieved in order to avoid the dominance and predominance of specific sectors/actors/stakeholders upon the decision-making process (Allmendinger & Haughton 2007). The complexity of the science and the highly technical and dynamic nature of climate change require new approaches that need to foster better relationships and build trust between government and community (Bulkeley 2000; Jamieson 2006). Under this perspective, addressing climate change will require a genuine commitment from all levels of government. Without the appropriate level of commitment and guidance from higher order governments, local and regional adaptation will continue to be frustrated.

Amongst the challenges related to adapting to climate change, the planning scale (temporal or spatial - macro or micro) is understood as having a central role in minimising the levels of exposure and vulnerability of human settlements to the impacts of a changing climate (Lindley et al 2006). In addition, the notion of the planning scale has to consider the multi-scalar, multi-sectoral dimensions involved in policy formulation and delivery also to guide pragmatic planning decisions such as identifying areas which are not suitable for future development as well as those that require urgent adaptation strategies (Lindley et al 2006). For the last two decades, planning practice has pursued a model of policy delivery at the regional scale based on the premise that regions and regional institutions are the most appropriate scale to manage highly complex and contested problems (Smith et al 2007). This has been justified by the belief that: ‘regions are potentially on a scale at which social organisation and institutional learning can be more adaptive and responsive to change’ (Dore & Woodhill 1999, p. 15); that regions are adequate to deal with cross scale issues; and in linking local policy with state and federal policy (Smith et al 2007).

Nonetheless, despite efforts in establishing multi-level integration of governments, the
responsibility for regions and regional planning continues to be spread across various levels of government and non-statutory bodies (Collits 2007) and, consequently, planning at the regional scale is challenging. Regions are highly contested spaces and are highly diverse (Dore & Woodhill 1999). Regions and regional institutions are equally diverse in their capacity to respond to climate change. Regional variation is more than just a ‘function of their location and resources, but also as a consequence of the responsiveness of institutional actors and their ability to manage environmental stresses and adapt to new conditions’ (Ivey et al 2004, p. 37). Moreover, delivering regional scale imperatives remain untested in the context of climate adaptation (Urwin and Jordan 2008). Given the current lack of research and evidence to support the effectiveness of regional scale planning and policy delivery in the context of climate adaptation, it is then plausible to explore other scales at which adaptation may be addressed.

Planning at the landscape scale has initially emerged as a strategic response to countryside change in Europe and gained significant momentum under the sustainability challenge over the past decade (Council of Europe 2010). Given that climate change is an essential part of the sustainability challenge, planning at the landscape scale offers immense potential to address the impacts from climate change through improved cross-sectoral/cross scalar integration. Landscapes are a product of the relationships between its social, economic and biophysical components in which humans are an integral part of it. Landscapes are ‘socio-economic systems’ (Matthews & Selman 2006, p. 201) in which human and biophysical variables interrelate at different levels and rates through nonlinear feedback loops. They comprise dynamic and self-organising components with sudden and unforeseen changes in which stakeholders’ values and perspectives guide the choice of which landscape’s features/topics are relevant and acknowledge the challenges in ensuring that social and institutional dimensions are incorporated into systems models (Murray et al, in Selman & Knight 2005, p. 11).

As socio-economic systems, landscapes are multi-scalar having a spatial, temporal and modification dimensions. The spatial dimension encompasses distinct physical units that are rationally and intuitively recognised as being a national, regional or local unit. The temporal dimension involves past, present and future features of the landscape that takes into account the on-going relationship between humans and the landscape and how these features are conserved or spoilt for future generations. Last, the modification dimension encompasses the transformations and rehabilitations that have occurred in the landscape shaping it into urbanised areas, agricultural fields or conservation areas and the like. These dimensions also provide the ability to incorporate future changes in the landscape, especially anticipating the consequences climate change impacts will have on human settlements (Selman 2006).

Planning at the landscape scale offers the opportunity for the collection of data and development of systems models that could inform interdisciplinary research leading to integrated policy delivery that enhances people’s liveability and social learning (Selman and Knight 2005). Another advantage is that policy delivery at the landscape scale goes beyond administrative and political boundaries that have traditionally been used. In addition, it also has the potential for cross-sectoral delivery of policies (Hamilton and Selman 2005). This is particularly relevant for climate change adaptation strategies as they will require a well-coordinated response that integrates cross-sectoral and cross-scalar policies.

As observed through its implementation in England and Scotland during the last decades, the experience provided by the landscape scale planning in dealing with ‘wicked’ issues such as environmental conservation and cultural heritage could bestow valuable contributions.
to address climate adaptation (Landscape Character Network 2010). Such contributions include the incorporation and review of existing spatial, functional and temporal dimensions, in order to move beyond traditional political and economic boundaries to a more bioregional relationship; the creation of more transparent governance structures that can deal with the adaptive and changing nature of natural systems; and the adoption of timeframes that are not bound to political and economic cycles (Selman 2006).

Enhancing quality of life and maintaining the region’s liveability whilst managing population growth and addressing climate change are key challenges for SEQ’s planning process. Planning at the landscape scale could assist this planning process in addressing such challenges as it also favours a ‘virtuous cycle’ in which the quality of life or liveability of a place can be fostered and enhanced. The virtuous cycle enhances the quality of life of the community as well as the landscape quality. It does so through a feedback loop system in which the community is able to enhance its economic profile and well-being by creating economic opportunities derived from existing socio-economic characteristics and the landscape capital stock (e.g. buildings and ecosystems services) (Matthews & Selman 2006). The virtuous cycle aims to conserve traditional significant features of the landscape such as the ones associated with heritage values, as well as contribute to stabilising new socio-ecological systems (Matthews & Selman 2006). However, in order for a virtuous cycle to prevail, it is necessary that there be an allocation of sufficient investments in the social, economic and environmental arenas (Selman 2006). As previously stated, planning for effective climate adaptation will require strong leadership resulting from robust institutional arrangements and engagement of stakeholders.

Thus, based on this literature review, this assessment identifies a set of normative planning principles that could promote effective climate adaptation in the SEQ region. These principles are:

1) Planning avoids incrementalism by adopting an adaptive framework which is flexible, engaging and is based on thresholds of change (including changing institutional and governance arrangements as well as scientific uncertainties);

2) Planning adopts a systems based approach that includes social, cultural and biophysical dimensions beyond traditional political and administrative boundaries and promotes cross-scaler and cross-sectoral integration;

3) Planning fosters a ‘virtuous cycle’ which contributes to sustainability by creating, reinforcing, restoring, protecting and embedding political and economic mechanisms to reproduce valued places as well as environmental integrity;

4) Planning is based on extensive collaboration between government, private sector and civil society; and

5) Planning is buttressed by legislation, plans and polices at higher scales to support implementation and foster effective adaptation.
4.2.2 Current practice affecting SEQ

Rapid population growth over the past two decades has reshaped the SEQ regional socio-economic profile. Some of the observed trends include an increase in the total labour force by 13% between 2001 and 2006 and a steady increase in median family and individual incomes of more than 26% and 30% respectively. In addition, the quality of life in the region is relatively high as it offers higher levels of education, skills and resources compared to other Australian locations (Roiko et al 2010). Such trends, among others, place SEQ as a point of attraction for new residents and by 2031 its population is expected to reach 4.4 million (Department of Infrastructure and Planning 2009).

Managing regional growth is a key issue for planners and policy makers. Currently, planning efforts are focused on containing and consolidating a large proportion of this growth through infill or redevelopment of existing urban areas. However, on-going population growth will place pressure on the regional landscape through expansions of the existing urban footprint. In this case, development will possibly occur in greenfields located in areas currently occupied by natural vegetation or agricultural production.

Whilst a significant challenge has been to accommodate this growth sustainably to avoid detrimental impact on the natural environment and regional liveability (Low Choy 2008), there is growing recognition that new developments will also have to consider increased exposure to climate change-related hazards in the future. In addition, a significant proportion of the existing building stock is also potentially vulnerable to a changing climate. Thus, planning decisions regarding future strategies and policies for both existing and new settlements will need to consider future risks identified by climate change projections and scenarios (McDonald et al 2010).

This section identifies current urban planning and management practices that directly affect the planning process in SEQ. These practices are assessed against the set of planning principles identified in the previous section. Planning practices are grouped based on the following jurisdictions: national, regional and local levels. Although there are a number of State Planning Policies (SPP) at the State level only two SPPs have direct link to future climate change hazards. These are SPP 1/03 which addresses natural disasters such as bushfires and floodings, and potentially the State and Regional Coastal Management Plans, however, sectoral implications derived from these policies will be covered under the emergency management and coastal management sections respectively. No other relevant planning instruments were identified at the State level due to current institutional arrangements which establish planning regulations in SEQ to be coordinated at regional and local levels. At the local level, this report focuses solely on planning practices related to the four SEQ local authorities involved in the case studies, namely: Brisbane City Council; Gold Coast City Council; Ipswich City Council; and Sunshine Coast Regional Council.

National Level

Current planning practice at the national level is represented by the release in late 2009 of a National Planning Systems Principles under the auspices of the Local Government and Planning Ministers Council. Such set of principles were developed to assist Australian states and territories in improving their planning systems and enabling the achievement of sustainable outcomes, including social, economic and environmental outcomes. In addition, by setting national planning principles it is expected that current weaknesses of the planning system will be addressed. Such weaknesses encompass issues related to structure and governance, planning processes and scope and content (Local Government and Planning
Among other key issues and challenges to existing planning systems, the *National Planning Systems Principles* acknowledges that climate change is an emerging and evolving issue with implications no longer restricted to local governments but expanded to regional and national dimensions. In this context, the Systems Principles makes provision for the scoping of uncertainties by identifying the need for flexibility in planning instruments. It also advances planning practices in terms of encouraging cross-sectoral and cross-scalar policy integration to be delivered across non-traditional political and administrative boundaries such as biophysical regions and regional communities of interest.

Multi-level governance is also fostered by the Systems Principles through the recommendation for vertical and horizontal integration as well as linkages to private sector and community engagement. In addition, there is a call for clearer regulatory planning practices focused on hierarchic planning instruments as well as the legislation under which they operate (see Table 6).

**Regional Level**

The statutory planning process in SEQ first occurs at the regional scale and is governed by the *SEQ Regional Plan 2009-2031* (Department of Infrastructure and Planning 2009). The Regional Plan provides direction and guidance to state agencies’ plans, structure plans and local governments’ planning schemes (Low Choy 2009). The Regional Plan is in alignment with some key planning principles set by this assessment such as providing for the monitoring, evaluation and reporting of the plan implementation process in order to assist the achievement of Desired Regional Outcomes (DROs). It also identifies the need for collaboration between government, industry bodies and community groups as well as intra-governmental collaboration.

The Regional Plan is well aligned with relevant planning legislation and State Policies applied to SEQ. The plan, however, lacks strength in terms of adopting a systems approach with some partially evident attempts related to holistic integration in terms of achieving DROs. In addition, the Regional Plan also operates in conjunction with other planning instruments at various scales such State Planning Policies, local government planning schemes and the regional Infrastructure Plan and Program. This is particularly important, as climate change impacts as well as other conservation initiatives often involve issues that surpass administrative boundaries. The Regional Plan has provision for addressing climate change impacts, however, as those provisions are ultimately transferred to local government planning schemes the planning decisions are mostly bound to administrative boundaries rather than determined by landscape features. In this regard, planning based on a systems approach could offer more robust planning decisions that could deal with the complexity of climate change in SEQ (see Table 6).
<table>
<thead>
<tr>
<th>Principles</th>
<th>National Planning System Principle</th>
<th>Regional</th>
<th>National Planning System Principle</th>
<th>Regional</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Planning avoids incrementalism by adopting an adaptive framework which is flexible, engaging, and is based on thresholds of change (including changing institutional and governance arrangements as well as scientific uncertainties)</td>
<td>* Principle 4 – scope for changing circumstances; bets practice – flexible planning instruments and authorising legislation</td>
<td>* Implementation of the Regional Plan is underpinned by a monitoring, evaluation and reporting framework which is aligned to the desired regional outcomes (p. 153)</td>
<td>** Principle 1/ best practice - use of biophysical regions and regional communities of interest; cross-sectoral/ scalar policy integration</td>
<td>** The DROs are integrated and holistic. The regional plan operates in conjunction with other planning instruments at various scales (e.g. SPPs, local government planning schemes)</td>
</tr>
<tr>
<td>2) Planning adopts a systems based approach that includes social, cultural and biophysical dimensions beyond traditional political and administrative boundaries, and promotes cross-scalar and cross-sectoral integration</td>
<td>* Principle 1/ best practice - use of biophysical regions and regional communities of interest; cross-sectoral/ scalar policy integration</td>
<td>** The DROs are integrated and holistic. The regional plan operates in conjunction with other planning instruments at various scales (e.g. SPPs, local government planning schemes)</td>
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</tr>
<tr>
<td>3) Planning fosters a ‘virtuous cycle’ which contributes to sustainability by creating, reinforcing, restoring, protecting and embedding political and economic mechanisms to reproduce valued places as well as environmental integrity</td>
<td>***</td>
<td>* DRO1 – regional growth and changes are managed in a sustainable manner to ensure quality of life through sustainable use of resources, conserving the environment and increase community resilience to climate change impacts; DRO2- protection of the natural environment whilst encouraging social and economic development; DRO3 – protection of environmental, economic, social and cultural values; DRO4/11- protection and management of natural resources; DRO5 – strengthening rural communities; DRO 6/7 – community identity and social equity</td>
<td>* DRO1 – regional growth and changes are managed in a sustainable manner to ensure quality of life through sustainable use of resources, conserving the environment and increase community resilience to climate change impacts; DRO2- protection of the natural environment whilst encouraging social and economic development; DRO3 – protection of environmental, economic, social and cultural values; DRO4/11- protection and management of natural resources; DRO5 – strengthening rural communities; DRO 6/7 – community identity and social equity</td>
<td>* DRO1 – regional growth and changes are managed in a sustainable manner to ensure quality of life through sustainable use of resources, conserving the environment and increase community resilience to climate change impacts; DRO2- protection of the natural environment whilst encouraging social and economic development; DRO3 – protection of environmental, economic, social and cultural values; DRO4/11- protection and management of natural resources; DRO5 – strengthening rural communities; DRO 6/7 – community identity and social equity</td>
</tr>
<tr>
<td>4) Planning is based on extensive collaboration between government, private sector and civil society</td>
<td>* Principle 1 - vertical and horizontal integration; Principle 2 - vertical and horizontal coordination; best practice – linkages with private sector; Principle 7 – open and legible planning systems to stakeholders; Principle 10 – community engagement</td>
<td>* To facilitate and coordinate the implementation of the regional plan involves government working collaboratively with industry, other government agencies and the community</td>
<td>* Principle 1/best practice - clear hierarchy of strategic planning instruments; Principle 3/best practice - clear legislation regulating planning instruments</td>
<td>* To facilitate and coordinate the implementation of the regional plan involves government working collaboratively with industry, other government agencies and the community</td>
</tr>
<tr>
<td>5) Planning is buttressed by legislation, plans and polices at higher scales to support implementation and foster effective adaptation</td>
<td>* Principle 1/best practice - clear hierarchy of strategic planning instruments; Principle 3/best practice - clear legislation regulating planning instruments</td>
<td>* The regional plan reflects other legislation and state polices relevant to the region</td>
<td>* Principle 1/best practice - clear hierarchy of strategic planning instruments; Principle 3/best practice - clear legislation regulating planning instruments</td>
<td>* The regional plan reflects other legislation and state polices relevant to the region</td>
</tr>
</tbody>
</table>

* Evident ** Partially evident *** Not evident
DRO - Desired Regional Outcome
Local Level

This assessment reviews the planning instruments and climate change strategies in this study’s four case study local authorities (Brisbane City Council, Gold Coast City Council, Ipswich City Council and Sunshine Coast Regional Council). These local authorities have been prioritised as the research case study localities fall within their jurisdictions. Overall, the planning instruments identified by this assessment comprise the local planning schemes as other documents did not provide sufficient information that would allow their testing against the set of planning principles. Where applicable, the assessment also focuses on current climate change strategies adopted by the Local Authorities (see Table 7.1).

In the Brisbane City Council case, the instruments assessed were the City Plan 2000 (Brisbane City Council 2000) and the Climate Change and Energy Taskforce Report (Maunsell Australia Pty Ltd 2007) (see Table 7.1). The City Plan 2000 has a number of Desired Environmental Outcomes (DEOs) that are advanced in order to foster a planning system beyond incrementalism by promoting effective community consultation and participation as well as providing scope for social, economic and technological change. The Plan also encourages a virtuous cycle by pursuing environmental quality, community wellbeing and economic development with ecological responsibilities. However, the Plan offers very limited provisions towards planning under a systems approach, cross-sectoral and cross scalar integration and other arrangements for effective climate adaptation.

The Climate Change and Energy Taskforce Report proposes a number of recommendations that encourage planning practices to move beyond incrementalism by recognising the role that climate change will have on strategic and land use planning. The Report also recommends the integration of sustainability in the decision-making process as well as clearly highlighting the need for leaderships and partnerships that encompass government, non-government, industry bodies and community groups in addressing climate change. The Report is less proactive in terms of recommending an integrated decision-making process that includes social, cultural and biophysical dimensions beyond traditional geographic and administrative boundaries.

In the case of the Gold Coast City Council, the assessment comprises the Gold Coast Planning Scheme 2003 (Gold Coast City Council 2003) and the Climate Change Strategy 2009-2014 (Gold Coast City Council 2009) (see Table 7.1). There is evidence in the Planning Scheme of attempts to move towards planning for a virtuous cycle encompassed by ecological, economic and social DEOs in terms of securing the conservation of areas of biodiversity and natural values, whilst promoting economic development without undermining social qualities. In addition, the Planning Scheme also identifies the need to incorporate potential risks from climate change in planning decisions. To a lesser extent, the plan encourages planning practices beyond incrementalism by suggesting comprehensive approaches and monitoring for review. The plan also suggests the collaboration between the multi-levels of government but does not clearly state other cross-sectoral integrations.

With regard to the Climate Change Strategy 2009-2014, it does provide scope for the review of the strategy in order to incorporate new scientific knowledge as well as identifying the role research plays in supporting the decision-making process involving climate change impacts. While the strategy provides scope for community involvement, it is important to note, it is heavily focused on awareness rather than engagement. In addition, the strategy has a strong focus on mitigation rather than adaptation in terms of increasing regulations through the review of the Planning Scheme and strengthening governance and leadership.
### Table 7.1: Assessment of planning principles at local level – Brisbane City Council and Gold Coast City Council.

<table>
<thead>
<tr>
<th>Principles</th>
<th>Level</th>
<th>Local</th>
<th>Gold Coast City Council</th>
<th>Climate Change Strategy 2009-2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Planning avoids incrementalism by adopting an adaptive framework which is flexible, engaging, and is based on thresholds of change (including changing institutional and governance arrangements as well as scientific uncertainties)</td>
<td>City Plan 2000</td>
<td>Climate Change and Energy Taskforce Report</td>
<td>Gold Coast Planning Scheme 2003</td>
<td>** Planning studies to foster comprehensive approach to achieving ecological sustainability (Part 1, Div 2, Ch 4); Planning Scheme undergoes review process to ensure DEOs are met / State of the Environment Report process supply data source for monitoring and assessment (Part 2, Div 2, Ch 3,3,4) **</td>
</tr>
<tr>
<td>** DEO 3.2.2.5 – effective community consultation and participation; DEO 3.3.2.4 – social, economic and technological change</td>
<td>** Recommendation 6.4 – Strategic and land use planning – recom. 13/14 incorporating climate change impacts</td>
<td>** Recommendation 6.2 – Decision making – recom. 9 integrated decision making</td>
<td>** Researching climate impacts upon the council jurisdiction to support decision-making (Strategic outcome 3); Considering climate change in planning and regulation (Strategic outcome 7); **</td>
<td></td>
</tr>
<tr>
<td>2) Planning adopts a systems based approach that includes social, cultural and biophysical dimensions beyond traditional political and administrative boundaries, and promotes cross-scalar and cross-sectoral integration</td>
<td>***</td>
<td>** Recommendation 6.2 – Decision making – recom. 9 integrated decision making</td>
<td>** Coordinating and integrating planning decisions at state, regional and local levels (Part 1, Div 1, Ch 4)</td>
<td>***</td>
</tr>
<tr>
<td>** DEO 3.1 – protecting environmental quality and natural assets to ensure community wellbeing; DEO 3.2 – enhancing community life, health and safety; DEO 3.3.2.2 – enhancing amenity; DEO 4.1 – economic development encompasses environmental responsibilities</td>
<td>** Recommendation 6.2 – Decision making – recom. 8 sustainability integration</td>
<td>** Conservation of good quality agricultural land; protecting, enhancing and efficiently utilising resources of regional significance; achieving ecological sustainability (Part 1, Div 1, Ch 4); **</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3) Planning fosters a ‘virtuous cycle’ which contributes to sustainability by creating, reinforcing, restoring, protecting and embedding political and economic mechanisms to reproduce valued places as well as environmental integrity</td>
<td>** Planning Schemes are prepared in alignment with Regional Plan and other relevant state legislation</td>
<td>** Planning Schemes are prepared in alignment with Regional Plan and other relevant state legislation</td>
<td>** Strategic outcome 5, key actions 24-26 provides scope for community involvement focused on awareness</td>
<td>***</td>
</tr>
<tr>
<td>** DEO Ecol. 1/2 – conservation of areas of significance to ensure biodiversity and natural landscape values; DEO Econ.2 – economic opportunities whilst protecting residential amenity; DEO Econ. 4- protection and ecologically sustainable use of significant natural assets; DEO Soc.1- promoting local character and identity; DEO Soc.4- protecting cultural heritage</td>
<td>** DEO Soc.7- development location assessed against potential risk from natural hazards</td>
<td>** Related to mitigation with limited regulations in place but seeking regulation enhancement through review of planning scheme (p. 6); Governance and leadership aims to strengthen councils actions strongly focused on mitigation (strategic outcome 1); Considering climate change in Corporate Governance Framework (p. 16)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4) Planning is based on extensive collaboration between government, private sector and civil society</td>
<td>** Planning Schemes are prepared in alignment with Regional Plan and other relevant state legislation</td>
<td>** Planning Schemes are prepared in alignment with Regional Plan and other relevant state legislation</td>
<td>** Strategic outcome 5, key actions 24-26 provides scope for community involvement focused on awareness</td>
<td>***</td>
</tr>
<tr>
<td>** Recommendation 6.1 – Leadership and Partnering – recom. 2/3 create partnerships involving business, industry and community groups; and Queensland and Commonwealth Governments; Recommendation 6.3 – Communication and education</td>
<td>** Recommendation 6.1 – Leadership and Partnering – recom. 1 to pass a resolution to meet targets</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5) Planning is buttressed by legislation, plans and policies at higher scales to support implementation and foster effective adaptation</td>
<td>** Recommendation 6.1 – Leadership and Partnering – recom. 1 to pass a resolution to meet targets</td>
<td>** DEO Soc.7- development location assessed against potential risk from natural hazards</td>
<td></td>
<td>***</td>
</tr>
</tbody>
</table>

* Evident ** Partially evident *** Not evident  
DEO - Desired Environmental Outcome
The assessment of Ipswich City Council’s instruments is solely focused on the *Ipswich Planning Scheme 2006* as the council is yet to release a climate change strategy. The Planning Scheme provides some scope in terms of encouraging a virtuous cycle in its jurisdiction as well as identifying some possible linkages with other planning instruments in operation in the region such as the *Native Title Act 1993*. Nonetheless, there is no explicit direction in the plan towards adaptive planning, cross-sectoral and cross-scalar integration or other instruments fostering climate adaptation (see Table 7.2).

Given the recent amalgamation of Local Authorities in Queensland, the Sunshine Coast Regional Council is still in the process of elaborating a planning scheme that will reflect its current jurisdiction. Currently, planning regulations in the Council are guided by the previous planning schemes of the (former) Caloundra City Council (*Caloundra City Plan 2004*), Maroochydore Shire Council (*Maroochy Plan 2000*) and Noosa Shire Council (*The Noosa Plan*). Overall, through their DEOs, the three plans have significant provisions that encourage the region to manage growth and development whilst promoting a virtuous cycle. Of the three plans, only The Noosa Plan identifies the DEOs’ role in the plan’s review process.

The Sunshine Coast Regional Council has recently release its draft climate change strategy; *Draft Climate Change Strategy 2009-2020*. The strategy has four policy themes, including council leadership with a strong approach on partnerships and review which advances towards a more engaging and flexible framework avoiding incrementalism. The strategy also provides for the collaboration of governments and stakeholders as well as encouraging adaptation to be mainstreamed and linked with other Council’s strategic documents. The strategy, however, has a strong focus on energy matters and is mostly focused on climate change impacts (see Table 7.2).

### 4.2.3 Sectoral Implications of Spatial Vulnerability Assessment

Similar to other urbanising areas, the SEQ landscape has been subjected to significant change in the last two decades (Antrop 2004). Such change brought two key transformations to the regional landscape: 1) the intensification of urbanisation in the urban footprint with more infill development, including the coastal area; and 2) the change in the function of peri urban areas from mostly agricultural to low-density residential developments. These changes came as a response to the pressure to accommodate the population growth in the region, leading, for example, to the establishment of developed urban areas in close proximity to waterways and the shoreline. Although there have been deliberate choices of living in these areas as they offer high scenic amenity value and benefits to an enhanced lifestyle, such choices place these populations at a higher risk of exposure to forecasted climate change impacts for the region, such as extreme rainfall events and sea-level rise (CSIRO 2007).

The preliminary spatial vulnerability assessment presented earlier in this report indicates that there are a number of areas within the urban footprint that are susceptible to climate change related hazards. The assessment also identifies the challenges in interpreting vulnerability assessments, particularly in adopting their outputs as static and unchangeable end-products. This has many implications for the urban planning and management sector demanding on-going flexible approaches in the decision-making process.

The assessment also identified how local authorities in which the human settlements component case study areas are located might be susceptible to those climate change related hazards (see Table 5, Section 3). For instance, results for Brisbane City indicate a
Table 7.2: Assessment of planning principles at local level – Ipswich City Council and Sunshine Coast Regional Council

<table>
<thead>
<tr>
<th>Principles</th>
<th>Ipswich City Council</th>
<th>Sunshine Coast Regional Council</th>
<th>Draft Climate Change Strategy 2009-2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Planning avoids incrementalism by adopting an adaptive framework which is flexible, engaging, and is based on thresholds of change (including changing institutional and governance arrangements as well as scientific uncertainties)</td>
<td>***</td>
<td>***</td>
<td>** Planning Scheme highlights role of DEOs in its review process</td>
</tr>
<tr>
<td>2) Planning adopts a systems based approach that includes social, cultural and biophysical dimensions beyond traditional political and administrative boundaries, and promotes cross-scalar and cross-sectoral integration</td>
<td>** Division 2 – linkage between the scheme and Native Title</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>3) Planning fosters a Virtuous cycle which contributes to sustainability by creating, reinforcing, restoring, protecting and embedding political and economic mechanisms to reproduce valued places as well as environmental integrity</td>
<td>* Division 3 – protecting conservation areas and places of cultural significance from development; ** DEOs - (a) protection of significant natural features; (b) and environmental quality; (c) economic growth; (d) sustainable exploration of natural resources; (k) conservation of areas of cultural significance; (m) protection of agricultural areas</td>
<td>** DEO1 – diverse, dynamic and sustainable economic development; * DEO2/DEO4 – community wellbeing through encouraged diversity and identity, cultural heritage; DEO3 – sustainability of natural assets and resources – clear association with DEO2</td>
<td>** DEO1 – sustainability based on conservation of natural assets, community wellbeing and economic development; DEO2/5 – community inclusivity; DEO3- economic activity and development aligned with ecological sustainability and community wellbeing; DEO 6 – protection of built environment’s character and heritage</td>
</tr>
<tr>
<td>4) Planning is based on extensive collaboration between government, private sector and civil society</td>
<td>** Planning Schemes are prepared in alignment with Regional Plan and other relevant state legislation</td>
<td>** Planning Schemes are prepared in alignment with Regional Plan and other relevant state legislation</td>
<td>** Planning Schemes are prepared in alignment with Regional Plan and other relevant state legislation</td>
</tr>
<tr>
<td>5) Planning is buttressed by legislation, plans and policies at higher scales to support implementation and foster effective adaptation</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
</tbody>
</table>

* Evident ** Partially evident *** Not evident
DEO - Desired Environmental Outcome
number of pockets with extremely high net vulnerability to extreme heat and coastal hazards, and a significant number of suburbs with medium to high net vulnerability to extreme heat and extreme rainfall. In some locations this high vulnerability is aggravated when coupled with low adaptive capacity. In addition, the large proportion of suburbs with medium net vulnerability indicates that those impacts can disrupt the livelihood of a significant part of the population. For the area comprised by Moreton Bay Regional Council, results indicate a number of pockets with high vulnerability to extreme heat, extreme rainfall and coastal hazards. The area also has a couple of locations with extremely high total net vulnerability, particularly compounded by their low adaptive capacity. Results for the Gold Coast City also identified a number of hot spots with extreme and high net vulnerability to extreme heat, extreme rainfall and coastal hazards. Overall, those coastal areas also present relatively medium to low adaptive capacity which could adversely impact the response process. In the case of Ipswich City, results identified a number of hot spots with extreme and high net vulnerability and significant parts of the urbanised area present medium net vulnerability overall. Many of those areas in Ipswich also have relatively low adaptive capacity increasing the challenges in adapting to those events. The Sunshine Coast Regional Council area has a number of pockets with high and extremely high net vulnerability to extreme heat, extreme rainfall and coastal hazards. Results for this local authority area also identified a number of locations with medium net vulnerability to those hazards. The Sunshine Coast Region has no defined trend in terms of adaptive capacity with pockets of extremely high to extremely low net vulnerability. This illustrates the complexity involved in preparing and implementing climate change adaptation strategies (Cutter et al 2000), a process that is further compounded by the significant amount of the local authority’s population that could be potentially affected by climate change related hazards.

In summary, the preliminary spatial vulnerability assessment for SEQ re-enforces the region’s susceptibility to key climate change related impacts such as extreme heat, extreme rainfall and coastal hazards and the need for adequate preparation and response through adaptation measures. The vulnerability to extreme heat, for instance, will require the development and adoption of planning strategies that contribute to minimising the impacts of heat upon the region’s population, particularly those groups which are most at risk such as the elderly and young children. Urban design can play a key role in reducing such vulnerability through managing elements of the urban fabric that can reduce the occurrence of heat island effects which can be intensified during periods of extreme heat. Hence, urban planning can encourage urban design to take careful consideration for the choice of urban materials and their thermal properties, for the allocation of urban green spaces and types of vegetation in use, to improve air flow and ventilation, and the reconfiguration of impervious surfaces (Coutts et al 2010; Stone & Norman 2006). Although urban design can be easily addressed in new developments, the current urban containment and consolidation imperative carries a major challenge ahead for planners and urban managers in terms of improving their performance in the face of extreme heat. In addition, the planning system will also need to consider strategies towards the retrofitting of existing housing stock and developed areas to improve their performance in case of extreme heat events.

A number of floodplains in the region have been developed as a consequence of earlier planning decisions that did not consider climate change impacts. Those areas will configure a further challenge for the planning system in order to reduce their risk to flooding events subsequent to extreme rainfall events. As such, planning strategies will now play a key role in identifying suitable retrofitting measures to minimise and reduce the risk of harm in those areas to human life and property. In addition, planning strategies will also be crucial in
identifying appropriate areas for future greenfield and brownfield developments to manage current and future population growth whilst ensuring those precincts are not located in areas prone to flooding. In this context, existing and new planning schemes will require careful revision to ensure other flood-prone areas are excluded from future development.

Adding to the string of implications of climate change impacts upon SEQ’s planning process is the projected sea-level rise and increase in the occurrence of coastal hazards such as storm surge and beach erosion. Currently, SEQ has a significant amount of urbanised areas located nearby the coastal shoreline, including vast transport and other infrastructure networks (Wang et al 2010). Review of planning practices managing the region’s coastal shoreline will be required to address those climate related impacts in terms of retrofitting existing urban consolidated areas as well as exploring the possibility of retreating existing settlements to areas at less risk of harm. In addition, future infrastructure plans will need to consider the impacts of climate change such as storm surges and salt water intrusion and ensure sufficient funds are allocated to investigate alternatives as well as maintain existing infrastructure that could be at risk.

4.2.4 Sectoral Vulnerability (challenges)

The preliminary spatial vulnerability assessment identified that SEQ has many areas susceptible to climate change related impacts such as extreme heat, extreme rainfall and coastal hazards. Local authorities in the region have made considerable progress in developing policies geared toward climate change strategies in the last few years despite the fact that there was no statutory obligation to do so (see Tables 7.1 and 7.2). On the other hand, the analysis of the current planning schemes illustrates that adjustments will need to be made in order to improve planning practices. This include more flexibility in the planning process through adaptive management in order to deal with uncertainties and evolving climate science, better cross-scalar and cross sectoral integration in the policy delivery process, improved governance through better coordination between tiers of government, private sector and public engagement, as well as the establishment of provisions that specifically deal with climate change related hazards.

Additionally, a number of barriers will need to be overcome by local authorities to implement climate adaptation strategies in a well-coordinated manner that integrates multiple sectors as to achieve holistic implementation. Based on a United Kingdom study of local authorities, those barriers affect both the development and implementation of climate change strategies at the local level where the climate change hazards will have more severe impacts. These include the lack of statutory requirement for local authorities to prioritise climate change; the difficulty of cross-departmental cooperation and integration; the difficulty in community engagement aimed at minimising climate change impacts; and the lack of staff and skills to address climate change related issues (Allman et al 2004, p. 278). Hence, crucial challenges for the planning process in the SEQ region in terms of addressing climate adaptation include:

- Effective horizontal and vertical coordination and integration between planning and other adaptation instruments within the region, and between land use and infrastructure planning (including provision and maintenance of infrastructure);
- Inclusion of climate change impacts in local and regional statutory and non-statutory plans balanced with other non-climatic drivers of regional-scale landscape change;
- Adequate balance between mandatory and voluntary adaptation and
engagement of the non-government sector in the climate adaptation decision making process;

• Adequate adaptation strategies and planning for the urban landscape in synergy with adaptation options for adjacent natural areas to foster the long term biodiversity conservation and ecosystem services values of those areas;

• Identifying and overcoming legal and other barriers to climate change adaptation through statutory and non-statutory planning;

• Adequate prioritisation of policy response to specific climate change impacts at local and regional levels.
4.3 Coastal Management

Australia is one of the most sparsely settled, yet most highly urbanised, countries in the world (Williams 2007) with some 84 percent of the population concentrated within 50 kilometres of the coastline (ABS 2003). While there are many factors that contribute to the popularity of coastal areas perhaps the most influential reason is linked closely to historical settlement patterns and high scenic amenity values. The coastal zone is a highly dynamic and fragile environment influenced by coastal dynamics and climatic processes, such as sea-level rise and storm surge events. With increased pressure being placed on the natural resource base and the potential exposure of coastal areas to climate perturbations (Hennessy et al 2007), coastal localities have gained increased attention in the planning and policy domains.

Climate change has the potential to affect the whole coastal system, including the environment, settlements and industry (Department of Climate Change 2009). Of particular concern are sea-level rise and an increase in intensity and frequency of storm surge events. It is a combination of these processes that increases the risks of coastal erosion and inundation.

Current and emergent coastal management approaches are underpinned by an integrated framework. This approach utilises scientific and technical information, such as climate change vulnerability and adaptation principles, as its theoretical basis. As climate change projections carry significant uncertainties, approaches to coastal management also have to include integrated assessments of vulnerabilities and risks to inform adaptation options. While these approaches are yet to be widely applied worldwide, a number of countries with established coastal management traditions can provide valuable insights. In Australia, however, the integration of climate change in coastal management remains a key challenge. This is largely the result of limited statutory obligations and uncertainties surrounding climate change projections. At present, there are only certain aspects of climate change that have been considered in state coastal plans and policies. For example, sea-level rise projections have been considered for SEQ, but other drivers such as wave patterns and storm surge events have largely been neglected. As such, this section discusses the implications of climate change to coastal management through the review of current and emergent approaches and an analysis of current practice affecting SEQ. Furthermore, it also discusses climate change implications to coastal management in terms of the regional spatial vulnerability assessment presented earlier in this report.

4.3.1 Current and emergent approaches

Current approaches to coastal planning and management at the international scale are based on the theory and practice of Integrated Coastal Zone Management (ICZM). ICZM emerged in the early 1990s as a systemic and sustainable approach to governance to improve the integration between natural processes and coastal communities (Vallega 1999). The objective of ICZM is to manage complex problems through an iterative and participatory process to improve the quality of the coastal system as a whole, whilst adapting human uses, settlements and activities to complex changes, protecting sensitive ecosystems and maintaining flows in highly dynamic environments (Kay & Alder 2005). Key principles for the implementation of ICZM theory are widely reported in the literature (Clark 1996; Cicin-Sain et al, 1998; Vallega 1999; Chua 2006; Kay & Alder 2005), with the majority relevant to climate change adaptation. These principles include:

1. Systems approach: the coast is a complex socio-environmental system composed of dynamic physical processes, fragile ecosystems and vibrant
economies and communities. Components, relationships and processes inside the system must be identified, understood and used in the planning and management process.

2. Community engagement: ICZM processes are based on the construction of consensus around the recognition of coastal problems and the identification of possible solutions.

3. Spatial dimensions: the coastal zone is a broad fringe where borders are identified either by physical processes, ecological flows or human boundaries. A correct definition of the spatial dimension of the problem can avoid unintended consequences while implementing alternative solutions.

4. Data and information management: the system can be managed effectively if data and information is available and collected. Specific problems can only be described by specific information, either qualitative or quantitative. Improvement of the system performance should be measured and monitored over time.

ICZM theory has been addressing human-induced climate change and sea-level rise since its first steps during the preparation of UNCED’s Agenda 21 (UNCED 1992). While ICZM mainstream discourses from the late 1990s were strictly connected with global and climate change issues (see for example, Vallega 2001), there was the recognition that existing practices needed to be expanded to include the implications of climate change through more comprehensive vulnerability assessments. At the same time, climate change uncertainties had to be addressed by making ICZM a true adapting process (Nicholls et al 1999).

Current and emergent approaches in coastal management are mostly informed by integrated assessments of vulnerabilities and risks. Although these approaches address the complex relationship between coastal settlements and climate change, they are curbed by the limitations inherent to both risk and vulnerability assessments. For instance, risk assessment procedures used to inform coastal management provide quantitative assessments, measure the combination of the likelihood of an event and its consequences and follow standardised procedures to identify, analyse, evaluate and treat risks, such as the ones included in the ISO Standard 31000. This approach has been adopted by some of the most recent studies of coastal climate change risks (Department of Primary Industries and Water 2009). It provides guidance for developing risk management plans in the coastal zone, as it is designed to assist in the assessment of risks to specific coastal assets or discrete local areas, such as the number of assets at risk, and to identify realistic and effective responses (Department of Primary Industries and Water 2009). Risk assessments, however, often lack the inclusion of social components, such as demographic and socio-economic characteristics of coastal communities.

As such, information provided by risk assessments can be complemented by integrated vulnerability assessments, as they include social data. Few coastal vulnerability and risk studies currently available in the scientific literature, however, provide effective techniques that enable the transference of an integrated vulnerability approach into practical measures. Most of the studies focus on assessing coastal vulnerability based on physical variables, such as sea-level rise, mean wave climate, extreme storms, beach geomorphology and erosion rates. These studies, however, pay less attention to the social, economic and governance components of the system (Abuodha & Woodroffe 2006; Tol et al 2008). In addition, these vulnerability assessments focus mainly on the impact of sea-level rise or climate variability on the present without considering non-climatic changes in coastal areas,
which have characterized the last decades and are likely to continue in the future (Nicholls et al 2008).

Although risk and vulnerability assessments are distinct tools, the concepts themselves are often interchanged for communication purposes (e.g. Department of Climate Change 2009). It is important to configure such distinction as integrated assessments of coastal vulnerability to climate change should consider exposure, sensitivity and adaptive capacity of coastal communities, taking into account socio-economic and demographic characteristics and trends. Integrated vulnerability assessments, combined with the analysis of risks, can, for example, provide relevant information to guide investment priorities in climate adaptation. Hence the identification of adaptation options should be based on a systematic approach integrating technological solutions, social dynamics and the institutional context.

The international experience in coastal management of a number of countries could provide meaningful insights to inform the current challenges posed by climate change to coastal human settlements. The analysis carried out by Norman (2009b) shows that some countries, such as the Netherlands, are more adapted to coastal processes as a result of their long term natural vulnerability. Other countries, including New Zealand, present significant national commitment to adaptation by adopting a comprehensive risk management approach (New Zealand Ministry of the Environment 2008). Where a national emphasis on climate change has been absent, ICZM has provided an umbrella for adaptation responses such as in some parts of the United States, through the implementation of the Coastal Zone Management Act (CZMA).

In Australia, a number of adaptation strategies for coastal communities have been implemented in the last decades, such as coastal erosion policies in the Byron Shire and on-going beach nourishment and sea walls/groynes at the Gold Coast. In the absence of an overarching national coastal policy, coastal management in Australia is implemented at the state level, including the development of coastal policies to a changing climate and the integration of climate projections. The New South Wales Government, for example, has recently issued a Sea Level Rise Policy Statement reporting a projected rise of up to 40 cm by 2050, and 90 cm by 2100 for its coastline. This policy has prompted the Byron Shire Council to include sea-level rise projections into its earlier 2002 planning scheme, setting development standards in coastal areas at risk within the shire (Water Research Laboratory UNSW 2009). Despite the efforts at international, national and local levels, effectively addressing climate change adaptation in the context of uncertain futures remains a challenge (Adger et al 2005). The integration of flexible adaptation measures to an uncertain future is still an under-explored and poorly understood field of research.

4.3.2 Current practice affecting SEQ

SEQ is one of the most developed and fastest growing coastal regions in Australia (Department of Infrastructure and Planning 2009). This trend is set to continue as its coastal population is expected to grow by 60% in the next 20 years (Wang et al 2010). Given the high population concentration within the coastal zone, coastal settlements in SEQ are extremely vulnerable to climate change impacts, including sea-level rise, changing wave climate and extreme events.

The coastal management framework applicable to the SEQ region includes a range of policies, plans and schemes issued by the various tiers of government. While the federal government offers limited guidance to the States in the implementation of their coastal
policies, similar to all other states, the Queensland Government has the responsibility for natural resource management and statutory land use planning, including coastal zone management. Local councils are responsible for integrating state coastal policies into local government instruments, such as planning schemes and shoreline management plans.

The integration of climate change policies into coastal management practice at the state level has been a slow process, particularly due to the limited guidance provided by the Federal Government in addressing this specific issue at the national level. Despite this, the Queensland Government is reviewing its coastal planning and management framework to include the challenges posed by climate change, such as incorporating sea-level rise and increasing cyclone intensity into coastal policies. However, the most critical position is occupied by coastal local governments who face complex day-to-day decisions both when preparing climate-adapted planning schemes and when assessing new development proposals (Harvey & Caton 2003). According to Withycombe & Morrison (2008) the major roles and responsibilities of local government in coastal planning and management are:

- Land-use planning and development control including generic infrastructure provision;
- Planning, construction and management of specific coastal management infrastructure;
- Planning, construction and management of other civil infrastructure in the coastal zone;
- Planning, construction and management of water quality management infrastructure;
- Management of public access to and use of the foreshore;
- Community awareness and engagement; and
- Environmental protection, enhancement and management.

Changes in climate figures and the uncertainties in climate projections are likely to exacerbate current issues in the future and increase the challenges that local governments have to address in coastal management.

**National Level**

The Federal Constitution confers no specific responsibilities on the Commonwealth Government with respect to environmental management and land use planning – these powers rest with the State governments. It can, however, take a leadership role in coastal management through its responsibilities under international treaties and agreements and through its considerable financial powers. In the past, the Commonwealth has commissioned a number of reports and conducted a number of inquiries into coastal planning and management in Australia. The 1993 Resource Assessment Inquiry ultimately resulted in the development of the 1995 *The Commonwealth Coastal Policy* (Commonwealth of Australia 1995). This early Policy included consideration of climate change and sea-level rise as a priority issue. One of the objectives of this policy recognised the consequences derived from the dynamic nature of coastal environments. It also acknowledged the existence of natural fluctuations in sea level and climate change, as well as the impacts related to storm events and changes in the shoreline position. In 2006, the Commonwealth Government released the *National Framework for Integrated Coastal Management* (ICM) which included consideration of climate change (Commonwealth of Australia 2006). Whilst this document included an implementation plan, it has never been implemented. The House of Representatives recently concluded an inquiry into climate change and environmental impacts on coastal communities, with
submissions suggesting that there was a national role for the Commonwealth Government in coordinating state and local activities. This would include the provision of an agreed sea-level rise, a tool box of possible actions and a collaborative research agenda (Commonwealth of Australia 2009b). Whilst the recommendations and implementation actions contained in these reports and initiatives carry no statutory obligations for state and local governments, they are at times informally used to address and inform coastal policies at the state, regional and local levels.

State and Regional Levels

Queensland’s coastal management operates under the provision of the Coastal Protection and Management Act of 1995 (revised 2003) which establishes the requirement for state coastal plans. As a SPP the Plan has statutory effect under Section 50 of the Act and applies to the coastal zone in Queensland. The Coastal Plan of 2001 is currently under revision and a draft State Coastal Plan is currently undergoing a consultation process. This Plan has two major components:

1. a Draft State Policy Coastal Management providing guidance for land and coastal managers to effectively maintain, rehabilitate and protect coastal land; and

2. a stand-alone Draft State Planning Policy Coastal Protection to address land-use planning and development assessment decision making within the coastal zone.

A SEQ Regional Coastal Management Plan (2006) was also produced under the Coastal Act of 1995, but the review of the State Coastal Management Plan found that regional coastal management planning is a redundant instrument due to remote mapping technology and the regional planning process under the state planning provisions. As a result, the requirement for the preparation and revision of Regional Coastal Management Plans no longer applies to SEQ or other regions in Queensland. Despite this, along with the existing State Coastal Management Plan, the SEQ Regional Coastal Management Plan 2006 will continue to be statutory instruments under the statutory Regional Plan and can be used to guide relevant decisions (Department of Environment and Resource Management 2010). The Coastal Protection and Management Act of 1995 does not consider climate change or sea-level rise as issues to be addressed by coastal management plans. Despite this, the current Draft Coastal Management Plan (2009) is attempting to consider climate change having the following effects associated with coastal hazards:

- Acceleration of existing erosion processes;
- Increased frequency of extreme erosion and storm tide inundation events;
- Alteration of coastal sediment transport patterns and associated shifts in wave direction triggering changes to the form and location of shorelines;
- Permanent inundation of very low-lying areas due to sea level rise;
- More frequent inundation of areas affected by storm tides; and
- Extension of storm tide inundation further inland.

Detailed data for coastal planning have been produced based on the IPCC (2007) and CSIRO (2007). These data provides a basis to identify:

1. In the case of coastal areas not subject to a development commitment - a planning period of 100 years, involving a 100 year average recurrence interval of extreme water levels; a projected sea-level rise of 0.8 m; and an increase in cyclone intensity of 10% due to climate change.
2. In the case of coastal areas subject to a development commitment - a planning period equal to the expected asset life, involving: a 100 years average recurrence interval of extreme water levels; a variable sea-level rise depending on the life of the asset (e.g. an asset expected to serve for 40 years, such as a short term tourist accommodation, should consider a 0.3 m sea level rise by 2050); and an increase in cyclone intensity of 10% due to climate change.

These data can be used to determine hazard prone areas and to avoid development in areas at risk. The Draft Plan’s objective is to locate development outside the areas at risk (hazard prone areas). Coastal hazard areas must be determined and included in local government planning schemes and considered in developing new regional plans. The plan explicitly notes that these data can be subject to review as a new assessment will be realised in 2014 based on new scientific information and releases of IPCC and CSIRO.

**Local Level**

SEQ’s five coastal local government areas (Sunshine Coast Regional Council, Moreton Bay Regional Council, Brisbane City Council, Redland City Council and Gold Coast City Council) are characterized by different types of coasts and exposure to climate change. While each has the obligation to apply the provision of the State Government, they each have a different approach to coastal management, based on their coastal type and local priorities. The integration of climate change into local coastal policies is not homogenous across these councils, as illustrated in Table 8. This table shows that most of the councils have not integrated climate change policies into their planning schemes and development assessment processes. Most of the councils are considering sea-level rise as a broad risk to be assessed as a part of their climate change strategies. Changes in average wave climate and extreme events are also not considered. This could be justified by the lack of specific information and high uncertainties in current climate change projections.

**4.3.3 Sectoral Implications of Spatial Vulnerability Assessment**

The sedimentary nature of most of SEQ’s shoreline and coastal areas makes them extremely sensitive to changing physical processes, such as sea level fluctuations, extreme storms and changes in the sediment transport and supply. This sensitivity is not a major issue for pristine coastal environments that are naturally resilient to coastal change but it is a trigger for complex problems to human settlements and infrastructure developed near the shore.

One of the major concerns of coastal management is to address, control and adapt the relationship between the built environment and coastal communities with coastal processes and changes. This is not new to the discipline but climate change is likely to exacerbate and accelerate the impacts of natural coastal processes, such as erosion, recession and flooding.

Coastal erosion and recession is occurring in different parts of the SEQ coast, with the Gold Coast and the Sunshine Coast being the most sensitive areas. According to the *SEQ Regional Coastal Plan* (Environmental Protection Agency 2006), most of the region naturally includes coastal erosion prone areas. The identification of these areas was completed previous to any government commitment to climate adaptation and is based on a study carried out by the (former) Beach Protection Authority in 1984. Sea-level rise and changes in the mean wave climate and extreme events are likely to increase these erosion and recession processes, exposing highly developed areas across the region.

The previously discussed spatial vulnerability assessment shows that most coastal
<table>
<thead>
<tr>
<th>Organization</th>
<th>Instrument</th>
<th>Year</th>
<th>Sea-level rise</th>
<th>Changing average wave climate</th>
<th>Changing extreme events</th>
<th>Enforcement in coastal planning and management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Queensland Government</td>
<td>Draft State Coastal Management Plan</td>
<td>2009</td>
<td>80 cm by 2100 (CSIRO)</td>
<td>Not considered</td>
<td>10% Increase</td>
<td>Yes</td>
</tr>
<tr>
<td>Brisbane City Council</td>
<td>Climate Change And Energy Taskforce Report</td>
<td>2007</td>
<td>Narrative</td>
<td>Not considered</td>
<td>Narrative</td>
<td>N/A</td>
</tr>
<tr>
<td>Gold Coast City Council</td>
<td>Climate Change Strategy 2009-2014</td>
<td>2009</td>
<td>18-79 cm (IPCC)</td>
<td>Not considered</td>
<td>Not considered</td>
<td>No</td>
</tr>
<tr>
<td>Gold Coast City Council</td>
<td>Gold Coast Shoreline Management Plan</td>
<td>2007</td>
<td>Not considered</td>
<td>Not considered</td>
<td>Not considered</td>
<td>Not considered</td>
</tr>
<tr>
<td>Moreton Bay Regional Council</td>
<td>Moreton Bay Regional Council Climate Change Risk Assessment</td>
<td>2009</td>
<td>80-200 cm (Pfeffer et al 2008)</td>
<td>Not considered</td>
<td>Not considered</td>
<td>N/A</td>
</tr>
<tr>
<td>Redland City Council</td>
<td>Not Considered</td>
<td>Not considered</td>
<td>Not considered</td>
<td>Not considered</td>
<td>Not considered</td>
<td>N/A</td>
</tr>
<tr>
<td>Sunshine Coast Regional Council</td>
<td>Planning For A Sustainable Sunshine Coast</td>
<td>2009</td>
<td>Narrative</td>
<td>Not considered</td>
<td>Narrative</td>
<td>N/A</td>
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</table>
suburbs of the region are directly or indirectly exposed to sea-level rise and extreme storm surges. The potential impacts of these events, including erosion and inundation, are likely to raise awareness on the sensitivity of these coastal environments to natural processes. The response of the coastal communities and institutions will reflect their capacity and willingness to adapt. In this regard, physical adaptation options can be framed into three broad categories: (i) defend the coastline; (ii) accommodate sea level rise and storms; and, (iii) planned retreat towards safer areas.

The overall vulnerability of the system can only be reduced by increasing the adaptive capacity of the coastal community, as exposure and sensitivity are intrinsic properties of the coastal system and are not easily modifiable (e.g. they include climate forcing, coastal geomorphology, population age distribution). Adaptive capacity depends on the combination of a number of human variables including, but not limited to: technological solutions; financial resources; climate change awareness; and willingness to adapt.

This initial spatial vulnerability assessment, which includes coastal areas of SEQ, represents a preliminary first pass assessment based on the spatial analysis of the vulnerability of coastal suburbs using available data and information on exposure, sensitivity and adaptive capacity of the system. The exposure map for coastal hazards shows that many SEQ coastal suburbs lie, on average, in low elevated land exposed to sea-level rise. This exposure is exacerbated when the area combines highly erodible beaches, canal estates and dense and growing populations, such as in parts of the Gold Coast and the Sunshine Coast. Specific parts of Moreton Bay are also exposed to rising sea levels, such as the suburbs north and south of the Brisbane River mouth and the Port of Brisbane. In parallel, the sensitivity map for coastal hazards shows that most of the coastal suburbs lie in very sensitive sedimentary systems. The adaptive capacity of coastal communities is in general medium to high reflecting the high socio-economic status of most coastal communities in the region, characterized by higher income and education than other less advantaged areas. There are, however, some areas of low adaptive capacity along the coastline.

The net vulnerability assessment for the coastal region shows that there are numerous coastal suburbs that are highly vulnerable to coastal climate change in SEQ, namely Surfers Paradise and Palm Beach in the Gold Coast, Kawana Waters in the Sunshine Coast, the mixed industrial-residential suburbs near the Port of Brisbane and residential areas of Redcliffe City.

4.3.4 Sectoral Vulnerability (challenges)

The vulnerability of SEQ’s coastal areas and of the coastal planning and management system is high due to both the characteristics of the physical system and the human settlements, and the weaknesses of the current coastal planning and management system. The reduction of sectoral vulnerability should pass through the identification of sustainable options to defend, accommodate or retreat communities to safer areas to address the challenges posed by climate change. However, those options are highly context specific and require robust investigation to better inform decision-makers. Recent research by Bussey et al (2010) investigating past adaptation events suggests that it is more likely that communities will adapt using a reactive approach rather than a proactive and anticipatory approach, especially when uncertainties on future climate are still high (Bussey et al 2010). These issues should be considered while planning for adaptation in coastal areas.

Some of the major issues faced by coastal management include: the integration of climate
change projections into policies, plans and instruments; the flow of information between the scientific community and the policy makers; and the integration of a spatial buffer into coastal policies, plans and instruments to address uncertainties in sea level rise projections. In the last few years the scientific community has been focusing on climate change issues in the coastal zone, both worldwide and in Australia. This interest has grown exponentially and institutions are facing complex decisions to identify the most appropriate approach to integrate shifting climate change data into coastal policies at different levels of planning and management. This represents a critical vulnerability of the coastal management system to climate change.

According to Lowe & Gregory (2010), the climate science community needs to communicate effectively that sea-level rise is likely to continue, even if exact figures are uncertain. Whilst science cannot provide certainties, scientists must become better at explaining the uncertainties to decision-makers. These uncertainties imply the need to maintain an adaptive process that is able to change planning and management options, as new science and information is made available.

In summary, specific challenges to reducing SEQ’s vulnerability to climate change-related coastal hazards, include:

1. Reduce vulnerability of the system by increasing its adaptive capacity. This should include investments in technological adaptation options but also targeting social and institutional awareness through education, training and capacity building; and

2. Manage coastal adaptation in a context of uncertainty and changing climate projections. This may require flexible mechanisms to incorporate new sea-level rise and wave climate figures into coastal plans and shoreline erosion management plans. New concepts will need to be integrated into local planning schemes such as dynamical buffer zones capable of accommodating worst case scenarios with overall lower costs for the society in the long term.
4.4 Human Health

One of the most complex and widespread impacts of climate change is its potential to adversely impact on human health and wellbeing. Within the emerging literature it is generally understood that the impacts of climate change on human health will be uneven across different groups in society and different geographical or regional scales and will pose a range of vulnerabilities to processes within the health sector (Carey 2007; McMichael et al 2006; Tong et al 2008; Preston and Jones 2006). Understanding vulnerabilities associated with climate change is therefore an important component of the research agenda.

4.4.1 Current and emergent approaches

The impact of climate on human health is both direct (e.g. thermal stress, flood and fire injury and death, post traumatic stress and increased mental illness) and indirect, through disease (e.g. Ross River fever), contamination (e.g., food and water supply) and environmental degradation, such as poor air quality and loss of crop land (McMichael et al 2003; Confalonieri et al 2007; Patz et al 2005). Direct health impacts tend to be dramatic but, in relative terms, restricted in time and scope. Indirect impacts are more insidious with the potential for enduring and widespread social consequences. The drama of the immediate physical damage wrought by natural disaster, portrayed in images of incinerated structures, floating towns and highways of wind destruction, tends to obscure personal and social costs. Nevertheless, the longer-term damage to households and communities should not be underestimated.

The actual health consequences of climate change are strongly influenced by the socioeconomic context. The more cohesive and/or wealthy the community and the more developed the institutional and technological structure, the greater the capacity to respond to both the catastrophic and structural health challenges of climate change. The age structure of the impacted population is also important with the aged, infants and people with underlying poor health being particularly vulnerable. The health impacts of climate change also vary widely by environmental setting. Affected areas may, for example, be tropical or temperate, rural or urban, coastal or inland and so forth. The potential health impacts associated with climate change are described in Table 9.

4.4.2 Current practice affecting SEQ

A range of research literature has identified the potential health vulnerabilities confronting SEQ in the future. While a global review of health vulnerabilities identifies a range of possible issues, a broad SEQ regional vulnerability assessment identifies that fatalities, injuries and indirect health problems (i.e. mental health conditions) will be most likely to follow extreme heat wave events, extreme rainfall events and associated flooding. Modelling suggests it is unlikely that vector borne diseases such as malaria or dengue fever will be an issue as far south as the SEQ region unless an unforeseen vector is introduced.

As previously noted, the coastal area of SEQ is one of the most flood prone areas in Australia (Abbs et al 2007) and heavy rainfall escalates the potential for severe flooding in the region. It can be argued, on historical data, that fatalities and injuries from flood events pose a serious risk in the region. On average they are responsible for half of all fatalities attributable to natural disasters – or the same number as all the other forms of natural disaster put together. It is estimated at least 2,213 people died in Australian floods between 1788 and 1996 at an average of 10.5 deaths per year (Coates 1999). A greater but uncounted number
were injured. As both population and the frequency of flood increase, these numbers, in the absence of significant intervention, will rise. Modelling of flood fatalities and flood injuries suggest that the SEQ region will likely witness an increase into the future (McMichael et al 2003).

The Australian Bureau of Meteorology noted that heatwaves are probably the most under rated weather hazard in Australia, as it is viewed as a passive hazard. It is estimated that each year 1,100 people die in Australian capital cities who are 65 and above years old due to heatwaves (McMichael et al 2003). In January 2000, heatwave caused 22 deaths, 350 injuries in SEQ and the estimated costs were $2 million (Queensland Health 2004). The number of deaths increased to 185 in Brisbane when maximum temperature increased to 42°C in February 2004 (Tong and Ren 2006). During the February 2004 heatwave, 221 people were hospitalised in SEQ (Queensland Health 2004). Given this historical situation and the expected aging of the Australian population generally and the socio-economic and demographic context of the SEQ region in particular, heatwave related health issues will be an increasingly important regional climate change issue. Projections (McMichael et al 2003) suggest that for Brisbane alone the potential death rate attributable to heatwaves could

<table>
<thead>
<tr>
<th>Table 9: Potential health impacts of climate change and variability.</th>
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<tbody>
<tr>
<td><strong>Health concerns</strong></td>
</tr>
<tr>
<td>Temperature related morbidity and morality</td>
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<td></td>
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<tr>
<td>Extreme weather events</td>
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<td>Vector borne disease</td>
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<td>Food borne disease</td>
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<td>Water borne disease</td>
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<tr>
<td>UV radiation</td>
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<tr>
<td>Air pollution</td>
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</table>
Vulnerability and challenges for the health sector

Addressing concerns surrounding these potential diseases and health outcomes is a pressing challenge for the health sector. For the public health sector there is a need to concentrate on known health burdens that are likely to be exacerbated by climate change impacts, and the most effective, efficient and equitable approaches to managing and adapting to those exacerbated risks. The challenges for the public health sector revolve around how climate change vulnerabilities impact on traditional areas of public health influence. Examples of climate change challenges relevant to selected public health roles are set out in Table 10 (Frumkin et al 2008). How the public health system deals with these issues and the size of the issues that particular jurisdictions face will be governed by regional and geographical factors driving different climate change hazards, the population variability and characteristics which will determine how different individuals and groups/communities face health vulnerabilities and the overall complexity of the climate change issue. Some jurisdictions will already have

<table>
<thead>
<tr>
<th>Public Health Role</th>
<th>Climate Change Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Monitor health status to identify and solve community health problems</td>
<td>Tracking of diseases and trends related to climate change</td>
</tr>
<tr>
<td>2. Diagnose and investigate health problems and health hazards in the community</td>
<td>Investigation of infectious water-food and vector borne disease outbreaks</td>
</tr>
<tr>
<td>3. Inform, educate and empower people about health issues</td>
<td>Informing the public about health impacts of climate change</td>
</tr>
<tr>
<td>4. Develop polices and plans that support individual and community health effects</td>
<td>Municipal heatwave preparedness plans</td>
</tr>
<tr>
<td>5. Mobilise community partnerships and action to identify and solve health problems</td>
<td>Develop public health partnerships and recognise cross-sectoral limitations</td>
</tr>
<tr>
<td>6. Link people to needed personal health services and ensure the provision of health care when otherwise unavailable</td>
<td>Health care service provision following disasters</td>
</tr>
<tr>
<td>7. Ensure competent public and personal health care workforce</td>
<td>Training health care workers about new and emerging issues associated with climate change</td>
</tr>
<tr>
<td>8. Evaluate effectiveness, accessibility and quality of personal and population-based health services</td>
<td>Program assessment of plans</td>
</tr>
<tr>
<td>9. Research for new insights and innovative solutions to health problems</td>
<td>Undertake research into climate change and health impacts</td>
</tr>
</tbody>
</table>

Source: Frumkin et al 2008.
in place satisfactory monitoring frameworks and well developed communication strategies but will face other challenges.

How the health sector within SEQ deals with these potential challenges will be driven by several factors, however the principal issues and challenges will revolve around:

- Obtaining a clearer understanding of the extent of the future health burden and a greater focus on disease prevention in the region;
- Rethinking health planning timeframes from short term to more medium- and long-term;
- Ensuring that effective surveillance and response systems are in place to manage any increases in infectious diseases;
- Rethinking communications policies and procedures, to include behavioural, knowledge and attitudinal shifts (Frumkin & McMichael 2008). Queensland Health already maintains a number of communication and education avenues (i.e. recovery from disaster fact sheets). However it is likely that these will need to be fine-tuned to meet new demands;
- Developing integrated and inter-agency measures that help reduce the potential impact of events on vulnerable populations, especially as many climatic risks to health lie beyond the usual scope of the public health sector; and
- Developing measures to articulate the work of local public health responses into broader inter-state or national responses. This is especially important as the impact of extreme events may cross state boundaries or involve a broader national response.

4.4.3 Sectoral Implications of Spatial Vulnerability Assessment

The result from the spatial vulnerability assessment adds to the challenges facing the health sector and raise issues regarding how, in meeting its climate change challenges, the health sector needs to account for the spatial variability in vulnerability. The spatial vulnerability assessment illustrates those communities or suburbs considered most vulnerable to the prospect of extreme weather events associated with climate change. Queensland Health and associated health agencies and stakeholders are all keenly aware of the potential impact of climate related events in the SEQ region. Recent extreme events such as extreme storms and flooding have highlighted the spatially uneven nature of these events and the need for health approaches to be mindful of such outcomes. The spatial analysis of vulnerability outlined through the mapping of exposure, sensitivity, adaptive capacity and overall net vulnerability, will aid health planners and policy makers to effectively develop appropriate measures across all four phases of prevention, preparedness, response and recovery.

The main benefit of the spatial vulnerability assessment for the public health sector is in its ability to identify those communities with extreme vulnerability and develop approaches to deal with potential impacts in these areas. While care needs to be taken not to assume that in terms of health outcomes every individual in a vulnerable community will be at risk and everyone in a community with low vulnerability will be risk free, focusing on those places with extreme vulnerability will allow local or community level health prevention and adaptation approaches to be developed in conjunction with broader regional or state level approaches. For instance, the visualisation of the different components of extreme heat events across the SEQ region and the total net vulnerability mapping has identified particular regional ‘hot
spots' of vulnerability. By understanding, in conjunction with other epidemiological modelling, how local vulnerabilities are produced and the potential spatial extent of vulnerabilities, local and state level health programs could be better targeted.

4.4.4 Sectoral Vulnerability (challenges)

The unique small scale spatial characteristics of vulnerability, when taken along side of broader regional concerns, are a reminder that public health engagement should not be limited to understanding responses to hazards and vulnerability at a single level or scale, but should be placed in a context of multiple levels (both bottom-up approaches and top-down approaches) to ensure the acceptance and validity of proposed programs. How to bring together bottom-up approaches that allow local ownership of adaptation measures with bureaucratic top-down measures will be an important challenge.

The spatial vulnerability assessment also makes clear that in dealing with the challenges posed by climate change, the health sector needs to understand the complexity of stressors and external drivers impacting on human health as a result of climate events. It can also facilitate an understanding of the likely local impacts of adaption approaches. Although biophysical events and conditions create exposure to a health hazard, the features of human and urban systems including the socio-economic characteristics of local communities or individuals, built form, structure and density, access to material resources and social networks all impact to increase or mitigate the health risk from exposure. Understanding these complexities and how they are played out at the neighbourhood or community level will be an important issue for the sector. Being able to differentiate these complexities at the local level (or at least beginning to understand them) is especially important in terms of adaptive capacity because approaches that focus on broad regional measures of adaptive capacity may not automatically translate into successful adaptations at a smaller scale local area. Understanding this local impact is therefore an important challenge for the health sector.
4.4 Emergency Management

SEQ is a region already prone to natural hazards but is likely to experience an increase in the intensity and frequency of extreme weather events due to climate change. More frequent extreme weather events combined with the projected population growth and development in areas of high exposure, such as floodplains and along the coastline, will have significant implications for the emergency management sector.

This section analyses the vulnerability of the emergency management sector in SEQ to climate change. It establishes the theoretical background to emergency management and highlights the different paradigm shifts that have occurred since the 1970s and which explain the changes in emergency management practices and approaches in Australia. It then identifies current national, state and local emergency management policies and initiatives. Finally, it assesses the sectoral implications of the spatial vulnerability assessment (see Section 3) and highlights the key challenges for emergency management arising from climate change.

4.5.1 Current and emergent approaches

Theoretical background to emergency management

The theoretical background to emergency management comes primarily from the natural hazards and disasters research fields and more recently also from risk management. Although disasters research originated from disaster sociology and natural hazards research emerged within geography, both fields are strongly linked and have since developed in close association with several disciplines from the natural and social sciences, including geography, anthropology, sociology and development studies. Following criticism during the 1970s and 1980s of the narrowness of the theory, the singular focus on extreme natural events and ignorance of the anthropological literature on human-environment relations, natural hazards research in the 1980s and 1990s moved away from this central focus on extreme natural events and placed greater emphasis on the importance of social, economic and political conditions in modulating the impact of hazards (Cutter et al 2000). This new work in disasters and natural hazards research in conjunction with the developments in the related fields of political economy/political ecology (e.g. Watts and Bohle 1993; Blaikie et al 1994) and entitlements theory (e.g. Sen 1981) led to a better understanding of the causes of disasters and particularly the interaction between natural hazards and vulnerability. Hazards/disaster research now considers not only the hazards themselves but also the specific contexts within which they occur and recognises that ‘natural’ disasters are not ‘natural’ but are instead attributable to a combination of socioeconomic factors that modulate the impact of environmental/natural hazards on human systems (Alexander 1991 and 1997; Tompkins et al 2008).

In line with this theoretical development, the disaster management sector saw a paradigm shift with disasters no longer viewed as a simple outcome of natural hazards but as unresolved problems of vulnerability and development. Disaster management practices evolved from a primarily top-down relief and response effort to a more comprehensive approach with the recognition of the importance of prevention and preparedness activities. In the late 1970s, work from the National Governor’s Association in the United States led to the development of the prevention, preparedness, response and recovery (PPRR) approach as part of a comprehensive emergency management policy framework (Cronstedt 2002; McEntire et al 2002).

Another relatively recent development within disaster management practices was the
incorporation of risk management and vulnerability analysis with the development of the disaster risk management approach. Disaster risk management is defined by the United Nations International Strategy for Disaster Reduction (UNISDR) as “the systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster” (UNISDR 2009, p.4). Disaster risk management aims to reduce the probability of a disaster occurring by addressing the underlying social, economic and environmental vulnerabilities (Sperling & Szekely 2005). It involves the full spectrum of disaster related activities, including understanding hazards, vulnerabilities and potential losses, as well as the full spectrum of PPRR activities (Prabhakar et al 2009).

More recently, there has also been a move towards an ‘all-hazards’ approach, which considers the risks arising not only from natural hazards but also from all types of man-induced hazards/disasters, including terrorism. Since the 2001 terrorist attacks in New York, some countries have even seen a subtle shift away from the dominant PPRR approach to a crisis/consequence management approach (Pearce 2008). This shift could have significant implications, as Pearce (2008) argues that it would result in pre- and post-event/disaster activities occurring as separate processes and in resources being increasingly directed towards crisis management activities at the expense of consequence management activities.

Despite criticisms of the PPRR model, including suggestions that it creates an artificial division between the four elements, promotes a linear and temporal relationship between these elements and has led to a system focused on the response phase (see Salter 1997; Crondstedt 2002; McEntire et al 2002; Lewis 2006), it still enables a comprehensive approach to emergency management and remains the main model used by emergency management agencies.

**Emergency management approaches in Australia**

Australian emergency management organisations adopted the PPRR model following its development in the United States. However, during the 1990s emergency management in Australia went through a period of significant change. A paradigm shift was occurring (see Table 11), with a greater recognition of disasters as the ‘interface’ between extreme events and vulnerable populations, a shift in focus from response to mitigation and preparedness, and an increasing recognition of the importance of community involvement (Salter 1997;
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Pearce 2003; Pitman 2006). This shift took the focus away from specific hazards, thus allowing for a greater focus on vulnerability and the management of social impact, and a greater emphasis on community planning, such as land use policies and floodplain management (Salter 1997; Pearce 2003). In addition, the 1994 Senate Standing Committee Report argued that emergency management arrangements in Australia were too response focused and needed to switch to a more comprehensive and integrated approach, with a greater focus on prevention, preparedness planning, training and recovery activities (Angus 1998). The changes initiated during the 1990s attempted to address these deficiencies and led to the uptake of the ‘comprehensive’ and ‘all-agencies’ approaches by emergency management organisations.

Another important factor in the change in approach within emergency management was the development in 1995 of a risk management standard by Standards Australia and Standards New Zealand and its endorsement in 1996 by the then peak body for emergency management in Australia, the National Emergency Management Committee. This Committee required that the standard’s principles and processes be adopted by emergency management agencies. The adoption of these principles and processes further reinforced the comprehensive and integrated approach, as it supported a shift in focus away from managing hazards to managing risk. It encouraged a greater emphasis on identifying the vulnerability of communities to hazards and the development of strategies relating to the prevention of emergencies instead of a focus on the need for increased response capacity (EMA 2004).

Effective implementation of the comprehensive and integrated approaches, however, was still lacking, and in 2001 COAG commissioned a review of Australia’s arrangements for dealing with natural disasters. This review identified the strengths and weaknesses of the Australian arrangements. The key strengths of these arrangements included the strong capacity for disaster response, the importance of the volunteer sector and the effectiveness of the natural disaster relief arrangements in providing basic assistance to disaster affected communities (Commonwealth of Australia 2004). Some of the key weaknesses identified were: i) a focus on response and reaction at the expense of prevention, mitigation and recovery activities; ii) lack of independent and comprehensive post-disaster assessments to identify lessons learnt, and opportunities for improvement; iii) uneven recognition of the important role of local governments in emergency management; and iv) lack of effective inter- and intra-governmental mechanisms to support a coordinated national approach to disaster management (Commonwealth of Australia 2004). The COAG review concluded that the arrangements for dealing with natural disasters could be enhanced by broadening the focus of disaster management beyond response and reaction toward anticipation and mitigation of disasters (Pitman 2006). The review advocated a ‘new holistic approach’ for the management of disasters with a greater focus on mitigation and recovery (Dwyer 2006). Central to this approach is a systematic and widespread national process of disaster risk assessments. The review also recommended a unified national approach, with a strong focus on prevention of the consequences of disasters (Pitman 2006). More recently, there have been calls for the Commonwealth Government to play a greater role in emergency management, especially in terms of strengthening inter-state coordination and interoperability, capacity building and training, and policy development (Yates & Bergin 2009; Wilkins 2010).

Climate change impacts on the Emergency Management sector

Climate change has the potential to alter the hazard profile and interact with the vulnerability and risk profiles of countries and regions. Climate change may not only increase the intensity and frequency of natural hazards currently affecting a region but may also bring new types
of hazards to a region. An increase in the number of disasters affecting a country or region may undermine its disaster management capacities. Emergency management agencies have been on society’s frontline in dealing with disasters, but they will need to consider the new risks arising from climate change and how these will affect their ability to respond to disasters. Current disaster risk management planning tends to focus on reducing current disaster risks and is heavily reliant on risk assessments based on historical data of hazards at a given location. However, with the likelihood of risk profiles of regions being altered under climate change, a reliance on historical datasets for risk assessments will no longer be adequate. Risk assessments will need to look into the future vulnerabilities and risks and consider the changing frequencies and magnitudes of hazards (Prabhakar et al 2009). Current responses to disasters are likely to no longer be sufficient. A full understanding and preparation for the risks from climate change will require more than a simple multiplying of existing emergency management capacities and resources (Pearce et al 2009). Emergency management involves the full spectrum of prevention, preparedness, response and recovery activities and effective response/adaptation to climate change will require all agencies working across this spectrum to consider the impact of climate change on their activities. This will also require greater cross-sectoral coordination, especially with the planning and building regulation sectors, which have a critical role to play in the prevention of disasters. Australia has a clear and well defined emergency management framework, which consists of four elements: a comprehensive approach, an all hazards approach, an all agencies approach and prepared community principle. This framework may not necessarily need to change due to climate change, but significant improvements may be required to different elements of the framework, especially when multiple events coincide or when disasters larger than planned for need to be managed (Yates & Bergin 2009).

4.5.2 Current practice affecting SEQ

This section identifies the initiatives, policies and plans at national, state and local levels affecting emergency management in SEQ. At the local level, this report focuses only on the four local council areas involved in the case studies, namely: Brisbane City, Gold Coast City, Ipswich City and the Sunshine Coast Region.

National Level

In Australia, the Commonwealth Government does not have specific constitutional power in respect of emergency management — a similar situation with respect to the other sectors discussed above. The primary responsibility for emergency management falls to the local and state governments. The role of the Australian Government is to support the development by the states and territories of a national emergency management capability and to provide national coordination and resources in cases of major national disasters. There are no specific plans or policies at national level for emergency management, but there are several funding programmes and arrangements in place between the Commonwealth Government and the States and Territories, such as the Natural Disaster Relief and Recovery Arrangements and the new Natural Disaster Resilience Program (NDRP). The emergency management arrangements and the roles and responsibilities of each tier of government as well as of individuals and private sector stakeholders are outlined in the Australian Emergency Management Arrangements (Commonwealth of Australia 2009a). These arrangements are based on the comprehensive and integrated approach to emergency management adopted by Australia. Although there are no specific emergency management policies at national level, several initiatives have been developed to foster greater collaboration between states/
territories and the Commonwealth Government and to ensure greater consistency across all jurisdictions.

A **National Partnership Agreement on Natural Disaster Resilience** between the Commonwealth and State and Territory governments was signed in 2009. This Agreement provides for collaboration on natural disaster mitigation activities to enhance communities’ resilience to natural disasters where resilience is defined as “the capacity to prevent/mitigate, prepare for, respond to and recover from the impacts of disasters” (COAG 2009, p. 14). The expected outcomes from this partnership are a reduction in risk from the impact of disasters, appropriate emergency management capacity and support for volunteers. This Partnership Agreement requires states and territories to develop annual Implementation Plans, which include performance indicators. They are also required to produce an annual performance report assessing whether the activities put in place were effective in contributing to the outcome and how well the performance indicators were achieved.

**National Principles for Disaster Recovery** were developed by the Commonwealth, State and Territory governments and the Australian Red Cross and are used to guide recovery advice and assistance. These principles consist of a set of six elements required for successful recovery, namely: understanding the context; recognising complexity; using community-led approaches; ensuring coordination of all activities; employing effective communication; and acknowledging and building capacity (Community and Disability Services Ministers’ Advisory Council n.d).

A **National Disaster Resilience Framework** was developed in 2008. It articulates the high level disaster resilience agenda established by the Ministerial Council for Police and Emergency Management – Emergency Management (MCPEM-EM) and establishes a set of principles for the emergency management sector to contribute to a disaster resilience agenda across all jurisdictions and all tiers of government. These principles consist of a shared understanding between partners, a comprehensive approach to disaster resilience (includes consideration of all hazards and all aspects of PPRR) and a nationally integrated approach to the implementation of the Framework. The aim of the Framework is to “support measures to strengthen communities, individuals, businesses and institutions to minimise the adverse effects of disasters on Australia” (EMA 2008, p. 1). This Framework will be supported by eight action plans, including a Disaster Resilience Strategy, Climate Change Action Plan, Community Engagement Action Plan, Recovery Action Plan and Volunteers Action Plan.

In addition to these sector-specific initiatives, a **Climate Change Adaptation Action Plan** was endorsed in November 2009 by the MCPEM-EM and contains some sections relevant to emergency management. The aim of this action plan is “to ensure climate change adaptation strategies are an integral part of emergency management planning and processes, to help Australia prepare for the current and future impacts of climate change” (MCPEM-EM 2009, p. 2). This action plan recognises that the emergency management sector should engage with individuals, communities as well as key government, non-government and private stakeholders to develop and implement climate change adaptation strategies that will increase Australia’s resilience to disasters. The action plan suggests three broad actions, and several more specific strategies for each action, to help better understand the impacts of climate change on the emergency management sector and integrate climate change adaptation considerations into emergency management processes. Some of these strategies apply not only at national level but also at state/territory and local levels.
State Level

At the State level there are several pieces of legislation, policies and plans that concern emergency management. The Disaster Management Act 2003 (DMA 2003) forms the legislative basis for disaster management activities within all levels of government in Queensland and the Queensland Disaster Management System. The main objectives of the DMA 2003 are: to help communities prevent, prepare for, respond to and recover from a disaster; to provide for effective disaster management for the State; and to establish a framework for the management of the State Emergency Service (SES). The 2008 State Disaster Management Plan sets out Queensland’s approach to disaster management in accordance with the legislative responsibilities of the DMA 2003. Its purpose is to ensure a common understanding of State disaster planning arrangements, outline concepts, roles, responsibilities, processes and finances to stakeholders and agencies at each level of the arrangements, and provide the basis for the development of planning guidelines for Local and District Disaster Management Group plans. The 2008 State Community Recovery Plan outlines the agreed roles and responsibilities of the different agencies involved in the different phases of community recovery. It recognises that a cooperative, multi-agency approach to supporting individuals and communities is essential for effective community recovery following a disaster. The Disaster Management Strategic Policy Framework endorsed in 2006 is Queensland’s key strategic tool for disaster management. It sets out Queensland’s disaster management vision of a “safer community and a better quality of life in Queensland through world-class emergency and disaster services” and outlines strategic direction to guide the development of disaster management policies and programmes to achieve this vision (State Disaster Management Group 2005, p. 5). The Framework also aims to mainstream disaster mitigation into relevant areas of activity of government, NGOs and the private sector. It is structured around a set of disaster management elements. For each element, the Framework identifies a key objective, strategies to achieve that objective and key performance indicators. These elements and their associated strategies outline how a comprehensive, all hazards, all agencies and prepared community approach will be applied in Queensland.

Local Level

Local governments are required under the DMA 2003 to develop Local Disaster Management Plans. Three out of the four case study councils have developed local disaster management plans, namely: Brisbane City Council, Gold Coast City Council and Sunshine Coast Regional Council. These Local Disaster Management Plans establish the arrangements required for the prevention, preparedness, response and recovery phases of emergency management and outline the roles and responsibilities of the different agencies involved in these phases. These plans adopt the comprehensive, all hazards, all agencies and prepared community approach.

Summary

COAG’s review in 2001 of Australia’s disaster management arrangements led to a reform of those arrangements and the adoption of the comprehensive, all agencies, all hazards and prepared community approach throughout all levels of government – from national to local. Since then several national initiatives have been agreed between the Commonwealth and States/Territories governments, such as the National Partnership Agreement on Natural Disaster Resilience, and aim to provide for improved collaboration between levels of government and greater national consistency in approaches to disaster management. As these national initiatives are relatively recent it is as yet unclear how they will affect current
in institutional arrangements and plans for emergency management at the state and local levels. In addition, climate change is becoming an increasing concern of the Commonwealth and State governments but has received little and only recent attention by the emergency management sector. The majority of emergency management policies and plans at national, state and local levels do not integrate climate change adaptation considerations or even mention climate change as a future threat that the emergency management sector will have to consider. An exception to this at the national level is the National Disaster Resilience Framework, which mentions the need for the emergency sector to better understand the risk of disasters in the face of climate change, to better engage with climate change policies and to incorporate/develop greater flexibility and adaptability to future risks. The National Disaster Resilience Framework is also supported by the Climate Change Adaptation Action Plan. At the state level none of the emergency management policies or plans appear to mention or consider climate change. At the local level, the Sunshine Coast Local Disaster Management Plan is the only local disaster management plan that mentions climate change. However, it does not explain how climate change will affect emergency management on the Sunshine Coast nor the types of adaptation strategies that could be implemented.

Section 4.1 reviewed the different climate change adaptation plans and initiatives at national and state level and identified several implications arising from those initiatives for the emergency management sector. However, it is unclear whether, and if so how, the different adaptation strategies recommended in those climate change adaptation plans and initiatives will be adopted by the emergency management sector across all tiers of government. Climate change is projected to lead to more extreme weather events in SEQ and will therefore affect the emergency management sector’s operations and strategies/measures. Emergency management plans and policies at all levels will need to factor in climate change to ensure that measures developed for the PPRR phases remain effective and that populations are well prepared for and able to respond to the impacts of hazards. The emergency management recommendations developed in the national and state climate change adaptation initiatives should provide a good starting point for emergency management agencies.

4.5.3 Sectoral implications of spatial vulnerability assessment

The spatial vulnerability assessment discussed in Section 3 indicates that a number of areas in SEQ are vulnerable to extreme rainfall, extreme heat and coastal hazards, with all projected to increase with climate change. Although emergency management agencies are well aware that SEQ is a region prone to natural hazards, the value of this sectoral vulnerability assessment for the emergency management sector is not only in highlighting the vulnerable areas but also in explaining the pattern of that vulnerability through the exposure, sensitivity and adaptive capacity maps. These maps show not only where the hazards occur but the ability of the different suburbs to respond and adapt to these hazards. In order for emergency services to be effective and develop appropriate measures across all four phases of prevention, preparedness, response and recovery they need to understand the factors determining the vulnerability of areas to hazards.

The areas of interest for emergency services are predominantly those with extreme, high or medium vulnerability. Areas with low vulnerability are of less interest. In general, the low vulnerability areas are explained by the following two profiles/patterns: i) medium to low exposure and sensitivity and medium to high adaptive capacity; or ii) high exposure but low sensitivity and medium to high adaptive capacity. In both situations, the interaction between the social and economic conditions and the natural hazard is very unlikely to lead to a disaster.
and therefore emergency services’ intervention will not be a priority. By contrast, areas with extreme, high or medium vulnerability represent areas where emergency services will need to be highly active and develop appropriate PPRR measures. In general, extremely and highly vulnerable areas have a high exposure and sensitivity and medium or low adaptive capacity profile. For example, the coastal hazards vulnerability map for SEQ shows that selected suburbs of the Sunshine Coast and Gold Coast that appear extremely and highly vulnerable have extreme or high exposure and sensitivity and low or medium adaptive capacity (see Section 4.3.3). Coastal hazards occurring in those areas will likely result in the disruption of the livelihoods of large numbers of people, especially as the majority of those coastal areas are highly populated during the peak holiday periods. The adaptive capacity map also highlights the variation in adaptive capacity between suburbs within the Gold Coast and Sunshine Coast and, therefore, the need for locally-specific response by the emergency services in order to target those least able to respond to and recover from the impact of the hazards.

In addition to the areas of extreme or high vulnerability, areas of medium vulnerability can also be of interest to the emergency services, as the vulnerability of these areas can result from a variety of combinations of different levels of exposure, sensitivity and adaptive capacity. For example, certain areas may have high exposure but medium or high adaptive capacity, which will facilitate their response to and recovery from the impacts of the hazard. Such a scenario is illustrated in the extreme heat maps, where some areas within Brisbane City and Gold Coast City have a high exposure to extreme heat but low sensitivity and medium to high adaptive capacity and thus only medium vulnerability. These areas may be well prepared or able to respond to periods of extreme heat and thus require only minimal assistance from emergency management agencies. However, some medium vulnerability areas may have low exposure but low or extremely low adaptive capacity. When a hazard does occur in those areas the potential for response and recovery will be very low. In these areas moderate events may lead to significant consequences, as the population is ill-prepared and does not have the ability to respond to such events. Such a situation is evident in Ipswich City with regards to extreme rainfall. Ipswich City has a low exposure to extreme rainfall but some of its suburbs have a medium sensitivity and a low to extremely low adaptive capacity. As a consequence of extreme rainfall, moderate flooding events or rare extreme flooding events may occur leading to a disproportionately large number of people affected because the population of those areas may be ill-prepared and will struggle to effectively respond and recover.

A final value of these maps for emergency services is in highlighting areas that are vulnerable to multiple hazards. For example, several suburbs of the Gold Coast and Sunshine Coast are highly or extremely vulnerable to both extreme rainfall and coastal hazards. Another example is Ipswich City, as some of its suburbs have a medium vulnerability to extreme rainfall and a medium to extreme vulnerability to extreme heat. These Ipswich City suburbs are of special interest as many of them have low to extremely low adaptive capacity. The occurrence of multiple hazards whether in quick succession, in the same year or in different years is a concern to emergency services, as it can stretch a population’s ability to respond to the impacts of the hazards as well as the emergency services’ own resources for the prevention, preparedness, response and recovery phases. Emergency management agencies may need to increase or improve their prevention and preparedness efforts and measures in areas of low adaptive capacity to enhance the ability of those areas to deal with the impacts of hazards.
4.5.4 Sectoral vulnerability (challenges)

The projected climate change impacts anticipated to affect SEQ, including the incidence of more extreme weather events, has major implications for the emergency management sector. Although emergency management agencies have a long experience of dealing with extreme weather events, the projected increase in extreme weather events with climate change is likely to have a significant impact on their activities and operations. Emergency management agencies will need to take into consideration how climate change will change the occurrence, intensity and frequency of disaster events and therefore their activities and strategies across the PPRR spectrum.

Although the disaster management framework/approach adopted by the Commonwealth and State/Territory governments may not necessarily need to change, an improvement in all elements of that approach will be required. An improvement in disaster risk assessments and the four PPRR phases of disaster management will be needed to deal with the expanding and changing risks caused by climate change. Disaster risk assessments can no longer be simply based on an analysis of historical risk but will need to incorporate the future risks arising from climate change. Emergency management agencies will need to adjust to a constantly changing risk profile and, therefore, build in more flexibility in their activities, policies and plans to allow for a continuous re-evaluation of that risk and a re-adjustment of those activities or policies when required.

In line with the recommendations arising from COAG’s 2001 review of disaster management arrangements in Australia, a greater emphasis on prevention and preparedness will be required for effective adaptation to a changing risk profile due to climate change. The vulnerability maps presented in Section 3 indicate that many areas within SEQ are vulnerable to multiple hazards and their communities may be ill-prepared and lack capacity to effectively respond to their impacts. In these areas, greater prevention and preparedness measures will be required to reduce the risk of disasters. Greater cross-sectoral coordination and involvement of emergency managers in land use planning and management will be essential to improve the prevention of disasters, especially in those highly vulnerable areas. Preparedness measures will need to be strengthened to ensure that individuals and communities are better prepared for disasters. A recent study on the Sunshine Coast revealed that there is limited community engagement with disaster awareness and preparedness (Dyer et al 2001). Emergency services will also need to determine how climate change will affect the supply and continuity of their services, especially if multiple disaster events occur at the same time. For example, during the response and recovery phases the emergency management sector is heavily reliant on an extensive network of volunteers. The implications of this reliance need to be assessed, as any increase in the frequency of extreme weather events will place greater demands on volunteer time (McLennan et al 2009). The volunteer sector may need to be at times reinforced to manage the expected increase in disasters resulting from climate impacts (Howard 2009). The coordination mechanisms between the local, state and national level agencies involved in emergency management will also need to be highly effective to deal with larger than planned events or multiple events occurring at the same time.

Climate change will bring new challenges to the emergency management sector in SEQ. However, many of the principles adopted by the emergency management sector – including development of multi-agency partnerships, shared responsibility, a comprehensive approach, community engagement and preparedness – overlap with climate change adaptation principles, suggesting that some of the arrangements, strategies and measures already in place may support and benefit climate change adaptation. Further work is required to
better understand the impacts of climate change on the emergency management sector and the effectiveness and appropriateness of current strategies in light of climate change. In addition, emergency management plans and policies at national, state and local levels will also need to be reviewed, as the majority of these plans and policies do not consider climate change and its implications for the emergency management sector (see Section 4.5.2). As climate change adaptation policy develops and expands across all tiers of government, it will need to be increasingly integrated with emergency management policies and initiatives. Indeed, it is as yet unclear whether the recommendations emerging from the national and state climate change initiatives will be taken up by the emergency management sector.
5. Conclusions

Current projections of climate change in SEQ suggest an increase in average annual temperatures, sea-level rise, a change in average rainfall, an increase in the frequency of dry days and a decrease in the frequency of wet days. In addition, more extreme weather events are projected, with an increase in extreme rainfall events, an increase in the number and frequency of more intense cyclones and an intensification of east coast lows.

Whilst climatic hazards are an important component of the region’s vulnerability to current and future climatic changes, this assessment of regional vulnerability to climate change has adopted a systemic approach, which also includes socio-economic components of vulnerability, rather than a purely climate change hazards approach. The vulnerability assessment has utilised an integrated framework which includes both external (exposure) and internal (sensitivity and adaptive capacity) dimensions of vulnerability, as it is the most common approach currently used in global environmental change and climate change research. Preliminary regional spatial vulnerabilities have been developed, based on a set of indicators to illustrate the region’s exposure, sensitivity and adaptive capacity for three key climate-related impacts projected to affect the region, namely: extreme heat, extreme rainfall and coastal hazards. The selection of these key climate-related impacts was determined by the availability of robust data sets for the vulnerability dimensions. Conversely, the absence of reliable data precluded the mapping of other important natural hazards that will be affected by climate change, such as bushfires and storms, at this time. However, as more reliable and robust data becomes available, further vulnerability assessments can be completed to complement the current vulnerability assessment of extreme heat, extreme rainfall and coastal hazards.

**Extreme heat:** The initial spatial vulnerability assessment indicates that areas associated with the region’s urban footprint (including coastal urban areas) are generally more exposed to heat impacts due largely to heat trapped in the urban canopy as a result of expanded impervious surfaces. This is the case in urbanised coastal areas of the Gold Coast and the Sunshine Coast, plus the bay side areas of Brisbane City and Moreton Bay Regional Council areas, which include a number of localities assessed to be extremely vulnerable to the impacts of extreme heat events. Other areas of similar exposure include isolated localities in the western corridor (Ipswich and Brisbane Cities) and Logan City. Many of these localities that have been identified as highly vulnerable to extreme heat are also areas with low adaptive capacity. This is particularly noticeable in the south west of Brisbane City and in north east portions of Ipswich City. Local government areas of Lockyer Valley, Scenic Rim and Somerset have been assessed as low to medium vulnerability to extreme heat due to their low exposure, low to medium sensitivity and their medium to high levels of adaptive capacity.

**Extreme rainfall:** Most of SEQ has been assessed to have low vulnerability to extreme rainfall. However, some areas within local government areas of Gold Coast, Brisbane, Logan, Moreton Bay and Sunshine Coast present a medium, high and extremely high vulnerability to extreme rainfall. Of particular concern are a number of assessed extremely vulnerable areas to extreme rainfall within the Sunshine Coast and Gold Coast jurisdictions. This is largely due to the topography, the significance of impervious surfaces and relatively high rainfall events associated with these locations. Subsequent flooding events due to extreme rainfall affecting these areas could also be potentially intensified if there was a coincidence with coastal hazards, such as storm surges and king tides.
Coastal Hazards: The most vulnerable areas to coastal hazards have been assessed as locations associated with the local government areas of the Sunshine Coast, Gold Coast, Moreton Bay, and Brisbane. Whilst Redland City demonstrates a medium level of exposure and extremely high level of sensitivity to coastal hazards, its high level of adaptive capacity resulted in the area’s overall low vulnerability to coastal hazards.

The overall spatial vulnerability assessment of SEQ to climate change related impacts indicates that there are a number of vulnerability hot spots in the region that deserve closer assessment in order to address climate change adaptation. Several of those localities are spread throughout coastal and inland areas of the region. In view of the complexity of these vulnerability assessments and their outputs, a cooperative monitoring program needs to be established across the region to collect and update relevant regional and local climate science in order to better inform future vulnerability assessments, which in turn will greatly assist planning and decision making processes. Notwithstanding the challenges of this undertaking, this process could result in more effective climate adaptation strategies across the region and across sectors.

The spatial vulnerability assessment has been complemented by a sectoral assessment of vulnerabilities related to the current policy domains of the key sectors comprising the Human Settlement’s component of the project, namely: urban planning and management including coastal management; human health; and emergency management. This latter assessment has investigated current tools, strategies, models and mechanisms adopted by each sector that directly influence sectoral practices in SEQ as well as future climate adaptation options. This institutional analysis combined with the spatial vulnerability assessment resulted in the identification of SEQ’s major sectoral challenges to address climate change adaptation.

Overarching all sectors are a number of national and state level climate change initiatives. The National Climate Change Adaptation Framework and the Position Paper on Adapting to climate change in Australia are the current principal national level initiatives on climate change adaptation. It was noted that these documents include many of the adaptation principles emerging from the literature, especially the key principles of early action, inter-governmental collaboration and mainstreaming. Hence, state/territory and local governments, industry and the community, as well as the individual sectors, have top level direction and guidance for climate change adaptation. However, it has been concluded that effective coordination and integration of climate change adaptation policy into sectoral policies represents the key challenge that will need to be addressed to avoid duplication of efforts and gaps and to ensure effective implementation of adaptation measures across all sectors and jurisdictions.

At the state level, ClimateQ and ClimateSmart Adaptation represent Queensland’s current main climate change and climate change adaptation initiatives. They incorporate many of the key adaptation principles emerging from the literature and from the Australian Government’s National Climate Change Adaptation Framework, including the importance of early action, the need for action at different scales, working in partnerships and mainstreaming adaptation into decision making processes. Again, it has been concluded that the successful integration of climate change adaptation into sectoral decision making processes and policies remains a key challenge for the State.

Urban planning and management: Local governments are crucial to addressing climate change because they are at the forefront of land use planning and development control in the State. This is particularly important given that present and future land use has a major influence on the magnitude of climate change related impacts. Local authorities in the region
have made considerable progress in developing policies geared toward climate change strategies in the last few years despite the fact that there was no statutory obligation to do so.

Critical principles for addressing climate change adaptation through planning include: the adoption of an adaptive framework to avoid the pitfalls of incrementalism currently associated with traditional forms of planning; the adoption of a systems based approach (including social, cultural and biophysical dimensions) that promotes cross-scalar and cross-sectoral integration; fostering a ‘virtuous cycle’ in order to protect and enhance valued places as well as environmental integrity; establishing a collaborative arrangement linking government, the private sector and civil society; and provide support implementation and foster effective adaptation through appropriate legislation, plans and polices at higher scales.

A number of barriers will need to be overcome, especially by local authorities, to implement climate change adaptation strategies in a well-coordinated and holistic manner that integrates multiple sectors. Crucial challenges for the SEQ planning process in terms of addressing climate change adaptation include the achievement of: effective horizontal and vertical coordination and integration between planning and other adaptation instruments within the region and between land use and infrastructure planning; the inclusion of climate change impacts in local and regional statutory and non-statutory plans; a balance between mandatory and voluntary adaptation and engagement of the non-government sector in the climate adaptation decision making process; a synergy between planning with adaptation options for the urban landscape with its region to foster the long term biodiversity conservation and ecosystem services values for the whole region; addressing legal and other barriers to climate change adaptation through statutory and non-statutory planning; and prioritisation of policy responses to specific climate change impacts at local and regional planning scales.

Coastal management: The spatial and sectoral assessments highlighted that the vulnerability of SEQ’s coastal areas and the region’s coastal planning and management system is high due to the characteristics of the physical system and the human settlement and to the weaknesses of the current coastal planning and management system. A reduction of sectoral vulnerability will need to consider the identification of sustainable options to defend, accommodate or retreat communities to safer areas to address the future challenges posed by climate change. Some of the major issues faced by coastal management include: the integration of climate change projections into policies, plans and instruments; the flow of information between the scientific community and the policy makers; and the integration of a spatial buffer into coastal policies, plans and instruments to address uncertainties in sea level rise projections.

Specific initiatives to reduce vulnerability to climate change-related coastal hazards in SEQ should seek to increase the adaptive capacity of coastal systems. This could include investments in technological adaptation options as well as in education, training and capacity building programs to enhance social and institutional awareness and capacity. In addition, the management of coastal adaptation in a context of uncertainty and changing climate projections will require more flexible mechanisms to incorporate new sea-level rise and wave climate figures into coastal plans and shoreline erosion management plans. New concepts will need to be integrated into local planning schemes, such as dynamical buffer zones capable of accommodating worst case scenarios with overall lower costs for the society in the long term.

Human Health: The spatial vulnerability assessment for the public health sector has identified those communities with extreme vulnerability and where there is a need to
develop approaches to deal with the potential impacts in these locations. Focusing on those places with extreme vulnerability will allow local or community level health prevention and adaptation approaches to be developed in conjunction with broader regional or state level approaches. For example, the SEQ regional vulnerability ‘hot spots’ likely to incur extreme heat events that have been identified through the spatial vulnerability mapping need to be understood in conjunction with other epidemiological modelling. Thus, local and state level health programs could be better targeted through this improved understanding of how local vulnerabilities are produced and their potential spatial extent across the region. In essence, the spatial analysis of vulnerability outlined through the mapping of exposure, sensitivity, adaptive capacity and overall net vulnerability, will aid health planners and policy makers to effectively develop appropriate measures across all four phases of prevention, preparedness, response and recovery.

Specifically, the spatial vulnerability assessment makes clear that in order for the health sector to successfully address the challenges posed by climate change it will need to understand the complexity of stressors and external drivers impacting on human health as a result of climate events. It will also require an understanding of the likely local impacts of adaption approaches. For example, the health risk from exposure can be increased or mitigated through the impact of: the bio-physical events and conditions that created the exposure to the health hazard; the features of human and urban systems including the socio-economic characteristics of local communities or individuals; the built form, structure and density; access to material resources; and social networks. Hence, it will be important to understand these complexities and how they are played out at neighbourhood or community scale in order to differentiate adaptive climate change strategies at this scale from broad regional measures, as there can be no guarantees that the higher order initiatives will successfully translate to the smaller local scale. Understanding this local impact is therefore an important challenge for the health sector in SEQ.

Emergency management: Whilst climate change is becoming an increasing concern of the Commonwealth and State governments it has received little and only recent attention by the emergency management sector. The majority of emergency management policies and plans at national, state and local levels do not integrate climate change adaptation considerations or even mention climate change as a future threat that the emergency management sector will have to consider. An exception to this at the national level is the National Disaster Resilience Framework.

The review of climate change adaptation plans and initiatives at national and state levels has identified several implications arising from those initiatives for the emergency management sector. Whilst the disaster management framework and approach adopted by the Commonwealth and State and Territory governments may not necessarily need to change, various elements of those approaches will require attention. An improvement in disaster risk assessments and the four PPRR phases of disaster management (prevention, preparedness, response and recovery) will be necessary in order to deal with the expanding and changing risks caused by climate change.

Climate change will bring new challenges to the emergency management sector in SEQ. Fortunately, many of the principles adopted by the emergency management sector, including development of multi-agency partnerships, shared responsibility, a comprehensive approach, community engagement and preparedness, overlap with climate change adaptation principles. This suggests that some of the arrangements, strategies and measures already in place may support and benefit climate change adaptation. Notwithstanding, further work
is required to better understand the impacts of climate change on the region’s emergency management sector and the effectiveness and appropriateness of their current strategies in light of climate change. Importantly, the recommendations emerging from the national and state climate change initiatives will need to be taken up and integrated by the emergency management sector.

This spatial and sectoral vulnerability assessment highlights the multiple challenges facing SEQ’s human settlements and the need for improved cross-sectoral integration. Although this first phase of work has focused primarily on the individual sectors of urban planning and management (including coastal management), human health and emergency management, the next phases will provide a more integrated and cross-sectoral analysis of the case studies and develop not only sectoral but also cross-sectoral climate change adaptation options. The assessment also indicates that there is considerable uncertainty in climate change projections at regional and local scales, which is further compounded by the paucity of existing datasets for the region. As such it is worth while exploring the implications involved in adopting the Precautionary Principle when developing adaptation options for SEQ. This is particularly relevant as many of the regional hot spots that were identified in this initial spatial vulnerability assessment are within the Human Settlement’s case study locations which will be the focus of on-going investigation and research in subsequent phases of this project.
References


Abuodha P. & Woodroffe C. 2006, International assessments of the vulnerability of the coastal zone to climate change, including an Australian perspective, Australian Greenhouse Office, Department of the Environment and Heritage.


Department of Climate Change 2009, Climate Change Risks to Australia’s Coast. A first Pass National Assessment, Australia Government.


Department of Primary Industries and Water 2009, Coastal Risk Management Plan: Template and Guidelines, Department of Primary Industries and Water, Tasmania.

Disaster Management Act 2003 (Act No. 91 of 2003) [DMA 2003].


Environmental Protection Agency 2006, South-east Queensland Regional Coastal Management Plan, Environmental Protection Agency, Queensland Government.


Bureau of Meteorology, Department of Industry, Science and Resources.


Harvey, N. & Caton, B. 2003, Coastal Management in Australia, Oxford University Press, Victoria, Australia.


Helman, P. & Tomlinson, R. 2009, Coastal Vulnerability principles for climate change, Queensland Coastal Conference.


Hennessy, K. 2004, Storms and climate change in Australia, International Conference on Storms. Storms Science to Disaster Mitigation, Brisbane, Australia.

Hennessy, K., Page, C., McInnes, K., Walsh, K., Pittlock, B., Bathols, J. & Suppiah, R. 2004, Climate change in the Northern Territory, CSIRO, Aspendale, Victoria.


Middelmann, M., Bruce, H. & Lacey, R. 2001, ‘Flood risks’, in Natural Hazards & the risks they pose to South-east Queensland, eds. K. Granger & M. Hayne, Geoscience Australia and Bureau of Meteorology.

Middle, G. 2002, Institutional Arrangements, Incentives and Governance – Unlocking the Barriers to Successful Coastal Policy Making, report for the Coast to Coast 2002 National Conference, Gold Coast, Australia.


Climate Change Vulnerability in South East Queensland: A Spatial and Sectoral Assessment


Norman B. 2009a, Planning for coastal climate change. An insight into international and national approaches, Department of Planning and Community Development, Victoria Government, Australia.


Prabhakar, S., A. Srinivasan, & R. Shaw. 2009, ‘Climate change and local level disaster risk
reduction planning: need, opportunities and challenges’, *Mitigation and Adaptation Strategies for Global Change*, vol.14, pp. 7-33.


Roiko, A., Mangoyana, R., McFallan, S., Oliver, J., Carter, R., Matthews, J. & Smith, T. 2010, *Socio-economic Trends for South East Queensland and Implications for Climate Change Adaptation*, unpublished report for the South East Queensland Climate Adaptation Research Initiative, Sustainability Research Centre, University of the Sunshine Coast, Sippy Downs, Qld, Australia.


Roads, Health, Transport, Mines and Energy, Treasury, Public Works, Primary Industries, and Natural Resources, CSIRO.


Water Research Laboratory UNSW 2009, Modification of the Byron Shire Coastal Hazard Lines, University of New South Wales.


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