Climate Change and Perth (South West Australia)

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Introduction

Perth is a rapidly growing modern city of 1.6 million people in the South West corner of Australia – over 2000km from the nearest city and 12 hours time difference from the US east coast, so we are literally down under. Our West Coast borders the Indian Ocean, which provides a powerful sense of place and identity for many Western Australians. As a favourite Western Australian novelist Tim Winton commented: "There is nowhere else I'd rather be than here. I am at the beach looking west with the continent behind me as the sun tracks down to the sea. I have my bearings (Winton 1983). However, the Indian Ocean and its adjacent continent are beginning to change climatically and so consequently will our lifestyles.

Perth is a miner's canary (Sadler 2004) for climate change, as modeling suggested very early in the global assessment of greenhouse issues that this corner of Australia would suffer rainfall decline (Pittock 1988) – and we did. Recording a 50% decline in rainfall run-off, the Water Corporation changed their policy in the late 90's to accept that this was not drought but climate change. This chapter will look at climate change impacts, mitigation of greenhouse gases and adaptation responses – from government, industry and grassroots community.

As global citizens we are disappointed that the world and our nation have not been able to find an adequate large-scale internationally accepted solution to this major sustainability issue. However, we are also aware that there are many smaller solutions that are well under way which need to be built on. Many good examples can be found in Perth and its bioregion. Out of this appreciative inquiry – in understanding the science, learning to adapt and beginning to mitigate – there may be lessons for us all. We may even find tipping points that can change the world.

Perth is the capital of Western Australia, the state that occupies the western third of the Australian continent (a land area of about 2,529,880 km^2) (Australian Bureau of Statistics (ABS) 2010a) (Figure 1). It is the most isolated capital city in the world. The state's population of 2 236 901 is 10% of the country's total population and it is a very sparsely populated state. Its population is highly urbanized and centralized with almost three quarters of the population (73%) living in Perth (ABS 2010b). The state is extremely rich in mineral and natural gas resources, has a very productive agricultural industry, and attracts a growing number of tourists. Both the state's population and its economy have been growing rapidly in recent decades, and these trends are projected to continue over the next two decades. Perth is the administrative and commercial centre for much of the economic activity of the state, including for the minerals and natural gas resource industries whose operations are located around the resource rich state. The mineral and energy resource industries together make a significant contribution to the economic growth and wealth not only for the state but for Australia as a whole.

Perth is located on the Swan Coastal Plain and centered on the Swan River and its estuary. The Swan Coastal Plain is roughly 100km wide, running far to the north and south of the

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City, and bounded to the east by the Darling Scarp which stretches along the coastal plain both north and south of the city. Perth has historically developed in a low density radial settlement pattern that has been modified by the parallel boundary constraints of the coast to the west and Darling Scarp to the east. Although a small proportion of urban and peri-urban settlements occur east of the Darling Scarp, it generally acts as a natural boundary beyond which state government managed native forests dominate a rolling landscape; this is dissected by the catchments for thirteen relatively small scale public water supply dams (Figure 2). Further east still, beyond the native forests is an extensive and largely cleared agricultural landscape within the high to medium rainfall southwest corner of the state.

Perth's climate is a temperate 'Mediterranean' climate with hot, relatively dry summers, and colder, relatively wet winters (with mean maximum temperatures in January of 30.8 degrees Celsius and 18.3 degrees Celsius in July) (ABS 2010b). The mean annual rainfall is 751mm (ABS 2010b).

In this chapter we briefly describe the observed and projected climate change impacts for Perth, survey some of the greenhouse gas mitigation responses in the city, and then describe some of the adaptation responses including adapting public water supplies to declining water availability, and coastal management and local government issues.

Impacts of Climate Change

Atmospheric temperature warming due to climate change has been observed in Western Australia, as has warming of the Indian Ocean. Ocean warming has contributed to sea level rise, and together with atmospheric warming it has also contributed to changes in atmospheric circulation patterns approaching the State. These changing patterns have in turn impacted on rainfall and as well as risks of extreme events. Each of these impacts is summarised in this section.

Temperature

Average temperatures have increased in Western Australia by 0.8 degrees Celsius between 1910 and 2005, with most of the increase occurring after 1950. The trend in mean temperature has varied over the state, and Perth is one of the areas of the State that has experienced amongst the highest levels of warming within the State (Cramb 2005). The trend in mean temperature for Perth from 1910 to 2009 was warming of 0.15 degree Celsius/10 years, and from 1970 to 2009 that has increased to 0.20 degree Celsius/10 years (BOM 2010); see Figure 3. The winter and spring seasons have experienced the greatest level of warming, and summer has experienced the least (Cramb 2005). There has also been a slow increase in the number of very hot days that Perth has experienced in the last 40 years.

The summer of 2009/2010 was the hottest and driest on record. Across the whole summer from December 2009 to February 2010, Perth recorded just 0.2 mm of rain, when the long-term average is 32 mm over the same period. Perth also experienced a total of 59 days on or above 30 degrees Celsius, also a new record (WA Today 2010).

The average number of days per year on which Perth experiences temperatures greater than 35 degrees Celsius is projected to increase from 28 days (between 1970 and 2000), up to between 34 to 41 days per year in 2040 (Hennessy, 2008). Projections for Perth's mean temperature suggest this could increase by between 0.6 to 1.5 degrees Celsius by 2030 (Hennessy 2008). Figure 4 shows projected summer temperature increases for 2070.

Sea Temperature

Western Australia is bordered to the west by the Indian Ocean. The Indian Ocean has a major influence on the atmospheric circulation patterns affecting the state, and thus on the regional

climate that these patterns bring. The Indian Ocean has been warming over the last 50 years. The sea surface temperatures of the Indian Ocean vary over its spatial extent and over various time scales. However, for the decade 1991 to 2000, the sea surface temperature averaged over the Ocean's basin increased by 0.6 degrees Celsius above the baseline from 1900 to 1960. It continued to warm after 2000 (Feng et al 2000). One of the areas of greatest increase in surface sea temperature for the Indian Ocean over the last 50 years has been the lower west coast of Western Australia, where Perth is located (Caputi et al 2009). Sea surface temperatures are projected to continue rising (Figure 5).

The coastal environment of the Perth region is dominated by the Leeuwin Current, a boundary ocean current that flows southwards along the coast bringing warmer waters south than would otherwise occur. The strength of the Leeuwin Current varies as a function of a number of factors, including occurrence of the La Nina and El Nino years. There has been an observed decline in the Leeuwin Current strength between 1950 to the 1990s, and a slight strengthening trend in the last decade or so (WAMSI 2010). Climate scientists think it is possible that climate change may further weaken the Leeuwin Current in the future. There are many implications for any future impacts on the Leeuwin Current for the Western Australian marine environment both ecologically and economically. For example the Department of Fisheries notes that "any seasonal variation in water temperature increase has important implications for fisheries and the marine ecosystem because it may affect many aspects of the annual life cycle such as timing of growth, moulting, mating, spawning and recruitment, which have to be taken into account in the stock assessment and management of fisheries" (Caputi et al 2009). One example of this is the Western Rock Lobster Fishery, which in the last few years has experienced a dramatic decline in the numbers of an important early life cycle stage of this economically important species. Figure 5 shows projected increases in sea temperature for 2070.

Sea Level Rise

Perth's port is located in the Fremantle area, and it has one of the longest time series of sea level data in the Southern Hemisphere. Mean sea level rise at Fremantle has increased by nearly 20cm since 1897. That represents an average rate of increase of 1.54 mm per annum (Figure 6). The increase is equivalent to 20% of the maximum tidal range for the port (Pattiaratchi & Eliot 2005). This average increase is also consistent with global average sea level rise of 1.7mm per annum. The rate of global average sea level rise is increasing; between 1993 to 2009 it rose by 3.0 mm per year (CSIRO 2010). It should be noted that what might appear to be relatively small increases in sea level rise can result in greater return frequencies for storm surge and other temporary high sea level rise events.

Further complicating the trends in sea level rise is the inter-annual variability driven by the El Nino Southern Oscillation (ENSO), with an amplitude of the scale of 30cm. This ENSO driven variability is superimposed on the sea level data, sometimes slowing the rate of observed sea level rise over a periods of years, and other times temporarily accelerating observed sea level rise. The latter reinforcing effect has contributed, along with the long term sea level rise, to the apparent increased frequency of coastal flooding in the period 1995 – 2004 (Eliot 2009), and the historic maximum sea levels being recorded in Fremantle in 2003 and 2004 (Pattriachi & Eliot 2008). The increased frequency of flooding events helped raise public awareness of coastal hazards (Eliot 2009).

In terms of projected sea level rise in the Perth region, "The predicted increase is up to 0.30 m and 0.88 m by 2040 and 2100, respectively. For sandy beaches this could result in beach recession of 30 m by 2040." (Pattiaratchi & Eliot 2005)

Rainfall Loss

The South West of Western Australia has experienced a 20% decrease in rainfall from the long term average (Figure 7). In this region a reduction in rainfall causes an even greater reduction in stream flows in the region that are rain dependent. This is illustrated by the reduction in stream inflow into the public water supply dams for the Perth region. Stream flows in some areas near Perth have reduced by 50% or more in recent years. The annual inflow into the Perth dams has declined from an average of 338 GL between 1911 to 1974, down to 177 GL between 1975 and 1996, and has dropped again to an average of just 81.8 GL between 1996 to 2008 (Water Corporation 2009a). This has been a dramatic reduction in inflow into the dams (Figure 8). In fact the average for the last decade reduced by 75% from the average for the average for up to the 1970s. This has resulted in a consequent dramatic reduction their capacity to supply water for the public water supply system.

Climate change projections for future changes in rainfall for Perth suggest that annual total rainfall could decrease from 0 - 20% by 2030, with mid-estimates being 5 – 10% (Hennessy 2008). Figure 9 shows projections for rainfall change to 2070.

Storms, droughts and bush fires

The Perth Region has experienced a decline in winter storm fronts in the last three decades. It is possible that climate change will result in further declines in the frequency of winter storm fronts. Projecting how climate change will affect storms and in particular cyclones is quite difficult. However climate scientists currently believe that there is a likelihood that the frequency of cyclones occurring in the North West of Western Australia will also decline, but the relative intensity of remaining cyclones may increase. Occasionally cyclones from the North West of the State travel as far south as Perth. This is likely to happen less often in the future, but the risk of those reaching Perth being more severe will increase. As the greatest risks come from the stronger cyclones or other extreme storm events, the risks of storm and cyclone damage is likely to increase in the future.

Furthermore, in coastal areas, a rising sea level of 0.5 m will radically increase the probable return rate of high sea level events such as storm-tide surges by 100 times in the Perth/Fremantle area. For example, storm-tide surges that occur once in 100 years in the 20th C will occur annually under 0.5 m sea level rise (Antarctic Climate & Ecosystems Cooperative Research Centre 2008). This shift in probabilities will have dramatic implications for coastal erosion and recession.

A report reviewing the recent history and future projections for droughts in Australia found that if the rainfall in the South West of Western Australia declined by 10% by 2030 this would triple the risks of droughts occurring. If the rainfall decline were 20%, this would create a sixfold increase in risk of drought (BOM & CSIRO 2008). Both these levels of rainfall decline are within the range of rainfall decline that climate change models have projected for Perth. The city is likely to face a substantially increased risk of drought in the future. The State Government owned water utility have recognised this in their 50 year plan for Perth's water supply, by basing their planning on a scenario of a 20% decline in rainfall by 2030, and a 40% reduction in rainfall by 2060 (see Water Resource Planning section below).

Due to the combination of climate, topography and vegetation, many regions in Australia have some of the most severe fire climates in the world. Many factors contribute to the risk of severe bushfires. Climate change is impacting on many of these factors and therefore also to bushfire risk. If existing bushfire prone areas become hotter, drier, and/or windier there will be an increase risk of bushfires (Bushfire CRC 2008). Due to observed decreases in rainfall, increased risks of droughts, and increases in temperature and the frequency of very hot days,

the risks of bushfires have already increased for Perth. Climate change projections for the Perth region suggest that these risk factors will continue to change in the future in ways that will further increase the risk of bushfires. The increased risks are partly associated with the greater risks of weather with severe bushfire conditions occurring more frequently. There may also be additional risks because of increased lightning frequency (a key cause of fires starting) associated with increased storm activity.

Mitigation Responses

Western Australia is the home of the 'wild west' economy as it appears to have almost limitless resources and few people (2 million in an area the size of Western Europe). However it has also had a strong environmental record over many decades with a substantial and growing set of national parks (among the most recent being 30 reserves of old growth forest set aside from logging). Part of the reason for this awareness is that the State is one of the world's biodiversity hotspots, possibly because it has been largely unaffected by geological or glacial activity for 2 billion years. With this kind of history the State has been one of the leaders in establishing programs and projects to do with climate change mitigation as well as adaptation as set out above.

This section will therefore cover Local, State and Federal Government responses as well as industry and community initiatives.

Local Government

One of the first initiatives globally was the establishment of ICLEI's Cities for Climate Protection (CCP) initiative that in the past year led to a reduction in greenhouse gases of 4.7 million tonnes, that is equivalent to taking around 1 million vehicles off the road. With Federal Government support the 40 or so local governments in Perth in the early 2000's all joined this program. The City of Perth has been a leader reaching the highest level of CCP's program and they have since been playing a global role as part of the World Cities Energy Partnership.

The City of Perth developed a Greenhouse Gas Emissions Reduction Strategy in 2001 and is on track to achieve a 20% reduction in greenhouse gases by 2010 from 1996 levels. An innovative part of this is to be part of a national program called City Switch Green Office program that enables any office to be given advice on energy savings. One of the key strategies in recent times in the city centre has been to improve the walkability of the city thus reducing car use; Jan Gehl did an original study of central Perth in 1995 that led to similar commissions across Australia and the US. He recently returned to assess the city's progress and see what can be done next (Gehl and Associates 2009). Significant increases in pedestrian traffic and people sitting and enjoying city spaces were found.

The City of Fremantle has recently become Carbon Neutral and is committed to demonstrating how an urban wind farm can be established at the port.

State Government

A WA greenhouse strategy was first developed in 1991[3] after grass roots support for approaches to this issue which began in the early 1980's. The strategy followed a state greenhouse gas audit, the first of its kind in Australia[4].

[3] Western Australia Greenhouse Coordination Council (WAGCC), 1991, *Greenhouse Strategy for Western Australia*, Perth, WA.

In 2003 the State Sustainability Strategy was developed as a comprehensive approach to long term issues across 42 areas of government (Government of Western Australia 2003). This was followed by a Western Australian Greenhouse Strategy in 2004 (Government of Western Australia 2004), which was then complemented by a Premier's Climate Change Action Statement (Government of Western Australia 2007). The Office of Climate Change was established to:

- Lead development policy advice on greenhouse issues in Western Australia and coordinate whole of government responses to climate change related issues.
- Implement the Government's adaptation to climate change program, coordinate the Indian Ocean Climate Initiative (IOCI) and translate and communicate climate change science for Government policies and programs, the community and industry.
- Work across each sector of the economy in conjunction with relevant State agencies to assess greenhouse gas abatement opportunities and policy measures.
- Work with conservation and natural resource management agencies and organisations to develop and monitor implementation of climate change policies and programs to protect biodiversity, create carbon sinks and other environmental benefits.
- Analyse monitoring and reporting data, and prepare advice to Government on trends and issues, and develop standards and methodologies for greenhouse gas monitoring, reporting, accounting and registration.
- Provide advice to the Environmental Protection Authority and other statutory authorities on climate change and greenhouse policy.
- Coordinate monitoring, reporting and evaluation of climate change policies and programs across Government.
- Implement climate change education and communication programs.
- Administer the Low Emissions Energy Development Fund (LEED Fund), a $30 million leveraged technology fund over five years.

The State Government is currently developing a new and up-dated state climate change strategy that will include an expanded focus on adaptation policy. A range of policies have been enacted to assist mitigation. Three important areas are carbon rights, Travel Smart and metropolitan planning and public transport.

Carbon Rights

State Legislation was passed in 2003 that enables landholders to claim carbon trading rights for reforestation of farmland. Much of the wheatbelt in the SW region surrounding Perth has been cleared before 1990. Since then major reforestation and revegetation programs have been implemented and much of this has developed carbon credits under the global voluntary trading scheme. A large Japanese energy utility developed a 1000 hectare project over 24 properties which used all the best methods of integration with cropping. Other large resource companies have followed this model with extensive integrated tree planting for carbon sequestration.

The Oil Mallee Association was established in 1997 to provide a means to advise farmers about the multiple benefits of tree crops such as salinity reduction, biodiversity enhancement, the potential for eucalyptus oil production and small scale power generation as well as carbon credits. By 2009, with the assistance of Commonwealth Landcare funding over 14,000 ha of Mallee Eucalypts had been established across over 1000 properties. The improved species, now referred to as an "oil mallee", is a very hardy native tree from the dry land areas of South

[4] Stocker, L. 1991. *Greenhouse Gas Audit for Western Australia.* Western Australia Greenhouse Coordination Council

West WA and has developed an extensive root system. The trees are known to last for hundreds of years and are ideal for carbon storage. They are also known as an ideal tree to harvest as they immediately regrow or coppice after every harvest, a process that is assumed can continue for decades. See www.oilmallee.com.au

Travel Smart

TravelSmart is a household behaviour change program that was one of the first to achieve real and repeatable results at reducing car use. The German sociologist Werner Brög has developed an approach to travel demand management (TDM) that is based in the social capital of communities. After some trials in Europe, Brog's approach was adopted in large scale projects in Perth. It has since spread across most Australian cities, to other European cities, especially in the UK, and has now been piloted in six American cities. TravelSmart has become a national program in Australia with a new $20 million project to reach 300,000 households in Brisbane.

The approach targets households directly (rather than mass media approaches) through a letter from the Mayor or State Minister (funds for the program are usually a partnership of the two) asking households to participate in the program. Follow up phone calls elicit the household's interest in receiving information and a potential visit from a TravelSmart officer. The trained officers (usually people with a real interest in sustainable transport) arrive at households by bike towing a trailer of material including specially designed TravelSmart bags with walking and transit information and free tickets for the local transit system, as well as with pamphlets on why its good for their health and the planet that they get out of their cars more. They encourage people to start with local trips, especially the school trip for children, which is now seen as an essential part of the healthy development of their sense of place and belonging in any community.

Results show a consistent 12-14 % of vehicle kilometres travelled is reduced by those in the community where TravelSmart has been conducted and that this seems durable for at least 5 years after the program. In places where transit is not good and destinations are more spread out then it may only reduce car use 8% but where these are good then it can rise to 15% (Ashton-Graham, 2009). This is not a revolution but then again there are very few silver bullets in transforming transport's impact. However, it has many synergistic positive outcomes.

People involved in TravelSmart become real advocates of sustainable transport telling their friends about how much better they feel after bicycling or walking or taking transit instead of driving. They show how much money it saves as well as making them feel so much better about doing their bit for global warming and oil vulnerability. There is evidence in Brisbane that over 50% more than those involved in the initial household interviews were found to be following the program when surveys were conducted; in other words people were spreading the message to their friends and colleagues (Ker 2008).

When people start to change their lifestyles and can see the benefits, they then become advocates of other sustainable transport policy. Governments find it easier to manage the politics of transformation to reduced car use and reduced oil when the communities they are serving have begun to change themselves.

Evidence comes from Perth where the city has been rebuilding its rail system over the past 20 years following a strong social movement that demanded a better system (see below). The extension of the rail system to far outer suburbs has been more positive and politically achievable than expected with a massive 90% support for the last stage, Southern Suburbs Railway. The fact that in parallel to this political process Perth had some 330,000 households

who had done the TravelSmart program is relevant here. The patronage on the rail system has gone from 7 million a year to 110 million in 17 years and has become an icon across Australia for other cities that are now determined to upgrade their rail systems. An OECD report said that this "support for expensive infrastructure is the prime benefit of these 'soft measures'" (Salzman 2008).

The TravelSmart program is recognising a fundamental principle about behaviour change – it works best when we are supported by a community, when it is part of the development of social capital. TravelSmart develops social capital around sustainable transport modes rather than the dominant culture of the car. It does this through relationships established with the TravelSmart officer and with others in the local community who people find making the same first steps to get out of their cars. When TravelSmart is applied to workplaces it is found to work well when a TS Club is formed that enables people to share experiences, bring in local speakers and lobby employers for facilities like showers for bike riders and transit passes instead of parking spaces.

When a government program in a city facilitates a social movement for more sustainable transport options, then that city can begin to imagine its transformation to a more sustainable future.

LivingSmart

The same approach to behaviour change has been applied to other aspects of sustainability at the household level – how to reduce energy and water use and waste whilst tackling the car as well. It began in Perth but similar approaches are developing across Australia as the politics of climate change emerges as a major political force.

Known as LivingSmart, the Perth program builds on the success of household education and social capital building by discussing educationally sound and locally relevant material one-on-one in their homes. The eco-coaches who have worked in the 30,000 household trial have found enormous enthusiasm from households who have been looking for this targeted assistance. From a cold call process the program is getting 80% of households interested in making changes to improve energy, water, waste and travel sustainability. Fifty percent of the households contacted are signing up to ongoing coaching for special meters, advice on gardens, workshops, and home audits. Unlike TravelSmart where change tends to occur slowly and incrementally, the LivingSmart program is getting reports from households of instant and radical changes (replacing inefficient lights, ordering Photovoltaic Panels (PV), solar hot water and grey water recycling systems). The program is on track for a 1.5 ton per household annual CO2 reduction out of an average in Australia of 14 ton per household. This will save the households more than 10 percent in gas, electric, water and petroleum bills (Department of Transport 2009).

The social capital being built up around these new technologies and lifestyles is also proving highly infectious and can become the basis of a major social movement if governments are prepared to adopt the approach more broadly.

The reduction of household greenhouse gases at such low cost has the potential to make a major contribution to climate change mitigation policy worldwide.

Metropolitan Planning and Public Transport

The WA Government has had a bipartisan approach to regional planning for 50 years, with the State having full planning powers to enable strategic and statutory planning at local government level to be co-ordinated for the whole of metropolitan Perth and other regional cities.

For most of this past 50 years the Metropolitan Region has been built around the car, though planning powers have enabled an extensive open space system and the reclaiming of all foreshores and beach frontages. In recent times the urban region has begun to try and accommodate public transport more extensively and to build in more integrated and less car dependant land use.

The revival of the metropolitan rail system has been spectacularly successful with the electrification and extension of fast rail down each corridor providing 172km of rail with 32 stations. The patronage has risen from 7 million passengers a year to 115 million in a 15 year period.

The State is now committed to increasing the number of Transit Oriented Developments (TOD's) around stations and its Directions 31 plan provides population and job targets for such centres. A Public Transport Strategy is under preparation to plan the next stage in this integrated approach to future development. Several of the TOD's are planning to be model developments of low carbon such as Stirling City Centre (www.stirling.gov.au).

Federal Government Programs

The Federal Government has created a number of programs that are being demonstrated in Perth and its bioregion.

Solar Cities: The eastern suburbs of Perth have been chosen to demonstrate how to make renewable energy a part of the future city. This program provides an opportunity to not only provide several thousand homes with PV but to trial how these systems with smart meters and electric vehicles can work together to demonstrate a renewable city (Droege 2009; Went et al 2008; www.sustainability.curtin.edu/renewabletransport).

Energy Efficiency & Household Assessments: As part of the stimulus package free insulation of any home has enabled 950,000 homes in Australia and 90,000 in Perth to be provided with a much more energy efficient home. Subsidised PV's have also been built into these grants. Householders can have a free assessment of their energy and water use and house specific recommendations for actions to improve their household sustainability through a trained assessor.

20% Renewable by 2010: This program is a statutory requirement for utilities to reach and this is now leading to some $20b of investment in wind farms, solar PV and other renewable projects across Australia. The South West region around Perth has a new wind farm to go with three existing windfarms that bring its renewables contribution to 9% of the electricity grid.

Industry

WA is the centre of a major gas production area. The most recent project to be approved, the Gorgon Gas Field, was controversial, as it is using an A-class Reserve, Barrow Island, as its place to bring their gas on-shore and process it for export. One of the reasons for doing this is that geological formations are available deep under the Island to enable CO_2 to be pumped down and stored ie sequestered there. The WA Government has thus required the project proponents Chevron and its Joint Partners to design and construct a Carbon Capture and Storage (CCS) system for this $30b project. This will be one of the largest Carbon Capture and Storage projects in the world. Perth will supply most of the labour for this project, much of which will be fly-in fly-out. The project will also contribute to Perth substantial amounts of energy for space heating, cooking and electricity generation resulting in much fewer greenhouse gases emissions than the use of coal, our other major energy source, would otherwise cause.

Non Government Organisations

Gondwana Link
One of the biggest and most visionary NGO initiatives in climate change has been the rebuilding of a natural link 2000km from one side of the State to the other. This project known as Gondwana Link is revegetating farmland to join up reserves linking the coastal Karri forests to the inland Kalgoorlie Woodlands. This will enable a biodiversity corridor to assist in long term species survival under climate change pressures as well as providing an opportunity for farmers, industry and NGO's to work together.

First envisaged by the Wilderness Society (in consultation with the Native Conservancy) the project now has partnerships with groups like Greening Australia and Men of the Trees. Industry has been a substantial contributor through carbon credits processes being developed for biodiversity planting along with reserve. Gondwana Link provides Perth residents wanting to buy carbon offsets with an opportunity to do so. (See www.gondwanalink.org.au)

Days of Change
An NGO has been set up in Perth to challenge householders, businesses, sporting clubs etc, to pledge various levels of greenhouse gas reductions in their own lives. Days of Change has a growing support base and recently covered 40% of the nearby town of York which promised substantial reductions in greenhouse gas (See www.daysofchange.org.au).

Hulbert Street, South Fremantle
Many households can't wait for governments, industry or even NGO's to help them contribute to climate change reductions. Hulbert Street resident's Shani Graham and Tim Darby decided they would help make a sustainable street and have fun doing it. In 2 years they have developed a street-based vegetable growing system based on permaculture involving nearly every household: over 20% of the street have installed PV's on their roofs; a skills register enables people to share tools, trades and tasks; a bicycle freight system is used to carry items between houses: a Hulbert Street Choir has been started; a Living Smart course has been workshopped by most residents and now they are taking it to other streets; each Friday night the street is closed off for outdoor movies on relevant topics, and each year they have a Sustainability Fiesta involving thousands of visitors who come to see how one street is setting its own goals for the future. (See www.sustainability.curtin.edu.au/CUSPfilms)

Adaptation Responses - Adapting to a Drying Climate

Indian Ocean Climate Initiative
There was considerable resistance by many in the 1990s that reduced rainfall in the Perth region could be due to climate change; these individuals preferred the explanation that it was a result in natural variability in the rainfall. This latter explanation was attractive for some because it implied that the decline in rainfall was temporary, and so higher rainfall weather would eventually return. Those who supported this view advised caution and delay with regards to investing to adapt the public water supply system to the potential of a permanently reduced rainfall scenario. There was considerable public debate during the 1990s as to whether natural variability, climate change or some combination of the two was responsible.

Acknowledging that there were observed reductions in the rainfall in the South West of Western Australia and projections that climate change may cause further reductions, the Western Australian State Government recognised the need to better understand the cause of the changes and chances of possible future changes. So the State Government established a climate science research program through a collaboration with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Australian Bureau of Meteorology

(BOM), the two premier climate science research institutions in Australia. The collaboration, called the Indian Ocean Climate Initiative (IOCI), has had three successive four year research programs, each of these stages based on separate funding and service agreement contracts. The IOCI State 3 is still underway and will be completed in 2011. (See www.ioci.org.au/)

The results of the IOCI States 1 and 2 have been pivotal to public policy making in the State, and influential in national climate science and policy scene. It was this research that concluded that climate change was indeed at least a significant contributor to the reduced rainfall. This result informed the decision relatively early in the drying trend to bring forward investment in water source development that had been planned for many years into the future (Water Resource Planning section below). As result, Perth has avoided the need for full scale water restrictions and the substantial economic costs that come with that. The IOCI research played a key role in convincing decision-makers to commit to large additional public investment in water source developments, when there were still voices arguing that such investment should be delayed. Perth therefore compares favourably to many other Australian capital cities, that have experienced reduced rainfall later than Perth, but did not avoid having to introduce full water restrictions because their public water supply systems couldn't cope with the reduced water storage in their dams. The value of the IOCI has been recognised by the other Australian states many of which have established similar dedicated climate research programs, in particular the South East Australian Climate Initiative.

Water resource planning

Relevant predictions are that under a climate changed future our rainfall levels will continue to decline; we will have a city with roughly twice its current population size; and we need to reduce the environmental impact of water provision. In Western Australia it is the Water Corporation that has primary responsibility for planning water supply and storage.

During the 1980s and 1990s major investments were made in systems to pump groundwater from major groundwater aquifers in the Perth region. This diversified the sources for the public water supply system and expanded the proportion of water being sourced from groundwater. The reduced rainfall has also resulted in a decrease in groundwater re-charge of major groundwater aquifers which are also major water sources for the public water supply system. This has meant that the sustainable water yield that can be pumped from the Perth's regions major groundwater resources has also been reduced. By the stage that a severe drought started in 2001, over 50% of the public water supply was able to be sourced from groundwater. However with the growing recognition that climate change was likely to be the cause of the decline in rainfall, it was also recognised that there was value in diversifying sources of groundwater further to include sources which were entirely independent of rainfall. Thus the State Government committed to building the largest seawater desalination plant in the Southern Hemisphere, and the first large scale plant in Australia. It cost A$387million and began operation in 2006. The since that initial commitment investments in desalination plants have been made in four of the other Australian States. The construction of a second large seawater desalination plant to supply Perth has also begun.

The reduction in rainfall, caused to a large extent by climate change, has led the Western Australian State Government to invest a total A$673 million in 10 separate water source developments between 1996 and 2006 that have increased water supply capacity by a total of 199 GL (Water Corporation, 2010). This can be compared with the total water use in Perth and surrounding areas in 2008 of 286 GL 9 (Water Corporation 2009b).

The Water Corporation has forecast that to cover both declining rainfall and increasing population Perth and its connected towns will need and extra 365 GL of drinking water by 2060 (Figure 10). In a new strategic study last year, titled 'Water Forever: Towards Climate

Resilience' the Water Corporation identified a 'three-pipe' strategy for meeting Perth's water needs in a changing climate.

The main strategies of the Water Corporation to meet the 356 GL are threefold.

Reduce water use
The Water Corporation aims to achieve a 25% per capital reduction in water use by 2060. This is a central requirement in a city that will have reduced rainfall. This strategy helps reduce the need to find further new sources of water; it reduces energy use, associated greenhouse gas emissions and land clearing; and it leaves more water in the environment where it is needed for ecosystem function. Examples of actions include:

- Continue the WA Waterwise Progam which helps the water-intensive industry sector reduce water usage; and expand the program to include one-to-one work with households and schools
- Work with the WA Planning Commission to promote water sensitive urban design, and to better integrate land and water planning
- Ensure metering, pricing and billing practices support reduced water use
- Explore mandated minimum water efficient approaches and appliances for new residential and commercial developments and work with national bodies to regulate for minimum WELS ratings for water efficient products.

Increase water recycling
The goal of the Water Corporation is to be recycling 60% of all metropolitan wastewater by 2060, as against the currently recycling rate of only 6%. Some individual households re-use their grey water on their gardens but the government has health concerns about this practice unless it is carefully managed according to official guidelines and regulations.

Examples of actions include:

- Supply industry with recycled water through Kwinana Water Recycling Plant, and expand the Plant to produce a further 3.5 GL per year
- Work with relevant agencies to ensure industrial estates are reticulated to be irrigated with recycled water
- Identify public and Water Corporation land that could be irrigated using recycled water
- Work with the WA Planning Commission and the Department of Planning to incorporate future wastewater infrastructure, recycling plants and pipeline corridors into strategic planning and to develop streamlined approval processes for alternative water supplies and recycled water
- Explore groundwater replenishment, where high quality recycled water is stored in groundwater for use in drinking water supplies.

Develop new sources
The degree to which new sources are required depends on the success of water recycling and efficiency approaches. In tandem with securing new sites for desalination plants and exploiting new water aquifers, the Water Corporation will have to mitigate the impacts of energy intensive processes by contracting for energy from renewable energy sources or by purchasing offsets. Reduction of other environmental impacts and consideration of other social and economic implications are also desirable.

Public Health Adaptation

The WA Health department has recognised that climate change represents a significant and growing threat to public health. In WA, impacts are thought to include:

- Extreme weather related health effects
- Air pollution related health effects
- Water and food borne disease health impacts
- Vector borne disease health impacts and
- Indirect health impacts including mental health[5].

In partnership with Curtin University, the WA Health department produced in 2007 an initial response to climate change induced health issues in a report titled 'Health impacts of climate change: Adaptation strategies for Western Australia'[6]. The two-phase project sought first to identify potential health impacts that could result from a scenario of climate change, in the context of our current ability to cope and the existing socio-economic vulnerabilities (Figure 11). Just one example presented in the report of the ramifying impacts of climate change on health can be seen in Figure 11 below. Second, a risk assessment was conducted. It was found that the lack of detailed information made a quantitative study impossible but a good understanding of current activities, their adequacy with respect to health, and a range of desirable adaptations and supporting research were established through a qualitative assessment. The research provides the basis for an active approach to the protection of the community from climate change impacts and for future planning and adaptation.

Local Government Adaptation and the Eastern Metropolitan Regional Council

Under the hotter, drier conditions projected for Perth, bushfires, declining water availability and waterway health present a range of hazards, which will only increase. The consequences are too great for local governments to handle alone, so a regional approach has been adopted in one cutting edge adaptation process in Perth.

The local governments of metropolitan Perth are grouped together into regional councils for the purposes of providing services such as resource recovery, environmental management, regional development, and risk management. The Eastern Metropolitan Regional Council (EMRC) is comprised of six member Councils which collectively cover one third of the metropolitan area and include large areas of native forest and bushland. These areas are vulnerable to bushfires and their impacts on human life, ecosystems, infrastructure, industry and homes. The river systems within these areas and water availability more generally are also under pressure from drying conditions.

The EMRC developed an idea for a regionally based climate change adaptation plan and obtained funds from the Australian Government's Department of Climate Change's 'Local Adaptation Pathways Program'. The EMRC also contributed core funding. The 'Future Proofing Perth's Eastern Region' framework was developed to complement regional mitigation actions by identifying the major risks of climate change relevant to the region and to assist in the development of a regional adaptation plan to address the risks.

A regional forum was held on 5 February 2009 which brought together key stakeholders and decision makers in the region. The ongoing consultation and data collection process included

[5] http://www.public.health.wa.gov.au/2/705/2/climate_change.pm

[6] Can be downloaded from http://www.public.health.wa.gov.au/2/705/2/climate_change.pm

a series of workshops with member Council staff during 2009 to ensure effective and relevant inputs into the risk assessment and asset identification process. The Future Proofing Perth's Eastern Region 'Regional Climate Change Adaptation Action Plan 2009 – 2013' has been approved by the Council of the EMRC and is now operational[7]. The EMRC and its six member Councils have provided four years of funding and commitment to help ensure actions would actually be implemented.

The ten priority risk areas identified by the EMRC project are:

1. Infrastructure failure
2. Impacts on essential services
3. Watercourse damage and loss
4. Fire
5. Water decline and quality
6. Greenhouse gas emissions and related air pollution
7. Ecosystem loss and public open space
8. Population health and displaced people
9. Economic decline
10. Changing leadership and development requirements

The EMRC is in the process of implementing actions. Examples include:

- identifying existing information gaps and partnerships in relation to the impacts of climate change on Local Government infrastructure (i.e. roads, paths drainage)
- investigating current research and directions on power and fuel supply solutions and technologies
- raising community awareness and behaviour change towards river bank erosion and subsidence issues
- advocating to state Fire and Emergency Services Authority to support better fire management measures
- raising community awareness about how and when to protect their houses ensuring that fire warning systems are in place
- promoting water efficient appliances, rainwater tanks and greywater use and
- advocating to state government to produce a state policy on climate change.

All six of the member councils are now in the process of developing their own local climate change adaption action plans, based on various forms of risk assessment, as a result of being motivated by the Future Proofing project. The EMRC is also sharing its best management practice with other regional councils such as the Western Suburbs Regional Organisation of Councils (WESROC).

According to the EMRC's Manager of Environmental Services, Naomi Rakela, it is logical and beneficial to deal with climate change at both the regional and the local level, which brings about a two level planning approach ensuring all the risks are captured at one of these levels and providing for a more holistic approach to climate change.

<u>Online Climate Adaptation Toolkit</u>

In 2009 the Western Australian Local Government Association, funded by the Department of Environment and Conservation commissioned the Curtin University Sustainability Policy Institute to build an online Climate Change Management Toolkit. The purpose of the Toolkit is to provide a set of resources and guidelines that will enable local governments to respond

[7] http://www.emrc.org.au/future-proofing-perth-s-eastern-region-climate-change-adaptation.html

to climate change. It steps the user through a series of actions that need to be taken, with a set of resources for each step. The website can be viewed at http://www.walgaclimatechange.com.au/. It has been rolled out throughout WA to a large number of local governments and has been well received.

Adaptation Response - Coastal Adaptation

Perth Coastline

In Perth, as in most places in Australia, Indigenous people have interacted with the coast for tens of thousands of years. There are cultural stories about the Nyungar occupation of land between Perth and Rottnest Island, which now lies underwater. The story 'When the Sea Level Rose', as told by Dr Noel Nannup, talks about the impact of the rising sea levels on his forebears' cultural world, probably at the end of the last ice age 7000 years ago. 'When the sea level rose' follows Nyingarn the Echidna, Kaarda the Goanna and their role in caring for the spirit of those who have passed. The story includes Wadjemup (Rottnest Island) when it was connected by a landbridge to the mainland, and goes on to introduce Mamong the Whale and Kieler the Dolphin who were to help Nyingarn and Kaarda. The story centres around when the sea level rose and trapped the spirits of children underneath the sea and the role that Mamong the whale and Kieler the dolphin played to help bring the children back to the land.' (Nannup 2006).

Many Indigenous peoples of the Australian coast have dwelt as clans whose occupation shares some common features: coastal clans use marine resources for subsistence, culture and exchange; 'saltwater country' or 'sea country' is inseparable from the land rather than radically discontinuous; cultural stories describe features of sea country and some names and sacred sites reflect these; and clan identity is closely related to the sea (Smyth 1997). Clans manage their estates through cultural ceremonies such as song and dance, and traditionally restricted access to the sea according to season, status of clan member, totem and presence of sacred sites (Smyth 1997). In the case of Perth, many of the names of the islands and coastal features relate to the cultural or 'dreaming' stories.

'Present-day Noongar oral history confirms the importance of the coast, the sea and the islands. In a restricted report made available to the AIC, several Noongar elders recounted Dreaming stories for the coast from Fremantle to Yanchep. In one version Crocodile, Shark and Whale encountered one another. Their fighting altered different parts of the landscape. Whale is associated with sand dunes at Leighton Beach. Shark and Crocodile fought in Cockburn Sound until the Creation Snake 'Waugal' intervened. Crocodile on Waugal's advice travelled to Yanchep where he metamorphosed into Emu (Waitj). (Colbung in Hill, 2006:10-13). In another Dreaming story, a fight between Crocodile and Waugal broke up the land and created Rottnest, Garden and Carnac islands (Wilkes in Hill 2006, 14-15). The Waugal is regarded as having created the sand dunes that follow the coast, as it has for all land features…' (Albert Corunna in Hill 2006, 18).' (Western Australian Planning Commission 2008).

Since white settlement, human uses of and impacts on the coastal zone have increased dramatically. Over 80% of the State's population currently lives within 30 kilometres of the coast. The contemporary Western Australian coast varies in its landform and patterns of human usage and includes:

- urban coasts, characterised by intensive residential, commercial and industrial development usually with a high recreational usage;
- natural coasts, with light residential and commercial usage, and providing access for tourism and recreation; and

- wilderness coasts, with little or no residential, commercial or industrial usage, and little access to tourists.

The Perth coastline is largely urban, with some natural coasts to the north and south of the metropolitan area. As the city is expanding rapidly, the conversion of coasts from natural to urban is occurring quickly, with much new development having occurred close to the primary dune.

Western Australians value a coastal lifestyle and the unique opportunities that our coast provides. The Perth coastal waters are still relatively clean, and residents fish, swim, dive, surf, picnic, sail and walk their dogs on the coast. For a holiday, they are most likely to visit another coastal location such as Rottnest Island or the Margaret River area.

However, pressures on the coast are increasing and they arise from: rapid coastal population growth and development; catchment land and water use; marine industries (shipping, tourism, aquaculture, oil and gas extraction, tourism and fishing); pollution; exotic species; and coastal infrastructure development. Climate change and extreme weather events have begun to interact with these existing pressures [8].

Governance of the coast is a challenge. The coastal zone is characterised by multiple jurisdictions, lack of integrated management tools and continuing controversy on major developments. Perspectives on what constitutes appropriate coastal zone management differ according to stakeholders' worldviews and values (Kellert 2003; Stocker & Kennedy 2009). This section describes attempts by different jurisdictions and stakeholders to adapt coastal development to climate change.

State Coastal Planning

2003 State Planning Policy No. 2.6 State Coastal Planning Policy

The Western Australian State Planning Policy No. 2.6: State Coastal Planning Policy (2003) (SPP 2.6) is the principal policy instrument for guiding new land developments in coastal regions. The policy's objectives are:

- protect, conserve and enhance coastal values, particularly in areas of landscape, nature conservation, indigenous and cultural significance;
- provide for public foreshore areas and access to these on the coast;
- ensure the identification of appropriate areas for the sustainable use of the coast for housing, tourism, recreation, ocean access, maritime industry, commercial and other activities; and
- ensure that the location of coastal facilities and development takes into account coastal processes including erosion, accretion, storm surge, tides, wave conditions, sea level change and biophysical criteria.

Under a climate-changed future, the first three objectives can only be met if the final objective is met.

To achieve these objectives, SPP 2.6 relies on the use of:

- measures to guide regional and local coastal planning;
- strategic coastal planning prior to development of an area; and
- development setback guidelines.

[8] http://www.csiro.au/science/ManagingCoastalWaters.html

Schedule One of the policy includes guidance on coastal setback requirements in relation to the potential impacts of climate change, sea level rise and the dynamic nature of coastal processes, including the calculation of:

- distance for absorbing extreme storm sequences/acute erosion;
- distance to allow for historic trends; and
- distance to allow for sea level change.

Although factors such as coastal geomorphology create variations in the calculated setback, a total setback in the order of 100 metres from the horizontal setback datum is expected. This has proved to be a highly controversial aspect of the policy, resulting in struggles amongst government, developers, local residents and conservationists over access to and use of the foreshore. A new sea level rise formula is currently being developed. However, the fundamentally complex and uncertain nature of climate change and sea level rise challenges instrumental policy-making and planning to its core. The need for reflexivity and adaptive planning is critical.

Other ongoing coastal planning initiatives include the LiDAR / Airborne Laser Bathymetric survey of the coast from Two Rocks north of Perth to Cape Naturaliste in the southwest corner of WA. This information will be used to support decision making on the coast, taking into account the effects of climate change, including storm surge and sea level rise. The baseline modeling will ensure areas of risk from coastal inundation and/or flooding, and the combined effects of storm surge and high winds will be identified and better managed.

A Perth Coastal Planning Strategy is also in the pipeline and has been through a public engagement process. The final strategy is due to be released in mid-late 2010. The aim of the strategy is to provide a regional overview, with strategic planning and policy guidance, for dealing with development on the metropolitan coast. The issues considered include: coastal processes; environmental (terrestrial and marine); urban, commercial and industrial; tourism, recreation, public use and access; visual and landscape; and cultural issues. Public submissions on the draft strategy highlighted the importance of climate change and the subsequent impact of sea level rise and associated concerns with coastal erosion. The final strategy will be an important planning tool for state and local government, and other agencies, to guide future planning decisions along the metropolitan coast.

Local Government Coastal Vulnerability Assessments

Coastal areas are at risk of sea level rise and inundation, storm surge events and erosion. Other areas are at risk of being isolated through flooding and storm events. Understanding the implications of locating development in particular areas is critical to managing and mitigating the impacts of climate change. Vulnerable areas in the greater Perth metro area include Trigg, Rockingham, Cottesloe and Mandurah.

The Town of Cottesloe includes one of Perth's favourite and most iconic beaches, and is a regional attraction. It attracts surfers, club-goers, sunbathers, families and coffee-drinkers. In March each year there is a sculpture festival on the foreshore, celebrating the interaction of culture and nature, which brings tens of thousands of visitors. Cottesloe Beach is potentially at risk from coastal erosion as development is very close to the present shoreline, with some structures right on the beachfront. In response to this threat, the Town of Cottesloe commissioned a report that would help the Town prepare for future challenges in the management and maintenance of its valuable coast, resources and infrastructure. The main aim of the 'Cottesloe Climate Change Vulnerability Assessment Project'[9] was to establish

[9] http://www.cottesloe.wa.gov.au/?p=942

potential risk to existing key coastal infrastructure under a range of future climate scenarios and to suggest adaptive pathways. The study found that the most extreme prediction of the modeling process was a shoreline recession of 97m, which would take out the main road and the front rows of houses.

A similar study is also underway for the City of Mandurah, an exceptionally vulnerable area featuring an erosive coastline, a large ramifying estuarine system of great ecological and cultural value, and wealthy canal estates. The local government is very keen to undertake serious climate change adaptation.

Community-Based Adaptation Planning

In July 2009, Curtin University Sustainability Policy Institute ran a community workshop in Fremantle, Western Australia. Fremantle is a site of very early white settlement in WA. It is a port town, once a Labor political party stronghold but now with an increasingly Green-leaning electorate and with a strong university, tourism, arts and designer fashion base to its economy.

The workshop ran for a day and used Google Earth and deliberation as the key consultation tools. The 150 participants listened to a series of short talks from scientists about the likely impacts of climate change on the Fremantle coastal zone. Local and state government speakers presented the governance perspective. Panel sessions provided time for questions and answers. Participants were then broken into groups of eight around tables and using large physical maps of coastal Fremantle chose five places of key importance to the group. We asked them to identify their values and uses for each of these places. Next, they deliberated on the key concerns they had about the likely impact of climate change on their chosen sites. Finally they deliberated on the possible adaptive pathways that should be considered as responses to their concerns. Each of the groups' deliberations were summarised at each stage and were placemarked in Google Earth, thus providing a spatially explicit account of the deliberations. These results were compiled into a single kmz file which was mounted on the CUSP website. (See the interim results at www.sustainability.curtin.edu.au - further analysis of the results is ongoing.) The workshop was the first of its kind in WA and allowed residents, scientists, policy-makers, planners and academics to sit together and work through the major climate adaptation issues facing Fremantle. A similar workshop will be undertaken by CUSP in relation to Rottnest Island, Perth's favourite island holiday destination, in order to help plan for sustainability and climate change.

Federal Research Initiative: Enabling Science Uptake In Governance of the Coastal Zone in the Face of Future Change

Of concern to Australia's government scientific organization, CSIRO (Commonwealth Scientific and Industrial Research Organisation), is the fact that while scientists have generated substantial scientific data and models detailing climate change impacts on the coast, and lay and traditional knowledge systems also report climate change impacts, progress in the governance of coastal adaptation has been too slow. CSIRO has therefore funded a major new research initiative, the Coastal Collaboration Cluster, led by Curtin University, to identify ways of enabling better climate change science uptake by decision-makers in the coastal zone (Wood & Stocker 2009; Stocker et al 2010).

According to the working model of the Cluster, in addition to favourable functions and processes in the broad socio-cultural context, knowledge uptake by governance requires both a receptive governance process, and accessible knowledge systems. This dialogue can be greatly enhanced, especially in the complex and uncertain domain of coastal management, by adaptive learning. Governance includes the institutional authorities, processes, and procedures used for guiding strategic and key operational decisions about the coastal zone.

As mentioned above, coastal governance in Australia comprises not only complexly interacting levels of formal government (Federal, State and Local) but also development commissions, Non-Government Organisations, Indigenous Native Title holders, and a wide range of other stakeholders. Curtin University's research contribution to this Cluster addresses what kinds of governance arrangements are most likely to enable uptake of knowledge about coastal adaptation and generate adaptive solutions, by drawing on post-normal methodologies such as transdisciplinary research, digital visualization and Google Earth, deliberative workshops, social network analysis, causal layered analysis and scenario development.

Conclusions

The attempts by Perth and its bioregion to come to terms with climate change are a modest contribution to this global issue. There is much to do by the global community in coming to terms with the issues quickly or else run-away climate change may result. Some innovations that could be globally significant have been shown here, but they are not nearly enough. By sharing our stories from around the world we hope that this can help develop the momentum for change so surely needed.

Bibliography

Antarctic Climate & Ecosystems Cooperative Research Centre 2008. Position Analysis: Climate change, sea-level rise and extreme events: impacts and adaptation issues. ACE CRC, Hobart, pp 12-13.

Ashton-Graham, C. 2009. 'TravelSmart+TOD=Sustainability+Synergy, *Transit Oriented Development Conference,* Fremantle, www.transport.wa.gov.au .

Australian Bureau of Meteorology (BOM) & Commonwealth Scientific and Industrial Research Organisation (CSIRO). 2008. *An assessment of the impact of climate change on the nature and frequency of exceptional climatic events*, July.

Australian Bureau of Meteorology (BOM) Climate Change Trends Maps, Trend in Mean Temperature, BOM website: http://www.bom.gov.au/cgi-bin/climate/change/trendmaps.cgi ..

Australian Bureau of Statistics (ABS). (2010a) downloaded from ABS website: http://www.abs.gov.au/websitedbs/c311215.nsf/20564c23f3183fdaca25672100813ef1/15ee398c42e0d992ca2569f900199507!OpenDocument , June 2010.

Australian Bureau of Statistics (ABS). (2010b) Western Australia at a Glance 2010, downloaded from ABS website: http://www.ausstats.abs.gov.au/Ausstats/subscriber.nsf/0/6599D80065E6323BCA25771B001516BE/$File/13065_2010.pdf , in June 2010.

Bushfire Cooperative Research Centre (Bushfire CRC). 2008. *Climate Change and its impact on the management of bushfire*, Fire Note Issue 25, October, 2008, downloaded on 27 March 2010 from: http://www.bushfirecrc.com/publications/downloads/Fire-Note-climate-change_25.pdf .

Caputi, N., S. de Lestang, M. Feng, & A. Pearce. 2009. 'Seasonal Variation in the long-term warming trend in water temperature off the Western Australian coast', *Marine and Freshwater Research*, **60**, 129 – 139, CSIRO Publishing.

Cramb, J. 2005. 'How Our Temperatures Have Changed; Climate Note 2/05', Indian Ocean Climate Initiative, Perth, August.

CSIRO. 2010. *State of the Climate*, CSIRO & Bureau of Meteorology, March.

Department of Transport. 2009 Living Smart: Acting on Climate Change, www.dpi.wa.gov.au/livingsmart .

Droege P. (ed) 2009. *100% Renewable,* Earthscan, London.

Eliot, M. 2009. 'Trends of Coastal Flooding in the Swan River Estuary', Greenhouse 2009 Conference, Perth, March.

Feng, M., M. Meyers & J. Church. 2005. 'How Our Sea Temperature Has Changed; Climate Note 3/05, Indian Ocean Climate Initiative, Perth, August.

Gehl, J and Associates. 2009. *Perth 2009: Public Space Public Life,* Perth City Council, Perth.

Government of Western Australia. 2003. Hope for the Future: The Western Australian State Sustainability Strategy.

Government of Western Australia. 2004. *Western Australian Greenhouse Strategy*, prepared by the Western Australian Greenhouse Task Force, Government of Western Australia, Perth, WA.

Government of Western Australia. 2007. Making Decisions for the Future: Climate Change; The Premier's Climate Change Action Statement, Government of Western Australia, Perth, WA.

Henessy, K. 2008. 'Climate change in WA: local perspectives', Presentation to 'Climate change capacity building for local governments' Workshop, Perth, 8 September 2008, Workshop organised by Office of Climate Change in the Western Australian Department of Environment and Conservation.

Kellert, S. 2003. Human values, ethics and the marine environment. In: Dallmeyer, D. (ed.) *Values at sea: Ethics for the marine environment,* University of Georgia Press, Athens: 1–18.

Ker, I. 2008. *North Brisbane Household TravelSmart: Peer Review and Evaluation*, Brisbane City Council, Queensland Transport, Australian Greenhouse Office, Brisbane.

Nannup, Noel. 2006. 'When the Sea Level Rose'. Swan Catchment Council, Midland, Western Australia.

Pattiaratchi, C. & Eliot, M. 2005, 'How our regional sea level has changed; Climate Note 9/05', Indian Ocean Climate Initiative, Perth, August.

Pattiaratchi, C. & Eliot, M. 2008. 'Sea Level Variability in South-West Australia: From Hours to Decades', ICCE 2008, Hamburg, August 31st to September 5th, 2008.

Pittock, A.B. 1988. 'Actual and anticipated changes in Australia's climate.' In, *Greenhouse: planning for climate change,* G. I. Pearman (ed). CSIRO Publishing.

Sadler, B. 2004. 'Informed adaptation to a changed climate state Is south-western Australia a national canary?', Indian Ocean Climate Initiative, Perth.

Salzman, R. 2008. 'Now that's what I call intelligent transport – smart travel', *Thinking Highways*, March, pp 51-58.

Smyth, D. 2004. Living on Saltwater Country. Review of literature about Aboriginal rights, use, management and interests in northern Australian marine environments. National Oceans Office, Hobart. Commonwealth of Australia.

Spickett, J., H. Brown and D. Katscherian. 2008. Health impacts of climate change: Adaptation strategies for Western Australia. WA Department of Health.

Stocker, L. & D. Kennedy. 2009. Cultural Models of the Coast in Australia: Towards Sustainability. *Coastal Management* 37(5): 387- 404.

Stocker, L., B. Pokrant, D. Wood, N. Harvey, M. Haward, K. O'Toole, T. Smith. 2010. 'Australian Universities, Government Research and the Application of Climate Change Knowledge in Australian Coastal Zone Management.' In, Leal Filho, W. (ed) *Universities and Climate Change.* Springer, Berlin.

Water Corporation. 2009a. 'Yearly Streamflow for Major Surface Water Sources', Downloaded from website 27 March 2010; http://www.watercorporation.com.au/D/dams_streamflow_large.cfm .

Water Corporation. 2009b. *Water Forever Towards Climate Resilience*, Perth, October.

Water Corporation. 2010. Downloaded from website on 27 March 2010; http://www.watercorporation.com.au/W/water_sources_new.cfm?uid=9809-4354-6198-5978

WA Today. 2010. Downloaded from: http://www.watoday.com.au/wa-news/perths-summer-the-driest-and-hottest-on-record-20100228-pay3.html .

Went, A., P. Newman P. and W. James. 2009. 'Renewable Transport' in Droege P op cit

Western Australia Greenhouse Coordination Council (WAGCC). 1991. *Greenhouse Strategy for Western Australia*, WAGCC, Perth, WA.

Western Australian Marine Science Initiative (WAMSI). 2010. Presentation at Western Australian Marine Science Initiative Node Symposium, 25 March 2010, CSIRO, Floreat, Perth.

Western Australian Planning Commission. 2008. 'Indigenous Heritage'. Appendices, in, *The Changing Cockburn Coast.* www.planning.wa.gov.au/Indigenous%20Heritage.pdf?id=1708

Winton, T. 1993. *Land's Edge.*

Wood, D. & L. Stocker. 2009 'Coastal Adaptation to Climate Change: Towards Reflexive Governance'. *The International Journal of Science in Society* 1(3): 137-145.

Figure 1. Map of Australia showing Perth's location.

Figure 2. Map of Perth showing land use, the Metropolitan Regional Scheme planning zones, and railways. The forested water supply catchments are denoted by the hatched areas east of the city. The Gnanagara Groundwater mound is denoted by the hatched area north of the city.


Legend
Legend
PERTH
FREMANTLE

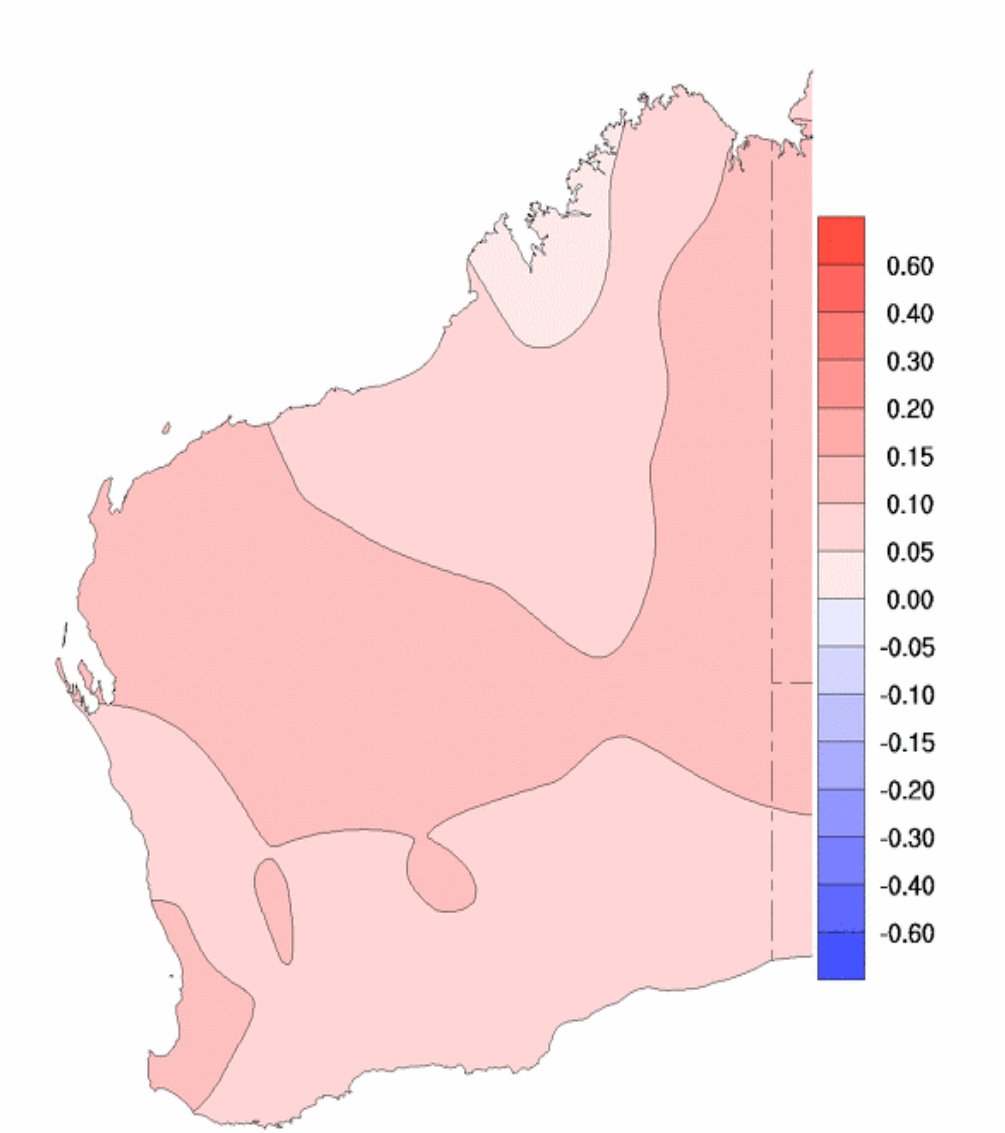

Figure 3. Map of Observed Trend in Mean Temperature for Western Australia from 1910 to 2009, in degrees Celsius per 10 years

Source: Bureau of Meteorology. 2010. http://www.bom.gov.au/cgi-bin/climate/change/trendmaps.cgi?map=tmean&area=wa&season=0112&period=1910

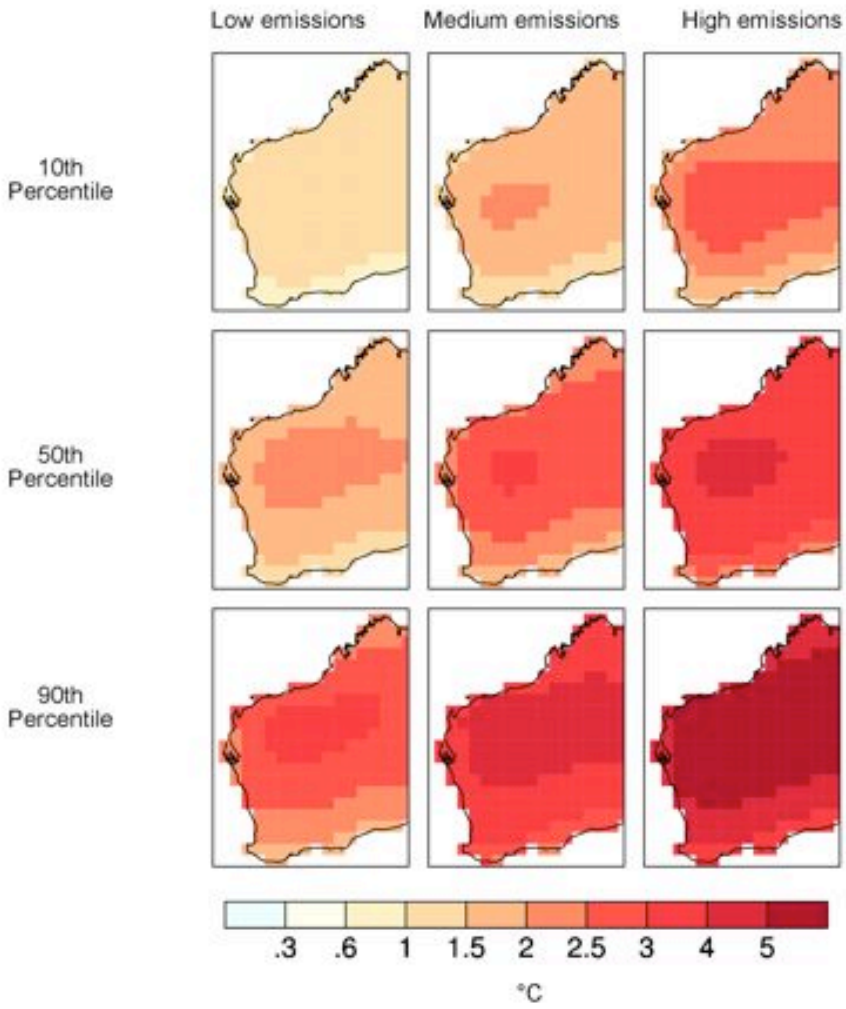

Figure 4. Projections for Temperature Change in Summer for Western Australia in 2070, in degree Celsius, for low, medium and high global emission scenarios.

Source: Bureau of Meteorology and CSIRO. 2010.
http://www.climatechangeinaustralia.gov.au/watemp11.php

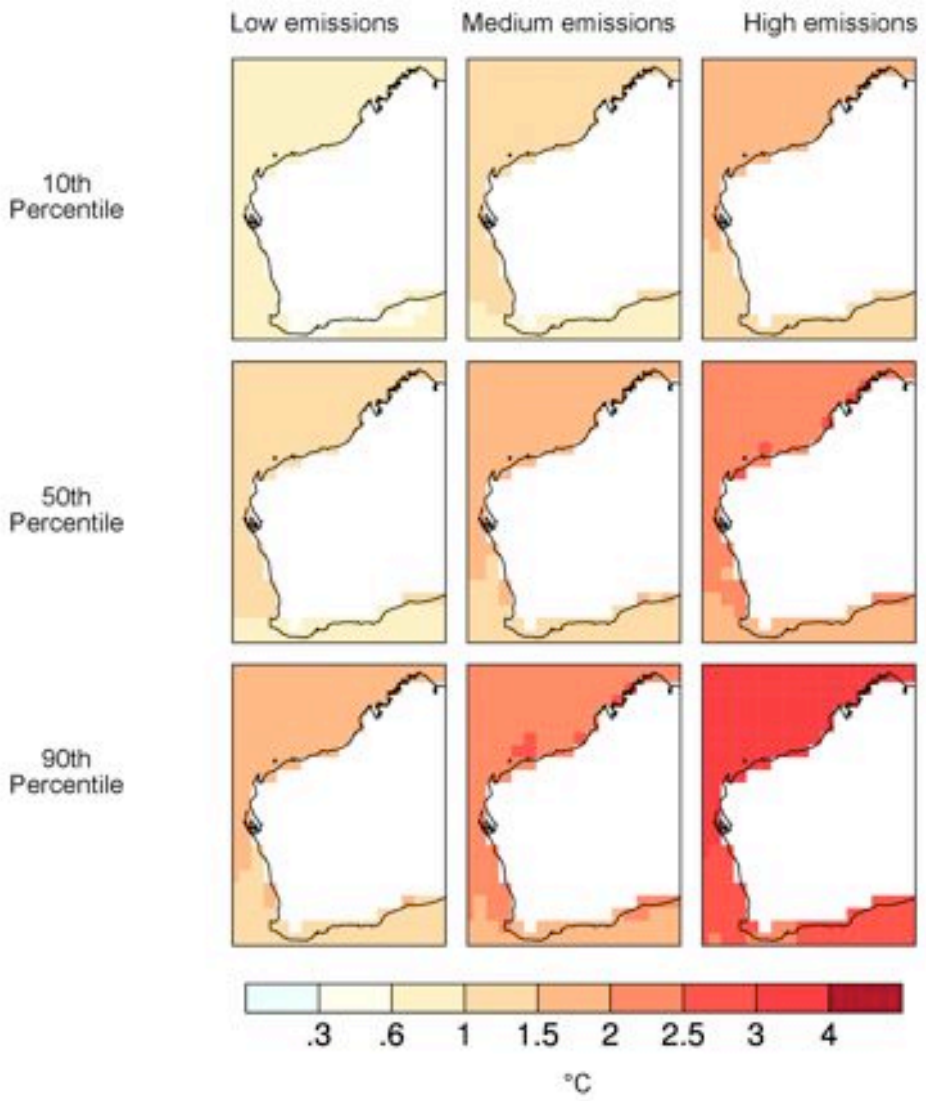

Figure 5. Projections for Sea Surface Temperature Change for Western Australian in 2070, for low, medium and high global emission scenarios in degrees Celsius.

Source: Source: Bureau of Meteorology and CSIRO. 2010.
http://www.climatechangeinaustralia.gov.au/wasea15.php

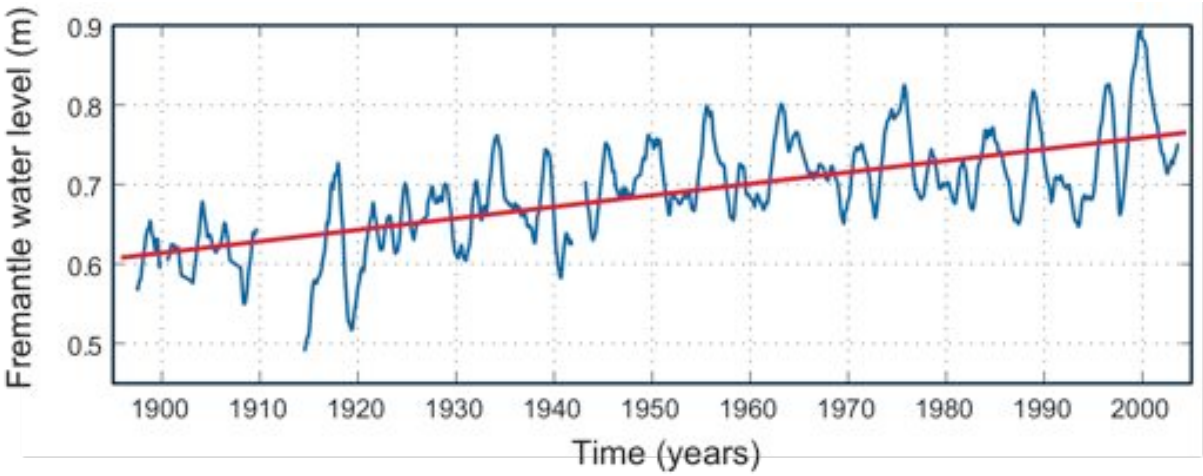

Figure 6. Time series of Observed Fremantle sea level (one year running mean) with the linear trend of 1.54 mm per annum superimposed in red.

Source: Pattiaratchi, C. & Eliot, M. 2005. 'How our regional sea level has changed; Climate Note 9/05', Indian Ocean Climate Initiative, Perth, August.

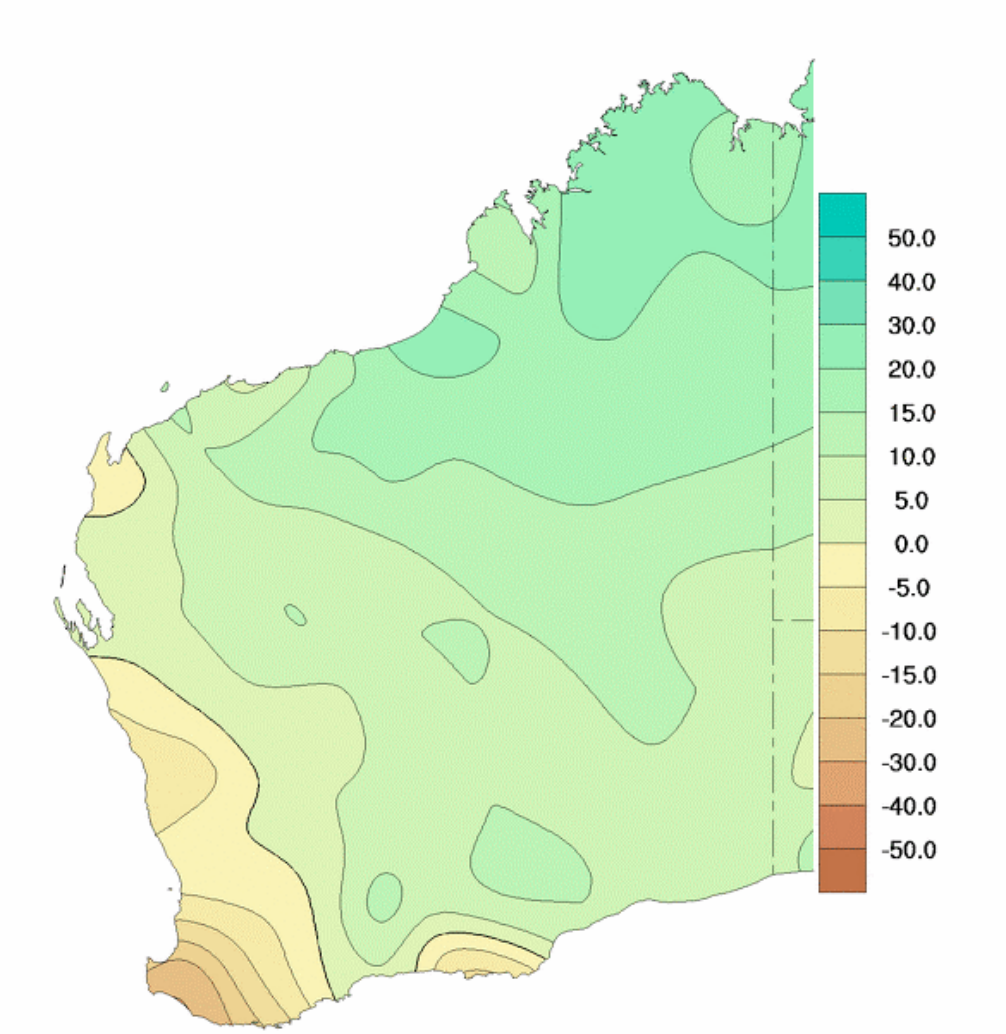

Figure 7. Map of Observed Trend in Total Rainfall for Western Australia from 1910 to 2009, in mm per 10 years.

Source: Bureau of Meteorology. 2010. http://www.bom.gov.au/cgi-bin/climate/change/trendmaps.cgi?map=rain&area=wa&season=0112&period=1910

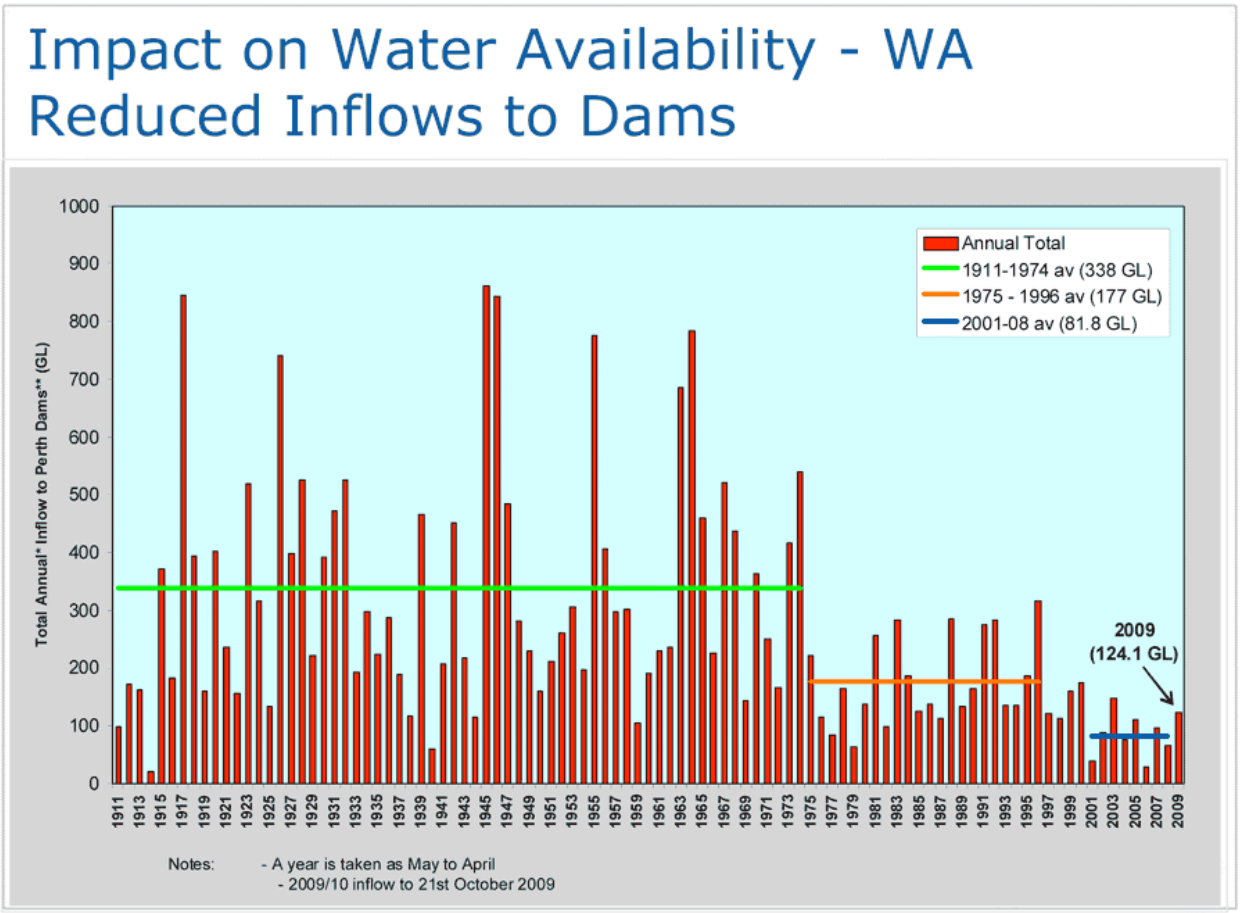

Figure 8. Annual Inflow to Perth Dams, 1911-2009

Source: Water Corporation, 2009a.

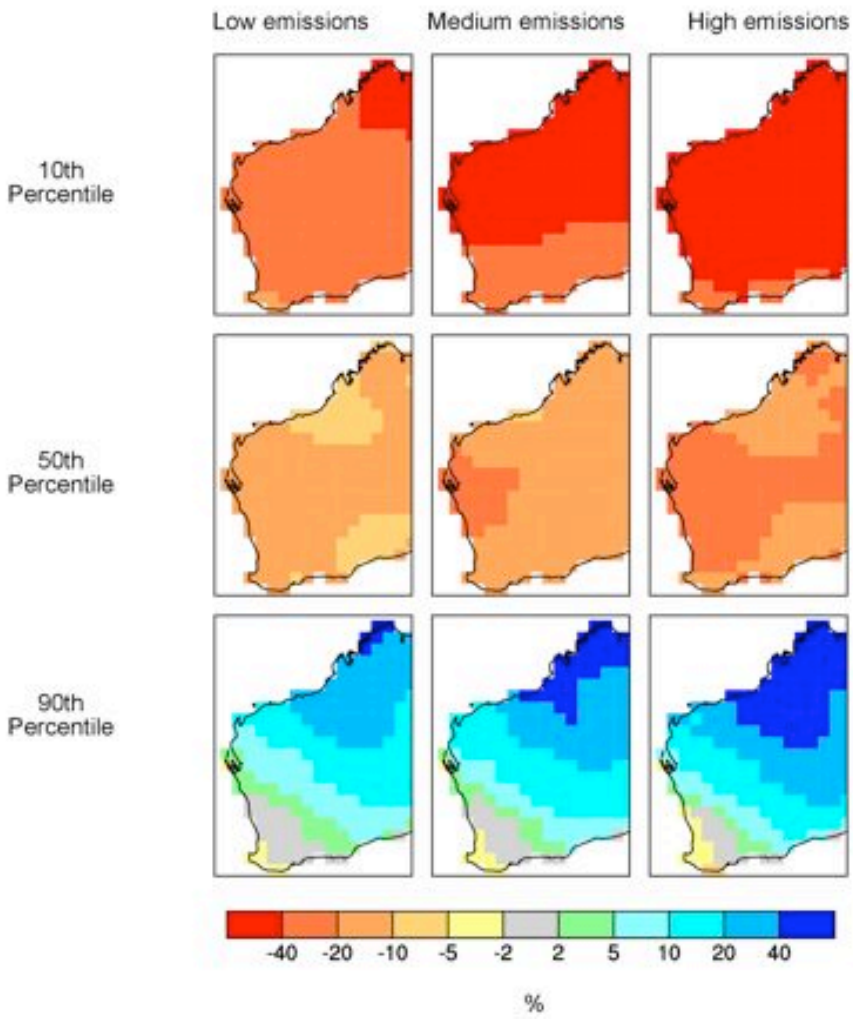

Figure 9. Projections for Rainfall Change in Winter for Western Australia in 2070, in percentage change, for low, medium and high global emissions scenarios.

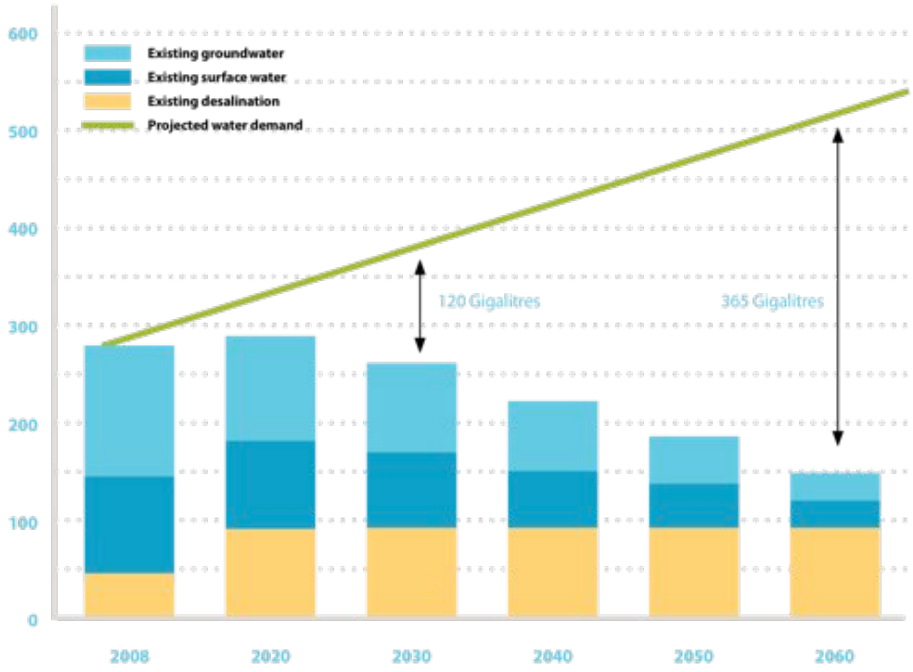

Figure 10. Perth's water needs to 2060

Source: 'Water Forever: Towards Climate Resilience' (Water Corporation 2009).

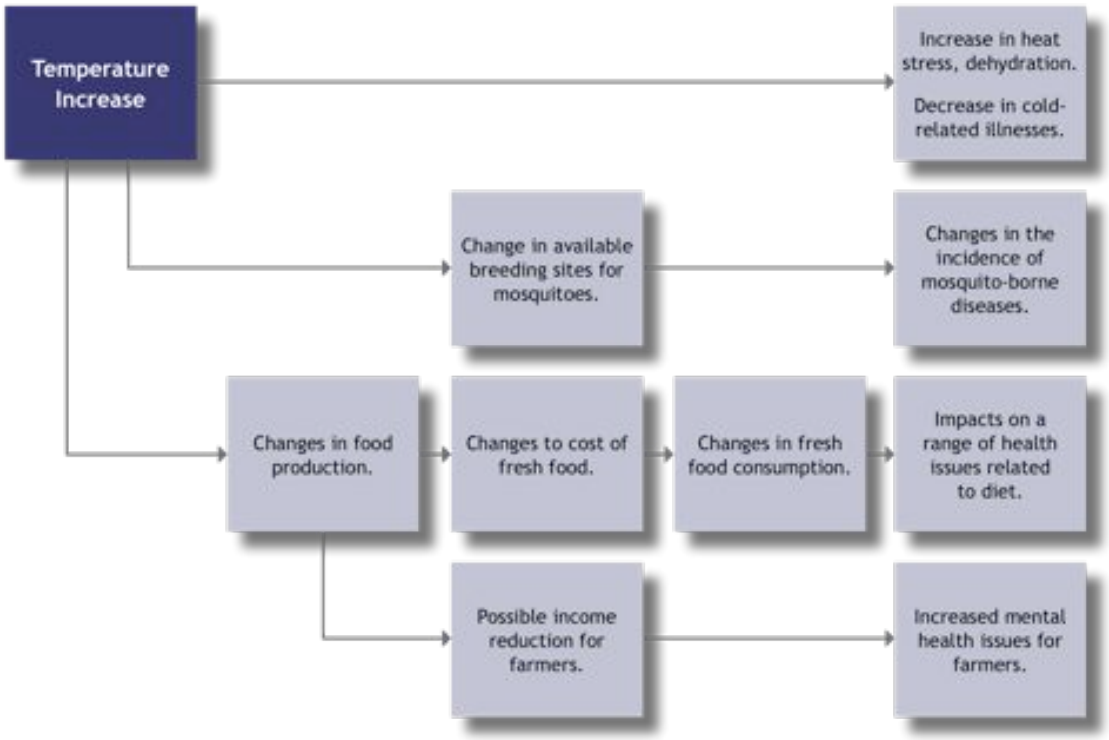

Figure 11. Examples of potential direct and indirect health impacts of temperature increase in 2030.

Source: Spickett et al (2008) Health impacts of climate change: Adaptation strategies for Western Australia. Department of Health