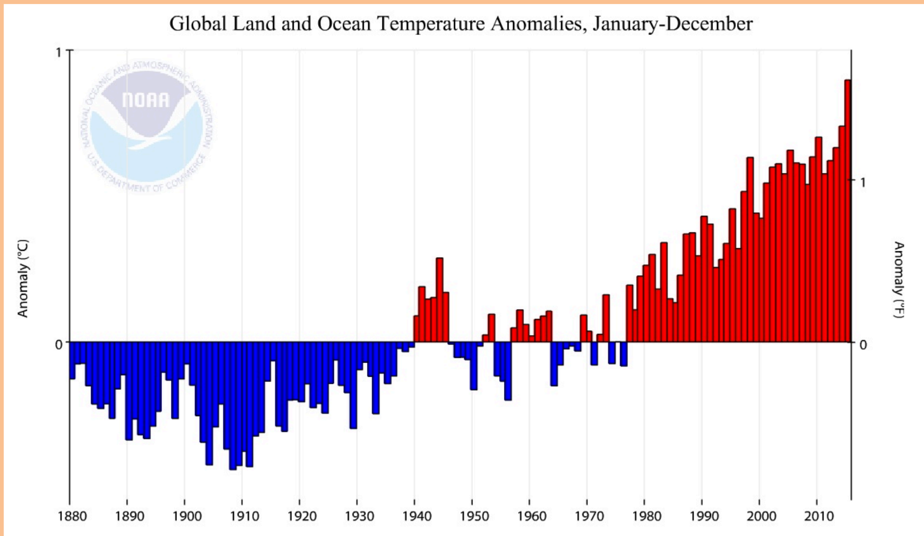
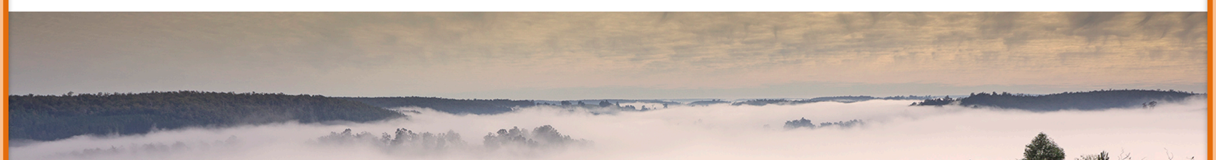
Climate Change Adaptation Planning for Local Government

A manual for the preparation for action plans



July 2019

Garry Middle



Acknowledgements and Disclaimers

Acknowledgements

This Manual was prepared by the Dr Garry Middle and published by Enviroconnect (ABN 89338951955)

Enviroconnect

Enviroconnect is a not-for-profit organisation aimed at improving the knowledge of Western Australia's natural environment, and planning for its sustainable use.

Website – www.enviroconnect.org

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Citation Information

This document should be referenced as follows:

Middle, G. (2019) Climate Change Adaptation Planning for Local Government: A manual for the preparation for action plans. Enviroconnect, Perth, Western Australia

Cover Figure: Source NOAA - https://www.climate.gov/sites/default/files/CaG_GlobalTempAnom_1.jpg

Cover photograph: Garry Middle

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ISBN

ISBN-13: 978-0-9943572-5-0

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1. Background and context

1.1 Purpose of this Manual

Local Governments in Western Australia have been leaders in taking action to mitigate the impacts of climate change. More recently, many Local Governments have begun to develop climate change adaptation plans, both corporate plans to cover internal agency risks that climate change poses, and community wide plans. Most coastal Local Governments have developed, or are in the process of developing, coastal hazard risk management and adaptation plans (CHRMAPs), but these have a narrow focus solely on the coastal zone.

This manual has been produced to help guide Local Governments develop both corporate and community wide climate change adaptation plans that cover all the risks that global warming/heating and subsequent climate change pose.

1.2 Source of the material for this Manual

The material in this manual has been developed by Dr Garry Middle based on:

- His experience in working with Local Governments in the development of climate change adaptation plans, mostly for coastal adaptation planning, but also more broadly across all the risks;
- Global experience as Curtin University's representative to the United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP) from 2009 to 2014;
- Teaching Climate Change as a subject to undergraduate and post graduate students at Curtin University from 2006 to 2014; and
- As a member of the International Association for Impact Assessment's special interest group of climate change.

This Manual is provided free to local governments as a resource. Garry is available to work with any Local Government to help develop and implement a suitable process to produce a climate change adaptation plan.

1.3 Structure of this Manual

Chapter 2 provides the basics of the greenhouse effect and the global heating (warming) physical process. It can be used in circumstances where participants lack an understanding of this process. The chapter can either be used as reading material or as the basis for a PowerPoint presentation.

Chapter 3 sets out the evidence that the Earth is warming/heating and the climate is changing. The material here can be used in circumstances where participants are unaware of the changes, or where there are sceptical people participating in the process. As with

Chapter 2, the material can either be used as reading material or as the basis for a PowerPoint presentation.

Chapter 4 describes the likely impacts of global heating/warming i.e. what will climate change look like? As with the Chapters 2 and 3, this is background information and can be used in circumstances where participants are unaware of the changes, or where there are sceptical people participating in the process. The material here can either be used as reading material or as the basis for a PowerPoint presentation.

Chapter 5 is aimed at officers preparing a climate change adaptation planning exercise within Council or the broader public. It describes a recommended broad framework for the process.

Chapter 6 provides specific advice on carrying out a consultative climate change adaptation planning exercise aimed at developing a climate change adaptation action plan.

2. The basics of the greenhouse effect and global heating (warming)

This chapter provides essential scientific information about the greenhouse effect as the basis for understanding global heating/warming. Many people will already have a good understanding of this so much of this material will not be relevant in all circumstances. The material here can either be used as reading material or as the basis for a PowerPoint presentation.

2.1 The Greenhouse effect

The Earth has a relatively stable temperature range although there are daily, seasonal and geographic (locational) variations. There have also been long term variations (over thousands of years).

If the Earth did not have an atmosphere all of the energy from the sun that hits the Earth would simple be re-emitted and the temperature on the surface would be very cold.

Instead, the atmosphere allows some of energy from the sun absorbed by the Earth to be trapped for a period of time before being released back out to space allowing the surface temperature of Earth to be much warming that it would otherwise be. This is the greenhouse effect.

We have all probably experienced a similar effect when we get into a car that has been left in the sun. The glass windows work to trap some of the heat that comes through the glass and heats the car up.

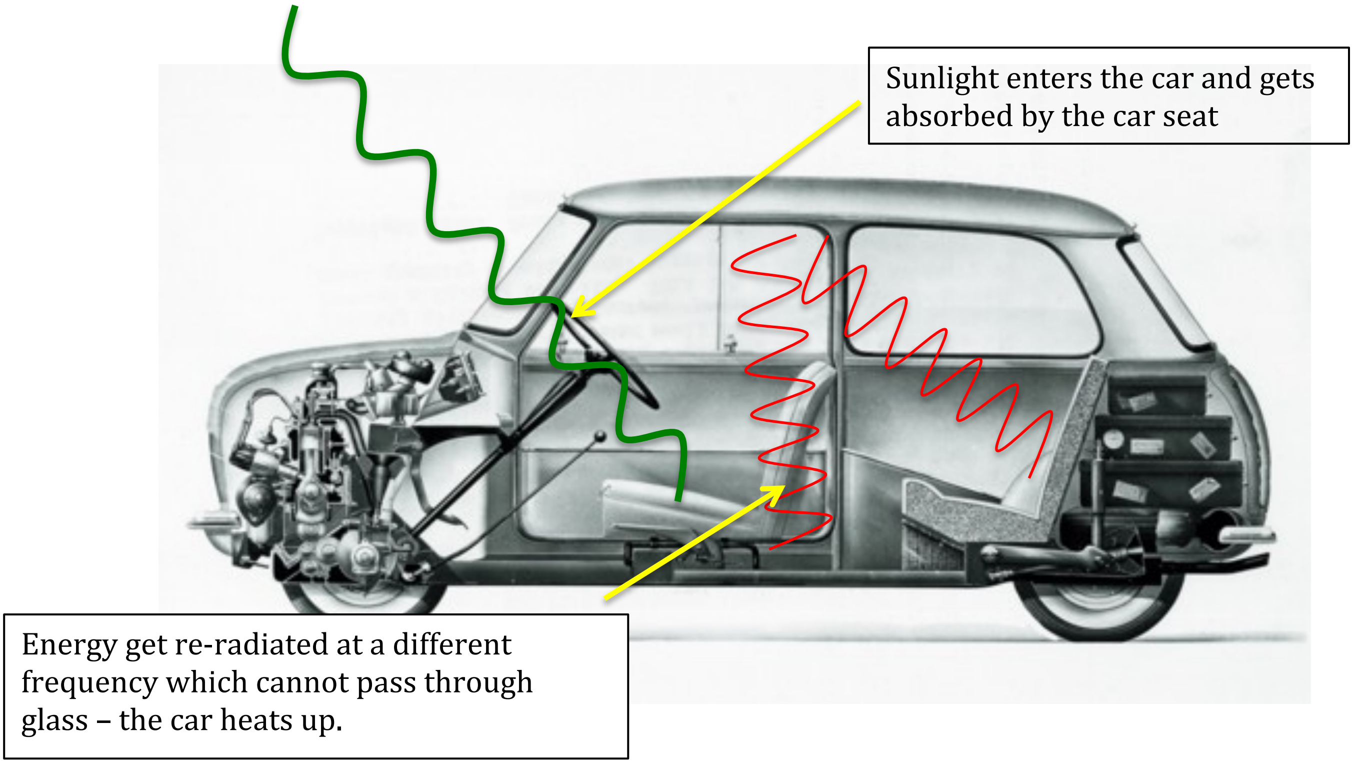
Glass has special properties that allow this to happen. First, whilst we see glass as being transparent – i.e. light passes through – in reality it is only partially transparent. Visible light (light that we see) will pass through glass (that's why we see glass as being transparent), but not all frequencies of light will pass through it. Sunlight is made up of a wide range of radiation types with a wide range of frequencies, most of which we cannot see with our eyes. The way our eyes 'see' different frequencies of visible light is the different colours from violet at a higher frequency to red at a lower frequency. Radiations like infrared (lower than visible red) and ultra violet (higher than violet) and not normally visible to humans. Glass is particularly 'opaque' to some of the lower frequencies.

Figure 1 over the page illustrates how the greenhouse effect works in cars.

As can be seen, some of the sunlight enters the car and gets absorbed by the seats, dashboard etc. inside the car. These items will then re-radiate the heat but at a different frequency than the light that entered the car. This re-radiated light is opaque to glass and gets trapped in the car causing it to heat up.

This greenhouse effect occurs in our atmosphere, with certain gases acting like the glass does in a car.

Figure 1: the greenhouse effect in a motor car (car image from http://jamjarnews.com/wp/wp-content/uploads/2009/10/MiniCrossSection.jpg)



2.2 Greenhouse gases and the atmosphere

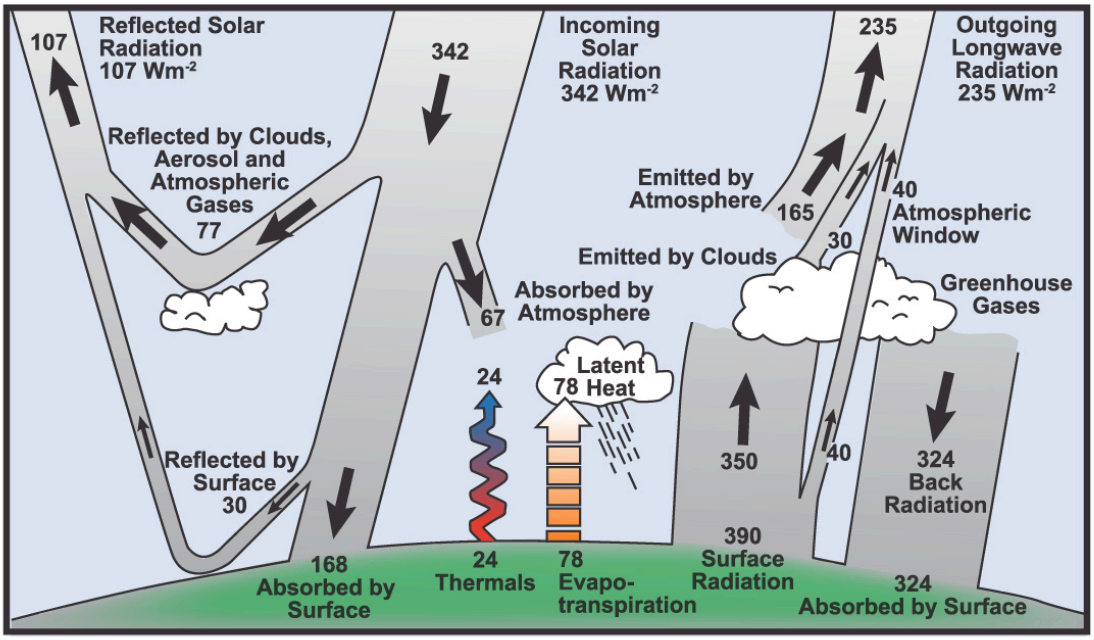
Carbon dioxide is the most commonly quoted greenhouse gas (GHG) but is not the only one. The main GHGs in order of significance of impact on climate are as follows:

- water vapour,
- carbon dioxide,
- methane,
- nitrous oxide,
- ozone, and
- chlorofluorocarbons (propellants).

It's worth noting that whilst methane (CH_4) is in relatively low concentrations in the atmosphere, it is 23 times more potent as a greenhouse gas compared to CO_2.

The figure below shows how these gases work to maintain a relatively stable temperature for Earth. The numbers are the amount of energy for each component, in watts per square metre.

Figure 2: Solar energy balance - (Source: Le Treut, Somerville et al. 2007)



Overall, the amount of energy absorbed by the earth and the atmosphere is about the same as the energy re-radiated. Some of the incoming solar energy heats the earth up, which then re-radiates but at a different frequency. The so-called greenhouse gases (GHG) are 'transparent' to the incoming radiation but are 'opaque' to the re-radiated and changed frequency energy - they reflect this energy back to the atmosphere and earth - thus the greenhouse effect.

Clearly, the higher the greenhouse gas concentrations the more energy is trapped in the atmosphere and the climate warms.

3. The evidence that the global is warming/heating and the climate is changing

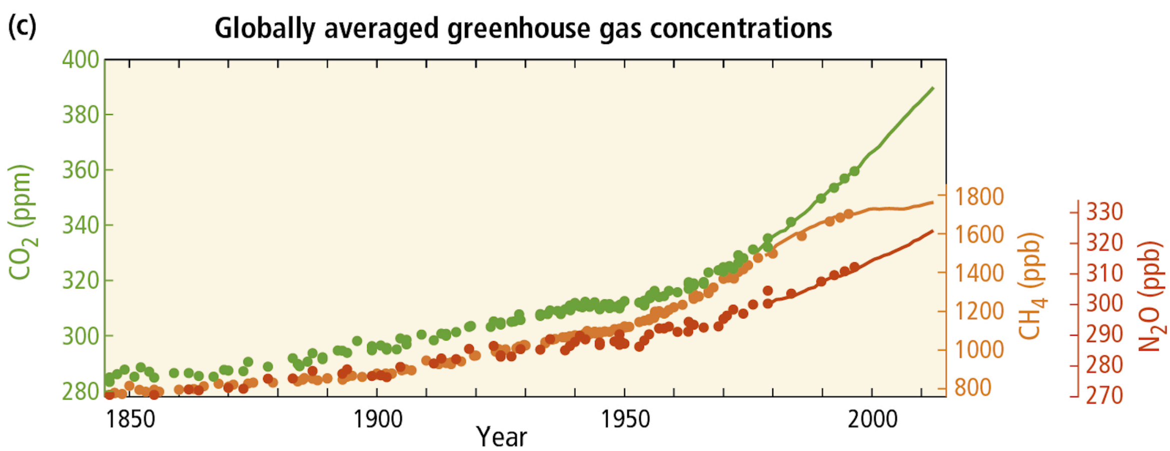
This chapter sets out the evidence that the Earth is warming/heating and the climate is changing. The material here can be used in circumstances where participants are unaware of the changes, or where there are sceptical participants involved in the process. As with Chapter 2, the material can either be used as reading material or as the basis for a PowerPoint presentation.

The climate of the earth is relatively stable over short periods of time (hundreds of years) but has changed when longer timeframes are considered, with cycles lasting many thousands of years. There have been both cooling (ice ages) and warming patterns to our climate. There have been several ice ages where the average temperature drops considerably, where much of the earth becomes covered in ice and sea levels drop considerably. Scientists believe that these changes in the climate have been caused by either changes to the levels of GHG in the atmosphere, or from catastrophic events like massive volcanic eruptions and comets colliding with the Earth. The latter two events release large amounts of dust and particles into the air (soot, smoke, ask etc.) that reflects the sunlight and stops it reaching the Earth.

The climate change we are experiencing today relates to global heating/warming because of increased GHGs in the atmosphere, primarily due of human activities, mostly burning of carbon based (fossil) fuels. This global heating/warming is causing a range of other changes to our climate – see Chapter 4. The levels of CO_2 in the atmosphere has increased by about 40% since the start of the industrial revolution when the rate of burning of fossil fuels increased significantly.

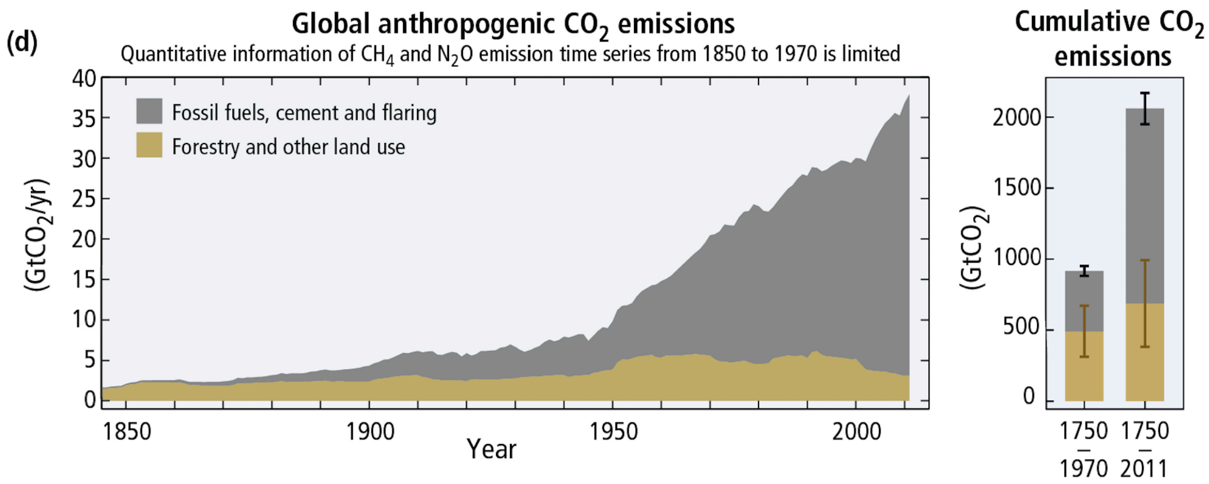
The figure below shows the changes in key greenhouse gases, including CO_2, since 1850, around the start of the industrial revolution.

Figure 3: Concentrations in key greenhouse gases in the atmosphere since 1850 (Source: IPCC 2014)



The next figure shows contributions of the global CO_2 concentrations since 1850 from natural sources and human (anthropogenic) sources.

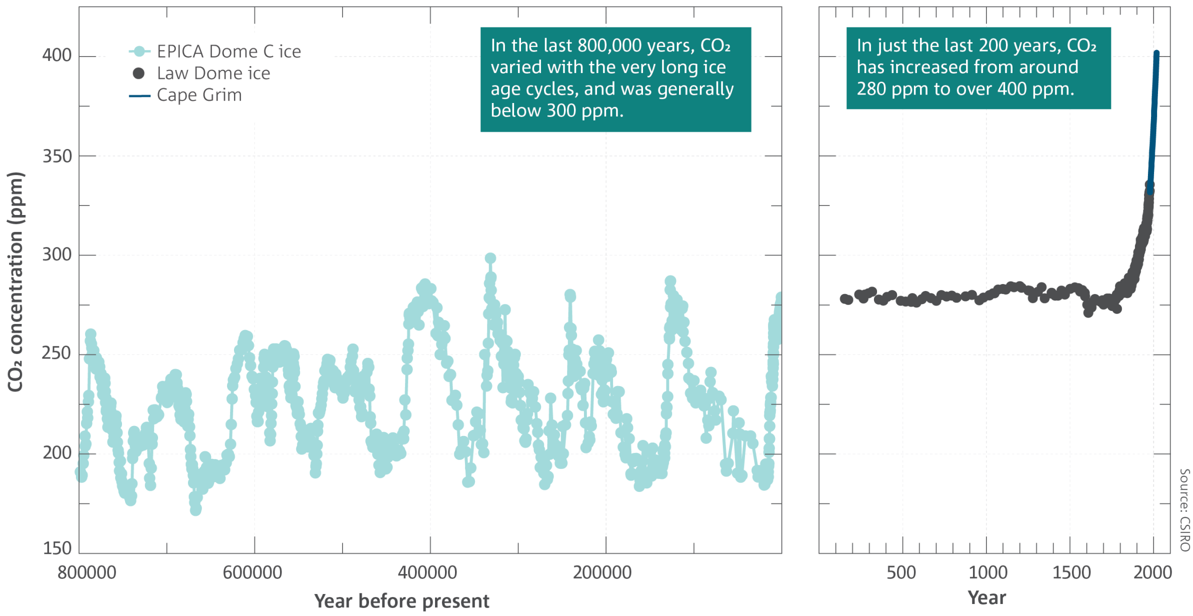
Figure 4: Sources of CO_2 since 1850, from natural and human sources (Source: IPCC 2014)



Global levels of CO_2 in the atmosphere have varied over a very long period of time, but the change since the industrial revolution has been significant and atypical. Figure 5 shows how the global levels of CO_2 in the atmosphere has varied over the last 800,000 years in the left graph, and the graph on the right highlights what has happened in the last 2,000 -

i.e. levels of CO_2 in the atmosphere increased steeply in the last 200-year period and have never been this high.

Figure 5: Concentrations of CO_2 in the atmosphere over the last 800,000 years (Source: CSIRO and Australian Government Bureau of Meteorology 2018)



These increases in GHGs has led to a measurable increase in global temperatures, as shown in Figure 6 (the different colours are different sources of the data).

Figure 6: Global average temperature increase since 1850 (Source: IPCC 2014)

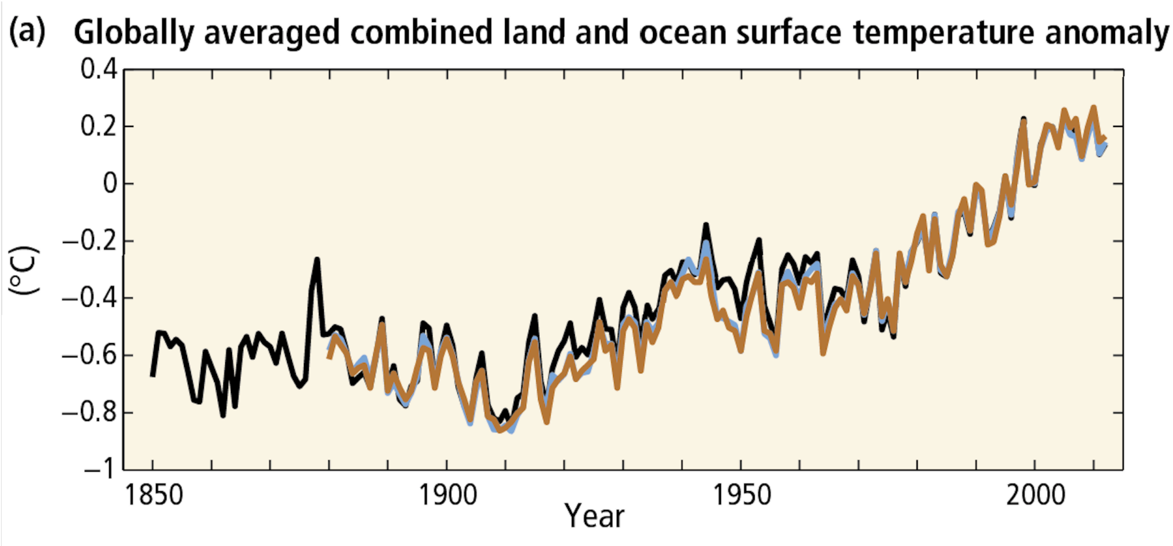
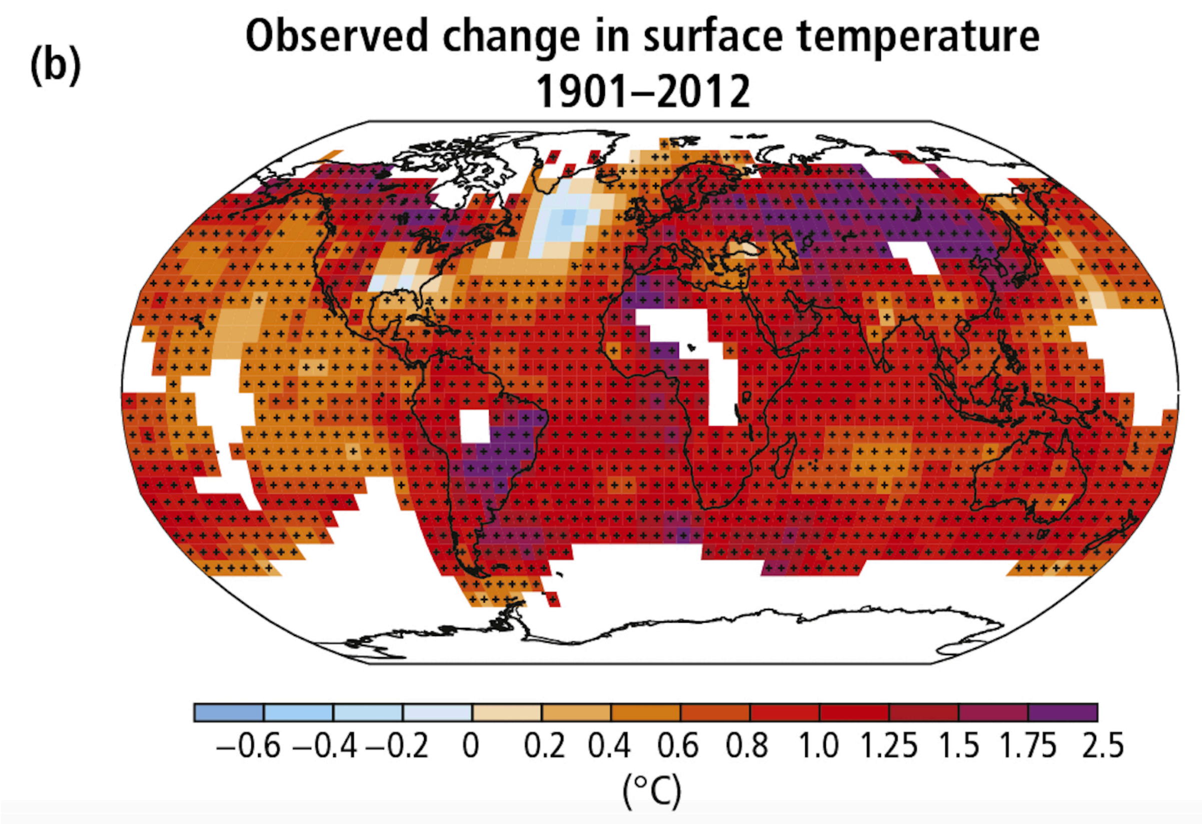


Figure 7 shows the observed change in surface temperature across Earth for the period 1901-2012. It is very course data but is shows that there are only small areas where temperatures have decreased with the rest of the globe warming.

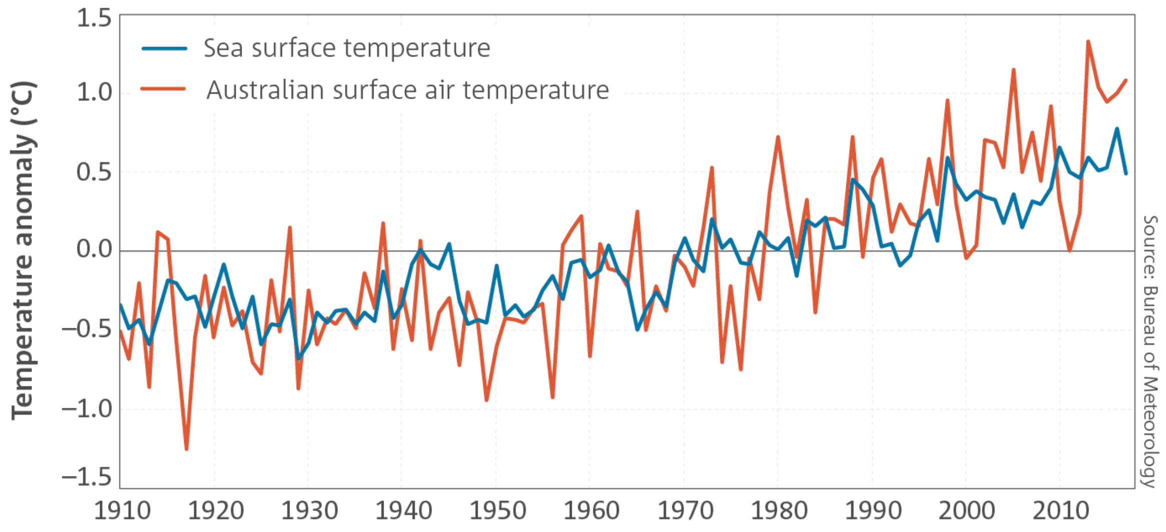
This rise in global temperatures since the mid 1800s is what scientists refer to as global warming or global heating.

Figure 7: Global temperature increase since 1901 (Source: IPCC 2014)



The data for Australia is consistent with the IPCC global data, as shown in Figure 8 below.

Figure 8: Measured sea and surface temperatures since 1910 (Source: CSIRO and Australian Government Bureau of Meteorology 2018)



In summary, there is credible data that show that the global average temperatures have risen since the start of the industrial revolution and the main cause of this rise is the increasing concentrations of GHGs in the atmosphere, primarily CO_2 from the burning of fossil fuels.

4. What at the likely impacts of global heating warming - what will climate change look like?

This chapter describes the likely impacts of global heating/warming i.e. what will climate change look like? As with the Chapters 3 and 4, this is background information and can be used in circumstances where participants are unaware of the changes, or where there are sceptical participants involved in the process. The material can either be used as reading material or as the basis for a PowerPoint presentation.

Global warming will have three key impacts: rising sea levels, changing weather patterns (climate change), and increasing ocean acidification.

4.1 Measured changes to-date

4.1.1 Sea level rise

Global warming/heating causes sea levels to rise for two reasons: thermal expansion – water expands when heated; and, when ice and glaciers located mainly in the polar areas (mostly Antarctica) and alpine areas melt this will add to the volume of seawater. Thermal expansion has account for most of the sea level rise that has occurred to-date.

There is already significant information showing that ocean levels are rising, although it is not experienced uniformly across the globe. Figure 9 shows global mean sea level rise as measured since 1880, the source of the data is primarily from tide gauges. As can be seen, there has been an acceleration in sea level rise since early 1990s.

Figure 9: Global means sea level rise since 1880 (Source: CSIRO and Australian Government Bureau of Meteorology 2018)

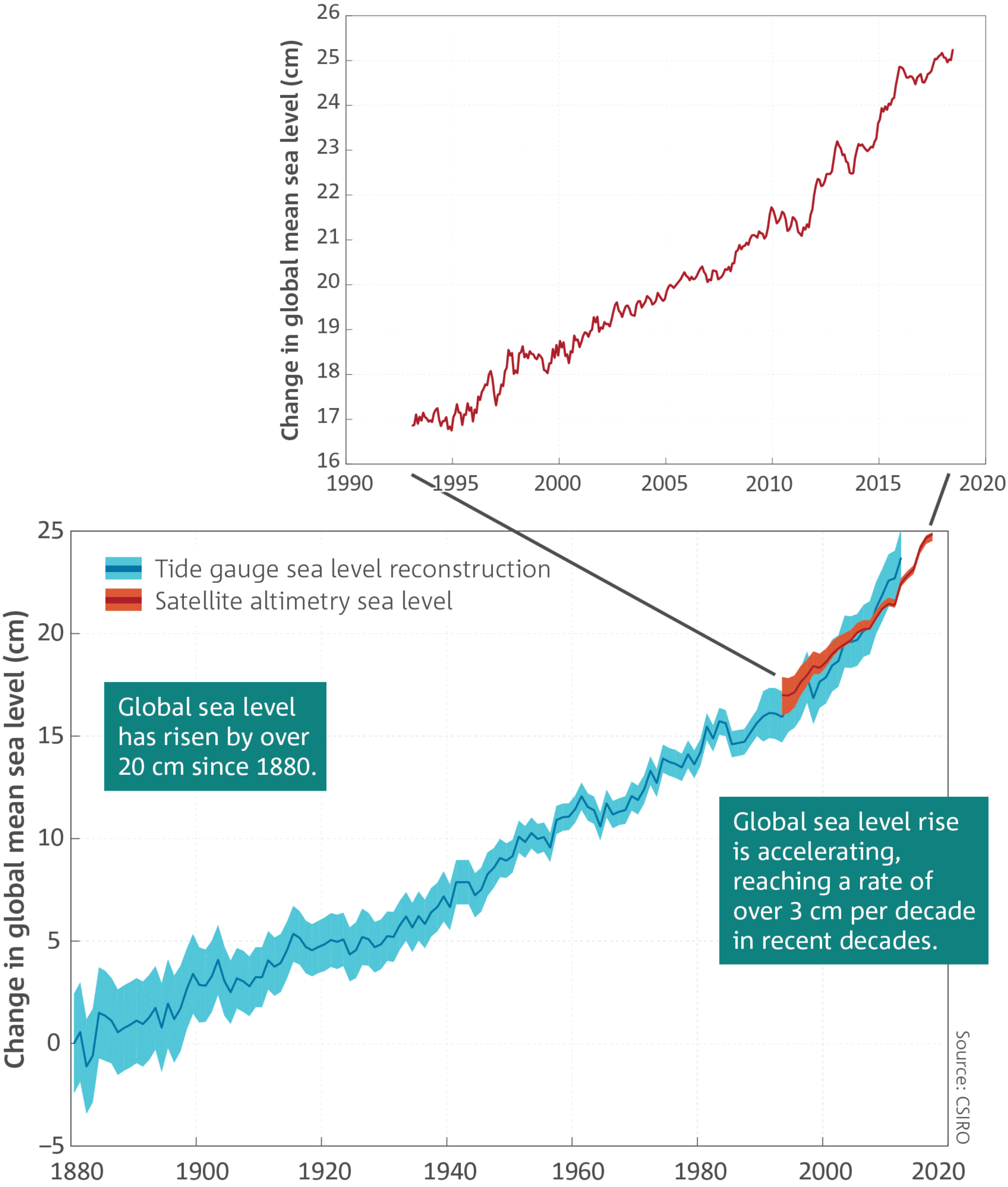


Figure 10 shows the data from Fremantle, and Figure 11 shows the variability in sea level rise around Australia since the early 1990s.

Figure 10: Annual mean tide gauge recordings at Fremantle (Source: Bicknell 2010).

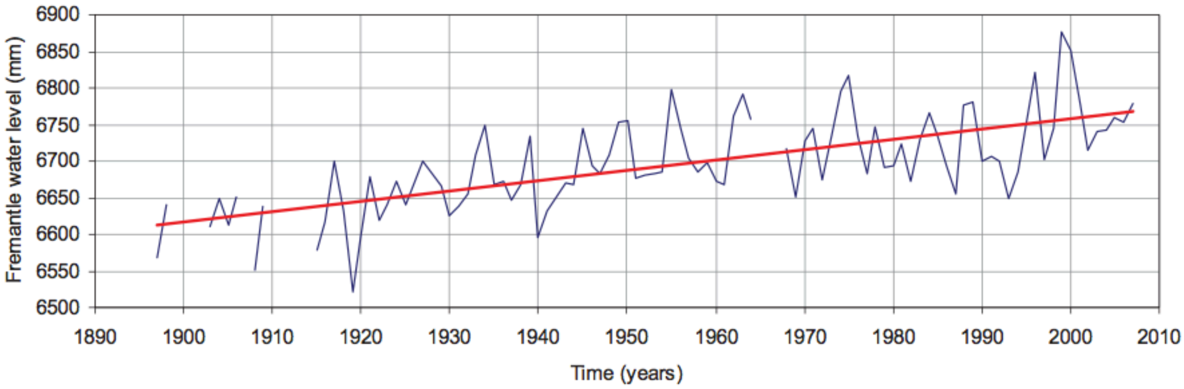


Figure 11: Measured sea level rises in Australia (Source: Department of Climate Change 2009)

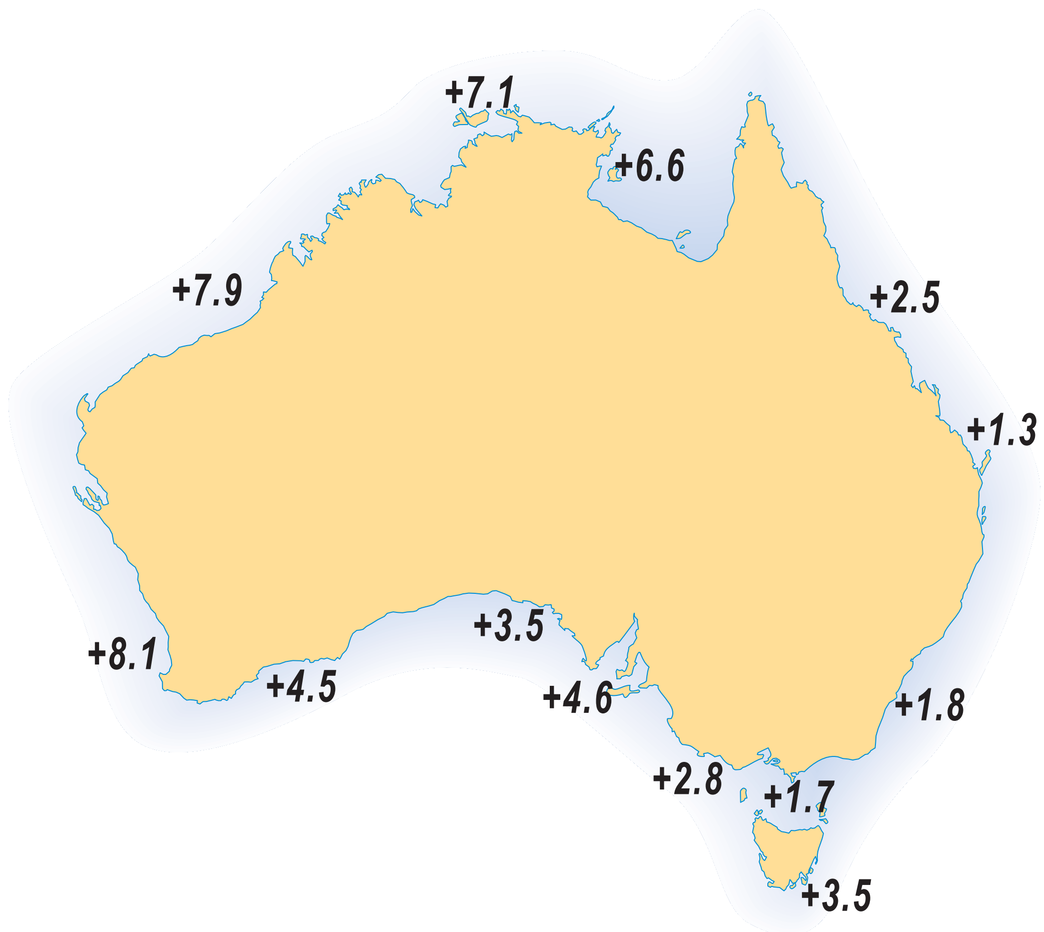


Figure 2.7 Local sea-level rise (mm/year) from the early 1990s to 2008.
Source: NTC 2008[20]

4.1.2 How much has the has our climate already changed?

Our climate has already shown measurable and significant changes since the mid 1800s. The key changes have been:

- Increased number of extreme hot days in summer;
- Changing rainfall patterns;
- Increasing wild fire risk.

These changes as shown in the following figures, showing the data for Australia.

Figure 12 shows the number of extreme hot days since 1910. There is a clear trend that the number of extreme hot days is increasing.

Figure 13 shows the average annual rainfall for the last 20 years against the long-term average (since 1900). It shows that rainfall in the southern half of Australia has decreased and rainfall in the northern half has increased over the last 20 years. For the southern half of Australia, this means that winter rainfall has decreased.

Figure 14 shows the average rainfall in the northern wet season for the last 20 years against the long-term average (since 1900). Overall, it shows summer rainfall is increasing other than in the far south west and south east of Australia. Any increase in summer rainfall in the southern half of Australia has not offset the loss in winter rainfall.

Figure 15 shows the trend in forest fire index between 1978 to 2017. This index is an indicator of the severity of fire weather conditions, with most of Australia showing an increase. This trend corresponds to both increasing temperatures and changing rainfall patterns.

Figure 12: Number of extreme hot days in Australia since 1910 (Source: CSIRO and Australian Government Bureau of Meteorology 2018)

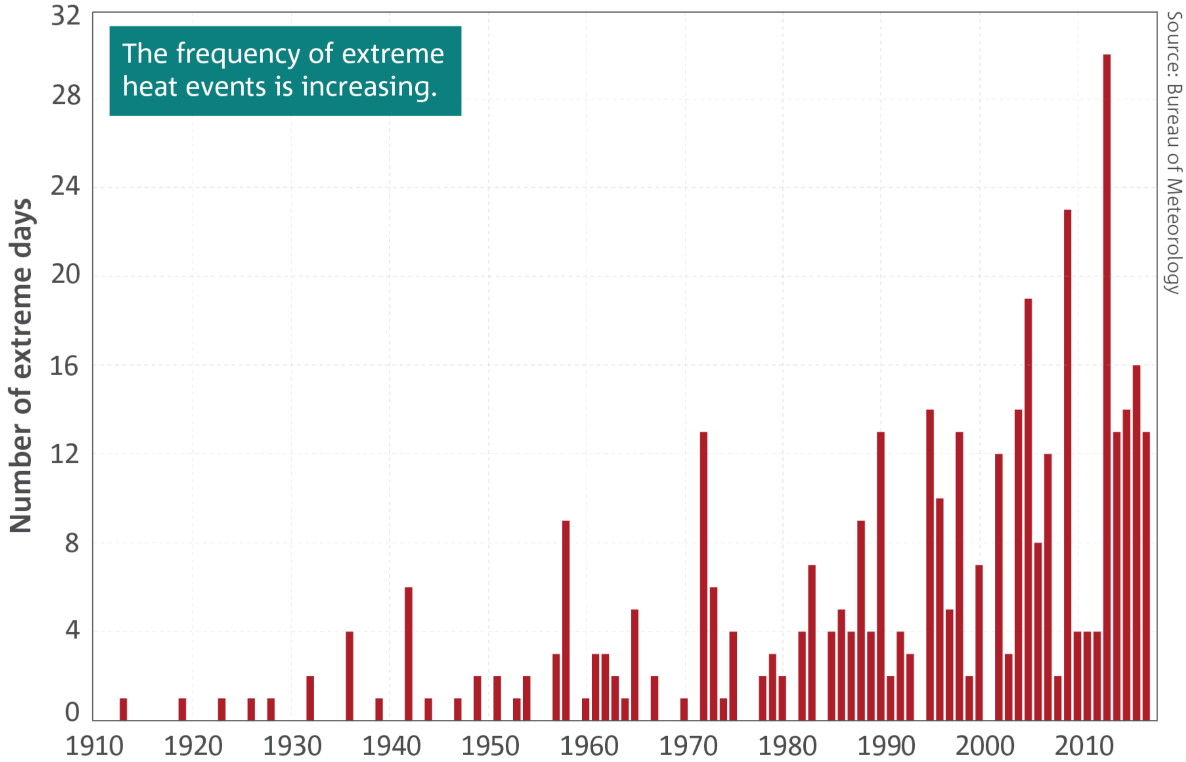


Figure 13: Change in average annual rainfall over the last 20 years compared to the long term average (Source: CSIRO and Australian Government Bureau of Meteorology 2018)

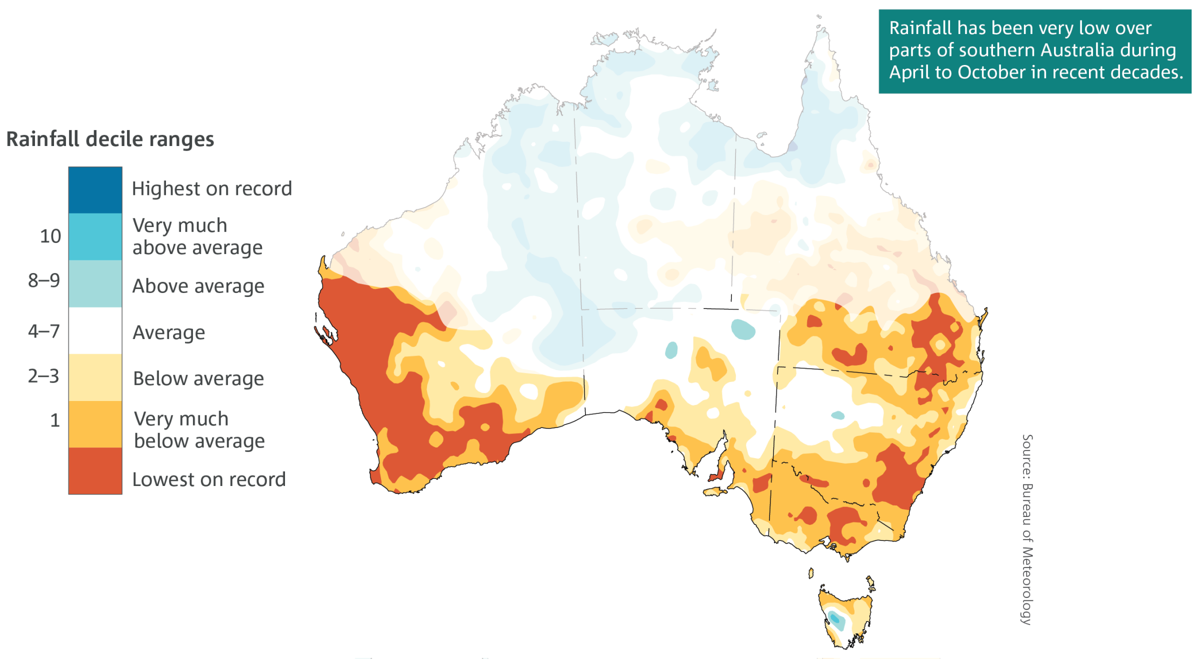


Figure 14: Change in average rainfall in the northern wet season over the last 20 years compared to the long term average (Source: CSIRO and Australian Government Bureau of Meteorology 2018)

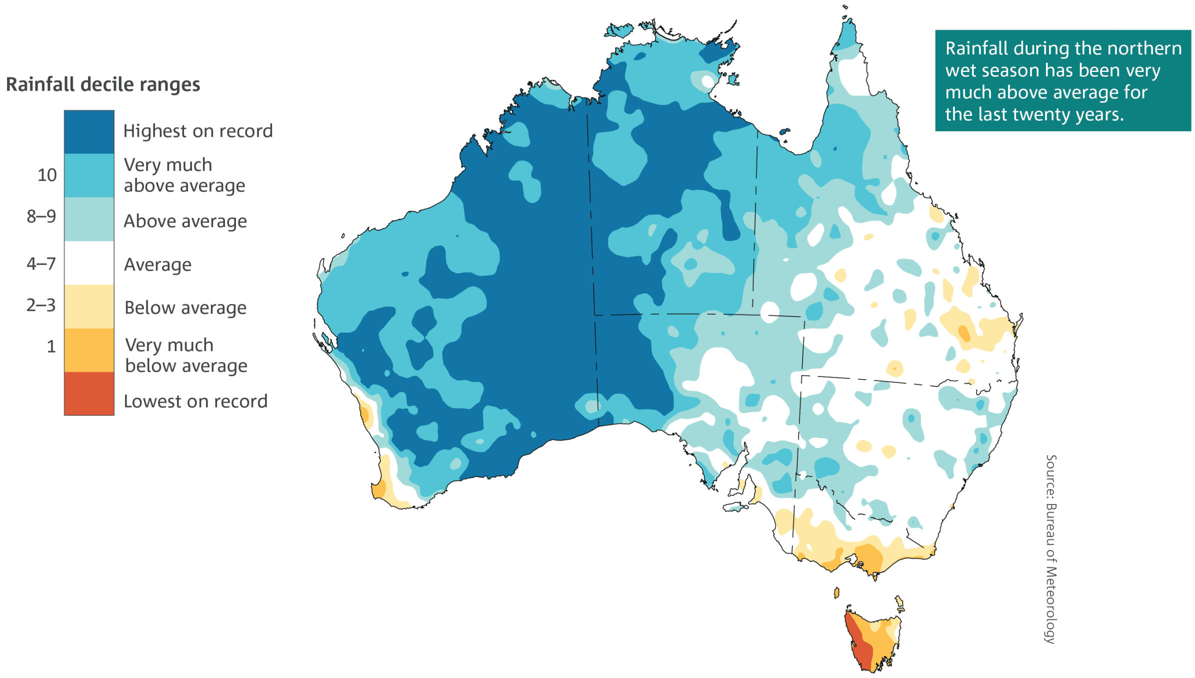
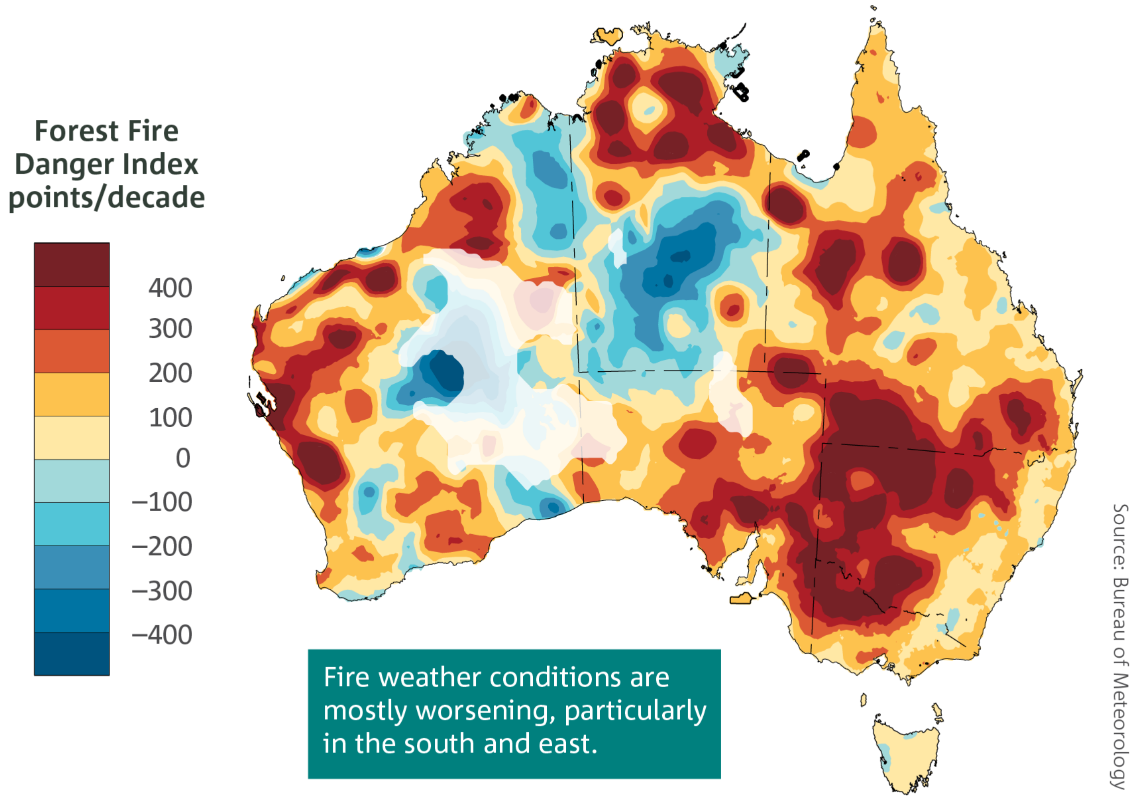


Figure 15: The trend in forest fire index between 1978 to 2017(Source: CSIRO and Australian Government Bureau of Meteorology 2018)



Scientists who study our climate have drawn a direct link between increasing levels of GHGs in the atmosphere (primarily CO_2) and increasing global temperatures and the changing climate. The extent of global warming/heating and related climate change will depend on how much additional GHGs we allow to enter the atmosphere.

4.1.3 Increasing ocean acidification

When CO_2 dissolves in water it reacts with water as follows:

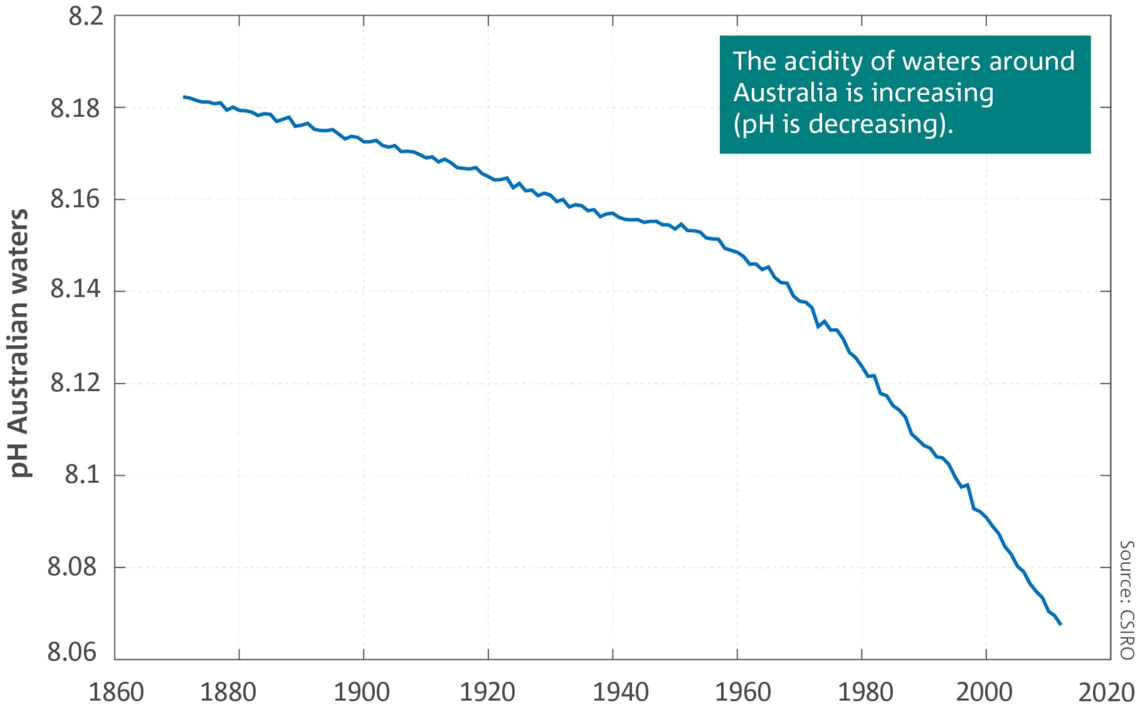
$$CO_2 \quad + \quad H_2O \quad \rightarrow \quad HCO_3^- \quad + \quad H^+$$

These H^+ ions are what make water acidic. As the concentration of CO_2 increases in the atmosphere more of it will dissolve into our oceans and other waterbodies, and the amount of H^+ ions will increase – i.e. acidity increases.

The most common way to measure the concentration of H^+ ions is the pH scale (a logarithmic scale), which is an inverse scale – i.e. low pH is acidic and high pH is alkaline (the opposite of acidic). Pure water (i.e. neutral concentration of H^+ ions) has a pH of 7, so any pH lower than 7 is acidic.

Figure 16 below shows the trend in the pH in our oceans since 1860, showing a particularly rapid decline since 1960. Increasing pH will impact on aquatic life, for example, molluscs are particularly vulnerable. The shells of mollusc are composed of calcium carbonate which is highly insoluble in neutral water (pH 7) but dissolve more readily in acidic water.

Figure 16: Increasing acidity (i.e. decrease pH in Australia's oceans since 1860) (Source: CSIRO and Australian Government Bureau of Meteorology 2018)



4.2 Likely future global warming/heating and climate change

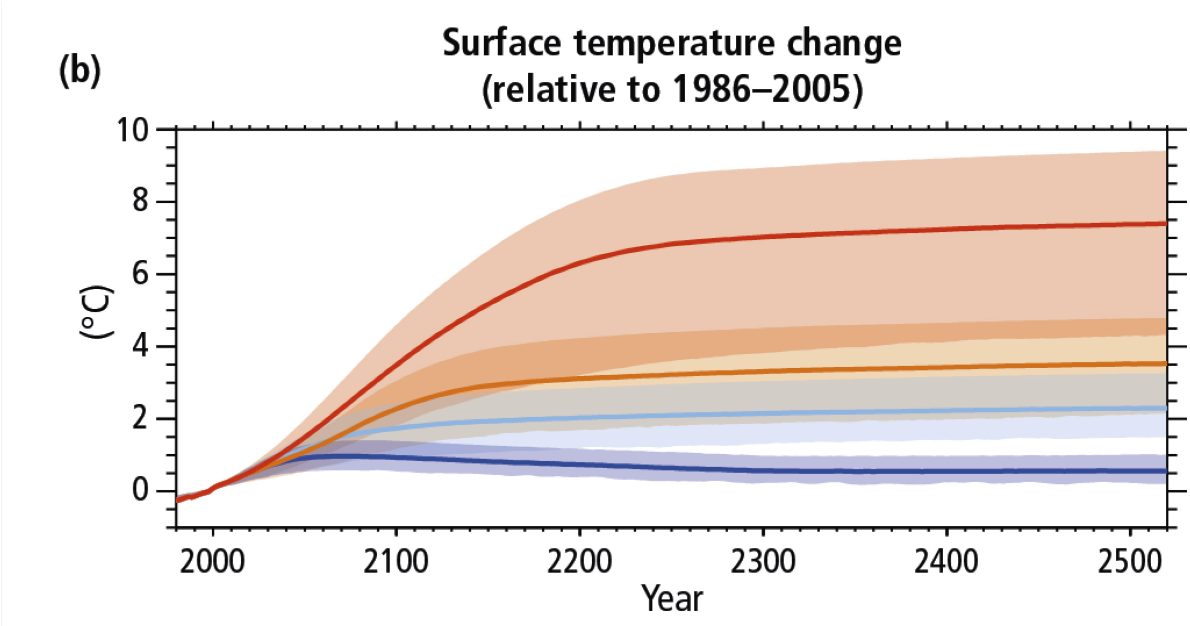
4.2.1 Likely future global warming/heating

Climate change scientists have used the data on increasing levels of GHGs in the atmosphere and the measured recent changes in the global temperature and climate to make predictions as to how much warming/heating will occur and how the climate will change in the future.

The key variable in making these predictions is how quickly we reduce the production of GHGs and stabilise and even reduce the levels in the atmosphere. Figure 17 shows the results of that global warming/heating modelling using different assumptions on how quickly and severely we reduce GHG emissions.

As can be seen, the best-case scenario is a 1C rise by 2100, which is based on an immediate cessation of the production of GHGs, and the worst-case scenario is a 4C rise by 2100 and rising a further 3C before temperatures stabilise.

Figure 17: Modelled possible global warming/heating depending on different assumptions on how quickly and severely GHG emissions are reduced (Source: IPCC 2014)



In 2015 a meeting of world leaders was held in Paris organised by the UN and attended by 196 nations (called COP 21) with the aim of reaching a global agreement on reducing climate change. The "Paris Agreement" was an agreement to keep global warming/heating to 'well below 2C' above pre-industrial levels, with the aim of keeping it to no more than 1.5C.

The key to reducing GHG emission is reducing the use of fossil fuels, which will require a global effort. Whilst significant progress is being made in some countries and levels of government, more work is needed – for example only 174 countries have formally ratified the Paris Agreement, with the most significant exclusion being the USA.

4.2.2 Rising sea levels

Should all the glaciers and ice caps melt (excluding the ice sheets of Antarctica and Greenland) this would lead to about 0.5 m of global sea level rise on top of what has already occurred (Intergovernmental Panel on Climate Change 2001). Should the Greenland and Antarctic ice sheets melt sea levels will rise an additional almost 13 m (Intergovernmental Panel on Climate Change 2001).

The State Government in WA is planning for a 0.9m sea level rise by 2100, and coastal Local Governments are required by State Planning Policy 2.6 (WAPC 2013) to carry out adaptation planning taking this in to account.

In 2010, the then Commonwealth Department of Climate Change release a report on the hazards of sea level rise for our coastal communities (Australian Department of Climate Change 2009). It carried out a very simple modelling exercise assuming a 1.1m uniform sea level rise across Australia.

One prediction in the report was the number of residential properties that could be affected, which is shown in Figure 18.

Figure 18: Predicted number of residential properties in WA affected by a 1.1m sea level rise (Source: Australian Department of Climate Change 2009)

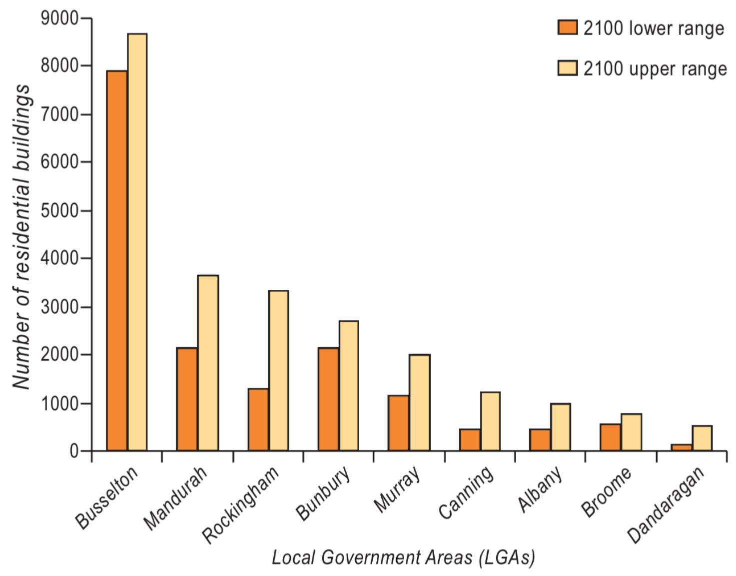


Figure 5.42 Estimated number of existing residential buildings in Western Australia at risk of inundation from a sea-level rise of 1.1 metres.

As can be seen, the settlements between Rockingham and Busselton will be the most affected.

The report also produced the following images showing the extent of likely inundation due to sea levels in Mandurah and Bunbury.

Figure19: Simulated amount of inundation due to sea level rise for Mandurah and Bunbury by 2100 (Source: Australian Department of Climate Change 2009)

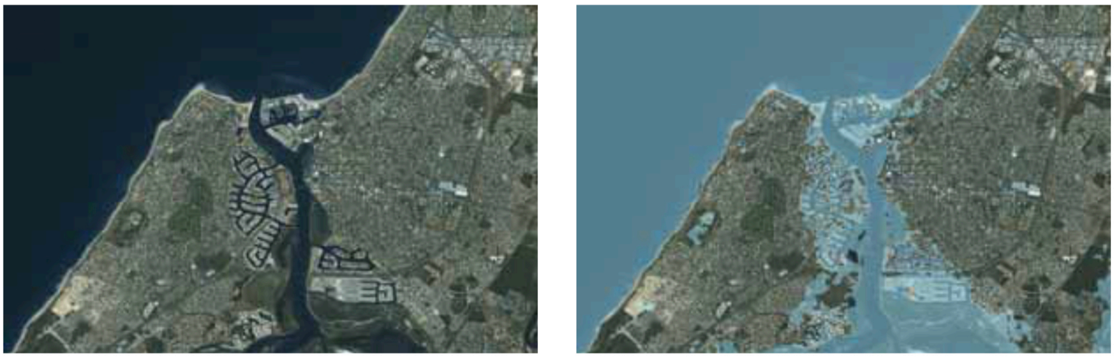


Figure 5.43 Images of Mandurah in 2009 and with simulated inundation from a sea-level rise of 1.1 metres using medium resolution elevation data (not suitable for decision-making). © CNES 2009 / imagery supplied courtesy of SPOT Imaging Services and Geospatial Intelligence PTY LTD.

Figure 5.44 Images of Bunbury in 2009 and with simulated inundation from a sea-level rise of 1.1 metres using medium resolution elevation data (not suitable for decision-making). © CNES 2009 / imagery supplied courtesy of SPOT Imaging Services and Geospatial Intelligence PTY LTD.

4.2.3 Likely changes to climate

Scientists have also made predictions about how the climate will continue to change. The most likely changes to our weather/climate in the future are:

- Further increase in temperatures, with more extremely hot days and fewer extremely cool days;
- More heat waves that will be longer and hotter;
- More frequent, extensive, intensive and longer-lasting marine heatwaves;
- Ongoing sea level rise;
- Further warming and acidification of the oceans;
- A decrease in cool-season rainfall across southern Australia, including the SW of WA;
- Likely increase in wet season rainfall in the north;
- More, longer and more intense droughts across southern Australia, including the SW of WA;

- More intense heavy rainfall throughout Australia, particularly for short-duration extreme rainfall events (storms);
- An increase in the number of high fire weather danger days and a longer fire season for southern and eastern Australia;
- Fewer tropical cyclones, but a greater proportion of high-intensity storms, with large variations from year to year; and
- Through a combination of many of these impacts, changes to biodiversity including increased species extinction.

Some agencies are already planning for climate change, for example, the Water Corporation. In 2009 it released a strategic water supply plan for WA titled Water Forever, which included projections of where our public water supplies would be sourced from in a drying climate (Water Corporation 2009). This is shown in Figure 20.

Figure 20: Projected future public water supply sources for Perth (Source: Water Corporation 2009)

Expected contribution from existing sources to 2060 *(table 2)*

Expected contribution from existing sources (GL / year)	2008	2020	2030	2060
Desalination sources	45	95	95	95
Surface water sources	90	85	75	25
Groundwater sources	145	110	90	30
Total	280	290	260	150

The impact of a changing (drying) climate can be seen with a significantly reduced contributions from surface and groundwater. Interestingly, the updated figures for 2019 show that the actual contributions are:

- 48% from desalination (compared to predicted 33% for 2020);
- 40% from groundwater (compared to predicted 38% for 2020);
- 10% from surface water (dams) (compared to predicted 29% for 2020); and
- 2% from groundwater replenishment from treated wastewater.

Predicted impacts on biodiversity include:

- Local extinctions of species at the edge of their range;
- Some species will move with the changing climate (for example, alpine species moving further up mountain slopes as the climate warms/heats);
- Similarly, vegetation ecosystem types will become locally extinct and shift with changing climatic conditions (for example, temperate forests will shift further south with a drying climate);
- Spread of species considered to be 'ecological generalists' which will then compete with, or predate on, local endemic species, this includes feral animals and weeds; and
- Increased fire frequency and intensity will alter the species structure of native vegetation, with species better adapted to fire (e.g. some weeds) out competing species more vulnerable to fire.

In summary, the nature and extent of these changes will depend in large part on the rate and amount of global warming/heating. These changes will need to be planned for and suitable adaptation measures and actions applied.

The remainder of this manual provides a guide as to how adaptation planning for climate change at an agency and community level can be prepared.

5. A framework for adaptation planning for climate change

This chapter is aimed at those organising and designing a climate change adaptation planning exercise within Council (or another agency) or the broader public. It describes the recommended broad framework for the process.

5.1 Context

Efforts to mitigate global heating/warming by reducing GHG emissions so as to minimise the impacts of climate change are increasing with some countries doing more than others, and some levels of government more committed to action than others. Notwithstanding the effectiveness of these actions, some level of climate change will be experienced over the next decades, which means governments, communities and businesses will need to adapt to these changes.

The expected changes due to climate change described above have a level of uncertainty associated with them. For example:

- What will be the peak level of GHG in the atmosphere, especially CO_2, and when will this occur? This will depend on the speed and intensity of actions taken to reduce GHG emissions;
- Whilst the number of extreme events is expected to increase (heat waves, storms, extreme fire risk days, droughts), there will be variability in the number and intensity from year to year;
- Whilst the rainfall trends are expected to be as predicted, there will be variations from year to year; and
- There could be some mega trends that accelerate or mitigate the actual climate change (for example, increased cloud cover could slow heating/warming, and, as the Tundra melts and large quantities of methane are released, global warming/heating would accelerate).

This suggests that the <u>likelihood</u> of certain changes and impacts is uncertain.

Further, the <u>consequences</u> of certain changes may vary from location to location. For example, decreasing rainfall in the SW of WA will likely have negative consequences for agriculture and public water supply. The north-eastern region of the SW of WA would likely be more impacted than the south-west corner as it already has much lower annual winter rainfall – i.e. there will be greater negative consequences.

This suggests that a <u>risk assessment</u> approach should be adopted in adaptation planning for climate change, where resources should be allocated to addressing those matters that have the highest likelihood of occurring and with the greatest negative consequences should be given priority over those matters less likely and/or with lower negative consequence.

5.2 Risk and risk assessment

Risk is an outcome of '*hazards*' or '*hazardous events*'. A *hazard* is the inherent property of an object to create damage or cause harm to humans or the environment. These objects are inherently dangerous, and exposure to them can cause injury, health problems, death or loss of environmental quality. Hazards can be natural (cliffs, jellyfish etc.) or caused by humans or human activity (dangerous chemicals). A *hazardous event* is an event where humans or other species are exposed to a hazard, and harm occurs (for example an explosion in a chemical factory or a spillage of toxic chemicals into a wetland).

Hazards can cause harm in one of two ways: through long-term exposure at low levels (for example exposure to toxic chemicals) – i.e. *chronic hazard*; or very short-term exposure at high levels (for example explosions) – i.e. *acute hazard*.

Typically, risk is seen as a combination of two factors: frequency (or likelihood) and consequences.

Frequency for chronic hazards is related to the length of time humans are exposed to, for example, a hazardous chemical, or the number of times that exposure occurs. As the length of time increases or the number of exposures increases, the likelihood of harm increases. For acute hazards, frequency is how many times a certain type of accident or event has occurred or is expected to occur, or how often things go wrong.

Consequences refer to the seriousness of the harm. For example, slipping on a wet surface would likely cause a sprained ankle, whereas falling off a tall cliff would lead to serious injury and even death.

The level of risk, therefore, increases with frequency of exposure and severity of the consequences.

In short Risk = likelihood x consequences

Risk assessment is the process of measuring the level of risk. This is typically done in one of two ways:

- Quantitative – where a number is calculated to represent the level of risk – for example a 1 in a million chance of an event causing a death; or
- Qualitative - where risk is typically assessed as being between low to very high.

Qualitative risk assessment is preferred where there is a high level of uncertainty associated with determining likelihood, which is the case for climate change: for example, determining the frequency and intensity of storm event in a particular year.

5.3 Qualitative risk assessment

5.3.1 Likelihood and consequences

Qualitative risk assessment is usually carried out in a highly participative way involving experts in the fields of risk, experts working in the areas where the risk is being assessed (for example climate change) and, importantly, representatives of the key stakeholder groups who will be subject to that risk (in this case, staff working for Council or members of the local community). Participants work together to exchange views and to arrive at a consensus on the risk level (likelihood and consequences).

Risk assessment tables are used to categorise a particular hazard's level setting out the ranges of both likelihood and consequences. Table 1 is a typical risk assessment table, and it is recommended that it be used in these exercises.

Table 1: Risk assessment table

	Consequences				
Likelihood	Insignificant (1)	Minor (2)	Moderate (3)	Significant (4)	Severe/ catastrophic (5)
Almost Certain (5)	Medium (5)	High (10)	High (15)	Very High (20)	Very High (25)
Likely (4)	Low (4)	Medium (8)	High (12)	High (16)	Very High (20)
Possible (3)	Low (3)	Medium (6)	Medium (9)	High (12)	High (15)
Unlikely (2)	Low (2)	Low (4)	Medium (6)	Medium (8)	High (10)
Rare (1)	Low (1)	Low (2)	Low (3)	Low (4)	Medium (5)

As can be seen likelihood ranges from 'rare' to 'almost certain' using a 1 to 5 scoring system. Consequences range from insignificant to severer/catastrophic, also using a 1 to 5 scoring system. Each hazard is assessed using this table.

Determining likelihood can be done more qualitatively in some cases by looking at the existing data and projecting to the future.

The following table can be used to help participants determine likelihood.

Table 2: Likelihood summary table

	Acute risks	Chronic & gradual change
Almost Certain	Previously unlikely events will occur often – for example many times a year.	Measured changes are unacceptable.
Likely	Previously unlikely events will occur regularly – for example a few times a few.	Measured change continue and are approaching an unacceptable level and higher-level mitigation actions need to be implemented.
Possible	Previously unlikely events will occur irregularly – once every year or every couple of years.	Measured change have reached the stage where lower level mitigation actions need to be implemented.
Unlikely	Previously unlikely events will occur more often than before but still quite rarely – once every 10 or so years.	Measured change now seen as greater than normal tolerances but still acceptable and there is no need to implement mitigation measures.
Rare	Previously unlikely events will still be unlikely to occur within the timeframe	Measured change seen as being within normal tolerances.

Determining the severity of the consequences is much more subjective.

As noted above, given the subjective nature if the risk assessment process, a facilitated workshop approach is required with the appropriate personal involved.

The final risk is calculated by multiplying the respective values of the agreed upon likelihood and consequences. As can be seen, risk levels range from Low (1-4), medium (5-9), high (10-16) and very high (20 and 25).

5.3.2 Climate change hazards

The starting point for a risk assessment approach is the list of relevant hazards. Taking into account the predicted climate changes described in Chapter 4, the climate change hazards for the SW of WA are shown in Table 3.

Table 3: List of climate change hazards for the SW of WA – general and specific

General climate change hazard	Specific climate change hazard (impacts)
Hotter summers with longer and more intense heat waves	increase heat stress especially for vulnerable populations – elderly
	greater use of cool refuges
	algal blooms in wetlands
	impact on staff who work outdoors
	infrastructure stress
	local economy – tourism
Fire frequency and intensity	Firefighting resources – staff, infrastructure, knowledge
	Damage to buildings and infrastructure
Reduced rainfall and water availability	Irrigation of green spaces
	Other high water uses – swimming pools, agriculture
Biodiversity loss – changing climate and impact of fires	Upland
	Wetlands
Increased storm activity and intensity	Storm damage (property, trees, infrastructure) and direct impacts
	Localised flooding – capacity of stormwater system
Sea level rise (ocean and estuaries)	Increased coastal erosion and loss of coastal land
	Permanent inundation of low-lying areas
Responding to emergency events (fires, floods)	Rescue
	Use of refuges
	Recovery and clean up
	Mental health
New health threats	Tropical diseases
Financial	Cost of adapting
	Cost of not adapting – e.g. insurance
Community attitudes	Resistance to adapting
	Pressure to do more

5.4 Use of thresholds and triggers

It can be useful, both in relation to determining likelihood level and also in planning mitigating measures to set both triggers and thresholds for certain impacts. It is not essential but is useful. Threshold levels are impacts or changes that are considered to be unacceptable and should be avoided – i.e. not-to-be-exceeded levels. To avoid these impacts, mitigating actions should be applied well before the threshold is reached. Trigger levels are those levels of impacts or changes below the threshold levels, and when a trigger level is reached, mitigation actions are implemented so as to reduce and, hopefully, halt the impacts or changes.

5.5 Summary

The recommended framework for carrying out climate change adaptation planning preparation is a participative qualitative risk assessment process. A list of climate change hazards has been suggested.

The key aim of the process is to identify those hazards that have the highest risk – a combination of likelihood and negative consequences. The plan sets out actions that would help mitigate these risks.

6. Advice on carrying out a climate change adaptation planning process

6.1 Overview

The critical outcomes of any climate change adaptation planning process should be:

- A list of agreed actions (an action plan) that address and mitigate the critical risks associated with climate change; and
- Raising awareness within the agency or community of the risks that climate change poses.

The first outcome is the critical 'hard' outcome whereas the second is a softer one that will be achieved by the process of arriving at the action plan (raising awareness in participants) and some the actions in the action plan (likely to involve some community education).

As noted above, a qualitative risk assessment process should be highly participative involving participants who have a key interest in the outcomes, have knowledge of the work areas that will be impacted by climate change and have some level of responsibility for implementing the agreed actions.

There are two parts to the climate change adaptation planning process:

1. The risk assessment where the hazards with the highest risk are identified; and
2. The action plan – i.e. the list of actions that address and mitigate these risks.

As noted above, the action plan is the critical hard outcomes and the risk assessment process is the method used to arrive at the action plan.

There are three broad steps ion this process. The first step is identifying those individuals that need to be participants in the process. The next step is to run a participative process involving the invited individuals to carry out the risk assessment and to develop the action plan. It is recommended that these two processes are run in separate sessions within a couple of weeks of each other. Two half-day workshops would be needed. The final step is the analysis of the outcomes of the workshops.

6.2 Identifying workshop participants

At an agency level, this means identifying the relevant departments and work areas, and the key individuals within these departments and work areas who should attend. These should be a mixture of management and non-management personnel. Managers are needed as they are the key decision makers. Non-managers are needed as these individuals usually have important knowledge relevant to implementation.

At a community level, it will usually mean identifying the key stakeholder groups and inviting each to nominate representatives to be part of the process. Involving the broader community is more complex and problematic. A likely key action will involve community education to raise the level of awareness of the risks of climate change, to enlist political support for the actions and to implement certain community wide and individual actions and changes. However, it is unlikely that ordinary community members would have the relevant knowledge and motivation to contribute to the process.

6.3 The workshops

Participants will work in smaller groups to complete the tasks.

It is recommended that participants of groups not be allocated at random but that participants work with people who either work in the same departments/teams or have the same specific interest, for example biodiversity conservation, planning, open space management, engineering etc.

6.3.1 First workshop

The first workshop is in two parts: scene setting, and risk assessment.

'Scene setting' is where appropriate climate change information is shared with participants. This is done to ensure participants have the appropriate level of knowledge to enable the remainder of the process to focus on risk assessment and action planning. The information in Chapters 2-4 can be used here.

The second part is the risk assessment. It is highly likely that few if any participants have been involved in a qualitative risk assessment (QRA) process before. QRAs can be confusing to participants, especially the subjective nature of determining likelihood and consequences. Tables 1 and 2, or version of these, should be provided to participants to work with.

The QRA process should broken down into two separate processes: identification of local climate change hazards/impacts; and risk assessment.

The first process involves agreeing on the list of specific impacts of climate change (i.e. specific hazards). This can be done in one of two ways:

- Provide participants with the list of general climate change hazards (column 1 of Table 3) and ask participants to identify their own work area specific climate change hazards/impacts. At the end of their deliberations participants can be provided with the second column as a check for their own work, in particular, to ensure that no critical hazard/impacts has been missed; or
- Provide participants with both columns of Table 3 and ask participants to review these and add or remove as required.

The second approach is more time efficient but will not engage participants as much as the first process. The first approach would more likely result in participants having greater ownership of the workshop outcomes.

Once this part is complete, a final list of specific hazards/impacts to drawn up and agreed to, which is then used in the second part of the workshop.

The second part is the QRA.

As mentioned above, this is the more tricky part of this workshop, and it would be best to select a couple of the specific impacts that all of the participates can relate to and work through these as a whole group. Once participants feel comfortable, they can then work in their groups to complete the table. They do not have to complete the whole table as there is likely to be specific hazards/impacts that relate to only one or two work or speciality areas.

A critical part is determining the timescale to work with – this effect the likelihood of the hazard. In general, either 2030, 2050, 2070 or 2100 is used.

The completed worksheets should be collected at the end of the workshop, to be re-distributed at the start of the second workshop

The role of the workshop facilitator is important. The facilitator needs to monitor the groups to ensure they remain on-task, provide clarity on any questions and uncertainty that arises, and help resolve any impasses that occur that would prevent consensus being achieved, for example agreeing on the severity of the consequences of a particular hazard/impact.

The Appendix of this manual has two template worksheets that can be used in the workshops.

6.3.2 Second workshop

The main task of the second workshop is to identify actions that either adapt to the hazard/impact or mitigates (reduces) the level of risk.

At the start of the workshop the partially completed worksheets from the first workshop should be given back to the groups, and participants should be given the opportunity to review their work from that workshop, looking for any 'fatal flaws'. This review should not involve re-opening discussion on all the items.

Participants, working in the same groups as in the first workshop, work through the table identifying relevant actions against each specific hazard/impact. Participants should not be restricted to identifying only one action per specific hazard/impact. It is not essential that each group identify an action/actions for every specific hazard/impact, as it is unlikely that every hazard/impact is relevant to a single work area/department.

The completed worksheets are then collected at the end of the workshop for analysis.

6.4 Post workshops analysis – from priority hazards/impacts to the action plan

The main purpose of the analysis after the workshops is to identify the priority actions which will make up the action plan. This is done by first identifying those hazards/impacts that represent the highest risk – <u>priority hazards/impacts</u>. The actions that either help adapt to the expected changes or help to mitigate the risks are the <u>priority actions for the action plan</u>.

This analysis can be carried out solely by the risk expert facilitating the workshops or by the risk expert in consultation with relevant expert staff within the agency.

6.4.1 Identifying priority hazards/impacts

In short, the priority hazards/impacts are those that the workshops consider having a risk level of either 'very high' or 'high'.

A suggested method for identifying the priority hazards/impacts is described below.

1. The risk assessments from the first workshop should be reviewed to filter out anything unrealistic or inaccurate, and modify the risk accordingly;
2. First pass identification of highest risk hazards/impacts: an 'initial priority list' is created which is any specific outcome from any of the group assessments that had a risk priority level of 'very high';
3. For each of the hazards/impacts on the initial priority list, the risk level given by the other groups is recorded and with the final risk level being a 'considered' average of the risk levels from all the groups. Some judgement is required here as weight should be given to the assessments carried out by groups with a special interest in or expert knowledge of a particular hazard/impact.

   Only those hazards/impacts that have a considered average risk level of 'very high' or 'high' would be considered a 'priority hazard/impact.
4. Second pass: This first involves identifying any hazard/impact that were not assessed as 'very high' in step 2 but had a rating of 'high' by any group. For each of these hazards/impacts, the risk level given by the other groups is recorded and with the final risk level being a 'considered' average of the risk levels from all the groups.

   If the 'considered' average of the risk levels from all the groups for any hazard/impact is 'high' then this hazard/impact is considered a 'priority hazard/impact'.

6.4 2 The action plan – priority actions

As noted above, the action plan is the critical hard outcome of this process, and the risk assessment process is the method used to arrive at the action plan. The priority actions are those that address the hazards/impacts that have 'very high' or 'high' risk levels from the analysis carried out after the workshops. The action plan presents these actions in a logical format.

The simpliest way is to organise these actions against the general and specific hazards/impacts used in the workshops, but this is unlikely to be the most effective way of reporting.

The recommended way is to set out the priority actions by action 'themes', which groups the actions under related categories

Below is an example of an action plan developed for a metropolitan Local Government. The table that makes up the action plan goes over 5 pages, so only a sample of that table is shown here.

6.4 3 Example of a Local Government climate change adaptation action plan organised by action themes

The priority actions are grouped under the following eight action themes:

- Water efficiency/ Alternative water supply;
- Natural / Structural shade development;
- Efficacy of infrastructure;
- Emergency (Fire, Flood, Storm) management/preparedness/responsiveness;
- Building efficiency/ Alternative energy/ Climate responsive design in all development;
- Biodiversity management;
- Governance; and
- Public health.

<u>The Action Plan</u>

Key Theme	Priority actions - overview
Water efficiency/ Alternative water supply	These actions involve making more efficient use of existing resources, reducing wastage, reusing water where possible, reducing the amount of high-water using vegetation (especially turf), use remaining turf areas more efficiently, introducing heat and drought tolerant species in parks and street verges, and educating park users, developers and the broader community about the nature of these changes.
The priority actions	
• Promote more efficient use of existing water resources by reducing wastage and reducing demand - install water efficiency mechanisms as part of irrigation systems including WaterWise treatments that better retain water in the soil. • Investigate the use of treated wastewater (grey and black), including backwash water from swimming pools. • Collect, harvest, store and use stormwater for re-use. • Install water saving devices in Council buildings. • Carry out a strategic rationalisation of the total area of turf – the playing surfaces and surrounding turf areas. • Carry out a strategic rationalisation of the number of grassed ovals (reduced the number?). • Manage community expectations through education on how parklands will look and be used – less turf and more natural (WaterWise) areas. • Implement more efficient use of ovals – reduce intensive uses and increased evening use. • Educate clubs about more efficient use of ovals including better sharing of ovals between clubs. • Revise landscape guidelines for new subdivisions to use heat and drought tolerant native species/variations, reduce turf areas, and adopt water efficient design and use of POS. • Revise landscape guidelines for new subdivisions to use heat and drought tolerant native species/variations, and reduce turf areas. • Rationalise the extent of grassed areas around wetlands and modify fertiliser use. • Educate and manage community expectations about how the parks will look and function in the future.	

Key Theme	Priority actions - overview
Natural / Structural shade development	These actions involve providing more shade structure (trees and artificial structures), reducing the amount of hard stand areas so as to reduce the heat island effect, and recognising that existing trees species may struggle under a warming and drying climate and that new species will be needed that are heat and drought tolerant.
The priority actions	
• Review extent of existing hard stand areas and shade areas in the City and identify opportunities to increase shade areas, including street verges, parks/reserves, and carparks, and reduce amount of hard stand. Increase shade using trees and built structures. Reduce use of heat absorbing impermeable surfaces. • Consider the use of green roofs and green walls in existing and new Council buildings. • Select tree species used for increased shading that are WaterWise and drought tolerant. • Use alternative water sources including stormwater capture for irrigation. • Review parking requirements, cross over and road width standards to facilitate retention/provision of more trees. • Monitor the health of existing shade trees to identify, treat or replace unhealthy trees. • Research and identify heat and drought tolerant tree species suitable for shade trees, and plant as appropriate. • Identify and plant replacement native species/variations that are more resilient to drought, heat, fire and weeds. Work with research institutions and consider joint funding.	

7. Conclusion

This manual has been produced to help guide Local Governments develop corporate and community wide climate change adaptation plans – actions plans - that cover all the risks that global warming/heating and subsequent climate change pose.

It contains background material that can be used in support of developing a climate change adaptation plan, including explanations of;

- The greenhouse effect and global warming/heating;
- The evidence that the Earth is warming/heating and the climate is changing; and
- The likely impacts of global heating/warming and the measured changes to-date.

As well, this manual describes:

- A recommended overall framework for developing a climate change adaptation plan – i.e., qualitative risk assessment; and
- Specific advice on carrying out a consultative climate change adaptation planning exercise aimed at developing a climate change adaptation action plan.

The manual has been provided free of cost as a reference document. Garry is available as an expert in this field to provide a range of advice and help on climate change adaptation and with developing an adaptation plan (action plan).

8. References

Australian Department of Climate Change (2009). Climate change risks to Australia's coast: a first pass national assessment. Canberra, Australian Dept. of Climate Change.

Bicknell, C. (2010). Sea Level Change in Western Australia: Application to coastal planning. Perth, Western Australia, Department of Transport, Coastal Infrastructure, Coastal Engineering Group.

CSIRO and Australian Government Bureau of Meteorology (2018). State of the Climate 2018. Canberra, ACT, Commonwealth of Australia: 24.

Department of Climate Change (2009). Climate Change Risks to Australia's Coast: A first pass National assessment. Canberra, ACT, Australian Government.

Intergovernmental Panel on Climate Change (2001). Climate Change 2007: The scientific basis. Geneva, Switzerland, United Nations Environment Programme, World Meteorological Organization.

IPCC (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Core Writing Team, R. K. Pachauri and L. A. Meyer. Geneva, Switzerland, IPCC: 151.

Le Treut, H., et al. (2007). Historical Overview of Climate Change. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. S. Solomon, D. Qin, M. Manning et al. Cambridge, United Kingdom and New York, NY, USA, Cambridge University Press.

WAPC (2013). "Statement of Planning Policy No. 2.6: State Coastal Planning Policy, Prepared under Section 26 of the Planning and Development Act 2005." Western Australian Government Gazette 136: 3507-3523.

Water Corporation (2009). Water Forever: Towards climate resilience. Perth, Western Australia, Water Corporation.

Appendix 1 - Workshop 1 worksheet (with specific climate change hazard (impacts))

General climate change hazard	Specific climate change hazard (impacts)	Likelihood	Consequ-ence	Risk level	Actions/treatments
Hotter summers with longer and more intense heat waves	increase heat stress especially for vulnerable populations – elderly				
	greater use of cool refuges				
	algal blooms in wetlands				
	impact on staff who work outdoors				
	infrastructure stress				
	local economy – tourism				
Fire frequency and intensity	Firefighting resources – staff, infrastructure, knowledge				
	Damage to buildings and infrastructure				
Reduced rainfall and water availability	Irrigation of green spaces				
	Other high water uses – swimming pools, agriculture				
Biodiversity loss – changing climate	Upland				
	Wetlands				

General climate change hazard	Specific climate change hazard (impacts)	Likelihood	Consequ-ence	Risk level	Actions/treatments
and impact of fires					
Increased storm activity and intensity	Storm damage (property, trees, infrastructure) and direct impacts				
	Localised flooding – capacity of stormwater system				
Sea level rise (ocean and estuaries)	Increased coastal erosion and loss of coastal land				
	Permanent inundation of low-lying areas				
Responding to emergency events (fires, floods)	Rescue				
	Use of refuges				
	Recovery and clean up				
	Mental health				
New health threats	Tropical diseases				

General climate change hazard	Specific climate change hazard (impacts)	Likelihood	Consequ-ence	Risk level	Actions/treatments
Financial	Cost of adapting				
	Cost of not adapting – e.g. insurance				
Community attitudes	Resistance to adapting				
	Pressure to do more				

Appendix 2: Workshop 1 worksheet (without specific climate change hazard (impacts))

General climate change hazard	Specific climate change hazard (impacts)	Likelihood	Consequ-ence	Risk level	Actions/treatments
Hotter summers with longer and more intense heat waves					
Fire frequency and intensity					
Reduced rainfall and water availability					

General climate change hazard	Specific climate change hazard (impacts)	Likelihood	Consequ-ence	Risk level	Actions/treatments
Reduced rainfall and water availability (Cont)					
Biodiversity loss – changing climate and impact of fires					
Increased storm activity and intensity					
Sea level rise (ocean and estuaries)					

General climate change hazard	Specific climate change hazard (impacts)	Likelihood	Consequ-ence	Risk level	Actions/treatments
Sea level rise (ocean and estuaries) (cont)					
Responding to emergency events (fires, floods)					
New health threats					

General climate change hazard	Specific climate change hazard (impacts)	Likelihood	Consequ-ence	Risk level	Actions/treatments
Financial					
Community attitudes					