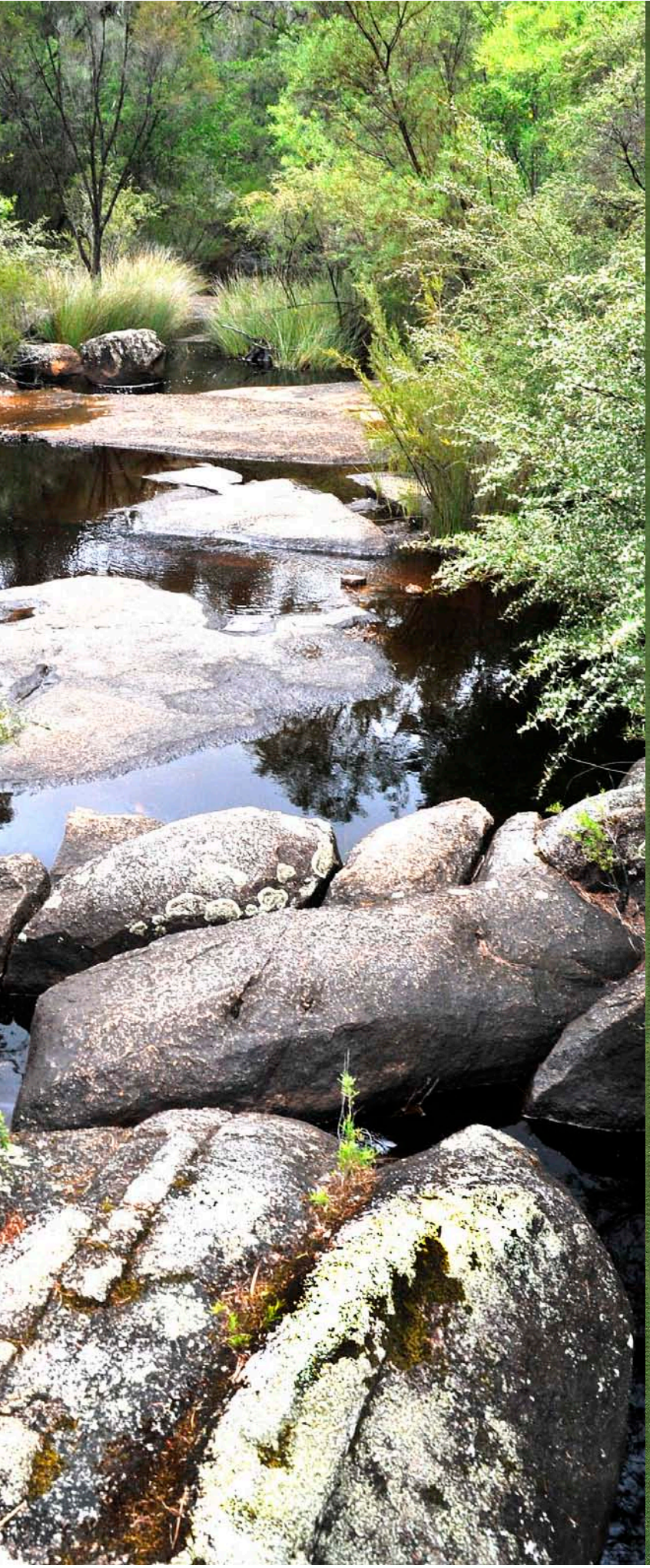

Climate Adaption Addendum

Southern Prospects 2011 - 2016

The South Coast Regional Strategy for Natural Resource Management

SOUTHCOAST NATURAL RESOURCE MANAGEMENT

Australian Government

National Landcare Programme

This project is supported through funding from the Australian Government's National Landcare Programme.

Australian Government

The Regional NRM Planning for Climate Change project is funded by the Australian Government.

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1 About this Addendum

Climate is always changing. It is the speed and scale of change that can present challenges.

As a regional Natural Resource Management (NRM) group, South Coast NRM has to consider how a rapidly changing climate will impact on the region's natural resources and how the people, plants and animals might respond and adapt. Climate change will exacerbate existing threats and pressures on natural resources

The effects of climate change within the South Coast region will be significant, particularly on water resources, agricultural systems and biodiversity, and our community that depends on these natural resources. Impacts from climate change include warmer and drier conditions across much of the South Coast region with increased risk of severe weather events, including storms, flooding, heatwaves, drought and bushfires.

There has been a significant decrease in rainfall in the South West of Western Australia (SW of WA) since the 1970s with projections for a further drying of the climate. Annual average temperatures are projected to increase and there are also projections for more abnormally hot days. Communities, stakeholders, primary producers and natural resource managers of the South Coast region all face the risks, uncertainties and opportunities of a changing climate.

In response to this, South Coast NRM applied for and received funding from the Australian Government to update the existing NRM strategy, *Southern Prospects 2011-2016,* to incorporate climate change. South Coast NRM was able to build on the report *Climate Change: Whole of Landscape Analysis of the Impacts and Options for the South Coast Region (Coffey et al. 2009).*

The Addendum adds climate planning to *Southern Prospects 2011 – 2016.* It reviews the key threats of a changing climate on the natural resources of our region including the impacts on coastal and marine, land, biodiversity, water and cultural heritage assets. It also examines the capacity of our community to adapt. *The Addendum* draws on a series of background papers prepared for South Coast Natural Resource Management on the themes in *Southern Prospects.*

With the background papers as a basis, South Coast NRM's reference groups assisted in incorporating climate planning into the Program Logic Process used in *Southern Prospects.* This means South Coast NRM now has a strategic approach to climate change planning which can continue into the next phase of planning after 2016.

A number of other projects funded by the Australian Government are supporting South Coast NRM in planning for climate change. These include:

- A spatial decision tool for planning biodiversity and carbon plantings *(Ecotones (2014).*
- Prioritisation and Biosequestration Modelling and Analysis, South Coast NRM).
- Consultation with community groups and South Coast NRM's Reference Groups on climate change (Specific Climate Change Meetings, Climate Forum and Climate Roadshow).
- Research at the UWA Centre for Excellence in Natural Resource Management supporting regional NRM groups for climate adaptation planning.
- Tools developed by CSIRO and the Bureau of Meteorology such as Projections Data, Regional Climate Change Explorer and The Climate Futures Tool (for trained users only).
- A Stakeholder Engagement Plan on Climate Change for South Coast NRM developed in 2014.
- Carbon farming projects.

The Addendum to Southern Prospects 2011-16 will be used as the basis for developing and prioritising climate related activities and projects in South Coast NRM's investment planning process. The *Addendum* uses the same structure as the main document.

The main challenge in planning adaptation to climate change is uncertainty. Climate projections are not predictions but are simply based on the best possible information at any time and provide a range of possible climate futures. Decisions have to be made with various uncertainties such as the level of emissions, climate futures and responses to climate change, so planning processes must be flexible and adaptable.

CSIRO has developed a useful guide *(Rissick et al. 2014)* to assist NRM groups with this approach. Progress on the goals and main outcomes in the *Addendum* will be reported and evaluated as part of South Coast NRM's adaptive investment planning process.

2 The Changes in the South Coast Climate

Climate refers to *"the atmospheric conditions for a long period of time, and generally refers to the normal or mean course of the weather," (BoM 2015).*

Most regions in Australia have a high degree of year-to-year variation in rainfall. This makes it difficult to assess underlying long-term climate changes and to distinguish natural variation from the impacts of global warming.

Large-scale circulation changes have already been observed in the SW of WA.

Although it has the same large-scale climate influences as the west coast, the South Coast region often responds slightly differently, with considerable variation from western parts of the region to central and eastern parts.

The summary climate projections from CSIRO and the Bureau of Meteorology therefore need to be viewed in that context. Confidence in climate model projections decreases at finer scales.

This is because at finer spatial scales ,the magnitude of natural variability in climate increases and local influences on climate become more significant *(CSIRO 2007, p41; CSIRO, BoM 2015).*

2.1. Projections for the South Western WA NRM Regions

The Australian Government established the Regional Natural Resource Management Planning for Climate Change Fund to provide the most up to date science to support NRM regions to plan for adaptation to climate change.

The NRM regions were grouped into 'clusters' based on broad scale climatic and biophysical features.

The South Coast region is included in the Southern and South-Western Flatlands 'cluster' and more specifically in the South West of WA 'sub-cluster' *(Figure 1).* The subsequent report *(Figure 2)* provided climate projections based on the best available climate science in 2014-2015 at three scales of reporting: Southern Australia, the Southern and South-Western Flatlands and the South West of WA.

The report contains technical information explaining the way the global climate models have been used to develop the projections and their limitations. This *Climate Addendum to Southern Prospects 2011-2016* has summarised the main points relevant to the South Coast Region. In addition South Coast NRM can access the latest projection data from CSIRO and BoM to assist in planning for climate change.

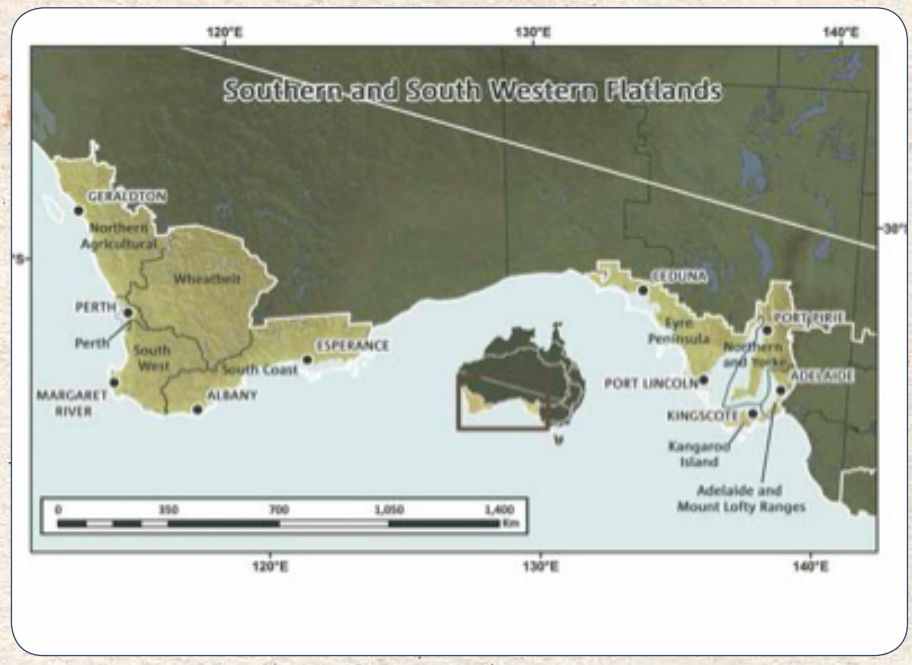


Figure 1: (left) Australian Government Regional Natural Resource Management Planning for Climate Change Fund - Southern and South Western Flatlands Cluster. **Figure 2:** Climate Change in Australia. Projections for Australia's NRM Regions. *Hope et al. (2015) CSIRO, BoM Canberra.*

These projections support impact assessment and adaptation planning for NRM groups, but it is important they are used in conjunction with the guidance material accompanying the *Climate Change in Australia Projections for NRM Regions (Hope et al. 2015).* These projections can be viewed at www.climatechangeinaustralia.gov.au.

The 2015 climate projections in the report are based on the latest Global Climate Model archive, the Coupled Inter-comparison Project Phase 5 (CMIP5).

The projections are based on historical and future climate simulations submitted by 20 modelling groups *(Hope et al. 2015).*

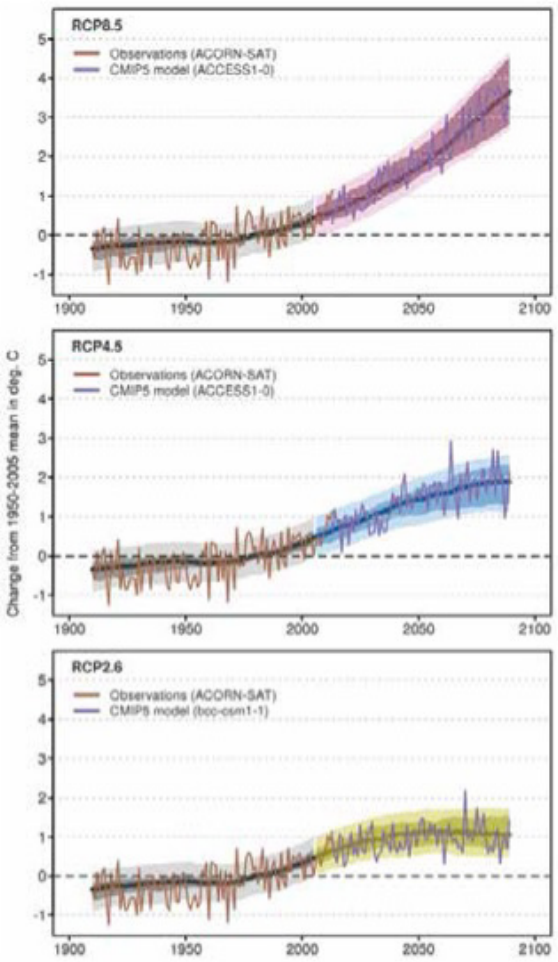


Figure 3: Time series for annual average surface air temperature (0C) for 1910-2090 as simulated in CMIP5 relative to the 1950-2005 mean SW of WA.The central line is the median value and the shading historical simulation. There are three future scenarios for low, medium and high emissions. (RCP 2.6, 4.5 and 8.5). Acorn-Sats observations and projected values from a typical model are shown. From *Hope et al. (2015, p19).*

CSIRO and the Bureau Meteorology have also produced a *Climate Futures Tool* to support regional NRM groups in assessing the impact of climate change. The projections are summarised in *Table 1 on page 11.*

They are based on a range of emissions scenarios from low emissions to high emissions, known as Representative Concentration Pathways (RCPs), as used by the IPCC in their fifth report.

Up until 2030 the projections for each emissions scenario are fairly similar, and climate responses are often masked by natural variation, but after 2030 they diverge quite radically depending on emission scenarios.

It should be noted that they are projections only, not predictions. High confidence in projections should not be translated directly into high probability.

The confidence level is based on the ability of the models to represent important features of current and past climate and knowledge of physical systems (CSIRO, BoM, 2015).

Models can never be totally realistic and climate models have many uncertainties.

Uncertainty does not preclude the need for adaptation planning. It just means planning needs to consider the most likely climate futures e.g. hotter, drier, more or less autumn rainfall and then also plan for uncertainties. Uncertainty increases at longer time scales.

Planners need to have options that will help achieve good outcome across this range of futures. At shorter timescales, this uncertainty is reduced, so decisions with a shorter lifetime can be made with more confidence. *(Rissik et al. 2014, p4)*

Figure 3 shows the projected temperature increase in the SW of WA relative to the current climate over time with a typical model, showing the impact of a high emissions scenario.

CLIMATE RESPONSE	CONFIDENCE IN PROJECTION	REASON FOR CONFIDENCE
Higher temperatures	Very high	Knowledge of physical processes and strong agreement in models and downscaling
Hotter, more frequent hot days	Very high confidence	Knowledge of physical processes and strong agreement in models
Less frost	High confidence	Strong model agreement
Less rainfall in winter and spring	High confidence	Strong model and downscaling agreement, good understanding of shift of winter storm systems and greater prevalence of high pressure systems
Rainfall in other seasons unclear	Low confidence in any projections, unable to project summer rain due to uncertainty of tropical rainfall	GSMs unclear, downscaling shows different results for autumn. GCMs show both wetter and drier for summer.
Increased intensity of rainfall events	Medium confidence but low confidence in magnitude of change	Southward shift of rain bearing systems may reduce extreme events
increase in drought duration	High confidence	High confidence in projected decline in rainfall
Decrease in winter mean wind speed	High confidence for 2030 and 2090	Related to decrease in winter storms
Increase in summer wind speed SW of WA	Low confidence	Models agree but poorly understood
Little change in solar radiation to 2030	High confidence	Models simulate little change
Increased solar radiation 2090	High confidence for medium and high emissions for winter, medium confidence for spring, little change in summer and autumn	Due to decrease in cloudiness and rainfall. High model agreement, and models may underestimate magnitude
Increased evaporation rates	High confidence, but not in the magnitude	Shortcomings in simulations in relation to magnitude
Decrease in relative humidity, in winter and spring, away from coasts after 2030	High confidence	Increased moisture holding capacity of warming atmosphere and greater warming of land compared to ocean
Reduced soil moisture and run-off by 2090	High confidence, but not in the magnitude	Related to decrease in rainfall enhanced by increase in evapotranspiration
Harsher fire weather climate, increased days of severe fire danger rating	High confidence but low confidence in magnitude of change	Increased temperatures, lower rainfall, magnitude will relate to rainfall changes
Higher sea levels and more frequent sea level extremes	Very high confidence, projections beyond 2030 depend on emissions scenarios	Due to thermal expansion and melting of sea ice and glaciers, collapse of Antarctic sea ice would increase projected magnitude
Warmer and more acidic oceans	Very high confidence, By 2090 1.5-3.9°C for highest emission scenario	Highly dependent on emissions scenario; rate of acidification proportional to carbon dioxide

Table 1: Summary of climate response, confidence in projection and reason, for the SW of WA sub-cluster, which includes the South Coast region. Information from *Hope et al. 2015.*

2.2 Downscaling from Global Climate Models

Downscaling from the global climate models enabled the CSIRO and Bureau of Meteorology climate scientists to input more detailed climate information.

The scientists used two different downscaling methods. For statistical downscaling they used 22 global climate models and for dynamical downscaling six models.

Downscaling from a Global Climate Model produces more detail and more plausibility in projecting climate changes for southern Australia, particularly areas with complex topography (such as Tasmania). *(Hope et al. 2015).*

Nevertheless there should not be too much emphasis put on downscaling from CMIP5 for the South Coast Region. Downscaling should only be used as a complementary source of information where it adds value *(CSIRO, BoM 2015).*

The downscaling used for our region showed little difference in the climate responses from the global climate models, except for summer and autumn rainfall. Different downscaling methods have differentstrengths and weaknesses and can show different results. For example, one of the downscaling methods showed decreased, and one, increased autumn rainfall.

A downscaling projection showing a wetter autumn or summer is another plausible projection but not necessarily a more plausible projection than that generated from the courser scale global climate model *(CSIRO, BoM 2015).* In other words finer scale doesn't directly translate into more accurate projections.

"While downscaling can provide added value on finer scale processes, it increases the uncertainty in the projections." *(Hope et al. 2015, p14)*

Figure 4 indicates the differences in seasonal rainfall with different downscaling methods ,while *Figure 5* illustrates the projected differences in seasonal rainfall compared to natural variation under different emission scenarios. The winter/spring projections are clearer than the summer/autumn.

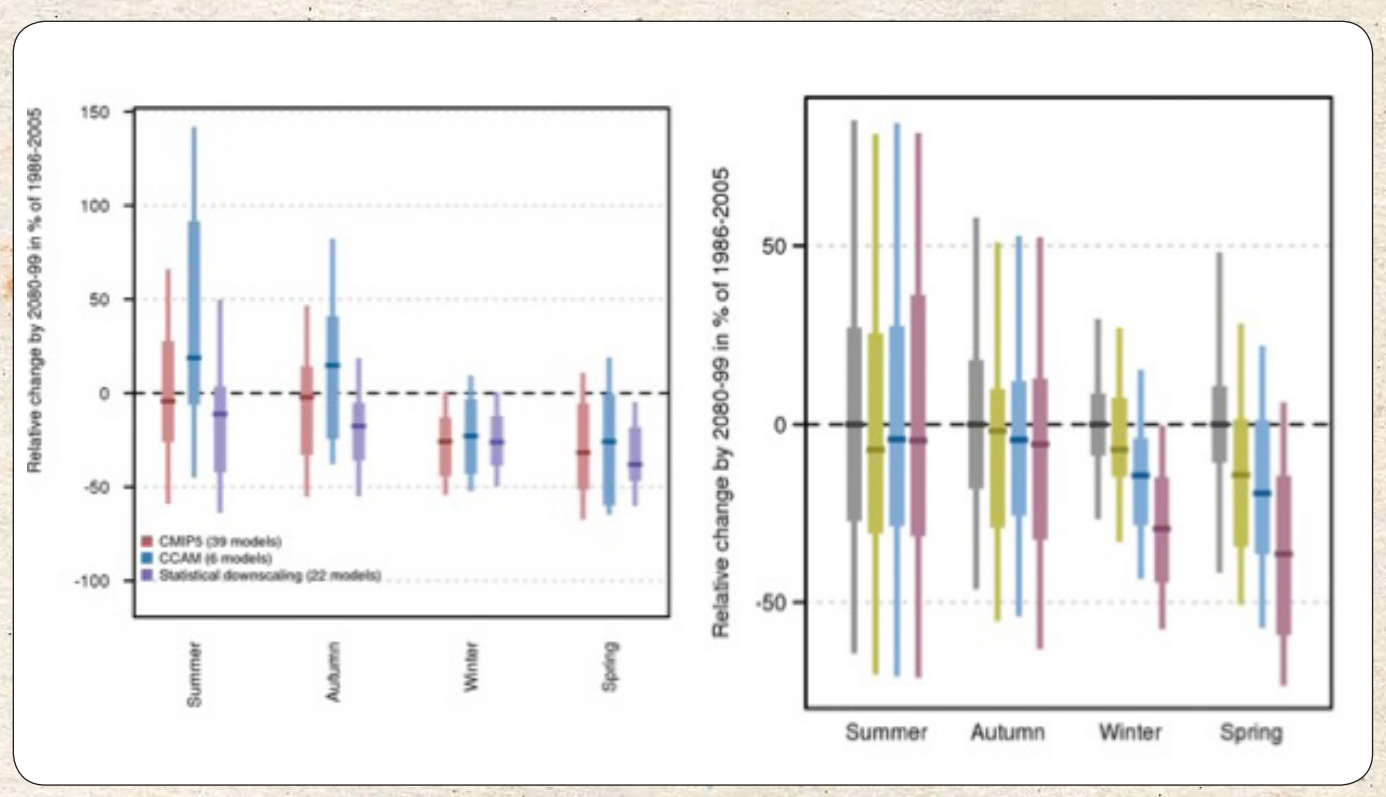


Figure 4: (left) Projected change in seasonal rainfall for 2090 for the Southern and SW Flatlands and two different downscaling methods with a high emissions scenario. Source *Hope et al. 2015, p27.*

Figure 5: Projected seasonal rainfall changes for SW of WA for 2090. Natural variation is in grey, and the three emissions scenarios are low RCP (2.6), medium RCP (4.5) and high (8.5) RCP. Source *Hope et al. 2015, p27.*

2.3 Impacts of Changes in Climate on the South Coast Region

The projections indicate with very high confidence that increases in temperature are one of the responses to increasing emissions and there is also high confidence in reductions in winter and spring rainfall. The combination of more dry seasons, more heat waves, higher temperatures and more evaporation will have impacts on biodiversity, agriculture and forestry and hydrological systems such as wetlands, waterways and groundwater.

Many of the South Coast's ecological systems are already under stress and there is a risk climate change will push them beyond their capacity to adapt. There will be changes in sea-level due to expansion of the oceans and melting of ice. The absorption of CO_2 by oceans is causing acidification. Climate change will also affect the region's cultural heritage and Aboriginal links with landscape.

This *Addendum* reviews the potential impacts of climate change on each of the themes in *Southern Prospects* including adaptive capacity.

In addition, it gives an overview of climate science: the complexity of climate; the influences on the South Coast climate and how it might be changing, due to natural variation and changes as a result of greenhouse gas emissions; the limitations of climate science and models and the uncertainties. There is further information in the background papers to the *Addendum* and in the technical report *Climate Change in Australia CSIRO, BoM (2015).*

2.3 The Complexity of Climate & Climate Science

The global climate system is highly complex. It is difficult to convey the complexities and the public finds it hard to accept the uncertainty associated with climate projections based on models.

There are also sub-regional and local variations in climate responses. The eastern parts of the South Coast region do not necessarily fit in with the projections based on the broader SW of WA sub-cluster.

The extent of natural variation in climate is also unknown. There are several large-scale influences responsible for variations in the climate in the SW of WA including the South Coast region *(Figure 6).*

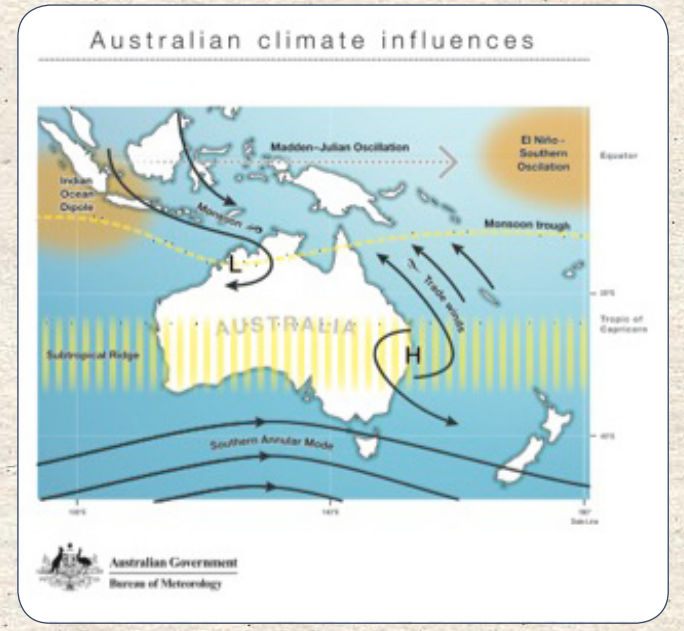


Figure 6: Large-scale climate influences *(BoM).*

2.4 Climate Influences on the South Coast Region

Winter rainfall in the SW of WA is influenced by the upper level jet stream, by fronts, lows and the high-pressure systems of the Sub-tropical Ridge.

The major source of winter rainfall is from fronts associated with a band of westerly winds encircling Antarctica. Cut-off lows, which are large low pressure systems cut off from the westerly winds further south, can occasionally bring very prolonged and heavy rainfall to the South Coast.

Summer rainfall is sporadic and can be associated, particularly in the east of the region, with the end of tropical cyclones.

Some of the reduction in rainfall in the SW of WA is thought to be due to global warming and some to natural variation. An unknown proportion may also be due to vegetation clearance *(Pitman et al. 2004; Timbal et al. 2006).*

There have been changes in the upper level jet stream so there are less winter storms coming to the SW part of WA. Southern Australia is also under the influence of the descending dry branch of the Hadley circulation resulting in the formation of high-pressure systems.

There are two major see-saw climate influences on the South Coast Region ; the Southern Annular Mode (SAM) and the Indian Ocean Dipole (IOD) bring more or less rain to the SW of WA depending on whether they are in a particular mode.

SAM is a westerly wind belt that circles Antarctica and moves north and south. When it moves towards Antarctica it is in its positive phase and this results in weaker westerly winds and more high-pressure systems over the SW of WA.

Although a positive SAM results in drier conditions in most of the South Coast Region it correlates with more rainfall in spring in the eastern part of the South Coast. There is an increasing trend for SAM to move towards Antarctica in the positive mode. The CSIRO and BoM projections are for this to continue; although ozone recovery may have an opposing effect. The increase in positive SAM may in part be due to ozone depletion *(Arblaster et al. 2011).* The increase in positive SAM may in part be due to ozone depletion (Arblaster et al. 2011).

The Indian Ocean Dipole (IOD) is an index based on sea surface temperatures in the western compared to the eastern, tropical Indian Ocean. When the sea surface temperatures are higher in the western part there is a decrease in rainfall over the South Coast.

The El-Nino Southern Oscillation (ENSO) has less of an effect on the South Coast region's rainfall than the other influences but may interact with the IOD.

ENSO is caused by changes in trade winds and temperature in the eastern and central Pacific Ocean. Some areas of the South Coast have a decline in winter-spring rainfall during El Nino events while some parts of the eastern South Coast appear to receive more summer rainfall. Because ENSO and the IOD are thought to be interrelated, determining the influence of ENSO is further complicated.

The Sub-tropical Ridge runs across a belt of high-pressure systems and moves south in summer and north in autumn. There also appears to be a regional atmospheric circulation over the SW of WA. This may affect winter rainfall in the SW of WA. *(Feng et al. 2010).* There have been changes in these large-scale climate influences in Australia in the past 30 years *(Figure 7),* including an expansion of the tropics, contraction of mid-latitude storm tracks further south, and changes in the jetstreams *(CSIRO, BoM 2015).*

Year-to-year variability in the intensity and position of the Sub-tropical Ridge influences the amount of rain in the SW of WA *((Figure 7, Hope et al. 2015.* Although there is a large amount of natural variation some of the changes occurring in the South Coast climate can be attributed human activities and the enhanced greenhouse effect.

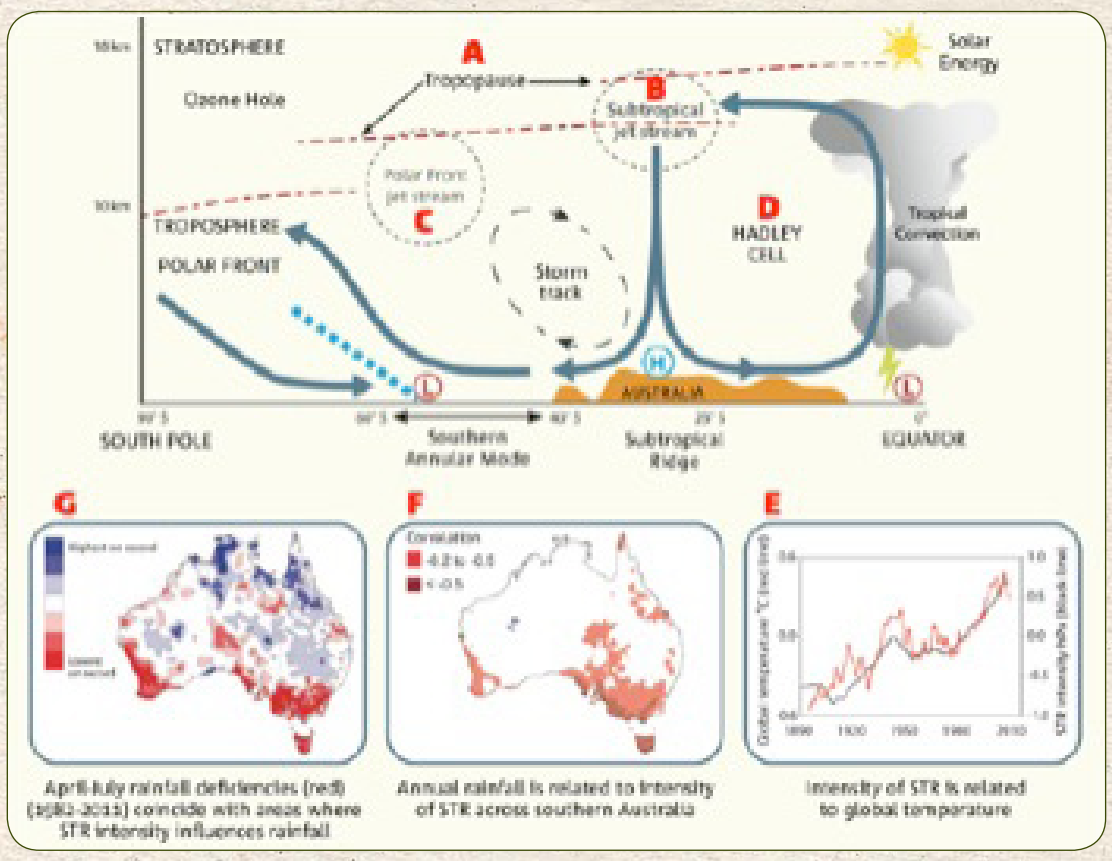


Figure 7: North-south cross section of the atmosphere in eastern Australia. The tropics have expanded in recent decades. The edge of the tropical tropopause (A) has trended poleward during the past 30 years *(Lucas et al. 2014* cited in *Hope et al. 2015).* The subtropical jet (B) has been observed to decrease in intensity while the polar front jet (C) has increased in intensity *(Frederiksen & Frederiksen, 2011).* The descending arm of the Hadley Cells (D) has trended poleward during the past 30 years (*Hope et al. 2015, p11).*

2.6. The Enhanced Greenhouse Effect

The greenhouse effect is the process whereby certain gases trap the heat in the earth's atmosphere. It is a natural process and it keeps the earth warm enough for life. Although many people simply refer to the greenhouse effect, the enhanced greenhouse effect is the technical term used to describe the extra warming from added greenhouse gases as a result of human activities.

Warming of the atmosphere and oceans causes complex reactions within the global climate system and this is why there is uncertainty and the possibility of climate shocks.

The oceans are currently absorbing much of the extra warming. The oceans don't warm uniformly and differences in temperature in different parts of the ocean can influence rainfall. It is therefore more difficult to project the impact of the enhanced greenhouse effect on rainfall than on temperature.

Evidence that the Earth's climate continues to warm is unequivocal. Multiple lines of evidence indicate that it is extremely likely that the dominant cause of recent warming is human- induced greenhouse gas emissions and not natural climate variability. *(CSIRO, BoM 2014a, p10).*

Australian scientists have been measuring greenhouse gases at Cape Grim in Tasmania for 50 years and the level of CO_2 has increased from 328ppm to nearly 400 ppm. Ancient air locked in the ice in Antarctica shows that the air and oceans contain more CO_2 than at any time in the last 800,000 years. *(CSIRO, BoM 2014a, p14).* Climate models represent the physical processes caused by changes in greenhouse gases.

2.7 Global Climate Models

Global climate models are also known as General Circulation Models (GCMs). These models do not provide predictions. They are simply tools to integrate very complex information and thereby reduce uncertainty. They have to be constantly tested against reality. General Circulation Models are mathematical models representing the physical processes in the atmosphere, ocean, cryosphere (ice) and land surface. The data put into the models are large-scale distributions of atmospheric temperature, precipitation, radiation, wind, sea temperatures, ocean currents and sea-ice cover *(IPCC 2014).* *Figure 8* shows the interactions in the models.

Different modellers incorporate different assumptions, and as a result the models provide variations in projections. Climate modeling and climate projections are coordinated globally through a series of major projects called Coupled Model Intercomparison Projects (CMIP). The Coupled refers to the coupling of Ocean General Circulation Models and Atmosphere General Circulation Models. CMIP 5 refers to phase 5 of the CMIP to correspond with the IPCC's fifth report.

Models will only simulate the interactions in the climate systems well if there is sufficient knowledge of the processes governing climate. Confidence in the projections is higher for some models than others and some simulate the patterns of high and low pressure systems in the SW of WA quite well.

Nevertheless the projections from global climate models need to be regarded with caution particularly at a sub-regional scale.

Therefore the model projections for the SW of WA may not agree with a local climate at a specific location on the South Coast and the experience of a particular landholder. This can lead to the wrong conclusions about the validity of the science.

Climate models and evidence from past climate change provide a plausible range of values. Climate changes over small regions and changes in rainfall patterns are very hard to estimate *(Australian Academy of Science 2010, p3).*

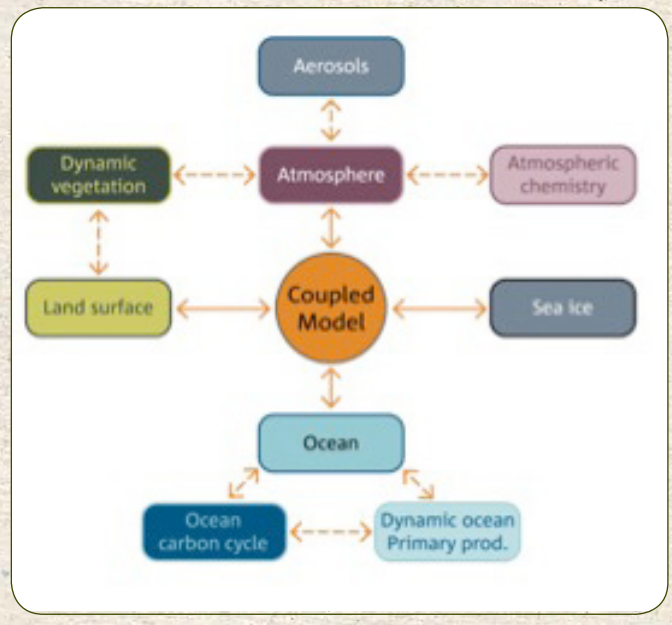


Figure 8: Global Coupled Model showing interactions. Not all interactions are represented in all models. Dashed line show interactions used only in some models in the projections, *CSIRO BoM (2015, p27).*

2.8 Representative Concentration Pathways (RCPs)

The CMIP 5 models used representative concentration pathways (RCPs) (Table 2), which are representative of possible future emissions based on four scenarios: early mitigation, stabilisation before 2100, stabilisation after 2100 and emissions continuing to rise after 2100.

SCENARIO	RCP	CO_2 IN PPM
Early Mitigation, with peak and decline before 2100	2.6	490
Stabilisation before 2100	4.5	650
Stabilisation after 2100	6	850
Emissions still rising after 2100	8.5	>1370

Table 2: Representative concentration pathways with different scenarios.

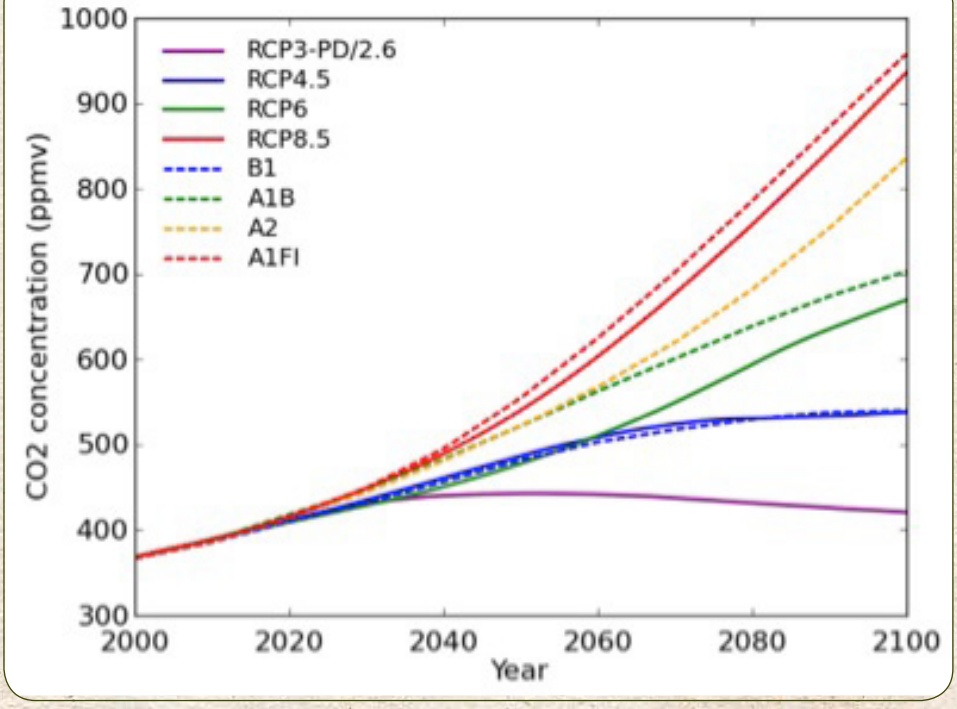


Figure 9: Comparison of carbon dioxide concentrations for the 21st century from the RCPs and SRES scenarios.

RCP8.5 is closest to A1FI, RCP6 is closest to A1B, RCP4.5 is similar to B1, and RCP2.6 is lower than any of the standard SRES scenarios.

The SRES scenarios were used in the third IPCC report. Source: *Jubb et al. 2013* (data from *Meinshausen et al. 2011* and IPCC TAR WG1 Appendix 2).

2.9 Downscaling & Regional Climate Models

Regional NRM planning requires more detailed information from finer spatial scales than provided by the coarse resolution of global climate models. CSIRO and BoM have provided downscaled information to regional groups.

There are different downscaling methods. Regional climate models are nested in the global climate model.

The regional climate model contains finer scale information such as coastline effects, land use and topography. The outputs from the global climate model are used as inputs for the regional climate model *(IPCC 2014)*. Downscaling does not reduce the uncertainty in the models, but can help to see how well the models are behaving. It also is likely to be more realistic in matching observations at the finer scale.

Uncertainty increases at smaller scale but also because, as highlighted earlier, different downscaling methods can produce different results *(IOCI 2012; CSIRO BoM 2015; Hope 2015)*. Another problem with downscaling is that it only uses a subset of models.

"It is becoming apparent, however, that downscaling also has serious practical limitations, especially where the meteorological data needed for model calibration may be of dubious quality or patchy, the links between regional and local climate are poorly understood or resolved, and where technical capacity is not in place.
*Another concern is that high-resolution downscaling can be misconstrued as accurate downscaling." (Wilby and Dessai 2010, p180).*Although the projections for the broader SW of WA are considered robust, information on local climate influences on the South Coast Region is more limited so any downscaling provided by CSIRO and BoM needs to be evaluated at a local scale.

There is more information on downscaling in CSIRO and BoM (2015).

2.10 Observed Changes in Climate in the South Coast Region

2.10.1 Variable Climate Change

The extent of climate change in the last decade has been variable across the South Coast Region and the Region's climate did not show the early drying trend of the west coast in the 20th century.

The rainfall decline on the west coast of WA has been greater than the Global Climate Models suggested. This is probably partly because of natural variation. It is difficult to separate natural variation from the impact of human activities but the models are helping to differentiate these effects *(IOCI 2012).*

The South Coast Region has a range of climates, varying from higher rainfall areas in the south-west of the region, to lower rainfall areas in the north-east of the region. These areas have shown different degrees of climate change in the last 40 years. The baseline for comparison is important because there appear to be two different climate change points; from 1975 for the reduction in low-pressure systems affecting western areas; and from 2000, for the increase in high-pressure systems affecting the wider area of the South Coast *(Hope et al. 2006; Hope and Ganter 2010).* There is not enough data yet to determine whether the trend from 2000 is a long term one because natural variability can mask any trends in short term data.

Table 3 shows some comparisons between changes in growing season rainfall for Kojonup, Ravensthorpe and Salmon Gums for the period to 2000. In Kojonup total annual rainfall for the period 1975 to 2010 compared to 1939-1974, decreased by 8 per cent while in Salmon Gums it increased by 5 per cent. The Salmon Gums increase was due to increases in rainfall outside of the growing season.

Between 2000 and 2010 there was a further decline in growing season rainfall in Kojonup of 7 per cent and in Salmon Gums of 2 per cent *(Farre et al. 2011a&b).* Changes in rainfall for Ravensthorpe can be regarded as insignificant.

Rainfall	Kojonup Changes 1975 - 2000 v 1939 - 1974	Ravensthorpe Changes 1975 - 2000** v 1939 - 1974	Salmon Gums Changes 1975 - 2000 v 1939 - 1974
Mean growing season rainfall (April - Oct*)	10% decline	0.17% decreaswe	2% decline
Rainfall distribution	Decrease in June rainfall.	Increase in May, decrease in June, small decrease in Nov, increase in Dec.	Decrease in June rainfall, increase in Nov rainfall.

Table 3: Rainfall change in the last 40 years for Kojonup *(Farre et al. 2011a)*, Salmon Gums *(Farre et al. 2011b)* and Ravensthorpe.

* April to October was used as growing season rainfall in the *Farre et al. (2011 a and b)* data for Kojonup and Salmon Gums. If May to October is used, growing season rainfall increased slightly in Ravensthorpe.

** Comparison of Ravensthorpe to Kojonup and Salmon Gums to 2010 could not be made because of data missing from BoM monthly rainfall statistics for Ravensthorpe for 2003 and 2008.

2.10.2 Changes in Rainfall

Figure 10 shows rainfall changes in the Department of Agriculture and Food's Southern Agricultural Region (which includes the South Coast Region). It gives a good regional picture of the changes in rainfall.

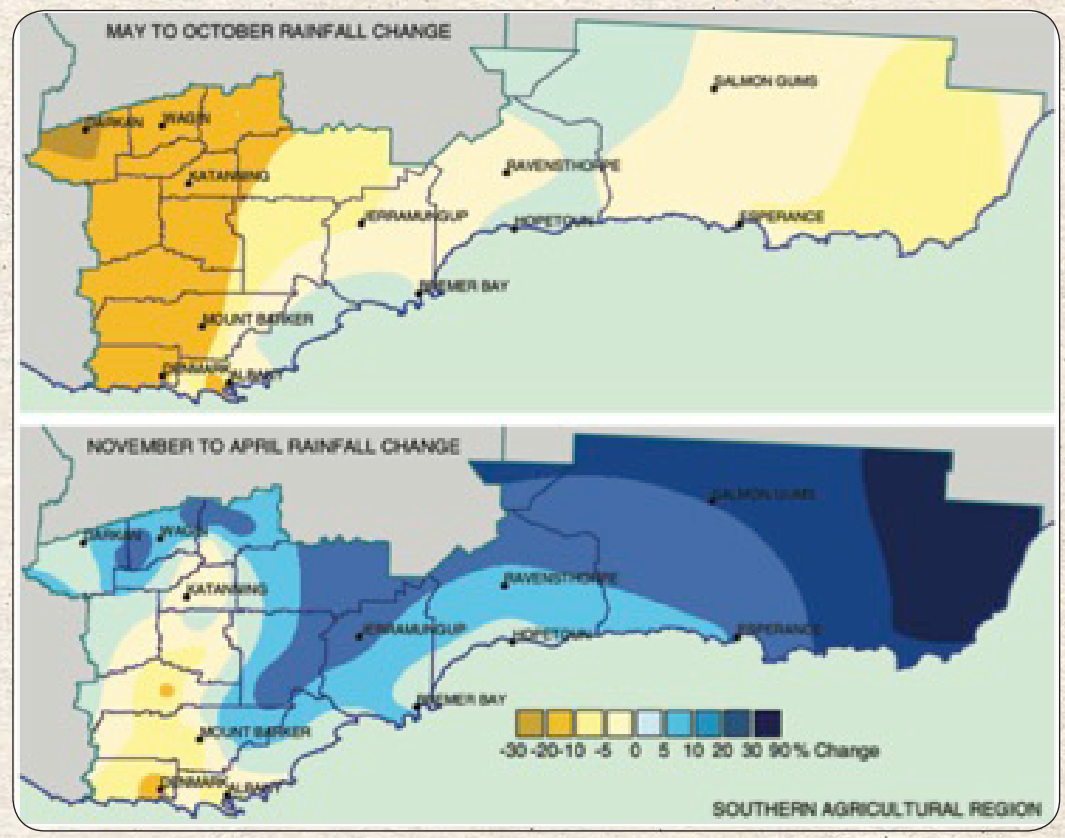


Figure 10: Changes in rainfall Southern Agricultural Region Department of Agriculture and Food 1910-1975 versus 1976-2008. *Source: Carmody et al. 2010.*

2.10.3 Changes in Large-Scale Circulation

There is no doubt that there has been major climate change in the SW of WA and this includes much of the western part of the South Coast region.

Weather patterns that bring wet conditions have declined and those that bring dry conditions have increased. The decline in rainfall has corresponded with changes in the large-scale circulation in the Southern Hemisphere *(Frederiksen et al. 2012)* and with a regional scale circulation *(Feng and Li 2010)*.

There has been a decline in the frequency and intensity of high rainfall events and a reduction in the sub-tropical jetstream, a strong belt of upper level westerly winds and this has led to a reduced likelihood of storms developing. There has been a weakening of low-pressure systems (from approximately the mid 1970s) and also a southward deflection of winter storms. *(Frederiksen and Federiksen 2007)*.

As discussed above, from the mid 1990s, there has been less of a decrease in the low-pressure systems but an increase in the persistence of high-pressure systems *(Hope et al. 2006; Hope and Ganter 2010)*. The increase in high-pressure systems has exerted its influence over a wider geographic area than the decrease in low-pressure systems *(Hope et al. 2012)*, which is why the western part of the South Coast Region had a drying trend from 2000, while the west coast climate changed much earlier.

Warming in the south has also reduced the temperature gradient between the equator and the pole, which in turn, lessens storm development in WA and increases storms further south in the Southern Ocean at latitudes around 60°S *(IOCI 2012, p27)*. Several factors, such as natural variation, vegetation cover change *(Pitman et al. 2004)* and greenhouse gases could have contributed to this climate change *(IOCI 2012)*.

2.10.4 Northwest Cloud Bands & Early Season Rainfall

Northwest cloud bands from the Indian Ocean have increased in the last 50 years *(Frederiksen et al. 2012)*. This may be very significant for South Coast rainfall in the early part of the growing season.

Northwest cloudbands arise off the northwest coast of WA during autumn and early winter and decline in late winter, moving from northwest to southeast *(Telcik and Pattiaratchi 2014)*.

Interaction of northwest cloudbands with frontal systems can increase rainfall in both intensity and spatial area to the SW of WA. When they interact with frontal systems they bring widespread heavy rainfall *(Wright 1997 cited in Telcik and Pattiaratchi 2014)* but they are related to a number of other major climate influences and so are highly variable *(Telcik and Pattiaratchi 2014)*.

If the warm ocean origin of these cloudbands moves south with global warming and the expansion of the tropics *(Frederiksen et al. 2012 p 35)* and they continue to increase, they could increase autumn and early winter rainfall in much of the South Coast in the future.

Telcik and Pattiaratchi (2014) showed that when there was a high frequency of north-west cloudbands, associated rainfall extended to the central and eastern South Coast, whereas with lower frequency cloud bands, rainfall was more limited to western coastal areas. Changes in the latitude of northwest cloud bands could bring more early season rain to the South Coast.

2.10.5 Factors Driving a Drying Climate

It is difficult to ascertain the proportion of the drying climate that is due to greenhouse gas emissions (greenhouse gas forcing), but modelling suggests that increasing concentrations of greenhouse gases have caused half of the winter rainfall reduction *(Cai and Cowan 2006)*.

Therefore the drying climate in the SW of WA is likely to be the result of several factors all driving the climate in one direction. The projected increase in SAM (i.e. moving further southwards) in the future, suggests a continuation of the drying trend and more frequent dry seasons in the SW of WA *(Cai et al. 2011)*. The models show that the higher the greenhouse gas emissions, the more the high pressure systems will dominate, and low pressure systems will move closer to Antarctica. Consequently Westerly winds will be much weaker over SW of WA.

2.10.6 Recovery of the Ozone Hole over Antarctica

Maximum temperatures in the South Coast Region have generally shown a different pattern to the west coast.

Maximum temperatures on the eastern part of the SW of WA (i.e. much of the South Coast Region) tend to be cooler when SAM is in a high phase due to more easterly winds associated with high-pressure systems *(Hope et al. 2012)*. *Hope et al. (2012)* suggest the Antarctic ozone hole may be responsible for the dominance of high-pressure systems and subsequent cooling effect in the south-east of SW of WA.

They speculate that with the closure of the ozone hole there could be a temporary warming effect on maximum temperatures in the South Coast Region (with less easterlies) and a temporary cooling effect on the west coast *(Hope et al. 2012)*.

Ozone interacts with atmospheric conditions and the timing of its closure cannot be predicted, only projected based on models. Although the ozone hole is projected to close in the next 50 years and this may have some effect on the SW, the impact of greenhouse gas concentrations is expected to override the effect *(Arblaster et al. 2011; CSIRO 2007; Eyring et al. 2013)*.

The counter effect of these two influences suggests accurately predicting the direction of maximum temperatures in the South Coast Region to 2030 may be difficult. As highlighted above, one of the main problems is that the South Coast Region appears to respond slightly differently to the large-scale circulation changes than does much of the west coast.

The eastern and central parts of the South Coast also respond differently to the western parts of the South Coast. The climate is changing but in the short term it is uncertain what the changes will be and whether they will be masked by natural variation.

2.11 Uncertainties in Climate Projections

Uncertainty in climate projections is a challenge in planning for adaptation to changes in climate. There are a number of levels of uncertainties associated with climate projections.

CSIRO, BoM (2015) classified uncertainties into three main categories: scenario uncertainty or that associated with the emissions scenarios; response uncertainty due to limitations in understanding the climate system and the ability to simulate it; and uncertainty associated with natural variability.

Natural variability includes not only internal variations in climate but also changes in solar radiation and volcanic activity. These uncertainties also interact and multiply *(Pittock 2003)*. There is effectively a 'cascade of uncertainty' (Wilby and Dessai 2010) with the uncertainty increasing at each level. *(Figure 11)*.

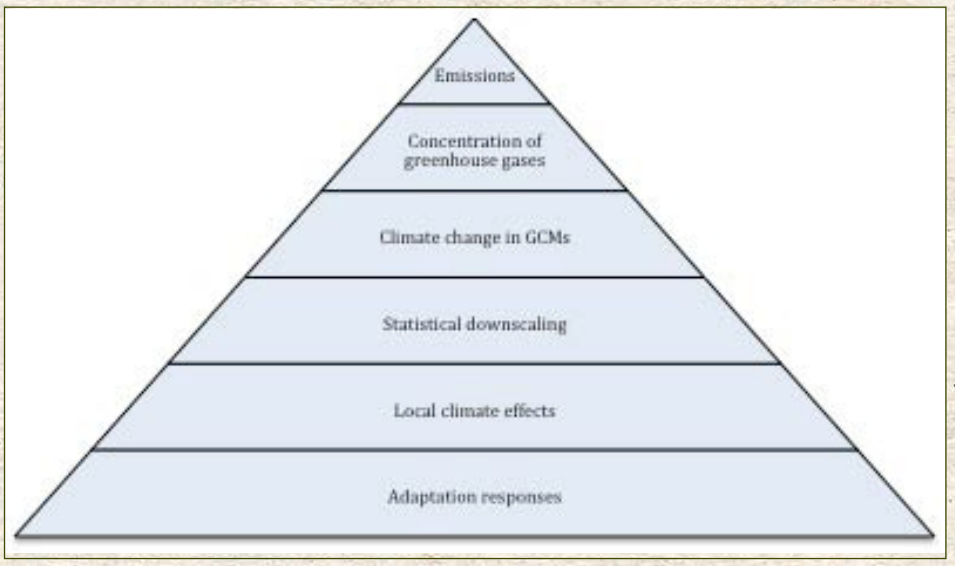


Figure 11: Cascade of uncertainty *(adapted from Wilby and Dessai 2010).*

The uncertainties also vary with time. For example the uncertainty in RCPs become much more important after 2030 *(Hawkins 2014).*

Uncertainties increase even further when modelling climate responses such as distribution of particular species, pests and diseases or agricultural impacts uses global climate models, or often, just a selection of global climate models.

Pittock (2003) argues that this is why it is important to integrate climate change with other NRM activities to make systems as resilient as possible so that NRM takes into account the combined stresses on natural systems. Planning has to be for climate uncertainty and interactions of changes in climate with other NRM threats.

2.12 Summary of Global Climate Science

The level of carbon dioxide in the atmosphere of the earth is the highest it has been for 800,000 years and is increasing rapidly.

Carbon dioxide and methane are important greenhouse gases, meaning they have a warming effect on the planet, like that of a blanket. This is a fundamental law of physics. The planet is getting warmer. At least nine of the warmest years on record have been since 2000 and ocean temperatures are increasing. Global mean surface air temperature has risen 0.85°C from 1880 to 2012 and at 0.12 C per decade since 1951.

Australian average surface temperature had increased by 0.9C since 1910.The warming of the planet corresponds directly with the increase in carbon dioxide and other greenhouse gases, as a result of industrialisation.

Carbon dioxide has risen from 285 ppm in 1880 to 400 ppm in 2015.Carbon dioxide is acidifying the oceans. This will almost certainly impact adversely on marine life as will ocean warming. The sea levels are rising.

In spite of some media coverage indicating dissent, most reputable scientists agree that emission of carbon dioxide, and other greenhouse gases, is causing the sudden increase in warming of the planet.

2.13 Summary of Climate Uncertainties for the South Coast Region

Climate systems are complex and there will be sudden shifts and surprises. Global Climate models (mathematical models) are used to project large-scale climate changes but they are not predictions.

For smaller spatial areas the model projections are more uncertain, therefore systems need to be robust enough to cope with uncertainty and sudden change.

It is unclear how much of the drying of the SW climate is due to natural cycles or human impacts, but it is likely that both are contributing. Volcanic activity, the closure of the ozone hole and pollution could temporarily lower the temperature in some parts of the earth.

As the ozone hole repairs itself this may cause some short term changes to the South Coast climate but carbon dioxide emissions will override these temporary effects in the longer term.

Although BOM and CSIRO model projections show a drying trend for the SW of WA, rainfall changes are difficult to predict for the South Coast.

Differences in temperature in different parts of the ocean can cause large-scale changes in rainfall patterns. There is uncertainty as to how this may impact, particularly on the eastern South Coast. The Northwest cloud bands can bring autumn and early winter rain to the South Coast, particularly if they combine with frontal activity.

If these cloud bands move further south with expansion of the tropics, they could bring more rain to the South Coast in early and mid-winter.

The interaction between higher carbon dioxide, temperature and rainfall on plant growth, including crops, native flora, carbon plantings and plantations is uncertain. The SW of WA has had dry periods before, so it is uncertain how well flora and fauna is adapted.

The difference this time is in the rapidity of the concurrent drying and warming and the presence of other threatening processes such as dieback, weeds, feral predators and habitat fragmentation.

The rate of sea level rise is uncertain, but it is unlikely to be linear. For example, there may be a sudden rise if Antarctic ice melts, or if warming progresses faster due to increases in emissions.

How much mitigation there will be globally and how well natural and human systems adapt is also uncertain. Up until 2030 natural variation in climate may mask human induced climate change.

The following sections of this Addendum examine each of the NRM themes in South Coast NRM's Regional Strategy, Southern Prospects, in terms of climate change. There is further, more detailed information in the background papers accompanying the *Addendum*.

3 Regional Adaptive Capacity

In this Addendum, regional adaptive capacity refers to the ability of communities, individuals, institutions and organisations to adapt to the major global threat of a warming and changing climate while adopting sustainable management practices.

Adaptation consists of actions undertaken to reduce the adverse consequences of climate change, as well as to harness any beneficial opportunities.

Adaptation actions aim to reduce the impacts of climate stresses on human and natural systems. *(National Climate Change Adaptation Research Facility nd).*

There are many challenges in planning for adaptation to climate change. One of the main challenges is that people have to make decisions about adapting to a range of possible future climates and they have to decide when to make those decisions. This means that they have to use flexible and adaptive planning processes.

The way forward when there is uncertainty is to increase the adaptive capacity of people and organisations (*Rissik et al. 2014).*

Because of the uncertainty about future climate, the Australian Government *(Australian Greenhouse Office 2006)* advocated using risk management and adaptive management approaches as a way to deal with the uncertainty.

CSIRO and BoM stress that care must be taken in using the climate projections in the risk assessment. It is particularly important to determine the spatial resolution and to consider the uncertainty.

The Australian Government recommends the framework for risk management is the Australian and New Zealand Standard AS/NZS 4360 Risk Management *(Figure 12).*

Risk management is defined as a five-step process that identifies, analyses and evaluates a risk and plans and implements a strategy to reduce the chances of the undesirable event occurring or reduce the scale of damage caused by the event *(Standards Australia & Standards New Zealand 2009).* The initial stage of risk assessment is in a workshop format.

Climate scientists from CSIRO and BoM stress the importance of making sure the climate and emissions scenarios used in risk assessment are internally consistent and under a consistent set of assumptions including choice of global climate models, time period and emissions scenario.

The scientists stress the importance of not mixing and matching projections *(CSIRO, BoM, 2015).*

The Climate Futures Tool on Climate Change is available at the website: www.climatechangeinaustralia.gov.au is useful for developing scenarios *(Hope et al. 2015).*

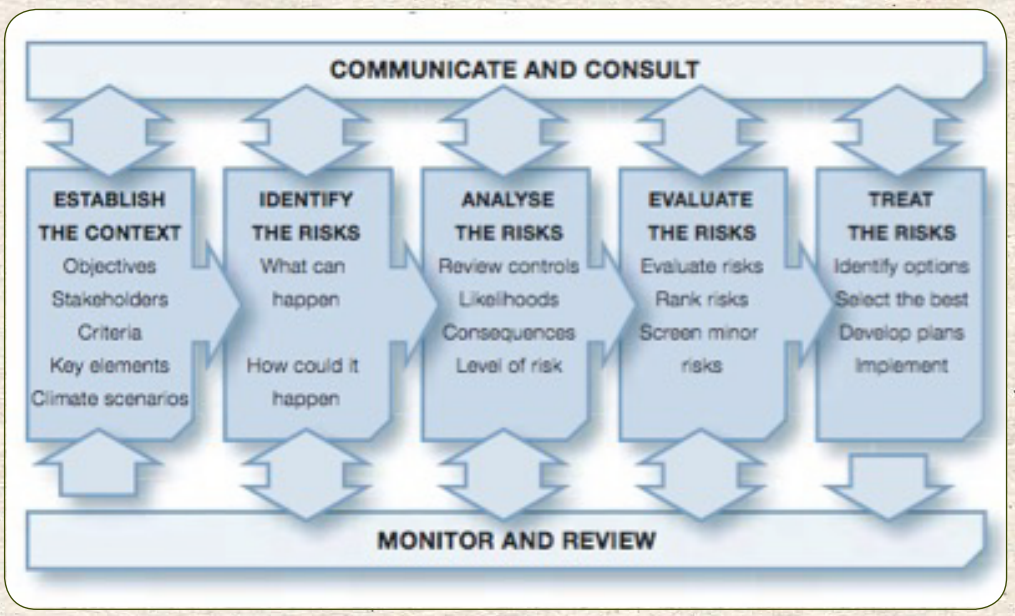


Figure 12: The Steps in Risk Management. Source: *Climate Change Impacts & Risk Management. A Guide for Business and Government Australian Greenhouse Office (2006).*

Strengthening adaptive capacity is advocated as an important part of the adaptation process and there has been a great deal of research and many published documents, books and academic papers theorizing on how best to do this. There is also research on some of the social, economic and institutional barriers to adaptation. South Coast NRM has a background technical paper to this Climate Change Addendum on the socio-economic aspects of adaptive capacity. The National Climate Change Adaptation Research Facility (NCCARF) website is a good resource for finding some of the national and international research at www.nccarf.edu.au. AECOM (2013, p7) in a report synthesizing NCCARF research for Western Australia listed the limits and barriers to adaptation as the following below:

- Lack of community support. Public opposition and poor communication can derail adaptation implementation. There can also be different perceptions of adaptation.
- Current institutional and legislative frameworks. Practical management strategies at the local or state level can be constrained by government, which may not take into account local conditions and institutional arrangements can create barriers to collaboration,
- Capacity and resource constraints. Local governments, in particular, find long-term, large adaptation projects are beyond their capabilities (Mukheiber et al. 2012 cited in AECOM 2013). There is also the situation where the person able to fund an adaptation intervention is not the one who benefits in terms of avoided costs.
- Lack of system understanding. Unknown thresholds of ecological resilience and lack of understanding about the interconnectivity within ecosystems limit the identification of effective adaptation options *(Hadwen et al. 2011 cited in AECO, 2013).*
- Lack of access to up-to-date and relevant information. There is a distinct lack of coordination of existing databases and data-sharing arrangements between relevant authorities (*Hadwen et al. 2011 cited in AECO, 2013).*

Regional NRM groups need to be able to translate research on adaptive capacity into actions that can be put directly into practice with limited budgets. This requires a strong emphasis on partnerships. The main attribute in adapting to uncertainty is flexibility, and this requires constant re-evaluation of the approaches being used.

Climate change adaptation needs a mix of long-term 'precautionary principle' planning and short-term flexible planning. There are a large number of community natural resource management groups in the region and partnerships with State Government, Local Government and universities, are providing much needed research, monitoring, planning and education. A GIS system with capacity in spatial analysis, good local climate data and downscaled climate modelling with specific South Coast climate inputs are important tools in regional adaptation to climate change.

Each natural resource theme has a number of strengths in adaptive capacity, which can be built on, but also important gaps, which need to be developed into actions.

There is more discussion of adaptive capacity in specific areas under each theme.Some of the actions to increase adaptive capacity identified by South Coast NRM's community workshops were:

- Education and awareness, particularly in layman's terms.
- Improving access to information.
- Providing access to web-based reports and information and more online resources.
- Improved local climate information.
- Risk assessment training.
- More information on climate science and communicating scenarios.

Farmers in the South Coast region are constantly adapting to a changing and variable climate. Two farmers from the South Coast region discussed their strategies.

Andrew Longmire, north of Salmon Gums (annual rainfall approximately 330mm).

"We rely on summer rainfall for sub-soil moisture. We have been getting more summer rainfall since about 1992. Every year is different and there is no pattern to the rainfall, we just have to work with it. We crop particular soil types depending on the season. We use liquid fertilizer in dry years. The main adaptation in the district is direct drill and chemical fallow."

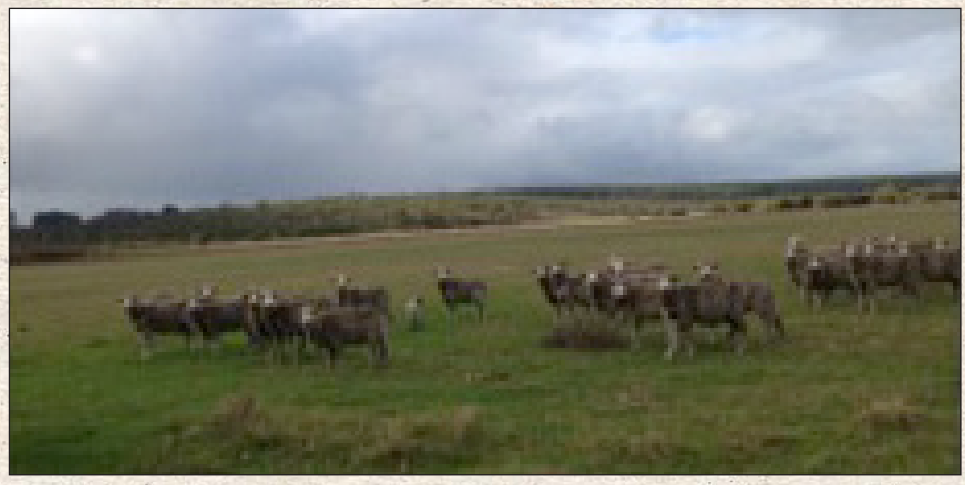
The biggest risk for Andrew is if there are heat events in August/ September. With appropriate varieties with better tolerance to heat, dry seasons, frost and boron, Andrew believes low rainfall farming will still be possible at Salmon Gums.

In contrast, in the high rainfall zone, farmers have so far benefited from climate change They have been able to increase the proportion of cropping so for many their main income is now from cropping and they have more profitable farms as a result. There is a smaller margin from prime lambs and beef than from wheat.

David Slade in the Kent catchment at Kendenup (annual rainfall approximately 600mm).

"We couldn't grow wheat 40 years ago. We are now getting Cranbrook to Tambellup weather. I have to accept that the climate is changing but we don't know whether it is due to all the clearing in the south-west or due to the warming of the sea."

The Slades' farm business has benefited from the drying climate in being able to put in a greater proportion of crop.



Changes from livestock to cropping enterprises are occurring in response to a drying climate in parts of the South Coast region.

4 LAND

4.1 Principles

From *Southern Prospects 2011-16.*

- Natural resource management may seem costly but is inexpensive insurance against accelerated decline of precious assets.
- Land use should be within its capabilities so degrading processes are minimised, managed or avoided.
- An intergenerational approach should be taken to land use and planning.

Some principles for Climate Change Adaptation Planning.

- There should be an adaptive planning, risk management approach, incorporating new climate information as it becomes available, with regular evaluation and monitoring.
- Recognising importance of maintaining resilient and sustainable agri-businesses while protecting land against the impacts of climate change.

4.2 Values & Threats

The South Coast region is diverse in climate and land use. Increasing variability in climate with a trend to warmer temperatures and lower rainfall in parts of the South Coast region is going to pose new challenges for agriculture and forestry.
Different parts of the region will have different climatic responses to global warming. There will be interactions between increased carbon dioxide, rainfall and temperature.
For example carbon dioxide could have production benefits in the short term before high temperature and variable rainfall changes impact.

Land Use	Impact Short Term To 2030	Response To 2050 (with no global mitigation of greenhouse gasses)
Cropping	Varies with rainfall zone. Increased variability in rainfall Overall reduction in grain yields but less than other regions. Some higher rainfall areas become more suited to cropping. Greatest impact on wheat and canola in hotter, drier northern parts of region. Soil type important factor in yield responses. Changes in distribution, abundance of pests and diseases	Major contraction of grain growing. Movement of low rainfall zone (e.g 300m rainfall isohyet) much further south and west.
Grazing	Risk to water supplies, heat stress in livestock, declines in pasture production, loss of clover with false breaks. Decreased groundcover.	Temperature and low rainfall both factors in very low productivity, high risk of soil erosion from livestock. Heat stress very high risk.
Viticulture and other horticulture	Temperature not a risk to 2030, and may be a benefit in some areas. Some changes in distribution of plantings likely. Water supplies at risk due to declining rainfall. Increased water use efficiency with well- managed catchments will be important. Changes in pests and diseases and smoke damage from increased fire are potential risks. Increased water catchment for farm dams and irrigation are a potential NRM risk.	Temperature becomes a risk. Dams may be unable to catch sufficient water even with well-managed catchments.
Forestry	Plantations have already contracted from marginal rainfall zones. Reduction in rainfall and an increase in dry seasons is a risk to growth rates of plantations. Length of time to harvest makes it difficult to be flexible to sudden shifts in climate. CO_2 may increase production in some parts of the region in the short term. Forestry has NRM benefits and risks, reducing salinity and inundation but also reducing stream-flow.	Higher temperatures will over-ride benefits of higher CO_2.
Intensive animal industries	Risks to water supply and heat stress.	Heat stress very high risk

Table 4: Potential impacts by main land use in the South Coast Region. *Fry (2015)*

NRM Issue	Interaction With Climate Change To 2030
Sub-surface acidity	Sub-soil acidity reduces water use efficiency, which will become increasingly important in dry seasons.
Water repellence	Management will become more important with an increase in dry seasons. Measures, such as stubble and other biomass retention, which increase soil carbon and reduce erosion risk, also increase water repellence.
Phosphorus export	There is an increased risk of losing phosphate from farms with intense rainfall events but this will depend on soil type and slope. With good stubble management, cropping has the potential to reduce P export compared to grazing
Salinity	Risks are different in different hydrozones (DAFWA 2013). The impact of rainfall on salinity is uncertain in the zone of ancient drainage. Salinity equilibrium may be delayed because of lower rainfall (DAFWA 2013). Some areas, such as the North Stirlings, are approaching equilibrium. With less rainfall, there is potential long-term for less flushing of salinity in high rainfall, high slope areas in some landscapes. There are risks for increased stream salinity in western areas and areas that have not reached equilibrium.
Wind erosion	There is potential for an increase in dry seasons, less groundcover and more wind erosion.
Waterlogging	There is likely to be a decrease in some soils with lower rainfall.
Water erosion	Increased risk, depending on slope, with intense rainfall events, particularly in late summer and autumn. There may be a decreased risk in high rainfall areas as rainfall declines and with reduced rainfall events at break of season (DAFWA, 2013). Rainfall events after dry seasons will increase the risk. Water erosion is a risk on sodic duplex soils of the South Coast (DAFWA 2013)
Structural decline and sub-surface compaction	Was labelled as low risk in the main body of the Southern Prospects but is an increasing problem in shallow soils and red soils due to surface sealing and hardpan development as a result of increased cropping (DAFWA 2013). Wet soils are more susceptible.

Table 5: NRM risks and climate change, *Fry (2015)*.

4.3 Managing the Impacts - Achievements

There have been a number of activities related to managing climate change in the South Coast Region by South Coast NRM, sub-regional groups, DAFWA, grower groups and individual farmers. These include:

- South Coast NRM funded a report *South Coast NRM Climate Change Whole of Landscape Analysis and Options for the South Coast Region, 2009, Coffey et al. (2009)*
- North-Stirlings- Pallinup Natural Resources, Gillamii Centre, developed Farming in a Variable Climate, 2011 on their website.
- A Changing Climates Agribusiness Forum was held in the Southern Agricultural Region in 2009 with 30 agribusiness attendees.
- DAFWA conducted a stakeholder consultation in Katanning, Ravensthorpe and Albany in March 2006 as part of Phase 1 of the Western Australian Greenhouse Strategy. Community input was on their experiences and adaptations to past climate change, and thoughts about the impacts of climate change in the future (*See Morgan et al. 2008).*
- DAFWA has an AcCLIMATise project that aims to build climate risk management capacity of the agricultural industry through the development and delivery of an integrated information package, tools and training *(DAFWA 2010).*
- The DAFWA land resource report card is important info for management of soils in a changing climate.
- DAFWA has established 24 weather stations in the South Coast region.
- There have been several other DAFWA workshops and projects related to climate change for different enterprises. For example, Climate change and Viticulture.
- Other DAFWA recent climate change activities relevant to the South Coast Region include the Royalties for Regions, stormwater re-use project, carbon farming fact sheets and projects on reducing livestock emissions.

4.4 Adaptive Capacity

Capacity to adapt to climate change and variability has economic, social, technological and biophysical components.

It depends on a range of individual farmer and farm business factors *(Table 6).* There is considerable academic literature on adaptive capacity in agriculture reviewed in Rickards (2013). Successful farming in the South Coast region depends on skilful risk management. Farmers in the region are already skilled in adapting to variable seasons, but there is strong evidence that climate variability is increasing and this will require even greater flexibility and strategies for resilience.

Socio Economic	Attitude to risk
	Level of education
	Age
	Debt to equity and income ratio and attitude to debt
	Succession plans
	Off-farm income or assets
	Farmer networks
	Attitude to climate change science and information
Biophysical	Rainfall zone
	Soil types
	Amount the climate has changed in recent decades
	Size of farm
	Distribution of land holdings

Table 6: Some factors affecting adaptive capacity of farmers.

The range of agro-climatic zones in the South Coast Region also means farmers can learn from other farmers in the Region in lower rainfall areas. Grower groups are providing links to research and development and local farm trials for adaptation to climate change.

Strategies such as multiple holdings in different climate zones; not cropping in dry seasons, minimum inputs in dry seasons; partial cropping to soil type, identifying soil zones and managing them to their constraints are being used by many farmers.

There has been a high level of adoption of management practices, such as minimum till and stubble retention, which increase water use efficiency and reduce erosion. An increase in controlled traffic farming is decreasing compaction and improving rainfall penetration and also reduces greenhouse emissions.

There has been an increase in perennial pastures in the region and a concurrent increase in knowledge of agronomy and grazing management. A few farmers are using pasture data from satellites to adjust stocking rates and improve decision making in a variable climate. This has not had high levels of adoption but may become more necessary in the future.

Level of debt can drive adaptive capacity. For example farm businesses with low levels of equity can become locked in to taking a risk with cropping even in poor seasons *(Anderton pers. com.)*.

Banks can also limit farmers' options (farmer interviewee). Reducing debt in good seasons and using income equalization schemes can make farm businesses more resilient when there is an increasingly variable climate.

The evidence is strong that providing there are no climate shocks, and the change in climate follows the projections to 2030, most South Coast farmers have the capacity to adapt.

If there is no mitigation and greenhouse gases continue to rise in the near future, adaptation beyond 2030 will be a much greater challenge. In the long term, more extreme changes in climate past mid-century, may require transformation in some farming systems in the region.

Climate change mitigation means actions to reduce greenhouse gas emissions and enhance greenhouse gas sinks; for example, implementing energy efficiency measures such as using less fuel, reducing emissions from crops or animals or capturing carbon through planting trees.

Storing carbon in soil is more contentious because there is uncertainty as to the potential of soils to store carbon and monitoring of soil carbon would be difficult to implement *(Sanderman et al. 2010; DAFWA 2013)*.

Boosting biomass production and reducing erosion are ways to increase soil organic carbon *(DAFWA 2013)* and recent research by UWA supported by South Coast NRM has shown carbon can be stored in soil by cropping into kikuyu.

The economic benefits of biochar are still not proven and there are no economical supplies (GRDC 2013).

4.5 Gaps

Climate information: more specific climate projections, increasing climate literacy and improvements in seasonal predictions, micro-climate effects.

Farming systems: working with grower groups for practical adaptations, research and development specific to regional and sub-regional climate scenarios, best management practices for particular soil-landscape types in response to climate variability.

Carbon farming: better information on the carbon economy, need for quantification of biosequestration level and biomass production of agroforestry, species for biodiversity plantings and those suited to South Coast soils, growth rates of trees for carbon farming in South Coast soils and rainfall, better information on costs and benefits of integration of trees into south coast agricultural systems, information on biofuels and bio-energy feedstocks.

Socio-economic: factors limiting adaptive capacity, vulnerability assessments at enterprise and local scale.

Water supply: information to assist better water planning, water storage and water efficiency.

Modelling: more detailed crop and pasture modelling based on South Coast soil types and climate scenarios

Monitoring: climate change over time at a wider range of locations, changes in pests and diseases, soil and hydrology.

4.6 Measures & Indicators

The land resource condition is the most important long-term indicator for South Coast NRM as in DAFWA Report Card on Natural Resources (DAFWA 2013) and the South Coast NRM Report Card.

Knowledge and understanding of climate change in the region is an indirect measure but climate adaptation skills such as productivity, management of dry seasons and changes in enterprises, varieties or farming systems could be useful direct measures of adaptation. Level of broad-scale mitigation can also be measured, such as hectares of carbon plantings (this indicator is currently highly dependent on government policy).

4.7 Trade-offs

Increasing water capture and storage will impact on the wider catchment area. Increasing streamflow by reducing tree plantations in the high rainfall zone will increase salinity and although an increase in forestry will increase biosequestration of carbon it could reduce streamflow in some landscapes. Some low yielding land may be used for carbon farming. This may represent an economic trade-off in some years where high grain prices and appropriate rainfall might have led to higher than normal yields. Some strategies may have benefits for some NRM problems but be a disadvantage for others. This will require consideration of the relative cost benefit for a particular soil type and farming system.

For example, an increase in livestock in farming systems could increase perennial fodder shrubs or pastures and thereby reduce water tables and salinity in some landscapes but increase greenhouse gas emissions.

The use of stubble for biomass energy production could have benefits such as additional income for growers and improved disease management through its removal from paddocks. But this must be weighed against the costs of removing stubble such as loss of organic carbon from the system, increased risk of wind erosion and nutrient depletion *(DAFWA 2010)*.

In forestry there is likely to be a trade-off between productivity and using local species to increase biodiversity. In some areas there may be a trade-off with land use change from farming to conservation plantings with a benefit for biodiversity but loss of farming community. There is a trade-off between risk (such as new enterprises and farming systems) and return in both NRM and economic benefits.

5 BIODIVERSITY

5.1 Principles

- Identify key biodiversity assets.
- Minimise incremental loss of native vegetation with goals of no net loss.
- Maintain and/or restore healthy resilient ecosystems by reducing threatening processes.
- Plan and manage natural ecosystems, communities, habitats and landforms at landscape scale.
- Facilitate delivery of strategic information to support actions.

5.2 Values & Threats

The South Coast is part of the South West biodiversity hot spot which means it has high biodiversity but also a high level of threat. It is difficult to determine the impacts of climate change on threatened species and communities because of the uncertainties in climate change projections, the lack of knowledge of capacity of species to adapt and how species will interact in their responses.

Interactions between climate change and other threatening processes will exacerbate the effects *(Table 7)* and will require different approaches to those used in the past *(Gilfillen 2015)*. Using a threat matrix, *Gilfillan et al. (2009)* categorised 80 per cent of threatened fauna and 95 per cent of threatened flora as extremely or highly vulnerable to climate change. There have been large changes in the climate in the past but there are several factors which make South Coast biodiversity vulnerable to rapid climate change:

- Fragmentation of habitat.
- The relationship between climate and distribution of species and communities.
- Isolation of plant populations with very small distributions to particular rock or soil types .
- Refugial/relictural species which may have limited capacity to adapt.
- A number of other threatening processes which will interact with the changing climate.

PRIMARY THREATENING PROCESS	IMPACT OF CLIMATE CHANGE
Fire regimes	Increased frequency, intensity and length of fire season
Phytophthora cinnomomi and other pathogens	Changes in distribution, potential for increased spread, increased vulnerability
Predation	Increased risk due to rapid dispersal
Altered hydrology	Reduced water availability for aquatic species, variable effects on salinity and waterlogging depending on rainfall and landscape.
Fragmentation	Reduction of species dispersal ability to climatically suitable areas
Small population size	Decreased genetic variability of small populations
Weeds	Increased risk of invasive species

Table 7: Impact of climate change on primary threatening processes *(adapted from Gilfillan et al. 2009)*.

CHARACTERISTICS OF SPECIES MOST AT RISK	EXAMPLES
Montane.	Stirling Range mountain tops, flora and relictual invertebrates.
Climate refugial and relictual.	Microclimates such as cool wet areas, granite outcrops, south west facing coastal hills.
Geographically localised species (known as short range endemics).	Many invertebrates e.g millipedes in Stirling Range, Cape Arid, Walpole and Porongurup.
Migratory species.	Shorebirds
Species in remnants.	Areas with highly fragmented habitat, eg. southern Wheatbelt.
Species in small populations.	Threatened species: naturally fragmented populations of plants.
Poor dispersal ability.	Mainly affecting fragmented populations, but also hindrance in moving to track climate change in unfragmented habitat (plants).
Low reproductive capability.	Noisy scrub bird, western ringtail possum
Whether species can use habitat preferences.	Burrowing to reduce impact of drying and high temperatures.
Those with susceptibility to pathogens.	Native vegetation susceptible to fungal pathogens such as *Phytopththora cinnamomi* or *Quambalaria coyrecup.*
Dependence on long periods without fire.	Noisy scrub bird in Two Peoples Bay Nature Reserve, obligate seeding plants with long juvenile period.
Dependence on other species in the ecosystem.	Plants and pollinators. Dependence on vertebrate pollinators or narrow range of insects.
Dependence on fire for regeneration.	Opportunities for regeneration are likely to be limited by the fire interval, obligate seeding plants with long juvenile period.
Low temp range threshold for seed germination	Montane plant species.
Species in freshwater ecosystems	Changes to stream flow, loss of wetlands, particularly in the western part of the region. Increasing salinity of estuaries due to sea level rise e.g freshwater fish such as trout minnow.
Highly habitat specific	Plants restricted to particular rock or soil type, animals restricted to certain vegetation types.
Susceptibility to seasonal variability in rainfall	Requirement for winter rain, seed germination.
Plants with low variability in germination strategies	Small range of temperature tolerance or specific rainfall requirements.

Table 8: Characteristics of species most at risk from climate change *(adapted from Gilfillen et al. 2009)*.

Some species have evolved and survived during periods of major climate change; others are relictual (have survived in localised areas) in the wetter parts of the South Coast region and may have limited capacity to adapt to drier conditions. Granite outcrops may also be important refugia.

Many plant and invertebrate taxa in the region have very small distributions (known as short range endemics). Thus some habitats and their taxa are likely to be particularly vulnerable to a hotter, drier climate.

5.3 Managing the Impacts - Achievements

There has been some recent work determining the biological attributes of species, which give more specific information on potential impacts of changes in climate and some work on managing climate vulnerable species.

Cochrane and Daws (2008) conducted plant germination and recruitment experiments for ten plant species from the Stirling Range, which showed recruitment in five species could be vulnerable to higher temperatures. There has been some limited modelling of plant distributions based on germination temperature tolerance and emissions scenarios. There is some current research on identifying climate refugia in granite outcrops.

Fine scale microclimatic, radiation and microtopographic data from the Ravensthorpe Ranges is being collected. *Moir et al. (2009)* identified areas of high species richness and endemism for millipedes as Stirling Range (east), Cape Le Grand, Cape Arid, the Walpole region and Porongurup.

There has been some research on the thermo-tolerance of key freshwater fauna from SW of WA *(Stewart et al., 2013)*. Although there has also been some species distribution modelling for SW of WA taxa and this may provide a useful staring point, species responses to climate change will involve much more complex interactions than the models have captured.

Recovery plans are being developed and these will attempt to identify species responses and capacity for adaptation. They will also incorporate ways to manage threats and increase resilience of species and communities to a range of possible futures.

There has been significant conservation, re-vegetation and restoration through property purchases and other aspects of the Gondwana Link strategy. South Coast NRM has funded re-vegetation on private land through projects such as Restoring Gondwana. Increasing connectivity and habitat has been identified as an important strategy. Carbon farming may provide more opportunities for revegetation and increasing connectivity of fragmented habitat.

There has been an improvement in knowledge and baseline information through projects such as systematic vegetation mapping of the Albany, DPaW's research on feral predators, dieback mapping and a report on fire responses of South Coast species The approach to reducing the impacts of climate change on South Coast species, communities and ecosystems is to increase the resilience of the systems by:

- Strategic habitat management and restoration, including increasing connectivity, habitat area and habitat quality.
- Identifying and managing species and ecological communities vulnerable to climate change.
- Managing other key threatening processes.
- Identifying and managing climate refugia.
- Using an adaptive management approach.
- Using an approach which provides a decision. framework or structure (e.g conservation action planning) enabling prioritisation of actions.

5.4 Adaptive Capacity

The South Coast region has research capacity in biodiversity through DPaW and the UWA Centre for Excellence in Natural Resource Management.

There are several national parks and reserves in the conservation estate, but there is also important biodiversity on private land, particularly agricultural.

Adaptive capacity has been improved by integration of climate change adaptation strategies into recovery plans for threatened species and communities. *DPaW's South Coast Threatened Species and Ecological Communities Strategic Management Plan*, detailed some specific objectives and actions.

Increasing community awareness and management of other threatening processes, increasing resilience of ecosystems through better management and protection of remnants and increasing habitat connectivity on private land is going to be an important on-going role for South Coast NRM.

DPaW has a Threatened Flora Seed Centre which stores and conserves seeds off-site. As part of this they are also researching temperature tolerances.

5.5 Gaps

There is a need for a network of climate stations at sites where species are at high risk from climate change. For example, stations in montane communities in the Stirling Range.

There needs to be more information on threatened species biology and ecology, particularly climate tolerances and how other threatening processes will interact with climate change.

It is important to continue assessment and review of vulnerability, using a threat matrix. There is a need for more information on how to build resilience at different scales.

There has been some research on climatic tolerances but much more is needed. It would be useful to identify indicator species for changes in climate; for example, the Australasian bittern or the noisy scrub-bird. Indicator species would provide a way of monitoring changes in ecosystems that have occurred in response to climate.

5.6 Measures & Indicators

- Use of indicator species for vulnerable communities or ecosystems.
- Proportion of native vegetation.
- Extent of spread of pathogens.

5.7 Trade-offs

The main trade-offs will be whether to focus on threatened species versus large-scale re-vegetation, on research versus on-ground actions.

Other trade-offs relate to maintaining agricultural production and any adverse effects on biodiversity. There is also a trade-off in carbon farming between plantations and biodiversity plantings.

6 Water

6.1 Principles

- Sustainable and efficient use of water resources for community and environment.
- Maintenance or improvement of the condition of rivers, estuaries and wetlands.

6.2 Values & Threats

Water demand is increasing with population growth, particularly in the west of the region and supply is reducing, and likely to reduce further with the drying climate.

Many Albany residents are unaware of how few water resources are currently available for human consumption. Denmark has experienced water shortages in the last few years. Many of the creeks, rivers and wetlands in the South Coast Region have been highly modified since European settlement. Clearance of native vegetation has caused changes in hydrology and sedimentation.

Nevertheless there are some near pristine river systems and valuable freshwater wetlands. The threats from climate change vary with the location and condition of waterways. For example, some wetland values are reduced by inundation due to clearance of native vegetation and a drying climate may improve their condition in the short term. Others will be threatened by reduced rainfall or increased intensity of rainfall events.

Threats from climate change need to be managed with other threats such as increased population, land use change, increased water abstraction, sedimentation and salinisation.

Reductions in streamflow are likely to be greatest in the west of the South Coast Region with a rule of thumb of a reduction in streamflow of three times the percentage decrease in rainfall. This part of the region also has valuable freshwater ecosystems.

Commercial plantations and carbon plantings affect hydrology and this can have both positive and negative impacts. There will be changes in estuaries due to reduced rainfall in catchments and in sea levels. There is likely to be less opening of seasonally closed estuaries such as the Wilson Inlet.

Potable water resources for coastal towns will be under threat due to reduced rainfall and stream-flow and potential for seawater inundation. There will be adverse impacts on agricultural and other industries dependent on rain-fed dams for water supplies.

Wetland and river systems may have reduced connectivity, salt -water intrusion, increased temperature and increased evaporation. This is likely to impact most on species with restricted ranges, salinity or thermal tolerances.

6.3 Managing the Impacts - Achievements

The Water Corporation is aiming to reduce per capital water consumption through water restrictions and encouragement of rainwater tanks.

There have also been some measures for water efficiency and water re-use in inland towns, for example the use of stormwater collection on town ovals. Both the Department of Water and the Water Corporation are decreasing dependence on rain-fed systems in water resource planning.

There is also research on the potential for improvement in water capture and efficiency for high value agriculture such as viticulture. Revegetation has led to a reduction in the salinity in the Denmark River.

There has been a considerable amount of riparian and estuary foreshore rehabilitation. The National Climate Change Adaptation Research Facility has conducted research on vulnerable aquatic systems and species.

6.4 Adaptive Capacity

Waterways on the South Coast have been modified and many are highly degraded. There are few water resources suitable for potable consumption and these are at risk with lower rainfall and increased population.

Some of the actions increasing adaptive capacity include:

- The Department of Water and Water Corporation are seeking climate resilient water resources and the Water Corporation is encouraging water efficiency and some re-use.

- There is capacity for regional scale research in relation to rivers, estuaries and wetlands. For example, there has been research on adaptation at the UWA Centre for Excellence in Natural Resource Management through the National Climate Change Adaptation Research Facility.

- There has been significant restoration in some priority catchments such as Lake Warden and Denmark River. There are skills in the community for catchment restoration work to improve hydrological balance and reduce sedimentation but there are also economic constraints.

6.5 Gaps

- Identifying key freshwater refuges.
- More assessment of ecological values of waterways.
- Identifying ecological impacts of sea level rise.
- Maximising the hydrological benefits of carbon planting.
- Monitoring of priority assets.
- Drought response plans and provision of emergency water sources.
- Climate change impacts included in rehabilitation work.
- Improved modeling on the impacts of climate change on coastal groundwater resources.

6.6 Measures & Indicators

Priorities for monitoring are freshwater systems in the west of the region, particularly wetlands and rivers dependent on local rainfall (rather than larger recharge areas and aquifers).

This monitoring would need to tie-in with biodiversity indicators of species health and diversity. Other monitoring would be required at a specific asset or management level.

For example, sea levels in Albany and Esperance and groundwater and streamflow in areas of extensive vegetation plantings, to assess the impacts on the hydrological processes.

6.7 Trade-offs

As water resources decline there is going to be a need to balance water resources for human use and environmental needs. Maintaining agricultural production may increase degradation of some waterways.

7 Coastal & Marine

7.1 Principles

- Increase understanding through research and information sharing of coastal and marine environments.
- Maintain the functional integrity and health of coastal and marine systems.
- Reduce conflicts between users through engagement, collaboration and consultation
- Use adaptive management and best practice methods for on-ground works.

7.2 Values & Threats

The impact of climate change on the coastal and marine environment will depend on how much and how quickly sea levels and temperatures rise.

The South Coast region includes approximately 1000km of diverse coastline. About 70 per cent of the terrestrial coast is in the conservation estate, with the largely intact coastal vegetation an important corridor.

The coastal reserves Two Peoples Bay Nature Reserve, Cape Arid and Fitzgerald River national parks are refuges for threatened fauna species.

The coastal wetland systems of Lake Warden and Lake Gore are internationally important (Ramsar) sites for migratory and resident birds.

There are several important estuaries with both biodiversity and recreational values. Offshore islands are also important habitat and breeding sites. Some are also used to translocate threatened species.

Recreational fishing is mainly concentrated around population and holiday centres. Commercial fisheries are relatively small and include abalone, purse seine, demersal gillnet and beach seine.

There is also some commercial fishing in estuaries. Aquaculture includes mussels and oysters from Oyster harbour and greenlip abalone at Bremer Bay

There are many high value areas including Recherche Archipelago, The Walpole and Nornalup Inlets Marine Park and the Bremer Canyon. The risks to South Coast marine and coastal values from climate change are expected to be low in the medium term but future risks include:

- Increased saline inundation of estuaries and coastal wetlands, also under stress from reduced rainfall.
- Changes in the Leeuwin current (currently projected to be a weakening), but these are likely to be overidden by natural variation in the short to medium term.
- Acidification from carbon dioxide.
- Sea level rise.
- Storm surges, although the South Coast at less risk than other coasts.
- Changes in species distributions such as southward movement of species with the warming of oceans.
- Loss of coastal habitat.

The projected sea level rise for 2090 for Albany under the high emissions scenario is 0.64 metres (0.43-0.87) and for Esperance 0.62 (0.42-0.85). Sea level allowance is the minimum height structures should be raised so that they are the same as current sea level conditions.

The CMIP 5 projections for sea level rise *(Table 9)* are rated as low confidence but by allowing for storm tides or extreme events a sea level allowance can be calculated to assist in planning *(Hunter et al., 2012)*.

Scenario	2030 Albany	2030 Esperance	2050 Albany	2070 Albany	2090 Albany	2090 Esperance
RCP2.6	0.13	0.13	0.24	0.36	0.50	0.47
RCP4.5	0.13	0.13	0.25	0.40	0.59	0.56
RCP8.5	0.14	0.13	0.28	0.50	0.81	0.76

Table 9: The allowance for structures for sea level rise. The (minimum height in metres) in Albany that structures would need to be raised for the future period so they are at the same as for 1986-2005 average sea level conditions for the four scenarios and four time periods based on projections *(Source CSIRO, BoM 2015, p156; Hope et al. 2015)*.

7.3 Managing the Impact - Achievements

There are many projects involving community such as:

- Fisheries Redmap allowing community to log sighting of marine species.
- Recherche advisory group and UWA research program with community marine surveys.
- Monitoring programs for species distributions and fish movements, school, university and community programs.
- Partnerships with OceanWatch, SeaNet, the Western Australian Fishing Industry Council and Department of Fisheries.

There have also been planning documents including *Southern Shores* for the whole South Coast region and local level coastal planning and management documents from Local Government Authorities such as Foreshore Management Plans and Coastal Reserves Management Plans.

7.4 Adaptive Capacity

Most of the coast is managed by local or state government but by working in partnership there are opportunities to increase adaptive capacity by working with the community.

The Australian Government review *Managing Our Coastal Zone in a Changing Climate* set out roles for state and commonwealth governments and ways to engage community.

It recommended the need to "*build understanding and awareness of coastal management issues to encourage the continued membership and support of volunteer networks in the coastal zone.*"

Two main strategies for increasing adaptive capacity are increasing knowledge and good planning. Increasing knowledge and education about the resource is occurring through:

- South Coast NRM marine education officer.
- WA Museum Albany young naturalists programs.
- Monitoring programs through universities, Department of Fisheries and community partnerships.

There are a number of coastal planning documents and tools to assist in adaptation. For example:

- South Coast Management Group and Coffey Environments produced *Southern Shores*. a coastal zone planning and management strategy.
- The Department of Planning intends to work with local government to initiate coastal vulnerability studies.
- The WA Local Government Association has prepared a toolbox to assist in the identification of risks and preparation of priorities for climate change adaptation planning.

Adaptation options include:

- Foreshore setbacks to avoid storm surge damage to infrastructure and housing.
- Relocation of recreation some reserves/caravan parks.
- Coastal engineering.
- Allocating appropriate environmental flows to maintain estuaries.
- Land use change.

Integrated coastal planning and vulnerability assessments of high value assets using a tool such as the WA Planning Commission recommended Coastal Hazard Risk Management and Adaptation Plan are important in increasing adaptive capacity.

7.5 Gaps

There is a lack of baseline data, especially digital elevation models. There is also a need for research on changes in South Coast marine biodiversity.

There is a need for vulnerability assessments of settlements, natural and cultural assets and an increase in community education and awareness about the risks to the coastal and marine environment.

Decisions will have to be made in relation to some coastal infrastructure

7.6 Measures & Indicators

The main measures and indicators will be changes to marine and coastal habitat and conditions related to climate change such as:

- Changes in marine and estuarine species.
- Changes in shoreline position.
- Changes in salinity in estuaries.

7.7 Trade-offs

The South Coast coastal and marine area is an environmentally, economically, socially and culturally important asset.

Existing stressors will exacerbate pressures on the coastal and marine environment from changes in climate and sea level.

Not all coastal areas may be able to be protected from impacts such as sea level rise and some areas may need to be left to find a new equilibrium without intervention.

Climate change and its associated threats and impacts are difficult to predict with certainty due to the many complex interactions between multiple elements.

Adaptation trade-offs related to possible changes in the coastal and marine zone need to be considered by the community (including loss or modification of foreshore reserves, private land and other NRM assets). Some opportunities may arise with the southward migration of marine species that are valued commercial resources.

8 CULTURAL HERITAGE

8.1 Principles

- Recognition of cultural knowledge.
- Respectful involvement and use of information.
- Building capacity for culturally appropriate processes.
- Build capacity for management of specific cultural site and the natural environment as a whole to address threats, including climate change.
- Identification of areas of key interest.
- Communication using agreed protocols with openness and transparency.
- Building resilience of Aboriginal people and communities across the region to adapt to climate change.

8.2 What We Know - Values & Threats

Cultural heritage encompasses a wide range of values including values of particular places and associated objects, traditions and spiritual connections. It includes both Aboriginal and non-Indigenous values.

The regional NRM strategy for the South Coast recognises the significance of natural land, water and seascapes for both Aboriginal and non-Indigenous cultural values, practices and well-being (South Coast NRM 2011).

There is an overlap between natural and cultural heritage and this is increasingly being recognised in their management *(Guilfoyle et al. 2013)*. It is clear to those of us involved in heritage conservation, that climate change will affect the full range of cultural heritage places and values including:

- Individual structures, building, monuments.
- Memorials, places of cultural meaning, name.
- Natural resources of cultural importance.
- Areas, landscapes, ecosystems, groups.
- Archaeological sites, material traces, signs. *McIntyre-Tamwoy (2008).*

The WA Department of Aboriginal Affairs has an Aboriginal heritage inquiry system with registered Aboriginal sites and their location. The South Coast region has a wide range of cultural evidence.

These include the Oyster Harbour, Kalgan River and Wilson Inlet fish traps and weirs as well as burial sites, lizard traps, grinding stones/grooves and many historical and camping sites. There are a number of sites on the Quaranup Peninsular including gnamma holes (water holes in rock). Some of these sites, such as fish traps, are particularly vulnerable to rising sea-levels.

Aboriginal cultural values are not only registered sites but are associated with connection to country and cultural landscapes. Quite often there is a discord between archaeological methods of site recording and analysis and the Traditional Owner concept of integrated cultural landscapes *(Guilfoyle 2013 np)*.

Rivers, estuaries and inlets were particularly important cultural sites in summer for ceremonies and gatherings, and although many have been highly modified since settlement, climate change is likely to impact further. Many of these rivers and estuaries remain important fishing places for Aboriginal people.

Possible impacts of climate change on cultural heritage are summarised in *Table 10*.

CHANGING CLIMATE IMPACTS	NON-INDIGENOUS CULTURAL HERITAGE	INDIGENOUS CULTURAL HERITAGE
• Sea level rise: coastal inundation, saltwater intrusion into freshwater systems including groundwater.	• Historic buildings and monuments in low-lying areas at risk of flooding. • Coastal environment that detracts from cultural aesthetic and use values.	• Estuaries, rivers, wetlands that link to cultural values. • Aboriginal fish traps in estuaries and foreshore middens. • Inundation of sites on the coast and on estuary and river foreshores.
• Increased temperatures: Evaporation of water bodies. • Temperature of waterways and water bodies.	• Water quality in rivers, wetlands and estuaries that detract from cultural aesthetic and use values	• Water quality in rivers, wetlands and estuaries that detract from cultural aesthetic and use values.
• Increased bushfires from: • Temperature increases. • Higher evapotranspiration. • Less rainfall and at different times of the year, less soil moisture.	• Damage to historic buildings and monuments. • Impacts environmental values that link to cultural values.	• Damage to scar trees, man made structures, burial sites, middens. • Impacts environmental values linked to cultural values. • Availability and continuity of bush tucker and medicinal flora and fauna.
• Increased drought. • Less rainfall • Rainfall at different times of year, variable across years. • Reduced run-off into rivers, storage dams and groundwater.	• Impacts environmental values that link to cultural values.	• Impacts on environmental values that link to cultural values. • Availability and continuity of bush tucker and medicinal flora and fauna.

Table 10: Possible impacts on Indigenous and non-Indigenous cultural heritage, adapted from *Duxbury et al. 2014.*

The Australian section of the International Council on Monuments and sites Climate Change and Cultural Heritage Working Group (Australian ICOMOS, 2015) recommended actions to:

- Identify the cultural heritage places and landscapes at greatest risk.
- Monitor and collect data about changes to cultural heritage places and landscapes due to climate change and associated effects.
- Establish standards of conservation planning and practice in the face of climate change
- Improve risk preparedness and disaster planning, including through the continued work of Australia National Committee for the Blue Shield.
- Underscore the indivisible relationships between tangible and intangible cultural heritage and between communities and their heritage places in planning processes.
- Engage communities in these processes to be prepared and able to respond to the impacts of climate change on our cultural heritage.

8.3 Managing the Impacts - Achievements

It is important Aboriginal people have a strong involvement in managing the impacts of climate change, so South Coast NRM has established an Aboriginal Reference Group.

Extensive cultural mapping to assess site vulnerability is the first step in managing climate change impacts. This has occurred at the Quaranup Peninsular near Albany with Traditional Owners and Elders through a partnership between the Albany Heritage Reference Group Aboriginal Corporation, South Coast NRM and the City of Albany. The Gabbie Kylie Foundation has also carried out cultural mapping, restoration and education projects on the eastern South Coast.

- Restoring Connections supported a community heritage management project at Lake Pleasant View, Manypeaks. This used a community led landscape based approach *(Guillfoyle et al. 2013)*.
- South Coast NRM Aboriginal community projects in Esperance have included restoration and protection work at Bandy Creek, Cape Arid, Stokes National Park, Mt Ridley and other locations. A survey at Culham Inlet and mapping at Stockyard Creek have also been delivered.
- Gondwana Link has involved Aboriginal people in management of properties and cultural mapping.
- Twenty-four priority heritage sites threatened by degrading processes have been identified.
- Aboriginal training and on-ground natural resource management work has been carried out.
- The Southern Agricultural Indigenous Landholder Service assists landholders in agriculture and NRM, including adapting to climate change.
- In 2009 management of the Oyster Harbour fish traps was handed over to a group representing the site's Traditional Owners.

Figures 13, 14 and 15) show Aboriginal cultural locations for the west, central and eastern parts of the region. Those coloured pink indicate the importance of landscapes to Aboriginal cultural values and are likewise key cultural sites for non-Indigenous communities. Red dots indicate South Coast NRM Aboriginal projects already delivered and possible future projects in blue dots for each sub-region.

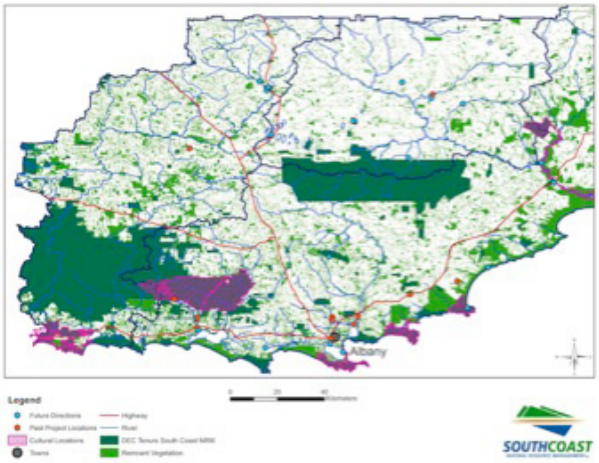


Figure 13: Natural cultural assets, cultural locations, past and possible future Aboriginal cultural heritage projects managed by South Coast NRM – western part of the South Coast region, *Duxbury et al. 2014.*

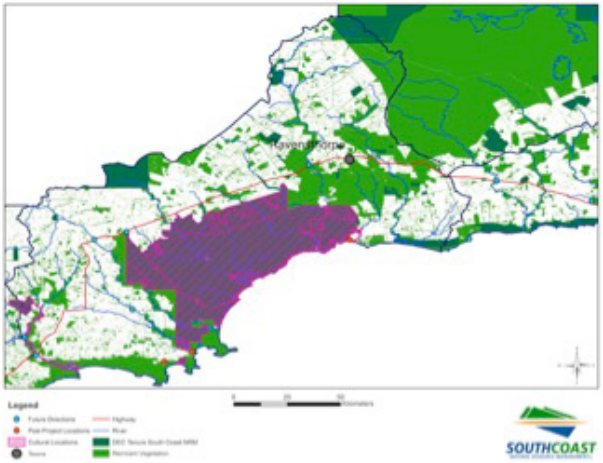


Figure 14: Natural cultural assets, cultural locations, past and possible future Aboriginal cultural heritage projects managed by South Coast NRM – central part of the South Coast region, *Duxbury et al. 2014*

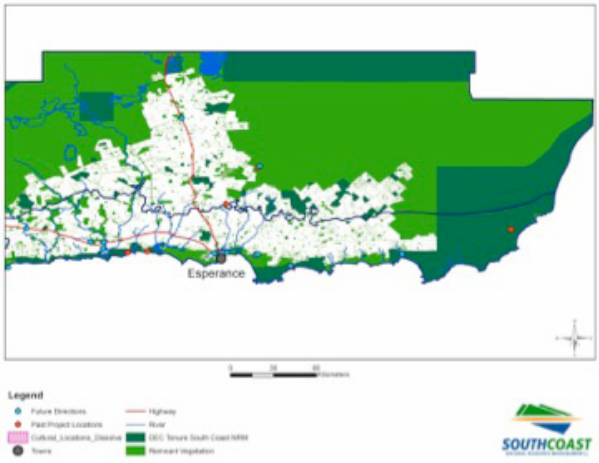


Figure 15: Natural cultural assets, cultural locations, past and possible future Aboriginal cultural heritage projects managed by South Coast NRM – eastern part of the South Coast region, *Duxbury et al. 2014.*

8.4 Adaptive Capacity

There are hundreds of registered sites but many culturally significant sites have not yet been registered. Increasing involvement of Aboriginal people is increasing capacity to document and protect important sites and restoring connection to country.

Some sites are only known to custodians and much knowledge is also being lost with the passing of Traditional Owners and Elders. The South West Land and Sea Council have proposed a Noongar Standard Heritage Agreement as a minimum standard for heritage survey processes and procedures in the south west of Western Australia.

There is also a Noongar Heritage Partnership Agreement, which provides a way to work in partnerships to identify, record, protect and preserve Aboriginal sites. It also aims to build the capacity of the Noongar community in heritage management.

It is important to draw on Aboriginal knowledge, which is part of their cultural heritage, in managing the environment for resilience to climate change.

Adaptive capacity can be increased by increasing opportunities to encourage the involvement of Aboriginal planning for adaptation and mitigation as well as increase the capacity of Aboriginal people to participate in climate discussions. Non-Indigenous cultural heritage although much younger than Aboriginal heritage also needs to be protected. Albany is the oldest settlement in WA and there are many historic settler sites throughout the South Coast.

Some heritage listings give statutory protection but others are local and do give any specific protection. Statutory listings include State Register, Conservation Order, Heritage Agreement, Town Planning Scheme Heritage List and National Heritage List. There is good knowledge of important settler sites through the WA Museum Albany and the Albany History Collection.

An increase in activity in cultural mapping and active partnerships with Aboriginal people is providing an increase in Aboriginal capacity to participate in climate change discussions. Settler sites vulnerable to sea level rise will be identified under coastal vulnerability studies.

Many important landscapes and seascapes are protected in national parks or reserves in the South Coast region.

8.5 Gaps

- Cultural mapping of more landscapes in the South Coast.
- Identifying sites not yet registered.
- Linking management plans to threats from climate change.
- Communication of potential climate responses to Aboriginal people and managers of non-Indigenous cultural sites.
- Vulnerability assessments of both Aboriginal and settler sites.

8.6 Measures & Indicators

- Number of climate vulnerable sites identified.
- Management plans for priority sites developed.

8.7 Trade-offs

There is a potential trade-off in investment in protecting natural versus cultural assets or settler versus Aboriginal cultural assets.

9 Program Logic for Climate Change Planning

The following are the specific climate change goals and outcomes, which were either developed from the *Addendum* planning processes, amended from the original document or restate climate aspirations, goals or outcomes from the main document. There are others listed in the main document, which although not specific to climate change, relate to or integrate with climate change goals and outcomes.

PLEASE NOTE: *Numbers relating to goals and outcomes correspond with those in the main document of Southern Prospects 2011-16.*

9.1 Adaptive Capacity

A number of other adaptive capacity goals and outcomes are listed under each of the themes.

Goal R10. Climate Change: Build adaptive capacity in the region to deal with increasing climate variability.

Outcome R4: Facilitated Change Management. Assist south coast community to identify, plan and implement changes to address climate change and other key challenges on a landscape scale basis by 2015.

9.2 Land

Goal L5. Climate Change Adaptation & Mitigation. Protection of priority land assets at risk from climate change and associated threats through implementation of adaptive management responses by 2020.

Outcome 11. Climate Change Adaptation. Develop and implement adaptive responses to climate change in priority areas, in partnership with industry and land managers by 2015.

Outcome L11(a). Land managers and associated industries have increased their knowledge and understanding of climate risk for the region.

Outcome L11(b). Climate risk and vulnerability analyses completed and reviewed regularly.

Outcome L11(c). There is an increased understanding of the factors, processes and constraints for adaptive capacity to climate change.

Outcome L13. Climate mitigation. Priority areas for climate mitigation identified, so that carbon sequestration, water and biodiversity outcomes can be integrated and adverse impacts avoided.

9.3 Biodiversity

Aspirations: Improved understanding of potential impacts of climate change on biodiversity and appropriate management responses.

Goal B3. Climate Change. Facilitate species, communities and ecosystems' ability to adapt to climate change by adopting a precautionary approach of building resilience at all scales, in conjunction with more targeted management of identified climate change vulnerable species, communities and ecosystems.

Outcome B2(a). Climate Priorities. Identify and prioritise for action, species, communities and ecosystems vulnerable to climate change.

Outcome B4(a). Climate Change. Develop an adaptive management framework in which monitoring programs are designed to inform the management of climate change impacts on species and ecological communities.

Outcome B4(b). Monitoring for Climate Change. Determine climate change monitoring priorities and protocols for communities and ecosystems using appropriate indicator species.

Outcome B5(a). Climate Change Threat. Incorporate potential interactions of climate change with other primary threatening processes in any threat abatement program.

Outcome B6(a). Climate Refugia. Manage existing remnant vegetation, increasing connectivity to allow distributional changes and identifying and managing climatically determined refugia and refuges.

Outcome B13(a). Education. Encourage and prioritise targeted research to inform the management of climate change impacts and to be long-term (10+ years).

Outcome B15(a). Climate Decision Making Framework. Develop a decision making framework to assist with the prioritisation of climate change management options.

9.4 Water

Aspirations: Maintained and/or improved quality and improved sustainable, efficient use of freshwater resources given increasing demand and reduced availability. Use of adaptive management to maintain waterway values in a context of change, including climate variability.

Goal W3. Water Resources (Surface Water and Ground Water Resources). Maintain and/or improve the condition of water resources through sustainable, efficient use and management to provide water for long term environmental requirements in a context of climate variability while meeting the needs of the community and commercial use, by 2030, with quantifiable targets reviewed by 2012 (modify existing.)

Outcome W3. Climate Change Adaptation and Mitigation. Increase knowledge and awareness of potential impacts of climate change and other stressors on water assets for the South Coast region by 2016.

Outcome W14. Climate Resilient Waterways. Undertake works to support the resilience of waterways within the context of climate change.

Outcome W15. Increase community understanding and awareness of climate change on waterway and water resource values, with downsizing of national models and a communications plan developed by 2016.

9.5 Coastal & Marine

Aspirations: Increased understanding and ability to predict potential impacts on coastal and marine habitats due to climate change (including biodiversity, social and economic values).

Established management priorities for coastal and marine environments to mitigate climate change impacts.

Goal C3. Coastal Zone. Identify, prioritise and develop management approaches for impacts associated with climate change in the coastal zone, based on vulnerability and risk assessment by 2024 with quantifiable targets set by 2016.

Goal C4. Marine Ecosystems. Identify, prioritise and develop management approaches for impacts associated with climate change in marine ecosystems, based on risk assessment by 2024 with quantifiable targets set by 2016.

Outcome C1(a). Establish Baseline Data. Establish community and agency based monitoring programs to inform baseline setting and detect changes in coastal and marine ecosystems from current and potential threats by 2012. E.g. shoreline photo monitoring and Red Map.

Outcome C2(b). Increased Knowledge. Increased knowledge of potential climate change impacts on coastal & marine assets for priority areas and assets by 2015.

Outcome C2(c). Evaluation and Feedback. Improved evaluation and feedback through 'State of the Environment' reporting for climate change related issues to allow for adaptive management by 2015.

Outcome C4. Improved Resilience. The resilience of coastal and marine systems is maintained and/or improved by implementing 75 per cent of priority actions relating to climate change from Southern Shores *(Coffey Environments and South Coast Management Group, 2009)* by 2016.

Outcome C5. Climate Change Adaptation. Priority coastal and marine assets at risk from effects of climate change, sea level rise, storm surge and associated threats are identified and appropriate strategies applied by the implementation of adaptive management responses by 2016.

Outcome C11. Increased Information Accessibility and Application. Increase accessibility of information through development of a regional coastal and marine database, with shared, validated, reviewed and up to date information applied to coastal and marine planning and management by 2016.

Outcome C12. Education and Awareness. Develop and implement education and awareness programs to enhance the knowledge and appreciation of risks and adaptive strategies related to coastal and marine climate change threats by 2016.

Outcome C13. Coastal and Marine Planning and Implementation. Apply best available information for climate change impacts to planning and policy frameworks through integrated regional and local planning and implementation initiatives involving key stakeholders by 2016.

Outcome C14. Integration of Regional Response. Develop coordinated climate change adaptation and response plans across the region in cooperation with key stakeholders and other regions by 2016.

9.6 Cultural Heritage

Aspirations: Protect natural heritage places.

Outcome H1 (a). Improved information to assist with managing impacts of climate change

Outcome H5(a). Protection of places of high cultural natural heritage significance. Identify current and potential Aboriginal and non-Indigenous cultural sites at risk of climate change impacts.

10 Flexible & Adaptive Planning for Climate Change

10.1 Flexible Planning with Reference Groups

South Coast NRM has a reference group for each of its natural resource thems. The reference groups each have a range of community and technical expert representatives.

The community members of the groups consult people in their sub-regions or local interest groups, which further increases consultation.

The reference groups therefore have the information to carry out both strategic and investment (project) planning. There are reference groups for the themes of *Land, Biodiversity, Water and Marine and Regional Capacity*. There is an Aboriginal Reference Group which advises on Aboriginal NRM and cultural heritage.

The Regional Capacity Reference Group focuses on socio-economic aspects of climate change adaptation and ways to increase adaptive capacity. It also provides integration across the natural resource themes. In addition the South Coast Management Group (SCMG) provides strategic planning for the management of the coast.

Membership of the SCMG is made up of the chief executive officer, two councillors and two community members from the shires of Esperance, Ravensthorpe, Jerramungup, Denmark and the City of Albany.

The reference groups meet three times a year and review and update the activities in investment plans in relation to the outcomes, goals and aspirations in *Southern Prospects* and in this *Addendum*.

This provides a flexible and adaptive planning process. The investment planning process also identifies the main partners for each activity.

South Coast NRM works closely with other regional NRM groups, catchment groups, grower groups, government agencies, universities and others with expertise in the region to deliver the activities in the investment plans.

At the back of this Addendum is the program logic for climate adaptation developed by the reference groups based on the technical and other information in the background papers.

The program logic goals and outcomes provide the basis for flexible and adaptive investment planning. Reference groups are provided with the most up to date information to assist their decisions.

10.2 Steps in South Coast NRM's Climate Change Adaptation Planning

1. Reference groups and other stakeholders develop Aspirations, Goals and Outcomes using a planning process called Program Logic. They do this based on technical background papers which synthesise available information. This planning process provided the program logic at the back of this *Addendum*.
2. Reference Groups carry out risk analyses and prioritise actions which are reviewed three times a year. All reference groups meet together once a year to ensure integration across themes.
3. Monitoring and feedback

Because climate is a complex system there will be sudden shifts. Monitoring for climate change adaptation will involve identifying these climate shifts and new risks, which mean the need to change actions.

South Coast NRM is using risk management with the most plausible future climates to identify priority actions. It has also developed a *report card* with major indicators of natural resource condition, which will assist in monitoring changes.

Monitoring climate change will involve:

- Accessing the most up to date climate modelling and new climate information.
- Examining differences between local climates broader scale climate models.
- Synthesising information from new automated weather stations throughout the region.
- Feedback from farmers with extensive rainfall records.
- The South Coast region has a range of climate zones ranging from low rainfall, higher temperatures in the north-east of the region to higher rainfall and lower temperatures in the south-west of the region. This enables planners to use climate proxies from within the region to determine likely responses.

10.3 Main Characteristics of South Coast NRM Climate Adaptation Planning

10.4 Recognising Uncertainty

Climate is a complex system and therefore even with the best possible information there is uncertainty about future climate. Uncertainty does not mean doing nothing but instead involves planning for a range of plausible climate futures.

10.5 Risk & Vulnerability Assessments

Assessing risk and identifying vulnerability to a range of plausible future climates is the best way to plan adaptation when there is uncertainty.

10.6 Reducing Vulnerability & Building Resilience

Many of the goals and outcomes identified in this addendum are related to reducing vulnerability of natural resource systems and increasing resilience. For example increasing vegetation connectivity across the region should increase the resilience of species to adapt. Planning also involves identifying the most vulnerable landscapes such as wet refuges, montane vegetation communities, low rainfall farming areas and freshwater resources and ecosystems.

Assessing & Increasing Adaptive Capacity

The Regional Capacity Reference Group will focus on this area but nearly all the reference groups have goals which relate to increasing adaptive capacity. Main initiatives to increase adaptive capacity include:

- Monitoring community actions and attitudes
- Providing the most up-to date climate information.
- Encouraging risk analyses.

10.8 Cross-Scale & Cross-Theme Integration

South Coast NRM recognises the need to integrate across the landscape at local, sub-regional, regional and wider geographical scale.

Although NRM planning is divided into themes, reference groups meet together to ensure integration across themes.

A good example of this is South Coast NRM's report card project, which is developing indicators of natural resource condition.

Integration across NRM regions occurred through the SW flatlands projects and through integrating spatial planning as well as cross-region projects through DAFWA.

10.9 Climate Communication

South Coast NRM recognises effective communication about climate as one of the most important tools in increasing adaptive capacity.

Translating the complexity of the science into everyday language enables people to understand the challenges. Simple clear messages are the key.

A main problem is the use of scientific terms. Words such as 'error bar', 'uncertainty' and 'theory' have different meanings to scientists and non-scientists and can get misunderstood or even exploited in disinformation campaigns *(Somerville and Hassol, 2011)*. Some ways South Coast NRM is improving climate communication:

- Recognising climate change is not uniform across the region. Some areas have already had major changes, other areas have seen less or little change.
- Linking to people's experience.
- Providing information on solutions or actions to adapt that are already ocurring.
- Not engaging in debates over whether or not climate change is occurring but relying on real data and the scientific consensus.
- Communicating solutions and opportunities.

10.10 Identifying Gaps & Information Needs

Identifying gaps was included as a field in the background papers. This assists in investment planning and enables reference groups to prioritise actions.

Gaps and information needs will need to be updated as new information becomes available.

10.11 Using Spatial Tools (GIS) & Modelling

Spatial tools help with planning by increasing knowledge about patterns, relationships and change in the landscape.

Spatial tools combined with modelling are useful in determining likely future climate effects on biodiversity, crop yields, spread of pathogens, fire risk and other changes.

Multi-criteria analysis combined with spatial tools has also assisted South Coast NRM in a participatory process about where carbon plantings are best located for environmental benefits. Geographic Information Systems (GIS) also provide a way to monitor change over time.

In addition maps (providing scale is appropriate) can assist in communicating with people about current changes and likely futures.

10.12 Using Scientific & Local Knowledge

Local knowledge is important in monitoring change. Local Aboriginal knowledge is assisting in planning both biodiversity and cultural heritage protection.

10.13 Partnering & Integrating with Commonwealth, State & Local Government & Other Planning Processes

In its planning South Coast NRM integrates with other planning processes in the region (see section 11).

The background papers captured many of the other climate adaptation planning initiatives. Many reference groups have state and local government representatives.

10.14 Identifying Opportunities as Well as Risks

The changing climate is providing opportunities for parts of the South Coast region. The South Coast is not warming as fast as many other parts of Western Australia. This is providing opportunities for expanding some agricultural industries.

The South Coast region also has a gradient and diversity of climate, which means with better connectivity there is a potential for some level of movement and adaptation of plants and animals.

It also means there are climate proxies within the region to assist some farmers to learn from others in developing new farming systems and that farmers expanding landholdings can purchase land in different climate zones to assist adaptability in different seasons.

11 Strategies, Plans, Policies & Legislation related to Climate Change Adaptation Planning in the South Coast Region

11.1 General Policies, Planning & Regulation

11.1.1 Regional Development Organisations

Each of the Western Australian Development Commissions has provided a *regional investment blueprint* to guide state funding to the state economic development regions.

The South Coast NRM region contains parts of the Great Southern and parts of Goldfields-Esperance development regions. These provide a more integrated planning system, which involves the Department of Planning, the Western Australian Planning Commission, the Department of Regional Development and the Department of Local Government.

The Goldfields-Esperance Development Commission has a *draft blueprint*. In the blueprint, agriculture and coastal assets were identified as very important. These connect to the themes of land and coast and marine in this Addendum. The Goldfields-Esperance Development Commission viewed climate change as a risk and an opportunity.

The Great Southern Development Commission's *regional investment blueprint* has a priority area of water security. This relates directly to the need to adapt to climate change and outcomes under South Coast NRM's water theme.

It also has a priority area as premium food production, which connects both to the land and water themes in this Addendum and to the opportunities for the cooler western parts of the South Coast region.

Regional Development Australia (RDA) also have strategic plans. The aspects of the RDA Goldfields-Esperance plan most closely linked to South Coast NRM are on sustainable rural industries, a healthy and valued natural environment and renewable energy.

The current four key priority areas are:

- Attracting and retaining population.
- Increasing access to affordable, adaptable and secure housing.
- Enhancing industry resilience and innovation.
- Ensuring a healthy and valued environment.

Regional Development Australia Great Southern has an emphasis on creating employment and a focus on the Great Southern as a learning region.

Its executive officer is represented on the Regional Adaptive Capacity Reference Group.

The priority areas for the RDA Great Southern that relate most closely to South Coast NRM's climate change adaptation planning are education, training and employment, and environment and NRM, including water and land use planning.

11.1.2 Western Australian Planning

The Western Australian Department of Planning and the Western Australian Planning Commission produce planning strategies and policies which guide local governments in their land use planning.

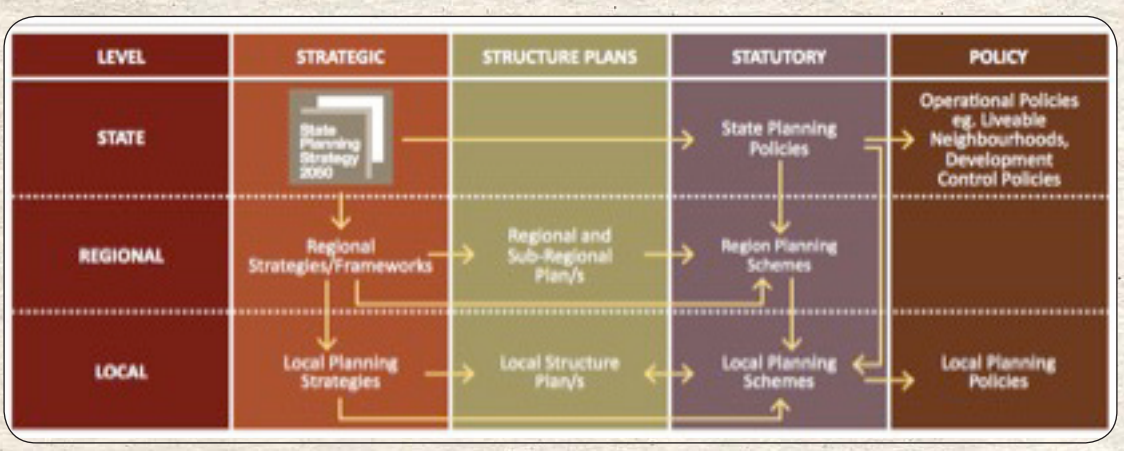


Figure 16: The Western Australian Planning System. *(Department of Planning).*

The State Planning Strategy 2050 highlights the challenges of climate change particularly in relation to water security and coastal infrastructure. The Strategy also discusses the need to consider the impact of climate change on land use planning. It also examines the opportunities for renewal energy industries such as the potential for wave energy on the South Coast.

The Lower Great Southern Strategy 2015 – Western Australian Planning Commission, The Lower Great Southern Strategy provides guidance for the future planning of the region and addresses broad planning considerations across the City of Albany and shires of Denmark, Plantagenet and Cranbrook. It has many common strategic goals as Southern Prospects. The main aspects relating to climate change adaptation were those on connecting biodiversity and the implications of sea level rise.

The Western Australian Local Government Association developed *the Climate Change Policy Background Paper 2009* to assist local governments to consider climate change in their planning activities.

Local governments develop planning strategies and local structure plans. South Coast NRM collaborates with local government in the region, wherever possible, to increase consideration of NRM in planning processes. Increasing local government awareness of and adaptation to, climate change will be an important component of the Regional Capacity theme.

11.2 Land Theme

The Department of Agriculture and Food Western Australia (DAFWA) aims to assist landholders with technical information, tools and resources to support climate change risk management. DAFWA has put in place a number of adaptation measures (*see Background Paper on Adaptation to Climate Change and Land)* to assist farmers.

DAFWA has regulatory functions for the protection of the land resource through the *Soil and Land Conservation Act 1945* and has developed a natural resource report card, which provides baseline data for measuring impacts of farming practices and environmental change. A number of state acts related to the land theme and mitigation activities include:

- *The Forest Products Act 2000* established the Forest Products Commission. The commission operates commercial forestry activities in Western Australian native forests. These include south west native forests in the higher rainfall western areas of the South Coast region and harvesting of *Sandalwood spicatum* in lower rainfall areas.

- *The Carbon Rights Act 2003* creates a carbon right in land in that it provides for a carbon covenant on land which is registered on the title. The carbon covenant may include provisions on management so that carbon sequestration is maintained. This Act is relevant to carbon farming and the forestry industry.

11.3 Biodiversity Theme

The Environment Protection and Biodiversity Conservation (EPBC) Act 1999 (Commonwealth) focuses on the protection of matters of national environmental significance, while the states and territories are responsible for matters of state and local significance.

The Environment Protection and Biodiversity Conservation Regulations support the Act.

The commonwealth and state governments work together on protecting the environment through the *Heads of Agreement on Commonwealth/State Roles and Responsibilities for the Environment.*

Australia's Biodiversity Conservation Strategy 2010-2030 is a national framework guiding the biodiversity conservation policies and programs of the commonwealth, state and territories.

It is reviewed every five years. The framework is *Australia's National Biodiversity Strategy and Action Plan* under the *International Convention on Biological Diversity.*

Although the *National Biodiversity and Climate Change Action Plan* hasn't been updated it provides some proposed strategies for assisting ecosystems to adapt to climate change.

The State Biodiversity Conservation Bill (introduced to Parliament in November 2015) will replace the outdated *Wildlife Conservation Act 1950.*

The Australian Weeds Strategy 2007 recognises climate change as a threat, particularly in changing distributions of weeds. It advocates risk management strategies to respond.

The Australian Pest Animals Strategy 2007 highlighted the need to understand the increased risk of certain pest animals in response to climate change.

Other relevant Acts include:

- The Conservation and Land Management Act 1984
- The Reserves (National Parks and Conservation Parks) Act 2004
-

These relate to biodiversity in State managed conservation areas. The Department of Environmental Regulation is currently progressing legislative amendments to the Environmental Protection Act 1986, Environmental Protection *Regulations 1987 and Environmental Protection (Clearing of Native Vegetation) Regulations 2004.* The Department declares Environmentally Sensitive Areas under the *Environmental Protection Act 1986.* It has a range of resources on climate change to assist with environmental planning.

11.4 Water Theme

11.4.1 Water Resources

The Lower Great Southern Water Resource Development Strategy, Department of Water 2010 formed the basis for South Coast NRM's strategic planning in relation to water and climate change.

This was followed by *The Great Southern Regional Water Supply Strategy – Department of Water, 2014* which outlined six major priorities.

1. Plan and develop new water sources for the lower Great Southern towns.
2. Where practical, maximise use of climate-resilient and cost-effective water sources for independent town water supplies.
3. Promote alternative water sources and efficient use of water to reduce use of potable town water supplies.
4. Investigate groundwater and surface water resources to support regional development.
5. Ensure emergency livestock water sources are available for areas with less than 600mm rainfall.
6. Promote community and inter-agency involvement in water planning and management.

The Water Corporation focused on rain independent water supplies and water efficiency in its plan, Water Forever Whatever the Weather A 10 year plan for Western Australia, Water Corporation 2012 . This plan relates strongly to South Coast NRM's water theme goals and outcomes.

The Country Areas Water Supply Act 1947 places clearing controls on the Kent River and Denmark River Catchment Areas to prevent further salinisation.

The Act overrides an Environmental Protection Act permit. The Kent and Denmark rivers are Water Resource Recovery Catchments. The Denmark River salinity is now at potable levels and is a back-up water resource for Denmark town. The impact of climate change on these two rivers will be important to monitor.

11.4.2 Waterways

The *Waterways Conservation Act 1976* gives the Department of Water statutory responsibility for the management of the Albany waterways and the Wilson Inlet and in the past this has been an important role for the department.

The large body of science on the Wilson Inlet assists South Coast NRM in planning for estuary management and monitoring. Managing these waterways will be increasingly difficult without involvement of the Department of Water, which currently has no management programs in place.

For waterways management planning, the Department of Water generally acts under the *Water Agencies (Powers) Act 1984*.

This Act enables the department to provide water science and advice to support policy development, planning, decision-making and management of the state's waterways.

The science from the Department of Water is integral to South Coast NRM's waterways planning but the focus currently is more on groundwater resources for the drying climate and less on waterways.

The Rights in Water and Irrigation Act 1914 also provides for a permit system for activities that degrade watercourses and wetlands in proclaimed rivers, surface water management areas and irrigation districts.

11.4.3 Wetlands - Including Esturaries

Changes in rainfall and sea level may impact on many wetlands on the South Coast. The *Ramsar Convention on Wetlands of International Importance* is an international treaty to protect certain wetlands.

Lake Gore and The Lake Warden systems in Esperance are Ramsar wetlands. They are an important part of South Coast NRM's planning process under the water theme.

Wetlands considered of national importance are in the *Directory of Important Wetlands in Australia*. This is available online as the *Wetlands of National Importance* database.

Some examples within the South Coast region are the Culham Inlet system, the Fitzgerald Inlet system, Lake Pleasant View, Pink Lake, Moates Lake and Oyster Harbour. Lake Pleasant View also has strong Indigenous cultural importance.

There is no single agency responsible for looking after wetlands in WA. DPaW is responsible for the management of wetlands on the conservation estate.

There is a *1997 Wetlands Conservation Policy* but there is no updated policy that specifically addresses the threat of climate change.

11.5 Coastal & Marine Theme

The most important strategic document for South Coast NRM region planning is *Southern Shores 2009-30*. This is a strategy to guide coastal zone planning and management in the South Coast region.

Southern Shores is very closely linked to South Coast NRM's Southern Prospects' Coastal and Marine theme planning. Southern Shores has a set of proposed actions in relation to climate change (p43).

The WA Department of Planning and WA Planning Commission have policies and guidelines in relation to coastal planning, including:

- State Planning Policy no 2.6 Coastal Planning 2013 which relates to coastal planning for sea level rise.
- Coastal Hazard Risk Management and Adaptation Planning Guidelines. Perth 2014

The Department of Planning also has a *Coastal Vulnerability* projects database and the Department of Transport Coastal has infrastructure baseline data relating to sea levels and major infrastructure. It also conducts coastal research projects and has coastal adaptation and protection grants for local coastal management.

The Fish Resources Management Act 1994 is the main WA legislation protecting marine organisms. It covers all aquatic organisms except reptiles, birds, mammals, amphibians and their habitat.

The Department of Fisheries has research activities on fish dependent indicators of climate change *(e.g. Caputi et al 2010)* and is an important partner for South Coast NRM in the marine and coastal theme.

11.6 Cultural Heritage Theme

11.6.1 The State Cultural Heritage Policy

State Cultural Heritage aims to work with representative organisations such as South Coast NRM to encourage appropriate use and enhanced conservation outcomes in the wider community. It also promotes and celebrates the value and diversity of Western Australia's heritage through partnerships that will enhance community appreciation.

The draft of the Heritage Bill 2015 is based on the 2011 review of the *Heritage of Western Australia Act 1990*, the first major initiative of the State Cultural Policy. The revised draft bill aims to improve cultural heritage protection and simplify processes. Local Heritage Surveys can include places and not just buildings. State Cultural Heritage protection is separate from Environmental Protection and Aboriginal Heritage Protection.

The Australian Environment Protection and Biodiversity Conservation Act 1999 protects World and National Heritage Places. The EPBC protects places that have been included on the National Heritage List, including Indigenous heritage values (see below).

11.6.2 The State Register of Heritage Places

The State Register of Heritage Places is a statutory list of places that represent the story of Western Australia's history and development. Places include buildings, structures, gardens, cemeteries, memorials, landscapes and archaeological sites. This registry will assist South Coast NRM with vulnerability assessments.

11.6.3 Aboriginal Heritage

The EPBC Act recognises the role Indigenous people play in the conservation and sustainable use of Australia's natural environment and Indigenous heritage. Objectives of the Act include:

- To promote a co-operative approach to the protection and management of the environment involving governments, the community, landholders and Indigenous peoples.
- To recognise the role of Indigenous peoples in the conservation and ecologically sustainable use of Australia's biodiversity.
- To promote the use of Indigenous peoples' Traditional Knowledge of biodiversity with the involvement of and in co-operation with the owners of the knowledge.

Indigenous heritage values are included on the National Heritage List.

The Aboriginal Heritage Act 1972 (currently being amended) makes provision for the preservation, on behalf of the community, of places and objects customarily used by or traditional to the original inhabitants of Australia or their descendants, or associated therewith, and for other purposes incidental thereto.

Under the *Aboriginal Affairs Planning Authority Act 1972*, the department supports the work of the Aboriginal Lands Trust, a body comprising Aboriginal people that holds about 11 per cent of the state in trust for Aboriginal Western Australians.

The department works with Aboriginal people to protect and manage places of significance and also provides advice to the public and private sectors and the community about Aboriginal heritage management and maintains a Register of Aboriginal Sites.

It also assists Aboriginal families and native title parties to access information that may assist them in reuniting families or demonstrating their connections to country.

Under the *Noongar Native Title Settlement* there may be legislation to ensure the Department of Aboriginal Affairs takes into account advice from Noongar Regional Corporations on Noongar Heritage.

The Noongar Standard Heritage Agreement and the Noongar Heritage Partnership Agreement are under negotiation as part of the Noongar Native Title Settlement. These will improve Aboriginal involvement in their heritage protection.

The aim of the Heritage Agreement is for heritage matters in a region to be managed through the relevant Noongar Regional Corporation. As a party to the Heritage Agreement, the Regional Corporations will have a range of administrative responsibilities that will require them to develop effective heritage management policies and procedures.

NOTE: *This is not a complete list but consists of those most relevant to South Coast NRM's goals and outcomes for climate change adaptation planning.*

12 Part of South Coast NRM's investment planning process identifies actions with potential partners and funding sources. Tables below show some proposed actions for climate change adaptation, roles and responsibilities.

12.1 Land

PROJECTED CHANGE	ACTION	ROLES & RESPONSIBILITIES
Higher temps, less growing season rainfall, potential for more summer rainfall.	Develop risk management and adaptation options for each enterprise. Outcome L 11a, b.	South Coast NRM, DAFWA and grower groups, forestry industry.
Westward movement of rainfall isohyets.	Using climate proxies from other parts of the region or other regions for changing farming practices. Outcome L11.	South Coast NRM, information from BoM and DAFWA.
Higher carbon dioxide.	Increased knowledge of the interactions between carbon dioxide, rainfall and temperature on crops, pastures and forestry. Outcome L11.	University research, grower group research, new research bodies (ex DAFWA), GRDC.
Local variability.	Database of climate information from all weather stations on the South Coast. Outcome L 11.	South Coast NRM and DAFWA and grower groups, sub-regional groups.
Reducing and mitigating emissions from agriculture.	Identify priority areas for carbon plantings and increase soil carbon storage. Outcome L13	South Coast NRM and reference groups, grower groups, sub-regional groups and individual farmers.

12.2 Biodiversity

PROJECTED CHANGE	ACTION	ROLES & RESPONSIBILITIES
Rapid changes & increased variability in climate. Drying climate in west of region. Higher temperatures away from coast.	Build resilience by large scale re-vegetation, build connectivity & improve mosaic landscapes. Outcome B6a	SCNRM, Gondwana Link & partners, community groups, carbon farming projects.
	Identify vulnerable ecosystems. Outcome B2a.	Universities, DPaW, WA Museum.
	Build climate projections into threatened species recovery plans. Outcome B5a.	DPaW.
	Manage threats that interact with climate change. Outcome B5a.	SCNRM, sub-regional/community groups, DPaW, Gondwana Link/partners.
	Monitoring using indicator species Outcome B4b.	Community, Mallefowl Group, DPaW, Gondwana Link & partners
Increased fire risk	Vegetation management & fire research. Outcome B5 & B13a.	Community, DPaW, Fire & Emergency Services, Bushfire CRC, universities.
Increased spread of pathogens	Manage current threats. Mapping of pathogens Outcome B5a.	SCNRM, Sub-regional groups, Community groups, DPaW.
Higher temperatures impacting on susceptible species	Assess vulnerability of species, e.g. montane species. Increase knowledge on thermo-tolerance. Outcome B2a.	Research by DPaW & universities.
Decreased streamflow	Assess impact on aquatic biodiversity. Outcome W3.	Research by universities.
Species movement	Protect remnants and build connectivity. Use participatory MCAS models for prioritisation. Outcome B6a	SCNRM, community groups, Gondwana Link & partners.
Drying climate reducing wet refugia	Identify wet refugia. Outcome B6a	SCNRM, DPaW, WA Museum.
Drying climate	Identify potential cooler, wetter refuges.	SCNRM, DPaW, WA Museum.

12.3 Water

PROJECTED CHANGE	ACTION	ROLES & RESPONSIBILITIES
Decreased rainfall and streamflow in west of region.	Monitor and model streamflow. Outcome W3.	Department of Water, universities, CSIRO.
Long term impact on groundwater supplies.	Monitor and model potable ground water resources. Outcome W3.	Department of Water, Water Corporation.
	Increase water efficiency through communication and regulation. Outcome W15.	South Coast NRM, Water Corporation, community.
Changes in estuaries.	Monitor estuarine ecosystems, salinity, species, sea grasses etc. Water and Coastal Outcome C1a.	Department of Fisheries, ASHS marine science, university research. Department of Water.
Changes in hydrology.	Monitor groundwater levels and salinity. Outcome W15.	South Coast NRM, DAFWA, universities, catchment groups. Department of Water.

12.4 Coastal & Marine

PROJECTED CHANGE	ACTION	ROLES & RESPONSIBILITIES
Sea-level rise.	Monitor changes in coastline. Outcome C1a.	South Coast NRM, community groups, Department of Transport
	Factor in sea -level rise in all planning. Integrate coastal planning. For example. Southern Shores. Outcome C4, C5, C13, C14.	South Coast NRM, local governments, Department of Planning. Dept of Transport.
Sea water inundation of coastal vegetation and wetlands.	Increase connectivity to inland vegetation and wetlands. Outcome C4.	South Coast NRM, DPaW, Gondwana Link and partners. Sub-regional groups, catchment groups, community groups e.g. 'Friends of' groups.
Sea water inundation of infrastructure.	Carry out vulnerability assessments. Outcome C1a and C2b.	Local and State Government. South Coast NRM (cultural heritage).
Acidification of oceans.	Monitor vulnerable species. Outcome C1a.	Dept of Fisheries and Western Australian Museum. citizen science and schools.
Changes in species distributions. Potential for southward movement of species.	Increase knowledge of South Coast marine ecology and potential impacts of climate change. Outcome C2b.	Universities, Western Australian Museum, Dept of Fisheries.
	Develop coastal and marine database. Outcome C11.	South Coast NRM, Fisheries Dept WA, Local Government, South Coast Management Group.
	Monitor changes in species. Outcome C1a.	Department of Fisheries, Community through Fisheries Red Map and other citizen science projects.
Changes in estuaries	Monitor estuarine ecosystems, salinity, species, sea grasses etc. Outcome C1a.	Department of Fisheries, ASHS marine science, university research. Department of Water.

12.5 Cultural Heritage

PROJECTED CHANGE	ACTION	ROLES & RESPONSIBILITIES
Sea level rise - damage to coastal aboriginal sites.	Carry out vulnerability assessments Risk planning Outcome H5.	Department of Aboriginal Affairs, South Coast NRM and Aboriginal groups. SW Land and Sea Council.
Changes in Aboriginal culture associated with seasons.	Communication of climate changes to Aboriginal people. Outcome H1	South Coast NRM, Aboriginal Reference Group and SW Land and Sea Council.
Increased environmental degradation to cultural sites.	Manage threats as in other themes. Outcome H5.	As in other themes.
Damage to settler heritage sites.	Carry out vulnerability assessments Risk planning. Outcome H1.	Local Government, Heritage Council, South Coast NRM.

12.6 Adaptive Capacity

INCREASE ADAPTIVE CAPACITY to PROJECTED CHANGE	ACTION	ROLES & RESPONSIBILITIES
Increase knowledge and understanding of climate and potential changes.	Website with up to date information. Climate conferences and seminars. Develop, review and adapt climate communication plans. Outcomes R4, L11a, W3,W15, C2B, C12, H1	South Coast NRM, partners and reference groups.
Increase adaptive capacity within each natural resource theme.	Build adaptive capacity actions into South Coast NRM's investment planning. Outcome R4 and theme Outcomes L11c, B4a, W15, C12, C14, H1.	South Coast NRM Regional Capacity Reference Group and natural resource theme reference groups.
Knowledge on building adaptive capacity for each theme.	Research and information on how to build adaptive capacity. Outcome R4.	Universities, Reference Groups, Community, South Coast NRM.
Risk management.	Risk assessment training. Outcome R4.	South Coast NRM, Department of Agriculture and Food. grower groups. Local Government. Great Southern Institute of Technology.
Flexible planning.	Build flexible planning into all climate planning. Goal R10.	South Coast NRM and all partners.

*** Note:** South Coast NRM can advocate and encourage collaboration with partners but changes in the strategic direction of State Government Departments and non-government organisations can mean the actions above may not always continue to align with South Coast NRM partners' priorities. These will be revised accordingly in the flexible investment planning process.

13 Planning Carbon Plantings

A range of farming methods can reduce greenhouse gas emissions or sequester carbon from the atmosphere. These methods come under the umbrella of carbon farming and they can be an important contribution to mitigating the adverse effects of greenhouse emissions on climate and ocean acidity.

Changes in farming methods, such as no-till or controlled traffic, can reduce emissions but the other main carbon farming activities in the South Coast region are aimed at sequestration of carbon (storing carbon in wood or plant material). Sequestration of carbon can offset emissions and contribute to the region eventually becoming carbon neutral.

Sequestration may be by establishment of new environmental plantings, which store carbon for long periods, such as forestry or biodiversity plantings, or it can be through soil carbon accumulation. It is important to plan so these plantings provide the best NRM outcomes.

13.1 Using participatory multi-criteria analysis to determine priority areas for carbon plantings

Carbon farming in Australia is encouraged by the Australian Government (under the Carbon Farming Initiative which became integrated into the Emissions Reduction Fund).

One of the important planning activities under Australian Government funding was determining priority landscapes for carbon plantings. Planning carbon plantings in the region is important to maximize the environmental benefits and avoid adverse impacts. They need to fit in with the other NRM goals of the region.

To assist in preparing guidelines for planning carbon plantings, South Coast NRM used a participatory process, which generated a series of maps. The process used was the Multi-criterion Analysis Shell for Spatial Decision Support (MCAS-S) developed by the Australian Bureau of Agricultural and Resource Economics.

MCAS-S is a multi-criteria analysis tool to assess spatial information which conveys complex information in a readily understood manner. This made it very suitable for the participatory process South Coast NRM and the South West Catchments Council used to determine which landscapes were most suited to carbon plantings.

The groups developed the spatial criteria, which therefore included their experience and expertise and meant they were able to accept the results of the process. Ecotone and Associates conducted the MCAS process and have prepared a full and detailed report: *Ecotones and Associates (2014) Biodiversity Prioritisation and Biosequestration Modelling and Analysis, South Coast NRM (Inc).*
The full report contains a large number of maps, a sample of which are included in this Addendum.

The participatory process in the South Coast region identified landscapes where carbon plantings would improve natural resource condition and not have adverse impacts. Landscapes were identified where carbon plantings could increase biodiversity and build habitat connectivity or where they would assist in reducing salinisation.

The planning process also identified those areas where carbon plantings should not occur because of potential adverse effects on hydrology, cultural sites or might affect expansion of towns, cause loss of population or infrastructure. It was also recognised that where there is high value agricultural land carbon plantings should be restricted to a percentage of the landscape.

As climate change impacts, the western part of the South Coast is likely to increase its proportion of high value agricultural land so it is important that this area not be locked into a large proportion of long-term carbon plantings.

The South Coast region has short-rotation commercial plantations of *Eucalyptus globulis* in higher rainfall areas. Although they store carbon for a period of time, these short-rotation plantations were differentiated from carbon plantings because they may revert to agricultural land following harvest.

As part of the carbon farming planning process the WA NRM groups agreed they would support projects which:

- Align with local, state and federal government policies and planning requirements.
- Identify social and community impacts and provide safeguards to minimise adverse impacts (loss of regional populations, social services and impacts on local infrastructure).
- Protect, restore and enhance natural resources and build landscape resilience.

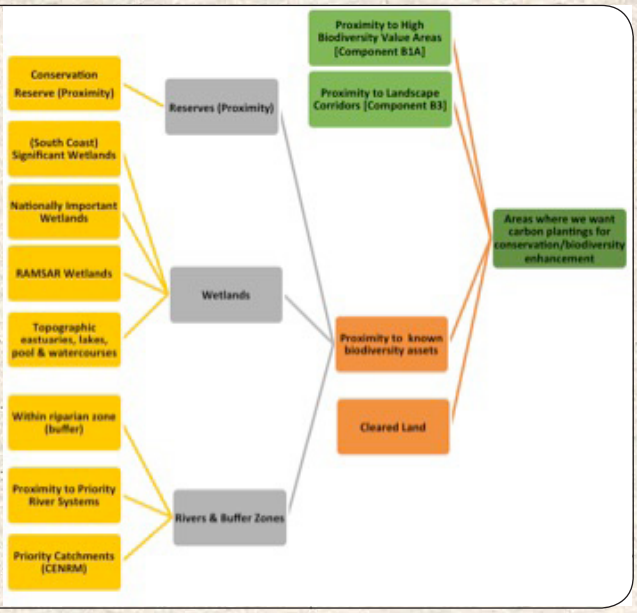
13.2 Carbon Plantings for Conservation/Biodiversity Enhancement

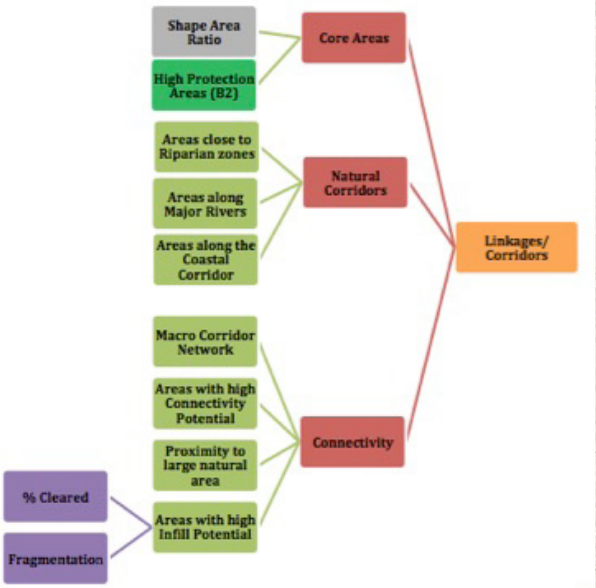
This used three major criteria:

- Proximity to high biodiversity value areas.
- Proximity to landscape corridors.
- Proximity to known biodiversity assets.

In all cases proximity to these various assets is used as indicating a priority for biodiversity plantings which are intended to enhance habitat (connectivity) corridors and protect high biodiversity areas.

Figure 17 (right) shows locations for biodiversity plantings.





13.3 Landscape Linkages & Corridors

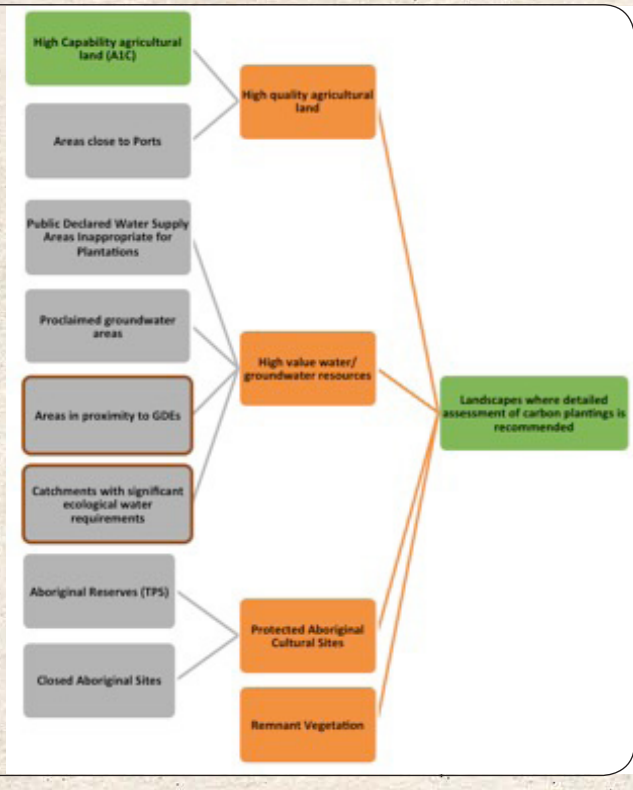
Natural corridors represent existing areas of connectivity, either along rivers of other riparian zones, or along the coast.

These are known as places of significant movement of animals and sometime plants by natural vectors.

Connectivity is the real or potential connectivity in the landscape, characterised by the existing macro-corridor network, proximity to the large areas and 'Connectivity Potential' – a measure of connectivity between all patches of vegetation.

Figure 18 (left) shows landscape linkages and corridors.

There were a number of areas where carbon plantings would need to be assessed because of the potential impacts. Landscapes where detailed assessment of carbon plantings is recommended is shown here in *Figure 19*.



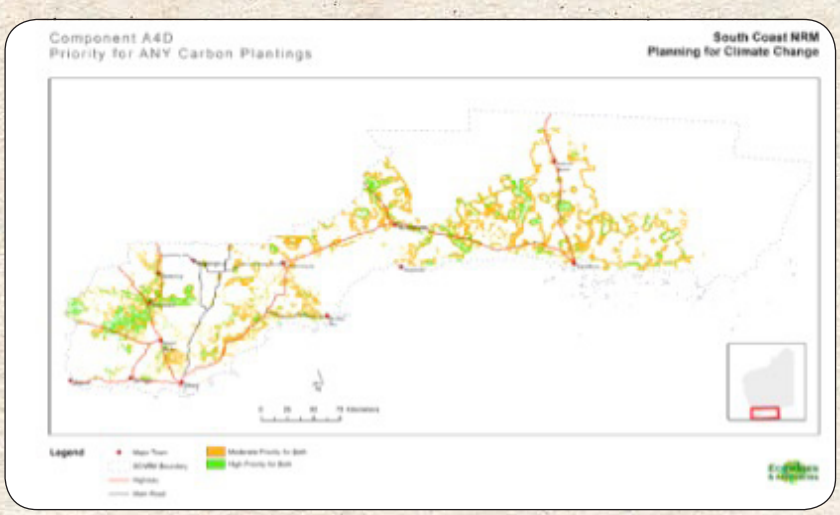


Figure 20: Priority areas for carbon plantings.

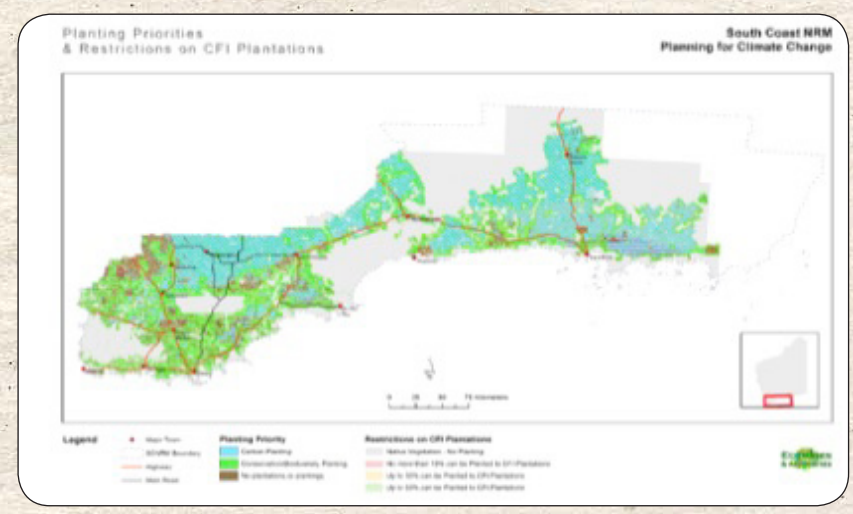


Figure 21: Combined map of planting priorities and restrictions on carbon plantings.

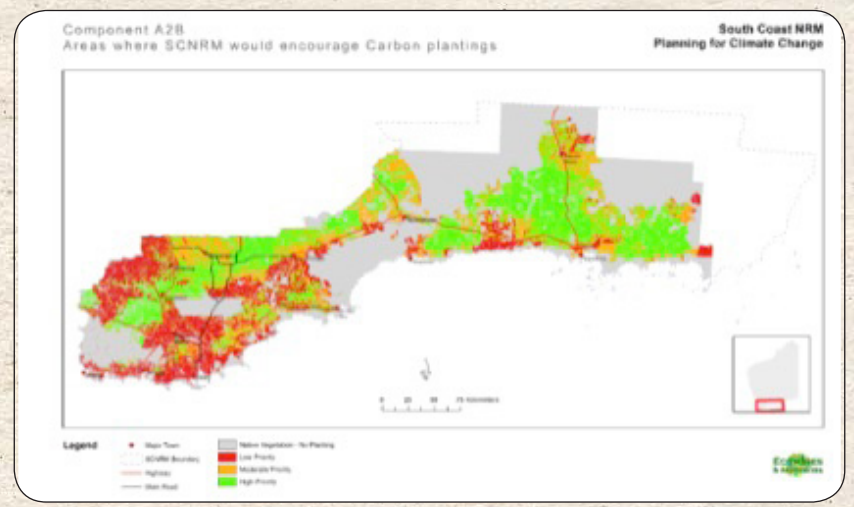


Figure 22: Areas where South Coast NRM would encourage carbon plantings.

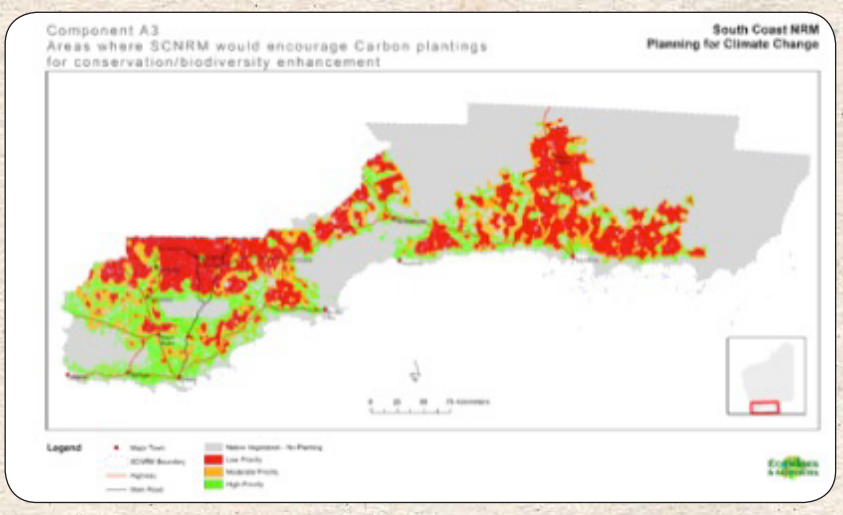
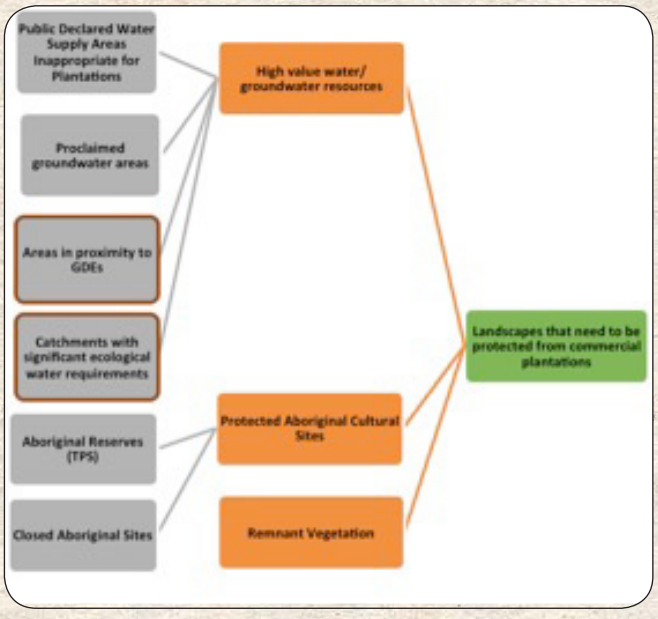


Figure 23: Areas where South Coast NRM would encourage carbon plantings for conservation biodiversity enhancement.

Separate models for commercial short-rotation plantations and longer term carbon plantings were run because long term carbon plantings are not suitable for high value agricultural land.

13.4 Commercial Short-Rotation Plantations

Commercial short-rotation plantations are generally harvested after 10 years.



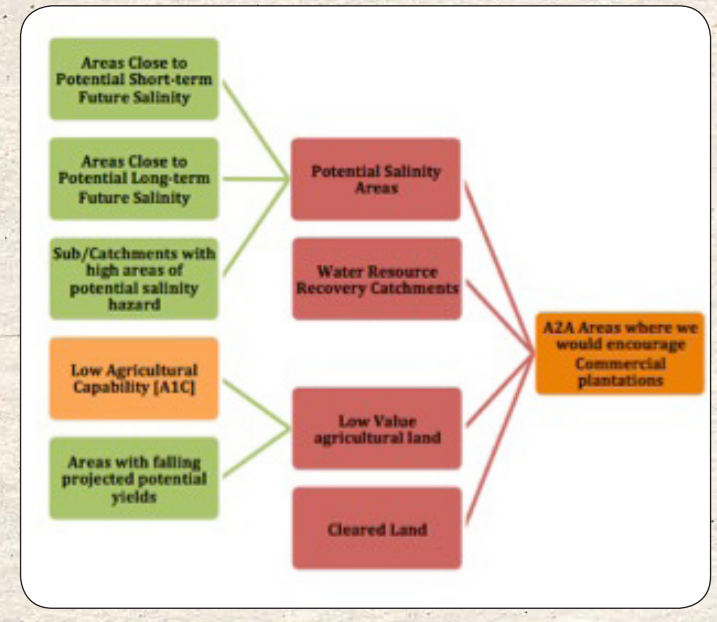


Figure 24: (left) Shows areas not suited to commercial short-rotation plantations, while **Figure 25** shows landscapes most suited.

For information on carbon plantings near Indigenous lands, see *Renwick et al (2014) http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0091281.*
A set of guidelines for carbon farming proponents was developed. To read the full report and discover how decisions were made see *Ecotones and Associates (2014) Biodiversity Prioritisation and Biosequestration Modelling and Analysis, South Coast NRM.*

14 Principles & Standards for Biodiversity Plantings for Adaptation to Climate Change

14.1 Introduction

Plants and animals can adapt to changes in climate through physiological, genetic or behavioral changes *(Steffan et al., 2009).* Increasing biodiversity is likely to improve opportunities for adaptation to climate change.

Bioclimatic modelling, while useful for research, does not provide sufficient information to assist in revegetation. Increasing revegetation and biodiversity protection at multi-scales, from individual paddock trees, through to large cross-regional scale connectivity is the best approach. *(Steffan et al., 2009).*

14.2 General Principles

14.2.1 Use South Coast NRM Biodiversity Prioritisation Process *(Neville, 2015)*

This was a participatory process using MCAS with regional workshops held in Albany, Ravensthorpe and Esperance and it developed an overarching set of criteria for investment by South Coast NRM in biodiversity. The full report is *Neville (2015) Biodiversity Prioritisation Process for South Coast NRM.*

4.2.2 Increase the Total Amount of Restoration

The best option to increase the resilience of ecosystems to climate change is to increase connectivity and provide alternative habitat.

The NCARRF project on designing landscapes for biodiversity under climate change found that : *The total amount of restoration is more important than detailed spatial configuration to counteract declines in biodiversity from climate-related changes in land use and suitable habitat, at least at very large landscape scales,* (Doerr et al. 2013 p6).

To provide the best opportunities for species to adapt to climate change in the South Coast Region the goal would be to increase biodiversity plantings to 30 per cent of the landscape.

To protect high value agricultural land this might mean higher percentages in other areas. Planning biodiversity plantings requires more information on the responses of species but there are a number of potential strategies in the literature.

14.2.3 Establish Corridors Across Climatic Gradients

Establishing vegetation corridors across a climatic gradient should enhance the capacity of species to shift to new, more climatically favourable areas, allowing species to respond to shifting climates through natural dispersal rather than requiring active intervention *(NCCARF)*.

In the South Coast region, large-scale corridors can also connect cooler wetter refuges to drying climate zones. The ability to disperse across the landscape will be an important factor in the capacity of species to adapt to westward shifting climate zones in the South Coast region. Increasing connectivity across the landscape needs to be monitored closely to ensure there are no adverse impacts.

In general, regions should have a diversity of levels of connectivity, provision for different rates of movement and provision for development of new combinations of species. This requires careful monitoring and adaptive learning to ensure connectivity does not result in unforeseen, perverse outcomes such as increased weediness and counterproductive species displacements, *(Steffan, 2009)*.

14.2.4 Build Stepping Stones

Stepping stones are smaller corridors linking smaller patches of vegetation but they still assist in dispersal of plants and movement of wildlife.

14.2.5 Improve Mosaic Landscapes as well as Establishing Corridors

Improving and extending remnants of vegetation can still provide useful habitat. This can be particularly important in areas such as granite outcrops.

Many of these patch areas can provide refuges for invertebrates and small areas of vegetation on farms can act as islands allowing some species, such as birds and bats, to move across the landscape. Increasing buffer areas around farms can also reduce off-site impacts.

14.2.6 Increase Paddock Trees

Isolatd paddock trees can provide important biodiversity benefits and shade for livestock, but they need to be protected by fencing.

Fencing is best offset from the tree to allow stock to benefit from the shade. Isolated paddock trees provide habitat for birds and bats.

14.2.7 Plant Windbreaks & Shade Belts on Farms

Well-designed windbreaks with understory plantings can have a production and biodiversity benefit. Long and wide windbreaks provide better protection of paddocks and can provide biodiversity benefits.

As temperatures rise it will become more important to provide shade for livestock. Shade belts are best planted on a north-south axis. This will allow enough sun for pasture growth in winter.

14.2.8 Increase Appropriate Wetland Biodiversity Plantings & Protect & Restore Wet Refuges & Refugia

Protecting wetlands from further degradation will be important in providing habitat refuges. Freshwater wetlands in the western part of the region are at particular risk.

14.2.9 Provide Linkages to Current Protected Areas

Current protected areas will not be large enough to enable ecosystems to adapt to climate change so it will be important to continue to provide linkages to protected areas as in the macro-corridors project and Gondwana Link. Linking protected areas provides the ability for movement and dispersal.

14.2.10 Reduce Invasive Species & Spread of Pathogens

Invasive species and pathogens are also likely to change in number and distribution with changes in climate. Revegetation to sustain ecosystem function cannot be carried out in isolation from protection from for example, feral predators and fungal pathogens.

14.3 Minimum Revegetation Standards for Climate Adaptation

Choosing the best plant provenance for re-vegetation for climate adaptation will require ongoing research *(Breed et al. 2012)*.

There is uncertainty about a particular seed source's ability to adapt and uncertainty about some aspects of climate projections Whether species are going to be resilient to changes in climate is difficult to determine at this stage. Choosing seed from a larger area than in the past may assist in increasing genetic diversity and hence the ability to adapt.

Selection should still be from the vicinity and should reflect the structure and composition of the native vegetation. In selecting species it is best to refer to a nearby healthy vegetation community or a benchmark revegetation site.

14.3 Minimum Revegetaion Standards for Climate Adaption (cont.)

In selecting species it is best to refer to a nearby healthy vegetation community or a benchmark revegetation site. A range of overstorey, mid-storey and understorey species should be planted.

The minimum standard for Australian Carbon Credits and the 20 Million Trees Program is currently for an overstorey that will be a minimum of 2m in height.

14.3.1 Seed Selection

Seed selection should be based on local provenance but should be suitable to the site and region over the longer term, taking account of changing climatic conditions. Genetic diversity may be more important than selecting from outside a species normal climate range *(Cochrane, 2015)*.

14.3.2 Planting Density

Planting density should allow for low germination rates (if direct seeding) and seedling death. Density of surviving plants should reflect local bushland.

14.3.3 Management

Management should include:

- Site protection. Appropriate site preparation.
- Weed control.
- Fencing and stock exclusion (may need to provide watering points).
- Fire control.

14.3.4 Monitoring

Photo monitoring of the site.

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