GOULBURN BROKEN
CATCHMENT MANAGEMENT AUTHORITY

Climate Change Adaptation Plan

for natural resource management in the Goulburn Broken Catchment, Victoria 2016

An assessment of the vulnerability of the Goulburn Broken Catchment's natural resources to climate change using spatially-enabled criteria and identification of adaptation and mitigation priorities and management options

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Australian Government

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Contents

1. Purpose

This Climate Change Adaptation Plan:

a. identifies priority landscapes for climate change adaptation and mitigation in the context of improving the resilience of natural resources;
b. identifies options for climate change adaptation and mitigation, including carbon sequestration, within focus areas and priority landscapes; and
c. identifies risks to catchment processes from carbon sequestration activities and mitigation actions.

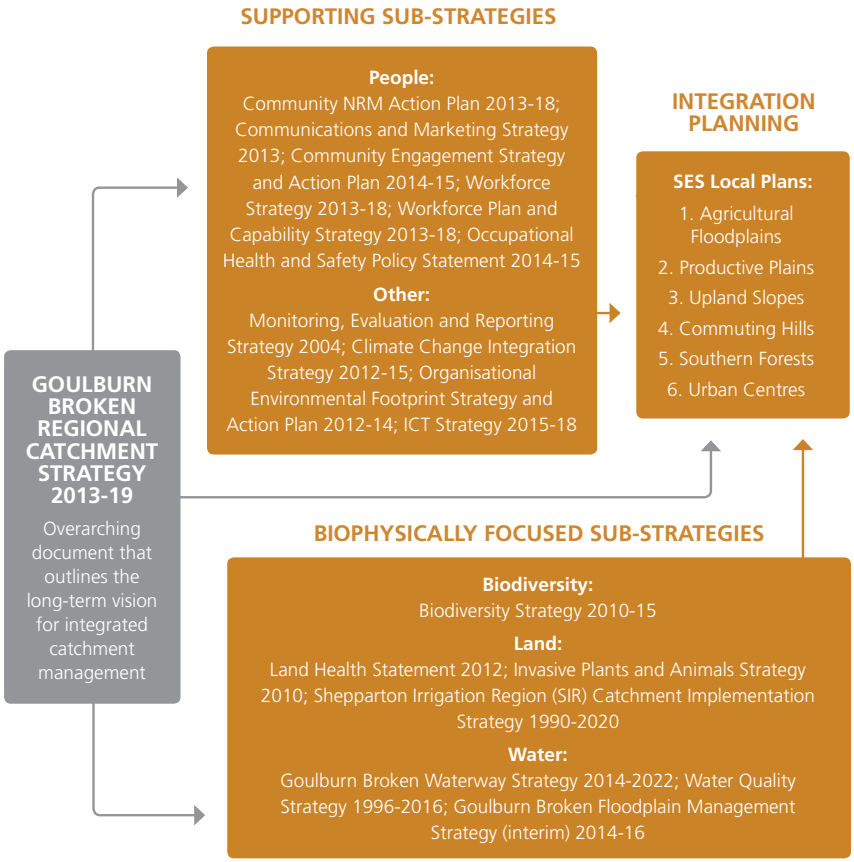
This Plan contributes to achieving strategic outcomes of the Goulburn Broken Catchment Management Authority's (CMA's) *Climate Change Integration Strategy 2012-2015* (GB CMA 2012), a sub-strategy of the *Goulburn Broken Regional Catchment Strategy (RCS) 2013 -2019* (GB CMA 2013) (see figure 1).

This Plan specifically contributes to the following Climate Change Integration Strategy strategic outcomes and associated goals and directions:

- integrate climate change into Goulburn Broken CMA programs;
- improve understanding of climate change; and
- build catchment resilience into sequestration activities.

This Plan has been developed primarily for natural resource management (NRM) planners but may inform the work of researchers and implementers.

Figure 1: The relationship between the Goulburn Broken Regional Catchment Strategy, sub-strategies and local plans for social-ecological systems (GB CMA 2013).



The priorities and management options specifically relate to the Goulburn Broken Catchment, however, the process for assessing vulnerability and identifying priorities and management options could inform NRM planning more broadly.

The adaptation and mitigation priorities and associated management options outlined in this Plan will be considered through the Goulburn Broken CMA's adaptive management planning processes for integration into NRM programs and strategies at various spatial scales (see section 9 for more details).

This Plan is not intended to incorporate all decision-making elements but provides an initial prioritisation for climate change adaptation and mitigation based on spatially-enabled criteria for vulnerability and values. Investigation of the interactions between social-ecological systems (SESs) identified in the *Goulburn Broken RCS*, (GB CMA 2013) drivers of change and how key points of vulnerability to natural resources may be overcome will continue.

2. Background

The Goulburn Broken CMA coordinates natural resource management (NRM) in the Goulburn Broken Catchment, Victoria, guided by the *Goulburn Broken RCS*. The Goulburn Broken CMA develops and coordinates the implementation of the *Goulburn Broken RCS* in collaboration with the community, all tiers of government, regional authorities and research and funding organisations.

Major challenges for NRM in the Goulburn Broken Catchment include degraded river health, reduced extent and quality of native vegetation, reduced water quality and quantity, dryland and irrigated salinity, loss of biodiversity, and pest plant and pest animal invasion. These challenges are all being exacerbated by climate change.

Regional climate projections developed by the CSIRO for the Murray Basin (of which the Goulburn Broken Catchment is part) indicate that climate change will have the following impacts on the future climate (Timbal *et al.* 2015):

- average temperatures will continue to increase in all seasons (very high level of confidence)
- hotter and more frequent hot days and longer warm spells (very high level of confidence)
- fewer frosts (high level of confidence)
- less rainfall during the cool season by 2090 (high level of confidence)
- increased intensity of heavy rainfall events (high level of confidence)
- a harsher fire-weather climate (high level of confidence)
- increased evaporation (high level of confidence)
- on an annual and decadal basis, natural variability in the climate system can act to either mask or enhance any long-term human-induced trend.
- snowfall and maximum snow depth will continue to decline (high level of confidence).

The development of this Plan was supported by funding from Stream 1 of the Australian Government's *Regional Natural Resource Management Planning for Climate Change Fund*. The Fund was established to improve regional NRM planning and use of climate change science, information and scenarios to plan for the impacts of climate change. This Plan aligns with the following principles of the Fund (DSEWPaC 2012):

- Identify priority landscapes for carbon plantings (see section 8) and strategies to build landscape integrity and guide adaptation and mitigation actions (see section 7) to address climate change impacts on natural ecosystems (see sections 4, 5 and 6).
- The planning process is logical, comprehensive and transparent (see section 3).
- Best available information is used to develop actions (see sections 3, 5 and 6) and are based on collaboration with government, community and other stakeholders (see below).

The development of this Plan has been managed by a multi-organisation steering committee (see Acknowledgements) and has been informed by extensive consultation with:

- Goulburn Broken CMA staff and Board
- local, State and Commonwealth government representatives
- representatives from NRM organisations across Victoria and the Murray Basin
- research institutions
- expert consultants
- community and industry representatives.

See Appendix A for more detail on stakeholder and community consultation activities.

3. The Climate Change Adaptation Planning Process

An assessment of the vulnerability of the Goulburn Broken Catchment's natural resources to climate change using spatially-enabled criteria was undertaken with adaptation and mitigation priorities and management options identified using the results of this assessment. Natural resources are defined as per the *Goulburn Broken RCS* in the asset categories of land, water and biodiversity (GB CMA 2013).

A vulnerability assessment was chosen as it is well suited to spatial analyses. Risk and vulnerability are similar, although not identical concepts. Both are widely used in the analysis of climate change issues.

Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change. It has three main dimensions: *exposure* to changes in climate; *sensitivity* to such changes; and the capacity of a system to *adapt* to them.

Risk is the effect of uncertainty on objectives and is assessed by considering the consequence of an event and its likelihood.

Although there are important differences, exposure and sensitivity broadly correspond with the likelihood and consequence components of a risk assessment. Vulnerability is used to highlight locations and issues to focus further analysis, including risk assessment and management. Multiple criteria and spatial data sets can be used to characterise each of the three main components of a vulnerability assessment to identify areas which may experience greater impact from climate change.

The vulnerability and adaptation priority assessment was undertaken in the following five stages:

1. Identification of assessment criteria
2. Development of a spatial assessment tool
3. Assessment of climate change vulnerability
4. Identification of focus areas for adaptation
5. Development of adaptation management options.

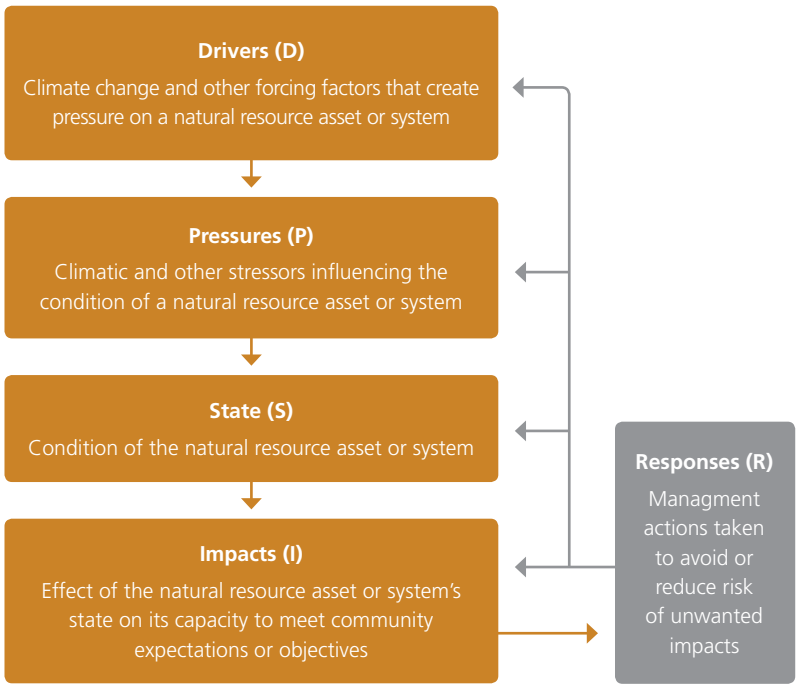
3.1 Identifying assessment criteria

Criteria for assessing the vulnerability of the Catchment's natural resources to climate change and identifying priorities for adaptation were identified through (Clifton and Pelikan 2014):

- a review of the Goulburn Broken CMA's regional NRM planning framework to understand and assess how climate change has been considered;
- an analysis of landscape processes that affect the condition of natural resources and current management actions to mitigate adverse impacts; and
- stakeholder engagement.

Landscape processes were represented using the *Driver-Pressure-State-Impact-Response* (DPSIR) model (see figure 2). The DPSIR analyses characterise landscape interactions that influence the condition and value of natural resources that may, in turn, be influenced by climate change. The DPSIR analyses include detail that seeks to explain the interconnection between the *Driver*, *Pressure*, *State* and *Impact* elements and document assumptions about the interactions and influence of specific factors. The model is not intended to represent the actual biophysical or ecological processes by which those interactions occur.

Figure 2: The DPSIR model (Clifton and Pelikan 2014)



Social, technical, environmental, economic, political and legal aspects considered for *Drivers* and *Pressures* were identified from documented threats to natural resources. Characteristics of the current *State* (or condition) of natural resources was documented as were the likely *Impacts* on natural resource values or services. Types of management actions *(Responses)* specified in the planning framework were matched at the appropriate point(s) in the D-P-S-I chain.

The DPSIR analyses also include assessments of the magnitude (local-regional scale) and trend (improvement/decline) of influence of Drivers and Pressures on the State of natural resources. The recent historical trend in *State* and Impact was also assessed. Responses were classified in terms of their influence on the *State* of natural resources.

The DPSIR also accounts for the influence of climate change, based on mid-century climate change projections under a relatively high emissions pathway, and identified responses that are specific to climate change. This enabled a broad assessment of how climate change may influence landscape processes and the *State* (or condition) and value of natural resources.

3.2 Development of a spatial assessment tool

A Spatial Assessment Tool was developed to help identify landscapes within the Goulburn Broken Catchment that are vulnerable to climate change to assist in focusing adaptation. The Tool can also help identify priority landscapes for carbon farming activities (mitigation).

The Tool assists NRM planners to develop scenarios of climate change impact based on spatial data and to incorporate any relevant local knowledge. Criteria can be weighted to assign higher importance to certain criteria over others with specific criteria and/or criteria weighting able to be changed between scenario runs, providing flexibility to customise inputs (Kelly and Davy 2014).

The Tool is not an end in itself, but instead is a means to help NRM planners and decision-makers to understand their complex planning and decision-making environment. The Tool is not for operational or every-day use, but can be used at strategic points in NRM planning cycles. It can also be updated as new information becomes available. The Tool runs assessments for the whole of the Goulburn Broken Catchment but users can extract subsets of this data and analyse them using GIS.

The Tool's data library contains spatial information that represents the vulnerability and priority assessment criteria. The Tool has the capacity to include additional criteria and associated data. The actual number of criteria and data sets deployed to inform this Plan reflects the available information, difficulty to create or represent criteria spatially and the project budget.

3.3 Assessment of climate change vulnerability and adaptation priority

The assessment of the vulnerability of the Catchment's natural resources to climate change and adaptation priority reflects four main attributes (see figure 3):

1. *Exposure:* the extent to which a system or entity experiences climatic conditions that may cause damage or alter landscape or ecological processes.
2. *Sensitivity:* the extent to which exposure to climate change results in damage or disruption to landscape, ecological or socio-economic processes.
3. *Adaptive capacity:* the extent to which a system or entity is able to anticipate and adjust to climate change.
4. *Value:* incorporating environmental, social and economic value of wetlands and streams, strategic values associated with native vegetation, consequence of loss for economic infrastructure, economic production and environmental values, financial and economic value of land and presence of drought refuge habitats.

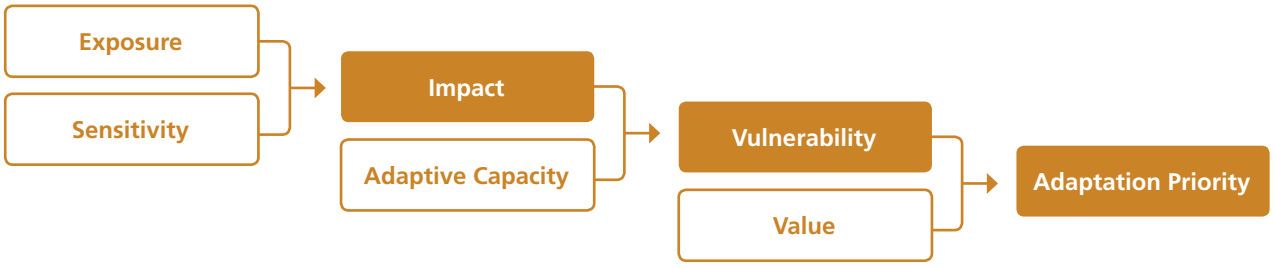
The regional NRM planning framework review and, particularly, the DPSIR analyses, were used, in consultation with regional NRM planning stakeholders, to identify a set of criteria that informed assessments of exposure, sensitivity, adaptive capacity and value. Factors considered in selecting criteria include:

- *Materiality:* the extent to which the criterion reflects a significant (or material) form of sensitivity to climate change to which natural resources and landscape processes are sensitive.
- *Differentiation:* the extent to which values of the criterion and/or its influence on natural resource assets, SES and landscape processes vary across space.
- *Data availability:* the availability of spatial data to represent the criterion or of data from which the criterion may be derived.
- *Confidence:* the level of confidence that the criterion will influence vulnerability.

The Tool uses a single climate change scenario in each 'run' to incorporate a specific time period, greenhouse gas emissions trajectory and/or global climate model (or ensemble of models) output. Climate scenarios are reflected in the exposure component of the vulnerability assessment. The vulnerability assessment was undertaken for the following three climate change scenarios (Timbal *et al.* 2015) using a criteria weighting scheme developed in consultation with regional NRM planning stakeholders.

1. *Low climate change:* warmer (0.5-1.5°C increase in annual average temperature), with little change in annual average rainfall (-5 to +5% change). This scenario is based on 2030 outputs for the ACCESS 1.0 global climate model under the Representative Concentration Pathways (RCP) 4.5 emissions pathway.

Figure 3: The climate change adaptation prioritisation framework (adapted from Schröter undated by Clifton and Pelikan 2014).



2. *Moderate climate change:* hotter (1.5-3.0°C increase in annual average temperature) and drier (5-15% reduction in annual average rainfall). This scenario is based on 2050 outputs for the GFDL ESM2M global climate model under the RCP 4.5 emissions pathway.
3. *High climate change:* much hotter (>3.0°C increase in annual average temperature) and much drier (>15% reduction in annual average rainfall). This scenario is based on 2070 outputs for the GFDL ESM2M global climate model under the RCP 8.5 emissions pathway.

Data representing the scenarios was provided by CSIRO under its *Climate Change Projections for Australia's Natural Resource Management Regions* project (Timbal *et al.* 2015), based on modelling undertaken for the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (2013).

The overall scoring for vulnerability and value criteria was used to identify two forms of priorities: those for planned adaptation and those for semi-autonomous adaptation. Planned adaptation focuses on areas of high value and high vulnerability and should be considered first when developing and implementing management programs to mitigate vulnerability to climate change. Semi-autonomous adaptation areas have high value but lower vulnerability under current tenure and management.

3.4 Development of adaptation options

The process for conceptualising and evaluating adaptation options was adapted from Smit *et al.* (2000) by Clifton and Pelikan (2014). The process draws on data outputs from the Tool as well as the regional NRM planning framework review and considers five questions:

1. Adaptation to what?

While climate change poses a significant risk for many of the natural systems managed by the Goulburn Broken CMA and its stakeholders, those systems' current state and the resulting impacts largely reflect the influence of other drivers and pressures. For adaptations to be taken up and successfully implemented, they need to be incorporated into responses that address climate-related and non-climate-related influences. In some instances, an adaptation's main influence will be to build resilience by reducing the effects of non-climate-related pressures.

This question is addressed with reference to two main sources of information:

- Tool outputs: the data set was interrogated using GIS to identify the main exposure, sensitivity and adaptive capacity criteria that are contributing to the vulnerability score.
- DPSIR analyses: the analyses were used to identify the broader set of drivers and pressures (climate and non-climate related) that influence on the state of natural resources to which adaptations are required to respond.

2. Who or what adapts?

The Tool data set was interrogated to determine the main values responsible for the focus area being identified. The components of the natural resource system that underpin those values should be addressed by adaptation actions. Components may include people and infrastructure, as well as natural assets such as land, water and biodiversity.

3. How are pressures and impacts currently being managed?

The Goulburn Broken CMA and its stakeholders are typically aware of the pressures faced by natural resources and systems and have well-developed responses to these pressures or the changes in state or impacts they have contributed to. Many of these also help to build resilience to climate change. The DPSIR analyses were interrogated to identify how pressures and impacts, including those potentially emerging as a result of climate change, are currently being managed.

4. How effective are these responses anticipated to be?

A high level assessment is made of the effectiveness of existing planned adaptations at managing the current suite of pressures and impacts and those which are anticipated to emerge as a result of climate change. This analysis indicated whether natural resources and systems are likely to be climate resilient without further adaptation.

5. What additional options could be considered?

The final step considered what new measures could be undertaken to develop or strengthen climate resilience of natural resources in the respective focus area. Options are considered in the following categories (after Willows and Connell, 2003) to encourage consideration of the full spectrum of climate change response opportunities. The DPSIR analyses have been considered where they specify new or additional adaptation options for climate-related drivers and pressures.

- *Modify the events:* Actions are undertaken to reduce the exposure of natural resources to climate events that may affect their condition. Provision of environmental flows or irrigation are examples of this type of adaptation to drought. Planned burning is an example of this type of adaptation to bushfires.
- *Respond to the effects:* Actions are undertaken to either protect against or reduce the sensitivity of the natural resources to climate change. These types of adaptation may include physical measures (e.g. construction of structures to provide environmental water), changes in operational or management practice (e.g. stubble retention to increase soil moisture retention and reduce drought sensitivity) and changes to planning, regulatory or institutional arrangements.
- *Reduce the risk:* Either the use of natural resources is changed to lessen or avoid impacts from climate change (e.g. changing from irrigation to dryland agriculture or vice versa) or the use is shifted to another location where there is less or no exposure to the relevant climate change risk.
- *Build adaptive capacity:* Research is undertaken to better understand and respond to risks from climate change and/or education and behavioural change programs are implemented to improve various key stakeholder groups' understanding of climate change and encourage appropriate adaptive responses on their part. Planning, regulatory or institutional options under 'respond to the effects' may also contribute to the development of adaptive capacity.

4. Influence of Climate Change on the Condition of the Catchment's Natural Resources

Information from the regional NRM planning framework review (see section 3.1) and stakeholder engagement has been used to describe the influence of climate change on each of the three regional natural resource classes identified in the *Goulburn Broken RCS*. Tables 1, 2 and 3 (below) summarise information from the DPSIR analyses (Clifton and Pelikan 2014) (see section 3.1), outlining the drivers and pressures with a **high influence** on natural resource condition and the trend that influence will experience under climate change based on mid-century projections under a relatively high emissions pathway. Some pressures have a high level of influence only under climate change.

The full DPSIR analyses (Clifton and Heard 2013, available from http://weconnect.gbcma.vic.gov.au/) identify links between *Drivers* and *Pressures*, *States* and *Pressures* and *Impacts* and *States*. As the Drivers and Pressures listed in table 2 all have a high level of influence on the condition of natural resources, all the drivers have an influence on all of the pressures to some degree which is why direct links have not been articulated here.

The DPSIR analyses are based on assumptions informed by expert consultants and regional NRM planners. These assumptions and the assessment criteria they inform will be updated as new information becomes available as per the Goulburn Broken CMA's Monitoring, Evaluation and Reporting Strategy (under review).

*Table 1: Summary of drivers and pressures with a **high influence** on the condition of land resources in the Goulburn Broken Catchment and the trend of influence under climate change*

Land: soil and land that is used for purposes other than nature conservation, including dryland and irrigation farming, timber production and urban and lifestyle uses

STRONGEST DRIVERS OF CONDITION	TREND OF INFLUENCE ON CONDITION UNDER CLIMATE CHANGE	DESCRIPTION OF ASSUMPTIONS
Water availability and policy reform	Increasing	Changing land use values interact with land use and management practice change as a driver. While this is not always the case, it often results in increased value on biodiversity compared with production and has contributed to private and public land conservation of biodiversity assets. As climate change adds to pressure on biodiversity condition, this may increase trade-offs between biodiversity and production.
Climate variability and change	Increasing	Climate has a strong and pervasive influence on land condition via precipitation and temperature patterns and their influence on land health and primary production. Direction of influence depends on climate phases, but overall assumed to be neither detrimental nor beneficial under historical conditions. Climate change is likely to have an overall detrimental influence on land condition.

STRONGEST DRIVERS OF CONDITION	TREND OF INFLUENCE ON CONDITION UNDER CLIMATE CHANGE	DESCRIPTION OF ASSUMPTIONS
Demographic change	No change to current level of influence	Demographic change is reflected in changes in age and density of population, as well as education, employment status and entrance of lifestyle landholders. Demographic change is not clearly influencing land condition in a particular direction, as expectations of land management/focus on stewardship and environmental values vary widely. Not clear how climate change would directly modify influence on land condition.
Land use and management change	Increasing	Much of the influence is a legacy, reflecting historical change in land use to agriculture and development of water resources for irrigation. Land use and management continues to change in the Catchment, with intensification (following irrigation system modernisation), neglect or improved management. Overall, land use and management change is considered to currently have neutral influence, reflecting the balance of positive changes (e.g. improved management of soil health issues in farming areas) and negative changes (e.g. neglect of land in some lifestyle areas). Climate change may lead to a more negative influence on land condition, reflecting impact of temperature and increased drought.
STRONGEST PRESSURES ON CONDITION	**TREND OF INFLUENCE ON CONDITION UNDER CLIMATE CHANGE**	**DESCRIPTION OF ASSUMPTIONS**
Change in fire regimes and management	Increasing	Key pressure on land state in public land areas. Severe fire weather is projected to increase with climate change, potentially placing further pressure on land condition.
Cultivation/ cropping/ grazing	Increasing	Legacy and ongoing effect of cropping and grazing on various measures of soil and land health. Improved practice in recent years is likely to reduce negative influence on condition rather than improve it (overall). Intensification of drought and extreme rainfall with climate change is likely to exacerbate influence on land condition.
Extreme weather & climate events (drought, fire, flood)	Increasing	Extreme weather, especially fire, flood and drought, continue to adversely affect land assets. Climate change is likely to increase adverse effects of fire and drought and may reduce flooding incidence.
Invasive plants and animals and disease	Increasing	Invasive species reduce agricultural productivity and, in some cases, expose soils to erosion (e.g. cape weed on ridges). Climate change may enable the introduction of new species and with more severe, extreme rainfall events, may exacerbate effects on land condition.
Irrigation and dryland salinity, high water tables	Decreasing	Legacy and ongoing effect of irrigation development and practice and dryland clearing, although the effects diminished in recent years compared to the 1980s and 1990s. With reduced rainfall under climate change, influence on land condition is likely to diminish further.
Irrigation - regulation, drainage, diversion and storages	Decreasing	Much of the influence on land condition is a historical legacy of elevated water tables and irrigation salinity. Effects of these on land condition have diminished in recent years and are anticipated to continue to do so with climate change.
Change in rainfall regime	Influence high only under climate change scenario	Land asset condition (e.g. erosion, agricultural production, salinity, soil carbon) tightly linked to rainfall. Changes will be pervasive across the Catchment and generally detrimental, although climate change is anticipated to further abate salinity issues.

*Table 2: Summary of drivers and pressures with a **high influence** on the condition of water resources in the Goulburn Broken Catchment and the trend of influence under climate change.*

Water: Waterways, floodplains, wetlands and groundwater aquifers and water used for consumptive and environmental uses

STRONGEST DRIVERS OF CONDITION	TREND OF INFLUENCE ON CONDITION UNDER CLIMATE CHANGE	DESCRIPTION OF ASSUMPTIONS
Water availability and policy reform	Increasing	Currently a positive influence on the condition of water assets as policy reform and water availability has recently provided for improved balance between environmental and consumptive water uses. With reduced rainfall under climate change, competition between environmental and consumptive water uses is likely to increase and water availability for environmental flows likely to reduce, leading to detrimental influence on the condition of water assets.
Climate variability and change	Increasing	Climate has a strong and pervasive influence on the condition of water assets via precipitation patterns and their influence on stream flows and water-dependent ecosystem processes. Climate influence is also expressed in terms of water temperature. Direction of influence depends on climate phases, but overall assumed to be neither detrimental nor beneficial under historical conditions. Climate change is likely to have an overall detrimental influence on the condition of water assets.
Land use and management change	No change to current level of influence	Much of the influence is a legacy, reflecting historical change in land use to agriculture and development of water resources for irrigation. Land use and management continues to change in many areas, with intensification (following irrigation system modernisation), neglect or improved management. Proliferation of farm dams affects water flows in lifestyle land use zones. Overall, considered to currently have a neutral influence, reflecting the balance of positive changes (e.g. improved management of sources of nutrient and sediment) and negative changes (e.g. farm dam proliferation). Climate change unlikely to directly modify influence on condition.

STRONGEST PRESSURES ON CONDITION	TREND OF INFLUENCE ON CONDITION UNDER CLIMATE CHANGE	DESCRIPTION OF ASSUMPTIONS
Change in fire regimes and management	Increasing	Key pressure on long-term water flows and shorter term water quality from wet eucalypt forests in key catchment areas (trend for excessive frequency in recent years). Severe fire weather projected to increase with climate change, potentially placing further pressure on water resources.
Extreme weather & climate events (drought, fire, flood)	Increasing	Extreme weather, especially fire and drought, continues to adversely affect water assets. Flooding has a generally positive influence on the condition of riparian, wetland and aquatic ecosystems. Climate change projected to increase adverse effects of fire and drought and may reduce flooding incidence.
Infrastructure development	Increasing	Legacy and on-going impact of irrigation and water infrastructure, as well as flood levees on flows, flooding into floodplain forests and movement of aquatic fauna. With less flow under climate change, influence on condition is likely to worsen.
Invasive plants and animals	Increasing	Invasive species compete with, displace, damage or prey on native flora and fauna, reducing populations and affecting recruitment in water-dependent ecosystems. Climate change may enable introduction of new pests.
Irrigation - regulation, drainage, diversion and storages	Increasing	Much of the influence on condition is a historical legacy of changes in flow and water regimes. While NRM programs are seeking to reduce the negative influence, this pressure still contributes to a negative trend in condition. Climate change will reduce water resource availability and likely increase detrimental impacts on condition.
Change in rainfall and run-off regime	Influence high only under climate change scenario	Water asset condition is tightly linked to rainfall, in terms of flows and water quality. Changes will be pervasive across the Catchment and water asset types and generally detrimental, because drier climate overall, increased drought incidence and intensity and increase in intensity of extreme rainfall events.
Increased temperature	Influence high only under climate change scenario	Aquatic ecosystems and incidence of blue green algal blooms is influenced by water temperature. Changes will be pervasive across the Catchment for aquatic ecosystems and water quality and will generally be detrimental.

*Table 3: Summary of drivers and pressures with a **high influence** on the condition of biodiversity resources in the Goulburn Broken Catchment and the trend of influence under climate change.*

Biodiversity: native vegetation communities, wetlands and waterways and associated plants, fungi, animals, microbes and genetic diversity they contain

STRONGEST DRIVERS OF CONDITION	TREND OF INFLUENCE ON CONDITION UNDER CLIMATE CHANGE	DESCRIPTION OF ASSUMPTIONS
Changing land use values	No change to current level of influence	Changing land use values interact with land use and management practice change as a driver. While this is not always the case, it has often resulted in increased value on biodiversity compared with production and has contributed to private and public land conservation of biodiversity assets. As climate change adds to pressure on biodiversity condition, this may drive stronger protections (or other interventions) for key biodiversity assets.
Water availability and policy reform	Increasing	Currently a positive influence on the condition of biodiversity as has recently provided improved balance of environmental and consumptive water uses. With reduced rainfall under climate change, competition between environmental and consumptive water uses is likely to increase and water availability for environmental flows likely to reduce, leading to a detrimental influence on biodiversity condition.
Climate variability and change	Increasing	Climate has a strong and pervasive influence on biodiversity condition via climate-dependent ecosystem processes. Direction of influence depends on climate phases, but overall is assumed to be neither detrimental nor beneficial. Climate change is likely to have an overall detrimental influence on biodiversity condition.
Land use and management change	No change to current level of influence	Much of the influence is a legacy, reflecting historical changes in land use to agriculture and development of water resources. Land use and management continues to change with intensification, neglect or improved management. Overall, considered to have negative influence on condition as biodiversity assets continue to decline. Climate change unlikely to directly modify influence on biodiversity condition.
STRONGEST PRESSURES ON CONDITION	**TREND OF INFLUENCE ON CONDITION UNDER CLIMATE CHANGE**	**DESCRIPTION OF ASSUMPTIONS**
Change in fire regime and management	Increasing	Key pressure on terrestrial ecosystems in forest and alpine areas (trend for excessive frequency) and rural land (trend for insufficient fire). Severe fire weather to increase with climate change, placing (especially) biodiversity in fire-sensitive systems in public land areas at risk.
Cultivation/ cropping/ grazing	No change to current level of influence	Much of the influence on condition is from historical activity, although, extension of cultivation to new areas (with changing technology and economics) and ongoing grazing is affecting native vegetation remnants in rural areas. No direct modification of influence on condition with climate change.

STRONGEST PRESSURES ON CONDITION	TREND OF INFLUENCE ON CONDITION UNDER CLIMATE CHANGE	DESCRIPTION OF ASSUMPTIONS
Extreme weather and climate events	Increasing	Extreme weather, especially fire and drought, adversely affects biodiversity in remnant native vegetation in rural areas and forests on public land. Flooding generally has a positive influence on condition of riparian, wetland and aquatic ecosystems. Climate change to increase adverse effects of fire and drought and may reduce flooding incidence.
Invasive plants and animals	Increasing	Invasive species compete with, displace, damage or prey on native flora and fauna, reducing population and affecting recruitment. Climate change may enable the introduction of new invasive species.
Irrigation – regulation, drainage, diversion and storages	Increasing	Much of the influence on condition is a historical legacy of changes in flow and water regimes. While NRM programs are seeking to reduce negative influence, this pressure still contributes to a negative trend in biodiversity condition. Climate change will reduce water resource availability and likely increase detrimental impact on biodiversity condition.
Change in rainfall regime	Influence high only under climate change scenario	Ecosystem processes tightly linked to rainfall. Changes will be pervasive across the Catchment in all ecosystem types and generally detrimental because drier climate overall and increased drought incidence and intensity under climate change.
Increased temperature	Influence high only under climate change scenario	Ecosystem processes are linked to temperature and fire (influenced by temperature). Changes will be pervasive across the Catchment for terrestrial and aquatic ecosystems and generally detrimental.

5. Impact of Climate Change on the Catchment's Natural Resources

The combination of exposure and sensitivity to climate change reflects the potential impact of climate change on the Goulburn Broken Catchment's natural resources (as per figure 4). See figure 5, 6 and 7 for results of the impact assessment. The criteria used for the impact assessment are outlined in table 4 (exposure) and table 5 (sensitivity).

Figure 4: Climate change impact assessment framework (adapted from Schröter undated by Clifton and Pelikan 2014).

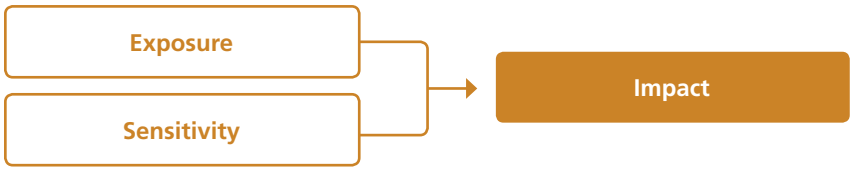


Table 4: Exposure assessment criteria with rationale (Clifton and Pelikan 2014)

WEIGHTING	EXPOSURE CRITERION	CRITERION RATIONALE
1	Maximum temperature: change in annual average	Temperature influences landscape processes that are important to all natural resource classes and social-ecological systems. Maximum temperatures influence processes including water balance, fire and senescence in some winter-growing agricultural species. The annual average rather than the seasonal average was selected due to it being able to broadly represent the suite of climate change-related temperature impacts across a year.
2	Average rainfall: Change in average spring rainfall	Rainfall is a critical influence on landscape processes across natural resource classes and social-ecological systems and is a key expression of exposure to climate change. River flows and farming systems, particularly, were considered to be much more sensitive to changes in autumn and/or spring rainfall than changes in annual average rainfall. Climate change is also projected to lead to changes in seasonal distribution of rainfall, with more change during winter and spring than at other times of year.
3	Average rainfall: Change in average autumn rainfall	
3	Surface water yields: change in mean annual flow	Mean annual flow integrates impacts of changes in rainfall regime (amount, seasonality and variability), as well as temperature and potential evaporation. It is a key expression of exposure to climate change for water resources (including irrigation farming and towns). Change in mean annual flow is more relevant to agricultural water uses in irrigation regions than for other irrigation users and the environment. However, it is the only readily available data set that incorporates climate change projections.
4	Waterlogging and salinity: current shallow aquifer depth to water table	Shallow aquifer depth to water table is a key pressure for natural resources in the Shepparton Irrigation Region and to a lesser extent in other irrigation areas and parts of the dryland. Shallow water tables are also important in sustaining groundwater-dependent ecosystems, which may be important drought refuges for native fauna. *Note: Only current conditions can be used as there is no other consistent data set available for the whole of the Goulburn Broken Catchment.*

WEIGHTING	EXPOSURE CRITERION	CRITERION RATIONALE
5	Flooding: area currently inundated in 1 per cent annual exceedance probability event	Flooding is a critical influence on ecological processes in rivers, wetlands and floodplains and also poses an important climate-related hazard for built infrastructure and some land uses. The current 1 per cent annual exceedance probability event is a good guide to flood extent under climate change, although it is likely that floods in the current 1 per cent annual exceedance probability area may increase in frequency. Recent flood studies have not necessarily considered climate change and hence only current flood extent can be considered consistently across the region.
5	Minimum temperature: change in annual average	Temperature influences landscape processes that are important to all natural resource classes and SESs. Minimum temperatures influence, for example, snow incidence and persistence and flowering patterns in agricultural and native species. The annual average rather than the seasonal average was selected due to it being able to broadly represent the suite of climate change-related temperature impacts across a year.

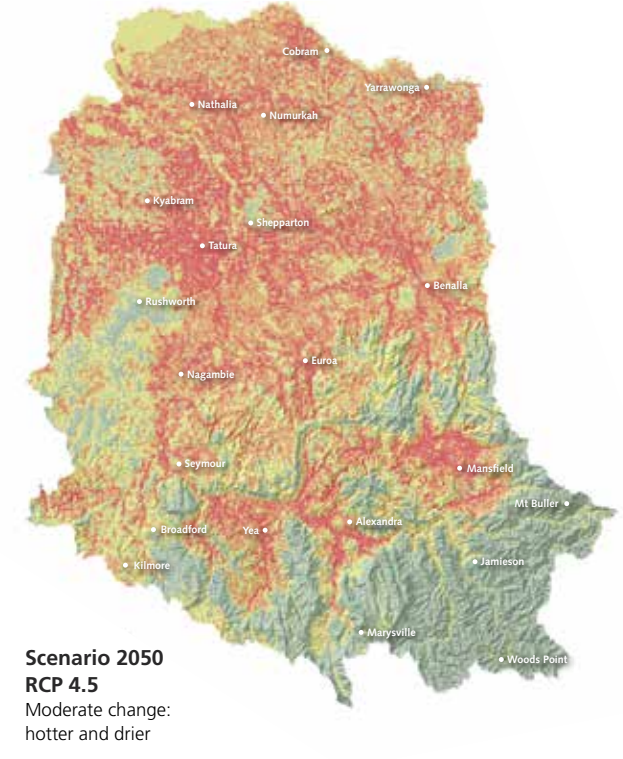
Table 5: Sensitivity assessment criteria with rationale (Clifton and Pelikan 2014)

WEIGHTING	EXPOSURE CRITERION	CRITERION RATIONALE
1	Habitat condition: native vegetation fragmentation or connectivity	The condition of native vegetation, particularly in terms of the level of fragmentation and disturbance, and its connectivity to large, contiguous areas is considered to strongly influence its vulnerability to a variety of pressures, including those arising from, or exacerbated by, climate change. These are critical sensitivity issues for terrestrial biodiversity and riparian and wetland vegetation.
1	Habitat condition: native vegetation condition	
2	River health: index of stream condition streamside zone	This is a measure of the condition of riparian vegetation and hence a key indicator of river health and the sensitivity of rivers to various pressures, including climate change. As this criterion incorporates vegetation condition and connectivity, it partly duplicates the habitat condition criteria.
3	Rarity: native vegetation range under current conditions	Ecological vegetation class bioregional conservation status was the data set used to represent this criterion, highlighting ecological vegetation classes that have a restricted distribution. These are considered to be vulnerable to climate change because: • they have a naturally small range and may therefore be adapted to quite specific climatic conditions that may no longer exist at their current locations as a result of climate change. • clearing and other disturbances have modified their natural range and hence they are likely to be subject to a variety of other environmental pressures and hence most likely less resilient to climate change.
3	Land use: current land use	Land use was classified according to sensitivity to various impacts of climate change. Data illustrates the variable nature of sensitivity to climate change.
3	Land and soil health hazards	Several topography and landform criteria have been included in this criterion, such as slope and susceptibility to various soil health hazards (e.g. acidity, salinity, erosion). This highlights sensitivity to climate change from a land and soil health perspective.
4	Wetland health: proximity to wetlands	The intention was to incorporate a measure of the hydrologic regime experienced by wetlands and hence their health from index of wetland condition datasets. However, there is insufficient data to represent the criterion across the Catchment. Proximity to wetlands is used as a surrogate, on the basis that wetlands are sensitive locations due to their dependence on strongly climate-influenced factors such as river flows and/or water tables.

Figure 5: Impact of climate change on the Goulburn Broken Catchment's natural resources in scenario 2030.

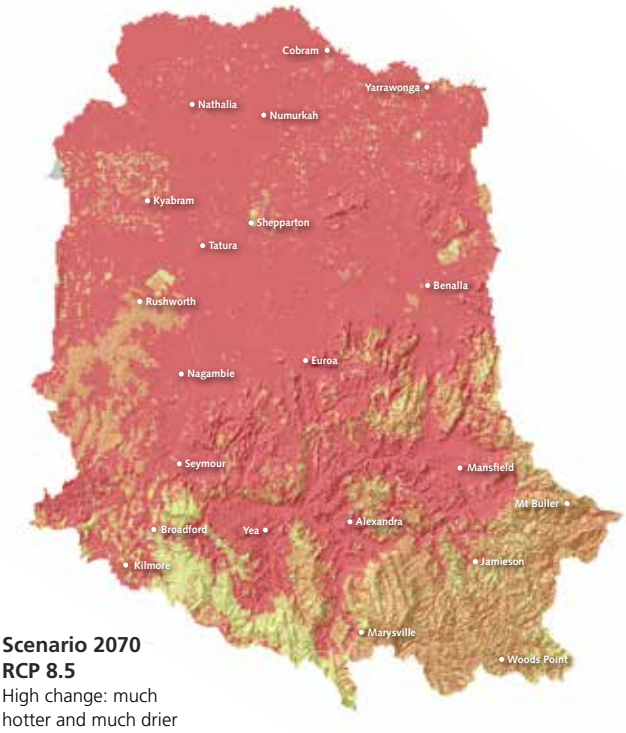
Scenario 2030
RCP 4.5
Low change: warmer
with little change in rainfal

Figure 6: Impact of climate change on the Goulburn Broken Catchment's natural resources in scenario 2050.

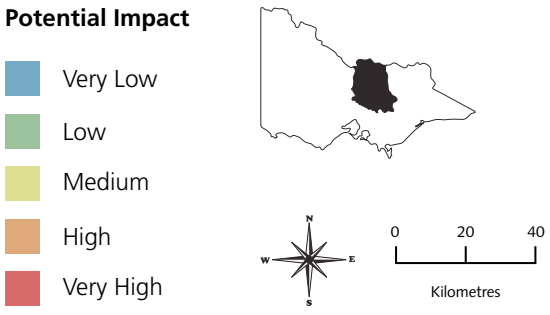


Scenario 2050
RCP 4.5
Moderate change:
hotter and drier

Figure 7: Impact of climate change on the Goulburn Broken Catchment's natural resources in scenario 2070.



Scenario 2070
RCP 8.5
High change: much
hotter and much drier



Please note: These maps are not intended to incorporate all decision-making elements but represent an assessment of climate change impact based on spatially-enabled criteria for exposure and sensitivity as part of a climate change vulnerability assessment. Vulnerability is used to highlight locations and issues to focus further analysis, including risk assessment and management. These maps should be considered in conjunction with the Climate Change Adaptation Plan for Natural Resource Management in the Goulburn Broken Catchment, Victoria, 2016 in its entirety.

Maps showing the exposure and sensitivity assessment results independently can be found in Appendix B and C respectively.

6. Vulnerability of the Catchment's Natural Resources to Climate Change

The vulnerability assessment is a combination of the impacts and adaptive capacity assessment (see figure 8). See figure 9, 10 and 11 for the results of this assessment. Table 6 outlines the criteria used to assess adaptive capacity.

Figure 8: Vulnerability assessment framework (adapted from Schröter undated by Clifton and Pelikan 2014).

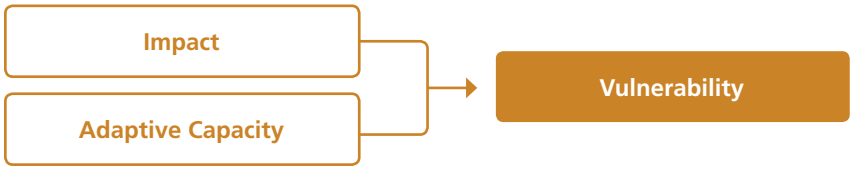


Table 6: Adaptive capacity assessment criteria with rationale (Clifton and Pelikan 2014).

WEIGHTING	EXPOSURE CRITERION	CRITERION RATIONALE
1	Biodiversity and river health: level of protection provided by tenure	The tenure of private and public land is classified in a way that indicates its likely exposure to pressures for disturbances, such as grazing, cultivation and timber harvesting. It is therefore considered indicative of adaptive capacity. Protective private land tenures include areas subject to management agreements and conservation covenants. Public land tenure looks at 64 tenure categories derived from the Public Land Management dataset.
2	Irrigation farming: access to irrigation supply	Access to irrigation water supply is considered to be a key measure of adaptive capacity for agricultural land uses, as (in regulated water catchments) it reduces dependency on annual rainfalls.
3	Natural resource management works	Previous engagement with NRM programs is considered to be a measure of planned adaptive capacity. All forms of NRM program works are considered, including, for example, fencing, revegetation, and waterway rehabilitation.
4	Land: whole farm or property planning	Whole farm or property planning is widely used to establish a framework for improved and sustainable management of farming operations in dryland and irrigation areas. It typically leads to other environmental works, including improvements in irrigation layout and drainage and protection and enhancement of environmental assets.

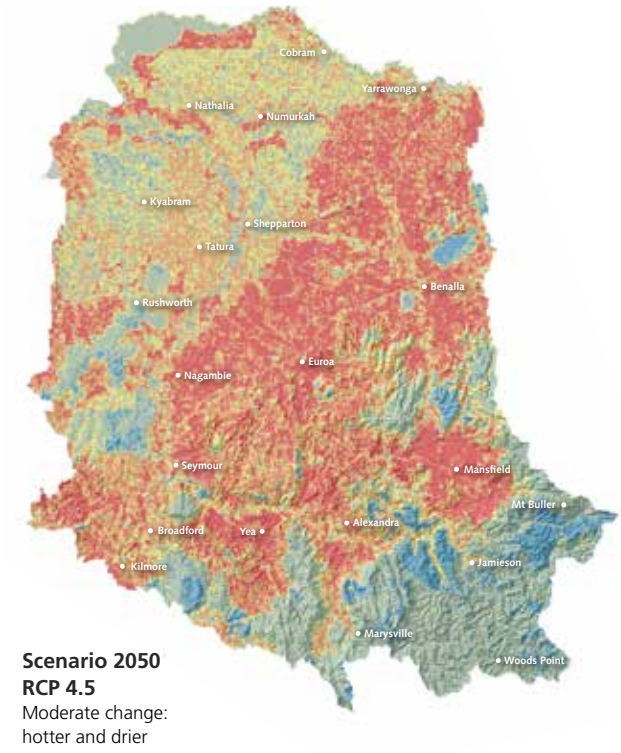
As outlined, the vulnerability assessment maps reflects criteria for impacts (exposure and sensitivity) (see section 5) and adaptive capacity (see above).

See Appendix D for a map showing the independent results of the assessment of current (from the year 2014) adaptive capacity of the Catchment's natural resources to climate change. Please note that ongoing investment in management actions will be required to maintain and increase adaptive capacity as climatic conditions change over time (see section 7.5 and 7.6).

Figure 9: Vulnerability of the Goulburn Broken Catchment's natural assets to climate change in scenario 2030

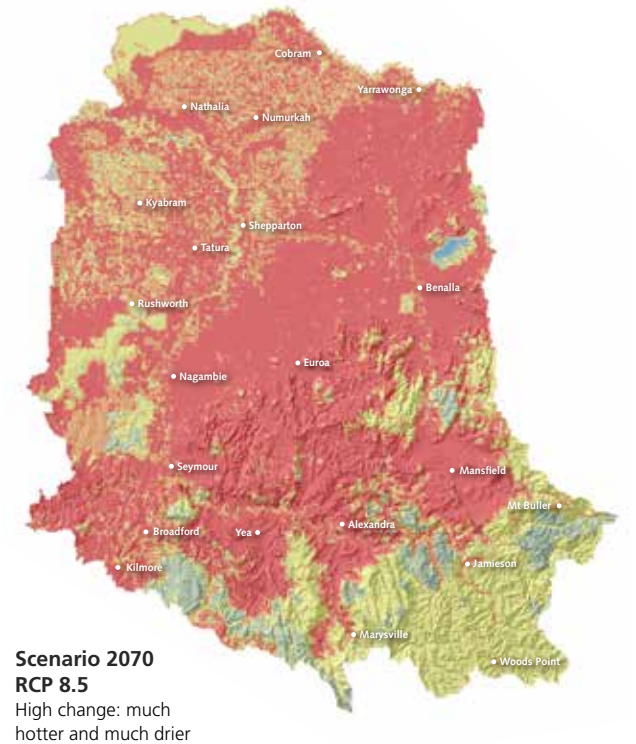
Scenario 2030
RCP 4.5
Low change: warmer
with little change in rainfall

Figure 10: Vulnerability of the Goulburn Broken Catchment's natural assets to climate change in scenario 2050

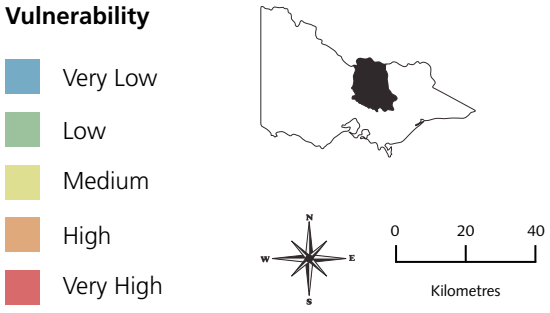


Scenario 2050
RCP 4.5
Moderate change:
hotter and drier

Figure 11: Vulnerability of the Goulburn Broken Catchment's natural assets to climate change in scenario 2070



Scenario 2070
RCP 8.5
High change: much
hotter and much drier



Please note: These maps are not intended to incorporate all decision-making elements but represent an assessment of climate change impact based on spatially-enabled criteria for exposure and sensitivity as part of a climate change vulnerability assessment. Vulnerability is used to highlight locations and issues to focus further analysis, including risk assessment and management. These maps should be considered in conjunction with the Climate Change Adaptation Plan for Natural Resource Management in the Goulburn Broken Catchment, Victoria, 2016 in its entirety.

7. Focus Areas for Climate Change Adaptation and Management Options

The assessment of adaptation priority considers vulnerability plus value (see figure 12). Table 7 outlines the criteria used to assess value.

Figure 12: The adaptation priority assessment framework (adapted from Schröter undated by Clifton and Pelikan 2014).

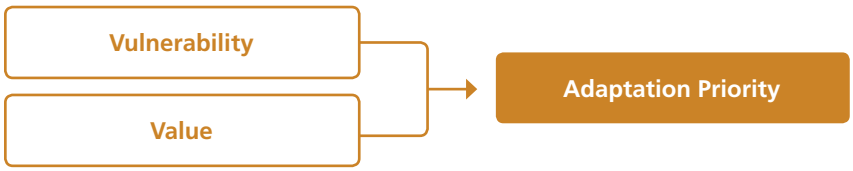


Table 7: Value assessment criteria and rationale (Clifton and Pelikan 2014).

WEIGHTING	EXPOSURE CRITERION	CRITERION RATIONALE
1	Biodiversity value	Relative priority for adaptation increases with biodiversity value. Key biodiversity assets provide core habitat or habitat corridors to allow migration of species towards core habitat areas that are potentially important climate refuges. *Note: NaturePrint was used to identify key biodiversity values in Catchment. The value of fragmented landscapes across the foothills of the Catchment, which provide key connections from the Murray corridor in the north to the intact vegetation in the south of the Catchment, was increased from the mid-range to high in order for NaturePrint to better reflect the values identified in the Biodiversity Strategy for the Goulburn Broken Catchment (Miles et al 2010).*
1	Stream reach and wetland value	Priority for adaptation increases according to the overall ecological, economic and social value attributed to particular stream reaches and wetlands. Value is considered in combination with the level of threat faced by each stream reach (which makes the approach consistent with the consideration of functional landscapes in biodiversity value). *Note: Incorporation of waterway and wetland values reflects the approach taken in the Goulburn Broken Waterway Strategy 2014-2022 (GB CMA 2014).*
2	Consequence of loss	Harm from pressures such as bushfire and flooding. The criterion incorporates three components, as follows: • Environmental: a measure of environmental values that may be at risk of loss at particular locations • Economic production: a measure of economic production values associated with land uses which may be at risk of loss at particular locations • Economic infrastructure: measure of economic infrastructure that may be at risk at particular locations.
3	Micro-refugia	Micro-refugia are locations in the landscape where topography and aspect, particularly, provide some protection from the effects of fire and drought and help to ensure a regular and consistent supply of water. *Note: this criterion contributes to a preference for drought and fire refugia being considered as priority areas for climate change adaptation.*
4	Land value	Economic value of land is represented by the land use classification. This will be interpreted in a different way to the sensitivity assessment. Priority for adaptation should increase with the attributed value of the land use.
5	Floodplain value	Economic value of floodplains is represented by land use classification. Environmental values are represented in biodiversity, stream reach and wetland values.

Please note: there is only a slight variation in weightings.

Eleven focus areas have been identified for climate change adaptation (see figures 13 and 14).

Focus areas have been identified in two types of landscapes; each are of high value but differ in vulnerability under the climate change scenario for 2030:

1. *Planned adaptation priority focus areas* have *higher sensitivity* and *lower adaptive capacity* and are of high value.

   Such areas should be considered first for developing and implementing management programs to address vulnerability to climate change. Subsequent assessments of factors such as feasibility of intervention, return on investment and natural resource condition with respect to impact thresholds should determine if such management programs proceed. Some major waterways showing a high priority for adaptation have not been included in the focus areas (for example, Broken Creek and upper reaches of the Broken River) as they are not associated with adjoining areas of adaptation priority. These waterways and other smaller or more dispersed areas showing an adaptation priority can be considered for investment in management options as resourcing allows.

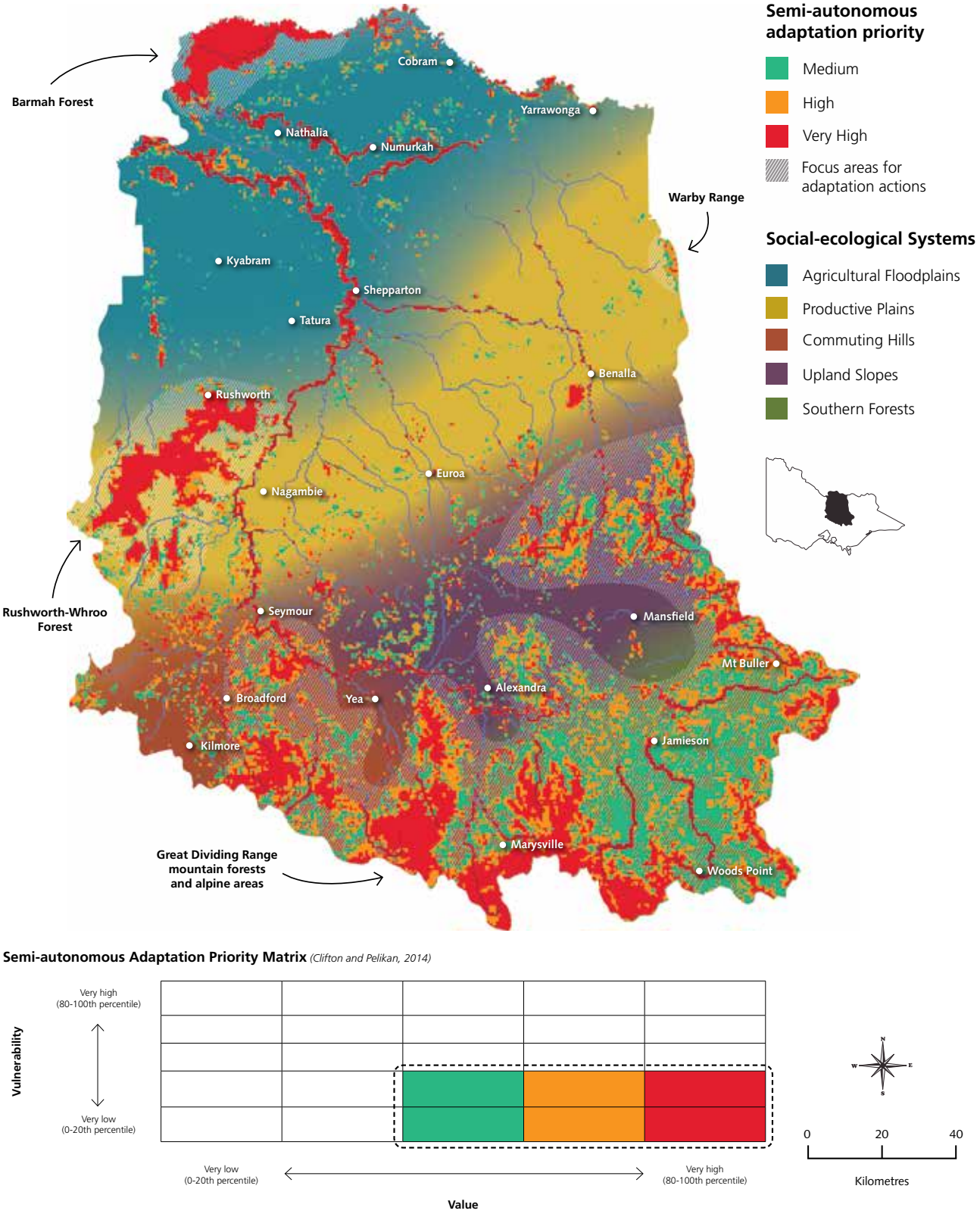
2. S*emi-autonomous adaptation priority focus areas* have *lower sensitivity* and *higher adaptive capacity* under current management and tenure arrangements and are of high value.

   This suggests that for these areas, specific adaptation management interventions may not be required above current management and tenure arrangements. However, given the relatively high asset values present, a "watching brief" should be maintained to detect any changes in natural resource condition that suggests the need for adaptation. Since vulnerability to climate change is projected to increase over time, it is possible that some semi-autonomous adaptation priority areas could become priority areas for planned adaptation in the future.

The development of management options in this Plan represents only the first step in a process of detailed adaptive management planning for the Goulburn Broken CMA. Subsequent steps will need to engage with stakeholders and communities while continuing to investigate and understand the interactions between social-ecological systems and drivers of change and how key points of vulnerability to natural resources may be overcome plus the feasibility and effectiveness of adaptation options.

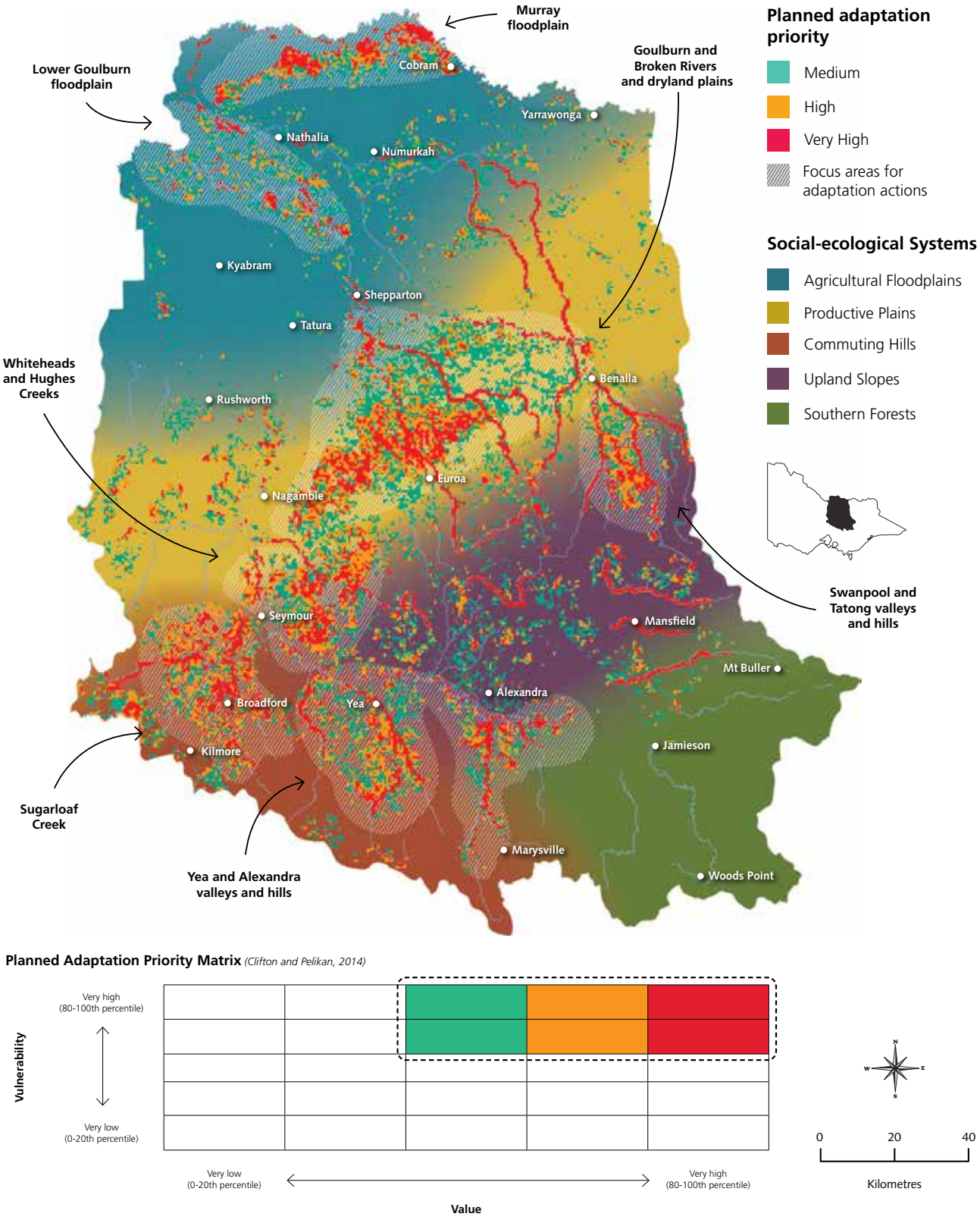
The process for conceptualising and evaluating adaptation options is outlined in section 3.4. The results of this process are presented below. The DPSIR analyses have been considered where they specify new or additional adaptation options for climate-related drivers or pressures (Clifton and Pelikan 2014).

Figure 13: Focus areas in the Goulburn Broken Catchment for semi-autonomous climate change adaptation under the 2030 climate change scenario RCP 4.5



Please note: These maps are not intended to incorporate all decision-making elements but represent an initial prioritisation for climate change adaptation based on spatially-enabled criteria for vulnerability and value. Vulnerability is used to highlight locations and issues to focus further analysis, including risk assessment and management. These maps should be considered in conjunction with the Climate Change Adaptation Plan for Natural Resource Management in the Goulburn Broken Catchment, Victoria, 2016 in its entirety.

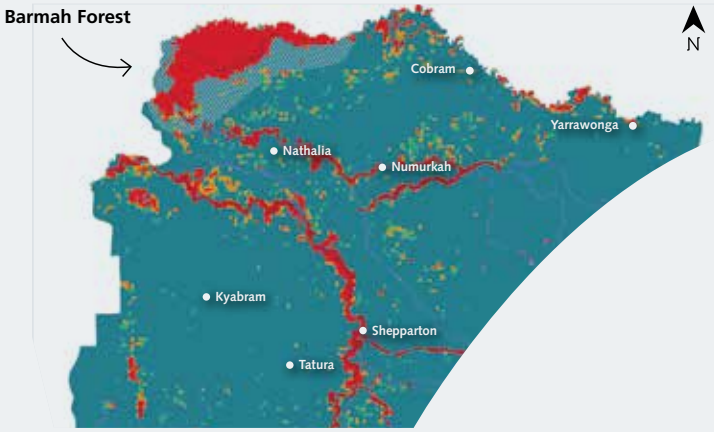
Figure 14: Focus areas in the Goulburn Broken Catchment for planned climate change adaptation under the 2030 climate change scenario RCP 4.5



Assessment criteria and rationale can be found in section 5 (exposure and sensitivity), section 6 (adaptive capacity) and section 7 (value).

7.1 Agricultural Floodplains Social-ecological System

Semi-autonomous adaptation focus area: **Barmah Forest**



Features:

- RAMSAR Wetland
- Part of the world's largest River Red Gum forest

Values *(criteria from the spatial assessment):*

- remnant native vegetation of high conservation status
- high environmental consequence of loss
- potential drought refugia in waterways and other low-lying land

Figure 15: Semi-autonomous adaptation priority areas in the Agricultural Floodplains of the Goulburn Broken Catchment

KEY VULNERABILITY FACTORS

Exposure:

- change in maximum and minimum temperature
- change in spring and autumn rainfall.

Sensitivity:

- areas of native vegetation with high bioregional conservation status
- soil hazards
- climate sensitive land uses

A feature of this area is the relatively low sensitivity.

Adaptive capacity:

Protective tenure arrangements result in this area having a high adaptive capacity score

KEY PRESSURES

Climate and weather:

- intense rainfall events
- reduced rainfall
- intensified and more frequent drought
- increased average and extreme temperatures

Land:

- bushfires
- recreation

Biodiversity:

- invasive plants and animals
- bushfires and changed fire regimes
- firewood collection
- recreation

Water:

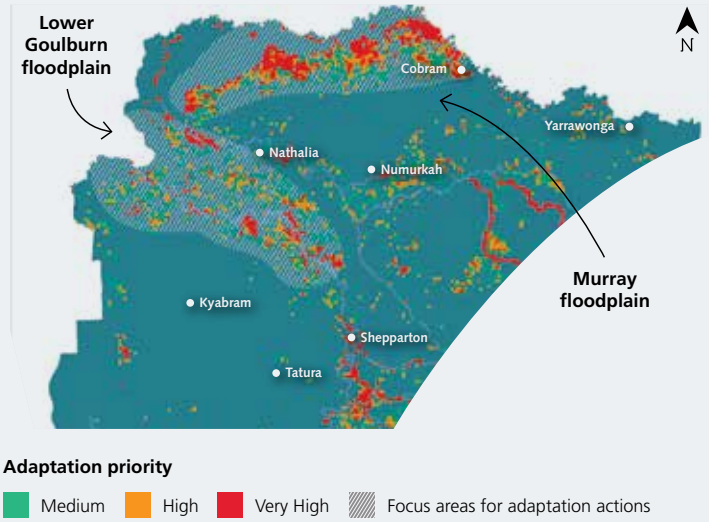
- bushfire impacts on stream flows and water quality
- changed water yields
- tourism
- recreation impacts on water quality

Community:

Changing values and expectations for land use from public land

Please note: These maps are not intended to incorporate all decision-making elements but represent an initial prioritisation for climate change adaptation based on spatially-enabled criteria for vulnerability and value. Vulnerability is used to highlight locations and issues to focus further analysis, including risk assessment and management. These maps should be considered in conjunction with the Climate Change Adaptation Plan for Natural Resource Management in the Goulburn Broken Catchment, Victoria, 2016 in its entirety.

Planned adaptation focus areas:
Lower Goulburn Floodplain (LGF) and Murray Floodplain (MF)



Features:

- LGF: Lower Goulburn River and Broken Creek floodplain
- MF: Agricultural areas on the Murray River floodplain

Values *(criteria from the spatial assessment):*

- remnant native vegetation of high conservation status
- high environmental and economic (production and infrastructure) consequence of loss
- potential drought refugia in waterways and other low-lying land
- high land value

Figure 16: Planned adaptation priority areas in the Agricultural Floodplains of the Goulburn Broken Catchment

KEY VULNERABILITY FACTORS

Exposure:

- shallow water tables
- flooding
- change in maximum and minimum temperature
- change in spring and autumn rainfall

Sensitivity:

- remnant native vegetation fragmented and in relatively poor condition
- disturbed riparian zone and wetlands
- concentration of remnant native vegetation with high bioregional conservation status
- soil hazards
- climate sensitive land use

Adaptive capacity:

- limited access to irrigation (especially LGF)
- limited history of natural resource management works
- land tenure not protective of natural resources

KEY PRESSURES

Climate and weather:

Intense rainfall events, reduced rainfall, intensified and more frequent drought, increased average and extreme temperatures.

Land:

Shallow water tables, invasive plants and animals, livestock grazing, cultivation, irrigation and land forming, soil health decline (acidification, erosion, carbon depletion, loss of groundcover), agricultural chemical use, dairy effluent disposal, peri-urban development (LGF).

Biodiversity:

Invasive plants and animals, historical vegetation clearing, incremental on-going tree loss (tree decline, land and infrastructure development, firewood collection), changed flooding regime, waterway barriers to aquatic species movement.

Water:

Flow modification, water quality decline (erosion, septic tanks, stock), loss of access to shallow groundwater by dependent ecosystems, irrigation water use, irrigation drainage, lower water allocations during extended drought.

Community:

Off-property income, time and/or finance for land management.

The key vulnerability factors have been drawn from an interrogation of the spatial assessment data (see section 3.3). The key pressures have been identified from the DPSIR analyses (see section 3.1 and 4).

Semi-autonomous adaptation focus area:
Barmah Forest

WHO OR WHAT ADAPTS?
Biodiversity: native vegetation and native fauna
Land uses: nature conservation, forestry production, recreation, tourism
Water: water inflows to reservoirs, waterways, aquatic environments and drought refugia
People: recreation and tourism providers
Infrastructure: buildings and other infrastructure exposed to bushfires

	HOW ARE PRESSURES AND IMPACTS CURRENTLY BEING MANAGED?	HOW EFFECTIVE ARE THESE RESPONSES ANTICIPATED TO BE?
State Government regulation and land management	• Bushfires: Code of Practice for Bushfire Management, Fire Operations Planning, planned burning programs, fuel hazard and post-fire monitoring, strategic fire break maintenance, fire detection and suppression • Conservation reserves: Park management plans; Park maintenance, feral and invasive species management • Water resource management: water resource planning that accounts for impacts of projected climate change; multiple large storages, provision of environmental flows, bushfire detection and suppression • Firewood collection: local and State government regulations	• Bushfires: likely moderately effective in addressing human safety risks, but incidence and impact of fires likely to be exacerbated with climate change, even with existing responses • Conservation reserves: likely moderately effective in containing existing pressures, less effective in containing pressures resulting from change in rainfall and temperature regimes • Water resource planning: likely effective in anticipating effects of climate change on resource availability, but limited effectiveness in containing impacts • Firewood collection: dependent on level of enforcement
Emergency management arrangements: preparation, management and recovery phases	Bushfire: planned burning, fire response arrangements, emergency warnings, bushfire recovery, Code of Practice for Bushfire Management.	Bushfire: fire warnings and response effective in reducing threats to human safety (community and responders) under most conditions. Disaster recovery arrangements likely effective in reducing pressures. Effectiveness of responses tested under catastrophic fire danger conditions, which will increase in frequency with climate change. Effectiveness of planned burning is yet to be determined.

Planned adaptation focus areas:
Lower Goulburn Floodplain (LGF) and Murray Floodplain (MF)

WHO OR WHAT ADAPTS?

- **Biodiversity:** terrestrial and riparian remnant vegetation and fauna, wetlands
- **Land uses:** agriculture, urban land use (Lower Goulburn Floodplain)
- **Water:** waterways, floodplain wetlands, aquatic environments, drought refugia
- **People:** farming landholders, town residents
- **Infrastructure:** buildings and other infrastructure exposed to flooding in urban areas

	HOW ARE PRESSURES AND IMPACTS CURRENTLY BEING MANAGED?	HOW EFFECTIVE ARE THESE RESPONSES ANTICIPATED TO BE?
NRM and other land management programs (including agricultural industry programs)	• community education and extension • whole farm planning, irrigation layout and drainage improvements • regional irrigation drainage programs (groundwater and surface water) • floodplain land retirement • invasive species management • native vegetation protection and restoration • riparian and wetland fencing and revegetation • groundwater management plan • protective tenure arrangements: conservation covenants, land management agreements etc. • irrigation, soil, land, vegetation, riparian, wetland "best management practices" • natural resource condition monitoring	• likely moderate to high effectiveness for managing pressures relating to remnant vegetation, groundcover, waterways and wetlands – where adopted by landholders • key constraints: resources (time and finance) for management
Land use planning and regulation	• development and building controls in flood prone areas • environmental significance, erosion and other land management overlays • vegetation clearing controls • Dairy effluent: management controls to reduce nutrient export to streams and avoid excessive loadings to land • multi-organisation regional coordination groups for planning strategy and implementation	• Land use planning and development controls: controls on development in flood prone areas likely to be at least moderately effective in reducing impacts, except under extreme conditions; • Vegetation protection: likely effective in retaining larger vegetation patches on private land, but not effective in containing incremental losses of small patches and paddock trees; • Dairy effluent: effective enforcement of dairy effluent management controls likely to contain nutrient impacts on streams
Emergency management arrangements: preparation, management and recovery phases	Flooding: emergency warnings, building, transport and other infrastructure placement and design, urban and rural drainage, flood mitigation infrastructure	Flooding: likely effective in managing impacts except for established infrastructure developed in floodways and where climate change will significantly change flood depth, extent and flow velocity
Water resource and irrigation management	• irrigation system modernisation (mostly LGF) • environmental watering plans for key floodplain wetlands and environmental flows for rivers • regional water resource planning and irrigation water supply infrastructure • groundwater management plan • water markets and water market information (mostly LGF) • regional irrigation drainage programs (groundwater, surface water; mostly LGF)	• water markets reduce economic impacts of drought, except where water supplies extremely depleted; • regional surface water and sub-surface drainage systems (especially LGF) effective in reducing shallow water tables and salinity and reduce impacts of flooding – particularly for less extreme events; • environmental water provision effective for wetlands and floodplains benefitting from water allocation.
Insurance	flood and/or fire damages	likely to offset damage costs for affected properties. Cost and/or availability of cover may be tightened with climate change if frequency and scale of impacts increase materially.

What additional actions can be considered?

Options are considered in several categories to encourage consideration of the full spectrum of climate change response opportunities (Willows and Connell 2003). The development of management options in this Plan represents only the first step in a process of detailed adaptive management planning (see beginning of section 7).

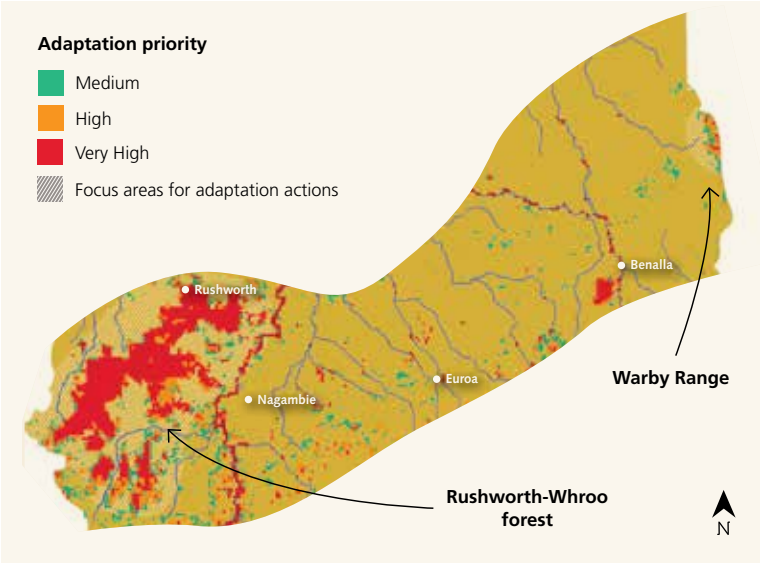
Barmah Forest is a semi-autonomous adaptation focus area that has lower vulnerability than the Lower Goulburn and Murray floodplains focus areas. No additional planned actions are proposed in response to climate change, rather, largely managed through current responses (outlined above) and the system allowed to react and respond to climate change in a largely undirected manner. At some future stage, planned interventions may be required if or as resilience thresholds are approached. In the meantime, adaptive capacity building options, such as research and monitoring, may assist in identifying triggers and mechanisms for planned interventions. A limited suite of other adaptation management actions can be considered, as described here.

Semi-autonomous adaptation focus area: **Barmah Forest**	
Modify the events	• Limited additional adaptation options
Respond to the effects	• Limited additional adaptation options
Reduce the risk	• Migrate settlements from interfaces with highest risk bushfire environment.
Build adaptive capacity	• Research into resilience of restricted range species whose habitats are at high risk from climate change • Research into long-term management of key fire sensitive environments under climate change • Research into water resource impacts of climate change and potential implications for irrigation, environmental watering and urban supplies • Monitoring of natural resource state to detect trends indicative of climate change impacts and to provide potential triggers for changed management

Planned adaptation focus area: **Lower Goulburn Floodplain (LGF) and Murray Floodplain (MF)**	
Modify the events	• Infrastructure construction to protect flood prone urban environments (MF) • Develop and implement streamflow management plans (in catchments without them) to reduce impacts of farm dams and other forms of water interception on riparian, wetland and aquatic ecosystems • Develop and implement groundwater management plans (in areas without them) to reduce impacts of groundwater use on groundwater-dependent ecosystems and drought refugia
Respond to the effects	• Strategic revegetation and native vegetation protection programs to identify and build the size and connectivity of key native vegetation remnants, for example, along roads and waterways to nearby public land forest areas and strengthen water quality protection • Strengthen native vegetation retention controls and planning to protect resilience features of high value remnant native vegetation patches and drought refugia • Modify land use planning in flood zones to reflect projected changes in flood depth and extent with climate change
Reduce the risk	• Reinstate floodplain function • Retire highly flood-prone agricultural land from use
Build adaptive capacity	• Research into the need and opportunity to introduce new species or provenances to maintain ecosystem function under climate change.

7.2 Productive Plains Social-ecological System

Semi-autonomous adaptation focus areas:
Rushworth-Whroo Forest and Warby Range



Features:

- Box-Ironbark Woodland

Values *(criteria from the spatial assessment):*

- remnant native vegetation of high conservation status
- high environmental consequence of loss
- potential drought refugia in waterways and other low-lying land

Figure 17: Semi-autonomous adaptation priority areas in the Productive Plains of the Goulburn Broken Catchment

KEY VULNERABILITY FACTORS

Exposure:

- change in maximum and minimum temperature
- change in spring and autumn rainfall.

Sensitivity:

- areas of native vegetation with high bioregional conservation status
- soil hazards
- climate sensitive land uses

A feature of this area is the relatively low sensitivity.

Adaptive capacity:

Protective tenure arrangements result in this area having a high adaptive capacity score.

KEY PRESSURES

Climate and weather:

Intense rainfall events, reduced rainfall, intensified and more frequent drought, increased average and extreme temperatures

Land:

- timber harvesting
- bushfires
- recreation

Biodiversity:

- invasive plants and animals
- bushfires and changed fire regimes
- timber harvesting
- recreation

Water:

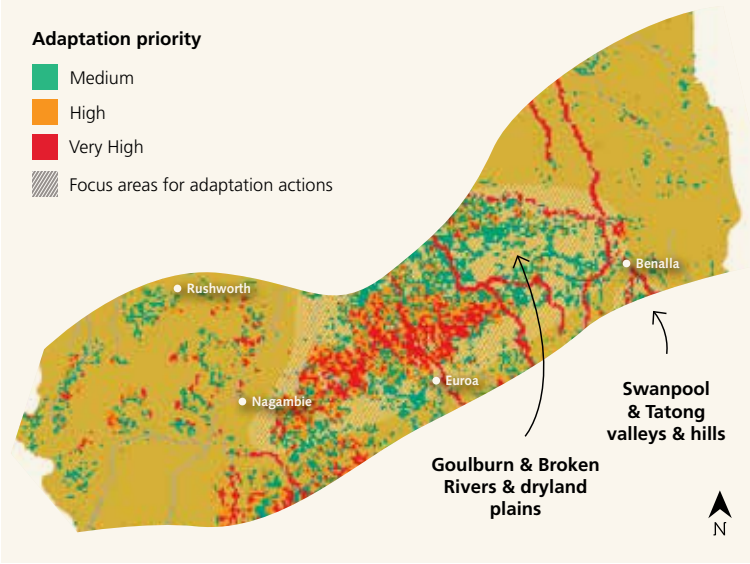
- bushfire impacts on stream flows and water quality
- changed water yields
- tourism
- recreation impacts on water quality

Community:

Changing values and expectations for land use from public land

Please note: These maps are not intended to incorporate all decision-making elements but represent an initial prioritisation for climate change adaptation based on spatially-enabled criteria for vulnerability and value. Vulnerability is used to highlight locations and issues to focus further analysis, including risk assessment and management. These maps should be considered in conjunction with the Climate Change Adaptation Plan for Natural Resource Management in the Goulburn Broken Catchment, Victoria, 2016 in its entirety.

Planned adaptation focus areas:
Goulburn & Broken rivers & dryland plains (GBRDP) and Swanpool & Tatong valleys & hills (STVH) (part)



Features:

- GBRDP: Agricultural area on plains between Goulburn and Broken Rivers; towns of Euroa, Violet Town and Kialla are located within the area, Shepparton is immediately downstream; includes reaches of Pranjip (Muddy), Seven and Honeysuckle creeks and the Broken River
- STVH: Cleared hill country and river flats south of Benalla; Broken River; Hollands, Ryans and Moonee Creeks; settlements of Swanpool, Tatong and Molyullah are nearby. Benalla is immediately downstream.

Values *(criteria from the spatial assessment):*

- remnant native vegetation of high conservation status
- high environmental and economic (production and infrastructure) consequence of loss
- potential drought refugia in waterways and other low-lying land
- high land value

Figure 18: Planned adaptation priority areas in the Productive Plains of the Goulburn Broken Catchment

KEY VULNERABILITY FACTORS

Exposure:

- shallow water tables
- flooding
- change in maximum and minimum temperature
- change in spring and autumn rainfall

Sensitivity:

- remnant native vegetation fragmented and in relatively poor condition
- disturbed riparian zone
- disturbed wetlands (STVH)
- concentration of remnant native vegetation with high bioregional conservation status
- soil hazards
- climate sensitive land use

Adaptive capacity:

- limited access to irrigation
- limited history of natural resource management works
- land tenure not protective of natural resources

KEY PRESSURES

Climate and weather:

Intense rainfall events, reduced rainfall, intensified and more frequent drought, increased average and extreme temperatures, catastrophic bushfires (Swanpool & Tatong valleys & hills).

Land:

Shallow water tables, invasive plants and animals, land value is high relative to value of production, intensification of settlement (urban and peri-urban), livestock grazing, cultivation, soil health decline (acidification, erosion, carbon depletion, loss of groundcover).

Biodiversity:

Invasive plants and animals, historical vegetation clearing, incremental on-going tree loss (tree decline, land and infrastructure development, firewood collection).

Water:

Flow modification, water quality decline (erosion, septic tanks, stock), loss of access to shallow groundwater by dependent ecosystems, downstream urban flooding.

Community:

Population growth, land ownership turnover, limited skills, time and/or finance for land management, absentee ownership, off-property employment.

The key vulnerability factors have been drawn from an interrogation of the spatial assessment data (see section 3.3). The key pressures have been identified from the DPSIR analyses (see section 3.1 and 4).

Semi-autonomous adaptation focus areas:
Rushworth-Whroo Forest and Warby Range

WHO OR WHAT ADAPTS?

- **Biodiversity:** native vegetation and native fauna
- **Land uses:** nature conservation, forestry production, recreation, tourism
- **Water**: water inflows to reservoirs, waterways, aquatic environments and drought refugia
- **People:** recreation and tourism providers
- **Infrastructure:** buildings and other infrastructure exposed to bushfires

	HOW ARE PRESSURES AND IMPACTS CURRENTLY BEING MANAGED?	HOW EFFECTIVE ARE THESE RESPONSES ANTICIPATED TO BE?
State Government regulation and land management	• Timber production: Code of Practice for Timber Production, Forest Management Plans, forest management zoning, Forest Audit Program, road construction and maintenance, invasive species management • Bushfires: Code of Practice for Bushfire Management, Fire Operations Planning, planned burning programs, fuel hazard and post-fire monitoring, strategic fire break maintenance, fire detection and suppression • Conservation reserves: Park management plans; Park maintenance, feral and invasive species management • Water resource management: water resource planning that accounts for impacts of projected climate change; multiple large storages, provision of environmental flows, bushfire detection and suppression • Firewood collection: local and State government regulations	• Timber production: largely effective in mitigating off-site impacts of harvesting operations, except for flow reductions from wet sclerophyll forests and those resulting from climate change • Bushfires: likely moderately effective in addressing human safety risks, but incidence and impact of fires likely to be exacerbated with climate change, even with existing responses • Conservation reserves: likely moderately effective in containing existing pressures, less effective in containing pressures resulting from change in rainfall and temperature regimes • Water resource planning: likely effective in anticipating effects of climate change on resource availability, but limited effectiveness in containing impacts • Firewood collection: dependent on level of enforcement
Emergency management arrangements: preparation, management and recovery phases	Bushfire: planned burning, fire response arrangements, emergency warnings, bushfire recovery, Code of Practice for Bushfire Management.	Bushfire: fire warnings and response effective in reducing threats to human safety (community and responders) under most conditions. Disaster recovery arrangements likely effective in reducing pressures. Effectiveness of responses tested under catastrophic fire danger conditions, which will increase in frequency with climate change. Effectiveness of planned burning is yet to be determined.

Planned adaptation focus areas:
Goulburn & Broken rivers & dryland plains (GBRDP) and Swanpool & Tatong valleys & hills (STVH) (part)

WHO OR WHAT ADAPTS?

- **Biodiversity:** terrestrial and riparian remnant vegetation and fauna, wetlands
- **Land uses:** agriculture, lifestyle/amenity uses, urban land use
- **Water:** waterways, riverine wetlands, aquatic environments, drought refugia
- **People:** farming and lifestyle landholders, town residents
- **Infrastructure:** buildings and other infrastructure exposed to flooding (in downstream urban areas) and bushfires (STVH)

	HOW ARE PRESSURES AND IMPACTS CURRENTLY BEING MANAGED?	HOW EFFECTIVE ARE THESE RESPONSES ANTICIPATED TO BE?
NRM and other land management programs (including agricultural industry programs)	• community education and extension • whole farm planning • invasive species management • native vegetation protection and restoration • riparian and wetland fencing and revegetation • protective tenure arrangements: conservation covenants, land management agreements etc. • soil, land, vegetation, riparian, wetland "best management practices" • Groundwater management plan • natural resource condition monitoring	• likely moderate to high effectiveness for managing pressures relating to remnant vegetation, groundcover, waterways and wetlands – where adopted by landholders. Low level of uptake likely (especially peri-urban areas of STVH) given population density, growth and transience – this will diminish the potential impacts of responses • key constraints: resources (time, finance, skills, experience) for management
Land use planning and regulation	• urban and peri-urban zoning, boundaries and property sizes • use of septic tanks • development and building controls in flood zones and bushfire prone areas (STVH) • environmental significance, erosion and other land management overlays • vegetation clearing controls • multi-organisation regional coordination groups for planning strategy and implementation	• Land use planning and development controls (mostly STVH): - can establish limits on population growth and density, but as these have not yet been reached, pressures on natural resource assets and values likely to increase - likely to contain impacts resulting from floods and bushfire, (possibly) except under extreme conditions • Vegetation protection: likely effective in retaining larger vegetation patches on private land, but not effective in containing incremental losses of small patches and paddock trees;
Emergency management arrangements: preparation, management and recovery phases	• Bushfire (STVH): planned burning, fire response arrangements, emergency warnings, bushfire recovery, Code of Practice for Bushfire Management • Flooding: emergency warnings, building, transport and other infrastructure placement and design, urban and rural drainage, flood mitigation infrastructure	• Bushfire (STVH): effective in limiting threats to human safety (community and responders) under most conditions; disaster recovery arrangements likely effective in reducing pressures; effectiveness of responses tested under catastrophic fire danger conditions • Flooding: likely effective in managing impacts except for established infrastructure developed in floodways and where climate change will significantly change flood depth, extent and flow velocity
Insurance	flood and/or fire damages	likely to offset damage costs for affected properties. Cost and/or availability of cover may be tightened with climate change if frequency and scale of impacts increase materially.

What additional actions can be considered?

Options are considered in several categories to encourage consideration of the full spectrum of climate change response opportunities (Willows and Connell 2003). The development of management options in this Plan represents only the first step in a process of detailed adaptive management planning (see beginning of section 7).

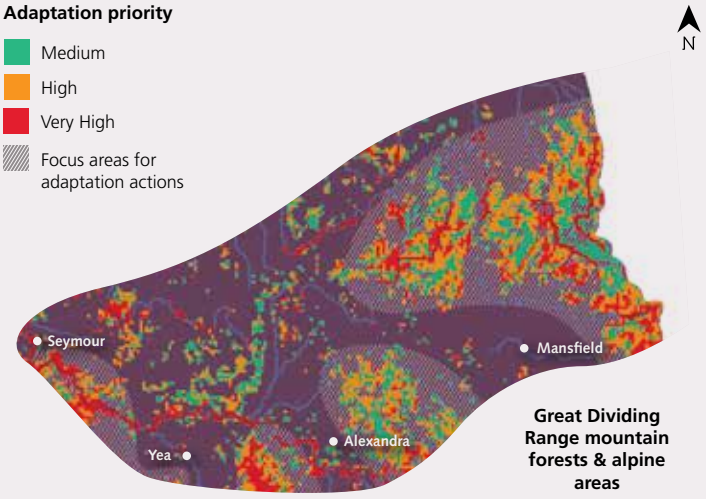
Rushworth-Whroo Forest and Warby Range focus areas have lower vulnerability than the Goulburn & Broken rivers & dryland plains and Swanpool & Tatong valleys & hills focus areas. No additional planned actions are proposed in response to climate change, rather, largely managed through current responses (outlined above) and the system allowed to react and respond to climate change in a largely undirected manner. At some future stage, planned interventions may be required if or as resilience thresholds are approached. In the meantime, adaptive capacity building options, such as research and monitoring, may assist in identifying triggers and mechanisms for planned interventions. A limited suite of other adaptation management actions can be considered, as described here.

Semi-autonomous adaptation focus area: **Rushworth-Whroo Forest and Warby Range**	
Modify the events	• Limited additional adaptation options
Respond to the effects	• Limited additional adaptation options
Reduce the risk	• Migrate settlements from interfaces with highest risk bushfire environment.
Build adaptive capacity	• Research into resilience of restricted range species whose habitats are at high risk from climate change • Research into long-term management of key fire sensitive environments under climate change • Research into water resource impacts of climate change and potential implications for irrigation, environmental watering and urban supplies • Monitoring of natural resource state to detect trends indicative of climate change impacts and to provide potential triggers for changed management

Planned adaptation focus area: **Goulburn & Broken rivers & dryland plains (GBRDP) and Swanpool & Tatong valleys & hills (STVH) (part)**	
Modify the events	• Infrastructure construction to protect flood prone urban environments • Perennial vegetation reinstatement in hill country to reduce flash run-off and flood, erosion and water quality impacts of extreme rainfall events • Develop and implement streamflow management plans (in catchments without them) to reduce impacts of farm dams and other forms of water interception on riparian, wetland and aquatic ecosystems • Develop and implement groundwater management plans (in areas without them) to reduce impacts of groundwater use on groundwater-dependent ecosystems and drought refugia • Address bushfire hazard in public land areas fringing the social-ecological system boundary
Respond to the effects	• Strategic revegetation and native vegetation protection programs to identify and build the size and connectivity of key native vegetation remnants, for example, along roads and waterways to nearby public land forest areas, and strengthen water quality protection • Encourage revegetation and/or perennial grass establishment on hills to maintain groundcover and protect against erosion, salinity and flash flooding • Strengthen native vegetation retention controls and planning to protect resilience features of high value remnant native vegetation patches and drought refugia
Reduce the risk	• Manage fire ignition risk, e.g. electricity distribution lines, in areas with high risk from catastrophic bushfires (STVH) • Migrate residential and other flood sensitive land uses away from flood-exposed areas
Build adaptive capacity	• Peri-urban and lifestyle landholder natural resource management programs to encourage such landholders to engage in measures to protect soil health and remnant vegetation and to develop the skills and capacity for implementation; and to strengthen bushfire preparation and response capabilities. • Research into the need and opportunity to introduce new species or provenances to maintain ecosystem function under climate change.

7.3 Upland Slopes Social-ecological System

Semi-autonomous adaptation focus areas:
Great Dividing Range mountain forests & alpine areas



Features:

- Mountain forests
- Alpine woodlands
- Meadows and wetlands of the northern fall of the Great Dividing Range

Values *(criteria from the spatial assessment):*

- high environmental and economic (infrastructure relating to water supply catchments) consequence of loss
- remnant native vegetation of high conservation status
- potential drought refugia in waterways and other low-lying land

Figure 19: Semi-autonomous adaptation priority areas in the Upland Slopes of the Goulburn Broken Catchment

KEY VULNERABILITY FACTORS

Exposure:

- change in maximum and minimum temperature
- change in spring and autumn rainfall

Sensitivity:

- alpine wetlands
- areas of native vegetation with high bioregional conservation status
- soil hazards
- climate sensitive land uses

A feature of this area is the relatively low sensitivity.

Adaptive capacity:

Protective tenure arrangements result in this area having a high adaptive capacity score

KEY PRESSURES

Climate and weather:

- intense rainfall events
- reduced rainfall
- intensified and more frequent drought
- increased average and extreme temperatures
- catastrophic bushfires
- changed snow regime

Land:

- timber harvesting
- bushfires
- recreation

Biodiversity:

- invasive plants and animals
- bushfires and changed fire regimes
- timber harvesting
- recreation

Water:

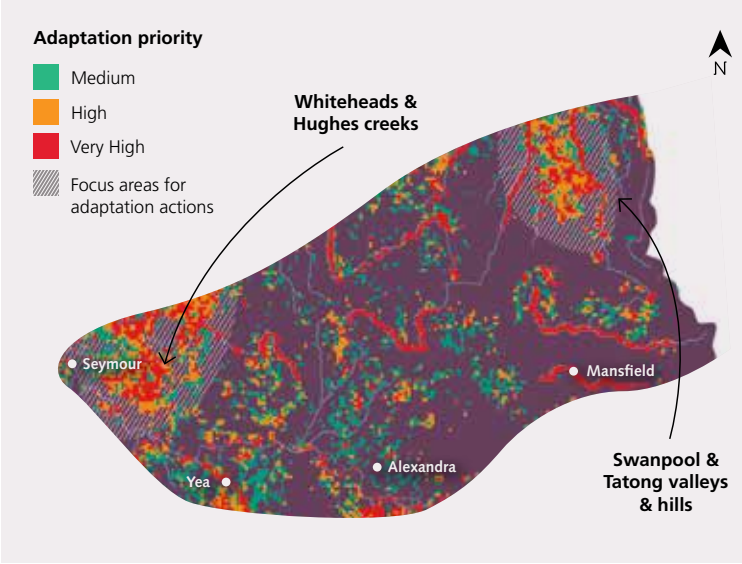
- bushfire impacts on stream flows and water quality
- changed water yields
- tourism
- recreation impacts on water quality

Community:

Changing values and expectations for land use from public land.

Please note: These maps are not intended to incorporate all decision-making elements but represent an initial prioritisation for climate change adaptation based on spatially-enabled criteria for vulnerability and value. Vulnerability is used to highlight locations and issues to focus further analysis, including risk assessment and management. These maps should be considered in conjunction with the Climate Change Adaptation Plan for Natural Resource Management in the Goulburn Broken Catchment, Victoria, 2016 in its entirety.

Planned adaptation focus areas:
Whiteheads & Hughes creeks (WHC) and Swanpool & Tatong valleys & hills (STVH) (part)



Features:

- WHC: Catchments of Whiteheads and Hughes creeks; towns of Avenel and Seymour located on perimeter of focus area
- STVH: Cleared hill country and river flats south of Benalla; Broken River; Hollands, Ryans and Moonee Creeks; settlements of Swanpool, Tatong and Molyullah are nearby. Benalla is immediately downstream.

Values *(criteria from the spatial assessment):*

- remnant native vegetation of high conservation status
- high environmental and economic (production and infrastructure) consequence of loss
- potential drought refugia in waterways and other low-lying land
- high land value

Figure 20: Planned adaptation priority areas in the Upland Slopes of the Goulburn Broken Catchment

KEY VULNERABILITY FACTORS

Exposure:

- shallow water tables
- flooding
- change in maximum and minimum temperature
- change in spring and autumn rainfall

Sensitivity:

- remnant native vegetation fragmented and in relatively poor condition
- disturbed riparian zone and wetlands
- concentration of remnant native vegetation with high bioregional conservation status
- soil hazards
- climate sensitive land use

Adaptive capacity:

- no or very limited access to irrigation
- limited history of natural resource management works
- land tenure not protective of natural resources

KEY PRESSURES

Climate and weather:

Climate and weather: intense rainfall events, reduced rainfall, intensified and more frequent drought, increased average and extreme temperatures, catastrophic bushfires (STVH).

Land:

Shallow water tables, invasive plants and animals, land value is high relative to value of production, intensification of settlement (urban and peri-urban), livestock grazing, cultivation (STVH), soil health decline (acidification, erosion, carbon depletion, loss of groundcover).

Biodiversity:

Invasive plants and animals, historical vegetation clearing, incremental on-going tree loss (tree decline, land and infrastructure development, firewood collection).

Water:

Flow modification, water quality decline (erosion, septic tanks, stock), loss of access to shallow groundwater by dependent ecosystems, downstream urban flooding.

Community:

Population growth, land ownership turnover, limited skills, time and/or finance for land management, absentee ownership, off-property employment.

The key vulnerability factors have been drawn from an interrogation of the spatial assessment data (see section 3.3). The key pressures have been identified from the DPSIR analyses (see section 3.1 and 4).

Semi-autonomous adaptation focus areas:
Great Dividing Range mountain forests & alpine areas

WHO OR WHAT ADAPTS?
Biodiversity: native vegetation and native fauna
Land uses: nature conservation, forestry production, recreation, tourism
Water: water inflows to reservoirs, waterways, aquatic environments and drought refugia
People: recreation and tourism providers
Infrastructure: buildings and other infrastructure exposed to bushfires

	HOW ARE PRESSURES AND IMPACTS CURRENTLY BEING MANAGED?	HOW EFFECTIVE ARE THESE RESPONSES ANTICIPATED TO BE?
State Government regulation and land management	• Timber production: Code of Practice for Timber Production, Forest Management Plans, forest management zoning, Forest Audit Program, road construction and maintenance, invasive species management • Bushfires: Code of Practice for Bushfire Management, Fire Operations Planning, planned burning programs, fuel hazard and post-fire monitoring, strategic fire break maintenance, fire detection and suppression • Conservation reserves: Park management plans; Park maintenance, feral and invasive species management • Water resource management: water resource planning that accounts for impacts of projected climate change; multiple large storages, provision of environmental flows, bushfire detection and suppression • Firewood collection: local and State government regulations	• Timber production: largely effective in mitigating off-site impacts of harvesting operations, except for flow reductions from wet sclerophyll forests and those resulting from climate change • Bushfires: likely moderately effective in addressing human safety risks, but incidence and impact of fires likely to be exacerbated with climate change, even with existing responses • Conservation reserves: likely moderately effective in containing existing pressures, less effective in containing pressures resulting from change in rainfall and temperature regimes • Water resource planning: likely effective in anticipating effects of climate change on resource availability, but limited effectiveness in containing impacts • Firewood collection: dependent on level of enforcement
Emergency management arrangements: preparation, management and recovery phases	Bushfire: planned burning, fire response arrangements, emergency warnings, bushfire recovery, Code of Practice for Bushfire Management	Bushfire: fire warnings and response effective in reducing threats to human safety (community and responders) under most conditions. Disaster recovery arrangements likely effective in reducing pressures. Effectiveness of responses tested under catastrophic fire danger conditions, which will increase in frequency with climate change. Effectiveness of planned burning is yet to be determined.
Recreation	• Snow making • Development of summer season activities	Snow making is likely to have reduced effectiveness with warming climate. Seasonal diversification is likely to offset some impact of reduced skiing season

Planned adaptation focus areas:
Whiteheads & Hughes creeks (WHC) and Swanpool & Tatong valleys & hills (STVH) (part)

WHO OR WHAT ADAPTS?
Biodiversity: terrestrial and riparian remnant vegetation and fauna
Land uses: agriculture, lifestyle/amenity uses, urban land use
Water: waterways, riverine wetlands, aquatic environments, drought refugia
People: farming and lifestyle landholders, town residents
Infrastructure: buildings and other infrastructure exposed to flooding (in downstream urban areas) and bushfires (STVH)

	HOW ARE PRESSURES AND IMPACTS CURRENTLY BEING MANAGED?	HOW EFFECTIVE ARE THESE RESPONSES ANTICIPATED TO BE?
NRM and other land management programs (including agricultural industry programs)	• community education and extension • whole farm planning • invasive species management • native vegetation protection and restoration • riparian and wetland fencing and revegetation • protective tenure arrangements: conservation covenants, land management agreements etc. • soil, land, vegetation, riparian, wetland "best management practices" • Groundwater management plan • natural resource condition monitoring	• likely moderate to high effectiveness for managing pressures relating to remnant vegetation, groundcover, waterways and wetlands – where adopted by landholders. Low level of uptake likely (esp. WHC and peri-urban areas of STVH) given population density, growth and transience – this will diminish the potential impacts of responses • key constraints: resources (time, finance, skills, experience) for management
Land use planning and regulation	• urban and peri-urban zoning, boundaries and property sizes • use of septic tanks • development and building controls in flood zones and bushfire prone areas (STVH) • environmental significance, erosion and other land management overlays • vegetation clearing controls • multi-organisation regional coordination groups for planning strategy and implementation	• Land use planning and development controls: - can establish limits on population growth and density, but as these have not yet been reached, pressures on natural resource assets and values likely to increase - likely to contain impacts resulting from floods and bushfire, (possibly) except under extreme conditions • Septic tanks: effective enforcement likely to contain additional nutrient inputs into streams • Vegetation protection: likely effective in retaining larger vegetation patches on private land, but not effective in containing incremental losses of small patches and paddock trees;
Emergency management arrangements: preparation, management and recovery phases	• Bushfire: planned burning, fire response arrangements, emergency warnings, bushfire recovery, Code of Practice for Bushfire Management • Flooding: emergency warnings, building, transport and other infrastructure placement and design, urban and rural drainage, flood mitigation infrastructure	• Bushfire: effective in limiting threats to human safety (community and responders) under most conditions; disaster recovery arrangements likely effective in reducing pressures; effectiveness of responses tested under catastrophic fire danger conditions • Flooding: likely effective in managing impacts except for established infrastructure developed in floodways and where climate change will significantly change flood depth, extent and flow velocity
Insurance	flood and/or fire damages	likely to offset damage costs for affected properties. Cost and/or availability of cover may be tightened with climate change if frequency and scale of impacts increase materially.

What additional actions can be considered?

Options are considered in several categories to encourage consideration of the full spectrum of climate change response opportunities (Willows and Connell 2003). The development of management options in this Plan represents only the first step in a process of detailed adaptive management planning (see beginning of section 7).

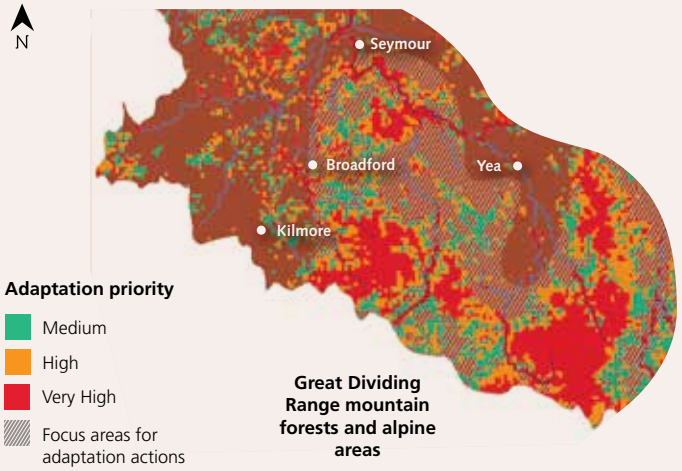
The Great Dividing Range mountain forests & alpine areas focus area has lower vulnerability than the Whiteheads & Hughes creeks and Swanpool & Tatong valleys and hills focus areas. No additional planned actions are proposed in response to climate change, rather, largely managed through current responses (outlined above) and the system allowed to react and respond to climate change in a largely undirected manner. At some future stage, planned interventions may be required if or as resilience thresholds are approached. In the meantime, adaptive capacity building options, such as research and monitoring, may assist in identifying triggers and mechanisms for planned interventions. A limited suite of other adaptation management actions can be considered, as described here.

Semi-autonomous adaptation focus area: **Great Dividing Range mountain forests & alpine areas**	
Modify the events	• Limited additional adaptation options
Respond to the effects	• Limited additional adaptation options
Reduce the risk	• Migrate settlements from interfaces with highest risk bushfire environment.
Build adaptive capacity	• Research into resilience of alpine and other restricted range species whose habitats are at high risk from climate change • Research into long-term management of key fire sensitive environments under climate change • Research into water resource impacts of climate change and potential implications for irrigation, environmental watering and urban supplies • Monitoring of natural resource state to detect trends indicative of climate change impacts and to provide potential triggers for changed management

Planned adaptation focus area: **Whiteheads & Hughes creeks (WHC) and Swanpool & Tatong valleys & hills (STVH) (part)**	
Modify the events	• Infrastructure construction to protect flood prone urban environments • Perennial vegetation reinstatement in hill country to reduce flash run-off and flood, erosion and water quality impacts of extreme rainfall events • Develop and implement streamflow management plans (in catchments without them) to reduce impacts of farm dams and other forms of water interception on riparian, wetland and aquatic ecosystems • Develop and implement groundwater management plans (in areas without them) to reduce impacts of groundwater use on groundwater-dependent ecosystems and drought refugia • Address bushfire hazard in public land areas fringing the social-ecological system boundary
Respond to the effects	• Strategic revegetation and native vegetation protection programs to identify and build the size and connectivity of key native vegetation remnants, for example, along roads and waterways to nearby public land forest areas and strengthen water quality protection • Encourage revegetation and/or perennial grass establishment on hills to maintain groundcover and protect against erosion, salinity and flash flooding • Strengthen native vegetation retention controls and planning to protect resilience features of high value remnant native vegetation patches and drought refugia
Reduce the risk	• Manage fire ignition risk, e.g. electricity distribution lines, in areas with high risk from catastrophic bushfires • Migrate residential and other flood sensitive land uses away from flood-exposed areas
Build adaptive capacity	• Peri-urban and lifestyle landholder natural resource management programs to encourage such landholders to engage in measures to protect soil health and remnant vegetation and to develop the skills and capacity for implementation; and to strengthen bushfire preparation and response capabilities. • Research into the need and opportunity to introduce new species or provenances to maintain ecosystem function under climate change.

7.4 Commuting Hills Social-ecological System

Semi-autonomous adaptation focus areas:
Great Dividing Range mountain forests & alpine areas



Features:

- Mountain forests
- Alpine woodlands
- Meadows and wetlands of the northern fall of the Great Dividing Range

Values *(criteria from the spatial assessment):*

- high environmental and economic (infrastructure relating to water supply catchments) consequence of loss
- remnant native vegetation of high conservation status
- potential drought refugia in waterways and other low-lying land

Figure 21: Semi-autonomous adaptation priority areas in the Commuting Hills of the Goulburn Broken Catchment

KEY VULNERABILITY FACTORS

Exposure:

- change in maximum and minimum temperature
- change in spring and autumn rainfall

Sensitivity:

- alpine wetlands
- areas of native vegetation with high bioregional conservation status
- soil hazards
- climate sensitive land uses

A feature of this area is the relatively low sensitivity.

Adaptive capacity:

Protective tenure arrangements result in this area having a high adaptive capacity score.

KEY PRESSURES

Climate and weather:

- intense rainfall events
- reduced rainfall
- intensified and more frequent drought
- increased average and extreme temperatures
- catastrophic bushfires
- changed snow regime

Land:

- timber harvesting
- bushfires
- recreation

Biodiversity:

- invasive plants and animals
- bushfires and changed fire regimes
- timber harvesting
- recreation

Water:

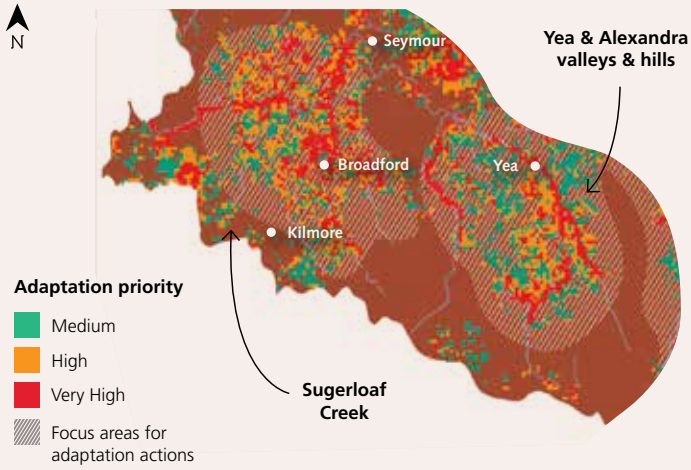
- bushfire impacts on stream flows and water quality
- changed water yields
- tourism
- recreation impacts on water quality

Community:

Changing values and expectations for land use from public land.

Please note: These maps are not intended to incorporate all decision-making elements but represent an initial prioritisation for climate change adaptation based on spatially-enabled criteria for vulnerability and value. Vulnerability is used to highlight locations and issues to focus further analysis, including risk assessment and management. These maps should be considered in conjunction with the Climate Change Adaptation Plan for Natural Resource Management in the Goulburn Broken Catchment, Victoria, 2016 in its entirety.

Planned adaptation focus areas:
Sugarloaf Creek (SC) and Yea & Alexandra valleys & hills (YAVH) (part)



Features:

- SC: Catchments of Sugarloaf, Mollison and Sunday Creeks, Broadford, Kilmore and Pyalong located on the perimeter
- YAVH: Cleared hill country and valleys of Acheron and Yea rivers and King Parrot Creek, south of the Goulburn River, Yea located within focus area

Values *(criteria from the spatial assessment):*

- remnant native vegetation of high conservation status
- high environmental and economic consequence of loss
- potential drought refugia in waterways and other low-lying land
- high land value

Figure 22: Planned adaptation priority areas in the Commuting Hills of the Goulburn Broken Catchment

KEY VULNERABILITY FACTORS

Exposure:

- shallow water tables
- flooding (YAVH)
- change in maximum and minimum temperature
- change in spring and autumn rainfall

Sensitivity:

- remnant native vegetation fragmented and in relatively poor condition
- disturbed riparian zone
- concentration of remnant native vegetation with high bioregional conservation status
- soil hazards
- climate sensitive land use

Adaptive capacity:

- no access to irrigation
- limited history of natural resource management works
- land tenure not protective of natural resources

KEY PRESSURES

Climate and weather:

Climate and weather: intense rainfall events, reduced rainfall, intensified and more frequent drought, increased average and extreme temperatures, catastrophic bushfires (YAVH).

Land:

Shallow water tables, invasive plants and animals, land value is high relative to value of production, intensification of settlement (urban and peri-urban), livestock grazing, soil health decline (acidification, erosion, carbon depletion, loss of groundcover).

Biodiversity:

Invasive plants and animals, historical vegetation clearing, incremental on-going tree loss (tree decline, land and infrastructure development, firewood collection).

Water:

Flow modification, water quality decline (erosion, septic tanks, stock), loss of access to shallow groundwater by dependent ecosystems.

Community:

Population growth, land ownership turnover, limited skills, time and/or finance for land management, absentee ownership, off-property employment.

The key vulnerability factors have been drawn from an interrogation of the spatial assessment data (see section 3.3). The key pressures have been identified from the DPSIR analyses (see section 3.1 and 4).

Semi-autonomous adaptation focus areas:
Great Dividing Range mountain forests and alpine areas

WHO OR WHAT ADAPTS?
Biodiversity: native vegetation and native fauna
Land uses: nature conservation, forestry production, recreation, tourism
Water: water inflows to reservoirs, waterways, aquatic environments and drought refugia
People: recreation and tourism providers
Infrastructure: buildings and other infrastructure exposed to bushfires

	HOW ARE PRESSURES AND IMPACTS CURRENTLY BEING MANAGED?	HOW EFFECTIVE ARE THESE RESPONSES ANTICIPATED TO BE?
State Government regulation and land management	• Timber production: Code of Practice for Timber Production, Forest Management Plans, forest management zoning, Forest Audit Program, road construction and maintenance, invasive species management • Bushfires: Code of Practice for Bushfire Management, Fire Operations Planning, planned burning programs, fuel hazard and post-fire monitoring, strategic fire break maintenance, fire detection and suppression • Conservation reserves: Park management plans; Park maintenance, feral and invasive species management • Water resource management: water resource planning that accounts for impacts of projected climate change; multiple large storages, provision of environmental flows, bushfire detection and suppression • Firewood collection: local and State government regulations	• Timber production: largely effective in mitigating off-site impacts of harvesting operations, except for flow reductions from wet sclerophyll forests and those resulting from climate change • Bushfires: likely moderately effective in addressing human safety risks, but incidence and impact of fires likely to be exacerbated with climate change, even with existing responses • Conservation reserves: likely moderately effective in containing existing pressures, less effective in containing pressures resulting from change in rainfall and temperature regimes • Water resource planning: likely effective in anticipating effects of climate change on resource availability, but limited effectiveness in containing impacts • Firewood collection: dependent on level of enforcement
Emergency management arrangements: preparation, management and recovery phases	Bushfire: planned burning, fire response arrangements, emergency warnings, bushfire recovery, Code of Practice for Bushfire Management.	Bushfire: fire warnings and response effective in reducing threats to human safety (community and responders) under most conditions. Disaster recovery arrangements likely effective in reducing pressures. Effectiveness of responses tested under catastrophic fire danger conditions, which will increase in frequency with climate change. Effectiveness of planned burning is yet to be determined.
Recreation	• Snow making • Development of summer season activities	Snow making is likely to have reduced effectiveness with warming climate. Seasonal diversification is likely to offset some impact of reduced skiing season

Planned adaptation focus areas:
Sugarloaf Creek (SC) and Yea & Alexandra valleys & hills (YAVH) (part)

WHO OR WHAT ADAPTS?

- **Biodiversity:** terrestrial and riparian remnant vegetation and fauna
- **Land uses:** agriculture, lifestyle/amenity uses
- **Water:** waterways, riverine wetlands (YAVH), aquatic environments, drought refugia
- **People:** farming and lifestyle landholders
- **Infrastructure:** buildings and other infrastructure exposed to flooding and bushfires (YAVH)

	HOW ARE PRESSURES AND IMPACTS CURRENTLY BEING MANAGED?	HOW EFFECTIVE ARE THESE RESPONSES ANTICIPATED TO BE?
NRM and other land management programs (including agricultural industry programs)	• community education and extension • whole farm planning • invasive species management • native vegetation protection and restoration • riparian and wetland fencing and revegetation • streamflow management plans (YAVH) • protective tenure arrangements: conservation covenants, land management agreements etc. • soil, land, vegetation, riparian, wetland "best management practices" • natural resource condition monitoring	• likely moderate to high effectiveness for managing pressures relating to remnant vegetation, groundcover, waterways and wetlands – where adopted by landholders. Low level of uptake likely given population density, growth and transience – this will diminish the potential impacts of responses • key constraints: resources (time, finance, skills, experience) for management
Land use planning and regulation	• urban and peri-urban zoning, boundaries and property sizes • use of septic tanks • development and building controls in flood zones and bushfire prone areas (YAVH) • environmental significance, erosion and other land management overlays • vegetation clearing controls • multi-organisation regional coordination groups for planning strategy and implementation	• Land use planning and development controls: - can establish limits on population growth and density, but as these have not yet been reached, pressures on natural resource assets and values likely to increase - likely to contain impacts resulting from floods and bushfire, (possibly) except under extreme conditions • Septic tanks: effective enforcement likely to contain additional nutrient inputs into streams • Vegetation protection: likely effective in retaining larger vegetation patches on private land, but not effective in containing incremental losses of small patches and paddock trees;
Emergency management arrangements: preparation, management and recovery phases	• Bushfire: planned burning, fire response arrangements, emergency warnings, bushfire recovery, Code of Practice for Bushfire Management • Flooding: emergency warnings, building, transport and other infrastructure placement and design, urban and rural drainage, flood mitigation infrastructure	• Bushfire: effective in limiting threats to human safety (community and responders) under most conditions; disaster recovery arrangements likely effective in reducing pressures; effectiveness of responses tested under catastrophic fire danger conditions • Flooding: likely effective in managing impacts except for established infrastructure developed in floodways and where climate change will significantly change flood depth, extent and flow velocity
Insurance	flood and/or fire (YAVH) damages	Likely to offset damage costs for affected properties. Cost and/or availability of cover may be tightened with climate change if frequency and scale of impacts increase materially.

What additional actions can be considered?

Options are considered in several categories to encourage consideration of the full spectrum of climate change response opportunities (Willows and Connell 2003). The development of management options in this Plan represents only the first step in a process of detailed adaptive management planning (see beginning of section 7).

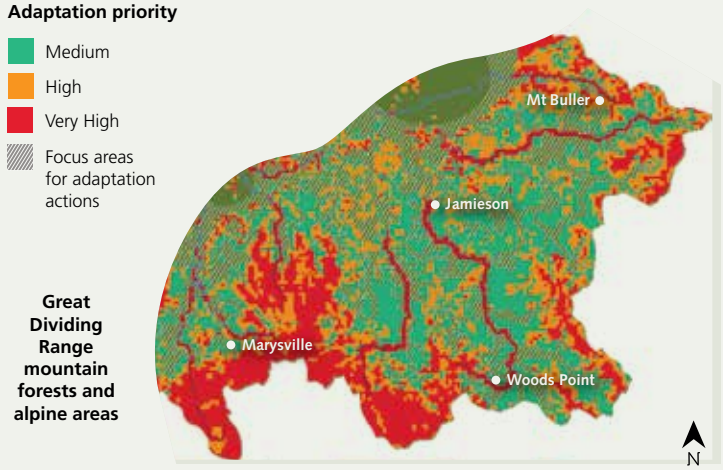
The Great Dividing Range mountain forests and alpine areas focus area has lower vulnerability than the Sugarloaf Creek and Yea & Alexandra valleys & hills focus areas. No additional planned actions are proposed in response to climate change, rather, largely managed through current responses (outlined above) and the system allowed to react and respond to climate change in a largely undirected manner. At some future stage, planned interventions may be required if or as resilience thresholds are approached. In the meantime, adaptive capacity building options, such as research and monitoring, may assist in identifying triggers and mechanisms for planned interventions. A limited suite of other adaptation management actions can be considered, as described here.

Semi-autonomous adaptation focus area: **Great Dividing Range mountain forests & alpine areas**	
Modify the events	• Limited additional adaptation options
Respond to the effects	• Limited additional adaptation options
Reduce the risk	• Migrate settlements from interfaces with highest risk bushfire environment.
Build adaptive capacity	• Research into resilience of alpine and other restricted range species whose habitats are at high risk from climate change • Research into long-term management of key fire sensitive environments under climate change • Research into water resource impacts of climate change and potential implications for irrigation, environmental watering and urban supplies • Monitoring of natural resource state to detect trends indicative of climate change impacts and to provide potential triggers for changed management

Planned adaptation focus area: **Sugarloaf Creek (SC) and Yea & Alexandra valleys & hills (YAVH) (part)**	
Modify the events	• Infrastructure construction to protect flood prone urban environments • Perennial vegetation reinstatement in hill country (esp. Yea River catchment) to reduce flash run-off and flood, erosion and water quality impacts of extreme rainfall events • Develop and implement streamflow management plans (in catchments without them) to reduce impacts of farm dams and other forms of water interception on riparian, wetland and aquatic ecosystems • Develop and implement groundwater management plans (in areas without them) to reduce impacts of groundwater use on groundwater-dependent ecosystems and drought refugia • Address bushfire hazard in public land areas fringing the social-ecological system boundary
Respond to the effects	• Strategic revegetation and native vegetation protection programs to identify and build the size and connectivity of key native vegetation remnants, for example, along roads and waterways to nearby public land forest areas, and strengthen water quality protection • Encourage revegetation and/or perennial grass establishment on hills to maintain groundcover and protect against erosion, salinity and flash flooding • Strengthen native vegetation retention controls and planning to protect resilience features of high value remnant native vegetation patches and drought refugia
Reduce the risk	• Manage fire ignition risk, e.g. electricity distribution lines, in areas with high risk from catastrophic bushfires • Migrate residential and other flood sensitive land uses away from flood-exposed areas
Build adaptive capacity	• Peri-urban and lifestyle landholder natural resource management programs to encourage such landholders to engage in measures to protect soil health and remnant vegetation and to develop the skills and capacity for implementation; and to strengthen bushfire preparation and response capabilities. • Research into the need and opportunity to introduce new species or provenances to maintain ecosystem function under climate change.

7.5 Southern Forests Social-ecological System

Semi-autonomous adaptation focus areas:
Great Dividing Range mountain forests & alpine areas



Features:

- Mountain forests
- Alpine woodlands
- Meadows and wetlands of the northern fall of the Great Dividing Range

Values *(criteria from the spatial assessment):*

- high environmental and economic (infrastructure relating to water supply catchments) consequence of loss
- remnant native vegetation of high conservation status
- potential drought refugia in waterways and other low-lying land

Figure 23: Semi-autonomous adaptation priority areas in the Southern Forests of the Goulburn Broken Catchment

KEY VULNERABILITY FACTORS

Exposure:

- change in maximum and minimum temperature
- change in spring and autumn rainfall

Sensitivity:

- alpine wetlands
- areas of native vegetation with high bioregional conservation status
- soil hazards
- climate sensitive land uses

A feature of this area is the relatively low sensitivity.

Adaptive capacity:

Protective tenure arrangements result in this area having a high adaptive capacity score.

KEY PRESSURES

Climate and weather:

- intense rainfall events
- reduced rainfall
- intensified and more frequent drought
- increased average and extreme temperatures
- catastrophic bushfires
- changed snow regime

Land:

- timber harvesting
- bushfires
- recreation

Biodiversity:

- invasive plants and animals
- bushfires and changed fire regimes
- timber harvesting
- recreation

Water:

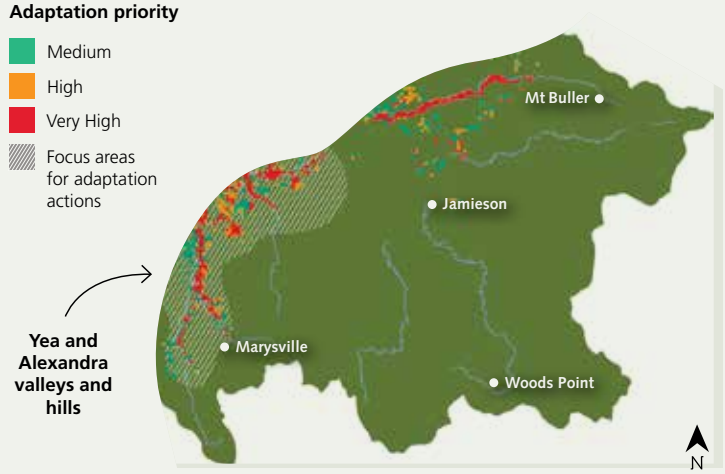
- bushfire impacts on stream flows and water quality
- changed water yields
- tourism
- recreation impacts on water quality

Community:

Changing values and expectations for land use from public land.

Please note: These maps are not intended to incorporate all decision-making elements but represent an initial prioritisation for climate change adaptation based on spatially-enabled criteria for vulnerability and value. Vulnerability is used to highlight locations and issues to focus further analysis, including risk assessment and management. These maps should be considered in conjunction with the Climate Change Adaptation Plan for Natural Resource Management in the Goulburn Broken Catchment, Victoria, 2016 in its entirety.

Planned adaptation focus areas:
Yea & Alexandra valleys & hills (part)



Features:

- Cleared hill country and valleys of Acheron and Yea rivers and King Parrot Creek, south of the Goulburn River, Yea located within focus area

Values *(criteria from the spatial assessment):*

- remnant native vegetation of high conservation status
- high environmental and economic (production and infrastructure) consequence of loss
- potential drought refugia in waterways and other low-lying land
- high land value

Figure 24: Planned adaptation priority areas in the Southern Forests of the Goulburn Broken Catchment

KEY VULNERABILITY FACTORS

Exposure:

- shallow water tables
- flooding
- change in maximum and minimum temperature
- change in spring and autumn rainfall

Sensitivity:

- remnant native vegetation fragmented and in relatively poor condition
- disturbed riparian zone
- concentration of remnant native vegetation with high bioregional conservation status
- soil hazards
- climate sensitive land use

Adaptive capacity:

- no access to irrigation
- limited history of natural resource management works
- land tenure not protective of natural resources

KEY PRESSURES

Climate and weather:

Climate and weather: intense rainfall events, reduced rainfall, intensified and more frequent drought, increased average and extreme temperatures, catastrophic bushfires.

Land:

Shallow water tables, invasive plants and animals, land value is high relative to value of production, intensification of settlement (urban and peri-urban), livestock grazing, soil health decline (acidification, erosion, carbon depletion, loss of groundcover).

Biodiversity:

invasive plants and animals, historical vegetation clearing, incremental on-going tree loss (tree decline, land and infrastructure development, firewood collection).

Water:

Flow modification, water quality decline (erosion, septic tanks, stock), loss of access to shallow groundwater by dependent ecosystems.

Community:

Population growth, land ownership turnover, limited skills, time and/or finance for land management, absentee ownership, off-property employment.

The key vulnerability factors have been drawn from an interrogation of the spatial assessment data (see section 3.3). The key pressures have been identified from the DPSIR analyses (see section 3.1 and 4).

Semi-autonomous adaptation focus areas:
Great Dividing Range mountain forests and alpine areas

WHO OR WHAT ADAPTS?
Biodiversity: native vegetation and native fauna
Land uses: nature conservation, forestry production, recreation, tourism
Water: water inflows to reservoirs, waterways, aquatic environments and drought refugia
People: recreation and tourism providers
Infrastructure: buildings and other infrastructure exposed to bushfires

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Recreation	• Snow making • Development of summer season activities	Snow making is likely to have reduced effectiveness with warming climate. Seasonal diversification is likely to offset some impact of reduced skiing season.

Planned adaptation focus areas:
Yea & Alexandra valleys & hills (part)

WHO OR WHAT ADAPTS?
Biodiversity: terrestrial and riparian remnant vegetation and fauna
Land uses: agriculture, lifestyle/amenity uses
Water: waterways, riverine wetlands (YAVH), aquatic environments, drought refugia
People: farming and lifestyle landholders
Infrastructure: buildings and other infrastructure exposed to flooding and bushfires (YAVH)

	HOW ARE PRESSURES AND IMPACTS CURRENTLY BEING MANAGED?	HOW EFFECTIVE ARE THESE RESPONSES ANTICIPATED TO BE?
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Land use planning and regulation	• urban and peri-urban zoning, boundaries and property sizes • use of septic tanks • development and building controls in flood zones and bushfire prone areas • environmental significance, erosion and other land management overlays • vegetation clearing controls • multi-organisation regional coordination groups for planning strategy and implementation	• Land use planning and development controls: - can establish limits on population growth and density, but as these have not yet been reached, pressures on natural resource assets and values likely to increase - likely to contain impacts resulting from floods and bushfire, (possibly) except under extreme conditions • Septic tanks: effective enforcement likely to contain additional nutrient inputs into streams • Vegetation protection: likely effective in retaining larger vegetation patches on private land, but not effective in containing incremental losses of small patches and paddock trees
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Insurance	Flood and/or fire damages	Likely to offset damage costs for affected properties. Cost and/or availability of cover may be tightened with climate change if frequency and scale of impacts increase materially.

What additional actions can be considered?

Options are considered in several categories to encourage consideration of the full spectrum of climate change response opportunities (Willows and Connell 2003). The development of management options in this Plan represents only the first step in a process of detailed adaptive management planning (see beginning of section 7).

The Great Dividing Range mountain forests and alpine areas focus area has lower vulnerability than the Yea & Alexandra valleys & hills focus area. No additional planned actions are proposed in response to climate change, rather, largely managed through current responses (outlined above) and the system allowed to react and respond to climate change in a largely undirected manner. At some future stage, planned interventions may be required if or as resilience thresholds are approached. In the meantime, adaptive capacity building options, such as research and monitoring, may assist in identifying triggers and mechanisms for planned interventions. A limited suite of other adaptation management actions can be considered, as described here.

Semi-autonomous adaptation focus area: **Great Dividing Range mountain forests & alpine areas**	
Modify the events	• Limited additional adaptation options
Respond to the effects	• Limited additional adaptation options
Reduce the risk	• Migrate settlements from interfaces with highest risk bushfire environment.
Build adaptive capacity	• Research into resilience of alpine and other restricted range species whose habitats are at high risk from climate change • Research into long-term management of key fire sensitive environments under climate change • Research into water resource impacts of climate change and potential implications for irrigation, environmental watering and urban supplies • Monitoring of natural resource state to detect trends indicative of climate change impacts and to provide potential triggers for changed management

Planned adaptation focus area: **Yea & Alexandra valleys & hills (part)**	
Modify the events	• Infrastructure construction to protect flood prone urban environments • Perennial vegetation reinstatement in hill country to reduce flash run-off and flood, erosion and water quality impacts of extreme rainfall events • Develop and implement streamflow management plans (in catchments without them) to reduce impacts of farm dams and other forms of water interception on riparian, wetland and aquatic ecosystems • Develop and implement groundwater management plans (in areas without them) to reduce impacts of groundwater use on groundwater-dependent ecosystems and drought refugia • Address bushfire hazard in public land areas fringing the social-ecological system boundary
Respond to the effects	• Strategic revegetation and native vegetation protection programs to identify and build the size and connectivity of key native vegetation remnants, for example, along roads and waterways to nearby public land forest areas, and strengthen water quality protection • Encourage revegetation and/or perennial grass establishment on hills to maintain groundcover and protect against erosion, salinity and flash flooding • Strengthen native vegetation retention controls and planning to protect resilience features of high value remnant native vegetation patches and drought refugia
Reduce the risk	• Manage fire ignition risk, e.g. electricity distribution lines, in areas with high risk from catastrophic bushfires • Migrate residential and other flood sensitive land uses away from flood-exposed areas
Build adaptive capacity	• Peri-urban and lifestyle landholder natural resource management programs to encourage such landholders to engage in measures to protect soil health and remnant vegetation and to develop the skills and capacity for implementation; and to strengthen bushfire preparation and response capabilities. • Research into the need and opportunity to introduce new species or provenances to maintain ecosystem function under climate change.

7.6 Incremental and transformational adaptation

The adaptation options are largely incremental in nature. They either involve doing incrementally more of what is being done to manage existing pressures on natural resources or making incremental modifications to the existing suite of management actions. Incremental adaptations are likely to be at least partly effective responses to climate change over short to medium term NRM planning timeframes (around 5 to 20 years). Climate change projections suggest little change in annual or seasonal rainfall and only modest increases in temperature (~1°C) over this period. These changes may push some aspects of climate variability (particularly extreme high temperatures) outside historic ranges and may affect particularly sensitive natural systems. However, they are unlikely to drive most natural systems beyond their coping ranges or resilience thresholds. The state of natural resources and systems may be more influenced by non-climate change pressures over this timeframe.

The climate is projected to change profoundly over the 50 year vision timeframe of the Goulburn Broken RCS, particularly under high greenhouse gas emissions pathways. Under such circumstances, climate change is likely to exert increasing influence on the condition of natural resources and systems.

It is likely that at least some of the impacts of climate change will not be able to be mitigated through incremental modifications to conventional responses. Transformational responses to climate change may be required.

Kates *et al.* (2012) recognise three classes of transformational adaptation:

- *Transformational scale:* existing adaptations that are adopted at a much larger scale or intensity.
- *Transformative idea:* adaptations that are truly new to a particular region or resource system.
- *Transformation of location:* adaptations that transform place-based social-ecological systems or shift such systems to other locations. These are more extreme examples of the "reduce the risk" adaptation options described above.

Several scenarios can be envisaged where there is a requirement for transformational adaptation, particularly for the Great Dividing Range forests and alpine priority landscape. These include:

- *Snow-dependent ecosystems of the Australian Alps:* increasing temperature is anticipated to increase the height of the snow line and reduce the incidence of snow and depth and duration of snow cover. Under long-term, upper range climate change scenarios, it is unlikely that incremental autonomous adaptation will be sufficient to maintain these ecosystems in place. Transformational adaptation will most likely be required if they are to do so and may be required to sustain key ecosystem services in these areas if these ecosystems cannot be retained in place.
- *Fire-sensitive wet sclerophyll forests:* greatly increased temperatures and declining rainfall with long-term, upper range climate change scenarios will greatly increase the frequency of extreme fire weather and may lead to more frequent fires in the fire-sensitive wet sclerophyll forests that comprise much of mountain forests. If fire frequency falls below the tolerable fire interval for these forest types, key fire-sensitive species may be lost. Again, transformational adaptation may be required to avoid this outcome or because it cannot be avoided.

Because of the value of natural resources and the ecosystem services provided by these areas, long-term adaptation planning will need to consider and develop transformational options.

7.7 Adaptation pathways

Descriptions of adaptation options give the impression that adaptation is a static, 'once off' process. While this may be appropriate in some instances, adaptation should generally be an 'adaptive' planning process.

Uncertainties associated with the scale, timing and impacts of climate change and adaptation actions suggest that adaptation should involve an iterative cycle of decision-making, action, observation and learning (Wiseman *et al.* 2011). Where possible, adaptation becomes a 'pathway' rather than a one-off response (for example) to the anticipated worst case for climate change or its impacts. Adaptation planning envisages the sequential implementation of options or tactics that are suited to particular stages of climate change or its potential impact. New adaptive measures (possibly involving higher levels of intervention) are introduced in response to risk-based triggers, learnings about the effectiveness of adaptation actions, observations or new analyses of climate impacts.

This 'adaptation pathways' approach potentially allows investment in adaptation to long-term climate change impacts to be deferred until it is clearly required. It may also allow benefits to continue to accrue from the use of land that is projected to become exposed to climate hazards (e.g. enhanced flooding due to climate change). This can reduce the cost of adaptation, as well as make it more acceptable to those with a stake in current land uses.

The types of adaptation considered in the conceptualisation process described in section 3.4 are consistent with the adaptation pathways concept. In the early stages of climate change, effort may focus in the development of adaptive capacity, to detect emerging climate change impacts and/or test and refine adaptation options. Low level climate risks may be accepted at this time. As climate change impacts (or risks) emerge, there may be greater focus on actions which will modify climate events and/or respond to their effects. Under severe climate change scenarios, transformational "reduce the risk" options may be considered. In the absence of feasible and cost-effective interventions, accepting the risk options may also be all that is available for some natural resources or systems.

Adaptation planning should consider long-term pathways for adaptation and incorporate monitoring and evaluation processes that support the required adaptive management processes (see section 10).

8. Climate Change Mitigation

This Plan focuses on climate change mitigation efforts described as a suite of bio-sequestration activities that are carried out on farming and other rural land to abate greenhouse gas emissions (carbon farming). The activities can be supported through a voluntary market or through the Australian Government's Emissions Reduction Fund. These mechanisms can support a range of activities across the land sector to mitigate climate change.

This Plan identifies regional priorities for carbon farming activities by considering the co-benefits of these activities and the potential risks to the Catchment's natural resources. As such, this Plan focuses on five carbon sequestration opportunities for which methods have been developed and are supported by the current Emissions Reduction Fund (Australian Government Clean Energy Regulator 2015):

- *Permanent even-aged native forests:* permanent native forests that develop following management changes to encourage natural regeneration
- *Native forest protection:* avoidance of legally permitted clearing of native forests and on-going management to maintain a composition similar to the same vegetation community in a nearby park or State forest
- *Permanent environmental plantings:* establishment of new plantings of locally indigenous native species on land that has not recently supported native forest
- *Permanent Mallee plantings:* establishment of Mallee eucalypts in blocks or belts on land receiving less than 600 millimetres of average annual rainfall and not recently supporting native forest cover
- *Afforestation and reforestation:* establishment of a new forest on land that has not recently supported native forest cover. The new forests may be environmental plantings, farm forestry plantings or long-rotation hardwood plantations and receiving less than 600 millimetres of average annual rainfall

The assessment of priority landscapes for carbon farming includes eligibility criteria for the methods described above plus principles for planning carbon farming projects.

8.1 Priority landscapes for carbon farming

Native Forest Protection

The eligibility criteria for the Native Forest Protection Method are consistent with regional principles for planning carbon farming projects. There is minimal opportunity for this activity in the Goulburn Broken Catchment as native forests are currently protected through State and local government planning regulations.

Environmental Plantings and Natural Regeneration

Environmental plantings and natural regeneration methods broadly align with natural resource management initiatives undertaken by government agencies, regional authorities (for example the Goulburn Broken CMA) or community groups (for example Landcare or Conservation Management Networks).

Natural regeneration can only take place within or adjacent to existing native vegetation or in areas with scattered tree cover, that is, where a seed source for regeneration exists.

Table 8 outlines principles to assist planning of environmental plantings and natural regeneration as part of a carbon farming project.

Table 8: Principles for planning environmental plantings and natural regeneration as part of a carbon farming project

PROMOTION PRINCIPLES	RATIONALE
Proximity to existing native vegetation	Location close to existing native vegetation has potential to enhance value, due to increased patch size and continuity
Regional priority for improving landscape vegetation connectivity/biodiversity value	Where possible carbon farming plantings and natural regeneration should complement regional priorities.
Carbon sequestration potential	Carbon farming has potential to generate returns from sale of carbon credits. Landholders may be more attracted to biodiverse plantings and natural regeneration where financial returns are greater.
Vulnerability to climate change	Plantings and regeneration should be encouraged in areas where the landscape is more vulnerable to climate change as a means of strengthening resilience.

AVOIDANCE PRINCIPLES	RATIONALE
Reduction in water yield with revegetation	Water interceptions increase with rainfall, ERF regulations do not address interception effects of environmental plantings
Land use	Weighted away from land uses which have high social and/or economic value (for current uses) and greater sensitivity to bushfires. This reflects emphasis of plantings away from land uses with high economic or social value (e.g. horticultural land, land adjacent to urban development).

In addition to the avoidance and promotion principles, carbon farming project proponents are responsible for ensuring consideration of Federal, State and local legislation and regulations regarding such issues including, but not exclusive to, water interception, fire management, native vegetation retention, land use planning, cultural heritage and invasive plants and animals .

Figures 25 and 26 outline areas in the Goulburn Broken Catchment that could support environmental plantings and natural regeneration for carbon farming whilst aligning with the Catchment's natural resource values.

Figure 25: Areas of the Goulburn Broken Catchment that could support environmental plantings for carbon-sequestration

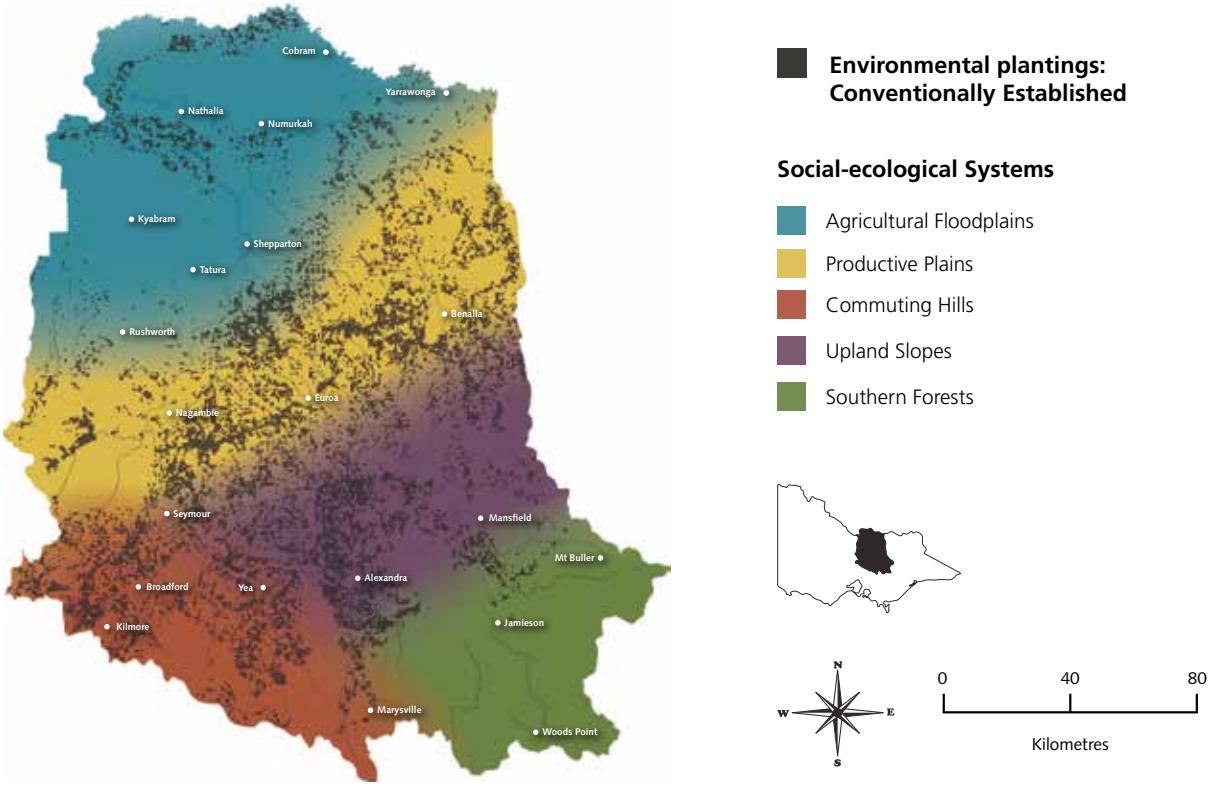
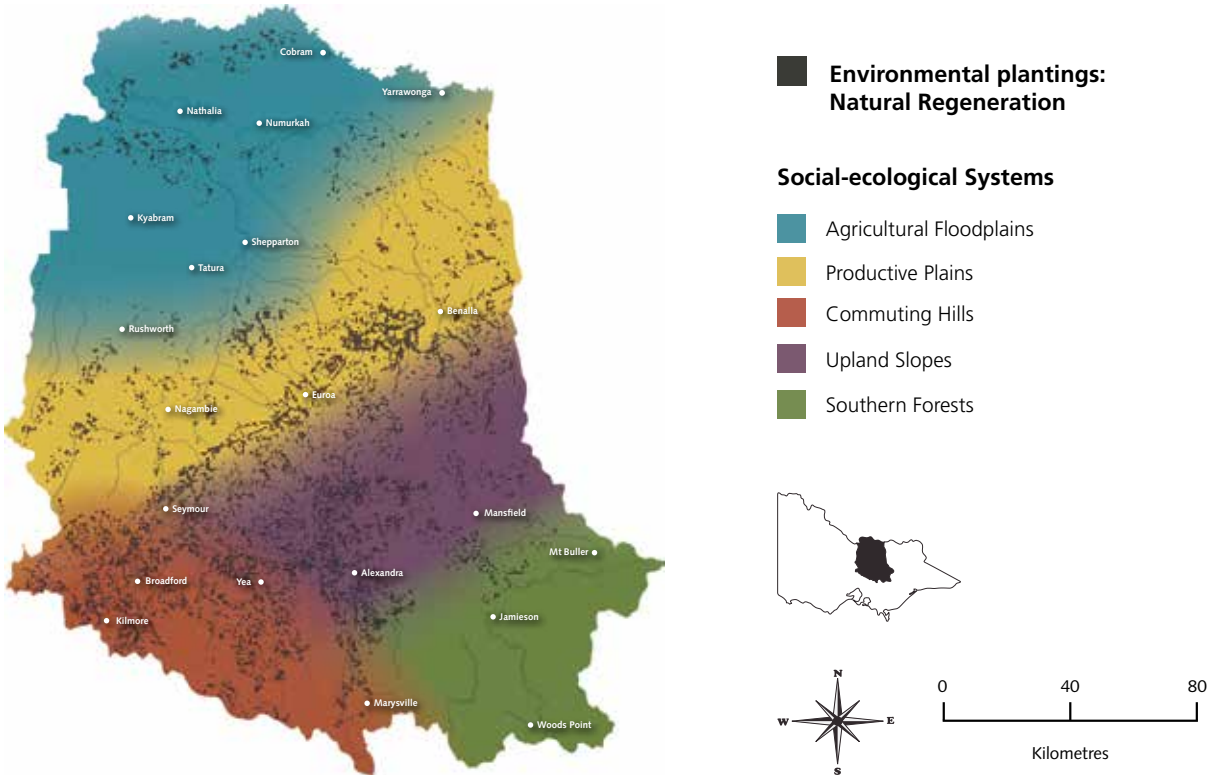


Figure 26: Areas of the Goulburn Broken Catchment that could support natural regeneration for carbon-sequestration



Please note: These maps are not intended to incorporate all decision-making elements but represent an initial prioritisation for carbon farming based on spatially-enabled method eligibility criteria and principles for promotion and avoidance of carbon farming. These maps should be considered in conjunction with the Climate Change Adaptation Plan for Natural Resource Management in the Goulburn Broken Catchment, Victoria, 2016 in its entirety.

Mallee and other non-environmental plantings (particularly high density hardwood plantations)

Since this form of planting involves the use of species that will not be locally indigenous, the Goulburn Broken CMA recommends that they are to be directed away from areas of existing native vegetation cover to reduce risks associated with the introduction of new genetic material.

Mallee plantations are only eligible under the current method in areas with less than 600 millimetres average annual rainfall. This eligibility requirement should also be applied to the voluntary market.

Non-environmental plantings pose the greatest water interception risk due to high density planting and growth rates. Although water access entitlements must be purchased in areas with more than 600 millimetres average annual rainfall, this will only mitigate water interception risks at the river basin scale and not in small upper catchment areas. To minimise genetic and water interception risks, the plantings should be directed away from locations that are adjacent to existing native vegetation areas and waterways.

Table 9 outlines principles to assist planning of non-environmental plantings as part of a carbon farming project.

In addition to the avoidance and promotion principles, carbon farming project proponents are responsible for ensuring consideration of Federal, State and local legislation and regulations regarding such issues including, but not exclusive to, water interception, fire management, native vegetation retention, land use planning, cultural heritage and invasive plants and animals .

Figures 27 and 28 outline areas in the Goulburn Broken Catchment that could support these types of activities whilst aligning with the Catchment's natural resource values.

Table 9: Principles for planning non-environmental plantings for carbon farming projects

PROMOTION PRINCIPLES	RATIONALE
Carbon sequestration potential	Carbon farming has potential to generate returns from sale of carbon credits. Landholders may be more attracted to biodiverse plantings and natural regeneration where financial returns are greater.
Vulnerability to climate change	Plantings and regeneration should be encouraged in areas where the landscape is more vulnerable to climate change as a means of strengthening resilience.

AVOIDANCE PRINCIPLES	RATIONALE
Proximity to existing native vegetation	Weighted away from areas of high biodiversity value.
Reduction in water yield with revegetation	Water interceptions increase with rainfall, ERF regulations do not address interception effects of environmental plantings.
Land use	Weighted away from land uses which have high social and/or economic value (for current uses) and greater sensitivity to bushfires. This reflects emphasis of plantings away from land uses with high economic or social value (e.g. horticultural land, land adjacent to urban development).

Figure 27: Areas of the Goulburn Broken Catchment that could support conventional non-environmental carbon farming plantings

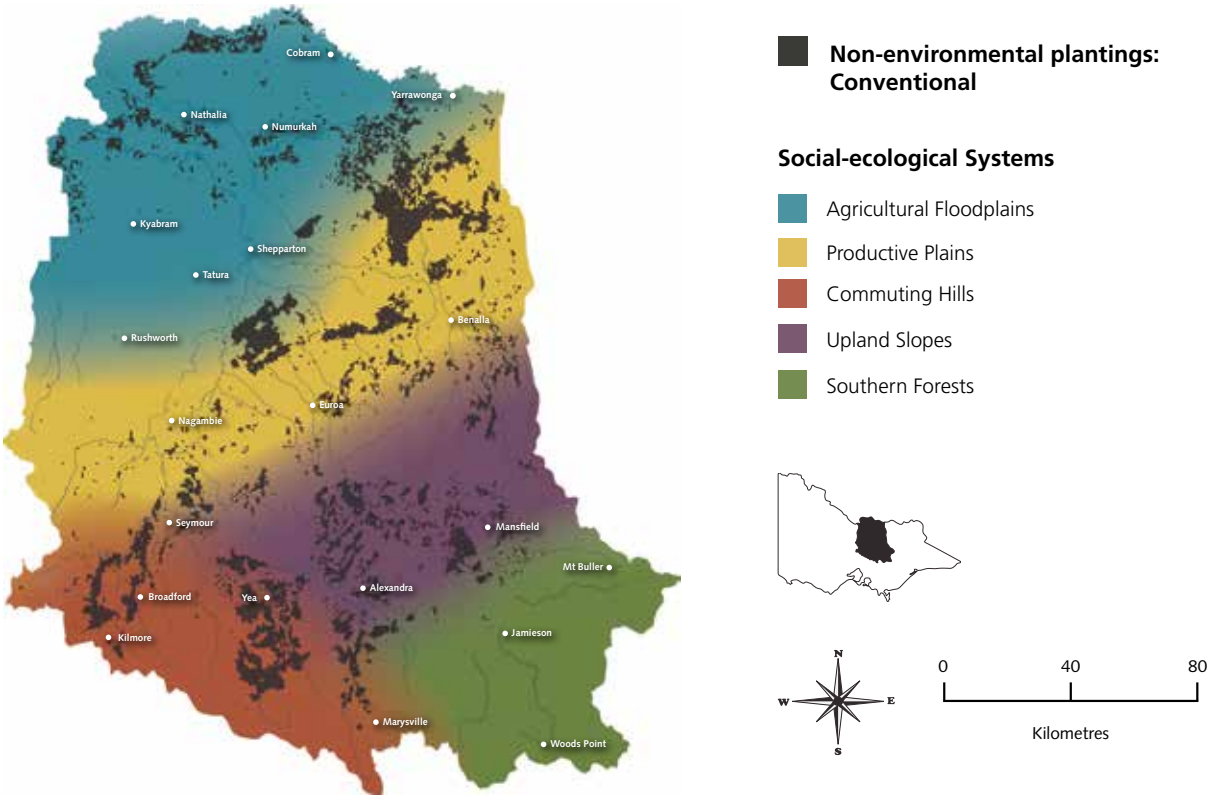
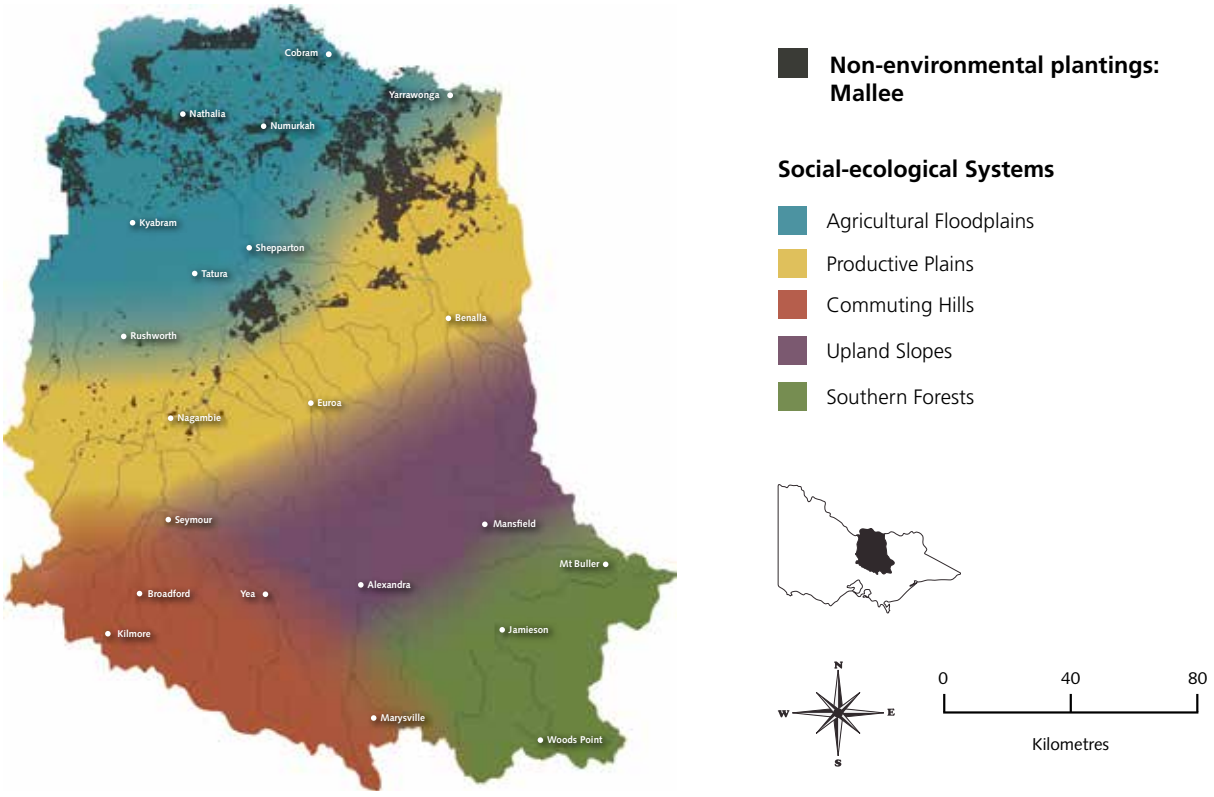


Figure 28: Areas of the Goulburn Broken Catchment that could support Mallee carbon farming plantings



Please note: These maps are not intended to incorporate all decision-making elements but represent an initial prioritisation for carbon farming based on spatially-enabled method eligibility criteria and principles for promotion and avoidance of carbon farming. These maps should be considered in conjunction with the Climate Change Adaptation Plan for Natural Resource Management in the Goulburn Broken Catchment, Victoria, 2016 in its entirety.

8.2 Management options for carbon farming

Native forest protection

Protection of any existing patches of high quality native vegetation for which legally valid clearing permits exist (Sugarloaf Creek and Yea & Alexandra valleys & hills focus areas).

Environmental plantings

Permanent environmental plantings and natural regeneration to increase the size of existing patches of native vegetation and build connectivity between them. In some settings the plantings may also reduce overland flow from hill country, salinity recharge and contribute to the filtering of overland flows entering waterways. This may also be used to occupy frequently flooded areas that have good native vegetation cover but few alternative uses (Lower Goulburn and Murray floodplains focus areas)

Non-environmental plantings

Plantings for commercially-oriented carbon sequestration projects which may also assist with the mitigation of some pressures on natural resource assets, for example, overland flow (focus areas Whiteheads and Hughes Creeks, Swanpool and Tatong valleys and hills) and salinity recharge mitigation (focus areas Swanpool and Tatong valleys and hills, Goulburn and Broken Rivers and dryland plains) and may be used to occupy frequently flooded, but poorly vegetated land with few alternative uses (Lower Goulburn and Murray floodplains focus areas)

9. Implementation: making use of better information

This section describes how this Plan, including the wealth of background data gathered to inform it, can be considered by the Goulburn Broken CMA and partner organisations.

As outlined in section 1, the purpose of this Plan is to provide information on climate change for the Goulburn Broken CMA and partner organisations to use in NRM planning and decision-making. Section 1 also highlights that this Plan should be used in conjunction with other technical and planning information, pointing to complementary decision making processes and data needs to inform good planning. It is not the intent of this Plan to provide all the answers but information for consideration in planning processes.

There is considerable scope now to improve how climate change is factored into decision-making, whilst allowing for new information to be integrated in the future.

The objectives of implementing, or "rolling-out", this Plan needs to be a part of integrating all aspects of climate change into decision-making. This Plan is anticipated to catalyse many decisions, giving tangible evidence that the following strategic outcomes of the Goulburn Broken CMA's *Climate Change Integration Strategy* (2012) are being implemented:

- integrate climate change into Goulburn Broken CMA programs
- improve understanding of climate change
- build catchment resilience into sequestration activities.

Action

Integrate this Plan and associated tools created during the development of this Plan into Goulburn Broken CMA and partner organisations NRM planning.

This is likely to require a program and project-level analysis, considering key questions such as:

- What climate change information can be used now to inform strategic directions and projects? That is, what are the priority areas for climate change adaptation and mitigation and what management options need to be implemented?
- What other data might be needed for decision-making?
- Who needs to be involved in further deliberations?
- What climate change-related data is a priority to obtain or improve?

The Plan and associated tools and information can be incorporated into planning at a range of scales and processes, including;

- assessing risk or vulnerability at the program-level incorporating key climate change impacts
- assisting in the prioritisation of on-ground works for key land, water and biodiversity assets
- reviewing the effectiveness of current management actions under climate change
- identifying of activities to support adaptation and mitigation to climate change
- assisting in local planning and program-level planning by providing key climate change information for consideration in relation to other drivers
- further refining the spatial climate change vulnerability assessment for local and program-level planning
- using the learnings from the Adaptation Pathways Trial to support local planning
- reviewing the assumptions documented as part of the DPSIR analyses as a corner-stone of adaptive management
- incorporating new methods into the carbon farming assessment.

This will be facilitated through the Goulburn Broken CMA's Planning Framework and the Monitoring and Evaluation Framework (GB CMA 2013).

10. Adaptive Management Framework

This section lists elements of an adaptive management framework and an approach to plan for a changing future via an 'adaptive pathways' process and a 'risk management' procedure.

The response to climate change must be adaptive: a learning-by-doing approach that is accompanied by a preparedness to respond to likely, extreme and unforeseen conditions.

There is a heightened sensitivity of preparedness to respond because of:

- the broad reach of climate change and climate change responses across the whole community and the environment
- uncertainties of how changes to the climate will unfold (trend data are still emerging)
- the infancy in understanding how to respond, including how to integrate responses into complementary and potentially conflicting programs.

During the development of this Plan, the elements of an adaptive management framework were formally identified and sequenced, including an emphasis on the steps in the decision-making or planning cycle. The framework prompts questions about data needed to inform decisions and the process (who and when) for making decisions.

Without being conscious of it, the NRM organisations in the Goulburn Broken Catchment managed natural resources according to an informal 'resilience approach' from the late 1980s until formalisation of the approach in the Goulburn Broken RCS 2013 update. Improving how the concepts of resilience thinking are translated into on-ground changes is challenging as it involves breaking down a highly connected system into the operational units that matter – and that are agreed to by many stakeholders. The adaptive management framework will become an essential tool in helping 'resilience thinking' become a practical reality. Although elements of the framework are instantly recognisable and are consistent with good natural resource management practice highlighted in the literature (Lockwood *et al.* 2008, Rissik et al 2014, M CMA 2013), the challenge is to commit to the discipline of considering each element as part of a cycle.

The development of this Plan facilitated the formal identification and sequencing of elements of the adaptive management framework and catalysed their use in several Goulburn Broken CMA plans for example the Shepparton Irrigation Region, Land and Water Management Plan. The framework will also be a feature of Goulburn Broken CMA's updated Monitoring, Evaluation and Reporting Strategy (under way).

10.1 Elements of an adaptive management framework

Given the need for timely responses at a large scale, involving many and varied stakeholders in joint action, the primary driver behind the framing of an adaptive approach is the need for shared agreement. This in turn drives the need for information to be sorted thoroughly in terms of timeframes and geographic scales to help target the different types of decision-maker.

Adaptive management has its roots in evaluation, with an added emphasis on what will be done about what is learnt from the evaluation.

The aim of the adaptive management framework is to ready or prepare for the unexpected, building in flexibility so that a response can be made as circumstances change.

The Goulburn Broken CMA's planning cycles for the Shepparton Irrigation Region/Agricultural Floodplains, which are common to many CMA endeavours, were used to establish key evaluation questions and identify and order items of evidence for answering the questions. These elements are subsequently being used, with minor modifications, for local plans for the other social-ecological systems identified in the Goulburn Broken RCS to initially structure a strategic approach to planning and establish a rigorous approach

to evaluation and adaptation (see table 10). Reviews of the Shepparton Irrigation Region Land and Water Management Plan and Goulburn Broken CMA Monitoring, Evaluation and Reporting Strategy are under way. Refer to section 11 for details of how this Plan will be evaluated.

Action

Use the Goulburn Broken CMA's adaptive management framework for SES local plans and for implementing the Goulburn Broken CMA's Climate Change Integration Strategy and Climate Change Adaptation Plan.

10.2 Adaptive pathways

Multiple possible futures and questions about possible transformation of social-ecological systems were important considerations in developing this Plan, and a project was trialed to test the feasibility of bringing together two planning approaches: resilience-based planning and adaptive pathways. Lessons from this test are being included as part of the adaptive management framework.

Adaptive pathways are a way of framing our thinking about the future so that strategies can be put in place to prepare for likely and unforeseen circumstances.

Table 10: Evaluation process for local plans for SESs in the Goulburn Broken Catchment

PLANNING STEP	KEY EVALUATION QUESTION(S)	EVIDENCE	TASK	SHORT-TERM ACTIONS	MID-TERM ACTIONS
Visioning and scoping	Example: Is the long term vision for the system right?	To be determined by stakeholders			
Strategic approach	Examples: • Do the mid-term (5-year) strategic approaches need to change? • What progress is being made towards the strategic approaches?				
Annual priorities	Example: Do the preferred investment priorities need to change this year?				
Reporting	Examples: • What annual progress was made? • What progress has been made in implementing the local plan? • What are the risks to the future of the system?				

Several possible futures, such as different climatic scenarios, are considered in the context of what a social-ecological system is now and what the community desires for its future. The desired future is defined in terms of resilience in the Goulburn Broken RCS and the adaptive pathway considers how close a system is to breaching thresholds of resilience, what the future would look like (and how the system would be functioning differently) if those thresholds were breached, and the interventions that would keep it on a desirable path.

Appendix E contains a case study for the Shepparton Irrigation Region (Agricultural Floodplains) that includes suggested steps for identifying adaptive pathways that create desired resilience. The case study was derived from workshops with representatives from the Goulburn Broken CMA and partner organisations and consultants: the adaptive pathways process has not been tested with community members.

The relatively long relationships and understanding between workshop participants, despite their different disciplines and organisations, was likely to have been a big contributor to the workshop's rich conversations in considering various futures: participants generally understood each other's mental models of how the Shepparton Irrigation Region and Agricultural Floodplains SES works. It is suspected that significant care would be needed when considering various futures involving participants with broadly different backgrounds.

An important element of the adaptive pathways process is to identify critical threats to a system's resilience, narrowing the focus for intervention on the five or six threats that are likely to matter in various future scenarios. The risk (likelihood and consequence) of breaching thresholds is a primary consideration in identifying these threats. The case study identifies these threats as 'key attributes': water tables, extent of native vegetation, water availability and farm processor viability.

10.3 Risk management procedure

Key evaluation questions in the adaptive management framework include prompts for considering what the desired future looks like, given prevailing and possible future circumstances, and what the threats and opportunities are of achieving that future. It is likely that this approach will also reveal the five or six critical threats to a system: there are strong correlations between an adaptive pathways approach and a risk management approach.

The use of a familiar management tool such as a risk management procedure is likely to expedite common understanding between stakeholders so that rapid, shared responses can be achieved. The Goulburn Broken CMA's risk management procedure, including use of its risk register, is being explored. The use of a risk management procedure in this way broadens its use beyond its usual focus on discrete issues to consideration of impacts on the resilience of the whole system.

The risk management procedure, as part of the adaptive management framework, includes regular, periodic reviews. The Goulburn Broken CMA Board's mandatory responsibility of regularly reviewing the risks highlighted in its risk register makes it a useful vehicle in implementing a truly adaptive approach.

Climate is one of several key drivers of a SES's functioning, and changes in climate will prompt the need for reviewing significant decisions on managing critical threats to the system.

Actions

Validate critical attributes, their thresholds and interventions by considering future scenarios (as part of an adaptive pathways approach) with a broader range of stakeholders in the Shepparton Irrigation Region/ Agricultural Floodplains.

Explore the use of adaptive pathways, considering multiple futures, across the Goulburn Broken Catchment's six SESs.

Explore the use of the Goulburn Broken CMA's risk management procedure, including the risk register, across the Goulburn Broken Catchment's six SESs

Use the tools developed as part of preparing this Plan to assess how climate change-related risks affect critical attributes and their thresholds within each of the Goulburn Broken Catchment's six SESs.

Explore how decision life times can be best used: monitor, trigger, prepare, decide, implement and response.

11. Evaluation and Improvement

This section details how this Plan will be evaluated and improvements made. The Plan will be evaluated against the purpose of this Plan.

As stated in the Introduction, the purpose of this Plan is to:

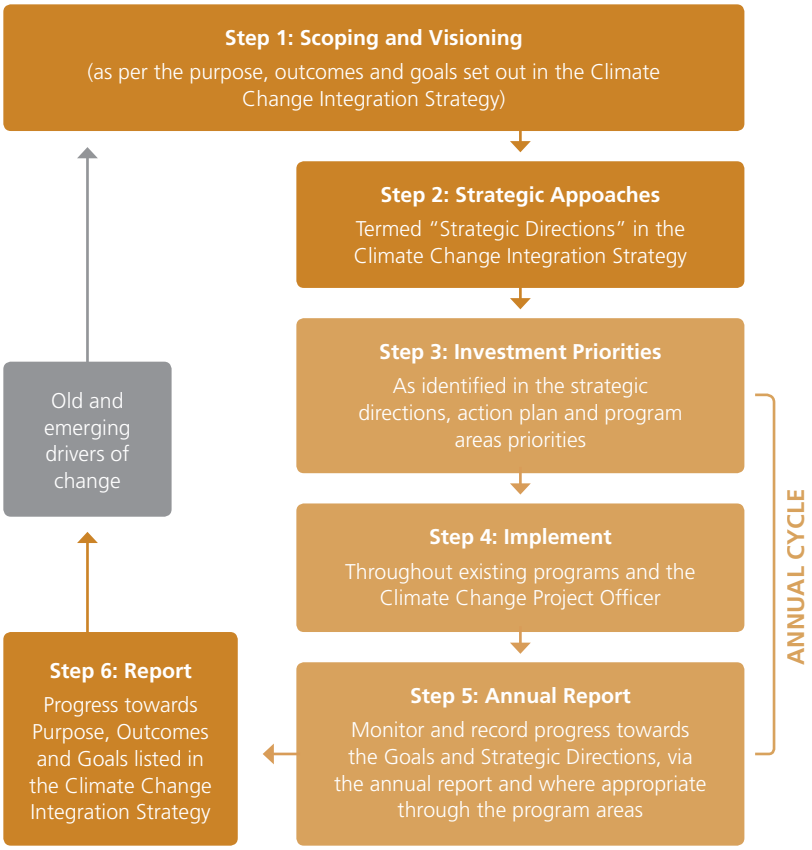
a. identify focus areas for climate change adaptation and mitigation in the context of improving the resilience of natural resources;
b. identify options for climate change adaptation and mitigation, including carbon sequestration, within focus areas; and
c. identify risks to catchment processes from carbon sequestration activities and mitigation actions.

This will be achieved through integrating this Plan (and associated tools created during the development of this Plan) into Goulburn Broken CMA and partner organisations' planning.

This Plan will align directly to the monitoring, evaluation and reporting process for the Goulburn Broken CMA's *Climate Change Integration Strategy 2012-2015* (see figure 29).

The progress of this Plan will be evaluated against key evaluation questions (see section 11.1) by key stakeholders.

Figure 29: Goulburn Broken CMA Climate Change Integration Strategy evaluation process (GB CMA 2012)



11.1 Key evaluation questions

Keeping in mind that the target audience for this Plan is NRM planners within the Goulburn Broken CMA and partner organisations, the key questions to guide evaluation are:

- Have the focus areas for adaptation and priority landscapes for mitigation and associated management options been considered in regional NRM planning, for example in reviews and updates of the Goulburn Broken RCS and associated sub-strategies and local plans?
- Have the tools developed to inform this Plan been used in other regional NRM planning?
- Are carbon farming activities in the Catchment being informed by this Plan?
- Have the tools developed to inform this Plan been updated to incorporate new information?

Abbreviations

CFI – Carbon Farming Initiative
CMA – Catchment Management Authority
CSIRO – Commonwealth Scientific and Industrial Research Organisation
ERF – Emissions Reduction Fund
NRM – natural resource management

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Appendix A: Summary of Communication and Engagement Activities

Throughout the development of this Plan a number of communication and engagement activities were undertaken to inform its development.

Regional NRM Planners and Technical Experts

This group was engaged early in the project to provide direct input into a review of the Goulburn Broken regional NRM planning framework, including an analysis of key landscape processes, how climate change is currently considered in planning and a SWOT analysis of the regional planning frameworks with respect to climate change.

The group participated in a number of workshops to establish criteria for an assessment of the vulnerability of the Goulburn Broken Catchment's natural resources to climate change that included assigning criteria weightings and informing and documenting assumptions underpinning the criteria.

The group also had input into the design and functionality of a Spatial Assessment Tool to spatially represent the vulnerability assessment.

Members of this group included NRM planners and technical experts representing the Goulburn Broken CMA, Goulburn Murray Water and the (Victorian) Department of Environment and Primary Industries (now Department of Environment, Land, Water and Planning) plus NRM consultants.

This group was given the opportunity to provide feedback to the first version of a draft of this Plan as part of a targeted consultation phase in July/August 2015 and then subsequently to the second version of the draft of this Plan as part of a broad consultation phase in October/November 2015.

A number of other NRM planners and technical experts were also engaged in an Adaptation Pathways Planning trial, exposing them to the climate change adaptation planning process.

Industry and Community Experts

This group was involved in a workshop offering participants the opportunity to provide input into the Plan. The objectives of the workshop were to:

- provide information about the Goulburn Broken CMA's regional NRM planning for climate change project;
- develop criteria which may be used to identify key areas of climate change vulnerability and priorities for climate change adaptation and carbon farming within the Goulburn Broken CMA region; and
- obtain feedback on a review of how climate change has been addressed in the Goulburn Broken regional NRM planning framework.

This group of participants was significantly interested in the Goulburn Broken CMA's strategic objectives with respect to climate change adaptation planning. They did not engage fully with the information that was intended to be discussed in the workshop and hence discussions diverged to more general climate change issues. The group was given an opportunity to provide comment on the draft of this Plan during a broad consultation phase in October/November 2015.

Key Partners

A number of key partners have been engaged through a variety of methods over the course of the regional NRM planning for climate change project.

- Formal presentations have been given on seven occasions as a part of seminars or conferences with attendees representing partners from research, state and federal government and other NRM organisations.
- Written reports have been provided monthly to the Goulburn Broken Catchment's NRM Partnership Team, providing an update on progress and major achievements.
- The Goulburn Broken CMA is a member of the Victorian NRM Planning for Climate Change Forum in which members share project development and collaborate on projects.
- Engagement and communication activities have also been facilitated through the Murray Basin Cluster of NRM groups for the Regional NRM Planning for Climate Change Stream 2 projects. Both NRM organisations and climate change researchers have had input into the projects.
- Briefings have also been provided to the Hume Region Managers Forum Environment Sub-group, Sustainability Victoria, Department of Environment, Land, Water and Planning, the Goulburn Broken Greenhouse Alliance and the Goulburn Broken Local Government Biodiversity Reference Group. This group was also given an opportunity to provide comment on the draft Plan during the broader consultation phase in October/ November 2015.

The Goulburn Broken Catchment Community

The broader community has been engaged in the project through a series of 'kitchen table' discussions to understand the community's perceptions about climate change and discuss what climate change adaptation options are needed both now and in the future.

The community was also given the opportunity to provide feedback to the draft of this Plan during a period of broad public consultation in October/November 2015.

Regional NRM Planning for Climate Change in the Goulburn Broken Steering Committee

Members of the Steering Committee include representatives from the Goulburn Broken CMA, the (Victorian) Department of Environment Land, Water & Planning, the Goulburn Broken Greenhouse Alliance, local government and the (Commonwealth) Department of Environment. The Committee meets quarterly to provide advice on project governance, direction and legacy and alignment with government policy and planning.

Appendix B: Exposure Maps

Figure 30: Exposure of the Goulburn Broken Catchment's natural resources to climate change for 2030.

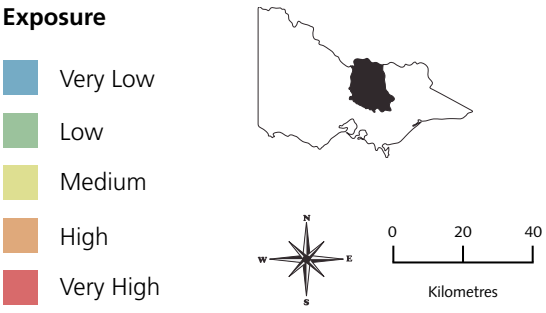
Scenario 2030
RCP 4.5
Low change: warmer with little change in rainfall

Figure 31: Exposure of the Goulburn Broken Catchment's natural resources to climate change for 2050.

Scenario 2050
RCP 4.5
Moderate change: hotter and drier

Figure 32: Exposure of the Goulburn Broken Catchment's natural resources to climate change for 2070.

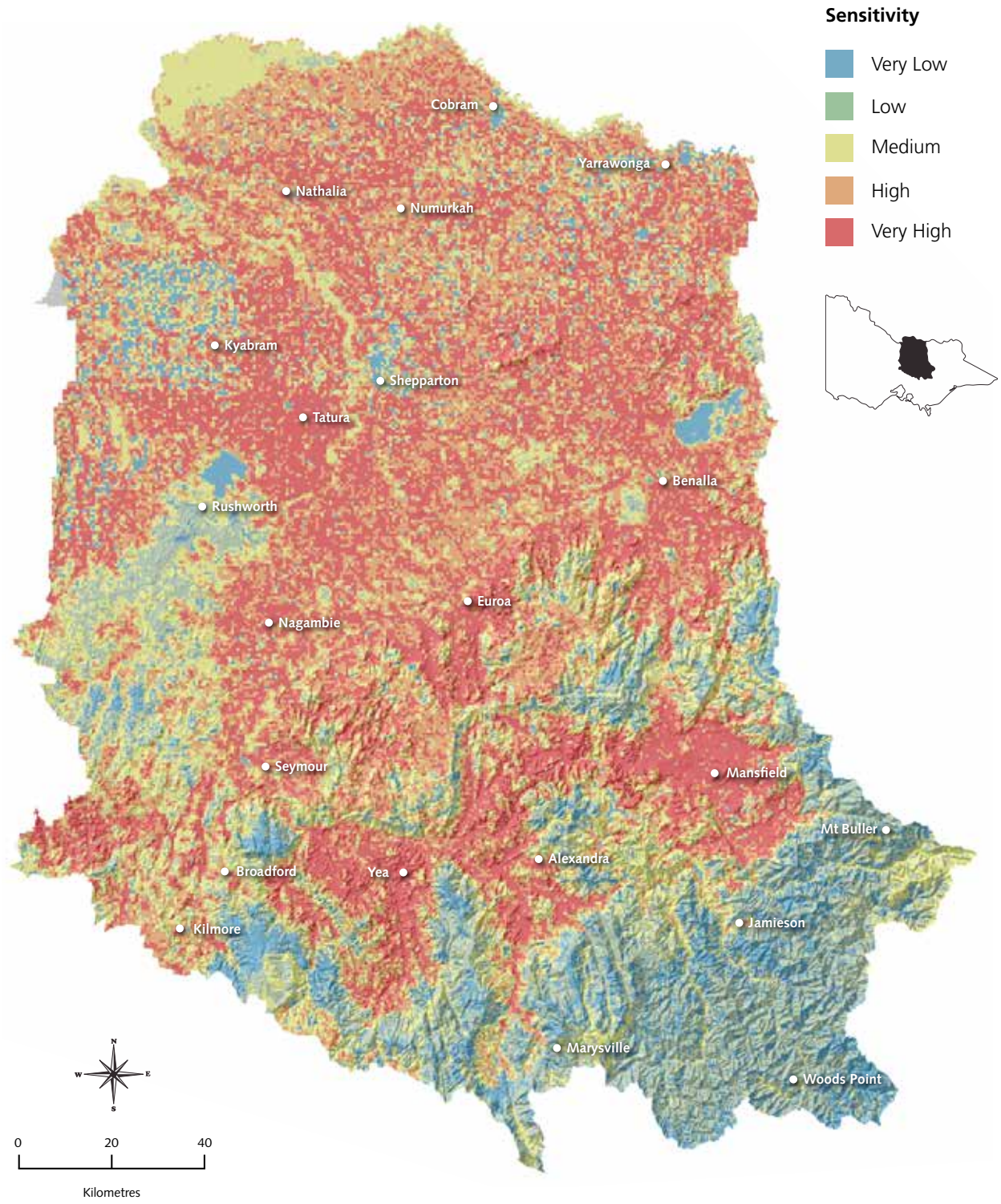
Scenario 2070
RCP 8.5
High change: much hotter and much drier



Criteria used for the exposure assessment is outlined in section 5.

Appendix C: Sensitivity Map

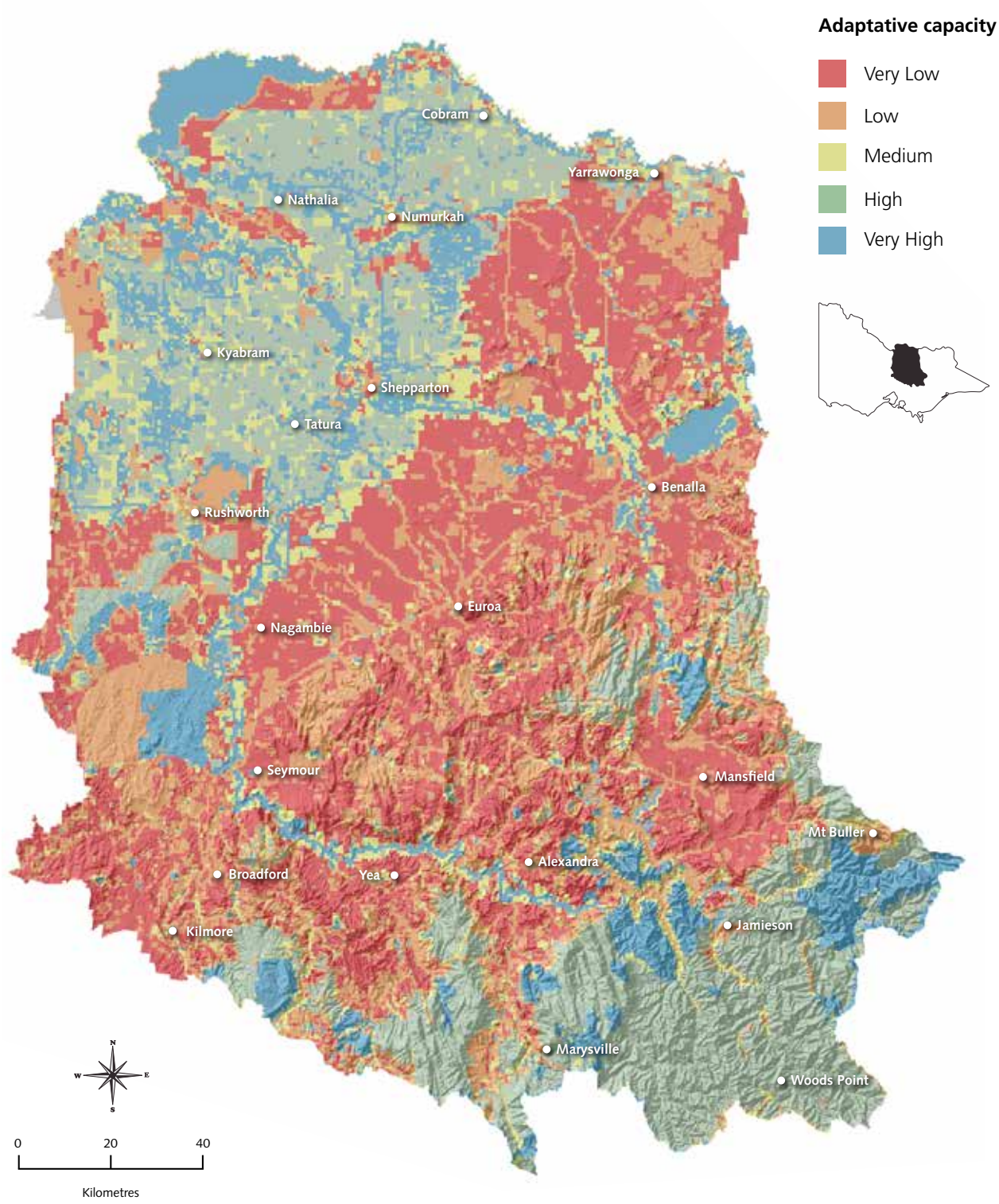
Figure 33: Map of an assessment of the sensitivity of the Goulburn Broken Catchment's natural resources to climate change.



Criteria used for the sensitivity assessment is outlined in section 5.

Appendix D: Adaptive Capacity Map

Figure 34: Map of an assessment of current (year 2014) adaptive capacity of the Goulburn Broken Catchment's natural resources to climate change. Ongoing investment in management actions will be required to maintain and increase adaptive capacity as climatic conditions change over time (see section 7.5 and 7.6).



Criteria used for the adaptive capacity assessment is outlined in section 6.

Appendix E: Case study; Planning for multiple futures in the Shepparton Irrigation Region

The Shepparton Irrigation Region (SIR) is a highly productive, intensively irrigated region, producing much of Victoria's, and indeed Australia's, agricultural production. Approximately 317,000 of its 500,000 hectares can be irrigated for dairy, cropping, stone and pome fruit production. The SIR uses around 1.2 million megalitres of water a year and creates agriculture products worth an estimated 1.38 billion dollars in 2006 and, in turn, supports a large food processing industry. The region is heavily dependent on agriculture and food manufacturing for employment.

A land and water management plan for the SIR was prepared in 1989. This was supported by a number of sub-strategies. All documents have been regularly reviewed and updated.

The SIR has been subjected to a number of significant pressures/ divers including:

- a significantly drier climate
- a major drought
- reduced consumptive water availability
- declining water tables
- increased opportunities for water trade
- irrigation system modernisation and reduced footprint of irrigation
- changing farm enterprises.

In addition, the outlook for the future climate of the SIR is for significant change including:

- higher temperatures in all seasons
- more hot days and fewer very cold days
- decline in winter rainfall
- increase in summer rainfall
- increased extreme rainfall intensity
- natural rainfall variability may mask trends to average rainfall particularly in summer
- evapotranspiration may rise particularly in summer and autumn

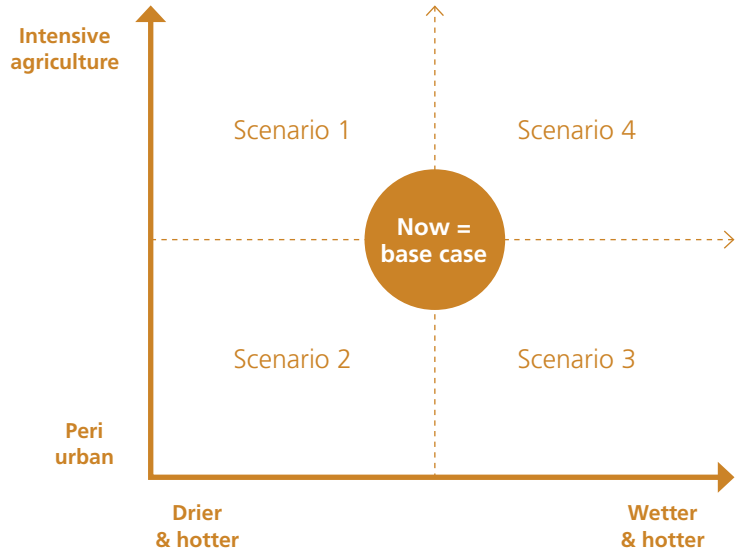
It has become apparent that the paradigm driving the development and implementation of the SIR's plans has changed significantly. The process of updating plans, currently under way, uses a combined resilience and adaptation pathways approach that involves:

1. *Identifying and describing key attributes of the region.* These describe the identity or state of the SIR, at a high level. They are attributes of the region that if changed beyond a certain point (threshold) would result in a fundamental change in the state of the region. There is a deliberate effort to try and identify only 5 or 6 big ticket items. The attributes identified are watertables, extent of native vegetation, water availability and farm processor viability. Indicators are attached to each key attribute.
2. *Identifying thresholds for each attribute.* The threshold is the point at which the key attribute changes and affects the fundamental state of the region. For example clearing of more than 97% of the native vegetation if the region would represent a fundamental change to the nature of the region. Further work is required to identify or refine thresholds for other key attributes.

3. *Describing 4-5 future state scenarios that include consideration of the likely impacts of climate change.* Simplistically, a number of regional future state scenarios (and a base or current state) can be described in the four quadrats outlined in figure 35 by two axes representing potential climate futures (drier and hotter through to wetter and hotter) and a range of potential land uses (peri urban through to intensive agriculture). The key here is to have just enough information to facilitate the process.

4. *Assessing the risk to key attributes in the future state scenarios.* This step identifies the likelihood of thresholds being crossed for each key attribute in each of the identified scenarios. For example, in a hotter and drier future state an increase in the area with watertables at less than 2 metres in depth is unlikely but in a wetter future state it is highly likely. This provides valuable information about the direction of required management in the future.

Figure 35: Potential Shepparton Irrigation Region Futures



5. *Assessing current and potential future management actions that are, or could be, used to mitigate risks.* Risks can be mitigated by implementing management actions. For example, the likelihood of the area of the region with watertables at less than 2 m in depth can be mitigated (managed) by encouraging farmers to pump groundwater. The confidence that the management action will achieve the desired outcome can also be assessed.

6. *Implement management and monitoring.* An outcome of this process is that management plans are developed (or updated) and implemented. Monitoring thresholds and actions will gather data that will inform management review and improvement.

7. *Reviewing and improving.* An annual planning cycle embedded within a longer, five year adaptive planning cycle requires monitoring of thresholds and management actions that will oblige managers to evaluate the state of key attributes and if necessary, revise and improve plans. Management actions will be focused on things that matter.

The process can be applied at a range of levels of detail. For example, a management board might focus at a strategic level on the key attributes listed above. A program or project manager will require much more detail including an expanded set of indicators (for example extent of native vegetation could be expanded to consider quality as well as quantity). The expanded set can be collapsed for upwards reporting.

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