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CLIMATE CHANGE
ADAPTATION
RESEARCH
PARTNERSHIP



IMPACTS & ADAPTATION
I N F O R M A T I O N
FOR AUSTRALIA'S NRM REGIONS



Southern Slopes Information Portal Report

Climate change adaptation information for natural resource
planning and implementation

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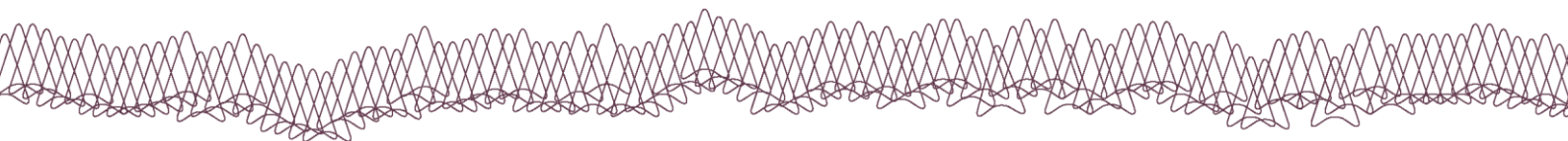
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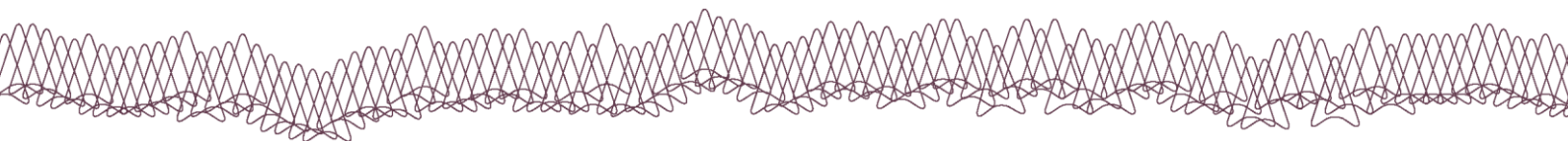
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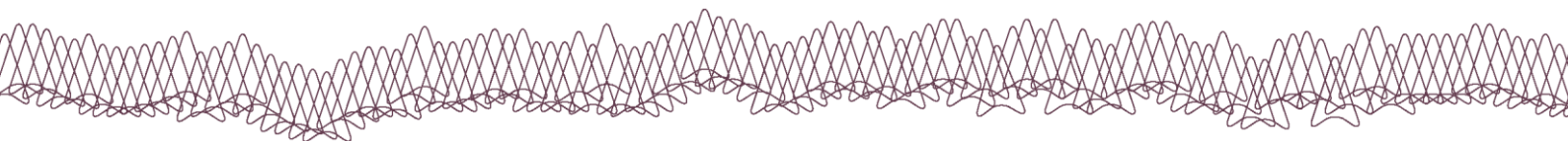


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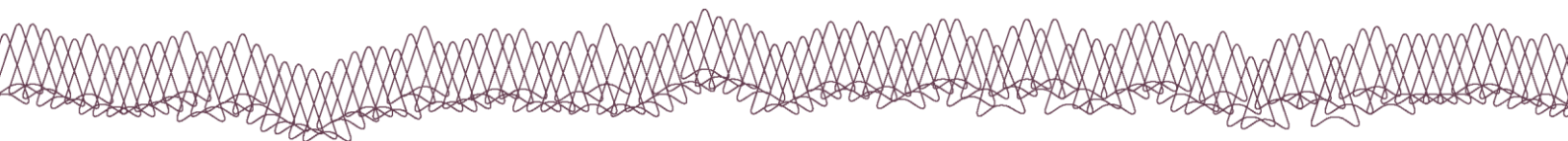
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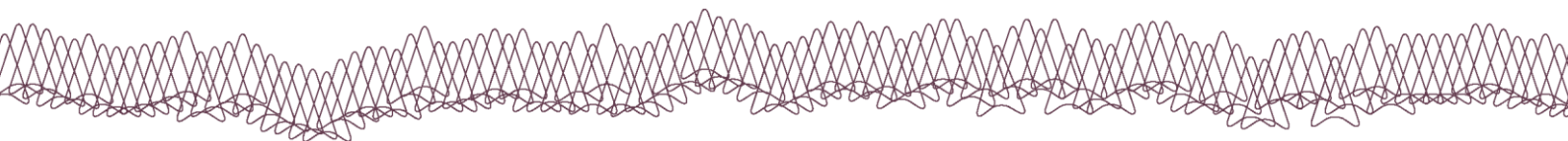
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Foreword

We know that climate change is with us but how can we plan for such an uncertain future? This is the challenge facing natural resources management (NRM) organisations and local communities across Australia. We know that the earth is generally getting hotter, but where and when will the rain fall? How will our overseas markets react to climatic and other challenges? Some land use changes that might seem sensible from an economic point of view, will not be viable with changed land and water regimes. How will our biodiverse ecosystems adapt and thrive in their changing environments? How can we plan to make sure they can adapt?

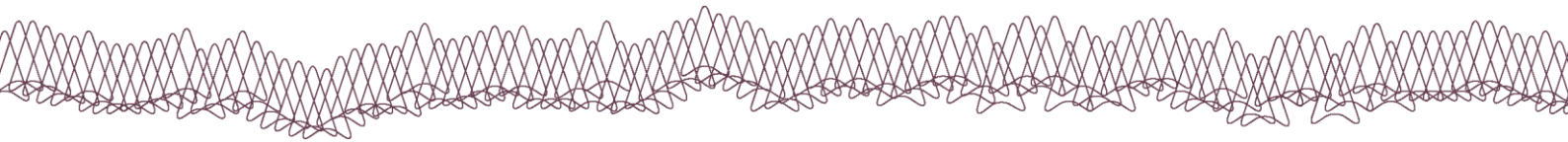
To address these challenges NRM organisations across the Southern Slopes Cluster have worked together with researchers from universities and state agencies involved in the Southern Slopes Cluster Climate Change Adaptation Research Partnership (SCARP). Together they have synthesised relevant information and importantly drawn on research in Australia and overseas to develop fit-for-purpose approaches which will assist NRM organisations to manage the ongoing challenge of climate change.

SCARP has shown us ways we can look at our challenge from different points of view in order to develop and implement strategies. These new strategies will need to be workable over normal planning horizons, yet not compromise our options for the future. The resultant Pathways approach to planning for climate change adaptation will help us to do this.

Partnerships and Pathways were the key elements in this endeavour. This Portal Report brings together the information necessary for the Southern Slopes NRM organisations to develop their strategies and plans for adapting to climate change, and to assist with ongoing implementation of options for adaptation.

Christine Forster AM

Chair, SCARP Steering Committee



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Overview

Our natural resource base is the primary source of our wealth and well-being. This means that looking after land, water and the other species with which we share the country underpins sustainability. Although there are some good news stories, widespread trends of continuing degradation indicate that we are unlikely to pass on the country to future generations in a better condition than we found it. Limiting such degradation, let alone maintaining or enhancing the condition of our natural resources, will be an increasing challenge under a changing climate.

This report contributes to addressing that challenge. It is a key output of a collaborative process, throughout 2013-14 that linked university researchers and government extension specialists with natural resource management (NRM) planners and practitioners across south-eastern Australia. This endeavour has been referred to as SCARP, the Southern Slopes Climate Change Adaptation Research Partnership.

This report is a key reference document to inform the development of regional NRM strategies, operational plans and even the development of specific programs and projects.

The central focus of the report is strategic planning for NRM in a changing climate. While much of material referenced in the report is generally relevant to NRM climate planning, we have specifically focused on the Southern Slopes region in south-eastern Australia as

shown in the map below.

While the specifics of the future remain unknown, research across the physical, biological and social sciences provide substantial insight into the plausible future impacts of climate change, and into possible ways to both mitigate risks and take advantage of future opportunities.

This report synthesises such research to provide a broad knowledge-base to inform the development of NRM strategies.

Using this report

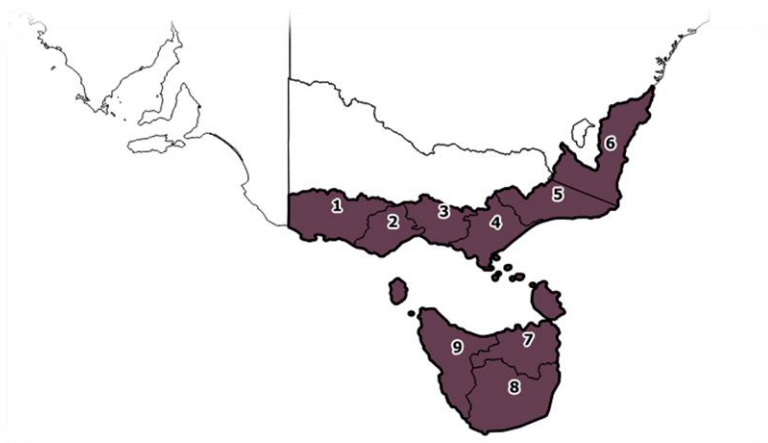
There is no single, ideal blueprint for climate change adaptation. Yet NRM needs to be both strategic and focussed on outcomes, while remaining agile in the face of change.

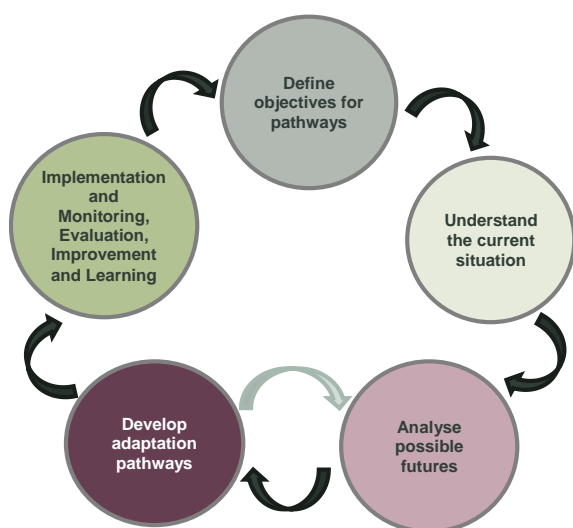
For these reasons the approach presented in this report is diagnostic. The report presents a way of proactively planning for future NRM by detailing the components of a pathways approach to adaptation. This approach is designed to be adaptable and useable at different scales, and in different contexts. It provides planners and stakeholders with a set of resources and tools that can be used in different stages adaptive management. The sections correspond to the five different phases of an adaptive management cycle with a pathways focus (see Figure).

The Southern Slopes Cluster

1. Glenelg-Hopkins CMA
2. Corangamite CMA
3. Port Phillip and Westernport CMA
4. West Gippsland CMA
5. East Gippsland CMA
6. South East Local Land Services*
7. NRM North
8. NRM South
9. Cradle Coast NRM

* Pre-2014 Southern Rivers CMA boundary shown





These phases correspond with sections of the report as follows:

- **Section A relates to defining objectives**, particularly framing goals and objectives that are ‘climate ready’;
- **Section B is about assessing the current situation** in relation to objectives, in order to diagnose the types of information processes and adaptation options that are likely to help achieve objectives;
- **Section C relates to assessing future climate change** and developing plausible scenarios of the future, against which options can be evaluated. This section contains a synthesis of climate drivers, climate change and impacts on NRM assets and regions across the Southern Slopes;
- **Section D is about identifying and prioritising options** for adaptation and mitigation of greenhouse gases. It provides detail about the sorts of options available and means of assessing them to build pathways towards achieving long-term objectives;
- **Sections E relates to working with communities** and stakeholders to implement preferred options, and;
- **Section F details options for setting up monitoring and evaluation** to underpin ongoing, learning, and adaptive management and governance.

Development of the Portal

The Portal Report has been developed using a collaborative digital ‘Portal’ through which NRM planners and SCARP researchers iteratively negotiated its content and shared ideas and resources.

The original design of the Portal drew on the VCCCAR Adaptation Navigator (<http://www.adaptation-navigator.org.au/>) and has evolved to focus specifically on NRM and the needs of NRM planners. Like the Navigator, the Portal is intended to be a reference document that readers can dip into at any starting point – it doesn’t necessarily need to be read from start to finish.

Through this portal process we have pulled together a suite of tools, methods and approaches, as well as an information base that can be applied to a diverse range of NRM issues.

Other reports in this series

SCARP has developed a summary report that is a guide to both the pathways approach and to this more detailed report: the *Adaptation Pathways Planning Playbook*.

Alongside SCARP’s *Playbook* and this *Portal Report*, SCARP has also produced the following reports:

- *A Guide to Adaptive Capacity for NRM*
- *A Review of Carbon Sequestration in Vegetation and Soils*
- *Spatial Prioritisation for NRM in a Changing Climate*

CSIRO and the Bureau of Meteorology also produced a technical climate report for the Southern Slopes Cluster:

Grose, M. et al., 2015, *Southern Slopes Cluster Report, Climate Change in Australia Projections for Australia’s Natural Resource Management Regions: Cluster Reports*, eds. Ekström, M. et al., CSIRO and Bureau of Meteorology, Australia. Available at: <http://www.climatechangeinaustralia.gov.au/en/publications-library/cluster-reports/>



Section A.

Determining the purpose and scope

A. Determining the purpose and scope

The purpose of this section is to provide concepts and ideas to assist in navigating the initial phases of a climate change planning process. Attention is drawn to the role of framing, some commonly-used principles for planning and frameworks for adaptation. Definitions are given for climate change adaptation and mitigation, as well as guidance for defining desired outcomes in a coherent framework.

A.1 Appreciating different frames

A person or an organisation's frame is the way that they interpret or make sense of the world (Goffman, 1974). Frames shape planning processes because they are based on selective interpretations of 'what the issue or problem is', 'what's causing it' and thereby (through this frame) 'what should be done about it' (Goffman, 1974; Schön and Rein, 1994; Creed et al., 2002). Rather than attempting to assert that there is a 'right frame', there is value in working with a diversity of frames, as different frames draw attention to different things.

A.1.1 Considering framing

Working with multiple frames assists in understanding an issue, including the range of stakeholder and community values, as well as helping to uncover novel options for addressing an issue. Exploring a range of frames can improve the robustness and flexibility of a plan (Bosomworth, 2015) and provide natural resource management (NRM) planners with opportunities for crafting innovative approaches that are meaningful to a wide range of stakeholders (Dewulf, 2013).

This section encourages NRM planners to seek out those different frames or perspectives. As Figure A.1 illustrates, how a problem or issue is framed (or represented) often remains hidden from view. Implicit decisions about the framing have substantial planning implications. For example, they set up often unspoken norms or rules for the identification and selection of options to address an issue or problem.

What are some natural resource management frames?

In this section, different framings of NRM and climate change are explored. The purpose is to highlight how different frames among communities, NRM practitioners, and other stakeholders have led to specific outcomes or actions.

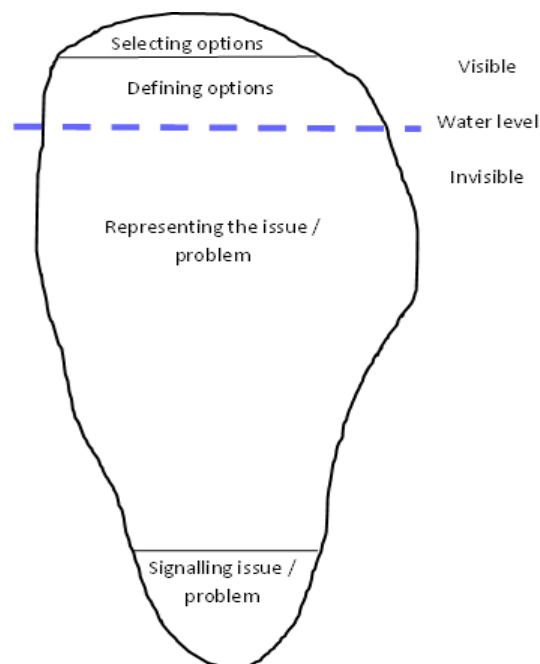
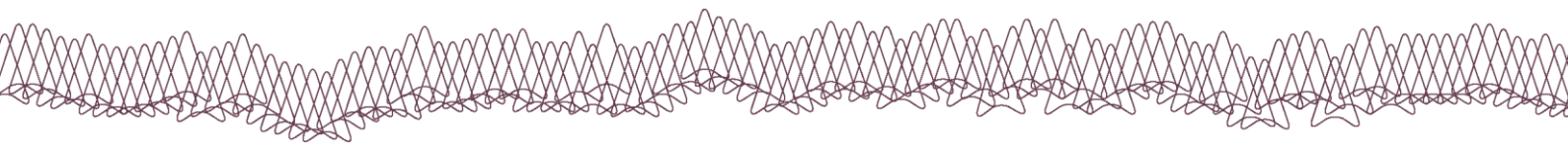


Figure A.1 The 'iceberg' model of decisions emphasises the importance of understanding how NRM issues are framed through problem signalling and representation, which then enables definition and selection of options (Adapted from Hoppe, 2011, p. 25).

There have been several historical shifts in our understanding of what regional NRM means in Australia. These 'paradigms' or 'models of doing NRM' are shaped and interpreted through various frames, each with their own underlying assumptions. These



assumptions are typically implicit, but nonetheless influential, in shaping the ways in which planning is done, what is planned for, who is involved, and who makes the decisions.

Robins (2007) documents several regional NRM 'paradigms' that continue to be widely-held. These paradigms frame ways of thinking and doing. Adoption of a paradigm tends to give rise to particular understandings of what the problem is and how to deal with it. By understanding these paradigms and related framings, NRM planners can make more informed choices about how to approach their work. The paradigms Robins identifies are all expressed to various degrees in current Australian NRM practice and in strategies.

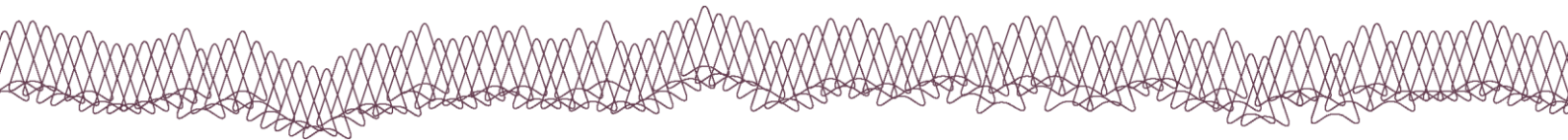
Firstly, the **land conservation** paradigm was typified by the emergence of the Landcare movement in the 1980s, which involved landholders working together to address regional environmental problems such as salinity and erosion. In this paradigm, while not specifically discussed in Robins (2007), one could interpret that the 'problem' is framed as looking after natural resources on and across land held privately by several landowners in a region. Likewise, the 'cause' of the problem could be framed in that government authorities can manage public land, but the heterogeneity of private land ownership means that no single landowner can be responsible for the whole landscape. The 'solution' then could be framed as building connectivity and enabling communities and individual landowners to take actions that benefit the landscape, even if the benefits are derived by other owners.

Secondly, the **integrated catchment management** paradigm, which has a long history going back to river improvement trusts and land drainage trusts (in the State of Victoria and elsewhere), involves 'integration' across biophysical units (such as land and water) and across organisations. This paradigm leads to a frame that views a river basin as a unit for planning and management; a concept that has evolved over time as argued by Molle (2009). A catchment is a 'political and ideological construct' that has undergone several historical shifts. Framing catchments as hydrological units has advantages, notably the ability to manage human and environment relations across the entirety

of a catchment. However, this framing makes it difficult for planners to address factors that cross catchment boundaries.

Thirdly, sustainable development has emerged as a more recent paradigm for regional NRM. One way that sustainable development can be understood, while open to wide interpretation and contestation (Stern, 1997), is across a spectrum from 'weak' to 'strong' sustainability, based on the extent to which natural 'capital' can be substituted by other forms of capital (e.g. human capital). Framed as weak sustainability, all natural capital can potentially be replaced with other types of capital, and hence natural assets can be 'run down' while maintaining the overall stock of capital. When framed as strong sustainability, natural capital cannot be substituted with other types of capital, and must instead be conserved. Hence, for NRM, the different framings of sustainable development draw attention to how different organisations, stakeholders and communities understand and value the relations between natural and human systems. Coffey and Marston (2013, p. 186), based on research conducted in Victoria, provide a useful summary of three dominant understandings of sustainability (Table A.1). 'Sustaining development' can be understood as a 'weak' form of sustainability, where the emphasis is on managing natural resources for human development. By contrast, 'focusing on sustainability' can be understood as a 'strong' form of sustainability, where the emphasis is on managing ecosystems for biodiversity outcomes.

Fourthly, NRM has been increasingly framed according to the emergence (and dominance) of the neoliberal paradigm. Neoliberalism is a set of ideas with diverse theoretical roots in liberalism, utilitarianism and post-Keynesian economics. Proponents argue for 'smaller government' and adhere to core beliefs in market mechanisms, competition and the privatisation of public assets (e.g. see Larner, 2000; Pusey, 2003). In NRM, a neo-liberal framing might be associated with the 'sustaining development' perspective outlined in Table A.1, though this not a perfect fit. In this framing, NRM issues are framed as "caused by the cumulative effects of individual choices" (Coffey and Marston, 2013, p. 196) rather than features of social and economic systems. Solutions rely on "the importance



of individual choice and behavioural changes” rather than ‘transformative’ or structural change (Coffey and Marston, 2013, p. 196). In terms of planning, such a framing can limit decision-making to “quantifiable benefits and costs and giv[e]... secondary importance

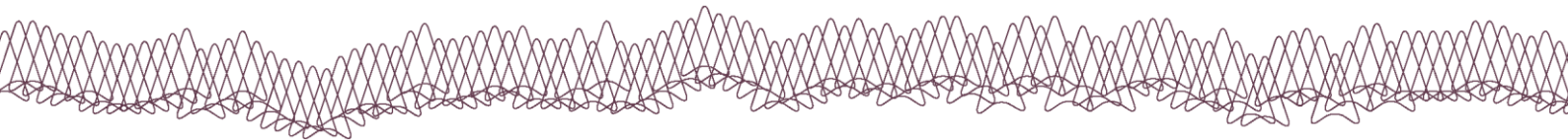
to ecological, social and cultural values” (Robins, 2007, p. 305).

Table A.1. ‘The discursive space associated with sustainability debate in Victoria, 1999-2006’ (Adapted from Coffey and Marston, 2013, p. 186).

| CORE ELEMENTS OF DISCOURSE | SUSTAINING DEVELOPMENT | ENVIRONMENTALLY SUSTAINABLE GROWTH | FOCUSSING ON SUSTAINABILITY |
|--|--|--|---|
| | A ‘weak’ form of sustainability, where the emphasis is on managing natural resources for human development | A ‘moderate’ form of sustainability, where growth and managing for biodiversity are balanced | A ‘strong’ form of sustainability, where the emphasis is on managing ecosystems for biodiversity outcomes |
| Approach to sustainability | Balanced Trade offs <i>Ad hoc</i> responses | Triple bottom line - win, win, win Integrated/balanced Journey | Interconnections Integration Destination |
| Representation of nature and the environment | Natural resource | Provider of ecosystem services | Integrated ecosystems |
| Source of concern | Narrow anthropocentric - sustain the resource base | Enlightened anthropocentrism - maintain ecosystem services | Range of motivations Ethical concern for biodiversity as well as humans |
| The magnitude of the challenge | Small steps Needs basis | Low-hanging fruit Journey | Fundamental shift Destination |
| Cause of problems | Inefficiency | Poor choices | Systemic characteristics |
| What should be done? | More efficient management | Better choices, behaviour change and adoption of improved technologies | Transformative change |

A fifth paradigm is **regionalism**, which follows two inter-related, though often divergent trends: (1) regional communities involved in and leading decision-

making; and (2) governments administering regions. Robins (2007, p. 306) notes that “governments have been more adept at devolving responsibilities (and



accountability) for programme management and delivery than providing the requisite power and resources”.

NRM regional strategies reflect implicit paradigms, for example, through expressions about organisational roles:

*The primary goal of each CMA is to **ensure the protection** and restoration of land and water resources, the **sustainable development** of natural resources-based industries and the **conservation** of our natural and cultural heritage.*

This example from the Corangamite CMA’s 2003-08 Regional Catchment Strategy (p. 111, emphasis added), demonstrates both the ‘land conservation’ and ‘sustainable development’ paradigms.

*The Glenelg Hopkins CMA acts as a **knowledge broker** and develops high quality regionally coordinated funding bids to **attract investment**. The Glenelg Hopkins CMA is the **regional** co-ordinator of the Waterwatch program.*

This example from the Glenelg-Hopkins CMA’s 2003-07 Regional Catchment Strategy (p. 114, emphasis added) highlights the ‘neoliberal’ context in which NRM bodies operate (as facilitators to attract investment), and the resulting strategies and identities adopted (acting as a knowledge broker), as well as reinforcing the regional scale of governance.

In this sense, Lockwood and Davidson (2010) suggest that NRM in Australia is shaped by ‘hybrid’ modes of environmental governance – that is, diverse combinations of different frames or paradigms.

What are some climate change frames?

Climate change has become a major policy challenge. At a global scale the level of international diplomacy and cooperation needed to shift the basis of our industrial economies is unprecedented. At a more local and regional level, the decisions and actions that communities and organisations need to take will be increasingly challenging as the projected changes in climate play out.

Leading academics suggest that it is useful to think about climate change from a variety of different perspectives (e.g. see Dewulf, 2013). A detailed

account of the many ways that climate change has been represented and understood can be found in Hulme’s (2009) book, *Why we disagree about climate change*. Hulme (2009, p. 361) concludes with the argument that the “idea of climate change should be used to rethink and renegotiate our wider social goals about how and why we live on this planet”. The following provides an overview of key framings that shape ways in which climate change issues are addressed.

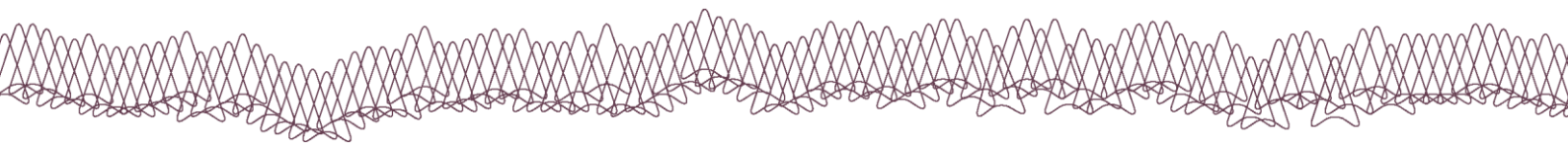
Scientific

The dominant framing of climate change has focused on climate science and the degree to which we can detect change in different meteorological parameters, attribute that change to human activity, and project change forward into the future (e.g. see Grose et al., 2015 for a technical report on climate change projections in the Southern Slopes region). Much work has been done on the science of climate and, for over two decades, there has been an increasingly strong consensus about the evidence for anthropogenic climate change (e.g. IPCC, 2014a). Substantial international effort in climate science has led to increasing confidence in global climate models (GCMs) to understand future climates under different emission scenarios. Increasingly, these GCMs are being supplemented with regional climate models (RCMs), providing fine-scale climate change projection information, more suited to the regional scale of NRM (e.g. in the context of Tasmania see ACE CRC, 2010). We do not cover this work in detail as it is the focus of the CSIRO Element 1 (projections) project (though see [C.1 Climate change projections](#)).

Social

Climate change (and addressing it) has been hotly debated over recent years, largely because it directly challenges people to reconsider the basis of economic and social life in western industrial countries (Lucas et al., 2014). As sociologist Urry (2009, p. 89) argues,

“to slow down, let alone reverse, increasing carbon emissions and temperatures requires the reorganisation of social life, nothing more and nothing less. The nature of ‘social life’ is central to the causes, the consequences and the possible ‘mitigations’ involved in global heating.”



There are many discourses about climate change, and many groups who argue passionately, often from polar perspectives (frames), about what should be done.

A large literature focussing on the use of imagery, narrative, and different problem framing provides a potentially useful resource for planners who are engaging with communities about climate change. O'Neill et al. (2013) provide a useful entry point into literature on imagery.

Economic

Economic framings of climate change have been critically important in developing approaches that can place monetary values on climate adaptation and mitigation actions at a variety of scales. For example, economists such as Stern (2007) and Garnaut (2011) have demonstrated the substantial financial value of acting as soon as possible to mitigate the impacts of climate change through rapid cuts in emissions.

How can framing be considered in a planning project?

Given the different potential ways of framing: (i) the purpose of NRM plans; (ii) the design of planning processes; (iii) what issues they address; (iv) what they are trying to achieve (vision, goals, objectives); and (v) the choice of strategies and actions, how can a planning project be scoped to both recognise and deal with this complexity? In the following, two strategies for managing this complexity are highlighted.

Draw on different ways of knowing (i.e. different frames)

Within the scientific frame highlighted above, there is a tendency to rely on subject-matter experts with hard technical solutions, particularly where there is ambiguity about what is at stake (Brugnach and Ingram, 2012). In particular, when people are confronted with complexity and uncertainty about the situation they are managing or planning for, they can reduce the problem down to manageable parts (reductionism). In NRM, this can mean separating social processes and systems from biophysical systems; in effect, decoupling what can be thought of as social-ecological systems. A way of addressing this

is to include different ways of knowing, including local and indigenous ways of knowing, within planning processes. These strategies are explored further in **E.1 Engaging with different communities**. One specific strategy might be to actively adopt a social-ecological systems approach (in itself a particular framing choice). Such an approach would firstly establish a preliminary high-level understanding of the key attributes of the system, and then use this to identify strategic priorities and potentially fruitful points of intervention. Cycles of implementation and monitoring allow for progressively greater understanding of the system.

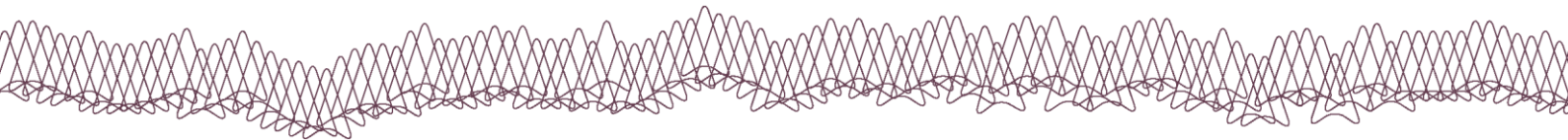
Monitor, evaluate and learn at each stage of the process

In the standard 'plan-do-check-adjust' management model, it can take some time before the effectiveness of the 'planning' and 'doing' phases are known. Alternatively, processes can be developed to incorporate monitoring, evaluating and learning at all stages of the planning and implementing process. This approach, explored in more detail in **F.1 Role of feedback in NRM planning** and implementation, is one means of reducing the likelihood of inappropriate framing choice.

In summary, when scoping how the planning process is designed and what the planning process will try to achieve it is worth considering the implicit framing assumptions of those involved and recognising framing choice, involving others who can bring different perspectives, and instituting mechanisms for monitoring, evaluating and learning in an ongoing way.

A1.2 Principles for planning

Different ways of framing NRM issues or problems are associated with differing approaches to NRM and climate change. For example, Briassoulis (1989) identified six approaches to environmental planning: comprehensive/rational; incremental; adaptive; contingency; advocacy; and participatory. As noted above, in practice planners often combine elements from these different approaches into 'hybrid' types. This combining is often done without guidance from



frameworks or principles, which relies heavily on individual experience and assessment capability.

Principles can be useful to underpin and guide planning, and make explicit the commitments and values central to decision making. For example, most planning processes involve some mix of expert judgement and community involvement, but the actual balance and relationship between these varies considerably (e.g. 'top-down' and 'bottom-up' planning). In the following we briefly outline: (1) key planning principles applicable to NRM; (2) governance principles relevant to NRM; and (3) the Australian

Government Stream 1 principles, that NRM practitioners may find useful in developing their plans.

These principles are useful to NRM planning more generally. See [D.2.1 Developing pathways of adaptation options for NRM](#), for an outline of some 'fundamentals for adaptation in NRM' that relate specifically to climate change adaptation planning.

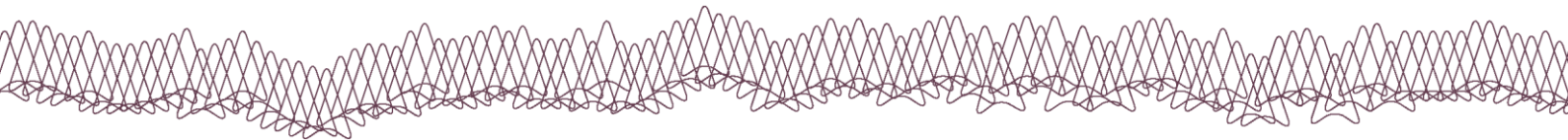
Key planning principles applicable to NRM

In Table A.2 principles of planning applicable to NRM are outlined, following Worboys et al. (2005).

Table A.2 Planning principles

| PRINCIPLE | KEY ELEMENTS |
|---|---|
| 1. Planners should consciously adopt a suitable mix of approaches that are: | (a) participatory at a level that matches the interests and concerns of stakeholders; (b) participatory in the identification of issues; (c) cognisant of the multi-value, multicultural context of [NRM]; (d) rational and participatory in the collection and identification of information to inform management; (e) rational in the application of formal procedures to assess any changes in land-use or major investments; (f) rational and participatory in the assessment of action options and selection of preferred actions; (g) adaptive in the implementation, assessment, refinement, and modifications of objectives and actions; and (h) incremental in addressing urgent or minor management requirements that, given information, organisational, or resource constraints, cannot be dealt with in any other way. |
| 2. Effective linkages should be established across planning levels such that: | (a) strategic planning occurs at the organisational and regional levels, including specification of goals and guidelines; (b) specific planning occurs at the local level, including development of measurable and realistic objectives that are framed in the context of strategic goals and have clear performance indicators; (c) explicit linkages are present between objectives and actions and outcomes; and (d) actions are consistent with strategic guidelines, and at a level of detail that allows for consistent interpretation and application. |
| 3. Effective implementation of actions arises from: | (a) availability of suitably trained staff to guide the planning process and implement the plan; (b) links between actions, available resources, the budget process, and performance evaluation; (c) definitions of roles and lines of responsibility in the managing agency regarding implementation of particular actions; and (d) works programs that are linked with the plan, contain dates for completion of actions, and are fed back into the performance evaluation. |
| 4. Formal evaluation of success is an essential part of a successful planning process and involves: | (a) lines of responsibility in the managing agency regarding evaluating performance against objectives; (b) mechanisms for formal recognition (and removal from the plan) of objectives that have been met and completed; (c) mechanisms for addressing objectives and/or actions that have not been met, including, where appropriate, their modification; and (d) clear guidelines for reviewing plans, objectives, and actions, including participants, responsibilities, and periodicity of revisions. |

Source: Worboys et al. (2005, pp. 217–218)



Governance principles are relevant to NRM

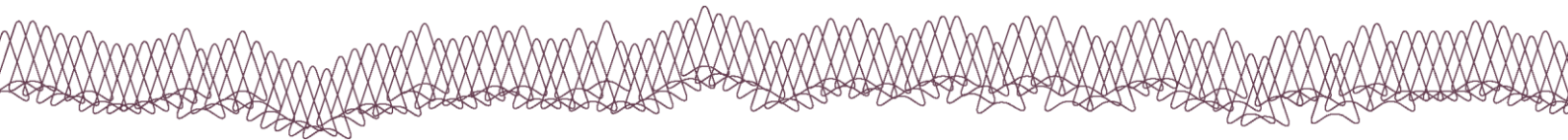
Governance principles inform the design and implementation of processes, arrangements and structures by which authority and power will be exercised, including who will be held accountable, and the roles and responsibilities of participants involved in the achievement of strategic and operational objectives. Lockwood et al. (2009; 2010) have developed a set of **eight governance principles** that

apply to NRM (Table A.3), noting that these principles are suited to “multilevel governance contexts in which important roles are played by both government and non-government institutions” (Lockwood et al., 2010, p. 987). The eighth principle, ‘adaptability’, underpins ‘adaptive governance’ by enabling systematic learning within and across organisations, and with intent to influence the broader social and institutional context (Folke et al., 2005).

Table A.3 Governance principles for natural resource management

| PRINCIPLE | KEY ELEMENTS |
|-------------------|---|
| 1. Legitimacy | (a) Validity of an organisation’s authority to govern that may be (i) conferred by democratic statute; or (ii) earned through the acceptance by stakeholders of an organisation’s authority to govern (b) Integrity and commitment with which authority is exercised |
| 2. Transparency | (a) Visibility of decision-making processes; (b) Clarity with which the reasoning behind decisions is communicated; (c) Ready availability of relevant information about the governance and performance of an organisation |
| 3. Accountability | (a) Allocation and acceptance of responsibility for decisions and actions; (b) Demonstration of how these responsibilities have been met |
| 4. Inclusiveness | (a) Opportunities available for stakeholders to participate in and influence decision-making processes |
| 5. Fairness | (a) Respect and attention given to stakeholder’s views; (b) Consistency and absence of personal bias in decision-making; (c) Consideration given to distribution of costs and benefits of decisions |
| 6. Integration | (a) Connection between, and coordination across, different levels of governance; (b) Connection between, and coordination across, organisations at the same level of governance; (c) Alignment of visions and strategic directions across governance organisations |
| 7. Capability | (a) Systems, resources, skills, leadership, knowledge and experience that enable organisations, and the individuals who direct, manage and work for them, to deliver on their responsibilities |
| 8. Adaptability | (a) Incorporation of new knowledge and learning into decision-making and implementation; (b) Anticipation and management of threats, opportunities and associated risks; (c) Systematic self-reflection on organisational performance |

Source: Lockwood et al. (2009, p. 174)



Australian Government Stream 1 principles

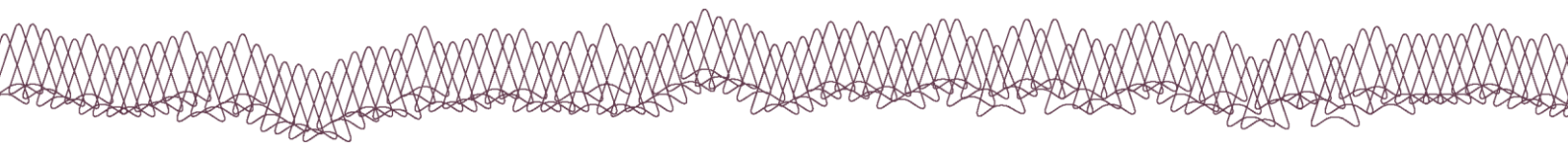
The Australian Government has specified three principles and associated attributes that NRM organisations can use to guide them when updating

their plans for climate change mitigation and adaptation. These principles (Table A.4) provide an indication of the desired scope of updated plans, and are the basis against which updated plans will be considered by the Australian Government.

Table A.4 Principles for the Regional NRM Planning for Climate Change Fund (Stream 1)

| PRINCIPLE | ATTRIBUTES |
|--|--|
| 1. Plans identify priority landscapes for carbon plantings and strategies to build landscape integrity and guide adaptation and mitigation actions to address climate change impacts on natural ecosystems | (a) Planning processes identify opportunities and management strategies to maximise environmental benefits and landscape resilience, including biodiverse plantings, wildlife corridors, landscape connectivity and protection of remnant vegetation; (b) Planning processes recognise, provide guidance to avoid and mitigate potential risks and adverse impacts associated with carbon sequestration in the landscape, including impacts to biodiversity, water resources and production systems; and (c) Planning processes identify priority landscapes for potential carbon sequestration opportunities, mitigation and adaptation in the context of improving landscape connectivity, resilience and wildlife corridors. |
| 2. Planning process is logical, comprehensive, and transparent | (a) Planning process consider previous planning and are consistent with relevant jurisdiction specific planning requirements; (b) Planning process are informed by a clear understanding of the regional stakeholder and community aspirations and objectives; (c) Planning process demonstrate a clear understanding of the regional bodies' business, roles and responsibilities; (d) Planning process show evidence of cooperation for cross-regional climate change impacts and land use planning; (e) Adaptive planning responds to new information and guide improvements as knowledge improves; (f) Planning process use information at an appropriate scale to spatially identify priority areas in the landscape for carbon sequestration projects and environmental co-benefits; and (g) Planning process demonstrate adaptive planning that responds to current and anticipated climate change research and additional information. |
| 3. Plans use best available information to develop actions and are based on collaboration with government, community and other stakeholders | (a) Plans demonstrate strategic alignment with relevant state and Commonwealth NRM policies (such as urban and regional planning, matters of National Environmental Significance, National Water Initiatives and the National Wildlife Corridors Plan); (b) Plans meaningfully engage community and stakeholders; (c) Where relevant plans identify and agree roles and responsibilities for partners in the region; and (d) Plans integrate biophysical, socio-economic and climate change information to fine tune strategies for improving landscape connectivity, function and resilience. |

Source: Australian Government (2012)



A2. Defining adaptation and mitigation in NRM

There are two broad categories of climate change responses: mitigation (avoiding or reducing greenhouse gas emissions and increasing sequestration of greenhouse gases); and adaptation. It is not a question of choosing between two options — we have to do both.

(Campbell, 2008, p. 2)

A2.1 Climate change adaptation

What is climate change adaptation?

The concept of adaptation has its origins in evolutionary biology, where it refers to an organism becoming better able to live and survive in its habitat. It is now widely used in a number of areas and disciplines, to describe a process of adjusting to external change. Such change creates risks and opportunities. Adaptation is the process by which we lessen risks or benefit from opportunities.

In the context of climate change, adaptation is mostly considered as adjusting to the medium and long-term impacts of climatic change, such as sea-level rise, temperature rise and changing rainfall patterns. In a broad sense, adaptation is about ensuring that species, including humans, and the systems they rely on for their living, are able to live and function in a changing climate.

According to the IPCC (2014b, p. 1758), ‘adaptation’ is defined as:

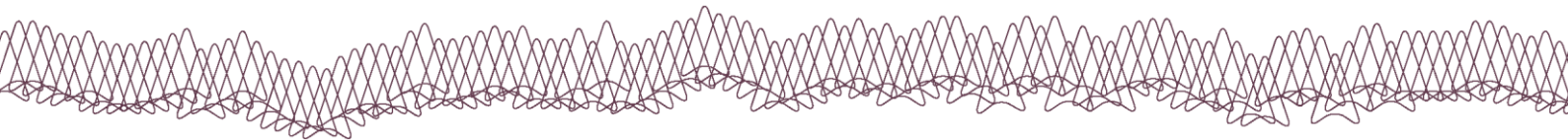
“The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.”

Adaptation can be considered a response to change in order to reduce vulnerability. In the context of climate change, vulnerability is defined as the potential impacts on a system that stem from its exposure to a

particular hazard, tempered by the sensitivity to that hazard, and the ability of the system to adapt or develop adaptive capacity. For example, if drought is taken as a hazard, an irrigation enterprise may be less sensitive to exposure to drought than a broadacre enterprise, depending on the duration of the drought. A family farm with off-farm income sources and mixed cropping, irrigation and livestock may be even less sensitive to drought. Thus, the potential impact of a drought can be understood in terms of this exposure and sensitivity. The impacts are things like loss of stock, degradation of soil, loss of income. Adaptive capacity will define the ability to delimit vulnerability through adopting new measures in the face of change. In the drought case, an entrepreneurial farmer might, for example, lease or purchase earth-moving machinery, recognising that during droughts there are often many farmers looking to expand or clean out dams. Communities who are commonly exposed to hazards often develop high levels of adaptive capacity over time (Nelson et al., 2010).

The terms noted above (see the **Glossary**) are important in order to understand different points and forms of intervention. For example, exposure to a hazard, such as increased risk of flooding in a catchment, is not a problem *per se*. It is the consequences of hazards – the impacts – that are the concern. Impacts of flooding might include loss of life, property or stock, interruption of transport and communication, erosion of stream banks and eutrophication of estuaries. These impacts might be lessened by a variety of interventions that reduce sensitivities or increase adaptive capacity, and thereby reduce vulnerability. For example, riparian planting may reduce the sensitivity of a stream bank to erosion associated with a flood. Such planting may involve an awareness of the problem and understanding of the costs and benefits of this particular intervention as well as the resources required to undertake the intervention.

These diverse resources can contribute to the development of adaptive capacity. Adaptive capacity is the “ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to



consequences” (IPCC, 2014b, p. 1758). Developing the adaptive capacity of relevant stakeholders within NRM is likely to be a key means of intervention to enable adaptation, and we have devoted a separate report to it (see SCARP’s report on Adaptive Capacity, Jacobs et al., 2015 for more information).

Adaptation therefore means changing the way humans do things in order to deal with the impacts of climate change, such as sea-level rise, changing temperatures and rainfall patterns, and their respective flow-on effects.

Within international science and policy communities there is a strong consensus that, at a global scale, we

need to mitigate the risks of climate change by slowing the rate of increase in atmospheric greenhouse gases (GHGs). This risk mitigation can be seen as a subset of adaptation – it is an adaptive response to avert problems by preventing them from getting worse. However, mitigation is usually talked about separately from adaptation (see separate section below). Nevertheless, mitigation and adaptation are linked and need to be considered together in responding to climate change. Table A.5, adapted from Fünfgeld and McEvoy (2011, p. 14) summarises and compares the objectives and definitions of climate change mitigation and adaptation.

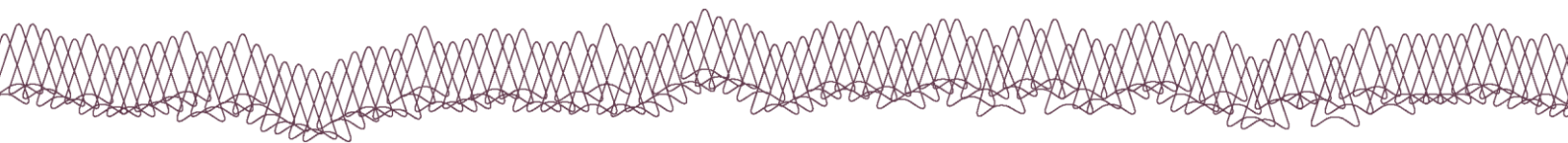
Table A.5 ‘Objectives and definitions for climate change mitigation and adaptation’ (Adapted from Fünfgeld and McEvoy, 2011, p. 14)

| | OBJECTIVES | DEFINITIONS |
|----------------------------------|---|---|
| Climate change mitigation | Stabilising greenhouse gas concentrations; Reducing greenhouse gas emissions; Promoting greenhouse gas sinks; Halting dangerous anthropogenic climate change. | “[S]tabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.” (UNFCCC, 1992, Article 2 Objective) “A human intervention to reduce the sources or enhance the sinks of greenhouse gases.” (IPCC, 2014b, p. 1769) “Technological change and substitution that reduce resource inputs and emissions per unit of output. Although several social, economic and technological policies would produce an emission reduction, with respect to climate change, mitigation means implementing policies to reduce greenhouse gas emissions and enhance sinks.” (IPCC, 2007a, p. 818) |
| Climate change adaptation | Reducing climate change related harm to natural and human systems; Reducing the vulnerability of natural and human systems to the impacts of climate change. | “The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.” (IPCC, 2014b, p. 1758) “Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects.” (IPCC, 2007a, p. 809) |

Source: Fünfgeld and McEvoy (2011, p. 14) and as indicated in table.

As Table A.5 shows, mitigation and adaptation differ with regard to their main objectives. While mitigation has a clear, universal aspiration (i.e., to reduce GHG emissions into the atmosphere), adaptation can have many objectives, depending on factors such as what

climate change impacts are expected to occur in a given place, which social, economic and ecological systems will be affected, and how able people and other living organisms will be to respond to these changes. These factors are the reason why adaptation is often said to



be 'context-specific' or 'place-based'. However, adaptation can also relate to larger-scale re-organisation of society, policy and politics which underpin global scales of decision-making, such as those on which mitigation depends.

What is the basis for adaptation?

The Intergovernmental Panel on Climate Change (IPCC), established in 1988, and the United Nations Framework Convention on Climate Change (UNFCCC), an international environmental treaty signed in 1992, have been two key means of bringing adaptation to the forefront of climate change policy.

According to Fünfgeld and McEvoy (2011, p. 13) the publication of the IPCC's (2007b) Fourth Assessment Report (AR4) in 2007 "marked a decisive point in the history of climate change policy and practice. Since the early 1990s, the reduction of global greenhouse gas emissions [i.e. mitigation] had been central to the agenda of decision-makers at all administrative scales... The AR4, however, provided scientific evidence that climate change was already occurring" and that not all future climate change can be averted even with the strongest possible efforts to reduce GHG emissions, due to time lags in the global climate system. More recently, the IPCC's (2014a) Fifth Assessment Report (AR5) has reiterated that adaptation to existing, as well as future, climate change, is required.

Adaptation has been justified where observed global and regional trends in climate drivers correspond with clear projections from sound models of the global climate system.

Adaptation is supported by economic arguments such as:

- Planned adaptation is a form of insurance for the private sector and/or governments. Small, relatively certain (precautionary) investments can be used to manage the consequences of uncertain and potentially much larger future costs (e.g. litigation).
- Autonomous adaptation tends to be ad-hoc and reactive, rather than anticipatory and proactive. This can be explained by diverse market failures.
- Adaptation can overcome market failures through proactive and anticipatory investment, or a range of

policy options, and defining appropriate roles for public and private sector organisations.

A2.2 Climate change mitigation

What is climate change mitigation?

The term mitigation refers to the act of making a condition or consequence less severe. Table A.5 provides some definitions of 'climate change mitigation' in use by the IPCC. Climate change mitigation is usually construed as action to reduce the rate at which climate change is occurring by decreasing the sources and/or increasing the sinks of GHGs. Thus it can be considered as an adaptation response that aims to reduce hazards and thus exposure to potential impacts.

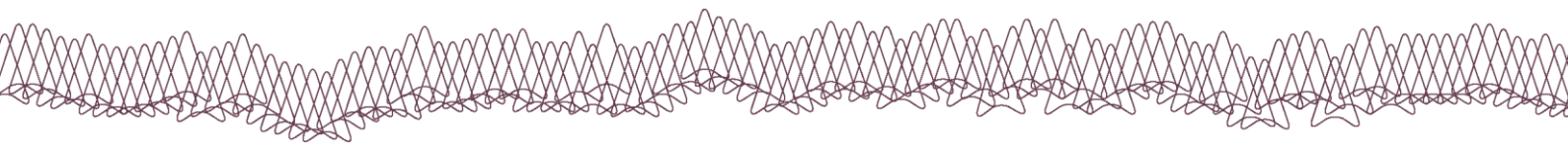
In the context of climate change, mitigation is about taking action to slow down human-induced climate change. This requires reducing and eliminating the sources of anthropogenic climate change, in particular reducing the emission and concentration of GHGs, which are responsible for the warming of the atmosphere.

Mitigation therefore means changing human activities in a way that less GHGs are emitted into the atmosphere and more get absorbed from the atmosphere.

What is the scientific basis for mitigation?

Climate science has played a major role in the process of ascertaining the rate of current and potential future climate change and in "deciding what levels of greenhouse gas emissions reductions are required to avoid a certain degree of global warming" (Fünfgeld and McEvoy, 2011, p. 14).

The Fifth Assessment Report published by the IPCC found that global warming was 'unequivocal' (IPCC, 2013a, p. 4), concluding that "[h]uman influence on the climate system is clear. This is evident from the increasing greenhouse gas concentrations in the atmosphere, positive radiative forcing, observed warming, and understanding of the climate system" (IPCC, 2013a, p. 13).



The evidence presented by climate science has “provided a strong case for addressing the impacts of climate change through adaptation, whilst simultaneously increasing the efforts towards reducing global greenhouse gas emissions to limit the magnitude of future climate change” (Fünfgeld and McEvoy, 2011, p. 13).

A3. Planning for adaptation

There are diverse approaches to adaptation that are applicable to different situations of NRM planning. For example, risk management may be appropriate where threats, risks or opportunities are well-defined. In other situations, uncertainty about the future drivers and interactions between (social, ecological and economic) elements in a system creates a need for scenario planning, adaptive management and other approaches. Whatever the adaptation approach taken, Smit et al. (1999, p. 204) have highlighted that a “rigorous description of any adaptation would specify the system of interest (who or what adapts?), the climate-related stimulus (adaptation to what?), and the processes and forms involved (how does adaptation occur?)”. One way to understand the different approaches to adaptation is to frame them according to three generalised adaptation pathways identified by Pelling (2011); a perspective SCARP has adopted.

A3.1 Frameworks for adaptation

SCARP draws on Pelling’s (2011) framework of three generalised adaptation pathways: (1) **resilience/coping**; (2) **transition**; and (3) **transformation**. No one pathway necessarily leads to ‘progressive’ or more equitable and efficient outcomes than the others. Those outcomes depend on context and perspective.

Resilience/coping adaptation

Resilience-based adaptation involves maintaining the status quo, and seeking “to protect priority functions in the face of external threat”. Resilient systems are “those that exhibit capacity for social-learning and self-organisation as well as displaying functional persistence” (Pelling, 2011, p. 67).

Transitional adaptation

Transitional adaptation is an intermediary form of adaptation, reflected in incremental change. Pelling (2011, p. 82) suggests that opportunities for transition emerge:

“...when adaptations, or effects to build adaptive capacity, intervene in relationships between individual political actors and the institutional architecture that structures governance regimes. Transitional adaptation falls short of directly challenging dominant cultural and political regimes, but can set in place pathways for incremental, transformational change.”

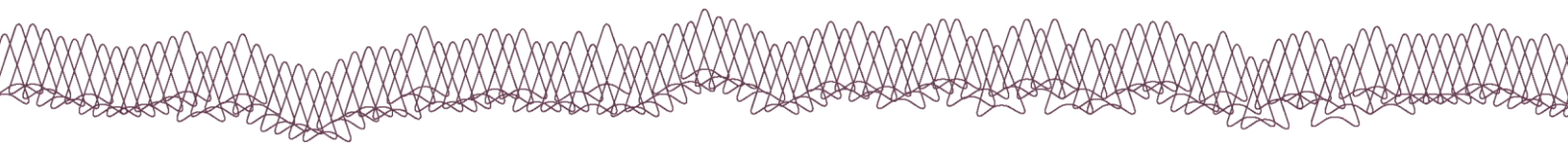
Transformational adaptation

Transformation adaptation provides “scope for revision and reform or replacement of existing social contracts and the meaning of security and modes of development, as well as defending social gains already won” (Pelling, 2011, p. 171). The extent to which adaptation planning can embrace transformation depends on how climate change is framed. For example, where vulnerability is attributed to unsafe buildings and inappropriate land-use, these may be more amenable to resilience and transitional forms of adaptation at the local level.

“However, if vulnerability is framed as an outcome of wider social processes shaping how people see themselves and others, their relationship with the environment and role in political processes, then adaptation becomes a much broader problem.” (Pelling, 2011, p. 97)

Within this framing, transformation becomes relevant. Ideally, transformational adaptation would be preceded by transitional adaptation, which takes into account planning and inclusivity, in order to avoid the possibilities of “uncontrolled and more anarchic forms of transformation” (Pelling, 2011, p. 103).

In a similar framing to Pelling, the IPCC (2014b, p. 1758) distinguishes between **incremental** adaptation “adaptation actions where the central aim is to maintain the essence and integrity of a system or process at a given scale” and **transformational** adaptation, involving “adaptation that changes the



fundamental attributes of a system in response to climate and its effects”.

Within each of these broad types of adaptation pathways there are numerous potential options, and there is the possibility to switch from one pathway to another over time as conditions change. Critical factors that are likely to affect the choice of pathway and thereby the framework and tools that are applied include such things as the level and type of predictability and (un)certainty, the rate of change, the temporal and spatial scale of concerns and the interests and values of relevant stakeholders (see **B.1 Assessing the current situation**).

What are some other ways of thinking about adaptation?

In developing a typology of adaptation, Smit et al. (2000, p. 224, emphasis added) have suggested that “[b]ased on their **timing**, adaptations can be reactive or anticipatory; and depending on the degree of **spontaneity**, they can be autonomous or planned”. These types of adaptation have been broadly defined as follows:

Planned adaptation

“Deliberate policy decision[s], based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state” (IPCC, 2007c, p. 869). Planned adaptation can involve both reactive and proactive adaptation, as well as provide for autonomous adaptations.

Reactive adaptation

Reactive adaptation is that which “takes place in response to the consequences of a particular event” (UKCIP, 2014); it is responsive or *ex post* - occurring after an event (Smit et al., 2000).

Anticipatory (or proactive) adaptation

Anticipatory adaptation is proactive or *ex ante*, taking place before impacts of climate change are observed (Smit et al., 2000; IPCC, 2007c).

Autonomous (or spontaneous) adaptation

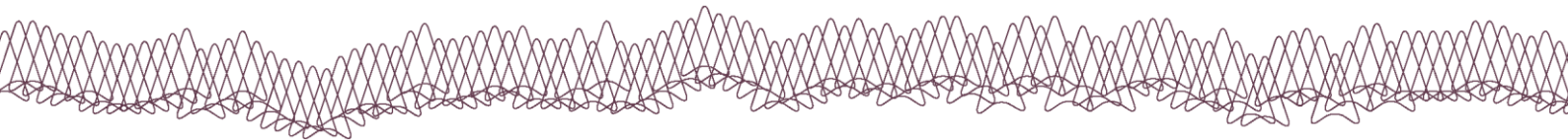
Autonomous adaptation is “[a]daptation in response to experienced climate and its effects, without planning explicitly or consciously focused on addressing climate change” (IPCC, 2014b, p. 1759). Smit et al. (2000, p. 240) argue that:

“adaptations in unmanaged natural systems are considered to be autonomous. Adaptations initiated by public agencies are usually conscious strategies, but adaptations by private individuals or communities may be autonomous or planned, or some combination of the two”.

Additional aspects that can be used to distinguish amongst different forms of adaptation include their **temporal scope** (are adaptations short- or long-term?), and their **spatial scope** (are adaptations localised or widespread?).

Is adaptation an outcome or a continuous learning process?

Is it both! Learning is an important outcome of adaptation processes, just as practice change or technological intervention can be (see **Q**).



Approaches to monitoring, evaluating and learning for a discussion of Bennett’s Hierarchy). However, the idea of reaching a final state of being adapted implies that change is not ongoing (Fünfgeld, 2012). Many adaptation measures will necessarily need to be reviewed at relevant timescales. This implies that adaptation itself is an ongoing process, with varied outcomes depending on the context.

A3.2 Approaches to adaptation planning

This section outlines some of the central ideas associated with four key approaches to adaptation planning as an ongoing, outcome-oriented process. These are: (1) **risk management**; (2) **vulnerability assessment**; (3) **adaptive management**; and (4) **adaptation pathways** (see also **D.2.1 Developing pathways of adaptation options for NRM**). As the IPCC (2014c) makes clear (see Box 1), adaptation planning does not adopt one approach in isolation and neglect the others. Rather, a combination of approaches can be used with differing weights placed on different elements, depending on the ‘issue’ at hand.

There are an increasing number of tools, methods and approaches that can be integrated into adaptation planning and implementation and none of them are necessarily ‘best practice’. Vulnerability assessments, for example, can provide the information base to underpin informed dialogue and decision-making in adaptation planning. Similarly adaptive management represents a commitment to move beyond ‘set and forget’ policy making and instead learn from the implementation of policy and practice in order to adjust and continually improve. The real challenge is finding a combination of approaches that are ‘best-fit’.

Box 1 The IPCC (2014c, p. 872) summarise the state of adaptation planning as follows:

“A variety of tools are being employed in adaptation planning and implementation depending on social and management context (high agreement, robust evidence). Uncertainties in climate change, coupled with the complexities of social-ecological systems, emphasize the need for a variety of tools in adaptation planning and implementation. Information and

knowledge on climate change risks from various stakeholders and organizations are essential resources for making adaptation planning. Multidisciplinary efforts have been engaged to develop, assess and communicate climate information and risk assessments across timescales. These efforts employ a mixed portfolio of measures from simple agroclimate calendars to computerized decision-support tools. Although a wide range of adaptations are possible with current technologies and management practices, development and diffusion of technologies can expand the range of adaptation possibilities by expanding opportunities or reducing costs. Monitoring and early warning systems play an important role in helping to adjust and revise adaptation implementation, especially on the local scale. Innovative tools have also been developed, such as ecosystem-based adaptation and a range of insurance tools.”

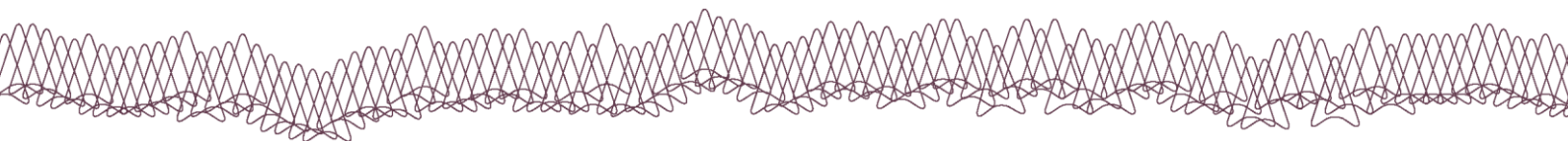
A.1.2 What is risk management?

A risk management approach to climate change adaptation involves the development of “plans, actions, or policies to reduce the likelihood and/or consequences of risks [of climate change impacts] or to respond to consequences” (IPCC, 2014b, p. 1772). Typically, a risk management approach utilises existing frameworks and processes for identifying, assessing, controlling and monitoring potential risks associated with climate change. For example, the Australian Greenhouse Office (2006) has developed a guide for applying *The Australian and New Zealand Standard for Risk Management* (AS/NZS 4360:2004) to encompass risks to business and government organisations arising from climate change impacts. Using risk assessment process such as AS/NZS 4360:2004 can be one means of dealing with the uncertainties associated with climate change.

Risk is typically understood as a function “of the likelihood of an occurrence and the consequence of that occurrence” (Australian Greenhouse Office, 2006, p. 18). For example, expressed as a formula:

$$\text{Risk} = \text{Consequence} \times \text{Likelihood}.$$

However, while this formula suggests that risk can be presented as a quantifiable amount, the Australian



Greenhouse Office (2006) guide makes it clear that given the uncertainties associated with the appraisal of climate-related risks, the use of qualitatively-based assessment techniques are just as useful, particularly when complex systems (i.e. socio-economic, ecological) are considered. Indeed, the process they outline to identify and prioritise risks “requires only standard climate scenarios, a general understanding of the impacts of climate change, comprehensive understanding of the business or organisation and sound professional judgement” (Australian Greenhouse Office, 2006, p. 18).

Disaster research tends to describe risk as being a function of hazard (climatically-driven, e.g. heat, fire, flood, storm, frosts) and vulnerabilities to that hazard. In this formulation,

$$\text{Risk} = \text{Hazard} \times \text{Vulnerability}.$$

This framing of risk places much more emphasis on the concept of vulnerability, which in turn is considered an outcome or function of exposure, sensitivity, and adaptive capacity (see the following section on vulnerability assessment).

Fünfgeld (2012, p. 27) argues that “climate change risk management is often primarily concerned with the financial impact of risks and with maintaining the financial sustainability of an organisation. Due to this affinity to questions of economic costs, cost-benefit-analysis and similar econometric tools are commonly used in conjunction with climate risk assessments.”

Advantages of risk assessment as a climate change adaptation planning approach are that it “can enable decision-making despite uncertainty by assigning value-based criteria” (Fünfgeld, 2012, p. 27) to key issues identified, facilitating their prioritisation and consequently the development of strategies and options for intervention. In addition, risk management approaches tend to align well with existing organisational and “institutional structures and processes, in both the public and the private sector, including financial management processes” (Fünfgeld, 2012, p. 27). The language of risk management is also generally well understood and translatable across different sectors and organisations, readily accepted by stakeholders, and rarely challenged.

The main disadvantages associated with risk management approaches to climate change adaptation stem from their applicability to organisational and institutional contexts. As such, “risk assessment tends to focus on specific expected impacts, thereby treating these in isolation from each other. Also, risk assessment tends to have an inward focus on organisational risks, rather than looking outwardly towards [wider and more complex] climate change impacts on communities, ecosystems and other human or natural systems” (Fünfgeld, 2012, p. 27). A number of theorists (Cannon, 2000; Jasanoff, 1993; Wynne, 2002) have suggested that factors or consequences lying outside prevailing scientific risk-knowledge are given limited standing because they are conceived to be indescribable within, or not amenable to the application of, probability calculations or cost-benefit analyses so often used in risk management.

What is vulnerability assessment?

A vulnerability assessment is a commonly-utilised approach often used to inform a climate change adaptation plan. Typically, a vulnerability assessment involves an evaluation of a discrete entity’s (e.g., an organisation, asset, system, sector, settlement or region) vulnerability to climate change impacts based on determining and analysing relevant attributes of exposure, sensitivity, and adaptive capacity. As the IPCC (2014b, p. 1775) notes, the concept of vulnerability is “the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt”.

Füssel and Klein (2006) have examined the conceptual underpinnings and development of vulnerability assessments, documenting a progression from climate impact assessments, to first and second generation vulnerability assessments, to adaptation policy assessments. The first in their evolution of approaches was **climate impact assessments**, which basically takes exposure to climate stimuli coupled with sensitivity to those stimuli to assess impacts of climate change. The second approach was **vulnerability assessment (1st generation)**, which adds climatic variability and non-

climatic risk factors into the equation to produce an assessment of vulnerability. A third approach outlined by Füssel and Klein (2006) was **vulnerability assessment (2nd generation)**, which while not yet in common use, adds in adaptive capacity and explicitly considers the effect of non-climatic drivers on the system. The fourth approach considered was **adaptation policy assessment**, which essentially addresses the kind of adaptive responses available to decision-makers, such as building adaptive capacity, or establishment of new institutions.

One key advantage of vulnerability assessments is that they can assist in the identification of the most significant system drivers, including the adaptive capacity to enable adaptation. If done well a vulnerability assessment can identify and prioritise the most salient issues to address, as well as support decision-making about how to address these issues (e.g. identifying those areas of most rapidly increasing hazard risk, or lowest adaptive capacity).

A major disadvantage of vulnerability assessments are that they can be difficult to do well, and often only include assessment of exposure to a threat or hazard (i.e. neglect hard to evaluate, but critical points for intervention such as adaptive capacity). Vulnerability assessments may also not lead to the development or implementation of options. Like many risk management processes, vulnerability assessments tend to assume that the components of vulnerability can be evaluated through technical or quantitative prediction/projection (e.g. mapping), ignoring the importance of emergent or unexpected events. Depending on the type of vulnerability assessment, they can assume factors are quantifiable and static. They can also frame climate change in negative and reactive terms rather than the more positive and proactive framing implied by the concepts of resilience and adaptive capacity.

What is adaptive management?

Adaptive management refers to a step-by-step process of planning, doing, monitoring and reviewing that forms a feedback mechanism for further iterative cycles of the same process. Figure A.2 shows how feedback to further planning makes management 'adaptive'.

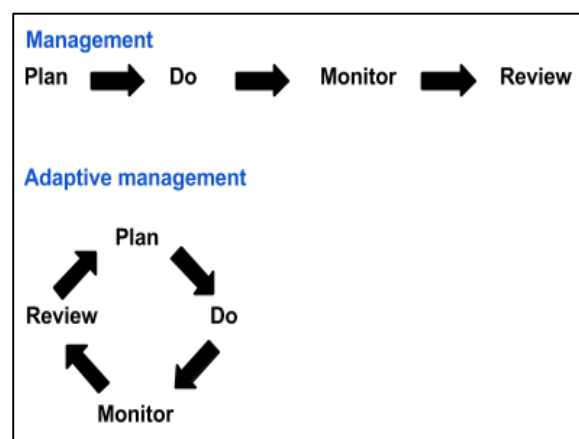


Figure A.2 Closing the circle turns 'management' into 'adaptive management'

There are more or less sophisticated versions of this basic model of adaptive management. Several different 'types' of adaptive management in NRM are the subject of ongoing research effort, including:

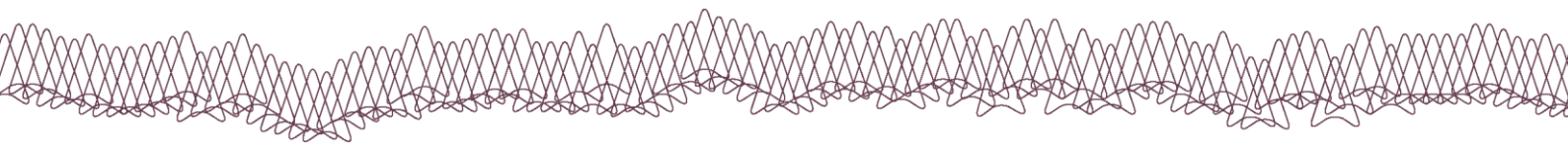
- **strategic adaptive management** - adding the term 'strategic' means that it takes a forward-looking approach towards a desired future direction (Kingsford and Biggs, 2011); and
- **adaptive co-management** - 'co'-management recognises the inclusion and sharing of responsibility with other stakeholders (Olsson et al., 2004; Armitage et al., 2009).

What are some principles for doing adaptive management?

The following principles are not definitive claims, but more a set of characteristics of adaptive management that appear across the literature.

Adaptive management (AM):

1. **Is a continuous process:** AM ideally continues for the life of any program or project;
2. **Is iterative:** AM cycles through different modes of activity, generally speaking from planning to doing to monitoring to reviewing;
3. **Incorporates feedback:** whether it is 'scientific evidence' or other forms of evaluation, AM ought to



be responsive to new information at any stage of the process;

4. **Leads to learning:** an ideal AM process leads to reflection and learning among those involved in the process;
5. **Can be very simple or incredibly complex:** AM can apply to a single short-term process, or to complex situations with several competing management outcomes;
6. **Involves collaboration:** bringing in multiple perspectives on the situation being managed improves outcomes;
7. **Can be more or less specific:** AM can apply to a very specific management target, or can be as general as a periodic revision of a plan; and
8. **Is experimental:** either in the sense of learning from experiences, or in the deliberate choice of management strategies as 'experiments'.

As outlined in **F.1.1 Monitoring, evaluating and learning at** all stages, the inclusion of feedback mechanisms at all stages of climate change adaptation is necessary for the process to be steered in a desirable direction. In planning, feedback is obtained through drafting, consultation and revision of a plan. Strategic planning can be an adaptive process.

What is 'adaptation pathways' planning?

Adaptation pathways planning draws on concepts from adaptive management and scenario planning. It is a process whereby organisations or groups can map current actions and future adaptation options or measures and assess these options in relation to a variety of relevant considerations. These considerations might include the current and future viability of options, potential for maladaptation, risk and uncertainty, costs and benefits, lead-in activities to develop future options, the degree to which options lead to irreversibility (path dependence), win-wins, or no/low-regrets (Haasnoot et al., 2012).

Multiple bundles of possible pathways are identified, with each pathway consisting of a sequence of actions to achieve targets under changing climate and socio-economic conditions. It is a form of planned and

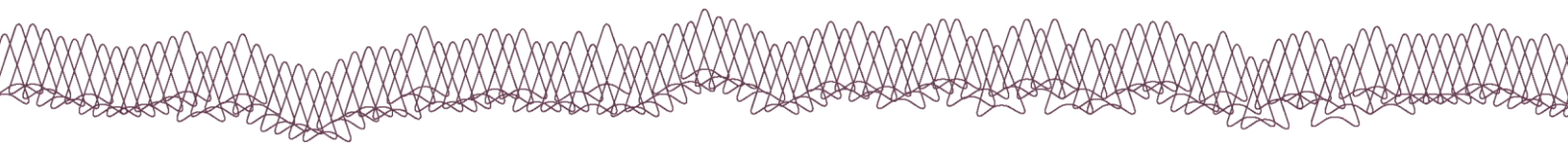
proactive adaptation that allows for autonomous adaptations (Haasnoot et al., 2012) and is based on a view of adaptation as an ongoing process of learning (as noted above). It is a decision-centred approach that uses "...pathways' as a metaphor to help visualise what adaptation is about...and provide an analytical approach for exploring and sequencing a set of possible actions based on alternative external changes over time" (Wise et al., 2014, p. 329). It is similar to, but not exactly the same as, a 'learn, then act' or sequential strategies (Lempert et al., 1996) approach to planning.

Pathways planning aims to allow organisations to plan and manage for change and uncertainties by identifying a suite of adaptation and mitigation actions that are flexible enough to be adjusted as knowledge, information, experience, values, and systems change (Haasnoot et al., 2012; Wise et al., 2014). It recognises that at some point the status quo for various management options may present an unacceptable level of risk, and that no single option will be robust indefinitely. It also avoids assumptions that adaptation to short-term climate variability and extreme events (proximate issues) will reduce vulnerability to longer-term climate change (Dessai and van der Sluijs, 2007). Social, economic and environmental systems will be changing as the climate changes, and those changes will be interacting leading to unforeseen outcomes.

Pros:

- Encourages innovative thinking, by considering current actions *and* potential future options;
- mixes strengths-based and critical approaches to the identification and evaluation of options;
- looks for opportunities as well as risks in defining options;
- provides potential for linking 'top-down' and 'bottom-up' approaches;
- can draw upon and combine a number of techniques (e.g. scenario planning with adaptive management);
- enables exploration and identification of possible transition paths towards transformation; and
- encourages the use of multiple perspectives.

Cons:



- 'Sell-by dates' or expiry timeframes for options can be hard to define in complex systems;
- relies on robust, inclusive processes which can be costly;
- like most planning processes can lead to overconfidence in outcomes and therefore, without ongoing monitoring, evaluation and learning, path dependency; and
- involves difficulties in 'imagining' unknowns.

A3.3 Linkages with broader planning and goals

While climate change presents a series of direct and specific challenges to natural resource management (e.g. sea-level rise impacting on coastal vegetation), the effects of climate change working in concert with other non-climate drivers (e.g. habitat loss in coastal areas from 'sea-change' development) are likely to exacerbate a range of existing NRM issues. Hence, there is a need to iteratively consider information about climate change across the breadth of NRM planning issues. Existing goals, objectives, strategies and measures will often need to integrate a variety of issues, including:

- transformational changes in landscape (e.g. irrigation, emerging industries, peri-urban growth);
- technological change and interactions with socio-economic systems;
- changing landscape values (e.g. sea/tree- change and other demographic shifts);
- policy and political change as risk and opportunity;
- market change and its effects on farm profitability, value chain drivers of NRM and production options; and
- costs of inputs into NRM and agriculture, including changes in fuel costs (e.g. peak oil research).

A4. Establishing a vision, goals and objectives

Charting a course of action through a changing and uncertain situation is an important and ongoing aspect of governing NRM adaptation.

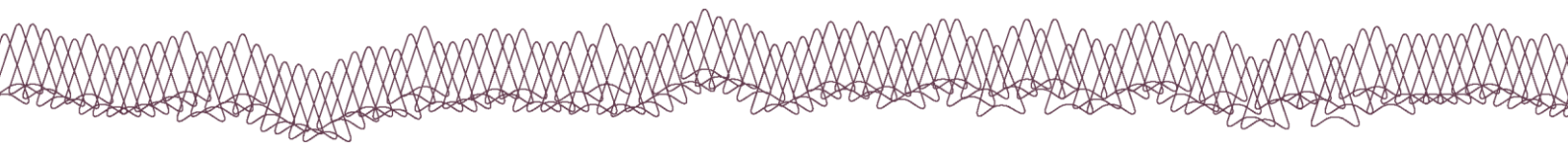
A4.1 Defining desired outcomes

A key step in any planning process is to develop statements that specify desired outcomes (otherwise referred to as 'ends'). These come in many different forms and can be conceptually confusing as different organisations use different terms, often interchangeably and in an ill-defined way.

How can coherent statements be developed?

People can use different terms to refer to the same thing, and sometimes use the same terms to refer to different things. This often results in confusion when trying to communicate! Strategic planning terms, such as vision, goals, objectives, strategies and actions, are keywords in planning and need to be discussed consistently. The SCARP research team uses the following terminology and definitions in this report, and recommends these definitions, but we don't prescribe the level at which they apply.

- **A vision** is the highest-level guiding statement about the desired transformation or achievement – the 'why' question.
- **Goals** outline broad aims and aspirations, and encapsulate general statements of intent and purpose – the 'what' question. Goals do not have to be measurable.
- **Objectives** detail specific, precise and measurable targets that relate to the achievement of a goal – the 'how' question. A useful acronym that is often used to define objectives is SMART: ideally, objectives differ from goals in being **Specific, Measurable, Achievable, Realistic** and **Time-limited**. In particular, measurable objectives provide the basis for monitoring, evaluation and learning – that is, adaptive management (see **F.1 Role of feedback in NRM planning** and implementation).



The following hypothetical examples of a vision, a goal and an objective meet these requirements:

Vision: A sustainable region with a profitable agri-food sector and resilient landscapes, supporting healthy communities.

Goal: Healthy waterways that provide for ecological integrity and economic productivity.

Objective: Environmental flows within the Hoppy-Hoppy River are maintained within an ecologically-appropriate range, as determined in the Riverplan baseline and benchmarking guide. Baselines and benchmarking will be reviewed and re-assessed every five years from the commencement of this strategy.

A4.2 Defining means to achieve desired outcomes

As with statements concerning outcomes, there are a number of terms that planners use to refer to the means by which outcomes are to be achieved. Again, different terms are often used interchangeably and in an ill-defined ways. Again, the SCARP research team uses the following terminology and definitions in this report, and recommends these definitions, but we don't prescribe the level at which they apply. **Strategies** give broad guidance as to the type of actions that will be undertaken. **Actions** are specific measures that will be implemented.

A plan should be written so that there are logical connections between actions and/or strategies and the objectives and/or goals that they are designed to address. In Section **F Monitoring, evaluating and learning**, we provide a variety of frameworks for developing these linkages.

A4.3 Climate-ready objectives

How can objective statements be 'climate-ready'?

While Dunlop et al. (2013) use the term 'objectives' in a less specific way than applied above (i.e. more like goals) they have developed a useful means by which to rethink established aspirations around biodiversity conservation. The approach takes into account the

likely impacts of climate change. They recommend that existing biodiversity strategies be framed as 'climate-ready' by abandoning static models of conservation. This approach applies to NRM strategies, which typically have goals that emphasise maintenance and improvement of condition. Climate change may make many such goals untenable in the longer term. Dunlop et al. (2013, p. 1) suggest the following adaptation propositions as guidelines to make existing goals 'climate ready':

- "1. Conservation strategies [i.e. plans] accommodate large amounts of ecological change and the likelihood of significant climate change-induced loss in biodiversity.*
- 2. Strategies [plans] remain relevant and feasible under a range of possible future trajectories of ecological change.*
- 3. Strategies [plans] seek to conserve the multiple different dimensions of biodiversity that are experienced and valued by society."*

Dunlop et al. (2013) have also developed a tool to help decision-makers determine if their current or proposed conservation objectives might be considered 'climate-ready'. During workshops with SCARP NRM bodies, participants explored and refined the use of this tool in defining both climate-ready biodiversity objectives as well as potential for using a modified version of the tool for other NRM objectives, not only biodiversity. This can be used as the basis for discussion of climate-ready objectives development at a range of levels. The tool is described and presented in Dunlop et al. (2013, p. 68).

Such a shift in thinking about planning for conservation outcomes can be understood as a movement away from resilience/coping towards transformation pathways, where climate change is understood as a 'game-changer'. As Dunlop et al. (2013, p. 1) note:

"under significant levels of climate change many of the current approaches to conservation will become increasingly difficult and ineffective (e.g. maintaining community types in their current locations). This challenge is fundamentally different from that posed by other threats to biodiversity, and the climate-ready approach is akin to a paradigm shift in conservation."



Section B.

Understanding the current situation



B. Understanding the current situation

The aim of this section is to provide a means of understanding the current situation in NRM as the basis for contextualising future options and planning. Current situation assessment is set up here to enable diagnosis of tools and approaches that are relevant and useful in any given situation, as well as to feed into decision-making and deliberation. Policy environments relating to international, federal and state arenas are summarised.

B.1 Assessing the current situation

B.1.1 Current situation assessment to aid adaptation planning

Clarifying relevant values, knowledge and uncertainty around management issues is central to effective planning. It can allow planners to avoid the well-known ‘hammer problem’ – in which every problem looks like a nail to those who only have (or know how to use) a hammer. By describing problems well we can define approaches to analysis and then options that are fit for purpose.

The framework and approaches in this section aim to do exactly that. They have been developed by SCARP with NRM planners, specifically for NRM planning for climate change. They are also informed through engagement with a broad literature across policy analysis (Hoppe, 2011) and applied science and technology studies (Cash et al., 2003; Sarewitz, 2004; Sarewitz and Pielke Jr., 2007) as well as research on climate change adaptation (Leith et al., 2014a). They have been further developed and tested through workshops and other activities with Southern Slopes NRM planners. They are targeted to build on and restructure existing understanding of the current situation in relation to assets, systems or sub-regions.

The theoretical work on which we have developed this original approach to current issue assessment is by no means uncontested, yet the SCARP team along with our NRM partners have identified the approach below as a useful means for NRM organisations to focus discussions for adaptation. Like much good adaptation

work it is experimental and open to ongoing refinement.

How can assessment of the current situation help to define adaptation options?

Planning for climate change adaptation can benefit when a knowledge base is developed and updated to enable ongoing learning and adaptive management. Such a knowledge base should include relevant and credible information and be able to be updated as new information arises. For instance, a knowledge base might summarise current scientific understanding as well as assumptions that are being made or tested through application of particular actions or policies. Recognising the importance of knowledge management, many regional NRM organisations have developed knowledge bases and ways of managing knowledge, information and data.

As we detail elsewhere, this framework can help to:

- Identify what forms of futures analysis will be most appropriate for a given management context (see [C.5 Analysing possible futures](#)), and;
- Establish the sorts of options that might be best adopted to achieve outcomes and a good process for identifying them (see [OD.2.1 Developing pathways of adaptation options for NRM](#)).

The framework enables work on these key adaptation planning activities by providing a platform to systematically consider or analyse dimensions recurrently. These are:

- i. The number of stakeholders;
- ii. The degree of values divergence among stakeholders (how strongly they agree or disagree on goals/objectives);

- iii. The extent of scientific uncertainty associated with defining or achieving the goals or objectives;
- iv. The scale of the issue (e.g. local, sub-regional, across whole of region);
- v. The capacity constraints, enablers and potential barriers;
- vi. The degree of urgency associated with the objective.

While each of these dimensions can inform the analysis of futures and identification of adaptation options, it is worth highlighting that the first three (number of stakeholders, values divergence among them, and the degree of scientific uncertainty) recur in the definitions of ‘wicked’ (Ison et al., 2014b; Rittel and Webber, 1973) or ‘post-normal’ (Funtowicz and Ravetz, 1993) problems.

Using these three dimensions, the typology of problems outlined in Table B.1 (and see examples in Table B.2) draws on the work of Hoppe (2011), Turnhout et al. (2013) and Leith et al. (2014a). It suggests that when high levels of agreement about goals exist alongside high levels of scientific certainty about issues associated with these goals, problems can be considered as ‘computational’. Computational problems are amenable to technical resolution, providing there are sufficient resources. NRM problems and associated desired objectives are rarely of this type. When they are, it is usually because they are tightly focussed on very specific issues (e.g. a single species), and involve little contestation about values (e.g. wildlife conservation within an existing reserve system).

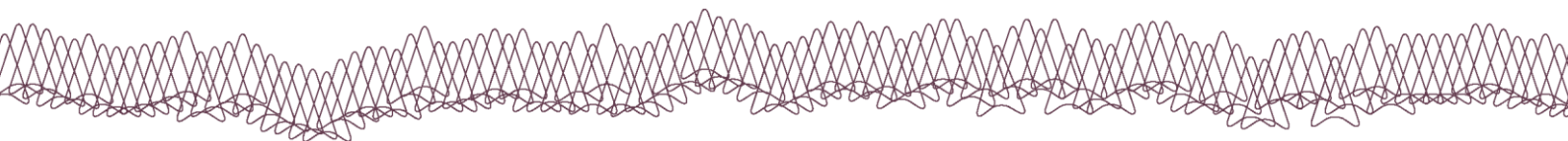
When there is a high degree of scientific certainty but disagreement about goals, technical intervention mainly enables a better understanding of trade-offs between competing objectives or goals of different stakeholders. The work of bargaining along with defining common ground and creatively redefining problems can be very useful, especially through participatory or inclusive processes which allow for thorough problem definition and credible assessment of options.

Table B.1 Framework and typology of issue types on two axes of scientific certainty and level of agreement / values divergence (following Hoppe, 2011)

| | | | |
|-------------|------|--|--|
| Uncertainty | High | Judgement Experimental intervention, adaptive management, social learning | Inspiration Leadership, reframing, social learning, adaptive management |
| | Low | Computational Analysis, identification and evaluation of options, implementation | Bargaining Trading off, collaboration, redefining frames, defining common ground |
| | | Low | high |
| | | Values divergence | |

Table B.2 Framework and typology with NRM objectives to exemplify the different problem types.

| | | | |
|----------------------------|------|--|--|
| Uncertainty/ understanding | High | Judgement 3) Maintain and improve water quality in rivers and streams across the region | Inspiration 4) Establish fire regimes that ensure protection of life and property while maintaining and improving ecological function, structure and composition |
| | Low | Computational 1) Reduce the impacts of motor vehicles on native animals in the Hoppy-hoppy National Park | Bargaining 2) Develop and implement a strategy to manage priority areas for retreat pathways for coastal ecological communities on private rural land |
| | | Low | High |
| | | Values divergence | |



In situations where there is a high degree of scientific uncertainty but where values divergence is low, judgement is required and options developed will often themselves be targeted to adaptive management or more formal experimentation through specific interventions. Evaluation is critical to better understand systems and the way they are affected by interventions.

Inspiration, leadership and substantial skill is needed to manage issues where there is both high levels of uncertainty and substantial values divergence. Such issues are often considered as ‘wicked problems’ and are not amenable to simple technical solutions. Rather technical information can help to open up problems, signalling potential issues and contributing to discussion where possible. These are problems that often result in the politicisation of science, scientists or scientific organisations.

This typology allows for systematic identification of appropriate broad forms of policy processes, application of research, roles for scientists and contextually useable knowledge (Table B.3). It allows planners to consider if and how objectives can be

made more tractable through reframing, research or various other interventions including relationship building, extension, and mediation.

How might assessment of the current situation be undertaken?

The prompting questions in Table B.4 comprise an adaptable tool (also in an Excel™ spreadsheet available from the authors) to assist with current situation assessment for a specific objective, asset, system or sub-region.

By addressing the questions below within an NRM organisation a solid foundation for later stages of adaptation pathways planning is laid. Mapping of the current situation is an analytical activity that should be done without jumping straight to solutions or options, yet groups/individuals can keep in mind and ‘park’:

1. Issues that are affected by future change, or ones that will affect that change (this will help inform futures analysis); and
2. Opportunities for intervention / activity (this will help with options identification and evaluation).

Table B.3 Issue types and associated policy processes and roles for scientists, as well as research and knowledge that is likely to be most useful

| KEY DESCRIPTOR | ISSUE TYPE | | | |
|---------------------------|----------------------|---------------------------------------|-------------------------------------|---------------------------|
| | Computational | Judgement | Bargaining | Inspiration |
| Policy process | Linear and technical | Negotiation | Compromise | Leadership, learning |
| Role of scientist | Solve problem | Policy options | Help to represent issues | Signal issue |
| Type of research | Disciplinary | Inter-disciplinary | Trans-disciplinary | Contributions to dialogue |
| Useable forms of research | Data | Contextualised information / argument | Conceptual knowledge, well-grounded | Options and perspectives |

Source: Adapted from Leith et al. (2014a)

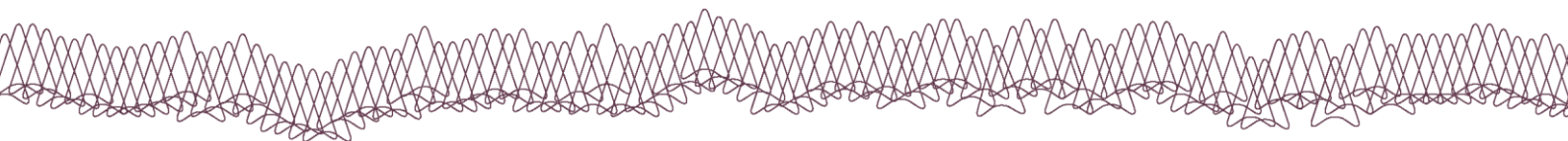
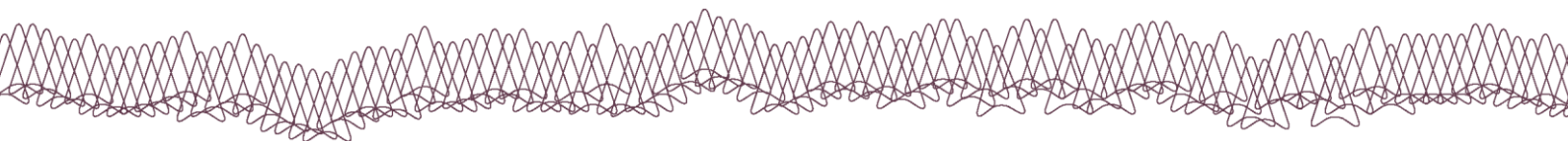
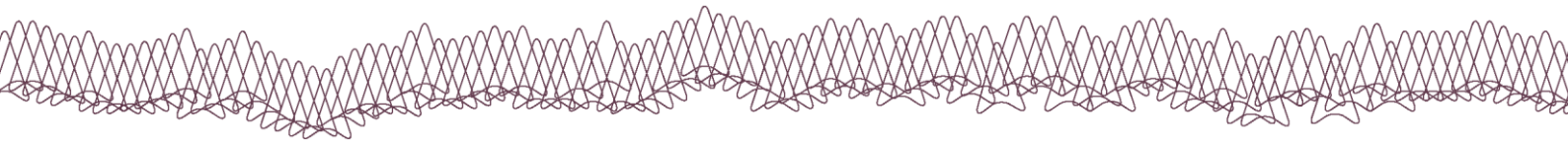


Table B.4 Key aspects that can usefully inform an understanding of the current situation and questions that can help in diagnosis for futures analysis, pathways development and MER

| ASPECT | PROMPTING QUESTIONS |
|---|---|
| <p>Values divergence:</p> <p>Where there are diverse groups of stakeholders with a lot at stake and a high degree of value divergence, options can be difficult to reconcile.</p> <p>Values are often best accessed through identifying the goals, aspirations or concerns of stakeholder groups.</p> | <ul style="list-style-type: none"> • How different are the values or interests among stakeholder groups? • Which groups are supportive, opposed or neutral with regard to the objective? • What are the areas of common ground and difference among stakeholder groups? |
| <p>Number of stakeholders:</p> <p>How many people really care about the issue, the impacts, cost of doing something or nothing, and who are these stakeholders?</p> | <ul style="list-style-type: none"> • Who are the relevant stakeholder groups? • Roughly how many stakeholders (individuals) in this group? • Why does this group have an interest in the objective? |
| <p>Systems uncertainty:</p> <p>This relates to the scientific understanding, different forms of uncertainty and ‘knowledge gaps’ about the status, mechanisms, dynamics and interactions within the system, or related to the objective. For example there tends to be much lower systems uncertainty about sea-level rise (SLR) related climate change impacts than about systems that rely on seasonal rainfall change, such as mean stream flows. There is usually less systems uncertainty about the response to climate change in ‘simple’ systems, such as cropping systems, than there is in complex ecological systems (and a lot more investment has gone into the former).</p> | <ul style="list-style-type: none"> • Reviewing relevant science and talking to key researchers will help establish where there is strong agreement and/or differences about ‘systems uncertainty’. • List the key issues /problems associated with this objective I.e. what is it that makes this system/objective vulnerable to hazards/ impacts? • Are there authoritative sources of information about the severity and extent of this issue? • Are the key mechanisms / processes understood? • How many studies are directly relevant to this issue? • If there is more than a single study, is scientific evidence consistent? • Are the main drivers of the system (function, structure, etc) understood and well agreed? • Are ecological triggers or thresholds or tipping points known for the system? • Are there defined approaches to manage this issue or to mitigate risks? • Are these approaches applied (e.g. in development? trialled by some? adopted by some?) |
| <p>Scale:</p> <p>The spatial extent of an issue is critical to understanding and coordinating collective action to address it. It also allows us to identify where others may be already doing innovative things on similar issues in Australia and beyond.</p> | <ul style="list-style-type: none"> • Identify geographically distinct manifestations of the issue • Estimate proportion of the land area of the catchment / region to which this objective is relevant • How are issues associated with this objective distributed (localised, subregional, region-wide)? |



| ASPECT | PROMPTING QUESTIONS |
|---|--|
| <p>Capacity constraints:</p> <p>Capacity can be defined as a function of the resources available to achieve a particular outcome and the capability to utilize those resources to achieve certain ends.</p> <p>There are a variety of ways of assessing capacity and things that constrain and enable capacity (see the SCARP Adaptive Capacity Guide Jacobs et al., 2015 for more details).</p> | <ul style="list-style-type: none">• What aspects of human capital (characteristic of individuals, e.g. skills, education, etc.) enable and constrain action on this issue?• What aspects of social capital (knowledge, networks, formal and informal rules that govern behaviour including policy, etc) enable and constrain action on this issue?• What aspects of physical capital (technology, tools, and infrastructure) enable and constrain action on this issue?• What aspects of financial capital (debt, equity, credit, funding environment) enable and constrain action on this issue? |
| <p>Urgency:</p> <p>In this context, urgency relates to the degree to which an issue needs to be dealt with soon. In discussion about urgency, other issues relating to the time horizons for decisions and the temporal consequences of them are important. For instance, some NRM investments, such as tree planting for connectivity, have long time horizons (the lifespan of the tree). These long time horizon decisions need to be informed as much by climate trends and projections as inter-annual climate variability.</p> | <ul style="list-style-type: none">• Is the issue considered as requiring urgent attention?• Are decisions relating to this issue likely to have ongoing consequences (can these be listed)?• What is the time horizon of the decision (i.e. seasonal, annual, inter-annual, decadal, multi-decadal)? |



B.1.2 Considering the dimensions of analysis of the current situation

Having a good understanding of the current situation relating to an objective can help to identifying the next steps of adaptation planning. Below we describe briefly some key ways that the above parameters or dimensions can be included in planning. We provide more detail about what the overall current issue assessment implies for analysing potential futures in [C.5 Analysing possible futures](#), and, in [D.2.1 Developing pathways of adaptation options for NRM](#), for using a variety of tools and methods, and identifying potential options for pathways.

How do stakeholder numbers, values, responsibilities affect the current situation?

In general, greater stakeholder numbers will exacerbate the problems associated with values divergence -- agreement on objectives and options to achieve them becomes harder as there are more people involved (Ostrom, 1990). Where there are many stakeholders it may be best to set boundaries around problems so that groups of stakeholders are small enough to be able to engage in meaningful dialogue, arrive at common understanding, and even achieve consensus, make decisions and follow through with action. For example, it can be more effective to develop plans to manage estuaries one at a time, focussing first on the estuaries with greater value coherence to build action plans that are implementable and that others can learn from and adapt to their situation. Attempting to develop a 'cookie-cutter' approach to managing estuaries across a state or region is likely to fail (Ostrom, 2007). If stakeholders have coherent values (as opposed to divergent ones) it will tend to be easier for them to identify and agree on priorities or objectives.

However, they may not be able to identify innovative approaches easily if their networks are closed and ways of thinking are relatively homogenous or conservative (Dowd et al., 2014).

The power and influence of stakeholders also matters. For example, sea-change and tree-change trends have increased not only the diversity of stakeholders within Australian rural communities (Holmes, 2008). A small

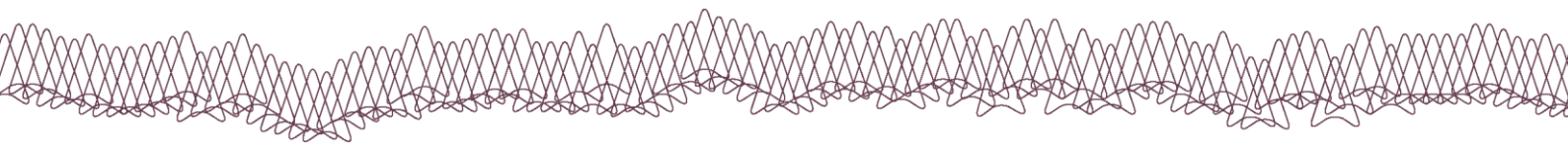
number of wealthy, highly educated and well-connected retirees with strong landscape and lifestyle values can have a disproportionate influence on politics as can a few well-connected farmers.

As the demographics of rural and regional communities changes through sea / tree-change trends, transparent and equitable processes of engagement and representation (i.e. who is selected to represent what groups) becomes more important (Bryson, 2004). Good processes can enable dialogue among groups through acknowledging both common ground and differences. Where there are substantial differences among stakeholder groups, good processes should mediate these differences to define areas where agreement is apparent / possible as well as those where it is currently unachievable.

How does systems uncertainty affect the current situation?

Research often focuses on filling 'knowledge gaps' or reducing uncertainty, and certainly there are many gaps in what we know about NRM issues. Some of this uncertainty can be addressed well through research, and some cannot. The distinction between reducible uncertainty and indeterminacy or deep uncertainty (things we simply cannot know because of the complexity of causal interactions) is an important one (Dovers and Handmer, 1992) especially for adaptation to climate change. For example, we may have projections of temperature change with a high degree of confidence, but little idea what increasing average temperature will do to a particular ecosystem. In such a situation it may be very difficult, very expensive or simply impossible to establish in advance what gradually increasing average temperature may do to an ecosystem.

The complexity of specific ecological systems means we can rarely identify when thresholds or tipping points are likely to occur or what will cause them. The larger, more open or complex a system the more likely it is that we will be unable to effectively predict system dynamics and change and that these systems will need to be managed as complex adaptive systems through learning and adjusting rather than predicting and acting (Gunderson, 2003). However, some aspects of these



systems may be more easily understood and foreseen than others. These can become key management foci. For example, in alpine ash forests the dominant canopy species (*Eucalyptus delegatensis*) is an obligate seeder, and there are clear threats to these forests from increasing fire frequency associated with climate (Bowman et al., 2014). Such an understanding of sensitivity and exposure of systems at the level of keystone species provides for specific and targeted management interventions, in this case added management of fire in the 20-year period between intense fires and when recruitment can recommence through seeding.

For relatively predictable change risk management can sometimes be used to identify appropriate adaptation options. Risk management can focus on reducing the likelihood of or the negative consequences of events. It requires that sources of risk are identified, assessed and mitigated through targeted action. As assessment of options in risk management is targeted to avoid a specific problem, care needs to be taken not to create a new set of problems. For example, hard engineering solutions to protect houses from storm surges have led to loss of public amenity when a seawall results in beach erosion.

Unlike risk management which tends to aim to find an optimal solution in a predict-then-act mode of decision-making, managing deep uncertainty can usefully focus on assessing a range of policy options (Weaver et al. 2013). Howden et al. (2013, pg. 61-62) suggest that the following types of actions and decisions that are useful in managing such deep uncertainty:

- **Avoiding irreversible decisions and deferring decision-making** - interim –decisions are made while seeking new information or creating preferred options (An example is building a low cost temporary groyne as an experimental intervention to manage beach erosion.)
- **Reframing the problem:** see framing discussion in Section 1 of this report. (An example could be including newer perspectives such as considering novel mechanisms by which a downstream town or city could pay for the ecological services of the upstream floodplain in buffering the town from flooding.)

- **Developing no regret or low regret options** – and applying different timescales to evaluate regret. (An example could be building a by-pass and/or pedestrian footbridge to reduce overall traffic pressure on the bridge, regardless of flood risk.)
- **Introducing redundancy** and enabling more than one mechanism to achieve the desired result (and accept some loss of short term efficiency) (For example, using different incentives and regulations to target the same biodiversity outcomes.)
- **Creating contingency arrangements**, which might be similar to redundancies but tend to be less formal; relying for example on generic forms of adaptive capacity. (Ensure there are good networks and relationships between emergency management, frontline services and NRM organisations and that each knows what the others can and should do at different stages of emergency management cycles to contribute to desirable social, economic and environmental outcomes.)

While it is difficult to pinpoint the systems uncertainty, on a scale from one to ten, it is clear that there are some issues or objectives which are relatively better or worse understood from a scientific perspective.

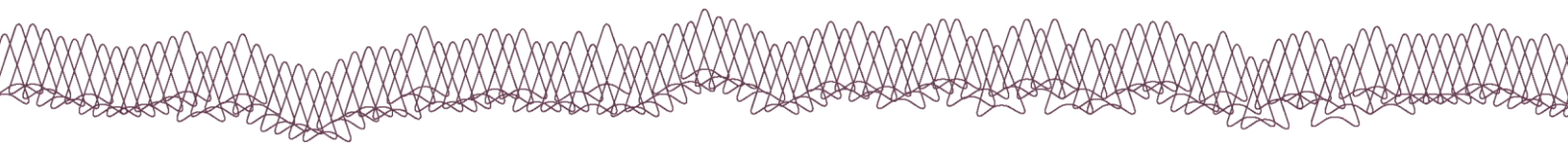
How does scale affect the current situation?

Much like the number of stakeholder involved, scale can make issues more or less complex to manage.

Large scale: if an issue is prevalent across a region, state or at a national scale or even large tracts of a region it may be possible to use a single technical analysis to decide (computational problems), set up testable hypotheses (judgement) or where there is substantial disagreement about goals (bargaining, inspiration) devise a robust scenario-oriented decision-making or adaptive learning process that can be applied across a region.

Medium scale: if an issue only occurs at a sub-regional scale, futures analysis will need to focus more on goals in bargaining-, or inspiration-oriented problems (e.g. foresighting / backcasting), and more on application of scientific analysis in computational problems

Small scale: if an issue is very local in scale, it may be difficult to get robust data and/or independent analysis.



Where there is local division, facilitation to find common ground and building on that ground (e.g. through strength-based or inquiry-based approaches) will often be needed before clear action can be taken across a locality. Working only with groups with specific values can lead to on-ground outcomes, but may also result in challenges to the legitimacy of organisations. Thus work in localities with sub-groups might be best framed and designed as trials, and results of these trials used to stimulate broader community discussion.

How do capacity constraints affect the current situation?

Capacity is a critical issue for adaptation. This is especially the case for implementation of NRM strategies which rely on partners and stakeholder to undertake many activities to achieve NRM outcomes (e.g. local government, landholders) (Leith et al., 2012). Adaptive capacity has been defined as:

“the ability to design and implement effective adaptation strategies, or to react to evolving hazards and stresses so as to reduce the likelihood of the occurrence and/or the magnitude of harmful outcomes resulting from climate-related hazards” (Brooks and Adger, 2005, p. 165).

Of course, adaptive capacity may be more broadly defined beyond climate, in which case adaptive capacity can be seen generically as the available resources of a group or an individual, and the ability to use them to adapt to changing conditions either pre-emptively or reactively (Leith et al., 2012). Approaches to evaluate and identify investment opportunities to overcome critical capacity constraints are detailed in the SCARP report on adaptive capacity (Jacobs et al., 2015).

In general, capacity and constraints will affect the ability to develop and implement options and even to invest in the processes and institutions which are used to develop them. While the effects of low levels of funding are obvious and often the focus of concern, it is also remarkable what can be achieved if there is agreement within a group in the absence of funding. Social capital, both the bonding capital within groups and the linking capital among them, can create high levels of volunteerism and good will to support activity.

Working with the willing can create high bonding capital but can also undermine the bridging capital that builds the broader legitimacy within a community. These forms of capital as well as institutional and political capital need to be maintained by NRM organisations through good processes and well defined, outcome-oriented activities. Adaptive capacity is thus closely linked to the principles that guide NRM governance, strategy and implementation.

How does urgency affect the current situation?

Issues that are more urgent are usually so because there are high stakes (for some, at least) involved in their resolution. Urgent issues are often politically charged and may not be amenable to resolution through deliberate, well-reasoned processes involving the best possible research and information.

However, urgency also creates moments in which good science, good processes and leadership can be brought together to address problems -- if the ground work has been laid in advance.

Many climate change adaptation issues are not yet politically charged but may become more so as climate impacts become more acute. Sea-level rise and storm surge activity provide a straightforward example. As sea-level rises, the effects of the same sized storm surges will be progressively greater. Each storm surge can be used to bring greater attention to the importance of sea-level rise planning or create potential for its implementation. In this way, extreme conditions can create opportunities for plans to provide a way forward when the community realises it needs it most. The same patterns recur in different ways for other extreme events: bushfires, heatwaves, floods, droughts. These moments of heightened urgency can be used to precipitate action and commitment, and thereby enable implementation.

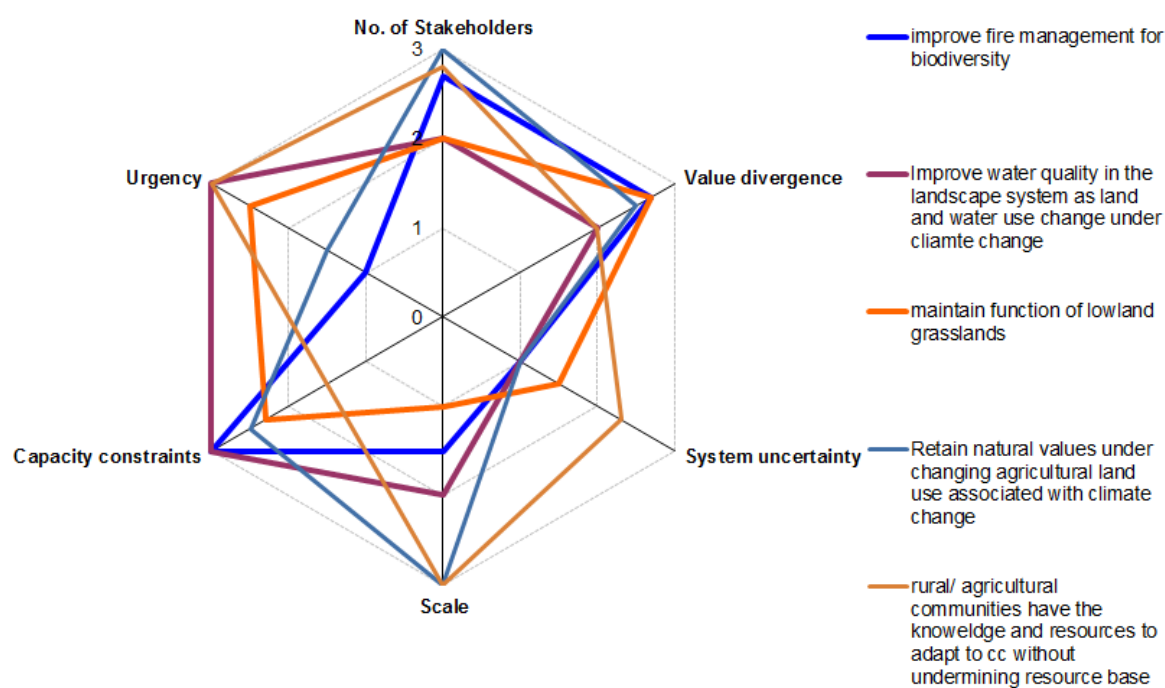
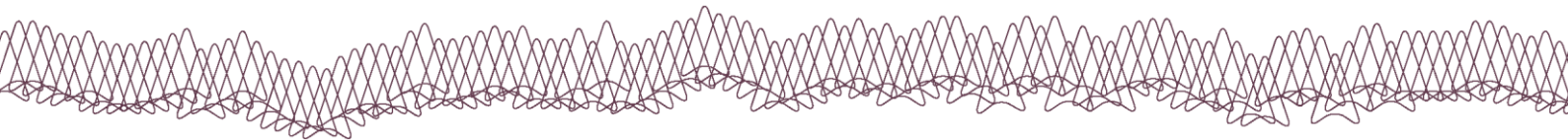


Figure B.1 Example subjective evaluations of ‘climate-ready’ objectives developed by NRM planners rapidly in a workshop setting, demonstrating the relative strength (1 - Low; 2 - Medium, and; 3 - High) of each of the 6 dimensions in the current situation assessment framework.



B.1.3 Representing and discussing the current situation

While detailed information repositories are crucial for developing and maintaining a knowledge base about issues/objectives within an organisation, it is also useful to have intuitively accessible and easy to use objects to facilitate discussion in workshops and other settings. SCARP developed a simple spider diagram for this purpose which can be used within small groups to facilitate discussion about the above dimensions and to try to define the relative importance of these dimensions for specific goals, objectives, questions or issues.

The example spider diagram in Figure B.1 was developed from outputs of a SCARP workshop in April 2014 in Launceston Tasmania. Stream 1 NRM organisation representatives filled out the template spider (or kite) diagram for a variety of hypothetical 'climate ready' objectives (see [A4.3 Climate-ready objectives](#)). Simple estimation of relative values of these parameters allowed for more detailed discussion of why values were selected, what low or high values meant for achieving the objective and the implications for strategies and their implementation.

These sorts of exercises can also be undertaken in workshops using radio frequency or smart phone polling, sticky dots or other approaches. In such settings the use of specific objects (such as spider diagrams) can be used to promote discussion and more detailed understanding of how and why people make their evaluations and consider the importance of the different dimensions in relation to an issue or objective.

B.1.4 Approaches to gathering data about the current situation

A wide range of approaches could be applied to analysing the current situation, some of which are described below. These are most fundamentally about collating and analysing relevant and credible understandings about assets, systems, regions or subregions. At the simplest level a current situation assessment can be achieved by bringing together existing institutional knowledge within an organisation

or a team, and cross checking with key researchers or stakeholder representatives.

The approaches below are more formal and can be employed in different contexts to engage with subject-matter experts, relevant literatures, and to involve stakeholders and community members. The approaches presented are just some of the many ways that NRM organisations can assess their current situation for planning and implementation.

The different dimensions of current situation assessment, detailed in Table B.4, can be formally assessed through a variety of approaches and methods. In this section we briefly outline three broad groups of methods: systematic review, stakeholder participation, and historical assessment.

Systematic review

A systematic review is collection, collation and synthesis of existing literature on a specific subject. It provides a formal and rigorous means of gathering and assessing current research to better understand a problem or issue.

Dimension

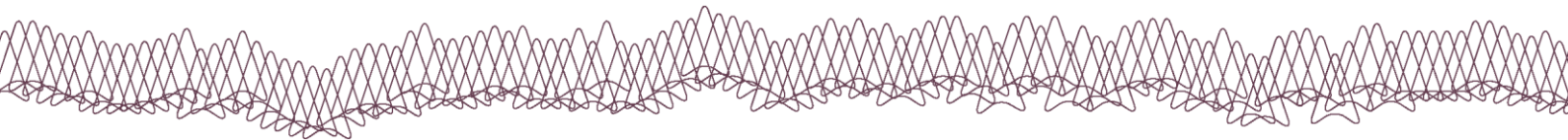
Systematic reviews mostly relate to reviews of science and so provide detail about knowledge and uncertainty, as well as evaluation of specific policy options.

Key references

The popularity of systematic reviews appears to be increasing internationally with clear methodologies for systematic reviews now in print. Useful guidelines for systematic reviews have been developed by the Centre for Evidence Based Conservation at Bangor University in the UK (see <http://www.environmentalevidence.org/>).

Stakeholder participation

The broad category of stakeholder participation encompasses numerous methods. Effectively engaging with stakeholders to assess the current situation can be as diverse as crowd-sourcing, or conducting focus groups or interviews.



Dimensions

The many forms of stakeholder engagement can provide information into any or all of the dimensions depending on how they are designed.

Key references

A useful first stop for defining what form of engagement to employ, and with whom, is the IAP2's participation toolbox and other resources (see <http://www.iap2.org.au/resources/iap2s-public-participation-spectrum>).

Approaches that are more targeted to expert elicitation include Delphi processes and Bayesian Belief Networks, and are reviewed briefly in **C.5 Analysing possible futures**.

Rapid appraisal refers to a bevy of techniques used in rural and regional development such as Participatory Rural Appraisal (PRA) and Rapid Rural Appraisal (RRA). These approaches can clarify how issues are framed and understood by different communities or groups. The key distinctions relate to the degree to which the project is owned and/or driven by a relevant community (e.g. RRA tends to be about outsider assessment of local knowledge, practices and perspectives, whereas PRA is focussed on a communities' self-determination). The International Institute for Sustainable Development provide some useful resources relating to these techniques (see <https://www.iisd.org/casl/CASLGuide/ParticipatoryApprach.htm>).

Reflecting on historical influences

Undertaking a reflection on history can help provide a sophisticated and informed analysis of the current situation. It is an active attempt to learn from the history through formal processes and can usefully include a wide range of stakeholders to broaden perspectives on historical actions and outcomes.

Dimensions

Reflecting on history is particularly useful in assessing stakes and value divergence, capacity constraints and systems uncertainty.

This reflection can be encouraged through the development of a simple timeline. Timelines can easily be constructed with participants using butchers paper or white boards. Such work can identify points in an organisation's history and importantly allowed for discussion and reflection on the impact of various key events, including organisational, community and even, personal responses.

B.2 Exploring climate change and related policy

This section presents a static summary of relevant policies at international, federal and state levels that affect regional NRM planning. The list of key legislation and regulations cited are listed, with website links, in a separate reference list following the main reference list, on Page 184 of this report. To enable access to the most current policy, website links are provided where relevant. While the information included is as accurate as possible, please check online for the latest policies.

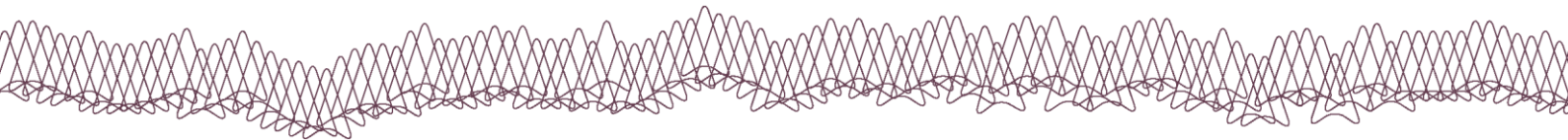
B.2.1 International conventions and agreements

The following is a summary of the key international climate change related conventions and agreements to which Australia is a signatory.

UN Framework Convention on Climate Change and the Kyoto Protocol

The Kyoto Protocol arose from negotiations amongst the United Nations Framework Convention on Climate Change (UNFCCC) signatories to strengthen the global response to climate change. The Protocol legally binds signatory countries to emission reduction targets. The Protocol's first commitment period ended in 2012. The second commitment period will end in 2020. There are currently 192 Parties to the Kyoto Protocol (UNFCCC, 2014).

Australia did not agree to ratify the Protocol until 2008. Australia's current commitment is to unconditionally reduce emissions by five per cent below 2000 levels by 2020.



Australia has agreed to join the second Protocol commitment period (2013 – 2020) along with more than 90 other countries, negotiates around emission targets and other climate change mitigation commitments. Under the second commitment period Australia committed to binding emissions targets, 5 per cent below 2000 levels by 2020 (Combet, 2012).

Intergovernmental Panel on Climate Change (IPCC) and the AR5 Climate Change 2014 Synthesis Report (IPCC, 2014d)

The IPCC is a scientific body established by the United Nations Environment Programme and the World Meteorological Organization in 1988. The IPCC “reviews and assesses the most recent scientific, technical and socio-economic information produced worldwide relevant to the understanding of climate change” (IPCC, 2014d).

The IPCC’s Climate Change 2014 Synthesis Report was released in Nov 2014, which integrates the findings of the IPCC Fifth Assessment Report, (AR5) consolidating the three working group reports:

- The Physical Science Basis (IPCC, 2013a);
- Impacts, Adaptation and Vulnerability (IPCC, 2014c); and
- Mitigation of Climate Change (released April 2014) (IPCC, 2014e).

Ozone Protection and Synthetic Greenhouse Gas Management (1989)

Australia is a signatory the Montreal Protocol on Substances that Deplete the Ozone Layer and all of its five amendments (UNEP, 1987). The Montreal Protocol aims to reduce the emissions of ozone depleting substances (ODSs) to the atmosphere as a means of protecting the earth’s ozone layer.

Australia’s Montreal Protocol obligations are implemented through the (*Ozone Protection and Synthetic Greenhouse Gas Management Act 1989 (Cth)*) which controls the manufacture, import and export of all ODSs and their synthetic GHG replacements.

B.2.2 International conventions and agreements that may influence regional planning

The Commonwealth government is signatory to, and is responsible for, meeting Australia’s obligations to the following conventions and treaties. The subjects of which may be relevant to climate change impacts and adaptation.

United Nations Convention on Biological Diversity (1993) and the Environment Protection and Biodiversity Conservation Act (1999)

Australia is a signatory to the United Nations Convention on Biological Diversity (1993). Australia’s obligations to this Convention are implemented under the Commonwealth governments’ *Environment Protection and Biodiversity Conservation Act 1999 (Cth)*, (EPBC Act). The Act provides the legal framework for protection and management of matters of national environmental and heritage significance.

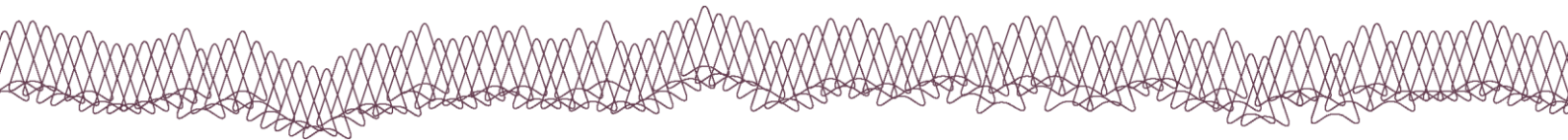
Federal Environment Minister approval is required for ‘controlled actions’ which may have a significant impact on matters of national environmental significance (MNES), (EPBC Act, Ch. 14). This includes the management of World Heritage properties and places.

The Act requires the Minister to take account of the Precautionary Principle when making decisions, such as whether or not to have a ‘threat abatement plan for a key threatening process’ (*EPBC ACT, s 270A*).

The Precautionary Principle is explained in the [Environmental Law Handbook](#) as follows:

“Lack of full scientific certainty should not be used as a reason for postponing a measure to prevent degradation of the environment where there are threats of serious or irreversible environmental damage.” (Environmental Law Handbook, Ch 15, 2013).

“As the impacts of climate change on biodiversity are better understood, further action may be taken under the EPBC Act to address (and avoid) those impacts.” (Environmental Law Handbook, Ch 16, 2013).



World Heritage Convention (1975)

Australia is signatory to the international treaty; the (*Convention Concerning the Protection of the World Cultural and Natural Heritage, 1975*) (World Heritage Convention). In Australia the *EPBC Act* protects places of World Heritage, National Heritage and Commonwealth Heritage. Two Natural World Heritage sites occur in the SSC region; Tasmania's Wilderness and Macquarie Island.

The Garnaut Climate Change Review assessed the exposure, potential impacts, vulnerability and adaptive capacity of Australia's 17 World Heritage sites to climate change. The report helped identify major knowledge gaps that need addressing to inform management plans and government policy on World Heritage and climate change adaptation (Heath, 2008).

Other Relevant Conventions and Agreements

A number of treaties for the protection of migratory and endangered birds have been agreed to by the Australian Government. These agreements aim:

"to co-operate in taking measures for the management and protection of migratory birds and birds in danger of extinction and also for the management and protection of their environments. However, as yet there is no governmental multilateral agreement for the conservation of migratory waterbirds and their habitats." (Asia-Pacific Migratory Waterbird Conservation Committee, 2001; p.10).

The key relevant conventions covering flora and fauna agreed to by the Australian Government include:

- The Convention on Wetlands of International Importance 1977) (the Ramsar Convention).
- Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention)
- Australia/Japan Agreement for the Protection of Migratory Birds and Birds in Danger of Extinction and their Environment (JAMBA).
- Australia/China Agreement for the Protection of Migratory Birds and their Environment (CAMBA); Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA).
- Association of the South East Asian Nations (ASEAN) Environment Programme.
- Convention on the Conservation of Nature in the South Pacific (Apia Convention).
- Convention for the Protection of Natural Resources and Environment of the South Pacific (SPREP Convention).
- South Asian Agreement on Regional Cooperation
- Programme for the Conservation of Arctic Flora and Fauna.

Australia is also signatory a number of bilateral migratory bird agreements/treaties.

B.2.3 Federal Legislation and Policy which Address Climate Change

Commonwealth climate legislation and policy continues to be amended. As such, the currency of information below may be only short lived. Hence, links to relevant websites have been provided to direct the reader to the most up-to-date published information.

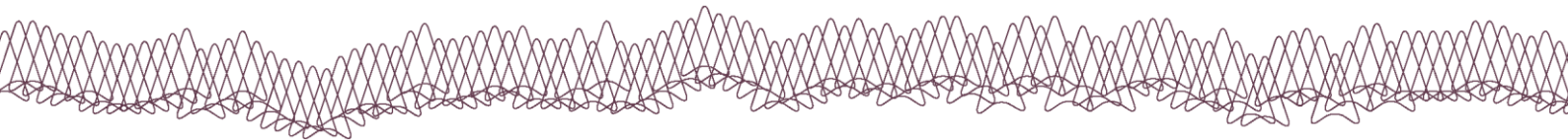
A good place to start is the comprehensive timeline of climate change policy in Australia compiled by the Australian Parliamentary Library (Talberg et al., 2013).

Australia's commitment on emissions reduction

The Federal Government currently has formal international commitments to reduce Australia's GHG emissions to five per cent below 2000 levels by 2020 (Climate Change Authority, 2014).

Current estimates confirm that on current trends, meeting Australia's five per cent emissions reduction target in 2020, will require emissions to be 126 Mt CO₂-e lower than currently projected (or no more than 530 Mt CO₂-e) (Climate Change Authority, 2014).

The federal Climate Change Authority is currently reviewing Australia's greenhouse gas emissions reduction target. A draft report for consultation is anticipated to be published for before the end of June 2015 (Climate Change Authority, 2015).



Direct Action Plan/Emissions Reduction Fund/Carbon Farming Initiative

The Federal Government commenced implementation of the Direct Action Plan on 1st July, 2014. The Plan includes an (ERF) to provide incentives for abatement activities across the Australian economy. The objectives of the ERF are to reduce emissions at lowest cost over the period to 2020 (Department of the Environment, 2015).

The Direct Action Plan aims to build on the (CFI) (Carbon Farming Initiative, undated). Projects registered under the CFI will automatically transition to the ERF (Department of the Environment, 2015a).

ERF supported projects will need to estimate emissions reductions consistent with an approved method. A number of methods exist or are under development. Of most relevance to CMA's is the method for the land sector which includes increasing soil carbon, reducing livestock emissions, expanding opportunities for environmental and carbon sink plantings, and reforestation.

The *Carbon Farming Initiative Amendment Bill 2014* was passed by the Parliament in November 2014. From 1 July 2015, new 'CFI' project applications will be assessed under the ERF eligibility rules and "must apply the most up-to-date version of the relevant methodology" (Department of the Environment, 2015a).

A key requirement under both the ERF and the CFI is 'additionality'. Australian Carbon Credits Units for eligible projects will only be issued where a "project or activity creates 'additional' emissions reductions that would not have occurred in the absence of the incentive" (Climate Change Authority, 2012)

ERF project proponents also need to confirm that their projects are consistent with 'Regional NRM Plans'.

The current status of the CFI and the transitional arrangements to the ERF are outlined on the Clean Energy Regulators website. CFI Methodology Determinations are also published on the Department of Environment's website.

Clean Energy Act (2011) (Cth)

This Act, which encouraged the use of clean energy and other purposes, was repealed on 1st July 2014.

Emergency Management Planning Legislation and Policies Relevant to Climate Change

The Council of Australian Governments (COAG) adopted the National Strategy for Disaster Resilience in 2011 which provides guidance and direction on disaster management to individuals, organisations and governments. The strategy covers the role that each of the Commonwealth and State Governments should play in managing their climate change risks, collaborative approaches to increasing disaster resilience, and reducing disaster risk to communities through amendments to the planning system, (Productivity Commission, 2012).

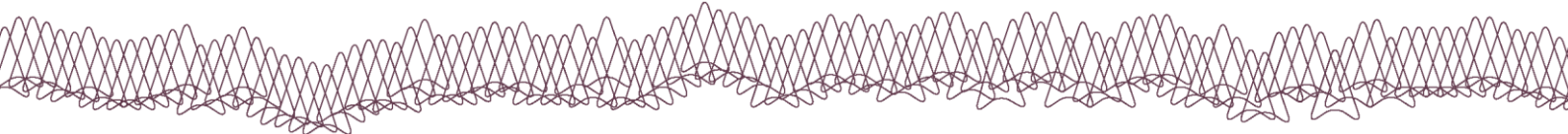
B.2.4 State legislation and policy relevant to climate change in Victoria

Key Victorian (Vic) legislation and related policy which makes reference to climate change is outlined below. Hence, links to relevant websites have been provided to direct the reader to the most up-to-date published information.

Climate Change Act (2010) (Vic)

The *Climate Change Act (2010)*:

- Requires decision makers to take climate change into account when making specified decisions under the Catchment and Land Protection Act 1994, Coastal Management Act 1995, Environment Protection Act 1970, Flora and Fauna Guarantee Act 1988, Public Health and Wellbeing Act 2008 and Water Act 1989.
- Requires the Victorian Government to prepare a Climate Change Adaptation Plan every four years to outline the potential impacts and risks of climate change in Victoria, the government's priorities in response and a synthesis of the relevant climate change science
- Creates new arrangements for the ownership, registration and transfer of forestry and carbon



sequestration rights to help Victorian landholders take part in carbon sequestration projects under the Commonwealth Government's Carbon Farming Initiative (*Climate Change Act, 2010 Vic*).

Forestry Rights

The (*Climate Change Act 2010, (Part 4) (Vic)*) and its amendments in the (*CCEPA Act 2012 (Vic)*) replaces the (*Forestry Rights Act 1996 (Vic)*) and provides a legal framework for carbon sequestered by forests and soil on private land (G. Ivancic, 2015, pers. comm.) This enables ownership of trees, forest products and/or sequestered carbon to be separated from the ownership of a parcel of land, between the tree owner and the carbon investor. The respective rights and responsibilities of each party are specified in an accompanying forestry and carbon management agreement. This system allows carbon investors to buy and sell carbon as a third party, without having to own or manage the trees or land where the carbon is sequestered, and to ensure that their carbon rights are legally protected (G. Ivancic, 2015, pers. comm.)

Carbon Sequestration on Crown Land

The (*Climate Change Act 2010, (Vic) (Part 5)*) and its amendments (*CCEPA Act 2012 (Vic)*), establishes detailed “rules under which Crown land can be managed and used for carbon sequestration purposes” (Department of Environment and Primary Industries Victoria, 2014). The government may manage its own land or by arrangements with third parties, via Carbon Sequestration Agreements. “For carbon sequestration projects on Crown land, the Minister declares specified Crown land to be available for carbon sequestration, and the Secretary of the Department of Environment, Land, Water and Planning:

- Holds carbon rights over Crown land subject to existing licences, leases and agreements, except in certain specified instances and
- Can enter into CSAs with other parties for carbon reforestation on Crown Land and grant carbon sequestration rights and soil carbon rights to third parties” (Department of Environment and Primary Industries Victoria, 2014).

Climate Change Adaptation Plan

The first *Victorian Climate Change Adaptation Plan* was released in March 2013, as required under the *Climate Change Act (2010)*. Subsequent plans must include a report on the implementation and effectiveness of the previous plan. The current plan sets out strategic priorities to coordinate respond to climate risk and includes six key strategies to:

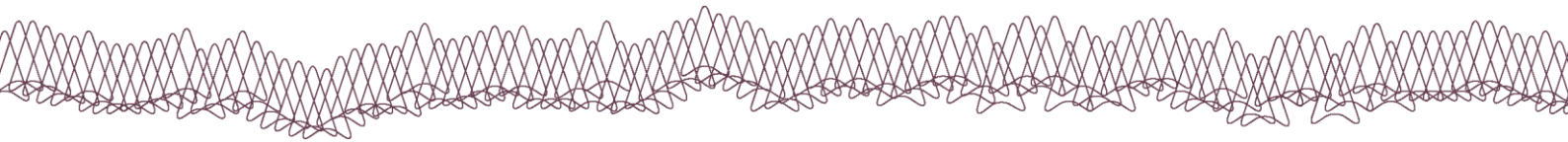
- manage risks to public assets and services managed by the Victorian Government;
- manage risks to natural assets and natural resource-based industries;
- build disaster resilience and integrated emergency management;
- improve access to research and information for decision making;
- support private sector adaptation;
- strengthen partnerships with local government and communities (Department of Sustainability and Environment Victoria, 2013).

Other key Victorian State legislation with requirements or clauses relevant to climate change adaptation, mitigation and carbon sequestration are outlined below.

Water Act (2014)

Over the past 25 years of water reform in Victoria, the water sector has developed a range of measures to adapt to climate change and variability. The main legislative basis for these measures are the *Water Act 1989 (Vic)* and the *Water Industry Act 1994 (Vic)*, and they have been implemented through a range of legislative instruments, policies, plans and infrastructure projects:

- An active water market that enables water resources to be put to their most efficient use. The water market provides entitlement holders with an effective way of managing varying water availability, and re-allocating water during prolonged drought and times of uncertainty.
- Investment in water efficiency on farms and irrigation districts, and in cities and towns, to



increase the value of all water used. Examples include the Wimmera-Mallee pipeline and irrigation modernisation in the Goulburn-Murray Irrigation District, significant water infrastructure, (including more networked water supplies through the North-South pipeline, Goldfields Superpipe and Hamilton-Grampians Pipeline) and new supply sources such as the Victorian Desalination Project.

- The *Water Act 1989 (Vic)* provides for the environmental water reserve and environmental entitlements, and establishes the Victorian Environmental Water Holder and a framework for delivering environmental water based on seasonal environmental needs and water availability.
- Significant investments have been made to recover water for the environment and install structural works to make better use of available water.
- Regional sustainable water strategies and regional waterway strategies identify and address problems with water resources and waterway health, and prioritise actions to improve the resource condition. Urban water corporations plan for the future using principles of scenario-based planning and adaptive management as part of a framework for decision-making under uncertainty (G. Ivancic, 2015, pers. comm.).

The *Water Act 1989 (Vic)* and the *Water Industry Act 1994 (Vic)* were recently consolidated into the proposed *Water Act 2014 (Vic)*. However, this new Bill recently went before Parliament but was not passed (G. Ivancic, 2015, pers. comm.).

Coastal Management Act 1995 (Vic)

The *Coastal Management Act 1995 (Vic)* (CM Act) doesn't make specific reference to climate change. However, the (*Climate Change Act 2010 (Vic)*) "requires the Minister responsible for endorsing the State's coastal policy to consider climate change" (Gibbs and Hill, 2011; p.13). The state-wide Victorian Coastal Strategy (2014), (VCS) is a requirement under the CM Act. The Strategy recognises adapting to climate change as one of five key coastal management issues and requires minimum sea level rise planning benchmarks to be reviewed and updated as part of future reviews of the Strategy. The Strategy provides criteria for use and

development on coastal Crown land including planning for climate change impacts (Victorian Coastal Council, 2014). Key VCS policies that relate to climate change impacts on coasts are incorporated into the state-wide provisions of Victoria's planning system (Victorian Planning Provisions).

The VPPs relevant to climate change are contained in Clause 12.02-1 (Protection of coastal areas), Clause 13.01-1 (Coastal inundation and erosion) and Clause 11.05-4 (Climate change, natural hazards and community safety) (Gibbs and Hill, 2011; p.19).

Planning and Environment Act 1987 (Vic)

Victoria's *Planning and Environment Act (1987) Vic* regulates Victoria's planning system. Victorian Planning Provisions (VPPs) are incorporated into all local Victorian planning schemes and "must be considered by the responsible authority before deciding on a development approval application" (Gibbs and Hill, 2011, p.20). Section 60 of the Act states which matters a responsible authority must consider under the VPPs. The following is one of a number of statements under Section 60 of the Act which allows climate change risks to be taken into account by decision makers:

"Any significant effects which the responsible authority considers the use or development may have on the environment or which the responsible authority considers the environment may have on the use or development". (Planning and Environment Act (1987), (Vic), s. 60(1) e).

Environment Protection Act 1970 (Vic)

Under section 14 of the *Climate Change Act 2010 (Vic)* the Environment Protection Authority (EPA) "must consider climate change in works approval and licensing decisions, as well as when recommending new or amended state environment protection policies and waste management policies" (Environment Protection Authority Victoria, 2013). This includes the requirement to:

- avoid and minimise emissions in accordance with the principles of the waste hierarchy;
- pursue continuous improvement;

- apply best practice to the management of their emissions.

The *Environment Protection Act 1970 (Vic)* includes controls requiring products applied to the land to be fit for purpose and not cause aesthetic or chemical contamination of land, which may have implications for agricultural application of products such as composts and biochar.

Sustainable Forests (Timber) Act 2004 (Vic)

Victoria's *(Sustainable Forests (Timber) Act 2004 (Vic)* provides for the preparation of a sustainability charter for Victoria's forests and requires the determination of criteria and indicators for sustainable forest management. The current criteria and indicators address the maintenance of forest contribution to global carbon cycles. Victoria reports on the criteria and indicators in the Victorian state of the forests reports (G. Ivancic, 2015, pers. comm.).

Catchment and Land Protection Act 1994 (Vic)

As specified in Schedule 1 of the Climate Change Act, the following decisions or actions under the *Catchment and Land Protection Act 1994 (Vic)* (CaLP Act) must have regard to climate change:

- Schedule 2, Clause 3: An approval or refusal of an approval of a management plan [Regional Catchment Strategy] by the Minister, or the return of a plan to the Authority with any recommendations for change.
- Schedule 2, Clause 7: The revocation of a management plan [Regional Catchment Strategy] by the Minister.
- In making either decision or action above, the Minister must consider sections 14(2),(3) and (4) of the Climate Change Act (*Climate Change Act, 2010 Vic*)

Public Health and Wellbeing Act 2008 (Vic)

The *Public Health and Wellbeing Act 2008 (Vic)* has obligations under the CC Act, "with s. 14 identifying councils as one of the decision-makers that must consider climate change during the preparation of a

Municipal Public Health and Wellbeing Plan". (Public Health and Wellbeing Act, 2008, s. 14).

B.2.5 State legislation and policy relevant to climate change in Tasmania

Tasmania's overarching climate change legislation and related policy is outlined below. Website links are provided where relevant for ease of access to updates.

Climate Change (State Action) Act 2008 (Tas)

Tasmania's *Climate Change (State Action) Act 2008 (Tas)* sets out:

- climate change regulations, including the 2050 target to reduce GHG emissions in Tasmania to at least 60% below 1990 levels;
- details for the establishment and administration of the Tasmanian Climate Action Council; and
- reporting requirements under the Act.

The supporting *Climate Change (Greenhouse Gas Emissions) Regulations 2012* to this Act prescribe the method for measuring and reporting Tasmania's GHG emissions.

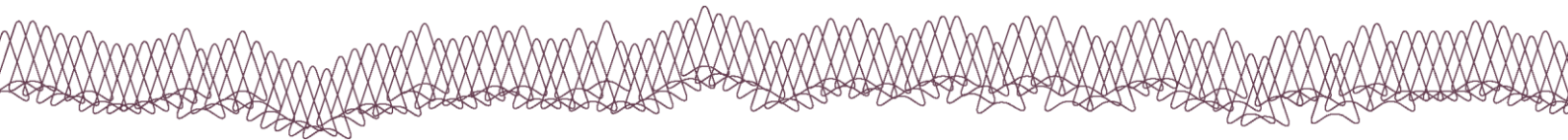
Resource Management and Planning System

Tasmania's Resource Management and Planning System (RMPS) provides the framework for management of natural resources. The RMPS integrates Tasmanian laws, policies and procedures.

According to the Environmental Defender's Office, for projects "where the State government is the proponent, climate change impacts must ... be considered" (Environmental Defenders Office Tasmania, 2013; p.25).

The principal Acts forming the RMPS, and in which the Tasmanian Planning Commission (the independent statutory authority), has a major role, are the:

- *Land Use Planning and Approvals Act 1993 (Tas)*;
- *State Policies and Projects Act 1993 (Tas)*; and
- *Planning Commission Act 1997 (Tas)*.



These Acts include statutory responsibility encompassing all aspects of statutory planning, assessment of major projects, use of public land, sustainable development, and the provision of advice to the Minister and local government on land-use planning issues. However, some major resource management activities, including forestry and mining, are exempt from the RMPS.

Note that 'sustainable development' is defined in the Land Use Planning and Approvals Act (Clause 2, Schedule 1,) which is integral to the RMPS, as:

"managing the use, development and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic and cultural well-being and for their health and safety while:

a) sustaining the potential of natural and physical resources to meet the reasonably foreseeable needs of future generations; and

b) safeguarding the life-supporting capacity of air, water, soil and ecosystems; and

c) avoiding, remedying or mitigating any adverse effects of activities on the environment." (Land Use Planning and Approvals Act, 1993)

In Tasmania, climate change risks are addressed at a regional level via Regional Land Use Strategies, (RLUS), which cover three regions of Tasmania. "Each of the strategies addresses [climate change] risks and suggests specific actions aimed at responding to climate change impacts, including SLR, coastal inundation" (Gibbs and Hill, 2011, p. 51) and areas prone to high bushfire risk.

While these regional strategies are not binding, planning schemes are required to align with the objectives and outcomes specified in RLUS (Tasmanian Planning Commission, 2014). The three regional bodies have recently completed new regional planning strategies, available on the Tasmanian Planning Commission website, <http://www.planning.tas.gov.au/>

Climate change risks are covered at the local level through Local Planning Scheme (LPS) provisions. However, each scheme addresses climate change risks

in different ways. Many of these schemes were under review with an aim of creating improved consistency across the state at the time of writing.

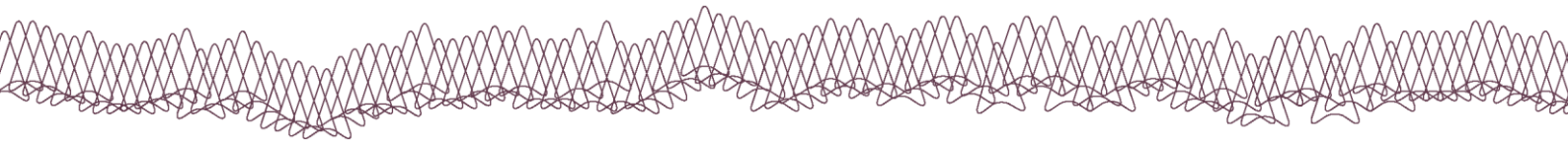
The extent to which climate change risks relating to new developments will be taken into account depend on the local planning scheme provisions. Local authorities, responsible for the content of LPS's, "are required to further the objectives of the overarching framework for planning in Tasmania, the Tasmania's Resource Management and Planning System, (which includes broad sustainability objectives)" (Gibbs and Hill, 2011; p. 26).

Coastal Management Legislation and Policies Relevant to Climate Change

Tasmania's State Coastal Policy 1996 (SCP) was undergoing review at the time of writing. Coastal Climate Change (CCC) risk management is dealt with under different legislative frameworks, hence there is no single Minister or responsible agency. CCC is a contested policy area in Tasmania (Gibbs and Hill, 2011).

At the State level, the Tasmanian Land Use Planning and Approvals Act) and the State Policies and Projects Act are the legislative forces behind the Tasmanian SCP. The principles of the SCP are protection of natural and cultural values of the coast, sustainable use and development, and integrated management of the coastal zone. The SCP recognises, (inter alia), the susceptibility of the coast to the effects of natural events, including SLR, (Department of Premier and Cabinet Tasmania, 1996: 5; 1.4.1). The SCP comprises 85 outcomes, 2 directly related to coastal hazards associated with SLR and climate change but provides no state-wide benchmarks in relation to CCC (Good, 2011).

In Tasmania, CCC risks are addressed at a regional level via Regional Land Use Strategies, (RLUS), (co-ordinated by the Tasmanian Planning Commission) covering the three regions of Tasmania. Each of the strategies addresses CCC risks and suggest specific actions aimed at responding to climate change impacts, including SLR, coastal inundation and shoreline recession and bushfire risk.



At the local planning level, provisions of the SCP prevail over inconsistent provisions in local planning schemes. (Gibbs and Hill, 2011).

Emergency Management Planning Legislation and Policies Relevant to Climate Change

Tasmania's *Emergency Management Act 2006 (Tas)* sets out emergency management arrangements. The Act defines an emergency as either an event, or the threat of an event, that requires appropriate measures, including "...to mitigate the risks associated with the threat and that possible resulting event" (Emergency Management Act 2006 (Tas) s.3).

There is a range of Federal, Tasmanian state and local government policies that collectively provide for managing the impacts of natural hazards, as a shared responsibility. However, these Acts and policies do not clearly assign responsibility for managing risk when mitigating the impact of natural hazards in Tasmania (Department of Premier and Cabinet Tasmania, 2013).

At the time of writing the Tasmanian Climate Change Office coordinated the following relevant projects (Department of Premier and Cabinet Tasmania, 2013):

- Tasmanian State Natural Disaster Risk Assessment, including a register of the most significant risks posed by natural hazards in Tasmania.
- Managing natural hazards through a land-use planning project; a series of policy statements to be developed outlining the State's land use planning approach to managing the risks posed by bushfire, landslide, coastal inundation, coastal erosion, and severe weather.
- Natural hazards and policy responses in Tasmania will also be examined through a Natural Disaster Resilience Program funded project.

Water and Floodplain Management Legislation and Policies Relevant to Climate Change

The Tasmanian *Water Management Act 1999 (Tas)* is part of the Resource Management and Planning System (RMPS) and provides for management of the States freshwater resources. The Act provides for the use and management of freshwater resources. No specific

reference is made in the Act regarding climate change impacts or adaptation.

The Tasmanian State Policy on Water Quality Management (State of Tasmania, 1997) provides the overarching framework for the sustainable management of surface waters, coastal water resources and water quality in Tasmania, identifying activities which may impact on various water resources and providing guidance on managing these activities. No specific reference is made regarding climate change impacts or adaptation

The Tasmanian Implementation Plan for the National Water Initiative (Department of Primary Industries and Water, 2006) refers to climate change risk assessment to guide implementation.

The Tasmanian *Environmental Management and Pollution Control Act (1994)(Tas)* enables regulation of activities which involve discharge of pollutants and hazardous substances to air, land or water consistent with maintaining environmental quality. The Act doesn't specifically include or monitor greenhouse gases as pollutants.

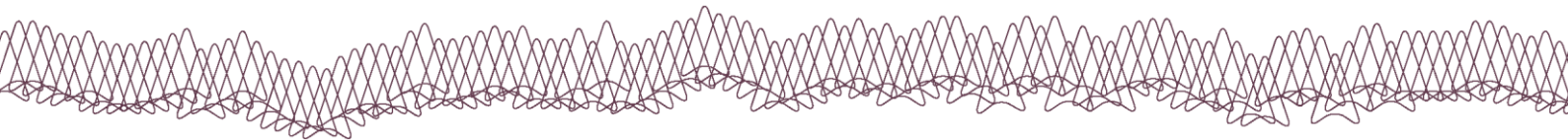
NRM Legislation and Policies Relevant to Climate Change

The Tasmanian *Natural Resource Management Act 2002 (Tas)* and the Tasmanian Natural Resource Management Framework (Department of Primary Industries and Water Tasmania, 2002) provide a structure and mechanisms for delivering management of natural resources in the State.

The Tasmanian *Nature Conservation Act (2002) (Tas)* and the *Tasmanian National Parks & Reserves Management Act (2002) (Tas)* makes provision with respect to conservation and protection of fauna, flora and geological diversity of Tasmania.

Soil, Land and Agricultural Productivity Legislation and Policies Relevant to Climate Change

Although Tasmania has some controls over vegetation clearance, it is the only state that has no specific soil



protection legislation (Environmental Defenders Office Tasmania, 2013; Ch. 10).

The *Tasmanian State Policy on the Protection of Agricultural Land* (Department of Premier and Cabinet Tasmania, 2009) has a primary objective of protecting agricultural land from development for other land uses.

The *Tasmanian Primary Industry Activities Protection Act (1995) (Tas)*, which was under review at the time of writing, prevents some common law 'nuisance' actions being taken against farmers for noise and other pollution caused by their activities, (Environmental Law Handbook Tasmania, 2013, Chapter 10).

B.2.6 State legislation and policy relevant to climate change in New South Wales

(The authors would like to acknowledge the NSW Office of Environment and Heritage (OEH) and particularly Chris Lee, who provided this section in draft form).

Key New South Wales (NSW) legislation and related policy which makes reference to climate change is outlined below.

The two pieces of NSW legislation which directly mention climate change are the *Energy and Utilities Supply Act 1987 (NSW)* and the *Electricity Supply Act 1993 (NSW)*. Other NSW legislation relates to the impacts of climate change, or ways to manage issues that may worsen with further climate impacts. This primarily relates to coastal zone management and flood prone areas.

Energy and Utilities Supply Act 1987 (NSW)

Administered by the Office of Environment and Heritage (OEH), the Climate Change Fund (CCF) was established under the *Energy and Utilities Supply Act* in 2007. Its purpose is to provide funding to reduce greenhouse gas emissions and the impacts of climate change associated with water and energy activities.

Funds are collected from water and energy utilities. These funds are distributed for activities of reducing greenhouse gases, reducing water or energy use,

demand management activities, investment in renewable energy or promoting energy and water savings to the public. The fund is used by the NSW Government to improve energy management in NSW. It does this via the *Energy Efficiency Action Plan* (State of NSW, 2014) and the *Government Resource Efficiency Policy* (State of NSW, undated). The CCF also supports renewable energy through the *Regional Clean Energy Program*.

The CCF was under review at the time of writing, with potential expansion to fund adaptation responses. More information on the fund can be found at the Office of Heritage and the Environment NSW (2014) website.

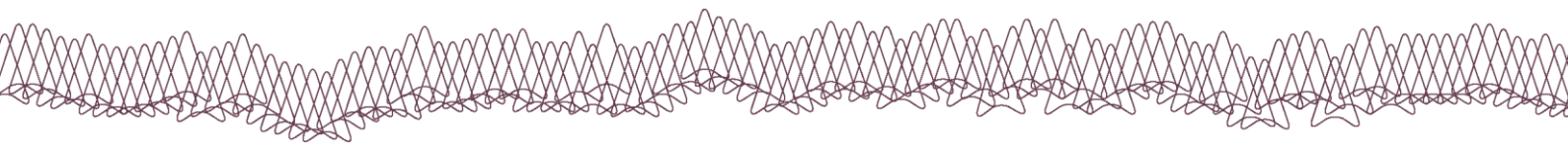
Electricity Supply Act 1993 (NSW)

This Act supports feed-in tariffs for those seeking renewable energy as a response to climate change. Whilst the *Electricity Supply Amendment (Solar Bonus Scheme) Act 2009 (NSW)* was enacted to further promote uptake of residential solar, the scheme finishes in 2016 and has closed to new applicants.

Coastal and Floodplain Management Legislation and Policies and Current Reforms Relevant to Climate Change

The *Coastal Protection Act 1979 (NSW)* is the principal legislation relating to coastal management in NSW. Key provisions of the Act include requirements relating to Ministerial agreements for certain developments in the coastal zone, and requirements relating to preparing Coastal Zone Management Plans (CZMPs). The CZMPs address risks from coastal hazards, such as coastal erosion, as well as managing threats to estuary health. CZMPs do not address the projected impacts on climate change, including projected sea level rise, on coastal erosion risks and estuary health.

The *Coastal Protection Amendment Act 2012 (NSW)* and the *Coastal Protection and Other Legislation Amendment Act 2010 (NSW)* amend the *Coastal Protection Act 1979 (NSW)* to allow landowners owners to more readily implement temporary coastal protection works in coastal erosion-prone areas.



At the time of writing, the NSW Government was conducting a two-stage coastal management reform process:

Stage 1 of the reform process, which is largely complete, focused on providing some regulatory relief to landowners and councils dealing with current erosion impacts. According to the OEH website (<http://www.environment.nsw.gov.au/coasts/stage1coastreforms.htm>):

“This included giving councils the flexibility to consider coastal hazards in the context of their local circumstances and regulatory changes to allow landowners to more readily place sand or sand bags as temporary coastal protection works”.

Stage 2 of the reform process is linked to the current planning reforms and local government reviews. The scope of the stage 2 reforms is in three key areas (website as above):

“Replacing current laws with a new coastal management Act - which will be less complex, and a better fit with land use planning and local government legislation;

New arrangements to better support council decision making, including a new coastal management manual and improved technical advice; and

Developing a clear system for funding and financing coastal management actions”.

Sea Level Rise

The NSW Sea Level Rise Policy Statement is no longer government policy. As part of Stage 1 of the above-mentioned coastal management reforms, the Government no longer prescribes state-wide sea level rise projections for use by councils; instead councils would have the flexibility to determine their own sea level rise projections to suit their local conditions.

The Office of Environment and Heritage uses the *Coastal Risk Management Guidelines* incorporating sea level rise into flood risk and coastal hazard assessment (DECCW, 2010). These documents will be revised as part of the reform process. In the interim, reference to the NSW sea level rise planning benchmarks should be

taken as referring to council's adopted sea level rise projections.

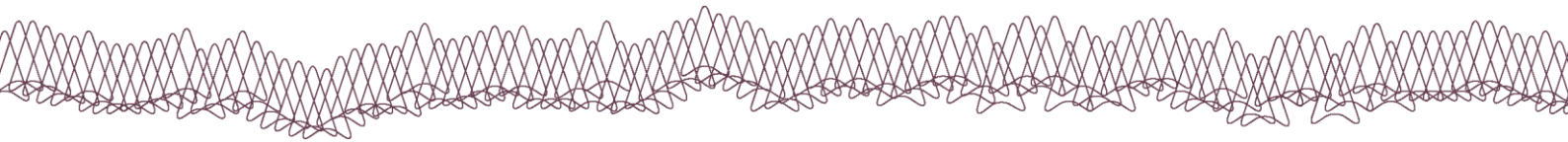
Additionally, the Department of Planning (DoP) & Environment NSW have developed guidance documents for councils on undertaking coastal hazard assessments and flood risk assessments, and on applicable zonings and development controls including the *NSW Coastal Planning Guidelines: Adapting to Sea Level Rise* (Department of Planning New South Wales, 2010).

NSW Environmental Planning and Assessment and Floodplain Management

Section 4.3 (Flood Prone Land) of the *Environmental Planning and Assessment Act 1979* (NSW) requires all Councils that contain flood prone land in their Local Government Area to include provisions in their Local Environment Plans that give effect to, and are consistent with, the NSW Flood Prone Land Policy and the principles of the Floodplain Development Manual 2005. This includes guidelines on development controls on low flood risk areas outlined in planning circular PS07-003. The majority of existing LEPs contain provisions specific to flood prone areas.

The *Environmental Planning and Assessment Regulation 2000* states that planning assessments must consider the likely impact of an activity on the environment. This includes *“any impact on coastal processes and coastal hazards, including those under projected climate change conditions”*.

Planning & Environment NSW and OEH are jointly responsible for preparing and maintaining the *NSW Floodplain Development Manual* which includes the *Flood Prone Land Policy*, outlining the floodplain risk management process. This process advocates the development of flood risk management plans to enable council to understand and manage their flood risk strategically. Additionally, Department of Environment, Climate Change and Water (DECCW) have also produced a range of documents to support the implementation of this Policy (DECCW, 2010).



Water Management Act 2000 (NSW)

NSW fresh water resources are managed via water sharing plans under the *Water Management Act 2000 (NSW)*. Both the Minister and the Natural Resources Commission can recommend changes to a water management plan that will result in a reduction of water allocations. Where compensation might be payable under section 87AA, they must prepare a statement or report as to whether the purpose is to restore water to the environment because of natural reductions in inflow to the relevant water source, including but not limited to changes resulting from climate change, drought or bushfires.

Section 87AA of the Act provides that the holder of an access licence is not entitled to compensation if the “*reduction in water allocations is for the purpose of restoring water to the environment because of natural reductions in inflow to the water source, including but not limited to changes resulting from climate change, drought or bushfires*”.

Threatened Species Conservation Act 1995 (NSW)

Schedule 3 of the *Threatened Species Conservation Act 1995 (NSW)* lists anthropogenic climate change as a “*key threatening process*”.

Local Government Act 1993 (NSW)

Despite the provisions in the Planning Acts and Regulations, the *Local Government Act 1993 (NSW)* specifically exempts Councils from liability in the event of failure to upgrade flood mitigation works or coastal management works, or actual impacts of climate change, as well as the provision of information about climate change or sea level rise.

NSW 2021 Plan

The 10 year NSW 2021 plan sets the Government's agenda for change in NSW. It has a target to minimise the impacts of climate change on local communities. This is done through delivery of climate projection information, supporting relevant actions in the States Regional Action Plans, and conducting adaptation research.

Asset management

NSW Treasury has issued *Economic Appraisal Guidelines – Guidance on climate change for asset and infrastructure assessments (2010)* to supplement NSW risk management guidance for agencies (NSW Treasury, 2010). These guidelines advise that each government agency should be responsible for carrying out its own risk management process and for deciding whether or not to assess its climate change risk. Risk management of NSW infrastructure and assets is currently under consideration (NSW Treasury, 2010).



Section C.

Examining potential futures



C. Examining potential futures

This section provides information about the Earth's climate, observed and future global climate change, as well as about climate modelling, climate science, and greenhouse gas emissions scenarios. Climate science has delivered an increased understanding of how the Earth's climate has developed over the millennia and how it may change in the future. An understanding of the current and potential future climatic conditions is necessary for NRM organisations to identify what it is they are adapting to.

C.1 Climate change projections

This section provides some context for interpreting and understanding the role of climate change projections in NRM planning. For the Southern Slopes Cluster, CSIRO and the Bureau of Meteorology produced a technical climate report (Grose et al., 2015), available at: <http://www.climatechangeinaustralia.gov.au/en/publications-library/cluster-reports/>.

C.1.1 Climate change and the global climate system

What is climate change?

Climate change, from a purely climatological perspective, is the change in the average weather over a long period of time, typically 30 years. Climate change can occur due to a combination of natural causes and human causes.

The IPCC (2013b, p. 126) definition of climate change is:

"...a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use."

The above definition differs from that in the United Nations Framework Convention on Climate Change

(UNFCCC, 1992, sec. 1) where climate change is defined as:

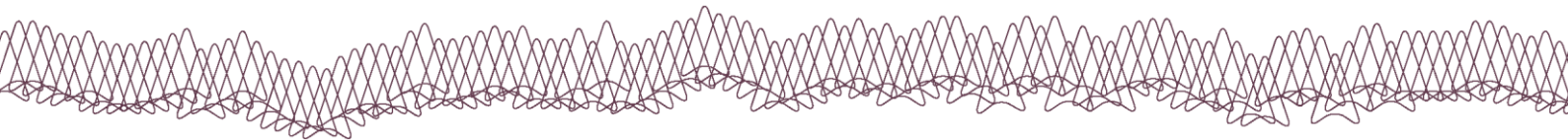
"...a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods."

The UNFCCC thus makes a distinction **between climate change** attributable to human activities altering the atmospheric composition, and **climate variability** attributable to natural causes (IPCC, 2013b).

How has our climate changed?

Over geological timescales, even rapid climatic change occurred much slower than the current rate of change. For example, it took centuries for the ice from the last glaciation to decline (about 10,000 years ago). By comparison, in the last century the global climate has changed rapidly, with an increase of around 0.74°C (1906-2005). Most of this change occurred during the second half of the last century, with eleven of the twelve warmest years occurring between 1995 and 2006.

This change has not been the same for different locations and seasons. Warming has been greater over land cover than over the oceans (IPCC, 2007d, p. 10), with the strongest warming occurring in the inland areas of Asia and North America. In Australia, there has been a warming of 0.9°C since 1910 (CSIRO and Australian Bureau of Meteorology, 2014, p. 3). Warming has also been stronger during the winter months, and the length of frost-free periods has increased in most regions outside the tropics.



Why has the climate changed so much?

Atmospheric concentrations of greenhouse gases (CO₂, methane, and nitrous oxide) are now at the highest level they have been for at least the last 800,000 years (CSIRO and Australian Bureau of Meteorology, 2014). Concentrations of CO₂ have increased by 40% since pre-industrial times, due mainly to fossil fuel emissions and also from emissions caused by land use change.

In its latest report, the IPCC (IPCC, 2013a, p. 15) states: *“It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century”.*

C.1.2 Climate variability

What is climate variability?

Climate variability is defined as “variations in the mean state of the climate and other statistics (such as standard deviations and the occurrence of extremes) across temporal and spatial scales beyond that of individual weather events” (IPCC, 2007c). It is important for climate variability not to be confused with climate change. Typically, climate variability relates to time frames of months, seasons or years (WMO, 2014). Weather is usually associated with day-by-day atmospheric change, whereas climate change refers to changes occurring over decades or centuries.

Example: Intense and heavy rainfall causing consecutive years of flood events can be described as climate variability, whereas an increase in rainfall over several decades is referred to as climate change. A single heavy rainfall event is part of daily weather.

What causes climate variability and how can it be measured?

Climate variability has a number of natural and human causes. Natural causes of variability are sometimes referred to as internal variability. These include:

- Changes in wind patterns occurring over the course of a season or decade;
- Changes in sea-surface temperatures and/or air pressure (e.g. El Nino Southern Oscillation, which typically occurs every 3-5 years and the Pacific

Decadal Oscillation (PDO) at scales of several decades;

- Changes to atmospheric processes caused by volcanic eruptions;

The human causes of climate change also contribute to changes to climate variability. These are sometimes referred to as external forcing or external variability.

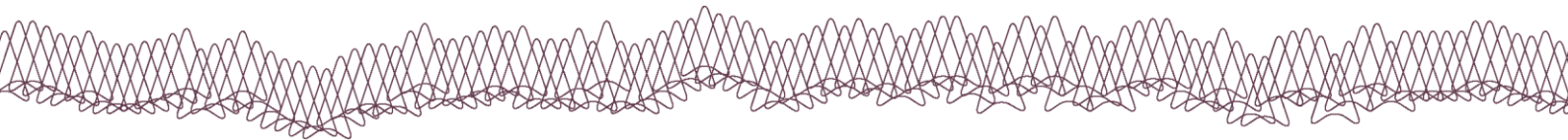
Climate variability is often difficult to observe. In general terms, any period of erratic, unusual weather lasting for several weeks, months or years can be considered as climate variability. This can be measured as a significant deviation from the average climate over time. If climate is defined as the average of weather over a 30 year period, this allows for determination of the ‘normal’ range of conditions expected for a locality or region. For example, a given month or season might be the hottest on record, or close to average at the 55th percentile of the long term median.

Climate scientists often use median (the middle value) rather than mean (the sum of the events, divided by the number of events) as a statistical average. This is because climate variability, especially rainfall variability, is not distributed as a bell curve – e.g. the distribution for rainfall typically has a very long tail with a small number of very large rainfall events.

Why is climate variability important for adaptation?

Climate variability can result in extreme weather events, such as droughts, heavy rainfall, fire weather, heat waves, hail storms and flooding. These extreme weather events can occur in increased frequency and intensity over a period of several weeks, months or years. They have a strong and immediate impact on human lives and assets as well as natural resources.

Climate variability, especially extremes, is a key short to medium term consideration for climate change adaptation. Farmers, for example, consider climate variability in their planning to manage seasonal climate variability – maximising profit in good seasons and managing through poor seasons. However, climate change adaptation can be more strategic and forward looking. Long-term change such as decreasing average rainfall or increased summer temperatures are taken



into account. As an example, farmers might think strategically about shifting some of their practices and sources of revenue to accommodate any medium and long term changes to the climate, or diversify their livelihoods to be less reliant on rainfall that experience and projections might indicate is becoming less reliable.

What is El Niño?

One of the most researched causes of global climate variability is a naturally occurring interaction between the Pacific Ocean and the atmosphere, known as the El Niño-Southern Oscillation (ENSO). ENSO is characterised by strong but recurrent fluctuations in sea-surface temperatures and atmospheric circulation across the equatorial Pacific Ocean (see Figure C.1). These fluctuations are strongly linked to rainfall and temperature across much of Australia (Nicholls, 1991).

They typically recur every three to five years, but this interval has ranged from two to eight years in the historical record.

During the warm phase of the cycle, called El Niño, above average sea-surface temperatures develop over much of the eastern Pacific. El Niño is strongly associated with dry conditions over eastern Australia, the western South Pacific, and Southeast Asia, while the South American coast experiences a warm phase and increased likelihood of rainfall and flooding. During La Niña, the cold phase of the cycle, widespread rain in the western Pacific and Australia is more likely and often results in significant flooding. ENSO also has significant effects on areas outside the Pacific Oceans, in particular in eastern Africa and eastern North America.

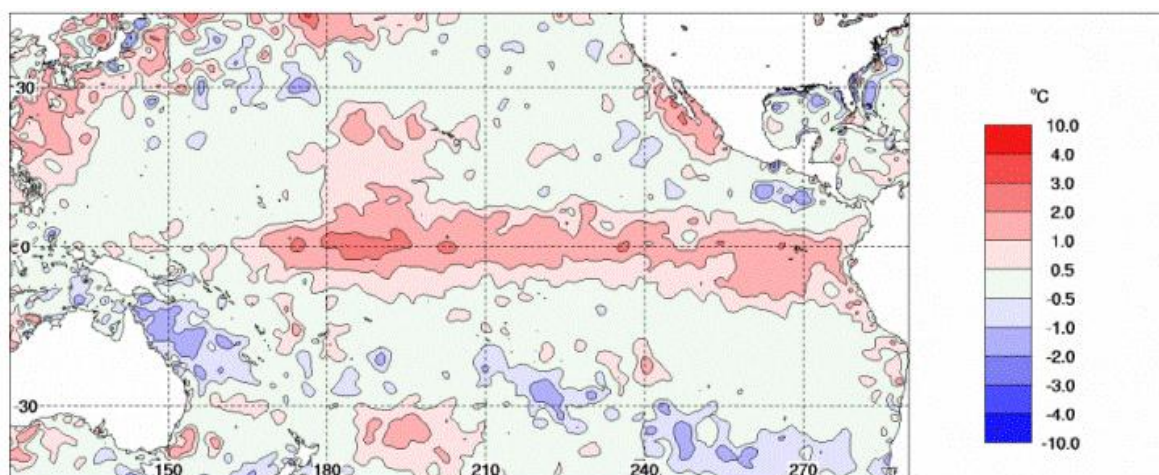


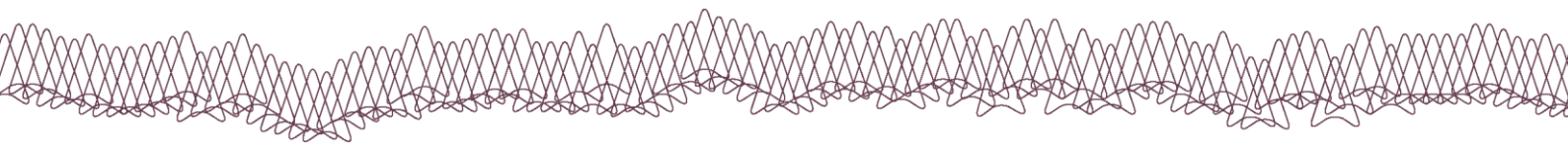
Figure C.1 Pacific sea-surface temperature anomaly typical of El Niño, Australian Government Bureau of Meteorology

C.1.3 Climate Projections and Models

What are climate projections?

Climate projections are scientific statements, based on the output of global or regional climate models, about changes in aspects of the future climate. For example, the projections for the Southern Slopes Region state:

“For the near future (2030), the projected increase of mean annual temperature is around 0.4 to 1.1 °C above the climate of 1986–2005, with only minor differences between RCPs. For late in the century (2090), there is a large difference between scenarios, with projected warming of 1.1 to 2.0 °C for RCP4.5 and 2.5 to 4.0 °C for RCP8.5.” (Große et al., 2015, p. 4)



Climate projections are dependent on a set of influential conditions, such as changes in atmospheric greenhouse gases. Because of these dependencies on external conditions, projections are not predictions of the future, but only an expression of a conditional expectation. That is, they model the changes in atmospheric and oceanic circulation and conditions given differing fundamental conditions such as greenhouse gas concentrations, particles (aerosols) in the atmosphere, or changes in solar activity. These fundamentals are described as ‘forcings’ in climate science terms.

It is not possible to predict the future climate, because of the uncertainty around forcings (such as future emissions), the uncertainty represented by the range in climate models, and the natural variability of the climate system.

The intention of simulating future climate is therefore not to make accurate predictions regarding the future state of the climate system at any given point in time. Rather it is to provide model-derived descriptions of possible future climates under a given set of scenarios of climate forcings (IPCC, 2007b).

What is a Global Climate Model (GCM)?

General Circulation Models, more commonly known as Global Climate Models, are a class of computer-driven model used for predicting weather, understanding climate, predicting seasonal and inter-annual climate and projecting climate change. They are mathematical representations of the real world which simulate processes in the atmosphere or oceans of the Earth. There are only a handful of countries in the world that have developed Global Climate Models.

Global Climate Models use the laws of physics to calculate how the climate system operates, including how various influencing factors interact. They can reproduce many but not all of the observed features of current climate and past climate changes, such as temperature, rainfall, and humidity.

More than 50 GCMs have been assessed as part of the most recent phase of the Coupled Model Intercomparison Project, and admitted to the CMIP5 archive. All archived climate models are considered

plausible representations of possible futures, and the IPCC avoids ranking models and treats each equally. As part of the most recent phase of the Coupled Model Intercomparison Project (CMIP5), Australia has developed the ACCESS1.0, ACCESS1.3 and CSIRO-Mk3.6.0 models, the UK has developed the HadCM3, HadGEM2-ES and HAD-GEM2-CC, and the United States has developed climate models in the CESM1 category, GFDL category and GISS category.

How do Global Climate Models work?

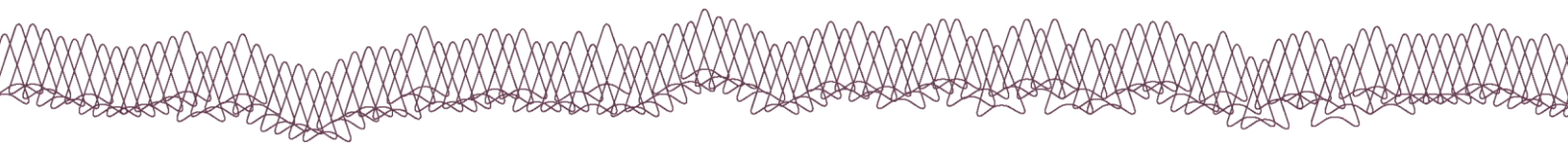
Climate models use a wide range of differential equations derived from the laws of physics, fluid motion, and chemistry, to replicate the way the global climate system functions. These equations are solved on supercomputers. For these calculations, the Earth is covered by a 3-dimensional grid (see the picture below). For each grid cell the equations are applied and factors such as radiation, moisture content, surface hydrology and wind are calculated. In addition, calculations are made on the interactions of each factor at each grid cell with neighbouring cells.

What is ‘downscaling’ of Global Climate Models?

In climate modelling, the term ‘downscaling’ refers to a range of methods that are used to bring the results of a Global Climate Model down to a regional or local scale.

Different methods for downscaling exist. Harris et al. (2014) provide a useful overview of datasets currently available for use in impact studies, and their strengths and limitations. These projections datasets fall into three main categories:

- **Statistical downscaling** uses historical climate records to establish statistical relationships between the global climate and their local variations. These are then used to convert the outputs of Global Climate Models to the regional scale. This technique is relatively quick and inexpensive but it is limited to areas for where climate observations exist. (example: CSIRO Climate Projections)
- **Simple scaling** (also referred to as the change factor method, the delta method or the perturbation method) adds the climate change trend to observed data to produce a “pseudo-future dataset” for



future periods (Harris et al. 2014). In contrast to statistical downscaling methods, simple scaling does not derive any information about local-scale climate change from changes to larger-scale predictors, so do not produce any new information in the climate change signal. These methods can account for temperature lapse rates with changes in altitude, but cannot incorporate more localised processes such as cold air drainage or differences in winds and radiation due to topographic exposure.

- **Dynamical downscaling** (also known as numerical downscaling and regional climate models) uses a high-resolution regional meteorological model that is driven by the outputs of a Global Climate Model. For example, Climate Futures for Tasmania used sea surface temperature from the host GCM, from which it creates its own pressure, wind, temperature and rainfall patterns in the atmosphere. The regional model therefore captures the regional climate processes that operate over small distances (5-10km). These models are based on similar physics to GCMs, and can be just as complex. For this reason, they are very computer intensive, time consuming and costly to run (examples: Climate Futures Tasmania, NARCLIM)

How well do climate models replicate the climate at different scales?

Climate models can replicate many observed features of past and current climates, and the confidence in using them for projections of future climate has improved over recent decades. The reliability of climate model projections can be assessed with tests that show that models have the ability to simulate:

- The present average climate and year-to-year variability;
- Observed climate trends in the recent past;
- Extreme events, such as storms and heatwaves; and
- Climates from thousands of years ago.

Global climate models are able to calculate credible quantitative projections of future climate change, in particular at continental scales and above.

Average climate features such as mean atmospheric temperature, rainfall, and radiation, as well as ocean temperatures, currents and ice cover, are well represented by these models. They are also able to model some aspects of regional climate variability, such as major monsoon systems and seasonal changes in temperature.

In contrast, Harris et al. 2014 point out that:

“the projection of wind and clouds, tropical cyclones, storms, and other extreme events is highly uncertain. These phenomena are linked to small-scale processes that cannot be represented explicitly in climate models owing to limitations in computing power or limited scientific understanding of the physical processes. Nevertheless, plausible future trends at large scales may still be simulated, and are useful in assessing potential responses into the future” Harris et al. 2014, p. 629). (See [C.5 Analysing possible futures](#)).

C.1.4 Uncertainty in projections of future climate change

Why are there uncertainties with climate models?

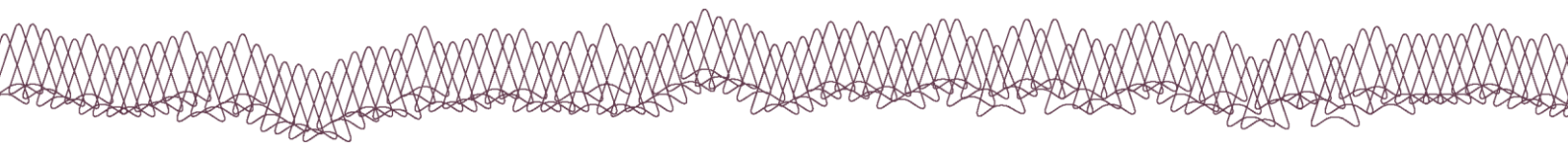
Uncertainties have three main sources:

1. natural climate variability in the climate system (discussed above);
2. uncertainty about the amount of future greenhouse gas emissions; and
3. model uncertainty.

At the regional scale of NRM decision-making, the largest source of uncertainty is likely to be climate variability, followed by uncertainty about future emissions, and finally model uncertainties.

Uncertainty due to climate variability

Australia has among the most variable rainfall climates from one year to the next. This is largely because of ENSO and other drivers of regional variability at these timescales. Scientific understanding of these phenomena currently provides some predictability at seasonal and inter-annual timescales. However the noise (or uncertainty) remains much greater than the



signal (or predictability). For example, we can produce probability forecasts of exceeding median rainfall or temperature over a three month period, but cannot predict how and when that rain will fall. This means that, decision must be based on probabilities of patterns that are not necessarily the system drivers of interest.

Future uncertainty about climate variability spans seasonal, inter-annual and inter-decadal scales. Unlike, seasonal climate *predictions*, climate change *projections* are not synched with real-time observations. Harris et al. (2014, p. 622), suggest that, especially in Australia and other areas of high inter-annual climate variability *“the climate change signal is more likely to be swamped by variability and harder to detect at the regional scale”*.

Uncertainty about emissions

There are clearly substantial uncertainties about the geo-politics of climate change mitigation. Such uncertainty is represented in climate models as emissions scenarios. These essentially simplify assumptions about climate diplomacy, technological change and development trajectories into scenarios of atmospheric forcing associated with greenhouse gas concentrations (measure in parts per million [ppm] of CO₂ equivalents).

These scenarios were represented in the IPCC’s AR4 (and earlier) reports as socio-economic scenarios (SRES) and replaced by Representative Concentration Pathways (RCPs) in AR5 reports. The highest RCP (RCP 8.5, roughly equivalent to SRES A1F1) assumes a concentration of 1350 ppm by 2100. Projected global mean temperatures associated with this scenario range from 2.6-4.8°C above current temperatures. A mid-range scenario assumes 650 ppm (RCP 4.5, SRES B1), projected increases range from 1.0-2.6°C.

Given that global emissions have consistently tracked at or above the highest emissions scenarios, it might appear safe to assume that mid-range scenarios should be considered as optimistic. However, the diversity of possible future interventions in atmospheric forcing should not be discounted in development on scenarios. Plausible futures could include a wide spectrum of market based or policy led changes to atmospheric

forcing, including geo-engineering, rapid development of adoption of renewable energy or even new forms of carbon sequestration.

Uncertainty due to the range in climate models

Modelling uncertainties are the only scientifically or technically reducible uncertainty as they reflect incomplete understanding of how the climate system works, or inability of models to operate at a resolution that can capture specific drivers of climate. There is currently a substantial effort to reduce this element of uncertainty through improving GCMs and developing RCM to address these issues. Some of these issues relate to mechanisms such as complex cloud dynamics that are poorly understood and can only be included in the climate model in approximate terms. This leads to different representations of the climate system for different GCMs.

How can uncertainty be dealt with in using projections?

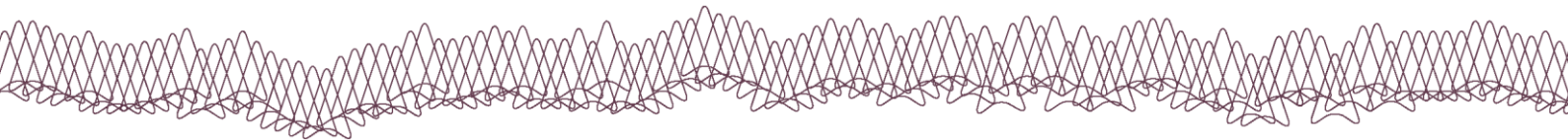
Uncertainties of climate projections can be challenging for planners if they expect certainty. However, to adapt to uncertain changing climate requires considering multiple futures as plausible and evaluating options across these futures. Managing uncertainty in climate projections thus rests on using plausible and credible scenarios. There are a variety of ways to do this, many of which are laid out in [C.5 Analysing possible futures](#).

C.2 Climate change drivers and impacts

The effect of climate change on key climate variables across south-eastern Australia is relatively well understood in general terms. Differences in the direction and magnitude of change are increasingly being resolved at the regional level. In contrast, the regional impacts associated with these changes are less well known.

This chapter is an overview of potential impacts of changes to the key climate variables:

- Air temperature
- Rainfall



- Sea Level
- Atmospheric CO₂ concentrations
- Wind and extreme wind events
- Radiation
- Humidity

Interactions between these variables can also have important consequences on, for example, evapotranspiration, fire weather, and the velocity of regional climate change.

The key climate variables are discussed in this chapter only briefly to provide an overview of which asset classes are most likely to be affected by which climate variable, and some of the key issues for NRM associated with different variables. More detailed explanations of the changes expected for each variable can be found on the NRM Climate Projections for Australia website (<http://www.climatechangeinaustralia.gov.au/>). There are also general resources for Tasmania from the Climate Futures for Tasmania project (http://www.dpac.tas.gov.au/divisions/climatechange/adapting/climate_futures), and for NSW through the Office of Environment and Heritage (<http://www.environment.nsw.gov.au/climatechange.htm>). Further information for Victorian CMAs can be found at the State Government site (<http://www.climatechange.vic.gov.au/>). References to more technical literature can be found via these sources.

We provide a summary of climate drivers relevant to NRM assets in the Southern Slopes. In Table C.1 we have identified the climate variables of most importance to each of the broad NRM asset classes. Table C.2 then provides more detail for terrestrial systems of interest. While climate change is likely to affect all systems, the aim is to highlight those variables and asset classes of greatest and most immediate importance. More detailed discussion of the impacts is then provided in separate sections for each system.

Firstly, changes to some climate variables are likely to have widespread impacts, across all ecosystems. For example, heat-waves affect all ecosystems, when daily maximum temperatures and overnight minimum temperatures stay high for prolonged periods. Physical drivers such as heatwaves can lead to large-scale

mortality events, which in turn can lead to changes to the demography of populations of both fauna and flora, and potentially ecosystem state change where competitive interactions are altered (Wernberg et al., 2012). The human impact of heatwaves is also highly visible and costly, in terms of economic and social costs. Changes to other variables, however, will have more specific impacts on particular ecosystems or regions. The effect of decreasing the number of frost days, for example, will have a greater impact on alpine ecosystems and agricultural systems.

Secondly, our level of understanding about the impacts of changes to the climate variables on natural systems is not complete. In some cases, such as sea level rise (Hunter, 2010) or ocean acidification (McNeil and Matear, 2008), the impacts are relatively well understood in general terms. The ecological response to changes in other variables is not as easily understood. For example, increasing CO₂ is expected to lead to changes in plant growth and competition, but how these changes will manifest in particular regions or ecosystems remains unknown and are difficult to predict. Individual species do not respond to climate variables in isolation; they are connected through interactions with others at the same or adjacent trophic levels (Walther, 2003).

Thirdly, the importance of changes to the climate variables is not consistent across all seasons or regions, and it is to be expected that different species and communities will respond in different ways to changes to climate variables. As more research is done, and long-term monitoring builds up greater knowledge of impacts and responses, some general trends are being highlighted, including species-specific responses which may in turn have further ecological impacts.

Fourth, some climate variables are known to have substantial influences on ecosystem structure and composition, but are not projected to change substantially. Radiation, for example, is an important driver of evaporation, which interacts with rainfall to determine water availability and therefore productivity. However, radiation is projected to remain relatively constant across the south eastern Australia over this century, and so it has been given a low ranking for importance in Table C.1.

Finally, many NRM-related impacts of climate change will manifest as a result of interactions among multiple climate variables, and with other influences such as biological systems, management and policy. The consequences of these interactions are very hard, if not impossible, to model or project. However, in some cases the influences of multiple factors pointing in the same direction provide greater confidence in projected impacts. For example, CO₂ fertilisation along with higher temperatures is likely to lead to increased primary production in forests and thus higher fuel loads, except in areas with low soil nutrient levels, or where rainfall is markedly reduced. Coupled with an increased frequency of fire-weather, these changes are almost certain to lead to more intense or more frequent fires in south-eastern Australia. Other interactions, particularly with biological, human, social, market and political phenomena are characterised by 'deep uncertainty'. Deep uncertainty occurs when there is poor understanding or agreement about the consequences of actions, and often occurs in the management of complex systems, with multiple, unpredictable system drivers. These can result in completely unpredictable, highly complex, nonlinear and sometimes abrupt events, some of which will have profound consequences (e.g. Black Swan events; Taleb, 2010).

Table C.1 Climate variables of most importance across generic asset classes in the Southern Slopes

| Key climate variables / associated indices | Terrestrial Biodiversity | Freshwater Systems | Coasts and Estuaries | Marine Ecosystems | Land, soils and agriculture | Community |
|--|--------------------------|--------------------|----------------------|-------------------|-----------------------------|-----------|
| Average annual temperature | | | | | | |
| Minimum daily air temperature | | | | | | |
| Maximum daily air temperature | | | | | | |
| Heatwave | | | | | | |
| Seasonal temperature regimes | | | | | | |
| Frost | | | | | | |
| Snow cover | | | | | | |
| Sea Surface Temperature (SST) | | | | | | |
| Marine heat waves (warm water pulse) | | | | | | |
| Average annual rainfall | | | | | | |
| Seasonal rainfall | | | | | | |
| Regional runoff | | | | | | |
| Seasonal runoff | | | | | | |
| River flow | | | | | | |
| Annual average wind speed and direction | | | | | | |
| Extreme wind | | | | | | |
| Total cloud cover | | | | | | |
| Average annual radiation | | | | | | |
| Annual average relative humidity | | | | | | |
| Evaporation | | | | | | |
| Incremental SLR | | | | | | |
| Extreme sea-level, storm surges and tides | | | | | | |
| Atmospheric CO ₂ | | | | | | |
| Ocean acidification | | | | | | |
| Intense rainfall | | | | | | |
| Drought / extended dry spells | | | | | | |
| bushfire intensity | | | | | | |
| bushfire frequency | | | | | | |

Table C.2 Climate drivers of most importance across generic sub-types of the terrestrial biodiversity asset in the Southern Slopes

| Key climate variables / associated indices | alpine | dry forest | wet forest | lowland grassland | heathland | coastal | moorland / peatland | wetland |
|--|--------|------------|------------|-------------------|-----------|---------|---------------------|---------|
| Average annual temperature | | | | | | | | |
| Minimum daily air temperature | | | | | | | | |
| Maximum daily air temperature | | | | | | | | |
| Heatwave | | | | | | | | |
| Seasonal temperature regimes | | | | | | | | |
| Frost | | | | | | | | |
| Snow cover | | | | | | | | |
| Sea Surface Temperature (SST) | | | | | | | | |
| Marine heat waves (warm water pulse) | | | | | | | | |
| Average annual rainfall | | | | | | | | |
| Seasonal rainfall | | | | | | | | |
| Regional runoff | | | | | | | | |
| Seasonal runoff | | | | | | | | |
| River flow | | | | | | | | |
| Annual average wind speed and direction | | | | | | | | |
| Extreme wind | | | | | | | | |
| Total cloud cover | | | | | | | | |
| Average annual radiation | | | | | | | | |
| Annual average relative humidity | | | | | | | | |
| Evaporation | | | | | | | | |
| Incremental SLR | | | | | | | | |
| Extreme sea-level, storm surges and tides | | | | | | | | |
| Atmospheric CO ₂ | | | | | | | | |
| Ocean acidification | | | | | | | | |
| Intense rainfall | | | | | | | | |
| Drought / extended dry spells | | | | | | | | |
| bushfire intensity | | | | | | | | |
| bushfire frequency | | | | | | | | |

C.2.1 Air temperature

Changes to the mean, variability and incidence of extreme temperatures are all projected to occur under climate change, and are likely to have a range of impacts on natural systems at different time scales.

Mean annual air temperature has already risen in Australia since the 1950's, at a rate of 0.16 °C/decade, and it is projected to continue rising throughout the century. The rate of change, or climate velocity, will not be exactly the same across all regions. For example, mean land surface temperatures have increased by 0.1 °C/decade in Tasmania since 1950, a slower rate of increase than mainland Australia (Grose et al., 2010).

A small change in the mean of a variable can cause a disproportionately large change in the intensity and frequency of extreme events. This is shown for temperature in Figure C.2, from White et al. (2010, p. 14).

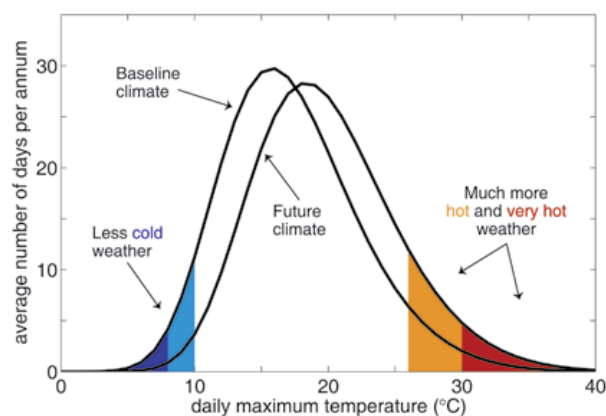
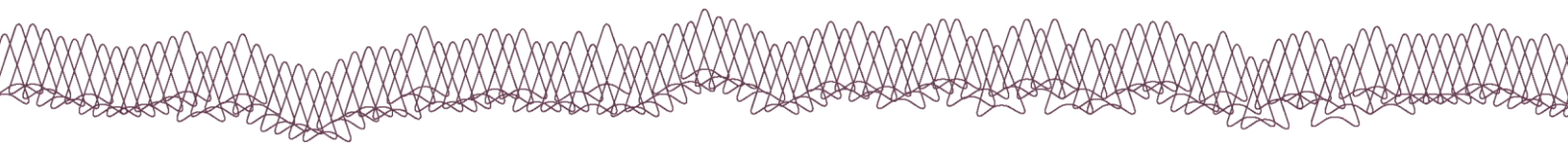


Figure C.2 Probability density functions (PDF) for simulations of daily maximum temperature at Launceston Airport, showing the effect of changes to the mean and variance. Dark blue and light blue shading represents the baseline 1st and 5th percentiles; dark orange and red shading represents the baseline 95th and 99th percentiles respectively. Source: White et al. (2010, p. 14).

Daily minimum and maximum temperatures are both anticipated to increase, with daily minimum temperatures expected to increase slightly more than daily maxima. These changes will result in an increase in extremely high temperatures and a decrease in frost



risk in many areas. Frost-risk (low overnight minimum temperature) has already reduced at some sites in recent decades, although this does not mean that damaging frosts will not occur (see Holz et al., 2010 for Tasmania).

What are the impacts of increases in mean temperature?

Air temperature is a key driver of many biological processes.

Species can respond to increasing temperature in three main ways:

1. phenotypic plasticity (such as changes in the size, shape or colour of bodies, leaves, etc.) and genotypic adaptation may minimise the negative effects of non-optimal temperatures;
2. species may shift their geographic range, to move out of unfavourable climates and into favourable ones;
3. they may become locally extinct, which may lead to global extinction if insufficient suitable habitat remains.

All of these processes have significant implications for biodiversity, from changes to key ecological traits such as body size, colouration and behaviour, to changes in species abundance and richness and community composition.

What are the impacts of changes in minimum and maximum temperature?

Many responses to climate change will occur due to changes in the variability, seasonality or extremes of temperature, rather than changes to the mean temperature.

Decreased Snow Cover

Increasing minimum temperatures will result in decreased snow cover. Studies on the impacts of climate change on snow cover by Hennessy et al. (2003, 2008) and Bhend et al. (2012) report that snow cover in Australia's mainland alpine region has been declining and will continue to decline under projected climate change. By 2030, average snow season length is

projected to be 5 days shorter under a low emissions scenario, and between 30 and 40 shorter under a high emissions scenario. This will cause a general loss of alpine habitat, changes in the distribution of alpine and subalpine species and communities, and extinctions of snow-dependant species (Maunsell Australia, 2008).

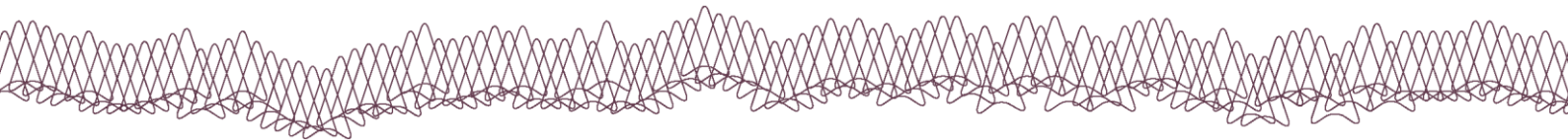
It will also have important implications for tourism, as skiing becomes less certain, and summer activities such as mountain biking increase. These changes will also have indirect effects on natural ecosystems.

Changing seasonality

The timing of periodic phenomena such as emergence, flowering or migration (known as phenology) is strongly determined by minimum and maximum temperatures. Changes to phenology could be one of the most important impacts of climate change on biodiversity, because periodic life cycle events are important determinants of species interactions, species distributions and the structure and function of all ecosystems (Root et al., 2003; Cleland et al., 2007).

Many studies have demonstrated shifts in spring phenology and growing season around the world (Parmesan, 2006), with the season starting earlier under warming temperatures. This can lead to mismatches between predator-prey and plant-insect interactions when dependent species rely on weakly correlated or unrelated seasonal cues or respond differently to the same cues (Berg et al., 2010).

Increasing minimum and maximum temperatures also have important implications for agriculture. Many temperate fruit trees such as apples, pears and cherries, and berry crops and nuts require low temperatures to break dormancy and hasten plant development and flowering. Changes to crops may become necessary in the future to match the optimal temperatures required. Increasing maximum temperatures in areas of South-eastern Australia are likely to result in increases in biological productivity and longer growing seasons (e.g. Holz et al., 2010). This may open opportunities to expand into new crops previously not able to be grown in the region. On the other hand, it also increases the likelihood of new insect pests and weeds emerging under future conditions (IPCC, 2014b).



What are the impacts of increases in the number of very hot days and heat waves?

Increased frequency of high temperature days and heat waves have substantial impacts on health and infrastructure (Steffen and Hughes, 2013) and natural ecosystems, particularly in regions not adapted to dealing with extreme temperatures.

These impacts can affect natural resource management directly in a variety of ways, by:

4. Shortening windows of opportunity for controlled burning (Fox-Hughes et al., 2014)
5. Increasing fire risks associated with machinery use (e.g. slashers)
6. Increasing heat stress and other heat related morbidity associated with outdoor work
7. Increasing demand for irrigation and stock water
8. Causing high mortality events in terrestrial and marine ecosystems, especially when heat waves coincide with drought conditions (for example, flying foxes at temperatures above 42 °C) (Welbergen et al., 2008)
9. Undermining the crucial role that insects and pathogens play in structuring plant communities and in maintaining diversity (Bagchi et al., 2014).

A key aspect of successful restoration projects is the sourcing of propagation material suited to the environmental and biotic conditions of the proposed planting site. Hancock and Hughes (2014) used open top chambers to simulate the projected summer heatwave temperatures for 2050 in Western Sydney, comparing the establishment success of *Eucalyptus tereticornis* and *Themeda australis*. No evidence of local superiority was found for survival or growth on non-reproductive tissues of either species. In fact, local provenance plants of *E. tereticornis* suffered significantly greater herbivory in the ambient temperature treatment than one non-local provenance.

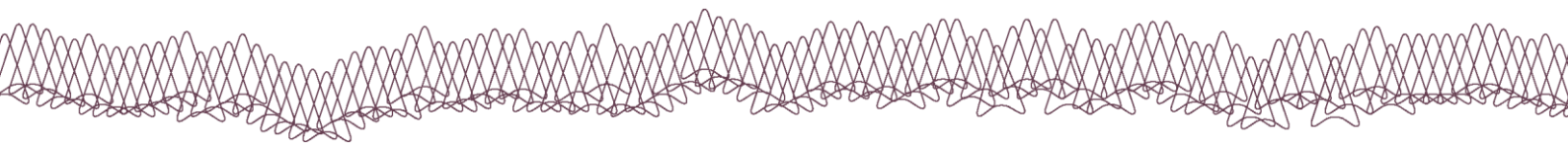
C.2.2 Rainfall

There is substantially lower confidence in projections of rainfall trends than there is for changes in temperature out to 2100. Natural variability is likely to stay the dominant influence on rainfall for the next few decades, but the emerging climate change influence will increase over time.

Projected changes to rainfall differ seasonally and in different regions. Rainfall decreases are projected in winter and spring in much of southeast Australia, with some regional exceptions. Under moderate or high emissions scenarios, spring rainfall is projected to decrease throughout Southern Slopes (-25 to 5% by 2090 under RCP4.5, -45 to +5% under RCP8.5), and winter rainfall is projected to decrease in Victoria but show little change or increase in Tasmania. Rainfall is projected to decrease in summer in western Tasmania, but increase or decrease elsewhere. Models project little change for autumn rainfall, however recent trends and limitations of modelling suggest that significant decreases are also possible in this season (Grose et al., 2015). Also see Climate Projections for Australia website: <http://www.climatechangeinaustralia.gov.au>.

As with temperature, changes to extreme rainfall events will be important. The intensity of heavy rainfall events is projected to increase in every season in all Southern Slopes regions, even those where mean rainfall is projected to decrease. A general increase in heavy rainfall is expected in a warmer climate; however, this effect can be counteracted by changes to weather systems that bring rainfall.

Since most of the streamflow in the southern parts of the region occurs in winter, areas projected to experience decreased winter rainfall (i.e. most of the south-eastern Australian region, but not Tasmania) may have a significant reduction in winter and therefore annual streamflow. Nevertheless, there is considerable uncertainty in the future climate projections. The modelled changes in long-term mean annual streamflow for 2030 in the southern Murray Darling Basin and Victoria ranges from -30% to +10% (with an average decline of -10%) for a 0.9 °C global warming (CSIRO, 2010).



What are the impacts of changes to rainfall and runoff?

There are numerous NRM impacts associated with changes in rainfall, which depend on the timing and extent of the rainfall, as well as interactions with other climate variables and factors affecting management. These include impacts to freshwater and terrestrial systems, and agriculture.

Heavier rainfalls interspersed by longer dry periods will affect water runoff and river flows. Changes to mean runoff follow the same direction as changes in rainfall, but changes are generally magnified. So, for example, a small increase in winter rainfall in a region would lead to a proportionally larger increase in runoff following the rainfall event.

Decreases in rainfall combined with increased evaporation rates are projected to lead to reduced soil moisture and less water in rivers and dams. This has implications for water planning and management. For example, the traditional 'filling season' for water-supply systems across most of south-eastern Australia may no longer occur in May through to November. Instead, dams (and soil moisture reserves) may depend on spring and summer rainfall events (CSIRO, 2012). However, in many regions spring rainfall is also projected to decrease, placing limits on the potential for replenishment.

Longer dry periods will place additional stress on plant and animal communities. This has implications for the success of revegetation programs, which often require planting of susceptible juveniles within a prescribed funding cycle, regardless of whether conditions are conducive to successful establishment.

Host stress due to waterlogging or drought modifies susceptibility to damage from a range of pests. For example, trees stressed by waterlogging are more susceptible to psyllid attack (Stone et al., 2010). In contrast, drought-stressed trees are less susceptible to this pest (Stone et al., 2010) but are more susceptible to stem borers (Pook and Forrester, 1984).

What are the impacts of increases in rainfall intensity?

"Intense rainfall events increase the risk of severe flooding with impacts for infrastructure, such as road washouts, and agriculture, such as damage to soil, crops and livestock." (Climate Commission, 2013, p. 1)

With higher peak flow regimes stream banks will change as will the extent of flooding with peak events. There is regional uncertainty about changes in average recurrence intervals of these events.

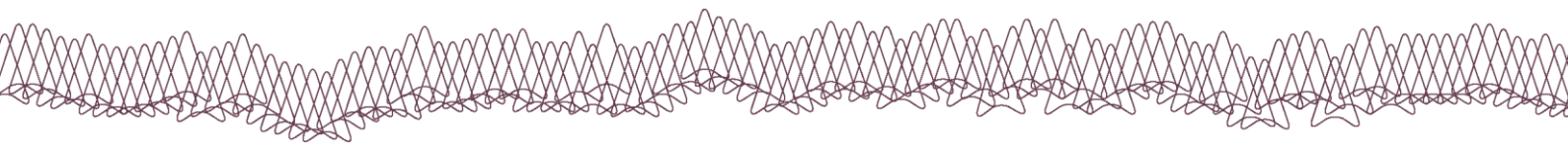
Because intense rainfall events will be increasingly likely to follow longer periods without rain (with higher temperatures and evaporation) they are likely to result in higher rates of soil erosion. Changes in groundcover management will become more important to mitigate against soil loss and associated loss of agricultural productivity, increased nutrient load and sedimentation of rivers, estuaries and dams.

C.2.3 Changes to Sea level

The climate projections for the Southern Slopes regions indicate a very high confidence in ongoing sea-level rise (SLR) throughout the 21st century and beyond (Grose et al., 2015, p. 37). The range of likely SLR associated with the mid to high emissions scenarios (RCP4.5 and RCP8.5) is 0.27 to 0.66 and 0.39 to 0.89 metres, respectively. Coastal inundation maps for Tasmania are available online through the Land Information System Tasmania (LIST; <http://www.thelist.tas.gov.au/>). These maps are based on the sea level rise planning allowance that was developed to ensure that all planning for the State's coastal areas allow for a sea level rise of 0.2 metres by 2050 and 0.8 metres by 2100. Similar allowance levels have recently been updated for Victoria (Hunter, 2014).

What are the impacts of rising sea levels?

Detailed studies from across the southern slopes have begun to examine the potential impacts of SLR on the region, using both bathtub models of inundation and more sophisticated approaches which attempt to model erosion of extant coastal features and storm surge impacts.



For example, the Gippsland lakes, including Ninety Mile Beach and Corner Inlet, are among Australia's most vulnerable coastal areas (Department of Climate Change, 2009). The region is already vulnerable to flooding, but 27,600-44,500 residential buildings will be at risk of inundation with a 1.1m sea level rise (Steffen and Hughes, 2013).

"The threats to the Gippsland coast are real, and are significant. The best scientific predictions are indicating that within 50 years parts of the Gippsland coast will be inundated to an extent requiring protection or relocation of assets, including dwellings and commercial buildings. Decisions need to be made now about how to deal with this situation." (Gippsland Coastal Board, 2008, p. 4)

Tasmania is similarly vulnerable to the effects of gradual sea level rise and storm surge. It has almost 6,400 kilometres of coastline, covering many significant coastal ecosystems, and most of the State's population centres and major industries are located within one kilometre of the coast.

C.2.4 Atmospheric CO₂

Global emissions of carbon dioxide (CO₂) reached a new record of 36 billion tonnes of CO₂ in 2013. This is projected to increase by a further 2.5% in 2014, bringing the total CO₂ emissions from all sources to more than 40 billion tonnes. This is 65% greater than they were in 1990, and the highest level in at least 800,000 years (Le Quéré et al., 2014).

What are the impacts of rising CO₂ concentrations?

The direct impacts of increasing atmospheric CO₂ on natural systems are relatively unknown compared to responses to changing temperature and rainfall. Significant investment in research is required before anything more than broad generalisations can be made about responses to CO₂.

There are two important and direct consequence of increasing atmospheric CO₂. Firstly, rising CO₂ decreases transpiration and increases intrinsic water use efficiency, thereby affecting plant water use efficiency and growth rates. In general, it is expected that global

warming will increase the dominance of C4 plants, which have higher water efficiency, greater drought tolerance, and greater persistence in warmer climates than C3 species. However, the effect of elevated CO₂ and competitive interactions between C4 and C3 plants under different nutrient conditions and seasonality are not well understood.

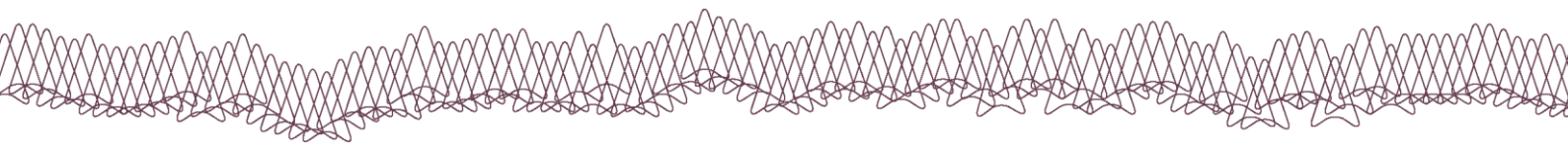
Different plant responses suggests that competition between species may shift, changing both the structure and function of plant communities. Changes to the structure of ecosystems such as grasslands may also occur. Existing scrub communities may become more widespread in response to increased atmospheric carbon dioxide (Bond and Midgley, 2012). This phenomenon of increased woody plant abundance, known as "woody thickening", has been well documented in recent decades.

The second direct consequence of increasing atmospheric CO₂ is ocean acidification (see <http://www.acecrc.org.au/Research/Ocean%20Acidification>), which has important implications for marine ecosystems, species and food chains.

Rising atmospheric CO₂ concentration has been shown to have an indirect influence the abundance of some insects and foliar pathogens. While there is some evidence of direct leaf chewer responses to elevated CO₂ (Stiling et al., 2010), it is mainly the effects on the host that are transmitted to the insect. Herbivores that feed on phloem do however show increased development and reproduction in response to elevated CO₂ (Whittaker, 2001). Elevated CO₂ is known to stimulate fungal pathogen growth rates, aggressiveness and fecundity (Gautam et al., 2013).

C.2.5 Other variables

There are several other climate variables that generally receive less attention in terms of their impacts on natural systems. Partly this is because of the difficulties in modelling these variables and the lower confidence in the values of the projected changes, and partly because the majority of ecological studies have concentrated on the impacts of temperature and rainfall. Nevertheless, variables such as wind, relative humidity and solar radiation do have important effects



on all systems, and the changes projected to occur may have consequences for natural resource management.

C.2.6 Wind

Projections indicate little change in annual average wind speed for the southern slopes but higher wind speeds during the cooler months/season (July to October) and lower wind speeds during the warmer months/season (November to May) (Grose et al., 2010). Tasmania is expected to experience an increased magnitude of severe winds (CSIRO, 2007), with increases in the extremes (peak wind gusts) greater than the mean increase. The projections for Tasmania suggest an increase of more than 15% in the winter, spring and summer seasons by 2070 (Cechet et al., 2012).

C.2.7 Solar radiation

The NRM Climate Projections for Australia indicate little change up to 2030 for solar radiation, but as the century progresses increases in winter and spring radiation of up to 10% are plausible. Little change in radiation due to changes in cloud cover is projected for other seasons (Grose et al., 2015). Over the 21st Century, Climate Futures Tasmania modelling indicates an east west gradient in changes in solar radiation across the state during autumn and summer, with the east coast being generally cloudier and the west coast less cloudy during these seasons (Holz et al., 2010).

C.2.8 Relative humidity

Decreases in relative humidity are projected for the Southern Slopes across all seasons. However, projected changes are generally small, except for a high emissions scenario by the end of the century in winter and spring where changes of up to -5% are projected. There is a tendency for decreases in humidity to coincide with areas of rainfall decline, leading to exacerbation of water availability through lower moisture inputs and higher rates of evapotranspiration.

What are the impacts of changes to these variables?

Wind, relative humidity and solar radiation are all important drivers of evapotranspiration and therefore changes have the potential to lead to agricultural and ecological impacts.

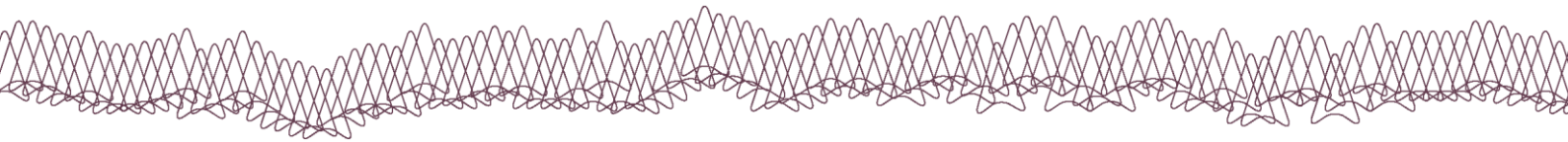
Increases in wind will increase evaporation and relative humidity at a local scale. Wind also plays an important role in fire weather, as well as influencing fire behaviour and spread, and our ability to suppress bushfires. Similarly, reduced relative humidity contributes to increased evaporation, fuel drying and fire danger (see C.2.11 Bushfire danger).

Increases to the strength and frequency of extreme winds are of concern with regard to planning, building standards, agriculture, water resources and emergency services (Cechet et al., 2012).

C.2.9 Evapotranspiration

Evapotranspiration is a result of complex interactions between multiple meteorological variables, including temperature, wind, solar radiation and relative humidity. Carbon dioxide levels also affect evapotranspiration through its influence on plant stomatal conductance (IPCC, 2014c). Increases in evaporation are projected to occur across all seasons for the southern slopes, especially from mid-century onwards (Grose et al., 2015). The percentage change in rates of evapotranspiration tends to be highest in winter and spring, however because evapotranspiration is much higher in summer across the southern slopes, this period has the largest total increase in rates of evapotranspiration. CFT projections, using the A2 emissions scenario, indicate that annual evapotranspiration might increase by around 40mm by the end of the century (based on 1961-1990 climatology) (Holz et al., 2010, p. 23).

Importantly, although Grose et al. (2015, p. 34) have high confidence that increases in evapotranspiration will occur, there is only medium confidence about the size of this increase over time. Evapotranspiration is expected to increase with increases in temperature; however changes to other variables can counteract this general tendency. In fact, recent trends in



evapotranspiration at many locations have been negative in recent decades despite the increase in temperature, which has been attributed to decreases in wind and increases in cloud cover (Donohue et al., 2010).

What are the impacts of changing evapotranspiration?

Changes to evapotranspiration affect soil moisture levels, water use efficiency by plants, biomass production and crop yields. This has substantial implications for the amount of irrigation required for agriculture, plant stress under higher temperatures and drought response, and potentially, plant-herbivore interactions.

C.2.10 Regional climate velocity

Climate velocity refers to the rate of change in climate variables across a landscape (Loarie et al. 2009). It is used to indicate how fast, and in what direction, an organism would have to move to maintain the same climatic conditions it currently lives in. Climate velocity is determined by the rate of change experienced in the region and the topography. For example, in mountainous areas climate velocity for temperature is low because the change in temperature over short distances is large. In contrast, in a flat landscape climate velocity for temperature is high, because an organism will need to move greater distances to track similar conditions as the climate changes. The average maximum speed of movement of a range of organisms (trees, plants, mammals, insects and freshwater molluscs) in relation to climate velocity under different emissions scenarios is shown for large flat regions of the world in Figure SPM.5, pg. 15, of the Summary for Policy Makers, Working Group 11 (IPCC 2014). Climate velocity based only on changes to temperature is likely to be lower than velocity based on both temperature and rainfall, because the interactions between variables increases the rate of change in climate (Dobrowski et al., 2013).

What are the impacts of different regional climate velocities

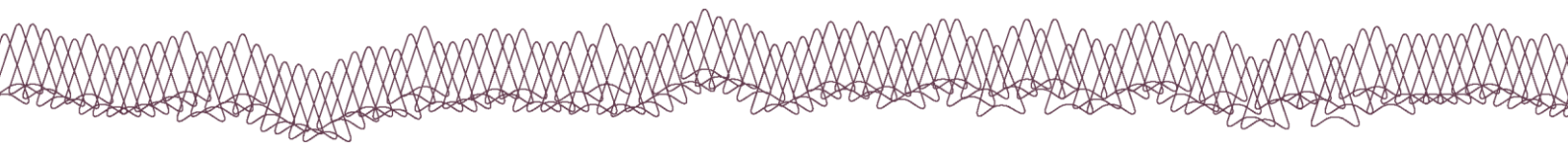
In general, species are expected to move poleward, towards higher latitudes, and up-slope, towards higher altitudes, in response to the increasing temperatures that have been observed in Australia, and globally, since the 1950's. However, interactions between changing temperature, rainfall and other important factors such as land use, and regionally variable climate velocity, can result in more complex range shifts that do not follow this pattern, and may differ between species (VanDerWal et al., 2013).

C.2.11 Bushfire danger

"Both weather and climate influence fire danger. Average conditions of temperature, rainfall, evaporation and radiation affect fuel growth and drying, whereas extremes of temperature, wind and relative humidity drive fire weather and fire ignition potential." (Fox-Hughes et al. 2014, pg. 1). All of these conditions are projected to change in the future.

South-eastern Australia is "one of the three most fire-prone areas in the world" (Hennessy et al., 2005, pg.11). Fire danger has increased over recent decades (Clarke et al., 2013), and is projected to increase further with climate change. According to the Victorian Government:

"The warmer, drier weather for Victoria expected as a result of climate change is likely to increase the frequency and intensity of bushfires. Fire-weather risk measures how a combination of weather variables influence the risk of a fire starting, its rate of spread, its intensity and the difficulty in suppressing it. Relative to the climate of 1974 to 2003, by 2020 it is expected the number of 'extreme' fire danger days will generally increase by between 5% and 40%. By 2050, under a lower emissions growth scenario, the number of 'extreme' fire days is likely to increase by between 15% and 25%, while under a higher emissions growth scenario, the number of days is likely to increase by between 120% and 230%." (DSE, 2008, p. 14)



Recent research in Tasmania also indicates a steady increase in fire danger, especially in spring; a lengthening of the fire season; and more days at the highest range of fire danger (Fox-Hughes et al., 2014). These findings correspond with the 2013 Climate Council Report on bushfires and climate change in Australia (Hughes and Steffen, 2013).

What are the impacts of changing bushfire conditions?

The 2013 Climate Council Report on bushfires and climate change in Australia (Hughes and Steffen, 2013) presents some economic and social impacts including costs of agricultural impacts of increasing by 50% to about \$148 million per annum by 2050, and the need to double the standing professional firefighting service over the same period. These marked changes associated with more frequent and intense fires are likely to have secondary and tertiary impacts, for example on mental health and planning regimes, as well as direct impacts on agricultural productivity, rural economies and biodiversity.

Changes to the fire regime, such as increasing fire frequency or changing seasonality, may cause shifts in the floristic composition of vegetation communities. Fire sensitive species, for example obligate seeders with long maturation times, will be disadvantaged, while fire tolerant species, such as resprouters or plants with fire-adapted seeds, will increase. This is likely to lead to changes to the structure of affected ecosystems, and in some forests may lead to a positive feedback where flammability is further increased.

Many temperate ecosystems are highly flammable, restricted in areas and contain species that are not well-adapted to survive fire. In Tasmania, iconic tree species such as the Huon pine, King Billy pine and the deciduous beech are particularly vulnerable to increasing fire frequency and intensity.

C.3 Effects on NRM Assets

C.3.1 Terrestrial Biodiversity

What is terrestrial biodiversity?

The term biodiversity (from biological diversity) refers to the variation in genes, functional traits, species and ecosystems in a region. It includes the variety of life represented by all plants, animals, protists and fungi.

Terrestrial biodiversity encompasses all biota which contribute to ecological processes and functioning in terrestrial environments, riparian systems and wetlands.

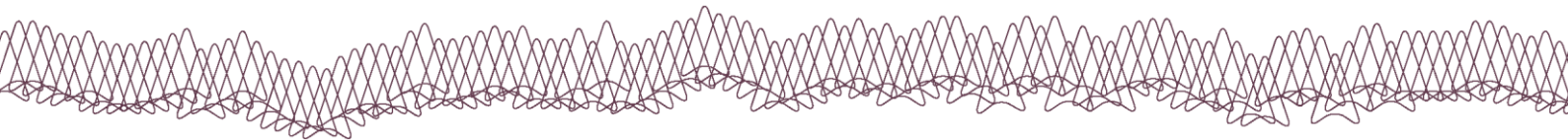
“There is now unequivocal evidence that biodiversity loss reduces the efficiency by which ecological communities capture biologically essential resources, produce biomass, decompose and recycle biologically essential nutrients..... There is mounting evidence that biodiversity increases the stability of ecosystem functions through time” (Cardinale et al., 2012, pg. 60).

The following citations are a small selection of works recommended by colleagues who are active researchers in the field of terrestrial biodiversity.

Overview of studies on climate change impacts on terrestrial biodiversity

NCCARF Terrestrial Biodiversity Network (2013) Terrestrial Report Card 2013: Climate change impacts and adaptation on Australian Biodiversity, National Climate Change Adaptation Research Facility, Gold Coast.

The Report Card provides a useful overview of research relating to climate change impacts on a broad range of terrestrial natural assets. It documents general climate and physical changes, as well as impacts on mammals, birds, reptiles, amphibians, invertebrates, freshwater fish, freshwater invertebrates and plants. The Report Card also argues that identified climate change impacts are likely to be exacerbated by acting synergistically with other threats to biodiversity such as habitat loss and land-use change, introduced species and diseases, and altered water resources. It highlights habitat loss



and land-use change; water extraction and pollutants; and introduced species, pests and diseases as just three examples.

An assessment of the vulnerability of Australia's biodiversity to climate change

Steffen, W., Burbridge, A., Hughes, L., Kitching, R., Lindenmayer, D., Musgrave, W., Stafford Smith, M. and Werner, P. (2009) Australia's biodiversity and climate change: a strategic assessment of the vulnerability of Australia's biodiversity to climate change.

This national assessment focuses on terrestrial biodiversity, and aims to inform policy and management. It outlines five things we must do to respond to the threat to biodiversity from climate change: (i) reform biodiversity management objectives *"We need to adapt the way we manage biodiversity to meet existing and new threats – some existing policy and management tools remain effective, others need a major rethink, and new approaches need to be developed in order to enhance the resilience of our ecosystems"* (pg. 2); (ii) strengthen the national commitment to conserving biodiversity; (iii) invest resources to support the environment; (iv) build innovative and flexible policy and legislative frameworks and reform governance structures; and (v) mitigate greenhouse gas emissions, because the ability of species and ecosystems to adapt is limited.

Climate change impacts on riparian ecosystems and their role in adaptation

Capon, S.J., Chambers, L.E., Mac Nally, R., Naiman, R.J., Davies, P., Marshall, N., Pittock, J., Reid, M., Capon, T., Douglas, M., Catford, J., Baldwin, D.S., Stewardson, M., Roberts, J., Parsons, M. and Williams, S.E. (2013) Riparian Ecosystems in the 21st Century: Hotspots for Climate Change Adaptation? Ecosystems 16, 359–381.

This recent paper considers the impacts of climate change on the vulnerability of riparian ecosystems (understood as semi-terrestrial areas influenced by freshwater close to water bodies), and also the potential for them to act as 'adaptation hotspots' with appropriate management. They contend that "in the absence of adaptation, riparian ecosystems are likely to

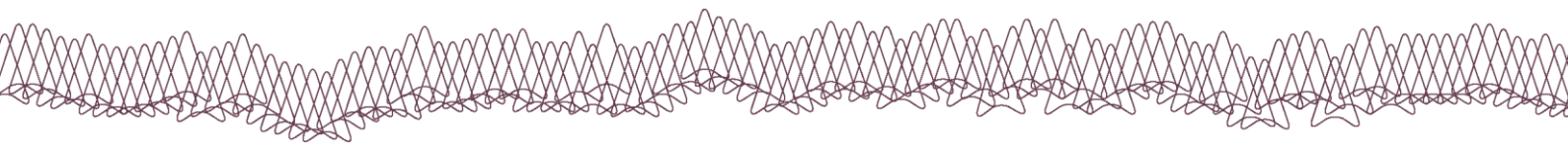
be highly vulnerable to climate change impacts". The article cites a large number of sources in relation to the exposure, sensitivity and adaptive capacity of riparian ecosystems, and proposes a suite of adaptation measures.

How will climate change impact on flora and fauna species?

Because the rate of climate change is likely to outpace the ability of most species to adapt, changes to the distribution of fauna and flora are expected to be a major response to climate change. Fauna which are sensitive to climatic conditions, particularly temperature, are generally expected to move pole-ward, towards higher latitudes, and up-slope, to higher altitudes, in response to increasing temperatures. Parmesan and Yohe (2003) found that species, on average, were moving pole-ward at a rate of 6.1 km per decade. For pests and pathogens, Bebbert et al. (2013) demonstrate a substantial average pole-ward shift of three (2.7 ± 0.8) kilometres per year since 1960, in observations of hundreds of different species.

In south-eastern Australia, latitudinal shifts are obviously limited by the lack of landmasses beyond Tasmania, but mobile species may find refuge from increasing temperatures by shifting to higher, cooler elevations or cooler, south-facing slopes. However movement to higher elevations will only be possible where rainfall, soils and topography are suitable for the species, and where habitat remains unfragmented. Species already restricted to high altitudes without the option of upslope migration are expected to become extinct unless they are able to adapt to the changing climatic conditions.

Species-specific responses are also likely to occur, due to complex interactions between changes in rainfall and temperature and the different thermal thresholds of different species. Some species will be more vulnerable than others to extinction. Species may not be able to shift to areas with suitable climatic conditions where they are located in fragmented habitats, or because of their limited dispersal ability. Species with small, isolated or fragmented ranges, or those with low genetic variation and specific thermal requirements, will be more vulnerable and local extinctions are likely.



Many species currently listed as threatened will therefore be most vulnerable to extinction.

Changes in life cycle events (phenology), such as flowering, emergence, breeding and migration, have been identified as one of the most important impacts of climate change on biodiversity. Periodic life cycle events are important determinants of species distributions, species interactions and the structure and function of all ecosystems. Chambers et al. (2013, np) estimated that the rate of change in phenology in Australia will mean that events occur about four days earlier per decade (4.2 ± 0.6 days). However, due to a lack of long-term phenological monitoring in Australia, the authors concluded that “our predictive capacity (to know) how phenology might change over time and in response to climate drivers for a huge range of taxa will essentially be guesswork for many years to come” (Chambers et al., 2013, p. np).

Allen et al. (2010) looked at the effects of drought and heat stress on tree mortality globally. Their review highlighted the potential for greater tree mortality under climate change, where drought and temperature increases were projected to occur. They also examined some of the interactions with other drivers of tree mortality, such as insect attack and fire, as well as the associated loss of sequestered carbon. Horner et al. (2009, 2010) looked at the mortality of trees in floodplain forests (river red gum) resulting from a drying climate and found that high-density stands were most affected. They found that thinning stands as a management intervention led to greater habitat quality and carbon sequestration rates. Bowman et al. (2014) reviewed the potential for increased fire frequency to substantially change floristic composition. Their case study of fires in the Australian Alps demonstrated how obligate seeders could quickly be eliminated from the landscape where fire occurs early in the regeneration of new stands. Keith et al. (2012) detailed various ways that climate variability and particularly drought conditions could affect synchronisation of lifecycles of insects, parasites and predators. These results suggest that increasing frequency of drought may change the floristic composition in forests as well as their potential for carbon sequestration through a variety of indirect mechanisms.

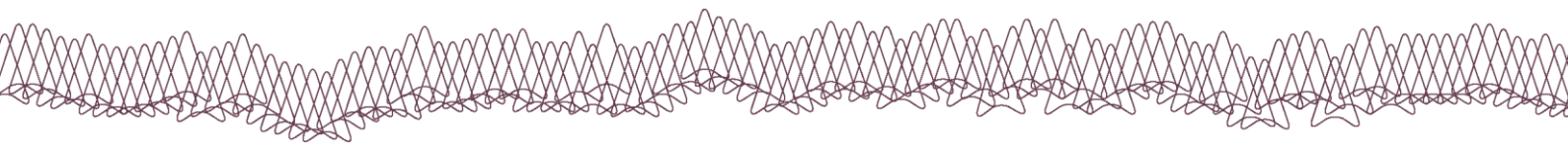
The impact of extreme events has the potential to affect the behaviour, and demography of populations of both fauna and flora. There is evidence that large-scale deaths of birds (McKechnie and Wolf, 2010) and flying foxes (Welbergen et al., 2008) can result from extreme heat waves.

How will climate change impact on native vegetation communities?

As the climate becomes less suitable for extant vegetation communities, it is likely that there will be a gradual change in the species composition and dominance as some species are replaced by others, leading to a shift in the floristics and structure of the community. While a lag could be expected between the climate shifting and the community response, some changes may occur earlier in response to the increased occurrence of extreme events such as droughts. Increased invasion by both native and non-native species can be expected. Tropical invasive species are expected to expand their ranges, while cool-climate invasive species are more likely to contract (Kitching et al., 2013).

Some vegetation communities will be more vulnerable than others to the direct impacts of climate change. Alpine communities, for example, are likely to be particularly vulnerable to increasing temperatures (Maunsell Australia, 2008), while grasslands may be affected by elevated carbon dioxide and changes to soil moisture, and wetlands may be affected by rising sea levels.

Attempting to maintain the status quo by conserving the current structure and composition of communities may therefore not be a viable management option in the long term. Management could focus on maximising the resilience of communities and maintaining ecosystem function. This approach fits well within a risk management framework because there will always be uncertainty associated with projections of future climate (Harris et al., 2014). Current condition is likely to be important for the long-term viability of a community, with those in better condition more resilient to change in the short term, and more adaptable in the long term, due to their greater genetic, floristic and structural diversity (Tilman et al., 2006).



When restoration is carried out, there has been a shift in focus from replacing local species to planting species or ecotypes expected to be more tolerant of new conditions (Bagne et al., 2011; Byrne et al., 2013). These species may also be more tolerant of pests (Hancock and Hughes, 2014).

The effects of elevated CO₂ are not well understood, but there is enough information available to know it will have widespread impacts on terrestrial biodiversity (Hovenden and Williams, 2010). Because of its importance in photosynthesis, elevated CO₂ has the potential to affect plant growth rates, their nutritional value, rates of herbivory, and water use efficiency.

Different plant species vary in their responsiveness to increasing CO₂. For example, the response of flowering plants, broad leaved plants, grasses, and conifers is different. A greater difference occurs between C3 and C4 plants, which have different photosynthetic pathways. A C4 grass such as *Themeda triandra* will have higher water efficiency, greater drought tolerance, and greater persistence in warmer climates than C3 species, such as *Poa labillardierei* (Edwards and Smith, 2010). In general, it is expected that global warming will increase the dominance of C4 grasses (Howden et al., 2008), although plant growth with CO₂ enrichment has been shown to be greater in C3 than C4 species (Wand et al., 1999). Different plant responses suggests that competition between species may shift, changing both the structure and function of plant communities.

Elevated CO₂ could mitigate some of the negative effects of hotter, drier conditions, because elevated CO₂ improves water use efficiency in many plant species by reducing stomatal conductance. This mechanism has been linked to an observed increase in woody vegetation (woody thickening) across Australia (Macinnis-Ng et al., 2011).

How will climate change impact on the major vegetation groups found in the Southern Slopes region?

There are 17 IBRA bioregions, 32 sub-regions and 26 of 32 Major Vegetation Groups (MVGs) in the Southern Slopes Cluster region. A report by House et al. (2012) describes the status of sclerophyll forests in south

eastern Australia and explores the potential impacts of climate change. Representing the MVGs 1 'Rainforests and Vine Thickets', 2 'tall open eucalypt forests', 3 'open eucalypt forests' and 4 'eucalypt low open forests', the sclerophyll forest biome accounts for more than 60 per cent of MVGs in the Southern Slopes region. According to the report, the environmental factors that drive the distribution of these forests include terrain, soils, fire and climate (House et al., 2012, p. 4).

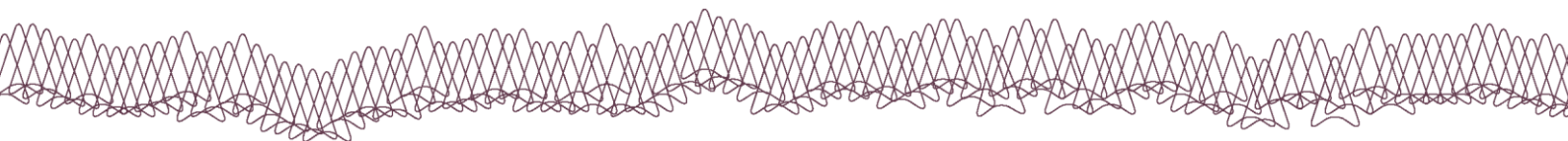
MVG 5 "Eucalypt Woodlands" are dominant although these are highly degraded and fragmented in the landscape. These eucalypt woodlands include sub-group MVS 9 "Eucalypt woodlands with a grassy understory", which are examined in detail in a report by Prober et al. (2012) on the status and climate change impacts on temperate grassy woodlands. They found that the climatic variable with the strongest influence on the distribution of this vegetation community type was moisture (Prober et al., 2012, p. 22), and that this could result in a decline in tree cover (p.31) as well as decreasing perennials and increasing annuals (p.33). The capacity of these grassland and grassy woodland ecosystems to adapt to climate change is limited by their degradation and fragmentation.

Recent work in Tasmania investigated the potential consequences of changing climatic suitability for several vegetation communities (Harris et al., 2015). Results suggest strong contractions can be expected to occur in the future in several grassland communities (Lowland *Themeda* Grassland community (GTL) and the Lowland *Poa* Grassland community (GPL), and the total loss of any suitable climate for alpine communities (e.g. the Highland *Poa* Grassland community (GPH)).

C.3.2 Freshwater Systems

What are freshwater systems?

Freshwater systems include wetlands, rivers, creeks, lakes, billabongs, ponds, pools and inland salt lakes. Coastal wetlands are included in the coasts section. Plants and animals in freshwater systems are adapted to water with low salt content.



The following citations are a small selection of works recommended by colleagues who are active researchers in the field of freshwater systems.

Projected effects of climate change on freshwater biodiversity

Bates, B., Bunn, S., Baker, P., Cox, M., Hopkins, A., Humphreys, B., Lakes, S., Willgoose, G. & Young, B. (2011) National Climate Change Adaptation Research Plan for Freshwater Biodiversity. pp. 64pp. National Climate Change Adaptation Research Facility, Gold Coast.

The National Climate Change Adaptation Research Plan for Freshwater Biodiversity identifies:

- “i) important gaps in the information, knowledge and tools needed to support effective climate change adaptation for freshwater biodiversity;*
- ii) adaptation research priorities based on these gaps, and*
- iii) capacity that can be harnessed, or needs to be developed, to carry out priority adaptation research.” (Bates et al. 2011, pg. 10)*

The focus of the report is on developing climate adaptation research priorities for freshwater ecosystems, rather than providing an overview of climate change impacts and vulnerability.

Projected effects of climate change on water resources

Chiew, F.H.S., Teng, J., Vaze, J., Post, D.A., Perraud, J.M., Kirono, D.G.C., Viney, N.R. (2009) Estimating climate change impact on runoff across southeast Australia: Method, results, and implications of the modeling method. Water Resources Research 45, W10414.

Most of the direct impacts of climate change on freshwater systems in southern Victoria are predicted to come from a decline in rainfall leading to a decrease in runoff. Chiew et al., (2009) modelled the Southeast Coast drainage division (including the area covered by the five coastal CMAs in Victoria) and found strong agreement across 15 climate models that runoff would decrease.

Climate change impacts on wetlands in Victoria

DSE (2013) Indicative Assessment of Climate Change Vulnerability for Wetlands in Victoria. Department of Sustainability and Environment, East Melbourne, Victoria.

This report, prepared by SKM and commissioned by the Department of Sustainability and Environment (DSE), assesses the vulnerability of wetlands in Victoria. They consider a very dry climate change scenario (continuation of 1997-2007 inflows) and a dry climate scenario (a relatively wetter medium scenario), as well as the effects of sea level rise. The main impact of climate change highlighted is “a reduction in the frequency and duration of inundation events and an increase in the duration of dry periods”, which is consistent with projected climate change for Victoria. They make recommendations for management actions, including using selected wetlands as sites for monitoring climate change impacts.

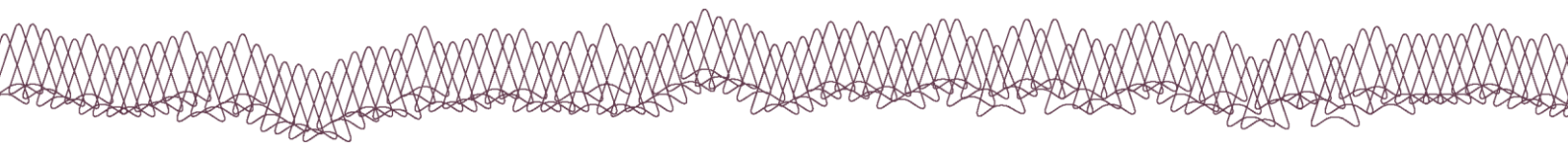
Impacts of drought on freshwater systems in south-eastern Australia

Bond, N.R., Lake, P.S. and Arthington, A.H. (2008) The impacts of drought on freshwater ecosystems: an Australian perspective. Hydrobiologia 600, 3–16.

This well-cited journal article provides a useful overview of the responses of freshwater systems to drought, in both standing and flowing waters. It puts into context the difference between the ability of freshwater systems to cope with natural hydrological variability and the effects of drought. The authors suggest a range of management principles for freshwater systems in drought, including refuge habitats, environmental flows and species/population conservation. They conclude with an assessment of the knowledge gaps (as of 2008) relating to impacts of droughts on freshwater systems.

Climate change impact on groundwater resources in Australia

Barron, O.V., Crosbie, R.S., Charles, S.P., Dawes, W.R., Ali, R., Evans, W.R., Cresswell, R., Pollock, D., Hodgson, D., Currie, D., Mpelasoka, F., Pickett, T., Aryal, S., Donn, M., Wurcker, B., (2011) Climate change impact on groundwater resources in Australia. National Water Commission, Canberra.



This report investigates the impact of climate change on groundwater resources, providing an Australia-wide snapshot quantifying the impacts of climate change on groundwater resources for representative aquifer systems around Australia.

What are the projected impacts of climate change on rainfall and runoff?

The impacts of climate change on rainfall and runoff is regionally specific, with annual rainfall decreasing in southern Australia, and increasing in some areas of Tasmania. More detail is given in [C.2 Climate change drivers and impacts](#). Changes to the seasonality of rainfall are projected to occur, which will have important consequences for runoff, river flows, and freshwater biodiversity.

The influence of climate on surface and groundwater availability is fundamentally important to freshwater systems. It determines the distribution and abundance of freshwater species, the distribution and structure of vegetation, and the rates of most ecosystem processes (Kernan et al., 2011). There is evidence in the Northern Hemisphere of biophysical effects of climate change, including increases in thermal regimes in lakes, decreases in ice cover of lakes, and increased dissolved organic carbon levels in lakes and streams (Bates et al., 2011). Attributing change is more difficult in Australia, where there are very few long-term monitoring datasets, but there are indications that changes to freshwater biodiversity are occurring (Steffen et al., 2009).

What are the impacts on rivers and creeks?

Freshwater biodiversity will be affected by climate change directly, through the effects of increasing temperature and CO₂ and changes to the frequency and intensity of rainfall, and indirectly, through impacts on ecosystem processes such as fire and species interactions. Freshwater biodiversity will also be affected by secondary impacts, such as water extraction in response to drought.

Higher air temperatures are associated with increased river temperatures, leading to eutrophication, with potential negative effects on water quality affecting

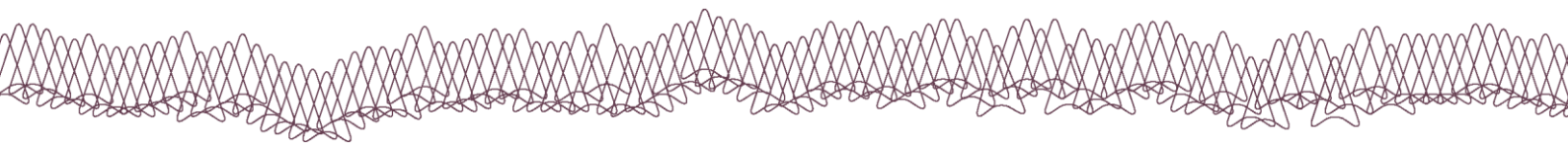
human health and ecosystems. Higher intensity rainfall events will lead to greater turbidity as erosion and deposition in river channels increase and sediment loads increase, potentially with the introduction of pollutants and nutrients from nearby agricultural areas. Acidification in rivers and lakes is also expected to increase because of acidic atmospheric deposition. Where streamflow decreases due to reduced rainfall, salinity may increase in estuaries and inland reaches.

Climate change has the potential to affect phenology (the timing of life cycle events), physiology, respiration, growth and reproduction in freshwater organisms. As with terrestrial flora and fauna, the response of freshwater biodiversity to climate change is influenced by behaviour, dispersal ability, thermal requirements and flexibility. Many freshwater species are unable to disperse between isolated water bodies, so are less likely to be able to track changing climate conditions. The impact will not be evenly spread across all species, so shifts in community structure and species interactions are likely. Species with highly restricted distribution, and those that are currently at their physiological limits are most susceptible to change.

Chessman (2009) looked at the impacts of climate change (mainly increasing water temperatures and declining flows) on aquatic macroinvertebrate assemblages. The paper noted that not all of the decline in streamflow could be attributed to climate change (river regulation also played a role). Climate change impacts would seem to have affected macroinvertebrate species dependent on certain stream environments, “with families that favour colder waters and faster-flowing habitats more likely to have declined” (Chessman, 2009, p. 2791). The extent of fast-flowing habitats (e.g. riffles) would likely decrease in response to reduced flows, while deep, cold pools and cold groundwater-fed stream could be affected by reduced flows and groundwater extraction.

What are the impacts on wetlands?

Nielsen and Brock (2009) consider the impact pathways of climate change on wetlands. Clearly this will vary significantly depending on the type and location of wetlands. For example, a reduction in rainfall and runoff could cause some temporary wetlands to dry up.



A reduction in water inflow also causes an increase in the salinity of some wetlands, and changes in the types of vegetation communities they can support. While some wetland elements may recover from limited exposure to saline conditions, there is no evidence to suggest that they will survive prolonged salt exposure.

C.3.3 Coasts, coastal wetlands and estuaries

What do the coasts, coastal wetlands and estuaries include?

Coasts, coastal wetlands and estuaries are at the interface between marine and terrestrial environments. They include beaches, cliffs, intertidal zones, coastal wetlands (with a connection to the sea), marshes, mangroves, lagoons, coastal floodplain forests and the estuarine portion of waterways.

The following citations are a small selection of works recommended by colleagues who are active researchers in the field of coasts, coastal wetlands and estuaries.

The risks of climate change on the Australian coastline

Department of Climate Change (2009) Climate Change Risks to Australia's Coast: A First Pass National Assessment. Canberra: Australian Government.

The first national assessment of the risks of climate change for coastal settlements and ecosystems across Australia identifies national priorities for adaptation to reduce climate change risk in the coastal zone. The report explains current understanding of coastal inundation and erosion, identifies areas most susceptible to climate change, and discusses potential impacts on coastal habitats and biodiversity.

Coastal hazards in Victoria

DSE, (2012) Victorian coastal hazard guide. Department of Sustainability and Environment, Melbourne.

The Victorian Coastal Hazard Guide provides information on coastal hazards, the effect climate change may have on these hazards, and approaches

that may be used to manage the effects of these hazards. It states that "it will not resolve the risks to assets...it provides information that can be used to inform policies and practices". Sections 2 to 7 are useful for those who wish to improve their understanding of coastal hazards and how climate change will influence the coastal zone whereas Section 8 is for those who are seeking guidance on what to consider when assessing and responding to the risks posed by coastal hazards.

Vulnerability assessment of seawater intrusion at a national scale

Ivkovic, K.M., Marshall, S.M., Morgan, L.K., Werner, A.D., Carey, H., Cook, S., Sundaram, B., Norman, R., Wallace, L., Caruana, L., Dixon-Jain, P. and Simon, D., (2012) National-scale vulnerability assessment of seawater intrusion: summary report. National Water Commission, Canberra.

The National-Scale Vulnerability Assessment of Seawater Intrusion, (SWI) was prepared for the National Water Commission in collaboration with state and territory water agencies. The assessment aimed to identify Australia's coastal groundwater resources that are most vulnerable to SWI.

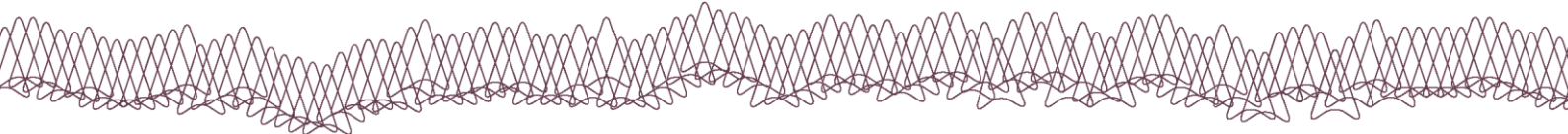
Planning and managing Victoria's coastal, estuarine and marine environments

Victorian Coastal Council, (2014) Victorian Coastal Strategy 2014.

The Victorian Coastal Strategy outlines the State Government's policy for the long-term management of the coast of Victoria. It aims to assist coastal, estuarine and marine agencies plan for sustainable management and development of coastal land and infrastructure, adapt to climate change, and engage the community. It also provides a framework for other policy instruments such as Coastal Action Plans, Regional Catchment Strategies and Management Plans.

Planning and managing Tasmania's coastal, estuarine and marine environments

Whitehead, J., (2011) Climate change mitigation - natural coastal assets: Derwent Estuary Program planning tool discussion paper for tidal wetlands & saltmarshes. Derwent Estuary Program, Tasmania.



Mount, R.E., Prahalad, V., Sharples, C., Tilden, J., Morrison, B., Lacey, M., Ellison, J., Helman, M. and Newton, J., (2010) *Circular Head Coastal Foreshore Habitats: Sea Level Rise Vulnerability Assessment: Final Project Report to Cradle Coast NRM. School of Geography and Environmental Studies, University of Tasmania, Hobart, Tasmania.*

Prahalad, V and, Pearson, J, (2013) *Southern Tasmanian Coastal Saltmarsh Futures: A Preliminary Strategic Assessment. NRM South, Hobart, Tasmania.*

This Derwent Estuary Program discussion paper covers many planning issues relating to coastal assets under threat from climate change. It covers a range of planning issues relevant to urban settlement, agricultural expansion and biodiversity conservation. While confined to the Derwent Estuary, many issues are relevant across all three Tasmanian NRM regions. Researchers at the University of Tasmania in conjunction with the three NRM regions have undertaken mapping of coastal habitats including condition assessments.

What are the potential impacts of climate change on coasts?

The current Victorian Planning Provisions (as of March 2015) states 'Plan for possible sea level rise of 0.8 metres by 2100, and allow for the combined effects of tides, storm surges, coastal processes and local conditions such as topography and geology when assessing risks and coastal impacts associated with climate change' (Clause 13.01-1).

Current IPCC (IPCC, 2014c, chap. 5) predictions indicate that if emissions continue to track at the top of IPCC scenarios, global average sea level could rise by nearly 1 m by 2100 (0.52–0.98 from a 1986–2005 baseline). If emissions track along the lowest scenario, then global mean sea level (GMSL) could rise by 0.28–0.60m by 2100 (from a 1986–2005 baseline). The IPCC also state that "with regional variations and local factors the local sea level rise can be higher than the projected for the GMSL" (IPCC, 2014c, p. 366).

Climate change will see increases in wind speed, storm intensity and frequency and changes in rainfall

frequency (Department of Climate Change, 2009). These climate variables will not produce new coastal hazards but are likely to increase the extent or frequency of existing hazards. Coastline regions are subject to coastal inundation, coastal erosion / recession, sea level rise and flooding which will be exacerbated because of a number of factors, including changes in:

- Mean sea level
- Storm climates, including storm surges, storm tides and atmospheric changes (see Figure C.3)
- Tidal ranges
- Wave climates
- Rainfall

What are the potential impacts on coastal wetlands?

Wetlands are among the most vulnerable ecosystems to climate change (Jin et al., 2009). They will be affected by increased drought frequency and intensity, decreases in freshwater inputs, rising sea levels and increases in coastal storm surges. These conditions may also change the character of coastal wetlands through a reduction in size, conversion to dryland or a shift from one wetland type to another (e.g. brackish to saline). The retention of coastal wetland will require planning approaches which allow for the landward movement of wetland communities in order to avert significant loss and degradation to coastal wetlands and associated biodiversity in south-eastern Australia.

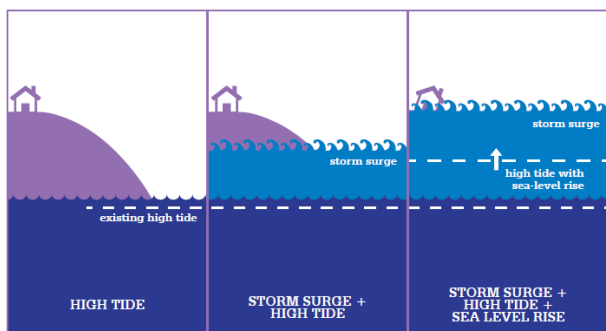


Figure C.3 Rising sea level is increasing the base level for a storm surge. (Source: *The Critical Decade*, 2013)

What are the impacts on estuaries?

Southeast Australian sea surface temperatures are increasing at a rate of approximately four times the global average (Ling et al., 2009) which has potentially significant changes for marine and estuarine species (Booth et al., 2011). Direct effects of climate change include changes to the in-stream habitat, degradation of riparian habitat, reduced water quality and the spread of non-native flora and fauna. These impacts are sometimes exacerbated by non-climate drivers including:

- Inappropriate development
- Inappropriate land use
- Loss of in-stream habitat
- Riparian degradation
- Reduced water quality
- Exotic flora and fauna
- Bank and bed instability
- Stock access to riparian zones and flow deviation

Unlicensed artificial estuary mouth openings can also have a negative impact on the form and function of estuaries (Glenelg-Hopkins CMA, 2013).

What are the impacts of sea water intrusion into Aquifers?

Seawater intrusion (SWI) refers to the landward migration of seawater into coastal aquifers. SWI usually results from extraction of groundwater for a range of purposes including agricultural, domestic and industrial

use. The occurrence of seawater intrusions depends on the relative pressure gradient between coastal groundwater systems and seawater. Two scenarios associated with climate change, rising sea levels and a reduction in freshwater input, are both likely to lead to greater salt water incursion;

The National-scale vulnerability assessment of seawater intrusion report summarises Australian and overseas studies which identify SWI impacts. The report indicates that:

“The Werribee River Delta is the only site in Victoria where SWI was found to be documented. It was identified within a bore adjacent to Port Phillip Bay. Seawater influx into the basalt aquifer was reported to have occurred as a consequence of high groundwater demand during a severe drought between 2002 and 2004. Other areas in Victoria that are potentially at risk of SWI include Point Nepean, the Gippsland region (Orbost, Sale and Venus Bay) and the Koo Wee Rup, Nullawarre and Yangery areas” (Ivkovic et al., 2012, p. 16).

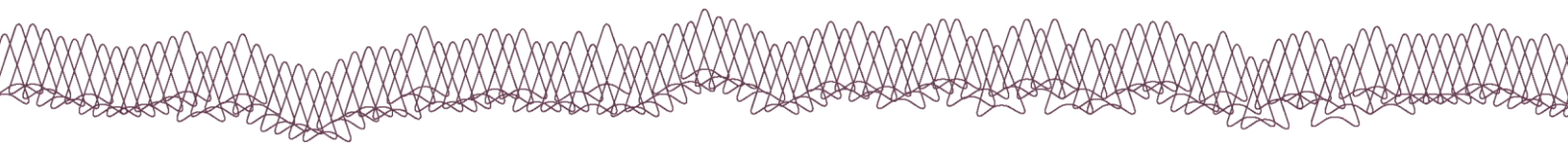
In Victoria, the greatest inter-decadal declines in minimum groundwater levels (>5 metres) were documented in Torquay and Yarram. Koo Wee Rup also showed substantial inter-decadal declines in minimum groundwater levels (between 2.5 and 5 metres) (Ivkovic et al., 2012).

McInnes et al. (2013) provide useful data and illustrations of storm tide heights for the Victorian coast under climate change. Sea-level rise figures, wind speed changes 1-in-100 year storm tide heights are shown for a range of locations. Detailed inundation maps are shown for Ocean Grove, Sea Spray and Aspendale.

C.3.4 Marine ecosystems

What are marine ecosystems?

Here we consider marine ecosystems, including all flora and fauna in the temperate marine environment of south-eastern Australia. These ecosystems provide “irreplaceable services including coastal defence, oxygen production, nutrient recycling and climate regulation” (Poloczanska et al., 2012, p. 1). They are



also the basis for human activities, including fisheries and recreational industries.

The following citations are a small selection of works recommended by colleagues who are active researchers in the field of marine ecosystems.

The Marine Report Card

Poloczanska, E.S., Hobday, A.J., Richardson, A.J. (Eds.), (2012) Marine Climate Change in Australia, Impacts and Adaptation Responses. 2012 Report Card. ISBN 978-0-643-10927-8.

The Marine Report Card summarises the current understanding of climate change impacts on marine ecosystems around Australia, and highlights important knowledge gaps and adaptation responses. The report highlights the rapid ocean warming occurring to the southeast of Australia caused by the southward movement of the East Australian Current, and the subsequent southward extension of seaweeds, phytoplankton, zooplankton, and demersal and pelagic fishes.

Climate change in Australian marine and freshwater environments

Hobday, A. J. and J. M. Lough (2011) Projected climate change in Australian marine and freshwater environments. Marine and Freshwater Research 62(9): 1000-1014.

This article provides background information about climate projections, including their strengths and limitations. It presents a range of projections for Australia's aquatic environments and considers potential species and ecosystem responses.

Literature review on Australia's marine biodiversity and resources

Holbrook, N.J. and Johnson, J. (2012) Australia's marine biodiversity and resources in a changing climate: a review of impacts and adaptation 2009-2012, National Climate Change Adaptation Research Facility, Gold Coast, 45pp.

This document provides a critical review and synthesis of literature relevant to the impacts of climate change and the adaptation options for Australia's marine biodiversity and resources.

What are key climate drivers of change in marine ecosystems?

The most important current driver of change in marine systems for south eastern Australia is the southern extension of the East Australian Current and the associated warming of the ocean, particularly off the southern coast of NSW, eastern Victoria and northeast Tasmania. These changes have resulted in range extension of many marine species (Madin et al., 2012). In some cases these provide for new opportunities such as the potential for a snapper fishery to develop in Tasmania. However, they also have potential negative consequences. One pressing challenge is the range extension of the sea urchin *Centrostephanous rodgersii* which has resulted in substantial degradation of kelp beds in some areas and is currently a threat to the rock lobster fishery of Tasmania's east coast.

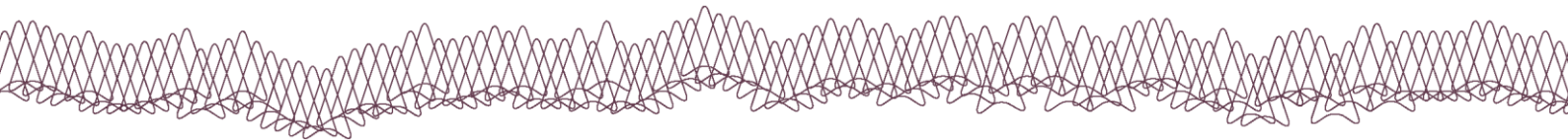
An emerging threat is associated directly with increasing atmospheric CO₂ - acidification. Ocean acidification increases the metabolic energy required for marine organisms to lay down calcium carbonate shell, this in turn can lead to substantial effects on the food chain and marine ecological systems. The effects of acidification are most pronounced in colder waters and a large scientific effort is underway to establish the rate of change in southern ocean systems and potential impacts of these changes.

C.3.5 Land, soil and agricultural productivity

What is land, soil and agricultural productivity?

In this context 'land' refers to the areas of catchments that are subject to intensive use by people. These areas are predominantly privately owned, and are used for agriculture, forestry, rural lifestyles, among other activities. Soils are the physical substrate on which these activities take place, particularly agriculture, and potentially soil carbon sequestration. Agricultural productivity includes the systems of production connected to agriculture, native and plantation forestry and freshwater aquaculture (Barlow et al., 2013).

The following citations are a small selection of works recommended by colleagues who are active



researchers in the field of land, soil and agricultural productivity.

Primary industries and climate change

Rickards, L. (2013) Climate change adaptation in the Australian primary industries: an interpretive review of recent literature. Primary Industries Adaptation Research Network.

This report presents a detailed synthesis of research relating to climate change adaptation in the primary industries sector. Starting on page 221, the report details climate impacts on primary industries, including soils and water, crops, livestock, forestry, freshwater aquaculture, infrastructure, natural resource management, trade and communities. The report is quite detailed and cites a large number of references.

Impacts on agricultural productivity in Tasmania

Holz, G.K., Grose, M.R., Bennett, J.C., Corney, S.P., White, C.J., Phelan, D., Potter, K., Kriticos, D., Rawnsley, R., Parsons, D., Lisson, S., Gaynor, S.M., Bindoff, N.L. (2010) Climate futures for Tasmania: impacts on agriculture technical report. Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart, Tas.

The Climate Futures Tasmania, (CFT) project published a series of reports providing information on the potential impacts of climate change on Tasmania, with a report dedicated to impacts on Tasmanian agricultural enterprises. The information in these reports has been condensed into information sheets for different agricultural industries (dryland and irrigated pastures, wine grape production and cereal production). One sheet provides a regional synthesis of projected impacts on agricultural productivity in the Meander Valley. The List (<http://maps.thelist.tas.gov.au/>) allows users to explore the potential impacts of climate change across Tasmania providing information on projected changes to rainfall, temperature, and frost events. The List also provides information on the potential suitability of some regions to support high value crops into the future. Additional modelling activities are underway for example a soil carbon map for Tasmania.

Impacts on agricultural productivity in Victoria

Soste, L., Christy, B., O'Leary, G., Goodwin, I., Aurambout, J.P., Liu, E., Stott, K., Morrison, G. (2013) Technical report on climate change adaption in agriculture. Department of Environment and Primary Industries, Victoria, Australia. This report presents information for 2030 onwards on climate change and variability impacts and risks to Victoria's key agricultural sectors; grains, dairy, livestock and horticulture (stone and pome fruit). It includes findings from over 200 peer reviewed papers and reports and also includes non-climate drivers.

Impacts on soils in Victoria

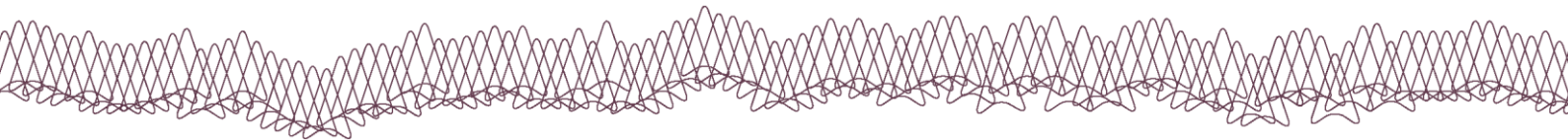
Nuttall, J.G. (2007) Climate change – identifying the impacts on soil and soil health. Department of Primary Industries, Horsham, Victoria.

James Nuttall from Victorian Department of Primary Industries produced this report, which contains a combination of literature review, analysis and expert advice. The report summarises the consequences of a warmer and drier climate on soils, including a reduction in soil carbon levels, increased risk of soil erosion and loss of nutrients, shifts in land suitability for certain types of agriculture, increases in the occurrence of 'transient' salinity, and water quality impacts, particularly following bushfires. Several recommendations are made for land management, including the maintenance of ground cover to protect soils, as well as moving agricultural industries to follow suitable climates.

A review of climate change impacts on soil health

Allen, D.E., Singh, B.P., Dalal, R.C., (2011) Soil Health Indicators Under Climate Change: A Review of Current Knowledge, in: Singh, B.P., Cowie, A.L., Chan, K.Y. (Eds.), Soil Health and Climate Change. Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 25–45.

This chapter appears in the book Soil Health and Climate Change, which presents a range of topics from impacts on soil attributes (e.g. pH, nitrogen, etc), to land use systems (e.g. cropping, rangeland grazing) to opportunities for soils to mitigate greenhouse gases (e.g. biochar, bioenergy, organic farming). The



highlighted chapter contains a review of research on climate change impacts on soil health more generally and provides a useful overview. The authors identify a range of physical, chemical and biological indicators of soil health, and conceptually connect these to soil processes affected and landscape-scale effects.

How will land, soil health and agricultural productivity be affected by climate change?

Soil health – direct impacts/climatic stressors

Soil Health refers to the 'fitness' (or condition) of soil to support specific uses (e.g. crop growth). MacEwan (2007, p. 27) stated that "Climate has a direct impact on soil health and has its most severe impacts in extremes of dryness leading to wind erosion and, in extremes of wetness leading to sheet, rill and gully erosion. Soil health is also linked to climate benefits on a global scale because soils can store carbon, improving soil quality and reducing greenhouse impacts." Climate directly affects crop production.

Carbon within the terrestrial biosphere can behave either as a source or sink for atmospheric CO₂ depending on land management and as such has the potential to mitigate or accelerate global warming (Nuttall, 2007).

"Climate change, through its influence on hydrological processes, will strongly influence soil degradation processes such as erosion and salinization" (Stokes and Howden, 2010, p. 157). Across all the Victorian land use zones the maintenance of the organic carbon pool is crucial for maintaining soil health (Nuttall, 2007). Assumptions used in Nuttall's report were based on rainfall decreasing by up to 14% from 1990 levels by 2030 and an average temperature increase by up to 2.0 °C, over the same period, across Victoria. The report summarised the impacts of climate change on soil health as follows in Box 2.

Agricultural productivity may increase or decrease under a changing climate depending on where the agricultural enterprise is located. In topographically variable regions, where farm businesses are often made up of multiple enterprises, risks from climate change may be less than for other regions which rely on single or dual enterprises.

Climate projections for south-eastern Australia indicate that minimum temperatures have risen and will continue to rise, providing favourable growing conditions for many enterprises located in cool-climate regions such as Tasmania and south-eastern Victoria.

Box 2. Impacts of climate change on soil health (Source: Nuttall, 2007, pp. ii–iii)

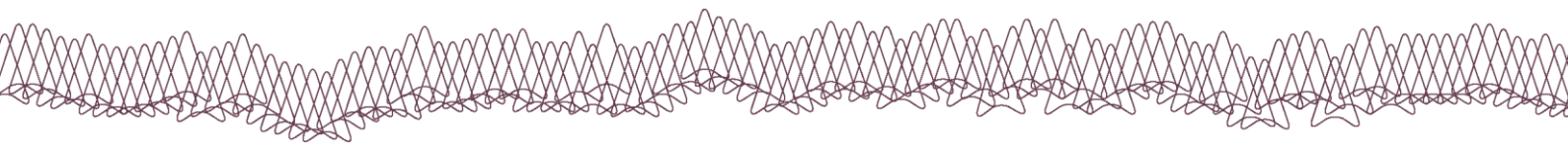
"Soil carbon is expected to decrease due to decreased net primary production. Any gains by increased plant water use efficiency, due to elevated CO₂ are likely to be outweighed by increased carbon mineralization after episodic rainfall and reduced annual and growing season rainfall. The quality of soil organic matter may also shift where the more inert components of the carbon pool prevail.

Increased risk of soil erosion and nutrient loss due to reduced vegetation cover in combination with episodic rainfall and greater wind intensities.

A shift in land suitability for farming due to greater significance of soil texture on plant/soil water dynamics and plant available water is likely.

Transient salinity may increase, bringing salts into the root zone on sodic soils. Leaching during episodic rainfall events may be limited due to surface sealing. Increased subsoil drying increases concentration of salts in the soil solution. Conversely, the severity of saline scalds due to secondary salinisation may abate as groundwater levels fall in line with reduced rainfall.

Soil biology and microbial populations are expected to change under conditions of elevated CO₂ and changed moisture and temperature regimes. As soil biology regulates nutrient dynamics and many disease risks, nutrient availability to crops and pastures could change as could the exposure to soil-borne diseases."



Products requiring a period of ‘chill’ hours may need to be grown at higher altitudes or on south-facing aspects if they were previously grown on north-facing slopes (Holz et al., 2010). Different wine grape varieties require different climatic envelopes, therefore wine grape producers will need to think and plan ahead to plant appropriate vines for expected climatic conditions (Holz et al., 2010).

Drought and heat stress are likely to impact on animal production systems as air temperatures increase. Pasture productivity is expected to be maintained or increase in cool climate systems, but may decrease in warmer regions if the thermal tolerance of pasture species is reached. Rye grass pastures perform best at a maximum temperature below 28 °C. Modelling has shown that the introduction of C4 grasses into C3 pasture dominated systems may sustain production levels in the long term. Biomass production may increase but the relative palatability of pastures may decrease under increasing CO₂. Soil biological activity may increase under higher temperatures if enough soil moisture is present. Nutrient cycling may increase, requiring an increase in fertiliser use to sustain crops and pastures under higher biomass production (Holz et al., 2010).

The incidence of fire is likely to increase over time which may affect agricultural production. Smoke taint is an issue for wine grape production. Fire will destroy crops, pastures and livestock. Access to harvest crops may be reduced to the fire risk from machinery on high temperature days.

Land that is already marginal for agricultural production may become more marginal in to the future. Competing land uses may affect the movement of agricultural enterprises into higher altitude regions in search of suitable climates for cool-climate crops such as berry production.

Pests and pathogens

Climate change is a significant driver of the increased potential for pest and pathogen incursions. Under climate change, conditions may become more favourable for the establishment and persistence of various weeds, insect pests and pathogens that negatively impact the yield and quality of agricultural

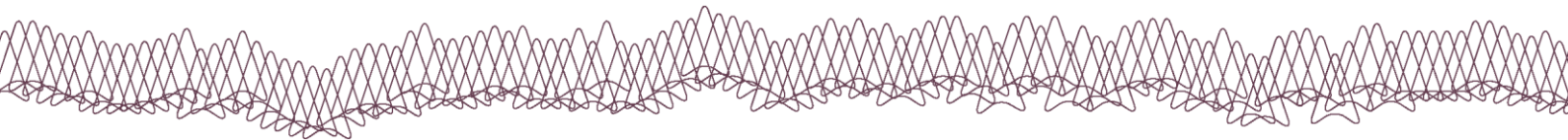
production (Peters et al., 2014; Sutherst et al., 2011). Shifts in population patterns, proximity to Asia, trade requirements, increased movement of product and people all enhance the risk of exotic incursions associated with changing climate. The prevention of pest and disease incursions is of vital importance to the viability of all rural industries but there are enormous knowledge gaps (Seidel, 2014). Such an incursion of a new pest or disease can have serious, possibly irreversible, consequences for agriculture. The effects on the British beef industry from Mad Cow disease are well documented (Millstone and Van Zwanenberg, 2007). In 2010, the potato/tomato psyllid cost the New Zealand industry approximately NZ\$43 million (TFGA, 2011).

Freedom from many of the world’s major pests and diseases is a clear advantage in both domestic and global markets e.g. fire blight in apples and ornamental plants (in the US and NZ), potato cyst nematode/zebra chip in potatoes (US and NZ) and fruit fly in Tasmania (Australian mainland) provide a key point of difference in the face of generally higher production and processing costs.

The Tasmanian climate is currently unsuitable for the persistence of Queensland fruit fly. However, with a warming climate, populations could establish on the Bass Strait Island and in the north and north-east of the state (Holz et al. 2010). Myrtle rust was introduced into Australia in 2010 and is present in Queensland, New South Wales, and Victoria but not Tasmania. Its impact in warmer regions is increasingly serious to native ecosystems and to agricultural production based on susceptible myrtaceous plants (e.g. lemon myrtle) (Pegg et al., 2014). Future climate change will extend the areas at serious risk in southern Australia, significantly increasing the risk to Tasmania (Kriticos et al., 2013).

Erosion

Australian agricultural soils lose 0.4 Tg CO₂-e yr⁻¹ (1.6 million tonnes) of soil organic carbon per year from wind erosion and dust storms (Chappell et al., 2013). Climate change presents an increased risk of drier, more denuded soils due to reduced vegetation cover, leading to increased soil erosion and nutrient loss in combination with episodic rainfall and greater wind



intensities (Nuttall, 2007). MacEwan (2007, p. 26) states:

“Loss of soil organic matter from erosion can lead to degraded surface structure and consequent problems of reduced water infiltration and impaired seedling emergence. Water erosion has major consequences on river health and on silting of infrastructure. Both wind and water erosion are significant soil health issues in Victoria.”

Historically, the region of Victoria most impacted upon by wind erosion has been the drier cropping areas of the Mallee and Wimmera regions. However, during the 1982/83 drought, considerable wind erosion occurred in higher rainfall areas (with up to 600 mm annual rainfall) including traditional grazing areas with little history of cultivation. The scenario of increasing temperatures and lower rainfall, could lead to some shifting land use from grazing (in parts of the south regions of Victoria) to cropping as has been an observed trend in parts of western Victoria. Hence, southern soils may, like the Mallee and Wimmera, become more prone to wind erosion (Soste et al., 2013). Reduced ground cover could lead to increasing wind and water erosion during dry periods and soil erosion is likely to be exacerbated by the projected increases in intense rainfall events where those rains fall on dry, denuded soils.

In parts of southern Victoria, increasing temperatures and lower rainfall could lead to some shifting land use from grazing to cropping, as has been an observed trend in parts of western Victoria (Sposito et al., 2008).

In combination, drier soils, reduced vegetation cover and more intense rainfall will present significant challenges to soil conservation even with moderate climate change (Nuttall, 2007).

Salinity

In broad terms, there are two types of salinity at a landscape scale; primary salinity caused by inundation or seepage from an existing source such as sea water or saline mineral deposits and secondary salinity caused by changes in surface vegetation or the volume of water applied to the land such as through irrigation. Much of the coast of Victoria, featuring low lying flood plains, estuarine inlets and coastal lagoon systems, is

already influenced by primary salinity; parts of the adjacent land is within a metre or two of mean sea level with some lower than spring/king tide levels on several occasions each year making them even more vulnerable to salinity (Victorian Coastal Council., 2014). The current Victorian government coastal planning benchmark is to plan for sea level rise of not less than 0.8 metres by 2100 and to plan for sea level rise of not less than 0.2 metres by 2040 for urban infill areas. The Victorian Coastal Council state:

“It is important to note that these benchmarks are for a horizon up to 2100. Sea level rise is likely to continue beyond this horizon. As the science continues to emerge, it is important that sea level rise planning benchmarks are reviewed and updated” (Victorian Coastal Council., 2014, p. 21)

Soil Acidification

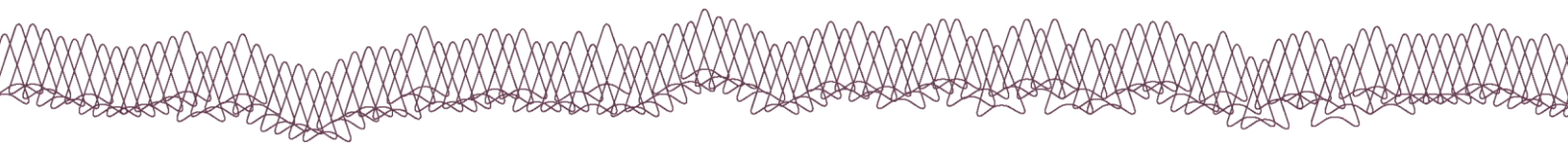
Large areas of acid soils occur in Victoria, with soils in south-west Victoria and West Gippsland known to be particularly acidic. Nuttall (2007) suggests that climate change will lead to a slowing in the soil acidification process as there will be less net leaching of alkaline materials though the soil profile.

Acid Sulphate Soils

While contained under water in wetlands, lakes and lagoons, Coastal Acid Sulphate Soils (CASS) remain relatively inert and harmless but they will react to produce sulphuric acid when exposed to oxygen; both the rapid depletion of dissolved oxygen and acidification of the surrounding waters are devastating to aquatic species

(http://vro.depi.vic.gov.au/dpi/vro/vrosite.nsf/pages/vr_ohome). Under hotter and drier conditions and reduced inflows, acid sulphate soils in coastal and riparian wetlands, and surrounding land will face an increased risk of being exposed.

Erosion along coastlines and lagoon systems can also mobilise acid sulphate deposits as has been observed at Apollo Bay, Lake Wellington and along the 90 Mile Beach; any rise in mean sea level is likely to add to this as are the projected incidence and severity of storm activity (DSE, 2009).



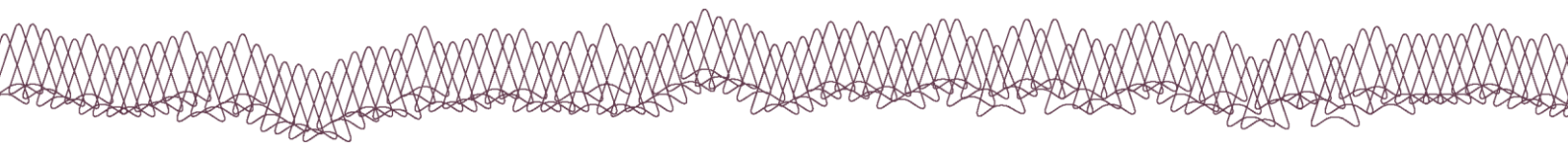
What are the impacts of higher temperatures on agricultural productivity?

Narrowing frost windows will affect distribution of species as well as potential expansion of species with low frost tolerance into new areas. Frost can substantially affect the phenology of native and agricultural species as well as pathogens, and invasive species. There are substantial uncertainties about the species specific responses to changing frost windows. However, there are some good rule-sets for requirements of agricultural species.

Where temperatures exceed thresholds they can lead to stress in plants and animals, causing reductions in growth and reproduction, and increased mortality. Heat stress associated with increasing maximum temperatures has the potential to reduce overall productivity in the beef, sheep and wool sector (McKeon et al., 2009).

The February 2009 heat wave caused extensive crop losses including sun burn of fruit, grapes and vegetables as well as bush fire destruction of crops and smoke taint of wine grapes. Heat damage on wine grapes was surveyed in ten regions after the February 2009 heatwave (Webb et al., 2009). Nine out of the ten regions experienced at least 20 per cent damage with almost 50 per cent of grapes in the Mornington peninsula suffering 80 per cent damage. The November 2009 heatwave also caused crop losses of fruit, vegetables and grapes.

Some pests and parasites, such as cattle ticks and invasive species, have minimum temperature tolerances which define the southern extent of their range. Increasing minimum temperatures are thus likely to extend the range of some pathogens and invasive species.



C.4 Regionally-relevant studies

This section presents a summary of selected relevant research publications in each of the nine sub-regions of the Southern Slopes cluster.

C.4.1 Glenelg-Hopkins

Impacts of sea level rise on flooding in an estuarine environment

Bishop et al. (2010) examined current and potential future flooding in Port Fairy, south-west Victoria. The paper investigated the effect of sea level rise on flood levels, the effect of dynamic ocean water level boundary and the balance of flood and storm tide risk under rising sea levels.

The modelling results showed that predicted sea level rise may have a significant local impact on peak flood levels within the estuary as Port Fairy's narrow channel and bridge constriction means that a small rise in flood levels can result in a large increase in flood risk. The impacts of sea level rise are predicted to extend 6 kilometres up the Moyne River, which has particular implications for development on the flood fringe. The impact on planning may be dramatic, as a 0.8 m rise in sea level by 2100 would exceed the typical freeboard allowance of 300 to 600 mm above the present 100 year ARI flood levels.

As much of the flood defence work in Port Fairy has been designed for 2010 conditions, the authors suggest that further modelling work is undertaken to include scenarios for the years 2030 and 2070 in order to identify the areas impacted first as sea level rises. With these results, mitigation work can be prioritised and staged accordingly.

Adapting to changing agricultural conditions in south-western Victoria

Sposito et al. (2010) developed a decision-making framework to identify adaptation issues in agricultural systems and rural production resulting from climate change. The framework uses a participatory approach

that integrates land suitability analysis with uncertainty analysis and spatial optimisation to determine optimal agricultural land.

Modelling of seasonal and long-term trends in lake salinity in south-western Victoria, Australia

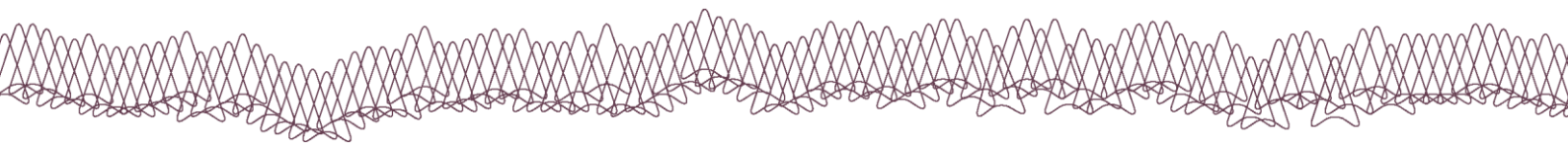
Yihdego and Webb (2012) investigated the hydrological components behind the increasing salinity levels of three lakes in south-western Victoria. The authors examined whether the effect of climate variables on water level and lake salinity can be separated from the effects of land use change to inform management decisions by the Catchment Management Authorities.

Detailed water and salt budget modelling was done for Lakes Burrumbeet, Linlithgow and Buninjon. Results showed that over the last decade, a time of drought with below average rainfall, the lakes all dried out, with salinity rising to very high levels as the water levels dropped.

Lake Burrumbeet is the least saline of the lakes because it has substantial groundwater outflow. This allows significant salt export to occur, and limits the amount of time the lake water is subject to evaporation. Lakes Linlithgow and Buninjon, in contrast, do not leak through volcanic necks. When the lakes dry out completely, salt is lost from the lake-beds, possibly due to wind deflation of salt crusts and leakage into the underlying groundwater. The drying-out phases therefore appear to play an important role in preventing the salinisation of lakes and wetland environments across the volcanic plains.

Identifying land-use change impacts on stream flow in south-eastern Australia

Yihdego and Webb (2013) report that the water table and lake level in the Glenelg-Hopkins catchment have been declining for the last 15 years, which is attributed to either the low rainfall over this time and/or a substantial change in land use. Stream flow modelling was carried out using monthly empirical water balance models for 37 stream gauges to assess whether the impact of land use change could be detected by a change in the magnitude of the resulting runoff. The empirical hydrological model was able to distinguish the



impact of land use change on stream flow from the climatic variables.

The study showed that the substantial decreases in stream flow in the 1970s–1980s were probably related to increasing livestock densities in the region. It also showed that the modelling tool can be used to monitor and evaluate the possible impacts of future land use changes. The study concluded that the use of empirical hydrological modelling greatly improves the ability to analyse the impact of land use on catchment runoff.

C.4.2 Corangamite

The impact of landslides and erosion in the Corangamite region, Victoria, Australia

Daulhaus et al. (2006) explain the process of the development of an erosion and landslide database that identifies assets at risk and priority areas for management for the Corangamite region.

A Geographical Information System (GIS) database was used to identify, map and reference landslides and erosion sites. Spatial correlations were tested against a variety of physiographic, climatic and land use parameters. Results showed that the strongest correlation of features were with geomorphology and rainfall. The information was mapped to examine the proximity of the erosion and landslide features to important regional assets, such as waterways, wetlands, roads, railways and ecological vegetation classes and bioregions. The spatial analysis determined that:

- Soil erosion and landslides represent a significant threat to assets such as waterways, wetlands and transport infrastructure,
- Landslides dominate the southern regions of the Corangamite region - the region is confirmed to be “one of the most landslide-prone areas in Australia” (Daulhaus et al., 2006, p. 7), and
- Sheet, rill and gully erosion are most prevalent in the three northern catchments.

The paper concludes that erosion has a greater impact on water quality, and landslides have a greater impact on infrastructure. Managing to minimise the effects of

erosion, including remediation, requires both extension activities and economic incentives to landholders. In contrast, landslides require a uniform approach to risk management by asset managers.

Assessing climate change impacts and risks on three salt lakes in western Victoria, Australia

Kirono et al. (2012) assessed three salt lakes for the impacts of climate change on lake levels and salinity. The lakes are of national (Gnotuk) and international significance (Keilambete, Bullenmerri) for their ecological, social, and scientific values. The authors note that the lakes’ levels have been declining since the mid-1800s due to decreased precipitation and increased evaporation.

To examine the impact of climate change, a lake water balance model was applied with inputs of climate observation data and modelled future climate variables. Lake levels were modelled through to 2100 based on scenarios from 14 Global Climate Models (GCMs). The results suggest that all lake levels are likely to continue to decline, with the declines for Bullenmerri, Victoria’s deepest natural lake, expected to exceed those of the other two lakes. Furthermore, the simulations suggest that salinity in each of the lakes is likely to increase, with the rate of increase likely to become more rapid over time.

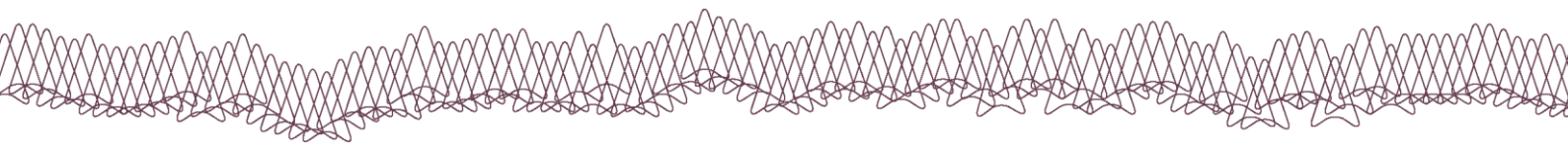
C.4.3 Port Phillip and Westernport

The effect of climate change on extreme sea levels

McInnes et al. (2009) investigated current and future storm tide levels at selected locations around Port Phillip Bay and used a Digital Elevation Model (DEM) to assess impacts associated with inundation due to extreme sea levels under current and future climate.

Beachfronts, low-lying wetlands and coastal reserve areas are the sites most susceptible to inundation from a 1 in 100 year storm tide. These areas are:

- Queenscliff region: Swan Island and the Edwards Point Wildlife reserve, as well as low-lying terrain at the northern end of Point Lonsdale.



- Point Wilson region: Extensive areas of coastal land around Point Lillias, and between here and Point Wilson.
- Point Cook to St Kilda: The Cheetham Wetlands, the Altona Coastal Park and the Jawbone Conservation Reserve.
- Mordialloc to Seaford: The northern part of the Edithvale Wetlands.

Under future climate conditions, more areas will be vulnerable to inundation from a 1 in 100 year storm tide:

- Queenscliff region: By 2030, the areas west and north of Point Lonsdale will be vulnerable to inundation, as will larger parts of the north of the town by 2070. By 2100, extensive parts of northern Point Lonsdale and southern St Leonards will be periodically inundated.
- Point Wilson region: Incrementally more extensive areas will be inundated in and around the Werribee Sewerage Farm, and the land north of Point Wilson.
- Point Cook to Brighton: Minimal additional inundation until after 2030. By 2070, additional inundation will occur in parts of the Altona Coastal Park and Elwood. By 2100, extensive parts of Elwood and the RAAF Base at Point Cook will be susceptible to inundation, and this will be extended to low-lying parts of Altona, Port Melbourne, South Melbourne, Middle Park and Albert Park if the higher estimates of sea level rise are reached.

The effects of climate on breeding in the Helmeted Honeyeater

The Helmeted Honeyeater is a critically endangered bird that exists as a tiny population in the Yellingbo Nature Conservation Reserve in the state of Victoria. Chambers et al. (2008) explored the role climate plays on the timing and success of breeding of this bird by examining the climate conditions from 1989 to 2006.

The results showed that the timing of the breeding and laying of eggs occurred earlier across the study period. The average number of eggs laid each breeding season also reduced. These changes correspond to a reduction in rainfall and mild warming. The authors note that if

these trends continue under projected climate change, the risk of further population decline will increase.

C.4.4 West Gippsland region

Climate change, sea level rise and coastal subsidence along the Gippsland coast

The Gippsland Coastal Board (2008) identified the Gippsland coast, from San Remo in the west, to the New South Wales border, east of Mallacoota Lakes, as one of the most vulnerable coastal areas in Australia (also see Department of Climate Change, 2009). The report investigates the potential impact of climate change, sea level rise and coastal subsidence on the coastline in order to support coastal managers in their long-term decision making and strategic planning.

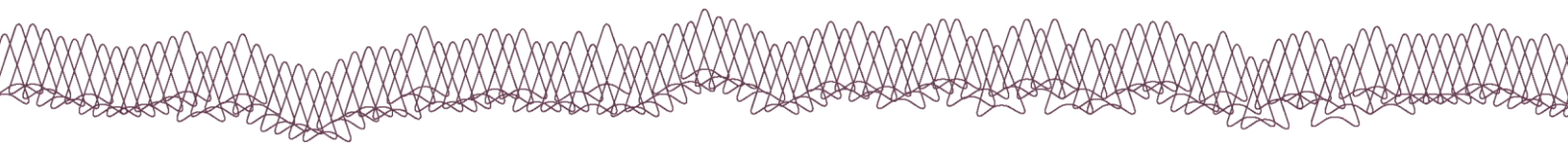
For Lakes Entrance, historical records indicate that flood levels have reached 1.8 metres. As a lot of the town has been developed below this level, it is particularly vulnerable to extensive flooding from increased rainfall and higher sea levels. Modelling indicates that in the longer term, it is likely to be permanently flooded from sea level rise, including the Princes Highway that runs through it. For the rest of the Gippsland coast, sea level rise and storms are likely to reshape the highly-erodible sandy beaches. Modelling results for the next 50 years indicate that inundation will require the protection or relocation of assets, including dwellings and commercial buildings. Additional risks include increased erosion of structures such as sea walls, roads and bridges, and flooding or erosion of commercial buildings, private residences, utilities (such as power lines) and stormwater drains.

C.4.5 East Gippsland

Vulnerability to bushfires in East Gippsland

Whittaker et al. (2012) investigated the nature and causes of vulnerability to bushfires in the Wulgulmerang district of East Gippsland, Victoria.

On 8 January 2003, a lightning strike ignited more than 80 fires in the areas of north-eastern Victoria and East Gippsland. Three weeks later bushfires swept through the Wulgulmerang district destroying six homes, twenty



hay, wool and machinery sheds, and killing thousands of sheep and cattle. The authors note that the fires came at a particular moment of vulnerability for the community who were dealing with pressures of prolonged drought, declining farm incomes, depopulation, and the inaccessibility of essential services. Many of these challenges increased the community's exposure to bushfire hazards, and reduced their capacities to cope and adapt.

The paper suggests that a warmer climate and fewer frosts could provide opportunities for developing new industries, such as horticulture and viticulture. However, the district's remoteness and lack of essential services represent a significant challenge to revitalisation. More immediately, fire and emergency services must develop policies and programs to provide remote, rural communities with greater protection and support before, during and after bushfires, recognising that these communities may have limited capacities to protect themselves.

Mountain Pygmy-possum (*Burramys parvus*)

The Mountain Pygmy-possum is the world's only hibernating marsupial and Australia's only mammal "limited in its distribution to alpine and subalpine regions, where there is a continuous period of snow cover for up to six months" (Department of the Environment, 2002, no page). This small distribution range makes them susceptible to even minor temperature increases. The species needs a snow depth over winter of at least one metre to provide enough insulation to keep it warm during hibernation.

The population currently exists in two isolated areas in Victoria: on Mount Buller and Mount Hotham, and in one area in NSW: the Kosciusko National Park.

This equates to a total available habitat cover of less than 10 square kilometres. Numbers of the Mountain Pygmy-possum have been declining since warming temperatures saw their alpine habitat retreat uphill, leaving the Mount Buller possums isolated from the Mount Hotham population. According to the Department of Environment (2002, no page):

"Sharing their mountain-top habitat with ski fields ... brings other problems for Pygmy-possums. Snow

compaction and the removal of boulders and vegetation cover, the development of noisy ski fields, villages, car parks and roads have altered, reduced and broken up Pygmy-possum habitat. Preyed on by foxes and feral cats, the surviving colonies also face a new threat from global warming. Warmer temperatures would fragment and thin the winter snow cover, reducing its insulation capacity and exposing the Pygmy-possums to colder temperatures, making it even harder for them to survive the winter."

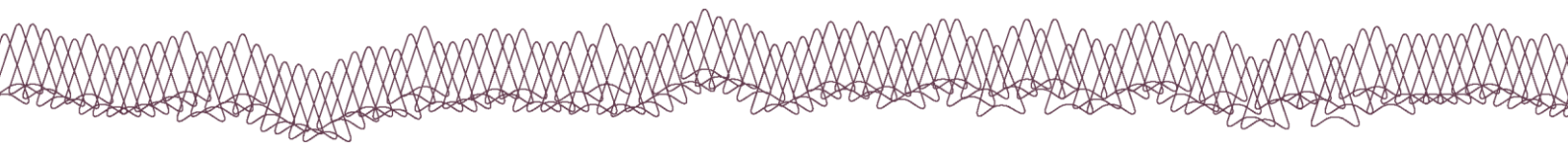
Studies estimate that a 1 °C rise in temperature may result in the loss of its bioclimate completely (Brooke and Hennessy, 2005).

C.4.6 South East NSW

The impact of climate change on snow conditions in mainland Australia

Hennessy et al. (2003) investigated the impacts of past and future climate change on snow cover in Australia. To examine past climate trends, temperature, precipitation and snow depth data were examined. Temperature data was analysed at eight sites in south-east Australia, four of which were above 1,300 metres in elevation and four which were below 1000 metres. Results showed that warming trends were slightly greater at higher elevations with sites above 1,300 metres showing a slight increase in temperature of +0.02°C per year. For precipitation, annual average data from the past 50 years showed evidence of slight decreases in the Victorian Alps and slight increases in the New South Wales Alps. Snow depth data was also analysed, and indicated a weak decline in maximum snow depths at three of four sites. For the NSW sites, percentage change in snow depth per decade was +0.7 for Deep Creek, -1.3 for Three Mile Dam and -2.2 for Spencers Creek.

To examine future changes in snow cover, simulations were used for the years 2020 and 2050, with the 2020 time period being the most relevant to the future management of ski resorts. Two scenarios were assessed; a low impact scenario, which had the lowest projected warming and highest rainfall, and a high impact scenario, which had the highest projected



warming and the least amount of rain. At all sites, the low impact scenario for 2020 only had a minor impact on snow conditions, with the average season length being reduced by around five days. This is considerably less than the high impact scenario for 2020, which showed a reduction in average season length of 30-40 days. Impacts on peak depth followed a similar pattern with moderate impacts at higher elevation sites and large impacts at lower elevation sites. By 2050, under a low impact scenario season, durations decrease to 15-20 days at most sites and under a high impact scenario, the season could be reduced by around 100 days.

The impact of climate change on the Australian wine industry

Webb et al. (2007) and the thesis by Webb (2006) report the impact of projected global warming on the Australian wine industry. Four wine regions are explored to understand the changes in phenology, or life cycle events, in response to warming. These regions are Coonawarra and Margaret River in WA and Clare Valley and the Riverina in NSW. These regions are also used, in addition to the Yarra Valley, to assess the impacts on grape quality. Although these regions are not within the South East Local Land Services, the information can be applied to the wineries within this region.

Temperature increases will also impact grape production and grape quality. The relationship between 'quality' and temperature varies considerably with variety, with some varieties more sensitive to temperature differences than others. Results showed that Pinot Noir displayed the greatest sensitivity to temperature, and both Chardonnay and Shiraz were less responsive. All Tasmanian NRM regions

Climate-driven range changes in Tasmanian intertidal fauna

Pitt et al. (2010) investigated the change in species distribution as a result of ocean warming, based on comparisons of surveys off the east coast of Tasmania in 1950 and 2007/2008.

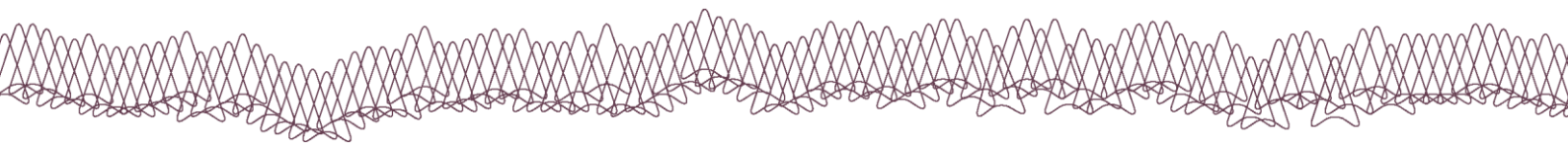
The results showed that no new species were detected in the re-surveys. However, 16 of the 29 species (55%)

were found further south (pole-ward) than in the 1950s, and two species were found at northern sites that were previously not recorded there. Of the 16 species to move south, gastropods had moved the furthest (range: 20 - 235 km), and barnacles had moved the second furthest (range: 20- 250 km). One species, the giant rock barnacle, was absent from Tasmania in the 1950s but is now widely recorded along the eastern coast of Tasmania. Previously, this species was only found on the Victorian coast at Wilsons Promontory, the closest mainland point to Tasmania.

Analysis of the data suggest that if the average rate (22 km per decade for an ocean warming of 0.22 C per decade) is maintained and the region experiences a 2C degree warming, the northern range of some species may move southward an additional 176 km, which is approaching the latitudinal length of Tasmania. As there is no land below Tasmania for some 1500 km, this represents a considerable dispersal and temperature-tolerance barrier.

Climate change adaptation in the Australian edible oyster industry

The oyster industry is situated in tidal lakes, bays and estuaries, bordering land and sea making the sector vulnerable to changes in terrestrial and oceanic environments. Oysters themselves, as filter feeders, are susceptible to changes in water chemistry, temperature, and availability of food. Leith and Haward (2010) investigated ways to manage the projected climate impacts and how to make the sector more adaptive and responsive to change. Recent disease outbreaks in oyster aquaculture reveal that the sector is not immune to dramatic changes in system function.



C.5 Analysing possible futures

This section details approaches to ‘analysing possible futures’, which is an important step in adaptation pathways planning. There are many ways to explore potential futures, so the following are intended as options to consider rather than specific recommendations. Moreover, it is unlikely that only one method would be used. Rather, where possible, a combination of quantitative and qualitative approaches used in a participatory manner would be ideal. As Innes and Booher (1999, p. 412) have argued, these sorts of participatory processes “are not only about producing agreements and plans but also about experimentation, learning, change, and building shared meaning”.

Some of the methods available for exploring possible futures are loosely categorised as quantitative and qualitative types:

Quantitative methods: typically use data to generate models and maps of potential futures. They are most useful to inform and mediate discussions. Examples include climate change projections, data on climate variability, or model-based methods such as the Victorian EnSym (Environmental Systems Modelling Platform; <https://ensym.dse.vic.gov.au>).

Qualitative methods: typically combine quantitative data with the advice of ‘experts’ and/or insights and perspectives of an array of others. Examples include Bayesian Network Analysis, Delphi processes, participatory scenario development and analysis, and design-led approaches. A summary of these types of future analysis methods is presented in Table C.3 following the typology by Hoppe (2011) presented earlier in Table B.1.

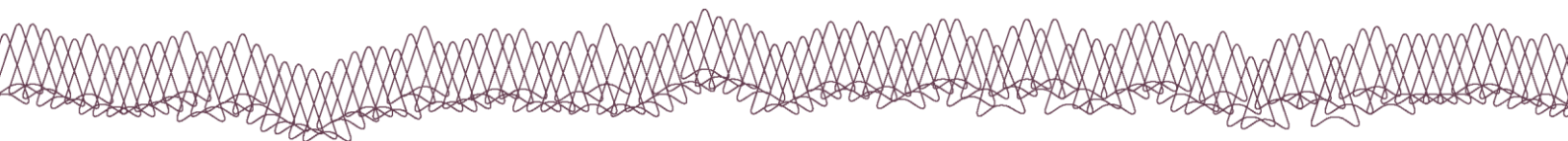
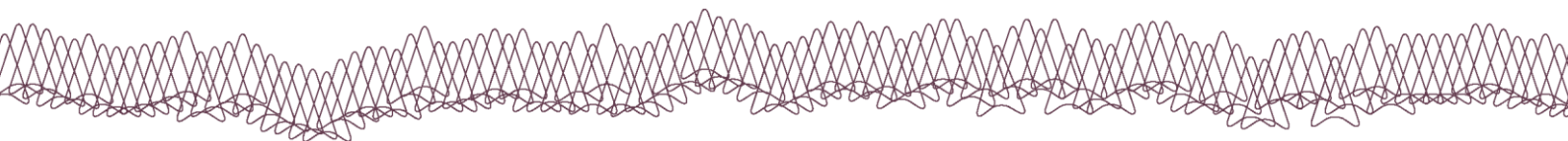
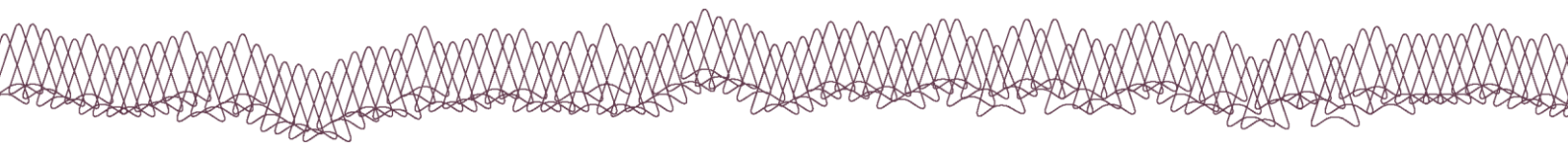


Table C.3 Futures analysis tools and their applicability to different problem types

| COMPUTATIONAL | | JUDGEMENT | BARGAINING | INSPIRATION |
|---|---|--|---|---|
| QUANTITATIVE APPROACHES | | | | |
| Climate observation | Useful background information (baseline), indicating trends and extremes. Allows for analysis of historical or geographical analogues for future conditions (e.g. events that become more frequent or rare; towns that 'migrate north' over coming decades, etc.) | Used to ground or challenge judgement about preferred policy options. How do they fare within existing climate variability? | Can assist in defining current risk profiles for different groups and creating demand for solutions to already existing problems (i.e. finding common ground around existing problems) | Underpins narratives about managing for variability and/or extremes and building constituent support (e.g. defining current flood risk) |
| Modelling-based approaches E.g. Climate change projections and ecosystem models | Provides range of plausible scenarios regarding potential shifts in key climate drivers (e.g. temperature, rainfall, etc) that can be combined with other modelling data to explore potential implications of CC. | Can be used to challenge assumptions about stability and change, where current goals appear to be threatened by change at decadal and longer timescales. | Can usefully be applied to provide futures to test the long term viability of different options in inquiry-oriented setting. | Can provide foundational information as the basis for starting discussion, broaching difficult subjects. Where CC science is clearly seen as contested, projections can be used 'validate' local experience of environmental change (which make CC science more legitimate) |
| Foresighting | More like the situations described above, where a range of data sets are combined to produce sophisticated future scenarios. Such quantitative approaches are generally used within these more participatory type approaches for exploring and analysing potential futures. | Participants can use the Foresighting process to develop pathways towards an agreed future vision | Participants can use the Foresighting process to develop an agreed future vision, and explore their preferred pathways for getting there, including their synergies and conflicts. Foresighting is often described as a technique for just this approach. | Could be used to explore both differences and commonalities among values and preferred futures, as well as synergies and potential conflicts among pathways identified by different groups. Foresighting is often described as a technique for just this approach. |
| Backcasting | | Participants describe | Could be used to | Some practitioners |



| COMPUTATIONAL | | JUDGEMENT | BARGAINING | INSPIRATION |
|--------------------------|--|---|--|--|
| | | preferred futures and then work backwards 'from these futures' to identify pathways (as combinations of actions) that would be needed to be taken to get there. | explore or 'unpack' values divergence; different preferred futures. Working back from those different futures could be used to explore and identify synergies and conflicts or trade-offs in preferred actions | argue that backcasting is particularly helpful when problems at hand are complex and when present trends are part of the problem (Holmberg and Robert 2000:291). Could be used to explore both differences and commonalities among values and preferred futures, as well as synergies and potential conflicts among pathways identified by different groups |
| Delphi processes | | Can be used to help identify preferred futures, pathways and options | Delphi processes can be useful in working towards agreement on preferred futures. It aims to get as close to consensus as possible while respecting minority views (Taylor and Ryder 2003:185) | Could be used to develop preferred futures, pathways and options, which are then used in broader scenario development and exploration processes such as Foresighting and backcasting. |
| Bayesian networks | | Similarly to Delphi processes | Similarly to Delphi processes | Similarly to Delphi processes |



C.5.1 Quantitative approaches

Quantitative approaches to analysing potential futures typically produce ‘models or maps’ of those futures. In practice, the outputs of modelling, observation data, projections or other analyses serve as the basis for discussions about future change. Such methods are sometimes called information-mediated approaches.

Three examples are given here: (i) using observations of current and past climate, (ii) using climate change projections, and (iii) using ecosystem models.

Climate observations

Observations of current and past climate are a useful starting-point for conversations about future climate change. Existing climate variability often creates its own set of climate-related risks, hazards and opportunities. For example, the occurrence of drought and associated reductions in surface water flows is a product of natural climate variability in south-eastern Australia (CSIRO, 2010, 2012). Climate observations thus provide the basis for discussion of how NRM takes into account existing climate variability and how it could cope with more intense variability.

Climate observations also provide a springboard for discussions with community groups about climate change. By grounding discussions in experiences of past climate (e.g. how communities coped with drought) it can enable assessment of which extremes are currently dealt with well or poorly. It can also provide a useful community-driven entry-point to climate change through questions such as: ‘are any of these extreme conditions changing?’ or, ‘have you noticed any change in the way seasons or patterns are changing?’.

Climate change projections

Projections of future climate change can also form the basis of conversation about the future. The science of climate modelling is complicated and dealing with concepts of uncertainty such as ‘model consensus’ and ‘representative concentration pathways’ can be confusing. However, climate change projections can be a useful input by enabling selection of plausible scenarios for discussion. For example, from the range of

projections and models one might choose to look at ‘worst case’ and ‘best case’ scenarios, where ‘worst’ and ‘best’ are defined in relation to existing climate (e.g. a dry location projected to be drier).

Projections can also be used to challenge assumptions about goals and objectives based on notions of stability and change. For instance, Milly *et al.* (2008) caution that managing water on the basis of ‘stationarity’ (variability within a limited envelope) is no longer viable in the face of climate change.

Models (e.g. Ecosystem models)

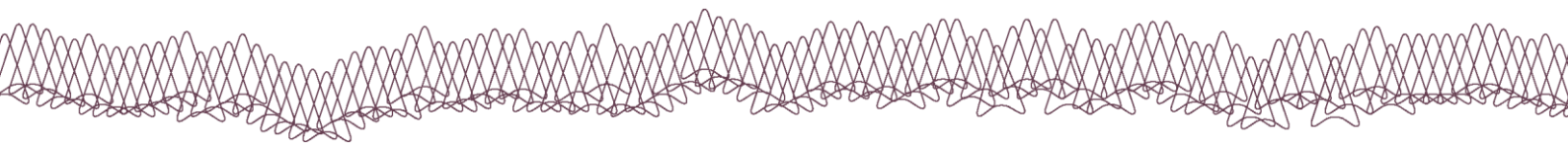
Broadly speaking, modelling is a process of representing real-world phenomena to better understand it or to make predictions. There are a range of different methods for modelling, so it is difficult to classify all of them as quantitative or qualitative. Kelly (Letcher) *et al.*, (2013) outlines the range as technical and involving the use of software such as system dynamic models, and some non-technical such as knowledge-based modelling (KBM). Those authors provide a “framework that aims to assist modellers and model users in the choice of an appropriate modelling approach for their integrated assessment applications and that enables more effective learning in interdisciplinary settings.” (Kelly (Letcher) *et al.*, 2013, p. 159). An example from Victoria, is the EnSym model (<https://ensym.dse.vic.gov.au>).

C.5.2 Qualitative approaches

Qualitative approaches to analysing possible futures typically combine quantitative data with the advice of ‘experts’ and/or insights and perspectives of an array of others including stakeholders and communities. Four examples are briefly outlined.

Participatory modelling

Participatory modelling here refers to the wide range of modelling techniques that involve open discussion about the value judgements that are implicit in models. These can include simulated role-playing games associated with agent-based models, developing conceptual models or even co-design of systems dynamics models. For example Greiner *et al.* (2014)



describe a process of participatory action research and scenario planning in developing a dynamic simulation model for pastoral systems.

Lynam *et al.* (2007) reviewed tools for incorporating community knowledge into NRM, several of which were participatory modelling techniques. See also Section [E.1.1 Building collaboration](#) for more on participatory modelling.

Scenario development and analysis

Scenario analysis can be useful where complex systems result in an incalculable number of possible futures; instead, a smaller number of scenarios can be developed for discussion. However, it must be remembered that scenario development and analysis is not a predictive technique, but rather a way of exploring possible futures and analysing their potential implications.

A variety of scenario approaches exists, each with their own strengths and weaknesses. Wiseman *et al.* (2011a, 2011b) through the Victorian Centre for Climate Change Adaptation Research (VCCCAR) reviewed approaches to scenario planning and provide a guide to scenario planning in climate change adaptation. The US National Park Service (2013) also produced a guide to scenario planning.

One of the weaknesses of dominant scenario planning approaches is that they do not recognise or take into account that the future tends to develop discontinuously, and that climate change is unlikely to occur along a monotonic curve (Jones, 2012, p. 1). Methods such as Foresighting can help address this type of weakness in a scenario planning exercise.

Participatory scenario planning works with a range of participants with interests in the issue for which the planning is being undertaken. For example, in 2005, the Scenarios Working Group (a team of 95 experts from 25 countries) of the Millennium Ecosystem Assessment project undertook an assessment of possible future scenarios for ecosystem services (Carpenter *et al.*, 2006, p. 1).

There are a number of techniques that can be used to generate or use existing scenarios. A brief discussion of four techniques - Foresighting, backcasting, the Delphi

process and Bayesian belief networks - are outlined below.

Foresighting

“Foresighting” combines “insight” with “forecasting”. Foresighting recognises that there are elements of the future that are controllable and predictable as well as elements that are neither. The latter are sources of sometimes-disastrous surprises. When we look back we can see that many things that have come as disruptive surprises were inevitable and could have been anticipated to a degree.

The European Commission describes foresight as providing “a framework for a group of people concerned with common issues at stake to jointly think about the future in a structured and constructive way” and that it “provides a number of tools to support participants (i.e. policy makers, experts and other stakeholders) to develop visions of the future and pathways towards these visions” (<http://forera.jrc.ec.europa.eu/>).

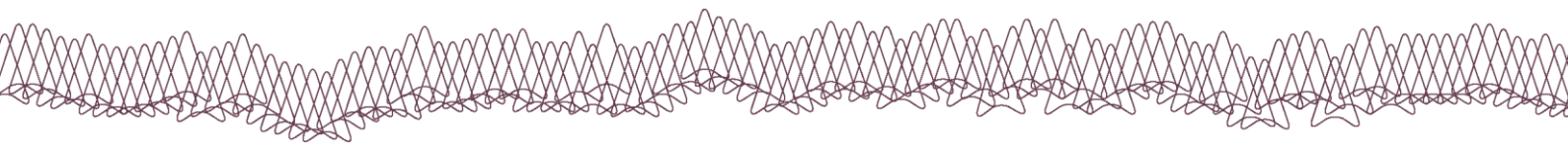
With reference to a multitude of literature, Amanatidou (2014, p. 274) summarises foresighting as:

“an action-oriented instrument for policy-making facilitating structured anticipation, considering alternative futures, requiring creative thinking and multi-disciplinary perspectives, enabling collective learning; proactive and path-breaking, interactive and participatory; enabling mediation and alignment, forging new social networks, guiding strategic visioning, creating, and committing actors to shared visions, and supporting deliberative democracy”.

Approaches to strategic foresight explore multiple plausible futures rather than trying to predict the most likely single future. They combine understanding of biophysical systems with theories of social, economic, technological, environmental and political change to explore what factors might influence the future and how those factors might play out.

Backcasting

Backcasting asks participants to describe a desired future state and then involves identifying a range of



options to reach this state (Dreborg, 1996). For example, what actions would we have taken to ensure a vibrant community with opportunities for young people in an environment that is appealing both now and on into the future? Backcasting is a way of avoiding looking at the future from the perspective of the past, which can be risky, if past trends (particularly those that may be driving current issues) are allowed to influence or even determine what is considered a realistic strategy (Holmberg and Robert, 2000, p. 293).

Van Vliet and Kok (2013) combined backcasting and exploratory scenario to develop robust water strategies in Europe. While van der Voorn *et al.* (2012) combined backcasting and adaptive management in developing an adaptation plan for the Breede–Overberg coastal region in South Africa where a catchment management strategy was developed.

Delphi processes

It involves multiple iterations of feedback that often include questionnaires or surveys given over a number of rounds (Hsu and Sandford, 2007). “The Delphi method brings together diverse ‘expert’ opinion on specific, unresolved issues, with the goal of achieving agreement – as close to consensus as possible while respecting minority views” (Taylor and Ryder, 2003, p. 185). Citing others, Taylor and Ryder (2003, p. 185) write:

“The quantitative estimates are combined to yield average optimum and range estimates, accompanied by the rationales for these positions, presented anonymously. Repeating the questionnaire, the experts reconsider their estimates in the light of the aggregated expert opinion and reasoning.”

Lockwood *et al.* (2012) provides a relevant example of using the Delphi process, where they apply it in developing an adaptive governance and management regime for marine biodiversity.

Bayesian belief networks

Bayesian belief networks (BBN) is a technique that graphically represents a network of nodes linked by probabilities.

*“Nodes can represent constants, discrete or continuous variables, and continuous functions, and how management decisions affect other variables. Nodes are comprised of states that are independent, mutually exclusive, and exhaustive propositions”. (McCann *et al.*, 2006)*

McCann *et al.* (2006, p. 3053) also argue that:

“In ecological modelling, BBNs are particularly useful for rapid scoping and intuitive presentation of ecological relationships. When applied to [NRM], BBNs can depict the influence of alternative management activities on key ecological predictor variables and thence on ecological and other response variables, and thereby help the manager choose the best course of action”.

Cain *et al.* (1999, p. 123) argue that while they are:

“mathematical in nature, belief networks are superficially simple and allow concepts to be expressed in terms with which a wide range of user will be familiar. This offers a participatory approach to the development of management strategies through consideration of the impact of potential management options with consequent benefits for strategy implementation”.



Section D.

Identifying and prioritising options



D. Identifying and prioritising options

This section introduces some options for both climate change mitigation and adaptation, as well as a summary of methods for spatial prioritisation of options. Mitigation options focus on mitigating loss of existing carbon, as well as sequestration of new carbon into aquatic and terrestrial environments. Adaptation options and strategies are presented in a ‘pathways planning’ framework, which is a flexible approach to sequencing adaptation activities over time.

D.1 Carbon sequestration and mitigation options

D.1.1 Overview and further information

This section provides high level information regarding carbon sequestration and mitigation options relevant to NRM planning across the Southern Slopes region.

What is carbon?

Carbon is an element of all living and dead organisms and is found in a vast array of organic and inorganic compounds on land, in soils and oceans and in the atmosphere. Carbon naturally flows between the atmosphere, oceans and terrestrial and freshwater systems over both short and long time cycles.

What is soil carbon?

The term soil carbon refers to the total amount of carbon stored in the soil comprising of organic carbon and inorganic carbon. Baldock et al. (2007) have identified four biologically significant types or fractions of soil organic carbon; the type and amount of each being an important indicator used to infer soil health status. Organic matter supports many soil processes associated with fertility and physical stability of soil across the various ecosystem services. Soil carbon can be a source or a sink for atmospheric CO₂, depending on factors including land management, and as such can potentially mitigate or accelerate climate change.

Where is carbon?

The CSIRO Australian Soil Carbon Mapping project provides national scale representation of SOC stocks

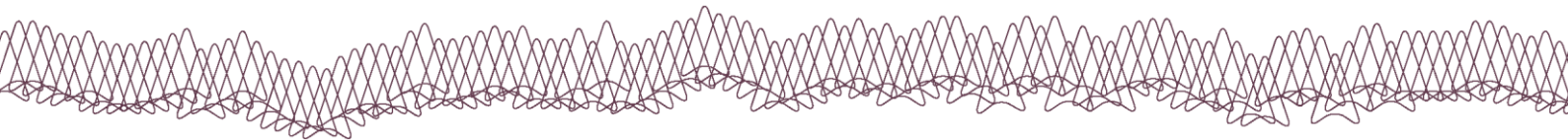
The authors (Vissara Rossel et al., 2014) concluded “the average amount of organic carbon in the top 30 cm of Australian soil is estimated to be 29.7 tonnes per hectare and the total stock for the continent at 25.0 gigatonnes (Gt= 1000 million tonnes) with a 95 per cent confidence of being within the range of 19.0 to 31.8 Gt. Victoria’s soil carbon stocks are estimated to be 1.68 Gt with 95 per cent confidence of being within the range of 1.38 – 2.02 Gt. Tasmania’s soil carbon stocks are estimated to be 1.05 Gt with 95 per cent confidence of being within the range of 0.85 – 1.27 Gt”.

Australia’s largest per hectare soil organic carbon stores occur in the cool, temperate zones, which have above average rainfall and extensive eucalyptus forests and rainforests (CSIRO, 2014). These forests types occur in parts of the Otway Ranges, the Central Highlands and East Gippsland as well as extensive areas of Tasmania.

The amount of organic carbon in Australian agricultural soils varies significantly, from peat soils under pasture where soil organic carbon (SOC) content can be as high as 10%, or less than 1% for heavily cultivated soils (Robertson, 2012; CSIRO, 2011). The CSIRO’s soil carbon map of Australia is available at <http://www.asris.csiro.au/>.

Under the Australian Soil Carbon Mapping project, regional-scale maps are being prepared for the Southern Slopes Cluster (SSC) CMAs to indicate priority areas for soil carbon in each of the respective CMA/NRM regions.

Norris et al. (2010) estimated the total, above-ground, carbon stocks on Victoria’s publicly managed land are estimated to be 750 million t (2750 million t CO₂). Their carbon accounting model simulations suggest that harvesting, wildfires and prescribed burns are major causes of change in carbon stocks on Victoria’s publicly



managed land. Meaningful estimates of carbon stocks on privately managed land in Victoria are not available.

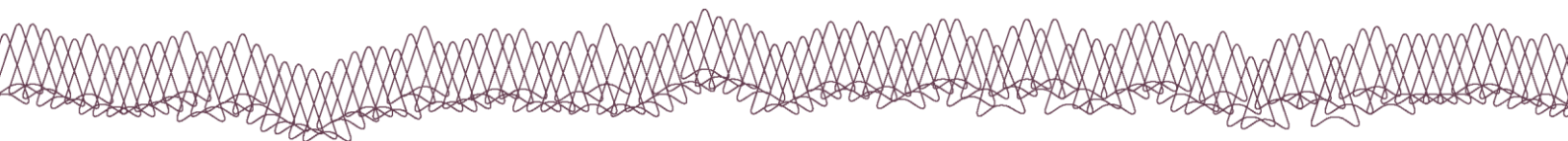
World-wide, the Agriculture, Forestry and Other Land Use, (AFOLU) sector is responsible for around 24% of anthropogenic (human-induced) GHG emissions, mainly from deforestation and agricultural emissions from livestock, soil and nutrient management (Smith et al., 2014).

Defining carbon sequestration and mitigation of loss of carbon

Carbon sequestration refers to the capture and long-term storage of carbon dioxide (CO₂) from the atmosphere. Carbon can be stored in biota, soils and long-lived products, and may be brought about through increases in the area of carbon-rich ecosystems, increased carbon storage per unit area, and increased wood use in construction (Smith et al., 2014). See Box 3 for more information about carbon sequestration in the land sector.

Box 3. Key considerations and constraints relating to carbon sequestration in the 'land sector'. This material also appears in Hamilton (2015) and Hamilton and Anderson (2015) in modified form.

1. Genuine carbon sequestration must result in an additional net transfer of carbon from the atmosphere to land, not just movement of a carbon source from one site to another (Powlson et al., 2011; Smith et al., 2014). This may be of consequence to farmers intending to participate in GHG reduction activities or schemes such as the Carbon Farming Initiative.
2. A management practice that is effective at reducing emissions at one site may be counterproductive elsewhere. For example, shifting from cropping to pasture, without any decrease in market demand for crops, could lead to other land being put into cropping, which would simply transfer SOC losses to another farm (IPCC 2014e; Powlson et al. 2011).
3. Accurate measurement of soil organic matter and statistical verification of changes in SOC stock is complex involving many factors affecting SOC sequestration, such as changes in vegetation cover and variability in soil environments (Baldock 2007; Sanderman et al. 2010).
4. Increasing carbon input rates, or decreasing carbon loss rates can improve soil carbon levels and have other benefits, including improved soil nutrient uptake (where nutrients are available), water holding capacity and overall productivity (Parliament of Australia, 2010).
5. SOC can function as a significant source of nutrients for farm production, however, it is important to also consider the reverse of this process; increasing soil carbon [levels] will also require nutrients to be locked away and bound up along with the sequestered carbon. (Grace et al., 2015; Kirkby et al., 2011).
6. Soil carbon occurs in a number of different fractions, each having different properties and rates of decomposition. The Particulate Organic Carbon or labile fraction can readily decompose in the soil and subsequently be released back into the atmosphere as CO₂ (Baldock et al., 2007).
7. The capacity for soils to sequester carbon is finite and there are specific maximum achievable equilibrium levels of soil organic matter for most farming systems due to climatic and primary productivity limits to plant dry matter production and decomposition rates (Powlson et al., 2011).
8. Changes in land management which lead to increased carbon in soil must be continued indefinitely if farmers wish to maintain the increased stock of SOC (Powlson et al., 2011; Sanderman et al., 2010). For many farmers, committing to long term land use may be undesirable if it reduces their ability to adjust land management to meet changing market or profitability drivers over the longer term.



9. Some management practices may only be reducing losses of soil carbon and not actually sequestering additional atmospheric carbon into the soil. Many Australian soils are still responding to initial cultivation of the native soil and experiencing soil carbon decline (Sanderman et al., 2010).
10. Increasing soil carbon may potentially lead to perverse impacts as a consequence of the links between soil carbon, nitrous oxide and methane cycles. For example, changing from annual crops to permanent pastures may increase soil carbon, but may also lead to an overall increase in total net emissions via increased ruminant livestock production. Soil carbon needs to be considered in a wider systems context (Barlow et al., 2011).
11. Climate change may reduce the ability of soils to sequester carbon (Baldock et al., 2012). Climate change and changing patterns of seasonal variability will affect the ability of soils to maintain or sequester carbon. For some regions maintaining or improving soil carbon levels may become increasingly difficult in future.

Mitigation refers to avoiding emissions of CO₂ into the atmosphere. Decay or combustion of organic matter leads to CO₂ release, and in most cases debate about emissions reduction centres on reducing use of fossil fuels. The IPCC (Smith et al., 2007, p. 499) state that “there is no universally applicable list of mitigation practices; each practice needs to be evaluated for individual agricultural systems based on climate, edaphic conditions, social setting, and historical patterns of land use and management”. For NRM in the Southern Slopes region, where large quantities of carbon are stored in soils and vegetation, mitigating the loss of these carbon stores ensures that large quantities of carbon will not enter the atmosphere and exacerbate climate change further.

The following citations are a small selection of works recommended by colleagues who are active researchers in the field of carbon sequestration.

Review of carbon sequestration in vegetation and soils

Hamilton, L.C. (2014) A Review of Carbon Sequestration in Vegetation and Soils: Options, Opportunities and Barriers for NRM in the Southern Slopes Cluster.

This report was prepared by the Southern Slopes Climate Change Adaptation Research Partnership (SCARP). This report is aimed at assisting Catchment Management Authority (CMA) and Natural Resource Management (NRM) organisations with climate change impact and adaptation planning. The report focuses on reviewing ways to sequester terrestrial and aquatic carbon in soils and plants, and how to prevent the loss of existing stocks of stored carbon. Sequestration

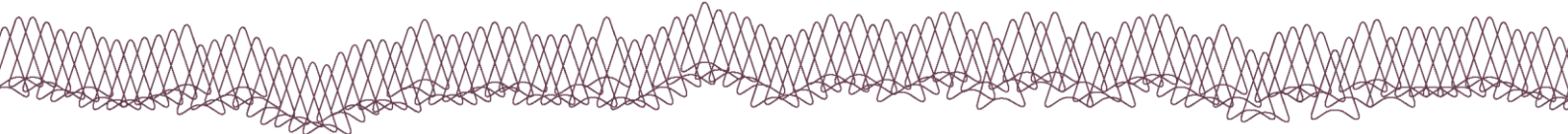
activities that reduce GHG emissions in the Agriculture, Forestry and Other Land Use (AFOLU) sector that are within the sphere of activities relevant to Southern Slopes Cluster CMAs are examined.

Analysis of the economics of carbon planting

Polglase, P., Reeson, A., Hawkins, C., Paul, K., Carwardine, J., Siggins, A. Turner, J., Crawford, D., Jovanovic, T., Hobbs, T., Opie, K. and Almeida, A. (2011) Opportunities for carbon forestry in Australia: economic assessment and constraints to implementation. CSIRO, Canberra, Australia.

This report analyses the economic returns from tree plantings, over a 40-year period, to offset carbon emissions and discusses some of the “practical constraints to wide-spread expansion of these planting types” (Polglase et al., 2011, p. 1). The modelling analysis uses 105 scenarios, encompassing 3 discount rates, 7 carbon prices, 2 costs for establishment of plantings and 2 comparative rates of carbon sequestration as well as the input cost of land values for local government areas. The authors (Polglase et al., 2011, p. 2) conclude that, in the long-term, carbon forestry can “help off-set greenhouse gas emissions and restore landscapes” although “there are few areas economically viable in Australia” under current or likely future policy and economic settings. Polglase et al. (2011, p. 2) suggest that “additional incentives (gap payments) may be needed to target trees in the right places to achieve other NRM objectives such as enhancement of biodiversity”.

Review of potential for soil carbon sequestration in Australia



Sanderman, J., Farquharson, R., Baldock, J., (2010) Soil carbon sequestration potential: a review for Australian agriculture. CSIRO Sustainable Agriculture National Research Flagship, Canberra.

This CSIRO report presents the findings from peer-reviewed studies of traditional management practices that are used to sequester soil carbon around the world. This report helps clarify some of these issues around soil carbon in agriculture, covering matters including the “potential of agricultural soils to store additional carbon, the rate at which soils can accumulate carbon, the permanence of [soil carbon] sinks, and how best to monitor changes in SOC [soil organic carbon] stocks” (Sanderman et al., 2010, p. iv). The authors also conclude that in many instances, Australian soils are still responding to the initial cultivation of the native soils and that they “may only be mitigating losses and not actually sequestering additional atmospheric carbon” (Sanderman et al., 2010, p. iv). The relative merits of various soil carbon sequestration options are summarized in an accompanying table.

Analysis of rural opportunities for land-based sequestration

CSIRO (2009) An Analysis of Greenhouse Gas Mitigation and Carbon Sequestration Opportunities from Rural Land Use. CSIRO Sustainable Agriculture Flagship, Brisbane.

Although this report was prepared for Queensland, national estimates have been made and many of the findings are applicable nationally. The authors concluded that carbon forestry and forest-related options are the most realistically achievable of the rural land carbon sink options but will require a concerted policy, research and implementation effort. This report also examines the uncertainties, risks, barriers to implementation, benefits and trade-offs of the various carbon sequestration options.

A critical assessment of soil carbon sequestration

Powlson, D.S., Whitmore, A.P. & Goulding, K.W.T. (2011) Soil carbon sequestration to mitigate climate change: a critical re-examination to identify the true and the false. European Journal of Soil Science. 62, 42–55.

The authors differentiate between increasing soil organic carbon (SOC) content, caused by a change in land management, and genuine soil carbon sequestration for climate change mitigation which occurs only “if the management practice causes an additional net transfer of carbon from the atmosphere to land” (Powlson et al., 2011, p. 42). The article examines the various carbon sequestration practices that are commonly thought to lead to an increase in soil carbon, and discusses whether or not they equate to genuine sequestration. They also suggest that:

“an over-emphasis on the benefits of soil C [carbon] sequestration may detract from other measures that are at least as effective in combating climate change, including slowing deforestation and increasing efficiency of N [nitrogen] use in order to decrease N₂O [nitrous oxide] emissions” (Powlson et al., 2011, p. 42).

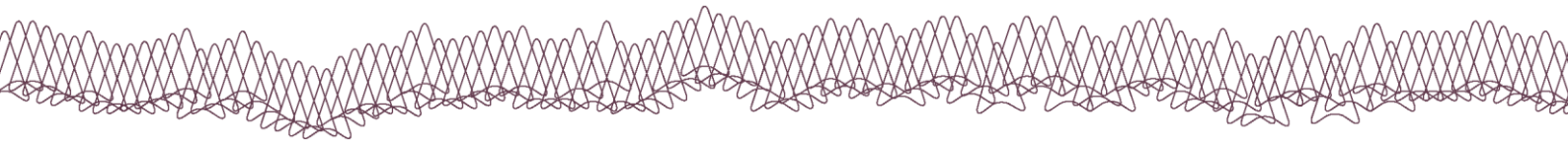
Parliamentary inquiry into soil carbon sequestration in Victoria

Environment and Natural Resources Committee (2010) Inquiry into Soil Carbon Sequestration in Victoria, the Environment and Natural Resources Committee, Parliamentary Paper No. 362 Session 2006-10. ISBN 978-0-9807561-1-1

The Victorian Environment and Natural Resources Committee (ENRC) undertook a comprehensive Parliamentary Inquiry into soil carbon sequestration in Victoria. The ENRC drew on Australia’s leading soil, climate and agricultural scientists, to investigate, in the words of the Chair, the:

“measurement of soil carbon sequestration; benefits of soil carbon sequestration for agriculture and the environment; costs and any possible detriments; and policy context and options to support soil carbon sequestration.” (Environment and Natural Resources Committee, 2010; p. xi).

The Committee recognised the various agricultural and environmental benefits associated with soil carbon sequestration, including improved; soil health, agricultural productivity, water quality and biodiversity outcomes. The Committee also identified considerable risks and challenges associated with the measurement of soil carbon and participating in carbon trading. They



also noted that some soil carbon sequestration practices may have adverse agricultural impacts and questionable economic benefits. The Committee identified a need for more scientific research to fill the knowledge gaps.

Potential for soil carbon sequestration in New South Wales

Chan, K.Y., Cowie, A., Kelly, G., Singh, B., Slavich, P. (2008) Scoping paper: soil organic carbon sequestration potential for agriculture in NSW. NSW Department of Primary Industries.

On behalf of the NSW DPI, Chan et al., undertook a worldwide review of peer-reviewed studies of field trials into a range of management practices known to sequester soil carbon. They presented their results of each management practice and the average carbon sequestration rates associated with each practice.

D.1.2 Options for carbon loss mitigation and carbon sequestration in the Southern Slopes

Blue Carbon Sequestration and Mitigating Carbon Loss from Aquatic Habitats

Coastal ecosystems, in particular tidal wetlands, mangroves and seagrass beds are important carbon sinks because they:

- are naturally highly productive ecosystems,
- efficiently trap sediments and hence, carbon, through continual tidal movement,
- sequester atmospheric carbon.

These ecosystems sequester stocks of carbon in the submerged sediments in their organic-rich soils, within living biomass both above and below ground, and within non-living biomass (e.g. dead vegetative matter). The coastal carbon stocks stored in the biomass and deep sediments in these aquatic ecosystems are often referred to as 'blue carbon' (Mcleod et al., 2011).

Blue carbon is captured and stored up to 100 times faster than in forests and stored for thousands of years (Department of Sustainability, Environment, Water, Population and Communities, 2012). However, blue

carbon is rapidly released back to the atmosphere as CO₂ and methane via conversion of ecosystems such as tidal marshes, mangroves to terrestrial land uses, or destruction of and seagrass beds (Pendleton et al., 2012).

Restoring, and or protecting coastal wetlands from degradation, has the potential to:

- stop drainage-induced releases of carbon and reactivate carbon sequestration.
- be a more economically viable way to store carbon stored (via protection and restoration of coastal aquatic ecosystems) than the alternative of terrestrial carbon storage.
- enhance industries such as fisheries and tourism
- enhance water quality, flood and storm surge mitigation.

Given the potentially large carbon emissions from degraded coastal ecosystems and other wetlands, blue carbon may offer a new opportunity for carbon sequestration, especially if incentives become available to encourage their maintenance, enhancement and/or restoration, and/or other ecosystem benefits are factored in.

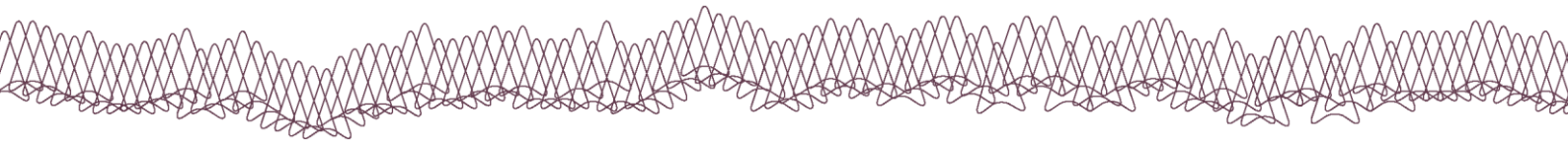
Terrestrial Carbon Sequestration and Mitigating Carbon Loss

Terrestrial (plant and soil) carbon sequestration methods fall under three general categories:

- changes in land use,
- maintenance or change in land management practices, and
- addition of carbon to the land from external sources.

An important challenge for NRM organisations across SE Australia is to ensure maintenance of existing stocks of carbon in soil and vegetation.

In order to define options for carbon sequestration across the Southern Slopes, we have developed an easy to use set of tables for common agricultural and silvicultural land-uses and systems (see Hamilton, 2014)



Carbon Sequestration and Mitigating Carbon Loss through Afforestation, Revegetation and Vegetation Management

Under Australia's Carbon Farming Initiative, Sequestration Offset projects are defined as those that:

"remove carbon dioxide from the atmosphere by sequestering carbon in living biomass, dead organic matter or soil; or remove carbon dioxide from the atmosphere by sequestering carbon in, and avoid emissions of greenhouse gases from, living biomass, dead organic matter or soil" (Department of Environment, undated).

Converting agricultural land to woody vegetation will remove carbon from atmospheric CO₂ and contribute to climate change mitigation. However, it may also have negative Indirect Land Use Change, (ILUC) impacts (Berndes et al., 2010; Powlson et al., 2011; Smith et al., 2014).

Establishing new forests, grass or perennial shrubs, (including perennial biofuel crops) where they can be successfully grown on degraded land or land of limited agricultural value, is frequently cited in most of the above - mentioned reports as one of the better options for implementing a carbon sequestration program. Powlson et al. (2011) suggest that such areas would potentially have minimal impact on food production, avoid ILUC and could include:

- polluted soils affected by past industrial activity,
- salt-affected soils;
- steep land with a large erosion and landslip risk, and
- land that has become degraded for various reasons, (excluding area with biodiverse remnants).

CSIRO studies suggest that a carbon price ranging from between \$18 - \$40/t CO₂/year (Polglase et al., 2011, 2013) is likely to be needed for carbon farming to be profitable in Australia under most plausible scenarios. A lower price (~\$18/t) is relevant to 3-4 row farm forestry belts established on areas of lowest productivity on farms in higher rainfall areas (Paul et al., 2013a). There are few areas economically viable for carbon farming-only focussed schemes. Co-benefits of revegetation such as enhanced biodiversity, connectivity and erosion control, need to be considered in any incentive scheme

design (Lin et al., 2013) and supplementary payments may be needed to make biodiverse environmental plantings competitive with other land uses. The negative aspects of carbon farming include the potential for monoculture plantations to be established replacing biodiverse remnants, and unintended off-site impacts such as reduced water security (Lin et al., 2013). (Polglase et al. 2011) discussed other social and economic factors including the availability of investment capital, loss of land management flexibility for the landholder and the economies of scale as potential constraints to carbon farming uptake.

Carwadine et al. (2015) provide an approach for assessing opportunities and spatial priorities for carbon sequestration and biodiversity restoration through biodiverse carbon plantings in Australia.

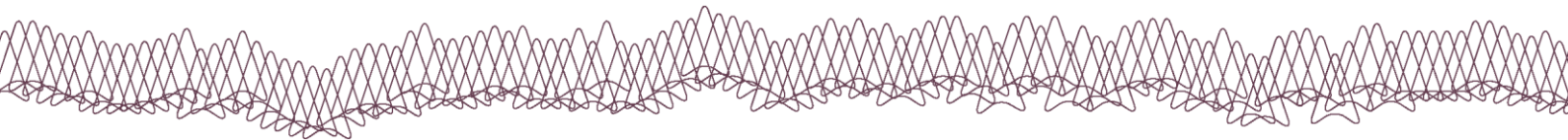
Current research indicates that revegetation may increase soil carbon significantly. However, CFI reforestation projects, do not currently include possible credits from soil carbon which requires the development of a sound carbon accounting methodology. A draft methodology is currently being reviewed for inclusion as a CFI methodology. A CSIRO-led study into soil carbon under environmental plantings is due to be completed in 2015 (K. Paul, pers. comm.).

Establishment of new industrial plantations are generally not considered to be economically viable without a carbon payment of about \$10–30 t CO₂-e (Paul et al., 2013b) under current carbon accounting rules, (which excludes carbon in wood products and soil). Even higher payments may be required to make extending rotation lengths economically viable (Paul et al., 2013b).

Polglase et al. (2008) concluded that compared to industrial plantations, carbon farming may have a potential economic advantage due to there being no associated harvesting costs.

Soil Carbon Sequestration and Mitigating Soil Carbon Loss

Soil carbon stores are in dynamic equilibrium between loss and gain of carbon. Any change in land management leading to increased carbon in soil or



vegetation must be continued indefinitely to maintain the increased stock of SOC (Powlson et al., 2011; Sanderman et al., 2010).

Carbon enters soil from a range of sources, primarily as plant residues. Thus practices to enhance growth and retention of plant residues will increase soil carbon levels. Any practice that enhances productivity and the return of plant matter (shoots and roots) to the soil is likely to lead to an increase in soil carbon, although any such increase may be short-lived, or difficult to detect for many years. Plant residue inputs are influenced by a number of inter-related factors including:

- type of plants being grown;
- amount of dry matter the plants accumulate over the growing season;
- environmental factors;

Plant and soil (terrestrial) carbon sequestration methods fall under three general categories:

1. changes in land use;
2. maintenance or change in land management practices; and
3. addition of carbon to the land from external sources (Smith et al., 2014).

A variety of management practices can slow the rate of soil carbon loss and/or increase soil carbon levels by increasing inputs.

Fire can increase in soil carbon by converting organic matter into charcoal, however this form of carbon is typically not available to plants and carbon is lost through combustion.

The CSIRO undertook a worldwide review of peer-reviewed studies of traditional management practices used to sequester soil carbon and concluded that:

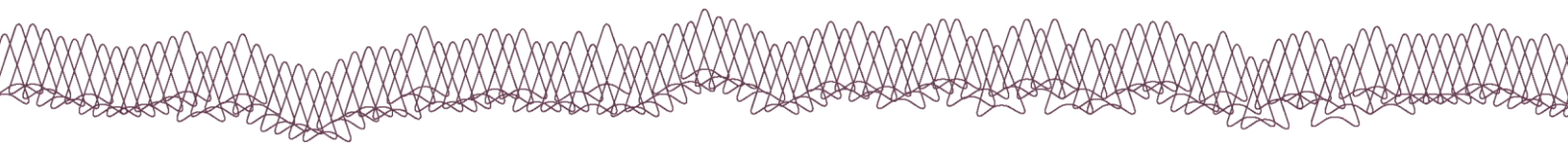
“Within an existing agricultural system, the greatest theoretical potential for [soil carbon] sequestration will likely come from large additions of organic materials (manure, green wastes, etc...), maximising pasture phases in mixed cropping systems and shifting from annual to perennial species in permanent pastures. Perhaps the greatest gains can be expected from more radical management shifts such as conversion from cropping to permanent

pasture and retirement and restoration of degraded land” (Sanderman et al., 2010, p. iv).

This CSIRO report concluded that overall farm productivity, profitability and sustainability, are likely to result from many of these management options that attempt to increase SOC tend and as such they are already being adopted in various regions of Australia.

Barlow et al. (2011) noted that CFI approved practices that increase soil carbon could significantly increase nitrogen-based GHG emissions in some regions of Australia.

The Victorian Parliamentary inquiry into soil carbon sequestration in Victoria into soil carbon sequestration recognised the various agricultural and environmental benefits associated with soil carbon sequestration, including improved; soil health, agricultural productivity, biodiversity and water quality outcomes. The Committee also identified considerable risks and challenges associated with the measurement of soil carbon and participating in carbon trading and noted that some soil carbon sequestration practices may have adverse agricultural impacts and questionable economic benefits. The Committee identified a need for more expanded scientific research to fill the knowledge gaps (Environment and Natural Resources Committee, 2010).



D.2 Identifying and prioritising adaptation options

This section describes a planning process that can address many of the challenges of adaptation planning; in particular managing uncertainties and change. Colloquially known as ‘pathways planning’, the approach can be readily incorporated into and expand upon existing adaptation planning processes. It aims to enable NRM organisations to develop an array of options that work reasonably well across a wide range of circumstances both now and in the future (Moss and Martin 2012), and that provide for inevitable changes in those circumstances.

This process described here is not meant to be prescriptive. Rather, it presented to be adapted and used at different scales and contexts.

Section **D.2.1 Developing pathways of adaptation options for NRM** outlines this pathways planning process. Broadly, the approach is used to identify and evaluate suites of adaptation options that collectively provide multiple ‘pathways’ towards an overarching vision. It also includes a proposed process for prioritising options and thereby pathways.

Section **D.2.2 Adaptation options for NRM**, presents an overview of categories and types of adaptation options that could be used to stimulate ideas and discussions about options for a pathways-based plan.

D.2.1 Developing pathways of adaptation options for NRM

A pathways approach to adaptation planning identifies various combinations and sequences of adaptation options that can be adapted as experience, knowledge and values change. Each pathway is directed toward achieving long-term adaptation objectives (Moss and Martin, 2012). See Section **A4. Establishing a vision, goals and objectives**.

To develop pathways, options are evaluated for their robustness and flexibility (Haasnoot *et al.*, 2013). Selection of preferred pathways and/or prioritising of

pathways is based on an evaluation of their constituent options using factors such as the current cost-effectiveness, feasibility, and potential maladaptation or side-effects (unintended consequences) (*ibid*).

Pathways can be developed in different ways, but the process typically starts with an agreed objective/s for an asset or area. The process can also be used to explore synergies and differences between various stakeholders’ objectives. It might also be used to identify synergistic and conflicting pathways, where one set of options (e.g. building groynes) creates benefits for one asset class (e.g. coastal vegetation) but reduces another (e.g. coastal amenity further along the coast). Used in this comparative way, the approach can help identify areas of contention and thereby, further discussion and exploration.

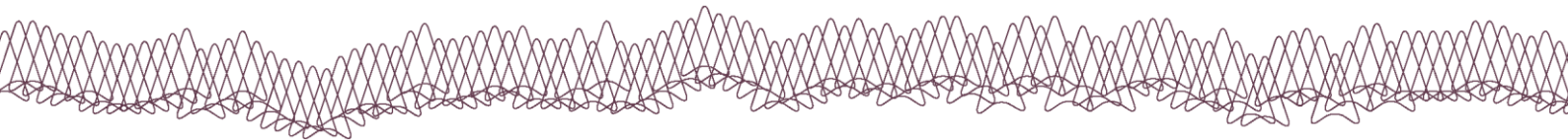
Importantly, the approach can be incorporated into and build on existing adaptation planning processes. For example, the [City of Greater Geelong’s Climate Change Adaptation Toolkit](#) includes steps around brainstorming, exploring, evaluating and prioritising adaptation options. Part 2 of that Toolkit asks whether the identified action ‘locks in’ outcomes and whether the outcomes are robust under different futures. The following process can help address these sorts of questions.

Finally, development of pathways plan does not have to result in a ‘train line’ diagram, although such diagrams are useful communication tools. For planning purposes a well-structured table can be just as useful.

One approach to pathways planning

The following outlines one potential approach to developing adaptation pathways where the objective (for an asset or area) is agreed. It also guides users to some tools and methods for undertaking these activities.

1. Explore the problem or objective
 - 1.1. Document existing activities
2. Analyse potential futures
 - 2.1. Identify tipping, turning and trigger points under potential futures



3. **Identify adaptation options**
 - 3.1. Identify adaptation options and further tipping, turning and trigger points (repeat)
4. **Develop pathways**
 - 4.1. Document and/or sequence potential options into draft pathways
 - 4.2. Analyse and evaluate the options
 - 4.3. Review and configure preferred pathways, and prioritise immediate activities
 - 4.4. Document and map pathways

Explore the problem/objective

This step is about exploring the ‘problem’ for which the planning is being undertaken in order to identify an objective for the pathways. Section A of this Report provides significant guidance on developing objectives. In pathways planning, the initial objective should be draft because it will likely change during the process of understanding the implications of managing for change. Sections A1 and A4 of the Report also explain why it is important to explore multiple frames or perspectives in developing objectives.

How a pathways approach might be used will depend on the type of issue or problem being addressed. Section B of the Report describes a process that helps to understand the issue, ‘the current situation’.

Document existing activities

An important part of understanding the current situation is identifying current activities that aim to achieve the existing objective (i.e. options aimed at

addressing existing pressures, threats and drivers of vulnerabilities). Futures analyses are not considered at this point, so options are considered within existing constraints and within the current climate.

Because people working through a pathways planning process know it is about planning for adaptation, they may raise ideas or options for addressing climate change. These ideas shouldn’t be lost, but can distract from the important process of understanding the current situation. We found the best approach is to document the ideas, ‘park them’ and then use them in the part of the process concerned with identifying potential adaptation options.

Why document existing activities?

A starting point for much adaptation planning is recognising strengths and limitations of existing actions, management and governance arrangements. In the latter stages, pathways planning extends this understanding by helping to consider how robust (insensitive to change) these might be under a range of plausible futures.

How might we identify existing activities?

This aspect is fairly straightforward. Existing options and activities can be found in relevant plans and/or in-house experts can simply be asked. Relevant documents can be collected, ‘experts’ queried, and if a workshop process is being used, then an obvious question such as “what are you/your organisations currently doing to manage this problem or achieve the objective?” can be asked of the participants. The most important aspect of this process is to seek a diversity of perspectives.

Table D.1 translates this typology into some hypothetical examples of objectives associated with issue types, and how a pathways approach might be adapted to these.

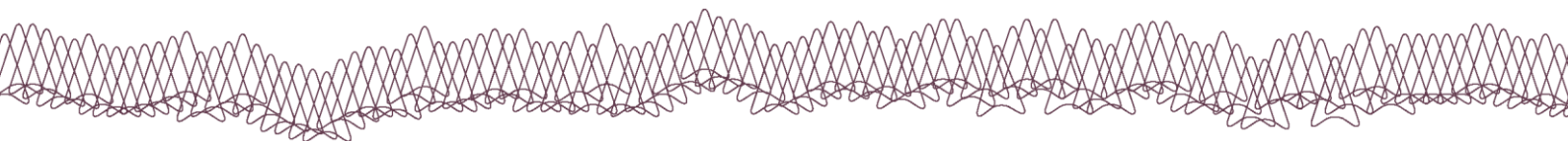


Table D.1 Issue types associated with NRM objectives with an example of a fit-for-purpose pathways approach

| | LOW VALUES DIVERGENCE | HIGH VALUES DIVERGENCE |
|------------------|---|--|
| HIGH UNCERTAINTY | <p>‘Judgement’ issue</p> <p>There is <i>high uncertainty</i> about the system and <i>stakeholders agree</i> on the objective (low values divergence).</p> <p>E.g. stakeholders agree that the objective is to maintain water quality or estuarine ‘health’, but factors impacting that objective are complex and there may be limited knowledge regarding some. In these instances, a Pathways approach could be used here to first describe their preferred future and then work to identify pathways (as combinations of actions) that would be needed to be taken to get there.</p> | <p>Issue requiring ‘inspiration’</p> <p>There is <i>high uncertainty</i> about the system and <i>stakeholders disagree</i> on the objectives (high values divergence).</p> <p>E.g. fire management for maintaining both ecological and socio-economic values. In this situation a pathways approach could be used to map out various pathways to achieving both objectives. The different pathways can then be compared to identify synergies and differences. The entire process can be used as a means to facilitate meaningful discussion surrounding the challenges of trying to achieve both objectives, and as a means of opening up potentially transformative and innovative options.</p> |
| LOW UNCERTAINTY | <p>‘Computational’ issue</p> <p>There is <i>low uncertainty</i> about the system and <i>stakeholders agree</i> on the objectives (low values divergence).</p> <p>E.g. providing retreat corridors for beach-nesting birds in the coastal reserve system. Because this land is set aside for the purpose of conservation (agreed objective) options can be developed by experts and assessed through modelling studies or other technical approaches because of extensive knowledge and research.</p> | <p>‘Bargaining’ issue</p> <p>There is <i>low uncertainty</i> about the system and <i>stakeholders disagree</i> on the objectives (high values divergence).</p> <p>E.g. retreat corridors for coastal ecosystems on private land. Unlike in the public reserve system, stakeholders are likely to have differing objectives. A pathways approach might be used to explore the implications of different possible futures and pathway options for various stakeholder groups to identify common ground and potential trade-offs.</p> |

Analyse potential futures

The next component of pathways planning involves exploring multiple possible futures. As described in Section C6 of this report, there are many ways to view the future. That Section describes a range of approaches to analysing and/or describing potential futures. Generating some possible future scenarios are then used to explore and test the robustness of potential adaptation options across multiple futures.

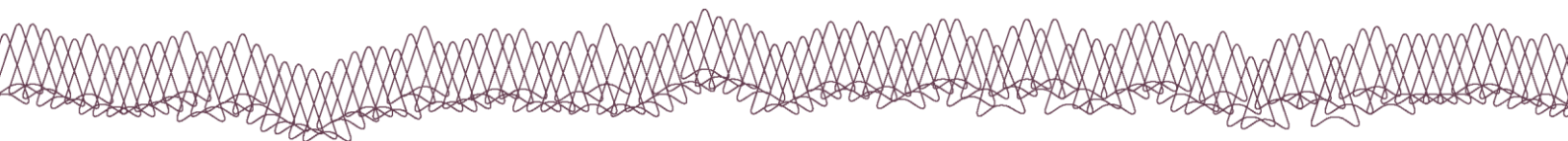
Identify tipping, turning and trigger points under potential futures

This part of the futures analysis seeks to explore potential implications of climate change for the asset/system and the robustness of current

management options across a range of plausible futures. Understanding these issues helps to inform the next step of identifying adaptation options, a range of alternate options and pathways.

Climate change becomes relevant to policy where it threatens current objectives or results in conditions that society perceives as undesirable (Werners *et al.* 2013). In adaptation planning then, the question is to what extent and for how much longer current policies and management might suffice and when adjustments will be required (*ibid*). This step seeks to explore and identify these points.

Combining information from the preceding work, this stage identifies potential possible tipping (threshold) and turning points (see definitions below) for

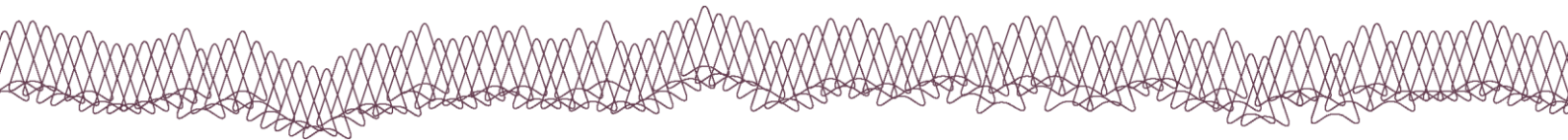


systems/assets or points in which current management and policies may perform unacceptably. As Moss and Martin (2012:410) argue, “if we can define unacceptable levels of risk and thresholds then we could potentially identify at what point we move from a low risk adaptation pathway (e.g. resilience approaches such as reducing pressure from grazing or current ‘best practice NRM’), to more high risk options (e.g. translocation, a more transitional or transformative option”.

This aspect of pathways planning is quite challenging in NRM because quantifiable indicators of tipping points are often difficult to ascertain for NRM assets. Proxies may be able to be used where system thresholds are understood. In many cases, it may be a combination of factors that push a system towards a threshold. Therefore, rather than trying to identify biophysical tipping points or thresholds, the process could seek to identify turning points - a social–political threshold, such as a threshold in societal preferences, stakes or interests.

Table D.2 Definitions and examples of Tipping (thresholds), Turning and Trigger Points

| DEFINITION | SOME EXAMPLES |
|---|---|
| <p>Tipping points - What is likely to significantly change the biophysical system?</p> <p>These are biophysical thresholds where the magnitude of change means the current management strategy will no longer be able to meet the objectives (Kwadijk <i>et al.</i> 2010). Identifying these helps to indicate whether and when other options are needed.</p> | <ul style="list-style-type: none">• an estuarine salt marsh or mangrove community unable to retreat because of geological or infrastructure constraints, or becomes permanently inundated• declining suitability of an ecosystem for a EPBC listed species• an ecosystem has shifted from threatened to endangered• more than X% of the system fails to meet connectivity measures....of.... |
| <p>Turning points - What are the plausible ‘game changers’ in the socio-economic conditions or rules?</p> <p>These are situations in which a social–political threshold is reached. This may be due to climate change (Werners <i>et al.</i> 2013), or changes in formal policy objectives as well as informal societal preferences, stakes and interests.</p> | <ul style="list-style-type: none">• A policy change relating to pricing carbon leading to landscape scale changes with implications for conservation, livelihoods and rural communities.• Proportion of regional ‘absentee’ landholders becomes too high to effectively enact current forms of community-based NRM• Community groups are consistently expressing concern about the health or absence of a species• Indigenous weather calendar markers no longer align• Ecosystem /vegetation type is approaching criteria for delisting under relevant legislation• Species shifts status (e.g. from threatened to endangered) under relevant legislation• Changes in land-use planning regulations surrounding revegetation and offsets• Proportional change in land (e.g. from grazing to cropping) indicates change in livelihoods & NRM foci• X proportion of the region’s landholders adopt ‘best practice NRM’ / become Landcare members• X proportion of Landcare coordinators seek training on ‘climate-ready’ revegetation |
| <p>Trigger points - When do we need to start?</p> <p>Trigger points mark the necessary lead time for action before a</p> | <ul style="list-style-type: none">• Obvious trend in shift of enterprise or landcover (e.g. from cropping to forestry)• Government announces review of relevant policies or legislation• Trend in ‘absentee’ regional landholders reaches trigger (x%) to change engagement |



| | |
|---|--|
| threshold is reached. They are also defined by how long a decision to change takes to be made and implemented. (This relates to the next stage of identifying alternate options). They are a crucial part of a pathways approach; enabling plans to be strategic and anticipatory, rather than reactive and ad hoc. They are useful in identifying priority actions, and are identified during the evaluation of pathways (see below) | <p>practices</p> <ul style="list-style-type: none">• Trends in ecosystem decline/change are identified and indicate x time to delisting (see turning point)• Opportunities for changes in policy, perspective, funding or governance reform (post event, elections) |
|---|--|

Why identify tipping, turning and trigger points?

‘Pathways planning’ is about identifying a range of potential adaptation options that are:

- Likely to be robust across a range of plausible futures, and
- Flexible enough to be changed or adapted as new information becomes available.

Identifying tipping points (thresholds) aims to identify how much longer and/or under what conditions current policies and management are expected to suffice and when adjustments will be required. (Alternative options in response to or ahead of these points are identified in the next step). The process not only helps to appreciate events that may cause a tipping point’ but importantly how we can prepare for it (Haasnoot *et al.* 2013), or perhaps even how we might avoid it.

This aspect of pathways planning helps planners and stakeholders discuss some of the more challenging aspects of adaptation. For example, some shifts will be unavoidable in some areas (e.g. shifts from alpine to sub-alpine systems) and in such cases, management will need to support or simply allow this shift. It is in recognising such challenges that climate change-ready objectives (Dunlop *et al.* 2013) are based. Such objectives do not aim to maintain existing ecological system but to ensure outcomes such as function, diversity and ecosystem services.

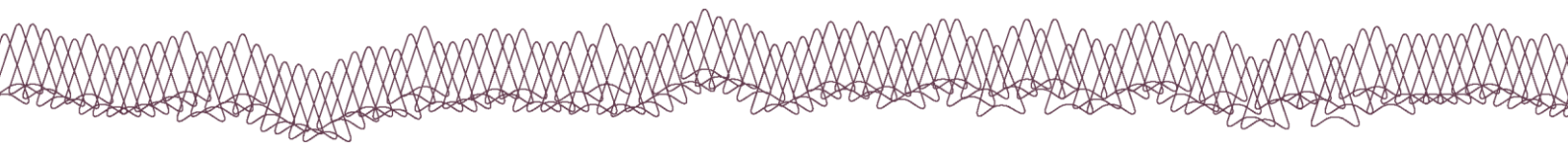
Identifying trigger points - points before a threshold where a change in action is needed - also enables an adaptation plan to be strategic rather than reactive and ad-hoc. This is also what starts to create ‘pathways’. By

enabling a strategic approach to adaptation, pathways planning allows organisations to take considered advantage of ‘windows of opportunity’ rather than reactionary responses to such opportunities. Organisations can only do this by understanding alternate system states and how to enable them (Holling *et al.* 1998), or understanding alternate options that might still enable attainment of the objective. Such opportunities could allow for transitional and transformational actions, such as where experimental sites or practices serve as case studies of what may be possible in changing from an existing regime to a new one.

‘Positive’ trigger points could include availability of funding, changes in or additions of staff, and community lobbying for alternate actions identified (or not) in the plan.

How might we identify tipping, turning and trigger points?

Methods from the Examining Potential Futures (C) of this Report can help in identifying these points. Understanding drivers of change in developing future scenarios can be informed by scientific (e.g. climate change projections) as well as creative processes. Recently updated climate change projections and dynamically downscaled outputs from Climate Futures Tasmania and NARCLIM are key scientific resources. So too are any risk or vulnerability assessments, as well as other studies regarding the potential implications of climate change for the asset, its landscape and for broader drivers or issues such as land use and socio-demographic change.



Other useful information includes some of the social-ecological systems literature that suggests systems can change abruptly, often following events (e.g. from scrubland to grassland, following two hot fires in close succession) (Holling *et al.* 1998). Such thresholds events may be identifiable (in this example, by fire frequency relative to time until reproductive maturity of dominant obligate seeders). Other thresholds are only identifiable in retrospect and trying to maintain a system in a 'desired' state can lead to perverse outcomes (e.g. reducing fire frequency in grasslands may reduce the ability of that system to function as a grassland, whereas increasing fire frequency in 'wet forests' can have significantly negative ecological impacts). Such considerations make reliance on thresholds and their identification a multi-dimensional problem.

The process also needs to identify **decision lead times** needed to change from between options - trigger points. Trigger points are typically identified after tipping and turning points have been identified, and as a result of evaluating what actions are needed to facilitate a transitional or transformational action and what kinds of decision lead-in times are required.

We could start by analysing the risk of doing nothing or waiting, and testing these across the range of plausible futures (Haasnoot *et al.* 2013). This simple process can help identify those options likely to be robust (insensitive to change) across multiple futures. It can also help identify no-regret actions.

Methods such as forecasting and back-casting (see Examining Potential Futures, Section C) that use the previously developed scenarios can be helpful in this process. The VCCCAR scenario planning guide (Wiseman *et al.* 2013) provides some guidance on developing and using scenarios in such situations.

The process attempts to identify, discuss or describe the level of change that might be considered unacceptable, as well as the kinds of conditions under which:

- an existing or potential future action may no longer be effective
- a system or asset threshold might be reached
- an asset or system might change (these changes may be directly driven by climate change, or driven

by changes in surrounding land use - which themselves may be driven by a changing climate)

- we might seek to encourage or manage the system/issue changing (e.g. from a wet to dry forest)

The EU MEdiation Adaptation project (<http://www.mediation-project.eu/>) provides an excellent guide to understanding tipping and turning points. Work by Kingsford and Biggs (2012:32) also provides potential example thresholds for freshwater systems and waterbird habitat.

Having identified a threshold or turning point, we can work back to define when that asset or system may be heading toward a threshold, or how we would know that a threshold is approaching. These indicators can then form 'trigger points' for changing options or actions. There may be a series of trigger points, which could be flagged with increasing urgency, such as yellow, orange and red.

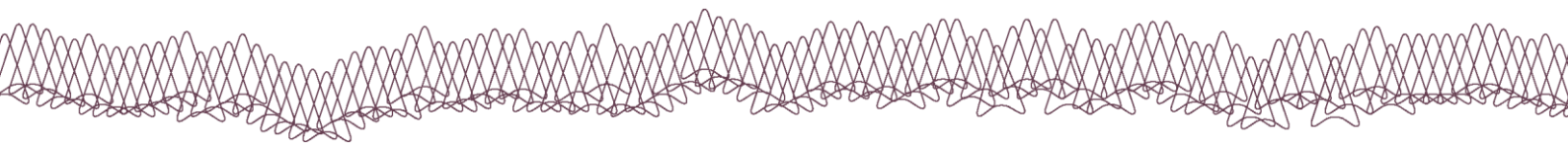
Identifying 'positive' trigger points - e.g. availability of funding, change in or addition of staff community champions or political will - can be done while potential pathways are drafted in the following stages. Identification of such trigger points is based on questions as simple as: what would we need to enable this transitional or transformational action?

Trigger points are also those points that indicate decision lead-times for enabling an adaptation option (See the next stage for this).

Kingsford and Biggs (2013:35) also provide some hypothetical examples of how trigger points can inform management actions in attempts to avoid reaching identified thresholds in freshwater systems and waterbird habitat.

Identify adaptation options (& further tipping, turning & trigger points)

This stage is about identifying potential adaptation options. These options aim to avoid, limit or remove impacts on the system (and/or threats and pressures) from a changing climate and other socio-political-economic and environmental factors, as identified in the exploration of potential futures above. As



previously discussed, options may also aim to address underlying drivers of a system or asset's vulnerability to climate change impacts.

Once identified, tipping, turning and trigger points for these options also need to be considered. Importantly, where an option is identified as an alternative to a potentially less robust option, the decision lead time they require (trigger points) before they can be implemented, also needs to be identified.

Why identify alternate and additional options as adaptation options?

This stage is part of the systematic approach to developing potential pathways. This is the crucial part of the process that enables a plan to be strategic and adaptive, rather than reactive and ad hoc.

How might we identify alternate and additional options?

As discussed above, the following sub-section D2.2 outlines key concepts and some ideas for NRM adaptation options. As discussed throughout this Report and the Pathways Planning Playbook (Bosomworth *et al.*, 2015), there are a range of tools and methods to help identify potential options. Some of these are outlined below. The choice of tools and methods is very much informed by the issue type identified in **C.5 Analysing possible futures**. The most important aspect of whichever tools and methods are adopted is working with a diverse range of perspectives and enabling creative enquiry.

The Tables below present some methods for identifying options. It uses the terms 'experts' and 'stakeholders' to differentiate between two subtly different roles in planning and management. However, experts can be stakeholders and stakeholders can be experts.

- 'Experts' can often identify the critical aspects of a system that the decision-makers (stakeholders) need to take into account. Such people could include researchers, people with local knowledge, and landholders.
- 'Stakeholders' pull together existing information to frame and address problems. They include government departments and statutory authorities,

landowners and managers as well as resource users and beneficiaries of management actions.

Scenarios developed in the Futures Analysis stage should be used here. Section C6 of the Report outlines the use of scenarios for exploring potential futures. Techniques such as foresighting and backcasting can again be used to identify means of accomplishing preferred futures by actions relevant to local or regional drivers of change. However, it is important that such methods are used to explore options under multiple plausible futures - the whole point of a pathways approach. In turn, the actions identified under different scenarios can then be 'tested' for robustness across the range of futures, and tipping and turning points of potential future options can also be explored.

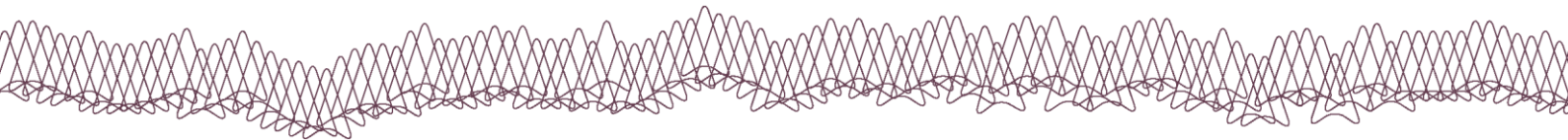
Identifying options is essentially a creative process, so it is important to have diverse and creative participants involved, depending on the type of issues associated with the objective. Participants should be able to constructively work together, and to raise, discuss and consider things that are not currently sanctioned or normalised (Robinson 2012).

There are potential trade-offs between inclusive and creative processes that draw on diverse perspectives (that potentially lead to a wider array of possible options) and more closed processes with 'the usual suspects' (who may be constrained by institutionalised ways of thinking, or may perceive more creative ideas as 'unrealistic'). The point of this process is to be creative and not evaluate potential options (yet).

Because of the need for creativity and imagination in this phase, computational approaches are unlikely to provide more than minimal guidance. Equally, the process requires more than a general 'brainstorming' session. Rather, participants should articulate how an options could contribute to the objective, over what time period and who would need to do what (in general terms at least) to implement it. Instruments such as the Bennett's Hierarchy might be used to help with clear description of outcome oriented options and the 'level' at which they operate (e.g. new knowledge creation, behaviour change, etc.).

Key questions to be considered at this stage include:

- What is the purpose or aim of the option?



- How does it contribute to achieving the objective?
- What roles might various stakeholders play, including the NRM organisation?

Once again, identified options can be included in a spreadsheet in which existing options were captured, remembering to include details about the conditions they are trying to address. Importantly, some options will require different forms of action by different stakeholders and these actions should be specified at this stage as specifically as possible. In particular, the role of the NRM organisation should be made clear.

Broadly, that role is likely to be one or more of the following:

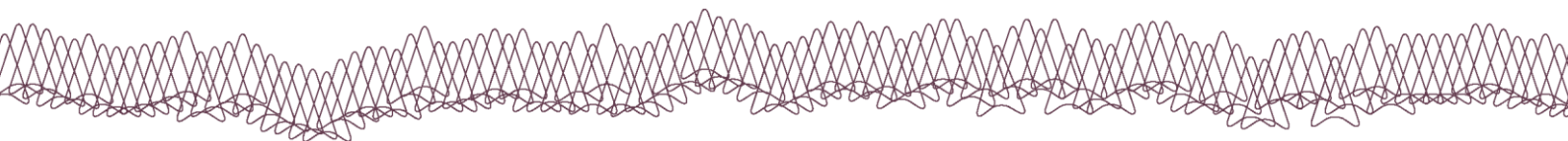
- On-ground activities
- Incentives - funding and policies
- Community engagement and development
- Advocacy - for policies, programs & regulations etc of stakeholders such as local governments
- Collection and/or provision of data - including maps such as floodplain maps

Table D.3 Examples of tools & processes for identifying and assessing potential options for computational issues and/or those requiring judgement

| PROBLEM TYPE | OPTIONS IDENTIFICATION & RELEVANT TOOLS | OPTIONS ASSESSMENT & RELEVANT TOOLS |
|---|--|--|
| Computational Low uncertainty on system dynamics and low values divergence regarding goals/objectives. | 'Experts' generate or list of possible options, and stakeholders add, edit and refine the list. <ul style="list-style-type: none">• Real Options Analysis (ROA)• Modelling | Computational tools or expert assessment <ul style="list-style-type: none">• Cost Benefit Analysis (CBA)• Real Options Analyses |
| Judgement Low values divergence on goals/objectives but high uncertainties. Stakeholders can agree on options but don't know if they will work. E.g. Maintaining high quality/health waterways through reduction of nutrient leaching from irrigation expansion (general agreement). We may not know enough system function or dynamics to understand whether actions will achieve outcomes, partly because uncertainty around rainfall changes/projections is high. There is a strong emphasis on learning through research and evaluation of options(i.e. adaptive management) | Experts identify risks and uncertainties and potential areas for future research with stakeholders. Stakeholders would participate in dialogue with experts to frame priority outcomes, and discuss 'contributions/ capacities' of stakeholders identified. <ul style="list-style-type: none">• Foresighting• Backcasting | Stakeholders & experts collectively evaluate potential actions and research <ul style="list-style-type: none">• Multi-criteria decision analysis• Real Options Analysis (ROA) |

Table D.4 Examples of tools & processes for identifying and assessing potential options for issues requiring bargaining and/or inspiration

| PROBLEM TYPE | OPTIONS IDENTIFICATION & RELEVANT TOOL | OPTIONS ASSESSMENT & RELEVANT TOOLS |
|---|--|---|
| Bargaining Low uncertainty but values diverge. E.g. Declining populations of, or Orange-bellied parrots. Estuarine wetland | Experts provide information regarding well understood system drivers or threats (drivers of the problem e.g. road kill). These system drivers help | Stakeholders & experts collectively evaluate potential actions and research, and explore reframing of the problem |



| | | |
|---|--|---|
| management. Floodplain management. | understand what is at stake for whom and how different management options effect stakes. Stakeholders would be involved in well-facilitated, participatory examination of relationship between threats and stakes. They would add to, edit and refine the options for addressing the threats. Collaborative Habitat Investment Atlas Citizen science | Multi-Criteria Assessment Participatory, deliberative processes |
| Inspiration High uncertainty and high values divergence regarding goals/objectives. E.g.s. Rain/tall forest conservation, oyster deaths in Georges Bay, fire management. | Many stakeholders need to be involved. Process requires leadership to effectively mediate and facilitate linkages between information and decision-making. NRM bodies can act as 'boundary organisation' to facilitate decision-making among parties, as well as capacity building and social learning among participants. Learning is a key interim outcome. Participatory scenario planning | Stakeholders & experts collectively evaluate potential actions and research, and explore reframing of the problem Multi-Criteria Assessment Participatory, deliberative processes |

Develop pathways

This 'final' stage is a significant piece of work, as it involves drawing all the previous work together to sketch out potential pathways. It does this by:

- Documenting and/or sequencing potential options into draft pathways
- Analysing and evaluating the options
- Reviewing and configuring preferred pathways (for whom), and prioritising immediate activities
- Documenting and mapping pathways

Why document, analyse, review and draft pathways?

Each pathway is a combination of adaptation options and needs to be evaluated against a range of criteria. This process may eliminate or alter some of the pathways. Evaluating options helps in choosing priority actions and pathways.

The evaluation also seeks to compare current organizational conditions and the areas of adaptation required for each scenario to identify key issues, risks and success factors that need planning for or addressing. This is particularly important for NRM

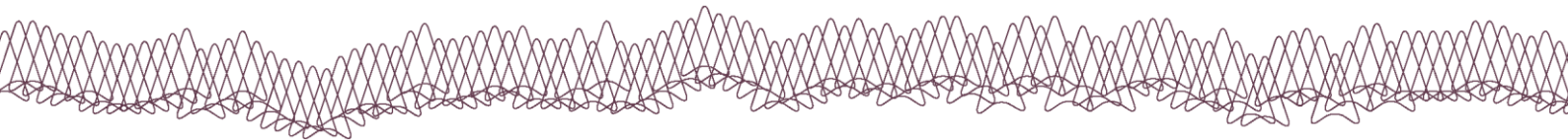
organisations such as CMAs, because they are often not the 'lead agency' for a particular action. In these cases, an NRM organisation may have to nominate its action as advocating for a particular action or change.

Documenting and analysing draft pathways enables an organisation to evaluate the 'gap' between current management practices and the resources, skills, political and community support, the language and culture needed to enable the transitional and transformative actions. This can be achieved by asking practical questions such as what sorts of resources, funding, skills, knowledge, and community and political support do we need to implement those actions? What systems, even cultures (organisational, community, political) might we need to explore and challenge to facilitate that support?

How can we document, analyse, review and draft pathways?

As described above, there are four main aspects in drafting pathways maps (and their supporting documents):

- Document and/or sequence potential options into draft pathways



- Analyse and evaluate the options
- Review and configure (negotiated) preferred pathways, and prioritise immediate activities
- Document and map pathways

There is significant amount of work involved in mapping pathways into comprehensible diagrams, and the additional analyses may alter and add adaptation options. Therefore, it is suggested that the options are simply documented at this stage.

Typically existing activities are documented first, with any tipping, turning and trigger points identified. Then no-regret options and options that are robust across most futures are documented or highlighted, with their tipping, turning and trigger points identified after this initial documenting (if they have any). Transitional and transformative options are lastly documented, with their own tipping, turning and trigger points identified.

Analyse and evaluate the options

As with all planning, potential options need to be considered against a range of criteria including cost, feasibility, acceptability and side-effects. The literature indicates a range criteria, including:

- Supports one or more of the Portal Fundamentals for adaptation in NRM
- Potential for maladaptation (e.g. negative impacts on other assets, species, or values; or creates a 'dead-end')
- Other constraints - physical, socio-political, financial, or social
- Flexibility: what options are left if a strategy must be adapted or replaced by a new one? (Haasnoot *et al.* 2011)
- Sustainability: Considering the performance of a strategy under different possible futures and the possibility to adjust a strategy, which adaptation pathways are then sustainable? Can we find pathways that are sustainable for both physical and social events? (ibid)
- Assess strategies actors may use to respond to turning points, consider different or additional strategies to postpone or resolve a turning point, and assess how easy it is to switch between strategies in time (Werners *et al.* 2013).

Table D.5 presents some tools or methods that can help in evaluating options.

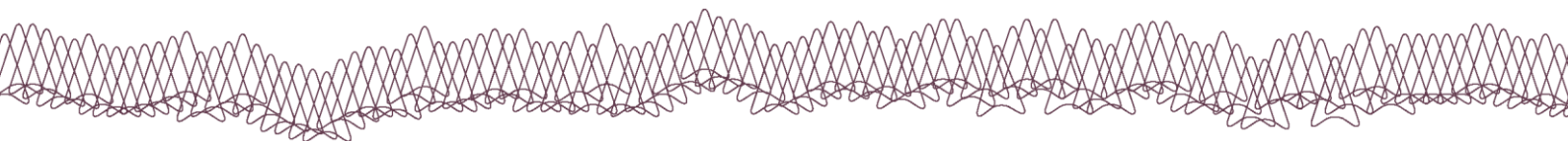
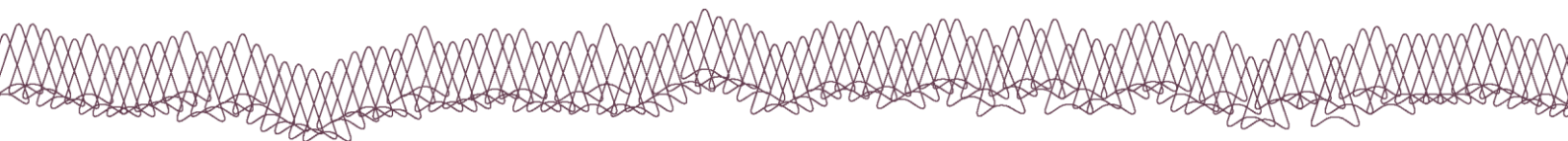


Table D.5 Tools or methods for evaluating adaptation options (adapted from Watkiss and Hunt 2013)

| METHOD | MOST USEFUL WHEN/FOR | STRENGTHS | WEAKNESSES |
|---|--|---|--|
| Cost-benefit analysis | Making single decisions Where data is quantifiable & agreed - computational problem | Simplified CBA identifies a clearly preferred option using a method that has credibility with many government agencies and that has been widely validated. Social welfare and equity concerns can be considered within the CBA framework | Cannot deal with indirect benefits Does not consider redistributional effects Highly dependent on discount rates |
| Cost-effectiveness analysis compares alternatives for similar outputs or objectives. | Where CC uncertainty is low, & good data exists for major cost/benefit components. For consideration of low & no regret option appraisal (short-term), especially for non-market sectors; As part of an iterative risk management framework | Avoids monetary valuation of benefits, but quantifies benefits in physical terms Short-term assessment, for market and non-market sectors Clear headline indicator & a dominant impact | Necessary metric for outcomes difficult to identify for adaptation Less applicable for cross sectoral and complex risks |
| Multi-criteria analysis | Judgements on the importance of the various criteria are needed to assess options Multiple objectives Monetary benefits are only part of the assessment criteria | Can provide a thorough analysis of the most suitable criteria that decision makers can adopt in their decision making, can categorize and rank promising and feasible adaptation options | Inevitably subjective, and/or requires very large stakeholder input, in relation to the scoring and weighting assessments |
| Real options analysis provide quantitative economic information on uncertainty & risk in cases with flexibility on timing of investment decisions & some potential for learning | Considering value of flexibility with respect to the timing of original capital investment, or adjusting size and nature of investment over a number of stages in response to unfolding events. CC risk probabilities are known or the range is within bounds Most relevant to large, capital intensive investments such as dam storage. | Economic comparison of investing now versus waiting, & flexibility, i.e. comparing if the additional marginal cost (or lower initial benefits) of added flexibility is offset by the option value for future learning. Can support initial enabling steps to help secure projects for future development (should they subsequently prove to be appropriate) even if they are not expected to be cost-efficient on the basis of traditional, static CBA | Primarily for project level rather than aggregate analysis Potential data constraints re probabilistic CC information and limited quantitative impact data. Identification of decision points in complex dynamic CC pathways and align with climate data (noting that time periods may not align) may prove difficult practice. Likely requires expertise |



| METHOD | MOST USEFUL WHEN/FOR | STRENGTHS | WEAKNESSES |
|---|---|---|--|
| Robust decision-making seek strategies that are robust, rather than optimal, over many future outcomes. | Situations of deep uncertainty, i.e. absence or limited probabilistic information on scenarios & outcomes. Where CC uncertainty is high (e.g. direction of change) | Can test many strategies & identify robust strategies. Can consider economic or non-economic (physical) benefits | Lack of quantitative probabilities can make it more subjective, influenced by stakeholders' perceptions. Formal application has a high demand for quantitative information, computing power, and expert resources |

The NSW Department of Primary Industries website also provides a list of additional assessment guides and tools across three broad areas:

- General economic impact assessment
- Integrated socio-economic impact assessment
- Social impact assessment

Review and configure preferred pathways and prioritise immediate activities

This step involves taking all the information produced in the preceding steps and drafting pathways. It then involves exploring management actions to support the identified potential options and pathways. For example, if translocation is identified as a potential option for a threatened species under a particular scenario, there is a need to identify the sorts of actions, knowledge, community support and partner organisations that may be needed (required) to enable such action. An analysis can then be made of the 'gap' between these requirements and current resourcing, programs, governance arrangements etc. This process may itself identify further adaptation options

The process reflects a kind of backcasting; wherein practitioners 'work back from' an action or option, and SWOT processes can help to explore these issues in a formal way (Wiseman *et al.* 2013). These authors also suggest however, that such explorations can raise significant 'unknowns, which can trigger other new issues that are uncertain and can distract from the planning process. To avoid this distraction, they suggest focussing on the boundaries of the objective that was developed early on and refined with stakeholders at the start of the process.

The process of choosing preferred pathways will be a negotiated process informed by the preceding evaluation of options. Prioritisation is then given to those options and actions that can be implemented or supported immediately. In many cases, these will be the no and low regret actions, as well as those that are robust across a multitude of futures.

Document or map pathways

There are several tools and methods available to help CMAs draw or depict potential pathways. Some of these are computer-based and some are as simple as initially working with pen, paper and informed, creative people. Some free online software (untested) includes:

- <https://www.treeage.com/>
- <http://www.smartdraw.com/>
- <http://www.palisade.com/precisiontree/>

This stage maps out or documents the sequencing of potential pathways. As was highlighted in the Introduction to this Section, the development of pathways does not have to lead to one of the currently popular 'train line' diagrams, although such diagrams are a useful communication tool. Pathways can also be documented in a well-structured table.

Nonetheless, some examples of the 'subway type' maps are presented in Figure D.1, Figure D.2 and Figure D.3.

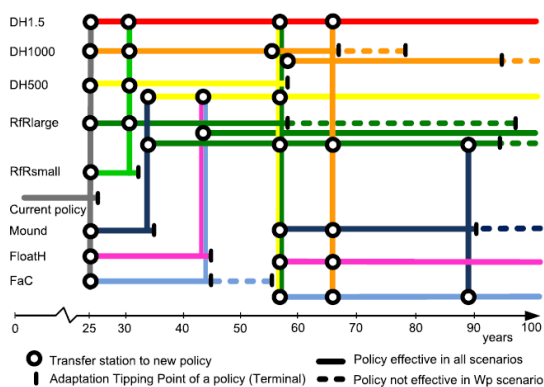
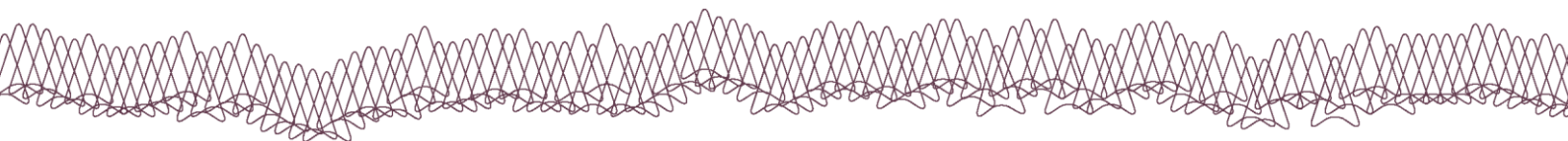


Figure D.1 Pathways for river deltas (Haasnoot et al. 2012)

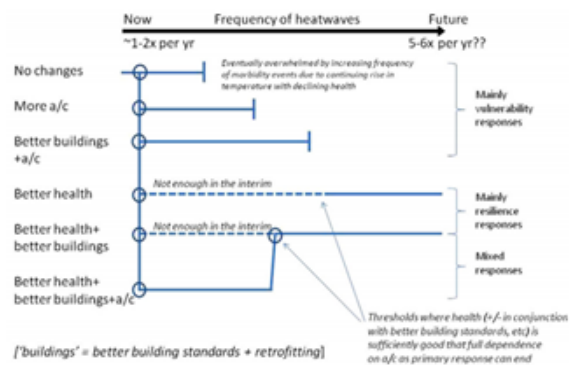


Figure D.3 Pathways for remote marginalised communities (Maru et al. 2014)

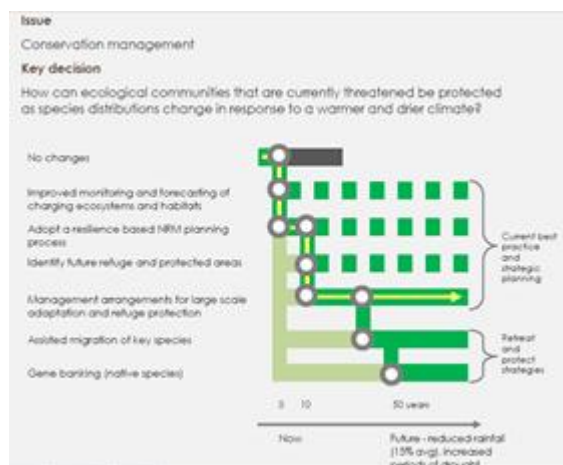
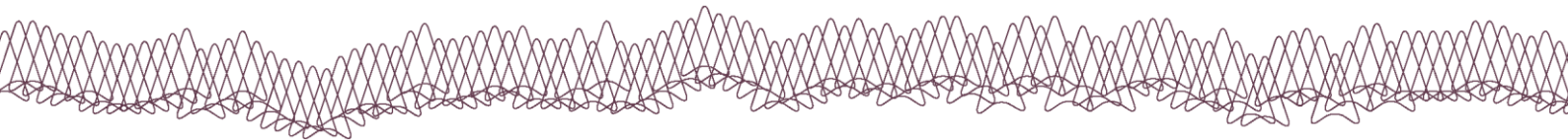


Figure D.2 Pathways for the Eyre Peninsula (Seibentritt et al. 2014)

Figure D.3 is from a Special Edition of Global Environmental Change, (Vol 28 2014), several examples of the use of pathways planning were discussed. These included the one below from Maru et al. (2014) regarding the use of adaptation pathways to discuss adaptation in remote marginalized communities.



D.2.2 Adaptation options for NRM

This Section can help planners consider a range of ways of conceiving adaptation in NRM, and consider options within adaptation pathways. It begins with an overview of generic ‘types’ of adaptation, before outlining some adaptation fundamentals as they relate to NRM. Finally, it draws on the literature and a variety of NRM plans and reports to present some examples of ‘asset’ adaptation options classified in terms of ‘resilience’, transitional or transformational type options. However, this last categorisation

Generic ‘types’ of adaptation

There are many ways to think about, describe and classify adaptation options. The list below presents some generic ‘types’ of adaptation actions:

No regret - these actions are usually beneficial for reasons beyond adaptation or mitigation and include actions that save money and/or energy or provide resilience to vulnerable systems from other non-climate threats. They are actions that would generate social or environmental benefits whether or not climate change occurs (IPCC 2014c:878; Hallegatte 2009:244), and tend not to involve significant trade-offs with among policy objectives (Moss and Martin 2012). They are typically options that are robust across the range of possible futures (Lempert and Schlesinger, 2000) For example: managing weed and pest invasions. Comer *et al.* (2012) suggest ‘no-regret’ options can be adopted immediately. Generally, current good activity NRM includes many ‘no regret’ actions (e.g. riparian fencing, weed eradication, capacity building, etc.)

Contingency arrangements are actions that enable preparedness for surprises or unprecedented extremes, and include building generic forms of adaptive capacity. Some examples include: providing seed stores, developing mosaic fuel reduction burning, procuring equipment and materials that can be repurposed for rehabilitation works before a possible extreme event. In California Comer *et al.* (2012: 41) note that some planners identify the range of actions that are needed to anticipate plausible events over the coming 5-15 year period. For example, they manage “water control structures at the system level to meet multiple

demands (including in stream flows)” (Comer *et al.* 2012: 41).

Win-win actions are those that will provide more than one positive benefit across social, environmental or economic outcomes if implemented. They contribute to adaptation whilst also having other benefits, such as greenhouse gas mitigation (Moss and Martin 2012). For example, improving water quality has habitat, agricultural productivity and human health benefits.

Low regret actions - incur relatively low costs and that provide a relatively high benefit through reducing climate change impacts or vulnerability, or increasing adaptive capacity (Moss and Martin 2012).

Safety margins - refers to inclusion of a safety margin to account for uncertainty in projections or future impacts. For example, designing the foundations of a sea wall to allow for future sea level rise and storm surge is best done with attention to extreme events and the error margin around their likelihood. These actions reduce vulnerability at null or low costs, and are thus also often considered as low regret options. For example, “water managers in Copenhagen now use run-off figures that are 70% larger than their current level. Some of this increase is meant to deal with population growth and the rest is to cope with climate change, which may lead to an increase in heavy precipitation over Denmark” (Hallegatte 2009:244).

‘Soft’ strategies - include institutional or financial tools, such as changes in the planning guidelines, implementation of adaptive management, insurance for extreme events, and creation of specific institutions to analyse coastal flood risks on a regular basis and to implement upgrades when required (Hallegatte 2009:245).

Short consequence actions – aims to reduce the length of the consequences of decisions. For example, planting of short-lived trees that can be replaced with others that become more suitable as the climate changes (Hallegatte 2009:245).

Preventative –approaches are targeted to avoid unsustainable investments, policies or other measures that promote areas that are already, or highly likely to become, at high risk from climatic events. For example, prohibiting the construction of homes in flood-prone

areas that are likely to be subjected to even higher flood risks due to sea level rise or increased rainfall intensity is a preventative approach.

Watch and Wait – refers to an active form of learning through observation or experience of change. This approach may be appropriate, where there is substantial uncertainty about the direction and/or

extent of local or regional change. It comprises part of a long term adaptation strategy where it has been determined that there is no significant benefit in taking a particular action immediately (EEA 2014). This can help identify potential actions to anticipate over the 15-30 timeframe, with indicators to monitor and inform that future decision (Comer *et al.* 2012).

Flexible/ Reversible - able to be changed. E.g. restrictive land use planning policies (Hallegatte 2009:244). Figure D.4 displays a way of ‘mind-mapping’ the various categories of adaptation options discussed.

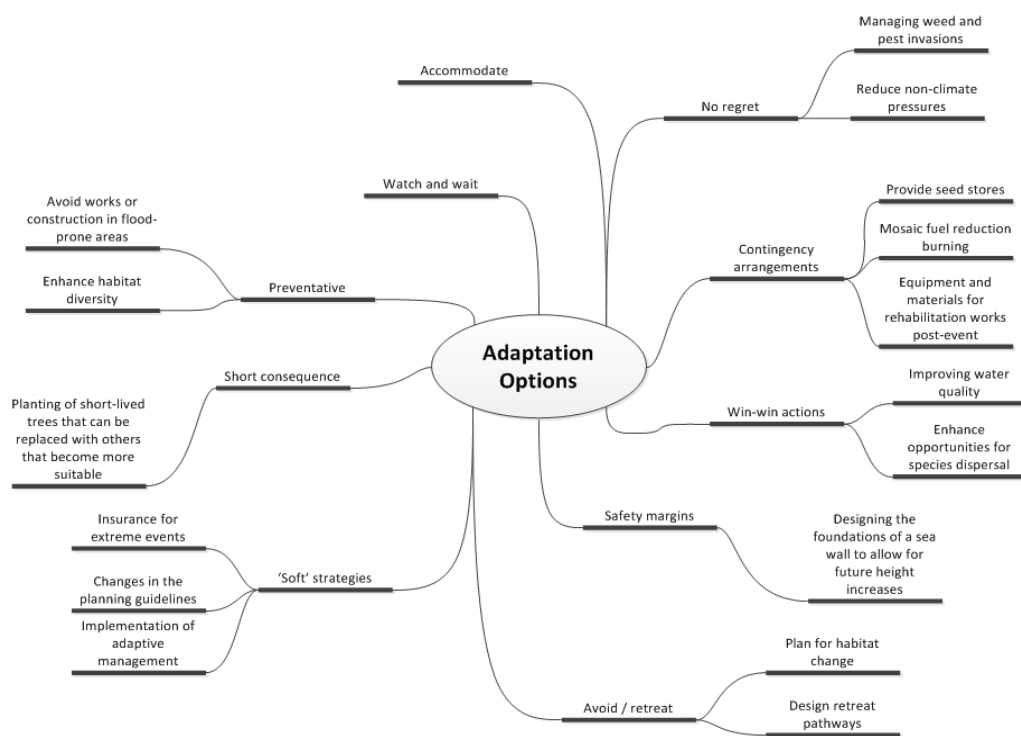


Figure D.4 A ‘mind-map’ of various options under these broad ‘types’ of adaptation

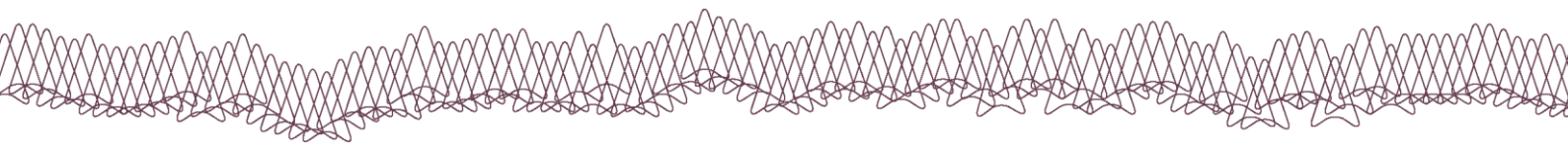
Fundamentals principles for NRM adaptation

The generic ‘types’ of adaptation discussed above can be expressed in terms of some fundamental principles for NRM adaptation.

“There are important synergies between being well positioned for climate change adaptation and best

practice regional NRM. Successful regional NRM bodies will incorporate climate change adaptation into their core business at all levels, bringing their communities with them” (Campbell 2008:vii).

There is international recognition that best-practice NRM is fundamental to adaptation. For example, Scottish Natural Heritage (2012:17) have identified



some fundamentals for adaptation in conservation that are consistent across the literature and are highly relevant to the Southern Slopes context:

- **“Reduce other pressures** on ecosystems, habitats and species – e.g. pollution, unsustainable use, grazing, habitat fragmentation and invasive non-native species”
- **“Make space for natural processes** including geomorphological, water and soil processes, and species interactions”
- **“Enhance opportunities for species dispersal** by reducing fragmentation and increasing the amount of habitat available”
- **“Improve habitat management** where activities such as grazing, burning or drainage cause declines in diversity or size of species populations, or where modifying management or increasing habitat diversity could improve resilience to climate change”
- **“Enhance habitat diversity**, e.g. by varying grazing management on grasslands or wetlands, or creating new habitats on farms”
- **“Take an adaptive approach** to land and conservation management e.g. by changing objectives and management measures in response to new information” [Developing and implementing adaptation pathways is a key way of achieving this]
- **“Plan for habitat change** where assessments indicate losses of habitats or species are inevitable, for example as a result of sea-level rise”

Examples of NRM ‘asset’ adaptation options

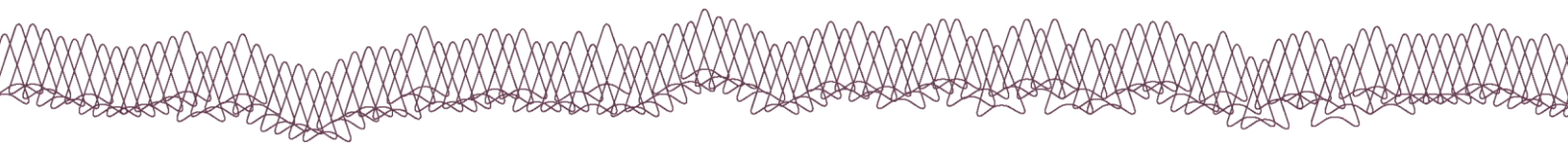
The potential options listed below are drawn from a broad literature but are by no means a definitive or exhaustive list. Rather, they are presented to help to stimulate ideas.

As described in the preceding sub-sections, adaptation options can aim to reduce exposure or sensitivity to climate drivers before a system reaches a tipping point or threshold. In NRM, some climate change impacts can be reduced by reducing non-climate pressures on systems, such as those from other human drivers of

degradation. Generally, options that seek to achieve these purposes might be considered to be aimed at the building or maintenance of a system’s resilience. However, as has also been discussed throughout this report, adaptation options might also aim to enable the transition or transformation of an ecosystem or a practice.

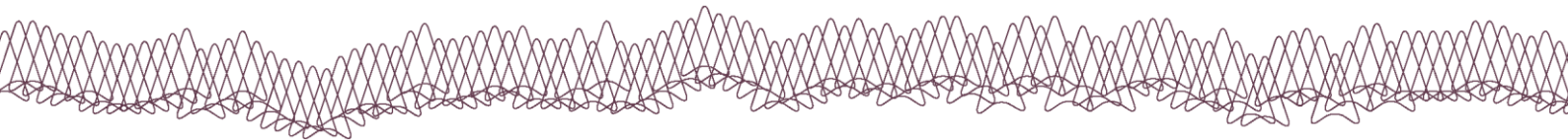
Consequently, adaptation planning requires us to think beyond merely direct management of an ecosystem. Like most NRM there are a range of activities that can support adaptation options in NRM, and the role of an NRM organisation in enabling these activities should be identified. Broadly speaking, adaptation activities can be aimed at resilience, transition and/or transformation, and can be typified under one of the following categories of activity:

- **Adaptive capacity building:** (see SCARP Guide to Adaptive Capacity). This includes development of capacities within the social system: for example, through community engagement, education and extension. Actions could also include R&D for targeted and improved understanding of systems, M&E, and building agreement amongst stakeholder groups for particular actions and/or research.
- **On ground works:** for example planting for habitat connectivity, fencing for protection of particular areas, engineering works such as levees and other hydrological works, and management of pest plants and animals, biosecurity
- **Incentives** - Are widely, but essentially encourage desirable behaviour through providing resources to encourage it. Instruments as covenants and acquisitions, and market-based instruments including tradeable permits or quotas, insurance arrangements and offsetting are examples.
- **Policy** - for NRM organisations this will generally involve working with local, state and/or federal governments in policy development or review, or advocating or lobbying for changes to policy including legislation and regulation.
- **Governance arrangements** – this can relate to reforming the way NRM organisations make decisions within themselves or with others, including improving processes and systems for



decision-making, transparency, inclusion, accountability, and other aspects of governance (see Section A of this report).

- **Research and innovation** – investment in research to better understand issues, represent problems or develop new innovative solutions to emerging policy challenges and opportunities
- **Information and communications** – dissemination of targeted or large scale information or communication campaigns. Communication efforts can be particularly effective when they are strategically embedded in broader engagement activities
- **Advocacy** – this would involve supporting other organisations in their activities that contribute to NRM objectives, such as supporting local governments in revising land use planning policies
- **Monitoring** - monitoring is a crucial component in all adaptation implementation. It is vital in identifying trigger, turning and tipping points in adaptation pathways (see **D.2.1 Developing pathways of adaptation options for NRM**) and to underpin learning (see **Q**



- **Approaches to monitoring, evaluating and learning).**

The following tables present a range of adaptation options (for a selection of NRM assets) that are grouped according to whether they are generally aimed at resilience, transition or transformation; against the ‘type’ of activity that might enable that resilience, transition or transformation.

These options have been drawn from the literature and other plans and reports. Collectively, they highlight that

adaptation in NRM is about more than directly managing an ecosystem or species. Table D.6 presents some potential adaptation options for coastal and estuarine assets. Table D.7 presents some potential adaptation options for assets grouped under the generic title of ‘water’. Finally, Table D.8 presents some potential adaptation options for biodiversity.

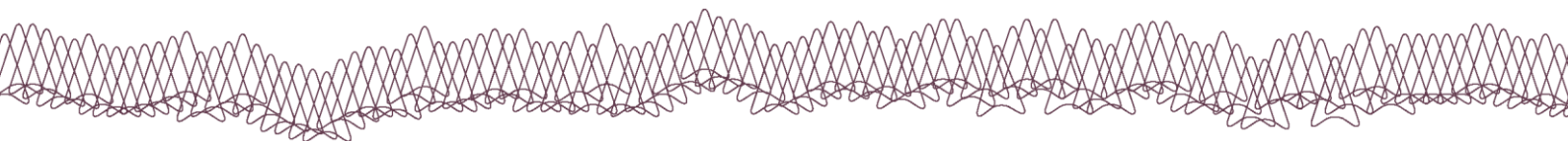


Table D.6 Coasts and estuaries: examples of resilience, transitional and transformational options

| | RESILIENCE (BAU) | TRANSITIONAL | TRANSFORMATIONAL |
|---|---|---|--|
| Social capacity (engagement, etc) | Community forums regarding the implications of climate change for coasts and estuaries, and adaptation options | Community forums regarding retreat pathways for coastal systems | Community groups are involved in establishment/management of retreat pathways |
| On ground works (active management) | Establish buffers and rolling easements around coastal reserves and wetlands to allow migration and displacement of habitats (AECOM 2013) Restore tidal marshes, seagrass meadows, and mangroves, since together these stabilise estuary function by providing diverse vegetation structure (Julius <i>et al.</i> 2013) | Establish buffers and rolling easements around coastal reserves and wetlands to allow migration and displacement of habitats (AECOM 2013) | Leave dunes to breakdown/erode through sea-level rise |
| Incentives | Establish water trading mechanisms to manage water between tidal estuaries and upstream habitats (AECOM 2013) | Grants for establishment of trial retreat locations | Grants for maintenance and establishment of 'retreat'/new locations |
| Research | Identify potential retreat locations for threatened habitats | Implement experimental sites for retreat locations | Facilitate retreat |
| Advocacy (for policy, legislation etc) | Support Coastal Board policies concerned with ensuring development is adapted to the expected impacts of sea level rise, including dune drift, flooding and coastal erosion (Words from relevant Coastal Board plan). Support policies protecting existing coastal habitats and estuaries | Support policies encouraging planned retreat in relevant locations | Support policies that protect/ enhance newly established 'retreat' areas |
| Planning | Update land use planning mapping to identify areas where climate change related threats are substantial including coastal (sea level rise and coastal erosion) and bushfire risks. Develop coastal adaptation plans which identify where the existing coastal buffer is of sufficient width to accommodate future impacts, where immediate protection or retreat is required, and how adaptation actions can be undertaken (AECOM 2013). | Experimental sites for retreat locations Experimental sites that allow saltwater intrusion | Allow transgression of sea in wide dune areas (E.g. trial near Perkpolder, Zeeland, the Netherlands Link) |
| Monitoring | Monitor SLR, salt-water intrusion, habitat loss and expansions, impacts, etc | Continue general monitoring program. Monitor experimental retreat or translocation sites. Review monitoring program | Continue general monitoring program. Include additional sites and issues into monitoring program. |

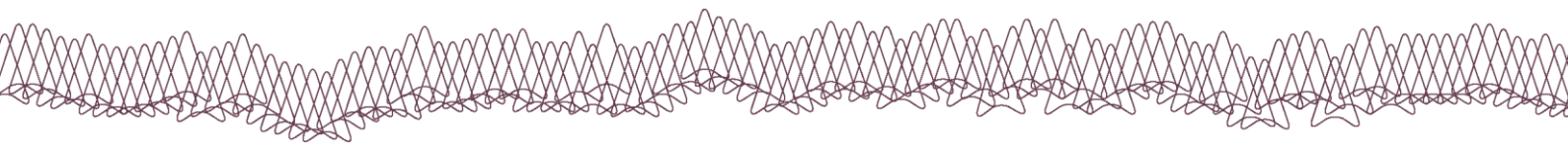


Table D.7 Water: examples of resilience, transitional and transformational options

| | RESILIENCE (BAU) | TRANSITIONAL | TRANSFORMATIONAL |
|---|---|--|--|
| Social capacity (engagement, etc) | <p>Develop opportunities for water reuse and harvesting, including fit-for-purpose water use in townships</p> <p>Increase genetic diversity in river systems and maintain habitat complexity to communities safeguard sources for recovery regardless of climate change (Julius <i>et al.</i> 2013)</p> | <p>Re-apportion reduced capacity of water resources between human, economic and environmental requirements under future climate scenarios so that there is a clear understanding of future water resource allocations for the region</p> <p>Change expectations of values & use of storages & wetlands (Campbell 2008:22).</p> | |
| On ground works (active management) | <p>Explore stormwater capture and storage options, that do not compromise existing environmental flows but which reduce demand on potable supplies</p> <p>Improve and manage connectivity across the entire landscape mosaic to maintain species and ecosystem diversity – including remnants of native vegetation (Balston <i>et al.</i> 2011; Campbell 2008:22; Mansergh and Cheal 2007; Steffen <i>et al.</i> 2009:149) - and protection of riverine processes</p> | <p>Ensure revegetation creates buffer zones that provide space for rivers</p> <p>Experimental flooding across public-private lands</p> | Establish flooding regimes across public and private lands |
| Incentives | Develop opportunities for water reuse and harvesting, including fit-for-purpose water use in townships | Floodplain/wetland (blue carbon) stewardship funding for private landholders | |
| Research | Research & monitor the effect on water demand in the region through changing land use and agricultural practices in response to the changing climate and water resource constraints | | |
| Advocacy (for policy, legislation etc) | <p>Support water sensitive urban design to minimise in situ and downstream impacts</p> <p>Support relevant Water Authority plans and policies</p> | Planning measures e.g. setback distances | |
| Monitoring | Research & monitor the effect on water demand in the region through changing land use and agricultural practices in response to the changing climate and water resource constraints | Annual evaluation of 'natural' flooding using remotely sensed imagery (Kingsford & Biggs 2013: 34) | |

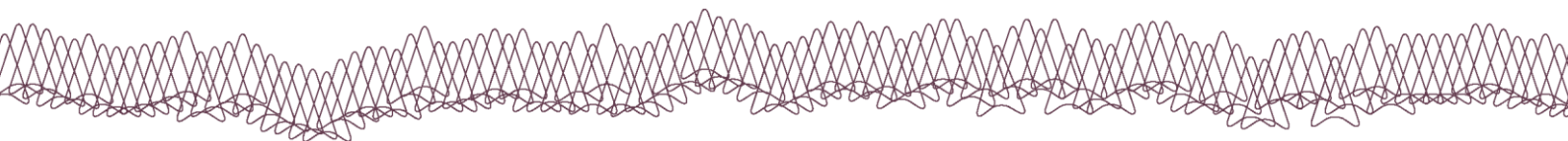
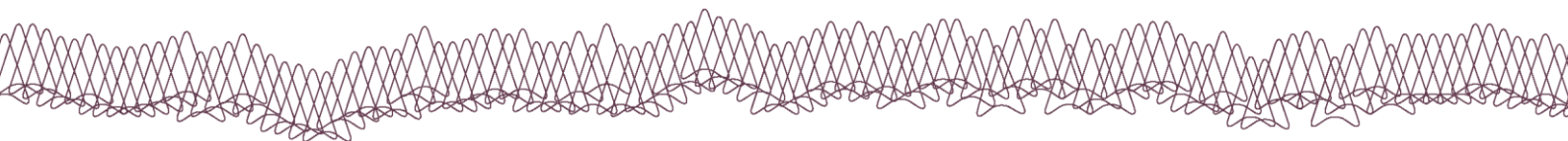
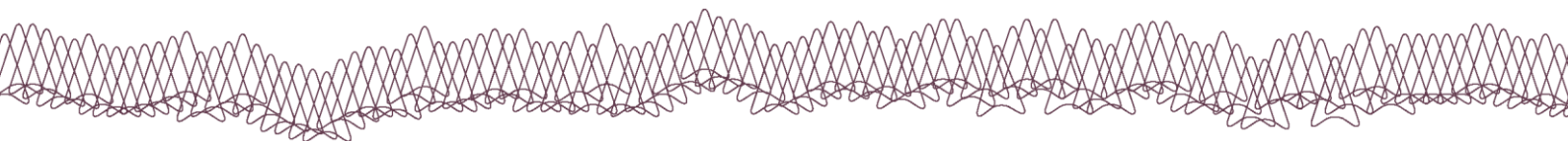


Table D.8 Biodiversity: examples of resilience, transitional and transformational options

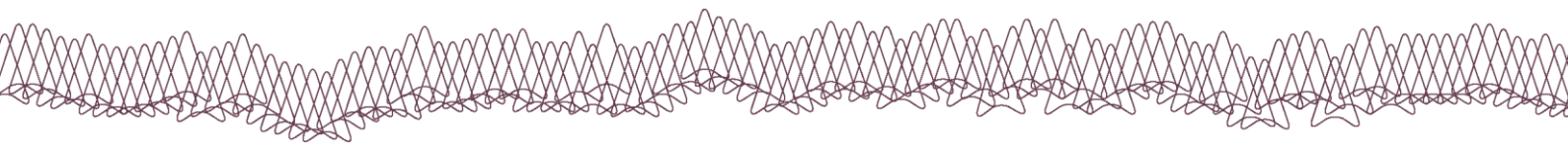
| | RESILIENCE (BAU) | TRANSITIONAL | TRANSFORMATIONAL |
|--|---|--|---|
| Social capacity (engagement, etc) | <p>Capitalise on opportunities in the region from climate mitigation strategies such as carbon sequestration and ensure programs deliver a beneficial biodiversity outcome (Balston <i>et al.</i> 2011)</p> <p>Community engagement program surrounding the importance of flooding regimes for waterbird breeding</p> | <p>Manage ecosystems as large units across boundaries through collaborative programs to ensure maximum possible biodiversity gains are made for investment effort and plan for reserves that encompass heterogeneity to allow for ecosystem self-adaptation (Balston <i>et al.</i> 2011)</p> <p>Citizen science and monitoring of key sites, indicator species, and experimental sites</p> <p>Invest in Aboriginal land management (Steffen <i>et al.</i> 2009:209)</p> | <p>Community engagement program supporting landholders in facilitating flooding regimes on private land that supports waterbird breeding as well agricultural and lifestyle objectives</p> <p>Extended Landcare type programs where landscapes are managed for multiple ecosystem services & income streams (Steffen <i>et al.</i> 2009:208)</p> |
| On ground works (active management) | <p>Improve and manage connectivity across the entire landscape mosaic to maintain species and ecosystem diversity – including remnants of native vegetation (Balston <i>et al.</i> 2011; Campbell 2008:22; Mansergh and Cheal 2007; Steffen <i>et al.</i> 2009:149)</p> <p>Revegetate and manage developed land to maximise connections between parks and other reserves (Biolinks/ migration corridors)</p> <p>Identify and protect key natural assets, refugia and transition zones to accommodate future changes in climatic conditions E.g. development plans include appropriate buffer zones for the movement of species under changed conditions (Balston <i>et al.</i> 2011)</p> <p>Protect complexity of landscape features in order to preserve critical buffer zones resilience and migration corridors (Julius <i>et al.</i> 2013).</p> <p>Restore degraded habitats</p> <p>Maintain or improve ecosystem</p> | <p>Revegetate and manage developed land to maximise connections between parks and other reserves (Biolinks/ migration corridors)</p> <p>Monitor/learn from species survival in unexpected combinations (Balston <i>et al.</i> 2011)</p> <p>Support the movement of beneficial or threatened species by providing appropriate structural mechanisms including connected landscapes & appropriate cover or structural trees and choose plant species & genetic provenance for restoration with climate change in mind</p> <p>Explore & discuss possibility of translocations</p> <p>Increase regeneration rate to allow more potential for selective pressures to work, and/or provide greater genetic diversity to assist natural selection (Moffat <i>et al.</i> 2014).</p> <p>Maintain populations in refugia and reintroduce when appropriate (e.g. When problem pests and</p> | <p>Undertake translocation of poorly dispersed and vulnerable species to suitable bioclimatic ones (Balston <i>et al.</i> 2011)</p> <p>Replace declining native ecosystem with most suitable type (Moffat <i>et al.</i> 2014).</p> <p>Maintain ecosystem services by replacing species, or increasing number of species that occupy same functional space, to maintain structure. (However, it may not be possible to preserve all aspects of biodiversity as an ecosystem service.) (Moffat <i>et al.</i> 2014).</p> <p>Transport fish populations with low thermal tolerances to cooler river reaches (e.g., at higher altitudes or in groundwater-fed systems) (Julius <i>et al.</i> 2013)</p> |



| | RESILIENCE (BAU) | TRANSITIONAL | TRANSFORMATIONAL |
|---|--|--|---|
| | functioning by creating new habitats within woodland area and increasing genetic and species diversity (Moffat <i>et al.</i> , 2014). | diseases are controllable) (Moffat <i>et al.</i> 2014). Increase resilience to abiotic threats such as wind and drought by altering structure (Moffat <i>et al.</i> 2014). Increase green spaces, green walls and roofs in urban areas to provide for biodiversity, urban cooling, storm water management and other health benefits (Norton <i>et al.</i> 2014). | |
| Incentives | Landcare grants | Trial roll-out of stewardship grants/payments for biodiverse carbon sequestration (Steffen <i>et al.</i> 2009:208) | Landcare grants for establishment and maintenance of 'translocation' habitats - stewardship incentives (Steffen <i>et al.</i> 2009:208) |
| Research | Identify species that might fill equivalent ecological roles as existing endemic species move out of an area due to changing climatic conditions; and evaluate whether native invaders are moving in response to climate change and whether they should be allowed to persist (Balston <i>et al.</i> 2011) Explore translocation needs, possibilities and risks | Apply biosecurity policies to limit human-induced movement of invasive organisms into new areas that may become habitable to them with changes in climate (Balston <i>et al.</i> 2011) Investigate gene banking and ex-situ conservation for species without current solutions where later restoration may be possible (Balston <i>et al.</i> 2011) Research ecosystem replacements (Steffen <i>et al.</i> 2009:208) Explore land buy-back schemes (Steffen <i>et al.</i> 2009:210) | Restoration/ establishment of 'new' habitat for 'gene-naked' species |
| Advocacy (for policy, legislation etc) | Reduce overfishing or correct altered hydrology to restore the ability of species or ecosystems to withstand a stressful climatic event (Julius <i>et al.</i> 2013:9). | Explore reclamation of disused roads for revegetation – habitat connectivity, Green and Open Spaces etc Support establishment of translocation policy (NSW example) | |
| Planning | Integration of private-land conservation planning with National and State Park planning (e.g. Habitat 101 program)(Steffen <i>et al.</i> 2009:222). | | Management of previously abandoned agricultural lands for 'new' biodiversity objectives (E.g. Steffen <i>et al.</i> 2009:221) |
| Monitoring | Monitor and manage habitat | Surveys of in-stream macropods | Maintain ecosystem services by |



| RESILIENCE (BAU) | TRANSITIONAL | TRANSFORMATIONAL |
|---|---|--|
| <p>change in near-coast wetlands in the region as a result of saline water intrusion into groundwater</p> <p>Identify indicators to monitor impacts (direct & indirect) of climate change on biodiversity & to assess vulnerability & adaptation (Harley & Van Minnen 2013:13)</p> <p>Establish survey plots for in-stream macropods.</p> <p>Monitor water-bird breeding occurrence (breeding events at least every 2nd year) (Kingsford & Biggs 2012:35)</p> | <p>during wet periods on set plots (Kingsford & Biggs 2012:34)</p> <p>Annual surveys of floodplain tree plots reporting on condition across protected area (Kingsford & Biggs 2012:34)</p> <p>Annual surveys of breeding occurrence for particular defined species at least every two years on river reaches and colony sites (Kingsford & Biggs 2012:34)</p> | <p>accepting diversity / maintained structure provided by invasive naturalised species. (However, it may not be possible to preserve all aspects of biodiversity as an ecosystem service.) (Moffat <i>et al.</i> 2014)</p> |



D.3 Spatial Prioritisation

D3.1 An approach to NRM spatial prioritisation for climate change

The following section is drawn largely from SCARP's Report (Leith et al. 2015) entitled: "A Means-to-an-end: a process guide for participatory spatial prioritisation in Australian natural resource management" which provides an outcome oriented process to use various.

There are often multiple outcomes from NRM activity. These occur at different scales and are sometimes very hard to predict. Desired outcomes can be associated with avoiding unintended negative consequences as well as trying to manage co-benefits. For example, riparian revegetation may stabilise creek banks and provide ecosystem services for farmers but also reduce the productivity of adjacent pasture or cropping; connectivity corridors may allow native species to migrate across the landscape and improve amenity values as well as providing habitat for pest species and weeds.

Spatial prioritisation processes for NRM – how we go about developing and addressing 'where' questions – thus need to be honest and critically reflective about these multiple, often conflicting outcomes, trade-offs, risks and co-benefits. The process also needs to be, simple and transparent enough that diverse stakeholders can understand or engage with both the mapping technologies and the rationale for selecting layers and criteria (Jackson et al., 2013). Ideally, spatial prioritisation should involve relevant stakeholders throughout the process.

This section reflects ongoing work between SCARP and NRM organisations, particularly in Tasmania, to develop a generic approach to spatial prioritisation for climate change and record the lessons learnt from this approach. The process, summarised below, will be documented in detail in a final report, with a particular focus on the processes spatial prioritisation and lessons learnt through its application.

The approach aims to develop scientifically credible, and regionally legitimate and relevant approaches to prioritisation that also meet the growing demand from

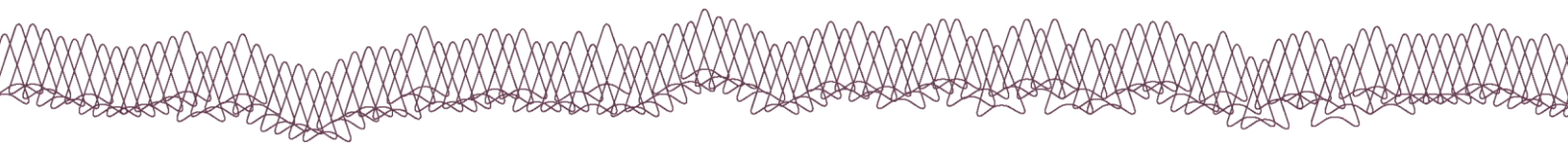
funding bodies for prioritisation to be transparent, accountable and efficient.

Our focus on process reflects a growing interest in approaches to link science and decision-making through good processes and arrangements, and the current lack of systematic consideration as to how scientific knowledge and community values and priorities can be well integrated via spatial prioritisation processes. This approach needs to be underpinned by rigorous scientific assessment. A variety of tools, approaches and technical methods are reviewed elsewhere for: conservation planning (Drielsma et al., 2014; Wintle, 2008), connectivity and landscape fragmentation mapping (Michaels et al., 2010), weed management (Scott et al., 2014), as well as policy evaluation options and assessing opportunity costs of NRM activity against foregone productivity (Bryan et al., 2011).

How can we develop and address 'where' questions?

Focussing on 'where' questions (e.g. where in the landscape should we invest in biodiverse carbon plantings?) requires paying close attention to 'why', 'what', 'how' and 'with whom' questions. Knowing what NRM interventions are most important for a given catchment firstly requires synthesis of community values or concerns into cohesive goals and objectives (see 0A4. [Establishing a vision, goals and objectives](#)). These goals might, for example, identify weeds as a common concern and weed management as a priority. This in turn could lead to very different activities ranging from investment in technical mapping of infestations, to identification of emerging threats, to working with councils or land managers to build capacity to identify and manage weeds. Addressing 'where' questions is thus only one component of prioritisation necessary to effectively and efficiently achieve weed management objectives and goals. If 'where' questions are treated only from a technical perspective they are likely to miss the mark. For instance, priority areas that are technically feasible may be owned by land managers who are not interested in undertaking the proposed investment.

The processes to develop and address 'where' questions can and should also build capability, so as to



engage appropriate people in the processes of framing and addressing these questions. In short, an important step in the process of spatial prioritisation for NRM planning building capacity and creating strong constituency support for the implementation of spatial priorities.

Climate change adds another layer of complexity to spatial prioritisation, emphasising that (for long term investments in particular) we should not assume stability in the climatic parameters that make a region or locality appropriate for a specific sort of investment.

What sort of process can be used in spatial prioritisation?

With the three Tasmanian NRM regions, SCARP developed a sequence of activities for developing a series of outputs, each building on the previous one. The stages use participatory approaches; initially with a broad array of stakeholders to frame broad goals and priorities, then with decision-makers and relevant experts and finally with stakeholders from the broader community to finalise an approach to prioritisation. In doing so, the process aims to build the knowledge base and incorporate values iteratively and embed these in a series of interim outputs. The ultimate goal is to be able to use the Multi-Criteria Analysis Shell for Spatial Decision Support (MCAS-S)¹. This tool allows groups to combine or reclassify spatial layers in decision-making processes or discussions. In turn such work enables identification of priority areas, to underpin implementation of activities in specific places.

The approach initially draws on discussion of values and goals and the knowledge of the project team and NRM representatives, and gradually growing to include broader state-wide consultation and regional prioritisation with stakeholders (see Figure D.5).

¹ <http://www.agriculture.gov.au/abares/data/mcass>

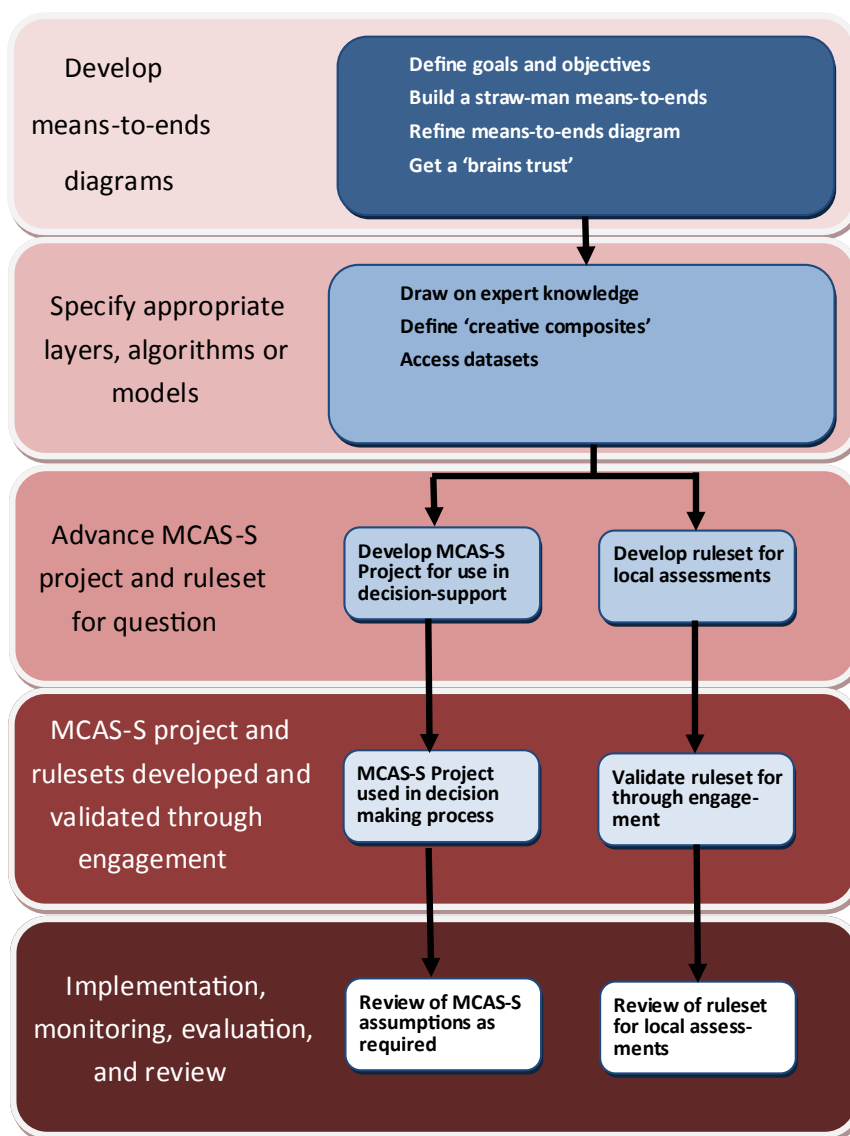
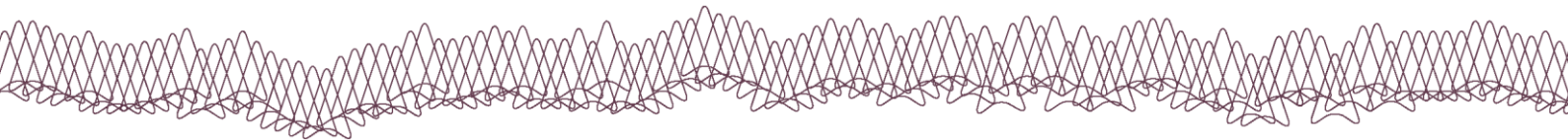


Figure D.5 Schematic of the process developed for undertaking NRM spatial prioritisation in a changing climate with Tasmanian NRM regions (from Leith et al. 2015)



The following five steps outline the process developed through collaboration between the 3 Tasmanian NRM regions and SCARP.

1. Means-to-an-end mapping

A means-to-ends diagram is developed to depict the logic between objectives of spatial prioritisation and the elements that enable one to answer the ‘where’ question. This first, crucial step benefits from several iterations and processes to draw on community or stakeholder views to define the priorities and views from knowledgeable people (e.g. disciplinary experts, systems thinkers and people with a good understanding of farmer/landholder concerns). It aims to provide the basis for developing ‘where’ questions that encapsulate the key concerns/values of the community, speaks directly to current or potential policy objectives, and can be guided by current and historical research. This stage can be very time consuming both to effectively frame the problem in terms of an objective, and to determine what we know, uncertainties, ambiguity and ignorance in the means to addressing the objective. As shown in Figure D.6, ultimately the primary inputs (e.g. slope and aspect) contribute to composites (e.g. steep north facing slopes) as components in answering ‘where’ questions (e.g. where are the areas of greatest risk of erosion following droughts?). However, Figure D.6 also indicates the direction of analysis is from the objective backwards, via ideal composites to primary layers (where necessary).

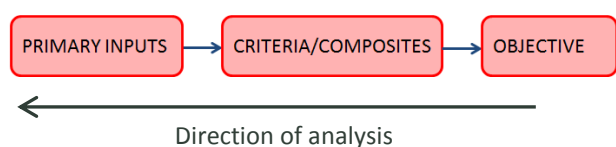


Figure D.6 A generic means-ends or means-to-an-end diagram for spatial prioritisation

2. Specify appropriate layers, algorithms and models

The second stage of the process is technical and oriented to defining the best spatial data available to meet the specified ends. Limitations of datasets need to be clearly stated and understood so that a straightforward description of each layer can be used to

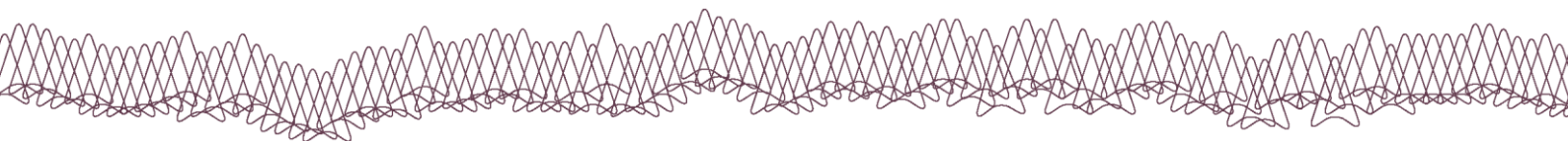
present it to groups at later stages and clarify any uncertainty of the spatial model and outputs. Clarifying uncertainty in spatial representation at a regional or catchment scale enables a clearer understanding of which aspects of the ‘means’ provide reliable enough estimations to allow assessment of ends. For example, attempts to develop means-to-ends diagrams (stage 1) for mapping potential changes in agriculture at a landscape scale, rapidly identified that the key drivers of change (currency markets, transport costs, markets for produce) were fundamentally unknowable. Therefore the idea of mapping changes in climate-related considerations (frost windows, growing degree days) appeared to be of little value – at least from an NRM perspective.

3. Advance MCAS-S projects and rule sets for each question

During the third stage of the MCAS-S project, development of a ‘rule set’ commences to augment the spatial analysis with a more place based assessment. A rule set provides criteria for local assessment, and may be as simple as a checklist for site characteristics to ground truth spatial assessments, or may require detailed fauna surveys, social research or other studies to ensure that local conditions are conducive to achieving objectives. For example, an area may be biophysically perfect for building connectivity corridors, but if no local land managers would even consider this land-use then there may be little point in further investment in the locality, at least in the short term. The rule set will later be used in a revised form to identify priority areas for investment at a sub-regional or local scale, and inform the monitoring and evaluation of the outcomes of such activity. The two outputs from this stage -- a draft rule set and an MCAS-S project -- should be designed to cover off on key issues across relevant scales and so support cross-scale prioritisation and implementation.

4. MCAS-Project and rule sets developed and validated through engagement

During the fourth phase, both the MCAS-S prioritisation and the rule set are progressed through the engagement processes to include stakeholder



perspectives, values, goals, knowledge and priorities. Participatory processes need to be well designed to empower participants to inform prioritisation. Information and insight captured through these processes should also be drawn out to review and refine rule sets for local implementation. This phase is critically important for informing NRM strategies which aim to be community plans and reflect the priorities of diverse stakeholders. Processes here should be open enough to allow for creative and unforeseen considerations to emerge and structured enough to enable prioritisation of issues and values to be adequately addressed.

5. Implementation, monitoring, evaluation, reporting and review

The final phase requires drawing on resources (such as policy or funding opportunities) to enable implementation, monitoring, evaluation and review. While this work is obviously crucial, it was not undertaken during the project due to time limitations and is therefore only dealt with briefly in the guide.

Across all these phases, outputs and processes were framed to create relevance and legitimacy. Prescriptive language was avoided. Use of MCAS-S avoided the need to work off paper maps; (the use of maps was noted to be something which land managers were universally suspicious of). Single, static maps are unlikely to be useful in answering complex, changing resource management questions, as there is rarely going to be a single correct answer.

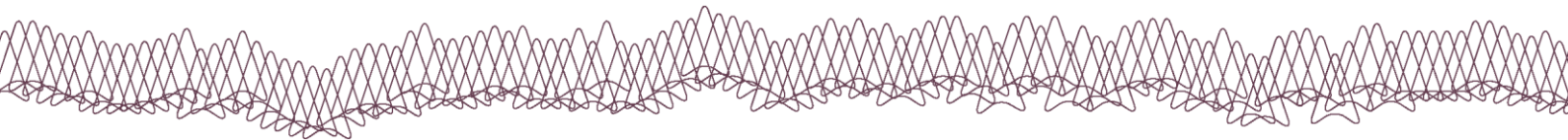
How can current and future climate layers be incorporated for spatial prioritisation?

Several issues need to be considered when choosing layers to answer questions about climate change. Guidance on how these questions might be addressed is provided in [C Examining potential futures](#). In summary these questions include:

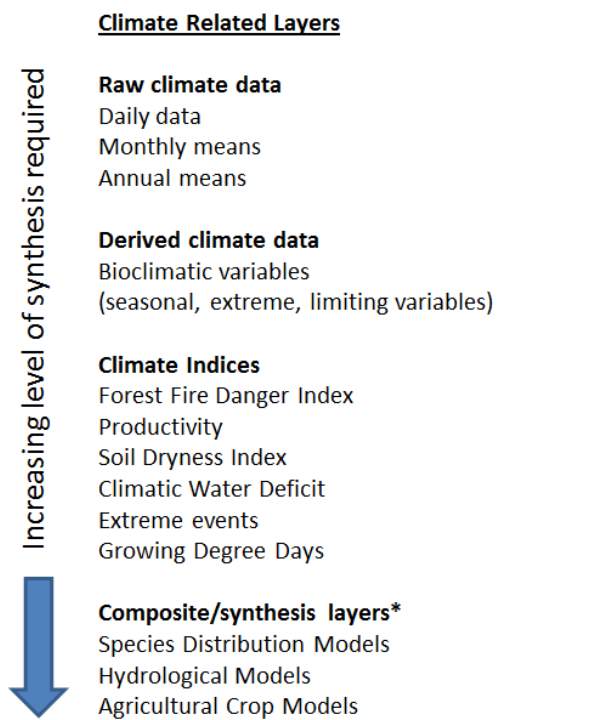
4. What climate variables are most relevant (e.g. temperature, rainfall, water availability)? Is there a composite or derived variable available that is more applicable than the raw climate data?

5. Are changes in annual, seasonal, monthly or daily variables most important? Alternatively, are natural communities more likely to respond to changes in extremes or variability in particular seasons?
6. Are the variables highly correlated? If so, perhaps one variable will suffice (e.g. change in annual temperature and summer temperature may reflect the same trends).
7. Which time period is of interest? (E.g. whether to select early, mid or end of century, will depend on the lifespan of the investment).
8. Which emissions scenario should be? used (e.g. where a high consequence decision is very expensive or where lives are at risk, a worst case scenario might be appropriate);
9. Are absolute values or change values, relative to past or current conditions, important? (E.g. is it important to know the rainfall in millimetres, or just that it is projected to decline by 5-10%).
10. What is the level of uncertainty associated with the values? (E.g. what is the model range; is it a variable that is not well represented by climate models, such as cloud cover).
11. How realistic is the ecological (or other systems) model? (E.g. if uncertainty is high, perhaps it is sufficient to know the general trends projected to occur in the future or, to consider both best and worst case scenarios).
12. What is the resolution of the layers? Does the resolution reflect real added information? (E.g. interpolation of climate data using a 30m Digital Elevation Model [DEM] makes a great picture, but is not adding real information about rainfall patterns at the fine scale, and may create a sense of false precision among decision-makers).

Building on these questions it is important to consider the range of climate related layers that might be appropriate to use, either as synthetic or composite layers or raw or derived climate data (Figure D.7). These considerations apply to spatial modelling of both current and future layers where climate variables are important. It is important to try to use climate



parameters or layer from current assessments that can be closely replicated from projections datasets.



*based on applied models that incorporate climate variables

Figure D.7 Examples of climate data, derived data and indices commonly available



Section E.

Facilitating collective action



E. Facilitating collective action

Building relationships with different stakeholders and communities is an important activity for ensuring support, buy-in and enthusiasm for any planning process. This is critical in the case of planning for climate change in NRM, as it is a complex and contested arena. This section describes some general considerations and strategies for building collaboration and understanding and communicating with different audiences.

E.1 Engaging with different communities

E.1.1 Building collaboration

Building strong collaborative relationships with regional, state and federal agencies, as well as with community members, researchers, consultants and industry, is a priority for regional NRM agencies to achieve an effective ongoing climate response. This is especially true for NRM agencies that identify themselves as ‘knowledge brokers’, which implies a need to connect with both ‘producers’ and ‘users’ of knowledge (Cook et al., 2013). Creating the circumstances for ‘collaborative dialogue’ is argued to be most productive in dealing with complex policy issues (Connick and Innes, 2003).

What strategies can help foster collaboration?

There are many strategies available to foster collaboration, depending on the people and organisations involved. The following review draws selectively on published empirical studies of research into collaborative processes in NRM. The value of NRM practitioner experience also cannot be underestimated, so this section is merely designed to complement this in-house experience.

Being aware of power

Opening an invitation to collaborate with an unfinished plan is a way of reducing the power imbalances that might exist between ‘planners’ and those affected by the plan, as it represents a genuine request for input into the planning process. Power, in this context, refers to the ability to influence, which in regional NRM is the

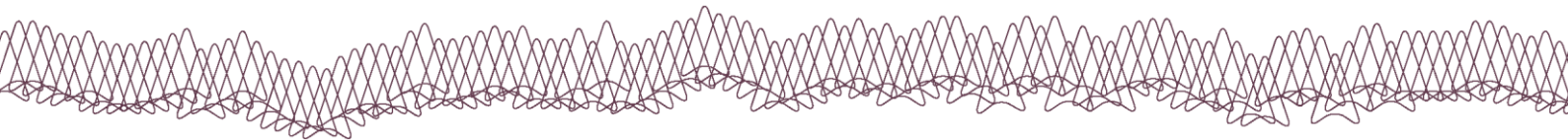
ability to bring about change through planning, facilitating partnerships and attracting investment.

Hardy (1996) provides an overview of different ‘types’ of power: in brief, the power of resources, the power of process and the power of meaning. These three types are summarised in Table E.1, adapted from Hardy (1996) to fit within an Australian NRM context.

In the context of NRM Planning for Climate Change funding, the power of resources stems from Commonwealth funding devolved to regional NRM agencies, as well as funding to Stream 2 clusters. This power can be extended to bringing in particular consultants or experts, by supporting staff in the planning process and through training and capacity-building.

The power of processes and of meaning arises from the activities that NRM agencies perform as part of the national planning and implementation process, albeit within the agenda set by the Commonwealth. An unfinished plan is an important example of the power of processes if the goal is to foster collaboration. For example, the development of the Guide to the Proposed Murray-Darling Basin Plan largely occurred in-house and, following its release at 4pm on a Friday afternoon, stakeholder engagement was framed as a process of ‘consultation’ on a document that was arguably finished (Ison and Wallis, 2011). Had public participation been initiated before its completion, or had the document been presented as a discussion paper at stakeholder workshops, then it may have achieved better community support.

The power of meaning, as expressed through language, is used to legitimise certain framings. For instance, talking about ‘climate variability’ rather than ‘climate change’ can legitimise the former at the expense of the latter. Conversely, in situations where many question

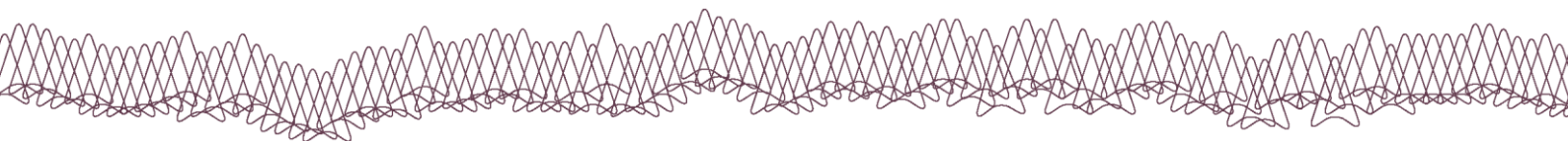


‘climate change’ it might help to foster collaboration by using more neutral language.

Table E.1 Some ‘types’ of power

| | POWER OF RESOURCES | POWER OF PROCESSES | POWER OF MEANING |
|------------------------|---|---|---|
| Source of power | Funding, allocation of staff on projects, ability to hire consultants or outsource work | Setting agendas, designing processes, participation | Framing, knowledge drawn on, language used in plans |
| How it works | <p>The availability of funding generates interest from NRM agencies and enables them to allocate staff time to planning.</p> <p>Resources can be used to bring in experts and outsource planning tasks, or could be used to build in-house capabilities.</p> <p>Being physically present to meet with others can build trust.</p> | <p>Agenda-setting is an important first step and can define how the whole process proceeds (e.g. whether plans focus on purely biophysical or social systems as well).</p> <p>Processes can be designed to be more or less inclusive of stakeholders.</p> | <p>Framing the planning process as, for example, a technical exercise gives different results to framing it as a participatory one. This affects the way resources are invested.</p> <p>Certain meanings, expressed through language, can be legitimised over others (e.g. climate change vs. climate variability).</p> |
| Limits | <p>Funding cannot buy good collaborative relationships.</p> <p>Rules tied to funding can both enhance and constrain the effectiveness of the process.</p> | <p>Setting the agenda can constrain the scope of the planning process, which can either help it succeed through improved focus, or fail through blind spots.</p> | <p>The use of certain meanings can exclude stakeholders from the process (e.g. using highly technical or jargony words).</p> |

Source: Adapted from Hardy (1996)



Building networks

A major strength of regional NRM agencies in Australia is their ability to build networks with other NRM groups, community groups, government, industry, and researchers within and beyond their regions.

In a useful journal article on the topic of fostering collaboration, Brugnach and Ingram (2012, p. 64) recommend building networks that “*cut across the usual divisions*”. This can be seen as a call to breaking out of silos and they give the example that if you only talk to academic economists, then you will end up seeing water problems as only solvable with market instruments. Likewise, talk to too many ecologists and you may want to conserve the whole catchment!

Networks take effort to maintain and incur transaction costs that grow with the size of the network, so getting the size and balance right is important. However, Connick and Innes (2003) document several examples of where outcomes would not have been achieved without the investment in collaborative dialogues.

Participatory modelling

A common concern with the use of tools is that they are ‘black boxes’; in other words, they are not sufficiently transparent for users to be able to independently understand how inputs become outputs and are often operated only by technical experts. Some models or tools are more transparent than others: it is possible to reveal the ‘workings’ of some simple numerically-based models, such as hydrological models. Other models require ‘subjective’² decisions to be made about some variable, for example assigning a value for particular ecological assets in a vulnerability assessment. Where such decisions are required, they ought to take into account multiple perspectives and be transparently documented.

This is the philosophy underpinning the move towards participatory modelling. In a special issue of *Journal of Hydrology*, Mooney et al. (2012) and Jackson et al. (2012) report on the use of participatory tools in water planning and decision-making. The general message

that come out of the special issue is that participatory models and tools assisted NRM (water) planners in understanding and capturing local knowledge. Also, the Collaborative Habitat Investment Atlas developed by Pert et al. (2013) in northern Queensland, is a ‘participatory tool for conservation prioritization with a strong visual and dynamic capability’. They suggest that it promotes ‘interaction among stakeholders through two aspects: stakeholders’ ability to alter variable weights to reflect different biodiversity protection requirements; and formula-based dynamic attributes that immediately update results visually’.

Drawing on local and indigenous ways of knowing

There are several reasons why drawing on local and indigenous ways of knowing is essential to ongoing adaptation at regional and especially the local scale of much decision-making (Ens et al., 2012). People often have their own conceptions of climate that are experiential and developed through conversations with their friends and colleagues about climate.

For climate change to be made real and tangible, many people need it to be linked to local phenomena and experience; this can be effectively achieved by (for example) asking people about their own experience of environmental change and then linking that local change to climate trends, drivers and even projections.

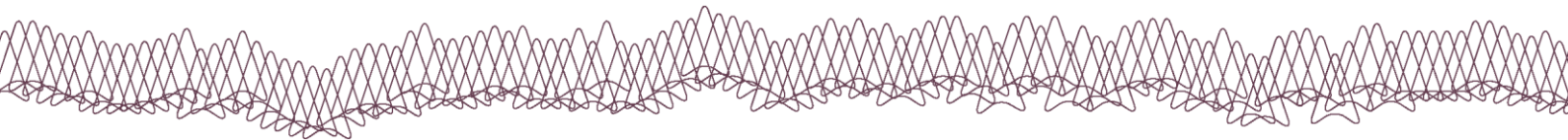
In local, and especially indigenous climate knowledge, signs from the movement and behaviour of plants and animals are often used as markers of seasonal change. People on the land often make careful observations of the natural world, which could be of benefit in building collaboration and supporting adaptive management, for example, to begin a dialogue or to understand how much systems are changing over time.

Why collaborate with local communities?

For many areas of NRM, especially on private land, land management is rooted in culture and history and thus knowledge of local people can be much more important to enabling change than scientific or managerial knowledge.

Appreciating these different contexts, culture and history in efforts to enable collaboration can support local management action (Patterson et al., 2013).

² ‘Subjective’ is used carefully here, as many seemingly ‘objective’ variables can also be traced back to ‘subjective’ decisions.



Essentially, to use a woodworking metaphor, it is easier to work with the grain than against it.

E.1.2 Communicating to different audiences

In NRM planning, sometimes engaging with different communities focuses on communication rather than collaboration. In other words, not all stages of a planning process require collaborative dialogue with all interested stakeholders; it may be sufficient only to keep some groups informed. However, communication needs to be fit-for-purpose for the different stakeholders.

Who are the different audiences in NRM?

Regional NRM managers can face a high level of stakeholder complexity, as demonstrated by a study of institutional complexity as seen from the perspective of the Goulburn-Broken catchment (Wallis and Ison, 2011). This complexity can be reduced by grouping different types of stakeholder. Table E.2 highlights five general stakeholder groups and what they might be more or less interested in learning from plans.

Obviously there are differences and subtleties within these stakeholder groups. For instance, members of different industries might have competing agendas - e.g. a peak industry body for farming would have different objectives to one for tourism and recreation, or within the 'policy community' a Minister is likely to have different interests than policy analysts and program managers. Identifying specific audiences and their interests is a useful first step towards preparing more targeted communications.

Table E.2 Stakeholder interests in regional NRM planning for climate change

| AUDIENCE | MORE INTERESTED IN | LESS INTERESTED IN |
|----------|--|--------------------|
| Policy | The purpose of a plan. How plans fit with other | Technical details |

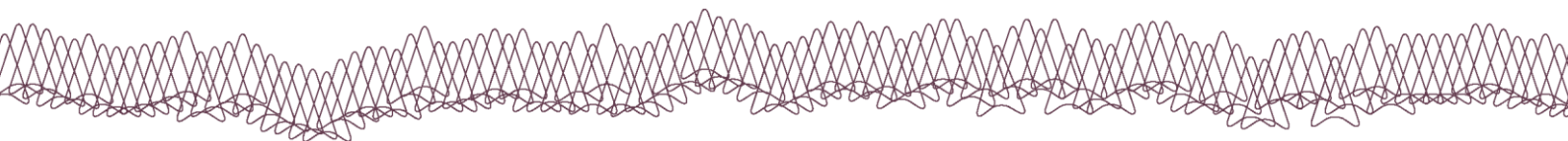
| | | |
|-----------|---|--|
| | policies. Governance of climate planning. | |
| Industry | Details of planned activities that may affect business. Opportunities arising from climate planning. Trends and risks to industry | Background information |
| Community | The purpose of a plan. How the plan will affect their region. Opportunities arising from climate planning | Technical details |
| Technical | Details of planned activities. Technical information - maps, models, diagrams, tables, etc. Sources of information. | Collaboration processes |
| Media | Areas of risk or controversy. Clear summary of the purpose. Opportunities arising from climate planning | Background information and technical details |

What are some ways of writing for different audiences?

In planning, written documents are one of the main avenues for communicating with stakeholders, and different styles of writing suit different audiences. Table E.3 gives a hypothetical example of a complex scientific statement and shows how this information can be presented in other ways.

Table E.3 Examples of different styles of writing

| STYLE | EXAMPLE |
|-----------------------------|---|
| Complex scientific concepts | [Hypothetical] A patch of eucalypt woodland in Victoria has been identified as an important ecological asset. Under |



| | |
|------------------------------------|--|
| | climate change (Model X, RCP4.5, 2055) the asset will be exposed to elevated air temperatures and decreased rainfall, resulting in reduced soil moisture and an increased bushfire risk. The presence of an important threatened species that relies on the patch as a food source means that the patch is considered to have high sensitivity to climate change, as the flowering of eucalypts is affected by moisture and temperature. Though isolated, the patch is fairly large and the condition of the habitat is good, so it has a moderate adaptive capacity. The overall asset vulnerability was rated as high. The patch could be joined to a nearby disconnected fragment via biodiverse carbon planting. |
| Plain-language scientific concepts | A vulnerability analysis conducted by scientific consultants of the woodlands of Corangamite have found that they are highly vulnerable to climate change, largely due to... |
| Generalisation | Trees under threat from climate change |
| The sell | Farmers have an opportunity under climate change |
| Loss avoidance | If we don't start preventing clearing of our woodlands, then climate change will result in their loss. |
| Metaphor | Last trees rounded up by climate change. Backed into a corner. Deal the final blow. Death by a thousand cuts / degrees. |
| Story | A tree had its family and friends and a network of support. Every day it sucked in CO ₂ and spat out O ₂ . But one day, the ground dried up. The trees around got hotter and hotter. Then the last tree was left standing. |

Table E.3 highlights some different styles of writing, which are explained here in more detail with reference to three criteria that are recognised as critical in presenting knowledge: salience (i.e. timely), credibility (i.e. respected), and legitimacy (i.e. accepted) (Cash et al., 2003; Clark et al., 2011).

Complex scientific concepts

Statements of scientific fact are evaluated on the basis of their credibility: the adequacy of the arguments presented and the technical rigour of the way in which evidence is created (Cash et al., 2003; Clark et al., 2011). However, to those who are not experts in the discipline of the research, these statements can be opaque and full of jargon, even if they are the most technically accurate depiction of the phenomena being investigated. Complex scientific facts are best used in communication between different scientific experts.

Plain-language scientific concepts

In NRM planning, the presentation of some scientific facts is unavoidable. For example, in a climate change plan some reference to climate science would be necessary to give adequate context to why planning for climate change is necessary. However, presenting these scientific facts can create a tension between preserving their scientific credibility and ensuring their legitimacy so that they are easily understood by a wide range of stakeholders. In these instances, some work is required to 'translate' or summarise complex scientific concepts into plain-language representations. Citing the original source of the concepts would be good practice.

Generalisation

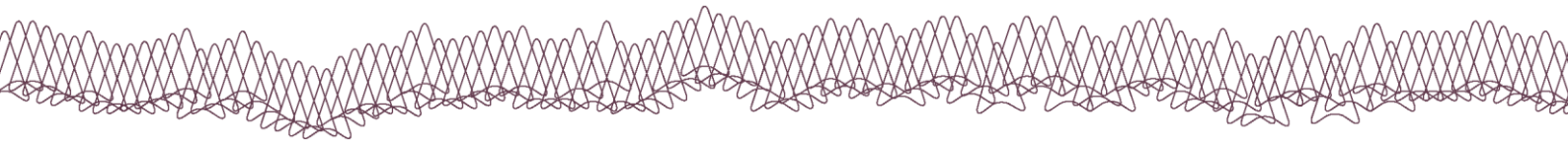
A generalisation of a complex scientific concept can create a short-cut to easy understanding (similarly to a newspaper headline), but can also create persistent misunderstandings by excluding necessary contextual information. Good practice would be to use generalisations sparingly in writing.

The sell

In the world of climate change policy, it can be depressing to be confronted with too many negative messages or messages of fear (Moser and Dilling, 2011) and it can cause people to disengage. A more positive way of framing policy is as a 'selling point' – i.e. a proposition to individuals or groups that can open up the possibility for action.

Loss avoidance

Conversely, behavioural research has shown that when a proposition is presented as a loss to be avoided, people respond better than when the same proposition is presented as a benefit to be gained (Kahneman and



Tversky, 1984). In other words, losses are a greater motivator than gains.

Metaphor

In their book *Metaphors we live by*, Lakoff and Johnson (2003) contend that metaphors are not just devices of language, but that they are pervasive in thought and action in everyday life. Metaphors can be used as a conceptual short-cut in helping audiences understand a new concept in relation to a concept that is already understood. Metaphors are a powerful technique for communicating complex climate change concepts; for example the metaphor of a bath tub spilling over to explain the idea that human emissions of CO₂ exceed the removal rate by natural processes.

Story

Stories, or narratives, are powerful ways of communicating concepts in a form that is more naturally understood by different audiences. Paschen and Ison (2014) argue that language has power in framing how issues are perceived (see reference to the ‘power of meaning’ in Table E.1. Communicating climate change concepts using real stories can help audiences relate to those affected.

In this section, two key aspects of engagement have been presented: (1) building collaboration; and (2) communicating to different audiences. These are two powerful ways that NRM agencies can engage with different communities and generate community support.



Section F.

Monitoring, evaluating and learning



F. Monitoring, evaluating and learning

In this section we focus on this process of monitoring and evaluation (M&E) from the outset of an initiative and particularly in the context of climate adaptation. We also briefly review and provide links to contemporary frameworks and resources that can assist with the implementation of M&E for adaptation initiatives with different scales and scope. Australian NRM is fortunate to have a strong tradition in M&E, and particularly through the MERI framework. This section provides information to update this framework for climate adaptation in NRM, and particularly for adaptive management and associated learning. M&E should be primarily viewed as an enabling activity, rather than a compliance activity – it enables teams to know why they are doing things the way they are in order to achieve their goals, and so reinforce or revise a common sense of purpose and vision.

F.1 Role of feedback in NRM planning and implementation

F.1.1 Monitoring, evaluating and learning at all stages

Over the last two decades, M&E has become increasingly prominent across spheres of government, research as well as the private and non-governmental sector. Good M&E can help groups and organisations to understand what works and why, and to develop an outcome-oriented rationale for their activities. These characteristics make M&E an essential part of adaptation and particularly adaptive management and governance which are premised on reflection and learning. Thus M&E enables feedback between activities and the development of strategies and their implementation.

M&E is also essential to adaptation to climate change because future consequences are not predictable so the effectiveness of adaptation actions cannot be known in advance. This means it is necessary to learn by doing, using M&E to underpin adaptive management (Villanueva, 2011). M&E helps make successes reproducible. It makes the strengths and weaknesses of different forms of activity, intervention and investment explicit.

In short, M&E is increasingly seen as a proactive approach to achieving desired outcomes, and to

continual improvement towards that goal. This outcome-oriented framing of M&E is important, and a useful place to start a brief review of M&E.

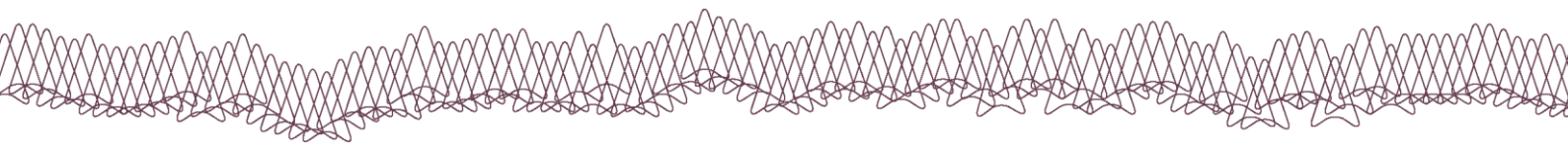
What is monitoring and evaluation?

M&E is the collection and analysis of quantitative and qualitative data that enables:

- Learning about what worked and why;
- Decisions to be made about how things will be done differently/better next time;
- Understanding of results or value of investment of resources;
- Organisations to tell stories grounded in data about their work and its outcomes.

Good M&E links high-level goals with objectives, strategies, programs and project activities designed to achieve them (hereafter, we use the generic term ‘initiatives’ to encompass these different levels). While initiatives vary widely, the outcomes of M&E itself are more consistent. Outcomes are often typified as some combination or variation of effectiveness, efficiency, equity, legitimacy (e.g. fairness, procedural justice), sustainability and legacy (we return to these qualities later). The desired outcomes of the initiative help to decide how these elements are weighted and defined.

M&E is necessary to gather and analyse data to be able to achieve three broad outcomes – learning, storytelling or reporting, and improvement or investment. NRM practitioners have historically focussed on reporting (R)



and improvement or investment (I) as key outcomes. MERI is now stipulated across Commonwealth funding programs to encourage collection of consistent forms of biophysical data related to *Caring for Our Country* and other projects (Australian Government Land and Coasts, 2009).

Recently attention has been given to learning as an important outcome of M&E. While there are many new and emerging frameworks for monitoring, evaluation and learning (MEL or ME&L), it often encourages learning through use of robust qualitative and quantitative data and/or reflection on assumptions, strategies and paradigms (see Armitage et al., 2008 for a useful review and critical appraisal of such learning in NRM).

As well as the standard outcomes of reporting, improvement and learning, the process of M&E implementation also encourages good planning of initiatives. For example, 'means-ends' rationalisation or a 'theory of change' are powerful design tools that can get team members thinking and working together in an outcome-oriented way. They encourage groups to make their assumptions explicit, and then test assumption via M&E of well-defined activities.

M&E depends on a transparent rationale that links what organisations or individuals are trying to achieve (their goals and objectives) and the activities they are using to achieve them. Such means-ends rationales and especially their implementation remain rare. This is not surprising as the development a logical approach or 'theory of change' to achieve goals can be hard in itself. However there are approaches to facilitating creative linking of means and ends that empower teams to embrace and test their theory of change (Robinson, 2012). Realistically, however, there is often a lack of resources to do good M&E, especially in areas such as NRM where projects can take many years to achieve desired results and often fail to do so because of the complexity of the systems in which they intervene (Lefroy et al., 2012). A good theory of change will help a group understand what part of the system they are contributing to, how, and what evidence they will need to collect to know if they have achieved these objectives.

When should monitoring, evaluating and learning take place?

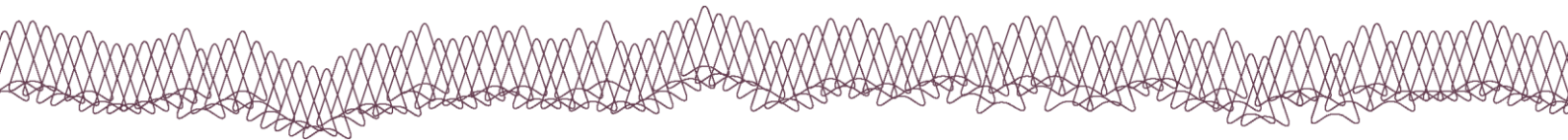
Ideally monitoring, evaluating and learning ought to take place from the very beginning and through all stages of an initiative. Too often it is tacked on to the end of an initiative, creating a deficit of useful evaluative data. Good M&E is part of program design and should start at the beginning of an initiative through development of goals and objectives, and linking these to activities designed and oriented to achieving objectives and outcomes.

In practice, answers to this question can be provided at a broad and abstracted level, but for any given initiative they will be very specific depending on the nature of the initiative, its goals, resourcing, timeframe and complexity. For example, what will be evaluated in a policy-oriented research project will be very different from the evaluation of the implementation of a strategic plan, yet the policy project might be part of the implementation of the plan and so results of its M&E should inform evaluation of a strategy and therefore help to review objectives and goals at different levels.

Linking M&E to goals and objectives

In abstract terms, an evaluation provides evidence about the degree to which any initiative meets a standard set of objectives. The NRM MERI framework (Australian Government Land and Coasts, 2009) highlights the following broad objectives relating to:

- Effectiveness: Did activities perform to the standard required?
- Impact: What was the outcome, or result of the activities - i.e. what were the changes in condition of environmental assets, management practices or institutions? Were these as intended?
- Appropriateness: Was the problem/issue dealt with appropriately? Was there good alignment with needs and expectations of stakeholders and activities undertaken?
- Efficiency: Were activities within budget? How was value returned on available resources? Could efficiency have been greater, or might it be improved next time?



- **Legacy:** What will be the ongoing impacts of the activities?

Under each of these categories, drawing on a well-developed logic, theory of change or other framework, M&E is often oriented to defining indicators that will be able to represent success or otherwise in achieving objectives. Many authors have emphasised the need to involve stakeholders effectively in defining these indicators and potentially in collecting and analysing the data (e.g. Kates et al., 2001). Such inclusion and the collaborative forms of social learning associated with it are especially important where substantial values divergence and uncertainty about biophysical systems collide, and result in disagreement about goals objectives or the reality of change (Funtowicz and Ravetz, 1993; Leith et al., 2014b).

These specifics of the objectives will define the types of indicators that are best used in monitoring and evaluation. For example, quantitative indicators can be suited to objectives that are related to process evaluation (number of trees planted), effectiveness (% of trees that survived) efficiency (metres of riparian revegetation per \$ invested), and in some cases practice change (e.g. % of land under minimal till cropping). Objectives related to intermediate outcomes such as changes in knowledge, attitudes, skills, aspirations, or public/community discourses or problem framing are much more likely to require qualitative indicators, although quantitative metrics can also be developed. Some objectives are likely to be suited to M&E through a mixture of qualitative and quantitative indicators; for example, objectives related to adaptive capacity and issues surrounding equity, learning and social impacts.

Setting indicators

It is important to ensure that any indicators used are relevant, credible and legitimate to key stakeholders (Cash et al., 2003). While qualitative indicators are often most appropriate for defining intermediate

outcomes of both NRM and adaptation initiatives, they have been frequently rejected by State and Commonwealth bureaucracies in Australia and so need to be defined and measured through legitimate and credible social research methodologies (Vanclay, 2012). On the other hand, quantitative indicators of an objective are usually a surrogate or proxy for the larger objective. When deciding the best form of indicators or measures it is useful to ensure they are fit for the purpose, the audience and that they adequately represent the degree to which an objective is met.

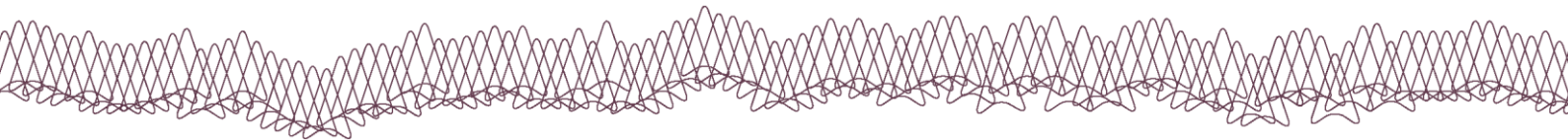
A widely used approach for defining good indicators is the SMART scheme (Adapted from UNDP 2009):

- **Specific** – target a specific area for improvement
- **Measurable** – suggest a qualitative or quantitative indicator of progress
- **Agreed / Achievable** – ensure stakeholders have agreed on indicators and specify who will monitor, evaluate and report them
- **Realistic** – state what results can realistically be achieved, given available resources
- **Time-related** – specify the timeframes over which the result(s) can be achieved

While these characteristics of indicators provide useful generic principles for selection of those that are workable and meaningful, they need also to be grounded in the context of adaptation initiatives. Rickards (2013, p. 159) provides a useful framework for thinking through categories of adaptation measures that might be monitored and evaluated over time, ranging from changes in climatic or meteorological parameters to the barriers and enablers of adaptation (see Table F.1). Rickards' scheme also suggests that monitoring against a static baseline may not be as applicable to monitoring against projected changes to baselines, to which we return in the next section.

Table F.1 Conditions and considerations in developing indicators for MERI relevant to climate adaptation (Source: Rickards, 2013, p. 159)

| | Emerging observations over time (Monitoring requirements narrowly defined) | Emerging projections over time |
|---|---|--|
| Conditions (biophysical, socioeconomic, cultural and political) | Baseline monitoring | Trend-based modelling |
| Changes attributable to climate change | Comparison of observations and expected climate change effects | Comparison of expected trends and possible impacts of climate change on them |
| Exposure | Tracking individuals'/groups' experiences of climate change impacts Tracking changes in exposure as result of social or behavioural change (re relocation, new work practices) | Projections of possible future spatial intersections of climate change impacts and population distribution |
| Sensitivity | Tracking changes in individuals'/groups' dependence on climate-sensitive resources (e.g. shifting role of agriculture in a regional economy) | Projections of possible future spatial intersections of climate change impacts, population distribution and population sensitivity to impacts |
| Adaptive capacity | Tracking changes in individuals'/groups' levels of natural, physical, social, human and financial capital, including decreases resulting from climate change impacts and increases resulting from adaptation efforts and accumulating know-how | Projecting possible changes in individuals'/groups' levels of natural, physical, social, human and financial capital, including decreases resulting from climate change impacts and increases resulting from adaptation efforts |
| Adaptation efforts | Tracking individuals'/groups' deliberate adaptation decisions and actions (including intangibles such as a change in mindset) Tracking others' adaptation efforts and their influence on oneself | Projecting what adaptation actions individuals and groups will undertake in the future and how they interact |
| Adaptation options | Analysing the adaptation options open to an individual or group over time and how these possibilities and their feasibility and desirability change as conditions change over different time scales | Modelling of adaptation options available under future possible conditions and their relative advantage |
| Adaptation outcomes | Analysing the outcomes of deliberate adaptation efforts in terms of impact reduction, costs, residual impacts, and learning and other effects on adaptive capacity; Tracking of these changes over time Analysing overall adaptation/resilience levels and the contribution of unintentional/serendipitous adaptations | Modelling of the effects of specific adaptation options and overall adaptation/resilience levels over time |
| Adaptation barriers and enablers | Analysing the factors shaping the feasibility, desirability and outcomes of specific adaptation efforts, including not only one's adaptive capacity but assessments of the broader environment including others' (in)actions, to facilitate learning about the factors involved and how they may be negotiated | Projections of future possible barriers to (e.g. climate change scepticism, social disrest) and enablers of (e.g. political and policy change) implementation of various adaptation options |
| Adaptation knowledge and tools | Regular reviews of adaptation knowledge (understanding, information, skills) and tools in light of emergent experience and needs Regular assessments of the distribution of and experiences in using knowledge and tools across different groups Tracking of RDE capacity and influences on it | Projections of future shifts in knowledge and learning (e.g. as a result of technological or institutional change) Projections of the rate of dissemination of specific knowledge or tools Projections of future RDE capacity and shifts in its drivers (e.g. training of certain graduates) |



What are some challenges in monitoring, evaluating and learning?

There are tensions surrounding M&E for adaptation. For instance, there is a substantial tension between developing robust indicators of an initiative's desired outcome (which is often complex and multi-faceted) and being able to use proxies of that change that are simple enough to monitor and measure efficiently and effectively. A common trap is to try to select metrics that are easy to capture and quantify but do not adequately represent the change that is actually desired. In the worst cases, metrics end up being the goals which can lead to perverse and sometimes disastrous outcomes. An example of such perverse outcomes is when tests become an important measure of a school's performance and teachers start teaching to test, rather than to create the educational outcomes for which exams are supposed to provide a proxy (Scott, 1998). As Einstein is reported to have said: *"Not everything that can be counted counts. Not everything that counts can be counted"*. The challenge in designing good M&E is to know what counts, and to monitor and evaluate it in order to tell a credible and robust story, and to ensure individuals and organisations are able to learn from inevitable shortcomings (Rickards, 2013).

Achieving and accounting for the achievement of goals is also difficult where there are no clear lines of responsibility and accountability. For NRM organisations, strategies encompass more than their own organisation creating a challenge for M&E of both activities and outcomes. The activities that lead to outcomes are necessarily distributed across organisations and individual landholders. However, strategies can provide a coherent and reasoned approach and so align responsibilities with activities with outcomes, and guide M&E across tactical initiatives. For example, strategies can encourage learning across organisations as a means of developing adaptive capacity, mutual accountability and responsibility in the face of ongoing change (in climate conditions as well as institutions, policy, resourcing, leadership, etc.).

M&E is increasingly being adopted as a requirement of externally-funded initiatives. There is growing

expectation from funders and stakeholders that M&E details the value of activities and efficient investment of public and private funds. The growing demand for evaluation creates risks for organisations. For example, without high-level guidance and institutional support for M&E, it can become a burden on small teams. Also, a large proportion of resources can be spent on evaluating at the expense of doing. This in turn can lead to rejection of M&E as a bureaucratic imposition. It is critical to build successful M&E and learning cultures so that these risks are well managed, for example, by:

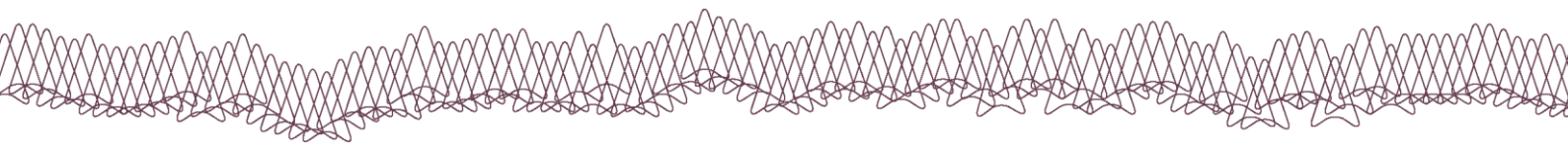
- Evaluation being built into the culture of an organisation so it is a key part of managing any initiative
- Training being provided to enable teams to incorporate evaluation activities with normal project and business activities as seamlessly as possible
- M&E (and processes for reporting and learning) being budgeted into and co-ordinated across as many projects as possible, and support for such budgeting coming from within organisations

F.1.2 Key considerations for designing feedback mechanisms for planning

Adaptation is an ongoing process rather than a specific outcome. This can make M&E very challenging, because M&E requires clear and logical linkages between goals and objectives and means of achieving them. Intentional and anticipatory adaptation pre-empts change, yet the actual change experienced may be quite different at local and regional scales to initial expectations. This implies that goals and objectives need to be set and regularly reviewed on the basis of salient, legitimate and credible evaluation data (Cash et al., 2003; Turner et al., 2014). Such review of goals and objectives can useful happen across scales from projects to programs to regional strategies or state-wide policies. To enable these linkages between scales can be difficult but is integral to cross-scale governance of problems (Ostrom, 2010).

What are some key considerations for M&E?

Here we draw on our own work in adaptation research and M&E as well as a recent literature review of M&E



for adaptation (Turner et al., 2014) to identify key considerations for M&E in adaptation planning. Firstly we describe key guidelines and principles for M&E in generic terms and then specifically in relation to adaptation in NRM.

M&E should be embedded in project/program design to:

- Ensure the project is based on a sound theory of change or means-ends rationalisation
- Ensure M&E data consistent with goals are collected at appropriate times in the project life

M&E should be fit-for-purpose and targeted to audiences:

- Oriented by objectives and goals, M&E should be set up to evaluate success at achieving stated objectives
- If the objectives are qualities (e.g. there is an increase in the knowledge of the community about management of climate extremes), good qualitative data or appropriate proxies should be considered
- It can be at least as important to ensure that data sources and stories are legitimate and relevant to the stakeholders who care about them as they are scientifically credible. This requires good initiatives to be managed to ensure that there is good communication, feedback and that stakeholders are clear about who is doing what, why and how success (or failure) will be defined.

Using tools like Bennett's Hierarchy (

Table F.2) identifies different levels of activity and outcomes of an initiative and so helps to define the staged outcomes, when things are going according to plan and when they are not.

- M&E should have a clear goal to assist with learning, reporting or targeting/justifying investment.
- M&E should help an initiative to tell its story in a powerful way based on credible data.
- M&E should use the best metrics and baselines possible (given constraints on time and resourcing) to achieve the goals of the specific M&E initiative.

Where there is a clear causal chain between interventions and biophysical outcomes (a theory of change) the steps on this chain need to be included in

evaluation. Where causality is uncertain, or external factors drive change, and where learning is a key goal, qualitative stories and perspectives will be invaluable.

M&E guidance for adaptation in NRM

Identifying success: success against goals and objectives will need to be regularly reviewed on the basis of changing values and concerns and well-defined indicators;

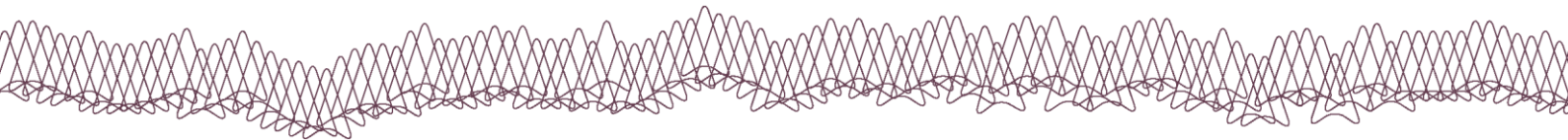
Monitor and evaluate for shifting baselines: in a changing climate, objectives will often be to reduce loss of condition (rather than maintain or enhance conditions) against a shifting baseline. The counterfactual (rates of loss without intervention) will be more important than starting (static) baseline conditions (see Figure F.1). These trajectories will often (perhaps mostly) be highly uncertain and require close collaboration between domain experts (researchers) and resource managers to establish realistic trajectories against which to measure outcomes.

Understand that in risk management, not all bets

payoff: investment in areas where there is a high probability of loss (for instance associated with extreme events) is not a bad investment if those extreme events are not as frequent or intense as projected. Risk management always relies on probabilities (formal probabilities or subjective estimation of risk in the case of climate projections) and rational assessment relies on using those estimates to make decisions which will sometimes be right in terms of probability, but wrong in relation to outcome.

M&E should be aligned with timeframes of objectives

and outcomes: Because interventions will have effects at different rates, M&E needs to be targeted to capture intermediary and longer term outcomes of initiatives. This imperative of adaptation presents a substantial challenge to Commonwealth and state governments to enable evaluation beyond the life of initiatives, or to institutionalise and resource M&E programs within NRM and/or partner organisations (e.g. universities). Some longitudinal data collection efforts are best co-ordinated at state and national scales to ensure comparability and credibility of methods.



Distinguish between the focus of data collection and the desired outcomes. The classic non-NRM case is ‘teaching to the test’ in which, because schools benefit from high test results, teachers end up training students to do well in tests rather than achieving the broader curriculum goals. In an NRM example, nitrate concentrations might be monitored as a proxy for estuarine health (where NOx is seen as the greatest threat at time A) and other threats ignored as all efforts focus on managing NOx concentrations. It is often necessary to find proxies for efficiency but these should be supplemented, especially with qualitative data sources that can alert organisations to unexpected system change.

Establishing indicators across scope and scale of adaptation: Because adaptation is a long-term and staged process many different indicators of social, financial, human, environmental, physical features may be of interest in evaluating change. In taking a pathways approach to adaptation some indicators may be considered to trigger new approaches to be developed or trialled. For example, cost of flood insurance claims in a city might serve as an indicator of political/market interest in development of different forms of upstream floodplain management to keep water in the landscape.

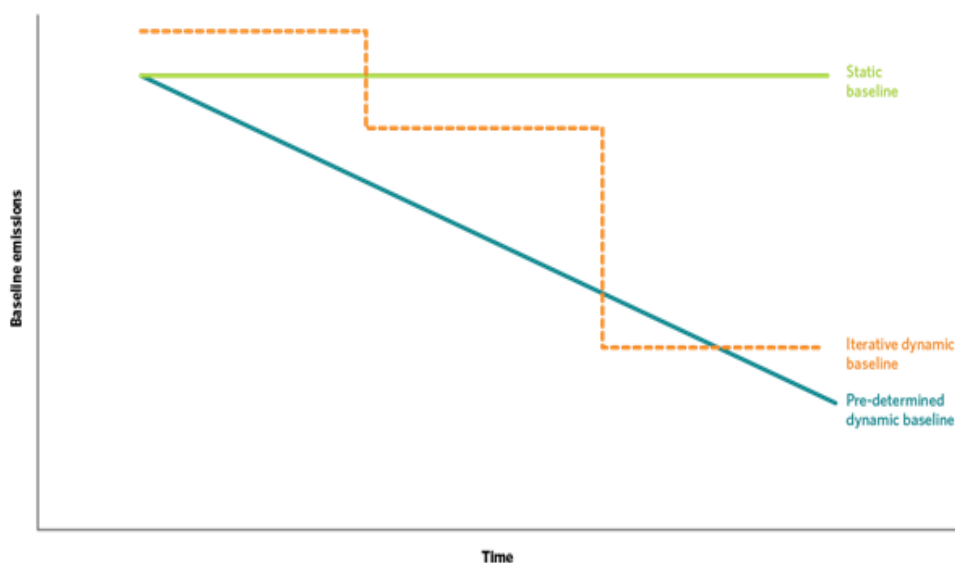
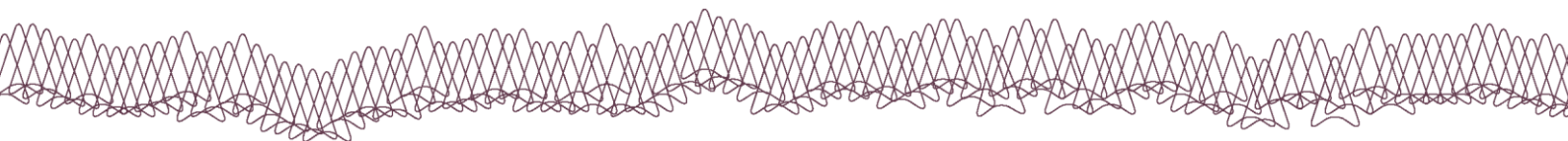


Figure F.1 Three options for developing baselines (in this case for carbon emissions): static, pre-determined dynamic and iterative dynamic (Source: Climate Change Authority, 2014)



F.2 Approaches to monitoring, evaluating and learning

In the previous section the general concepts of monitoring and evaluation (M&E) were introduced. In this section we look at particular M&E frameworks for practical use.

F.2.1 Monitoring and evaluation frameworks

In the first stages of M&E, practitioners develop lines of sight between clearly-stated goals and objectives, on the one hand, and the work that needs to be done to achieve them on the other. Later stages involve defining metrics or data sources to understand baselines and extent of change or improvement over well-defined time periods. There are a variety of useful frameworks to help to do this. The better ones enable practitioners to consider and review activities and work

at multiple levels. Below we provide an overview and links to further information on these frameworks that can guide the development of M&E.

The Bennett's Hierarchy

The Bennett's Hierarchy (Bennett, 1975) in

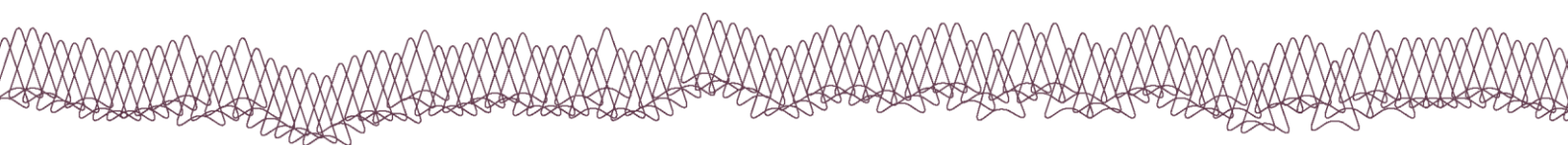
Table F.2 provides a logical way of laying out the linkages between means and ends and a layered approach to thinking these through:

- inputs necessary for activities to engage with participants
- participants react or respond in particular ways (with good planning, in 'desired' ways)
- so the knowledge, attitudes, skills or aspirations of participants change in some way
- leading to practice change
- and thereby the desired result – outcomes or impacts.

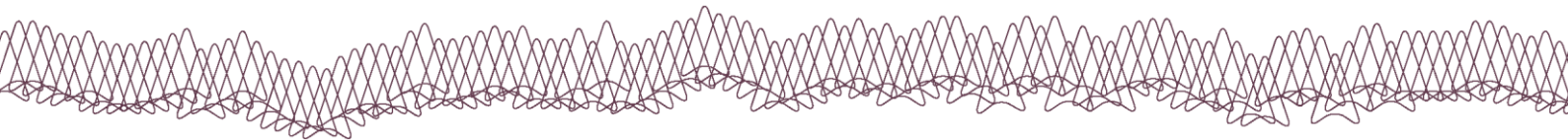
(NB: anyone, including project teams can be considered participants).

Table F.2 An example of the 'if/then' hierarchy in a project designed to contribute to change in social, environmental and/or economic (SEE) conditions. This process is based on Bennett's hierarchy (Bennett 1975) and the table is adapted from The Tasmanian Institute of Agriculture M&E materials (Evans et al. 2014).

| Level in hierarchy | Label | Descriptor | Description | Typical questions to ask |
|--------------------|---------|--|--|--|
| 7 | Outcome | Change in social, economic and environmental (SEE) conditions. | Aspirational Goal. 'The initiative contributed to....' | What does success look like at the highest level? Are we being too abstract? Too aspirational or unrealistic? Too high level? |
| 6 | Outcome | Practice change | Change to particular practices | What practices, systems or technologies must participants adopt (or disadopt) to bring about SEE changes? |
| 5 | Outcome | KASA-level change | Changes in knowledge, aspirations, skills and/or attitudes | What do participants need to know and what skills do they need to acquire for practice change? What values need to be addressed to bring about changes in attitudes and aspirations? |



| | | | | |
|---|------------|---------------------------------|--|---|
| 4 | Outcome | Reactions | How participants feel about messages and delivery process immediately after participation. | What are current attitudes and aspirations? What benefits must we deliver if we are to engage participants positively? How will activities engage/retain the interest of the targeted participants? |
| 3 | Output | Tangible and intangible outputs | Information, knowledge, products, services, processes, tools, systems, publications, graduates, relationships, networks or skills developed. | What outputs are needed to deliver the desired outcomes? |
| 2 | Activities | Activities | Research, development, extension, on-ground works, trials, linkage work, assessments, etc | What activities or actions need to be undertaken to deliver the outputs? What methods? Who will participate? Which stakeholders will be involved in developing the activities? How will they be engaged and how will they be supported? |
| 1 | Resources | Resources, inputs | Human, physical, financial. E.g. knowledge, plans, protocols. | What resources are needed? What knowledge base needs to be used/developed? Are people available or do they need to be recruited? What planning or foundational activity needs to be undertaken? |



Program logic model

Similarly, a program logic model (e.g. Figure F.2) provides linkages between inputs, activities, outputs and different levels of outcomes with greater consideration of assumptions about the external environment.

Achieving NRM objectives usually requires coordination between multiple organisations. There is much that can go wrong and prevent achievement of objectives. For example, the external environment and assumptions about how it will operate and change, as well as the ability of an initiative to govern that change (to understand where it sits in the ‘big picture’), should be explicitly considered in developing initiatives and thus be part of the M&E (Marshall et al., 2010; Leith et al., 2012). Through such broad based scoping, M&E can target objectives and indicators of them at different levels. Through such scoping, components or activities, as well as external drivers and other ‘system drivers’ can be part of the ultimate story of the success or failure of an initiative. This can help to overcome a common phrase: ‘we tried that and it didn’t work’. Instead we can review theories of change to identify barriers and how they might be overcome, or why they might actually present impassable limits.

Through being inclusive and reflective, teams can learn where they were more or less useful, efficient or effective and why their overall theory of change was itself faulty, deficient or realistic.

Mayne and Stern (2013, p. 26) define the terms in Figure F.2 as follows:

“Assumptions are events and conditions that need to happen for to create the outcome; that is the supporting factors needed for the intervention causal package to work. They are developed from a mix of stakeholder and social science theories and research.

Risks are external events and conditions that could put the causal link at risk.

Other explanatory factors are the conditions outside of the control of the initiative that might help explain the occurrence of the observed result other than the intervention causal package.

Unintended or unforeseen effects are positive or—more usually—negative unanticipated effects that occur as a result of the intervention’s activities and outputs.”

Evaluation implies thinking through what will work to achieve goals and objectives and then testing that theory (of change) in practice. Many projects do not base their activities on a well-reasoned or evidenced theory of change, but rather have an output focus. For instance the ‘loading dock approach’ focusses on the delivery of outputs (Cash, 2006). You write something (e.g. a ‘factsheet’) give it to people, have them respond favourably, they change what they do and so solve their problem. Some consider such approaches to be naïve.

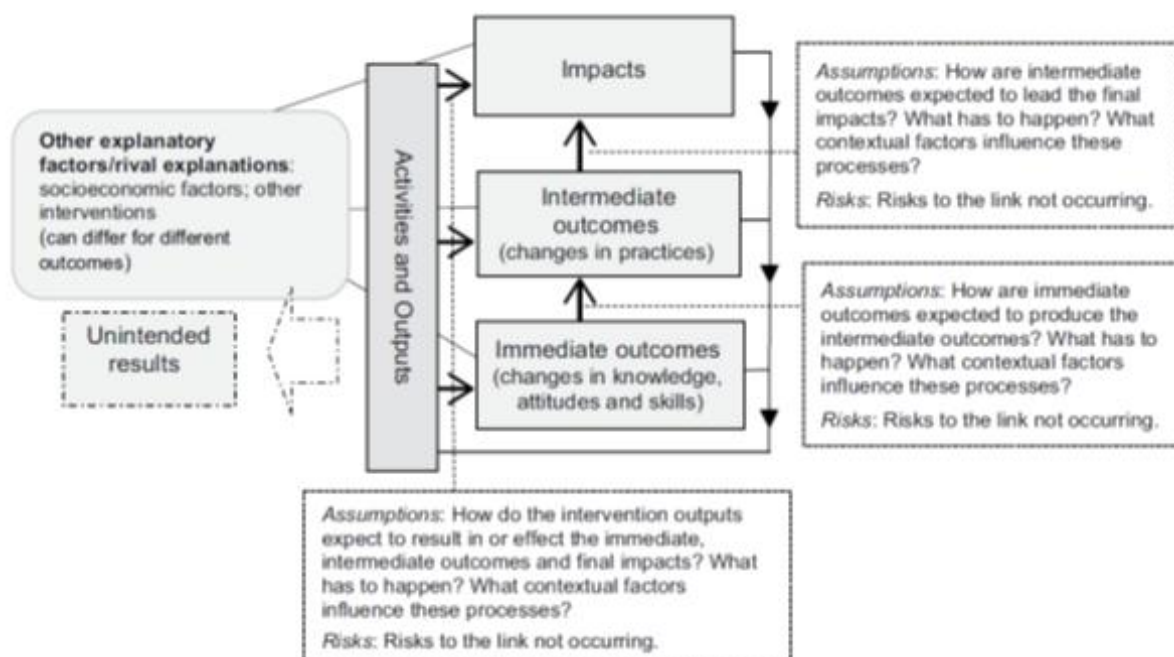


Figure F.2 An example of a generic 'Theory of Change' (Source: Mayne and Stern 2013, pg. 26)

Logframes and program logics

A Logframe Approach (LFA) (see Table F.3) uses a tabular format to link between inputs, activities, outputs, outcomes and goals, with an emphasis on assumptions as external drivers and measurable indicators with linked 'means of verification'. The logframe approach thus makes a clear distinction between an initiative and its external operating environment. Although there are undoubtedly external factors beyond the control of any given initiative, the theory of change model and the program logic (above) tend to treat these elements in a theoretically informed

manner and thereby encourage designers and practitioners to consider the arrows between boxes in an active sense, informed by social and psychological research.

Within a Program Logic (see Figure F.3) the linkages between inputs, activities, outputs and outcomes are more explicitly managed through, for example, making sure that we 'fund the arrows not just the boxes' (Campbell and Schofield, 2006). Thus coordinating, networking and capacity building become central to managing an environment which enables change, and a focus on project intervention and M&E activity.

Table F.3 The structure of a typical logframe (Source: Lamhauge et al. 2012)

| Narrative summary | Objectively verifiable indicators | Means of verification | Assumptions |
|---|---|---|--|
| Goal – the overall aim to which the project is expected to contribute | Measures (direct or indirect) to show the project's contribution to the goal | Sources of information and methods used to show fulfilment of goal | Important events, conditions or decisions beyond the project's control necessary for maintaining the progress towards the goal |
| Outcomes (or objectives) – the new situation which the project is aiming to bring about | Measures (direct or indirect) to show progress towards the objectives | Sources of information and methods used to show progress against objectives | Important events, conditions or decisions beyond the project's control that are necessary if achieving the objective is going to contribute towards the overall goal |
| Outputs – the results that should be within the control of the project management | Measures (direct or indirect) to show if project outputs are being delivered | Sources of information and methods used to show delivery of outputs | Important events, conditions or decisions beyond the project's control that are necessary if producing the outputs is going to help achieve the objectives |
| Activities – the things that have to be done by the project to produce the outputs | Measures (direct or indirect) to show if project outputs are being delivered | Sources of information and methods used to show that activities have been completed | Important events, conditions or decisions beyond the project's control that are necessary if completing activities will produce the required outputs |
| Inputs | Resources – type and level of non-financial resources needed for the project Finance – overall budget Time – planned start and end date | | |

Components of a Basic Logic Model

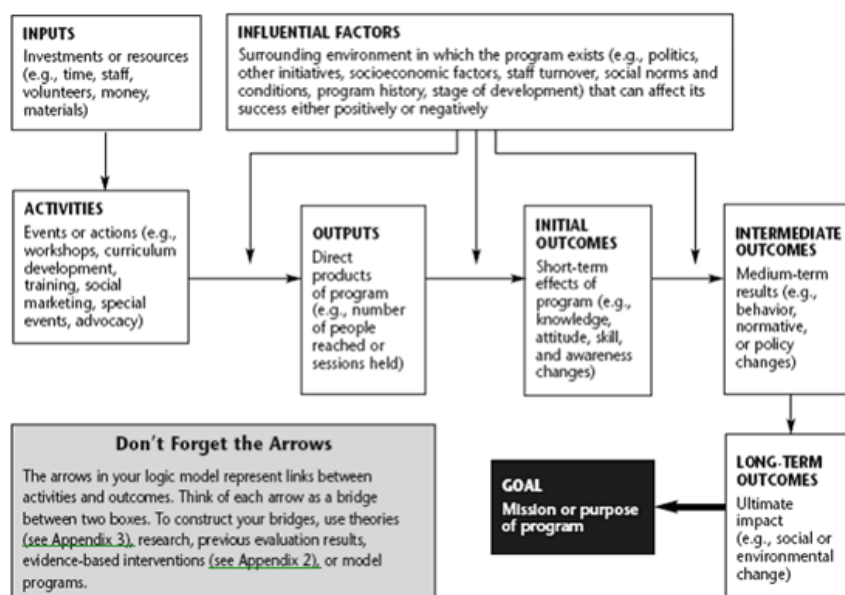


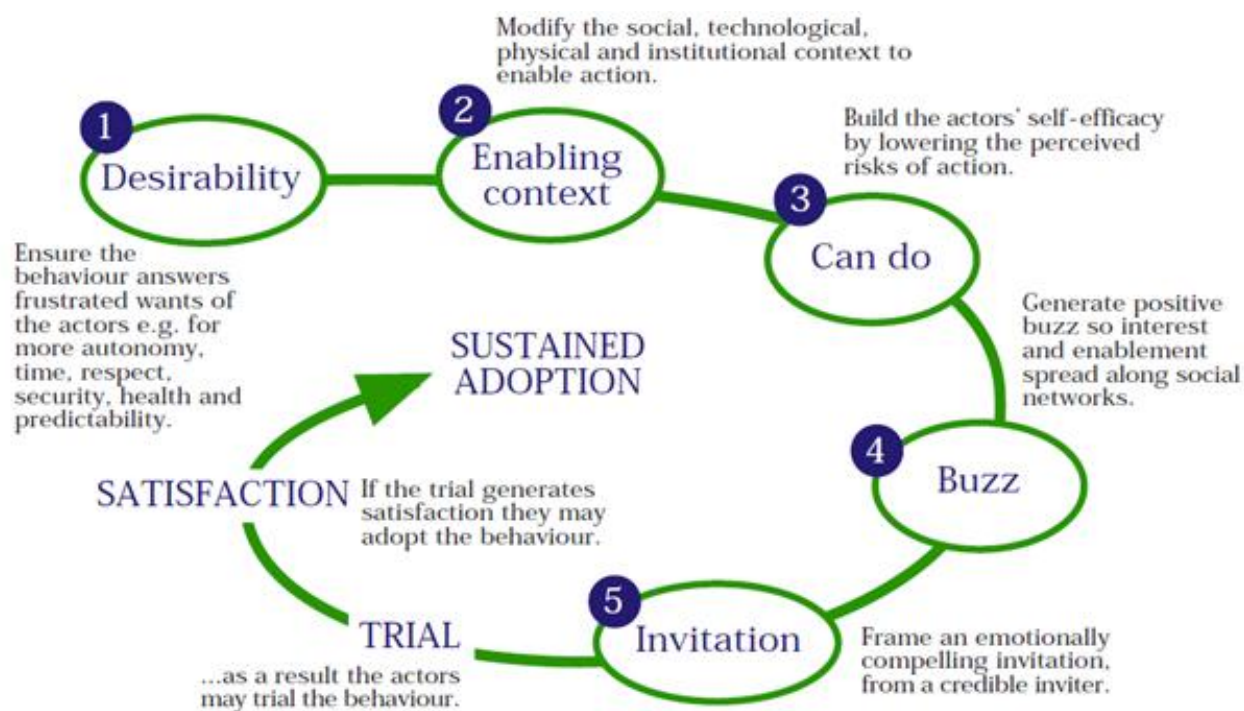
Figure F.3 Components of a basic program logic model. Source: Centres for Disease Control and Prevention³

3 (Website)

Enabling change

In reality, processes that result in practice change and desired social, economic and/or environmental outcomes require an integrated suite of activities targeted to outcomes. There is now a wide-ranging literature from social psychological research that suggests means of achieving such outcomes through diverse processes and mechanisms, a useful resource that summarises this literature in an accessible way with numerous NRM examples is Les Robinson's (2012) book *Changeology* (see Figure F.4).

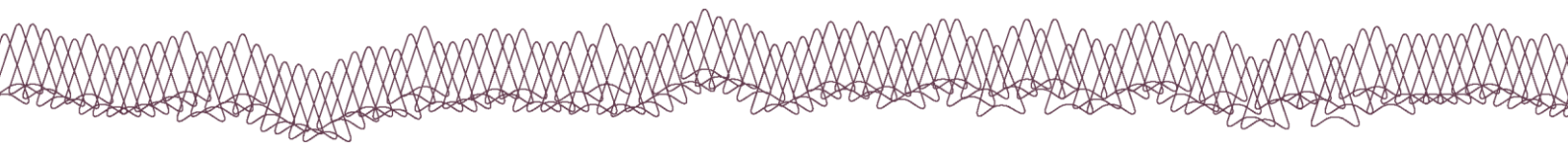
Robinson emphasises that practice change is social and psychological. This means that, while, monitoring environmental outcomes requires good biophysical science methods, it is often necessary to utilise techniques and indicators from social research methods to properly evaluate different levels of intermediate social and psychological outcomes. Capturing rich qualitative data (e.g. performance stories), can provide very useful and powerful input to program reviews, as well as to tell meaningful stories in media, policy and political contexts (Vancly, 2013).



5 Doors, an integrated model of behaviour change. Les Robinson (v3 July 2011)

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Figure F.4 Les Robinson's 5 doors theory of change that identifies stages for enable community change through adoption of new practices



Concluding comments

In providing a brief overview of key frameworks for project planning, which in turn guide the development of M&E, it is clear that different approaches have slightly different emphases. While they all consider a flow from inputs, through activities to outputs and outcomes, they also frame risks, uncertainties and factors that influence outcomes in different ways. In a theory of change, for instance, assumptions about the prerequisites for change are usually treated as hypotheses to be tested through M&E and, ideally managed through projects, networks, and other actions or rules. In a logic model more of these factors tend to be framed as 'external'. Bounding project activities and linking them with other networked or institutional activities can be critical for ensuring that the project does not just produce immediate outputs but leads to outcomes such as adoption and has a legacy in changing the broader operating environment (Leith et al., 2014b). This concern is reflected in Robinson's approach above, which provides substantial guidance on the steps that enable adoption or behaviour change but presume that the desired change is known or knowable. In planning adaptation to climate change this may not be the case.

F.2.2 Learning, narratives and stories

Alternative approaches to M&E have emerged in recognition that some program outcomes are not measurable by traditional, mainly quantitative, frameworks. For example, Lowe (2013) argue that 'outcomes' are not an appropriate measure of change (where outcomes = what you're trying to achieve in the short to medium-term, as compared to inputs or outputs). While Lowe's argument comes from a context of performance management in relation to social policy, it has relevance here because planning in NRM is mainly directed towards management activities, thus the 'outcomes' achieved in the landscape are a result of 'outcomes' achieved in and across organisations and networks of actors (Vanclay, 2013).

In the following sections, some learning-based approaches are considered that offer opportunities to complement traditional monitoring and evaluation frameworks, or replace them in the case of 'outcomes' that are organisation-oriented. Examples are then given that describe how organisational change, specifically adaptive capacity, can be evaluated using learning-based approaches.

What are some learning-based approaches?

Learning-based approaches are used here to refer to people-oriented ways of assessing the effectiveness of programs. That's not to say that conventional M&E frameworks do not incorporate or lead to learning, rather these are methods that start with the experiences that people have in processes of change. Four approaches are highlighted that range on a spectrum from more 'outside' the system to more 'inside' the system of interest. In other words, the first approach can be conducted entirely by 'external' evaluators, to the last approach that is primarily conducted by those embedded in the situation.

Objective-Reflective-Interpretive-Decisional (ORID)

The ORID framework (Stanfield, 2000) is an approach to evaluation that focuses on four different modes of thinking, as summarised in Table F.4 and populated with examples from NRM. The first mode is 'objective', involving discussion of what a group takes as agreed 'fact'. The second mode is 'reflective', where a group explores their individual perspectives and even 'feelings' about an issue. The third mode is 'interpretive', which involves consideration of possible issues or opportunities. The fourth mode is 'decisional', leading to decisions about how to move forward.

The ORID framework can be employed as a technique for facilitated group review of an activity. For example, it can be used by an evaluator in focus group interviews or facilitated group conversations to draw out responses.

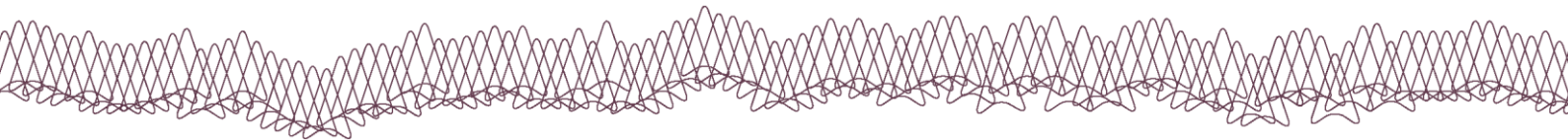
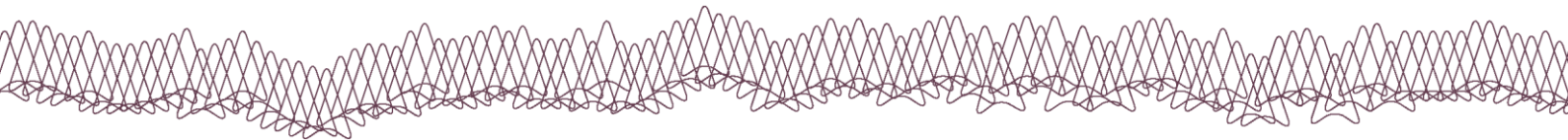


Table F.4 An overview of the ORID technique, with hypothetical examples from an NRM context

| MODE OF QUESTIONING | OBJECTIVE | HYPOTHETICAL NRM EXAMPLES |
|-----------------------------|--|---|
| 'O' stands for objective | Discover what the group takes as 'fact' | <i>"The spread of carbon farming projects in the region has been less than expected"</i> |
| 'R' stands for reflective | Explore feelings about the topic being discussed | <i>"I'm not surprised that this is the case - it was never going to take off"</i> <i>"I feel we can do better to promote the opportunities"</i> |
| 'I' stands for interpretive | Understand the issues and opportunities faced | <i>"The problem is that the incentives to convert land to biodiverse carbon plantings are not sufficient"</i> <i>"The information available to landholders could be much better"</i> |
| 'D' stands for decisional | Decide how to move forward | <i>"Let's align our promotion of planting opportunities with other landowner engagement activities"</i> |



Most Significant Change

Developed by Davies and Dart (2005), the Most Significant Change (MSC) technique is akin to qualitative social research methods in that it involves collection of data, or 'stories', that are then synthesised and analysed at a higher level.

Its purpose is to ascertain the effect of a program or intervention of some sort on the lives of people involved. In an NRM context, this might be through the stories and experiences of land holders, or of NRM managers. This technique can be particularly powerful in highlighting how unexpected events or change were dealt with, because the story form has the flexibility to include salient features that are not easily captured by pre-defined metrics. In a recent review of such narrative approaches to evaluation, Vanclay (2013, p. 11) highlighted the features of effective stories as follows:

"To be an effective story, it needs to conform to the standard basic elements of all stories. It needs to have a beginning, a middle and an ending. It needs to have a coherent and credible storyline. It needs to be multidimensional, but the different components need to be interconnected and the causal relations between the components need to become clear in the course of the story. It needs to be personal and emotional."

MSC has had several different names, including 'Monitoring without indicators' and 'the "story" approach' and developed out of experiences in monitoring and evaluation in complex development programs in rural Bangladesh. It has a participatory focus, in that stakeholders are involved in deciding what is being evaluated and how the data are analysed.

Procedurally, MSC follows ten general steps (as described in chapter two of the MSC guide):

1. Getting started: establishing champions and getting familiar with the approach
2. Establishing 'domains of change'
3. Defining the reporting period
4. Collecting stories of change

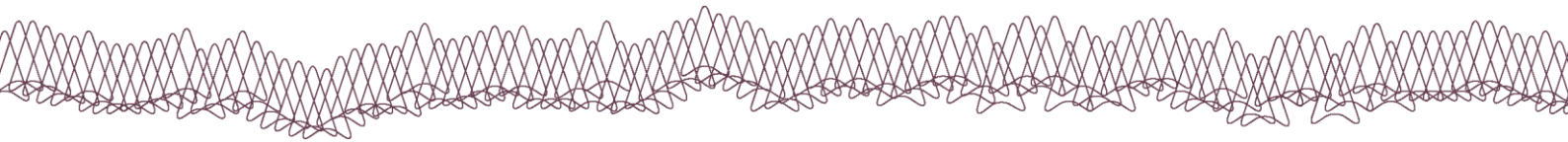
5. Reviewing the stories within the organisational hierarchy
6. Providing stakeholders with regular feedback about the review process
7. Setting in place a process to verify the stories if necessary
8. Quantification
9. Conducting secondary analysis of the stories en masse
10. Revising the MSC process.

One of the key steps is establishing the 'domains of change', which in other words is where you set the boundary around the system of interest - e.g. individuals, organisations, communities, etc. MSC relies on a high degree of facilitation or guidance, particularly in step 5 where stories are selected.

Inquiry-based approaches

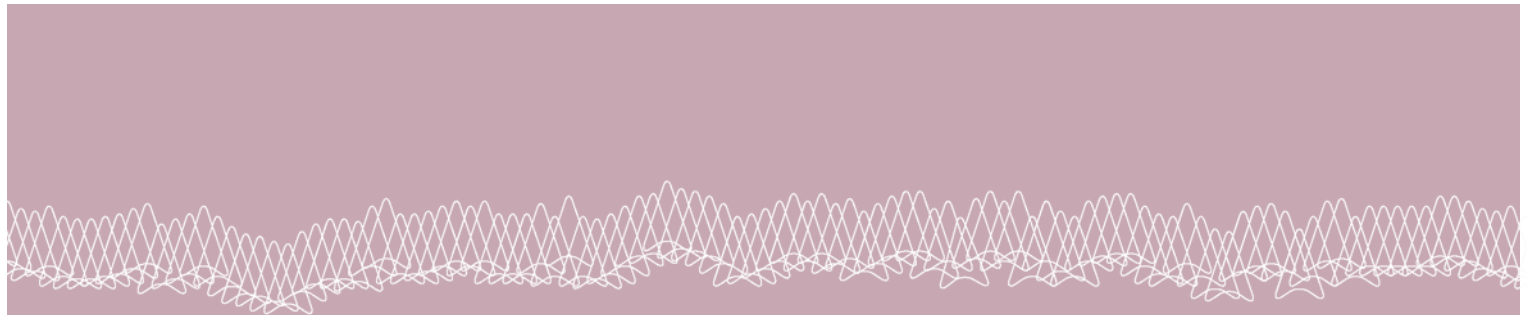
Another option is to design a 'learning inquiry' to explore the effectiveness of a program from the perspective of those involved. Ison et al. (2014a) provides an example of a multi-organisational co-designed learning inquiry in the context of an Australian-led food security program in Africa. In that case, a program-wide 'learning project' was co-designed among several of the research organisations involved. The focus was to reflexively assess the effectiveness of 'research for development' programs at an institutional level. Several 'emergent inquiries' were identified where specific issues were apparent. For instance, many research for development projects were designed by physical scientists with input from social researchers only invited at a late stage. The inquiry examined the consequences of this and considered how to design or redesign projects so that physical and social sciences were better integrated (Ison et al., 2013).

Another inquiry-type approach is systemic inquiry, which is about understanding situations in context and facilitating actions to improve that situation. A chapter of Ison (2010) gives a detailed explanation of how systemic inquiry can be understood and how to do it.



Concluding comments

Learning-based approaches involve moving from M&E as an objective process that is ‘external’ to an initiative, to a process that is ‘internal’ to the everyday practices of those involved in NRM planning and implementation. Such approaches can effectively tighten the circle of feedback, so that rather than waiting until an initiative is completed and evaluating it, the evaluation occurs at all stages in an iterative way.



Glossary



Glossary

Adaptation

“The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.” (IPCC, 2014b, p. 1758).

Adaptation pathways

‘Adaptation pathways’ describes a number of related planning approaches that draw on ideas from adaptive management as a way of addressing the uncertainties associated with climate change. These approaches are distinguished by an emphasis on identifying, selecting and sequencing options (i.e. pathways) that will be both robust and flexible in achieving desired objectives across a range of plausible futures.

Adaptive capacity

According to the IPCC (2014b, p. 1758), adaptive capacity is the “ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.” For Brooks and Adger (2005, p. 165) adaptive capacity is “the ability to design and implement effective adaptation strategies, or to react to evolving hazards and stresses so as to reduce the likelihood of the occurrence and/or the magnitude of harmful outcomes resulting from climate-related hazards”.

Adaptive management

“A process of iteratively planning, implementing, and modifying strategies for managing resources in the face of uncertainty and change. Adaptive management involves adjusting approaches in response to observations of their effect and changes in the system brought on by resulting feedback effects and other variables.” (IPCC, 2014b, p. 1758).

Climate change

“Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due

to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use.” (IPCC, 2014b, p. 1760).

Climate model

“A numerical representation of the climate system that is based on the physical, chemical, and biological properties of its components, their interactions, and feedback processes, and that accounts for all or accounting for some of its known properties.” (IPCC, 2014b, p. 1760).

Climate projection

“A climate projection is the simulated response of the climate system to a scenario of future emission or concentration of greenhouse gases and aerosols, generally derived using climate models.” (IPCC, 2014b, p. 1761).

Climate variability

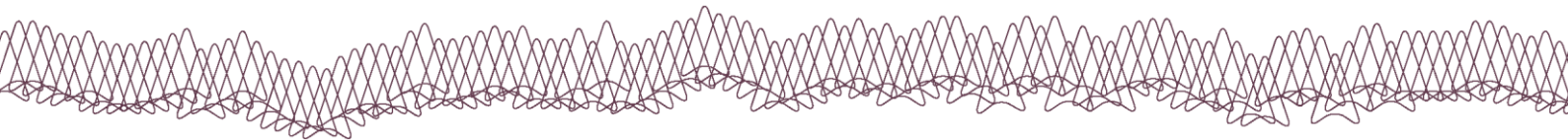
“Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate at all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability).” (IPCC, 2014b, p. 1761).

Exposure

“The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.” (IPCC, 2014b, p. 1765).

Governance

“The interactions among structures, processes and traditions that determine how power and responsibilities are exercised, how decisions are taken, and how citizens or other stakeholders have their say.” (Davidson et al., 2006, p. 31)



Hazard

“The potential occurrence of a natural or human-induced physical event that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources.” (IPCC, 2014b, p. 1766).

Impacts

“Effects on natural and human systems...the term ‘impacts’ is used primarily to refer to the effects on natural and human systems of extreme weather and climate events, and of climate change.” (IPCC, 2014b, p. 1767).

Measures

See options.

Mitigation

“A human intervention to reduce the sources or enhance the sinks of greenhouse gases.” (IPCC, 2014b, p. 1769).

Options

Options (or measures) are potential actions that could be taken in adapting to climate change. Options can be physical, social, institutional, or economic. Options may be directed towards moderating the impacts associated with climate drivers, taking advantage of opportunities, or (increasingly) focused on the underlying causes of vulnerability (IPCC, 2014b).

Policy

A policy is any specified course of action undertaken or advanced by an individual or organisation. Policies consist of various principles, guidelines, and rules that provide normative direction for decision making and/or the achievement of outcomes.

Projection

“A projection is a potential future evolution of a quantity or set of quantities, often computed with the aid of a model. Unlike predictions, projections are conditional on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realized.” (IPCC, 2014b, p. 1771).

Resilience

“The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation.” (IPCC, 2014b, p. 1772).

Robustness

In the context of adaptation pathways planning, robustness refers to how effective (insensitive to change) any particular option is in achieving a specified objective across a range of plausible futures. A robust option will continue to perform as conditions vary.

Risk

“The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard.” (IPCC, 2014b, p. 1772).

Sensitivity

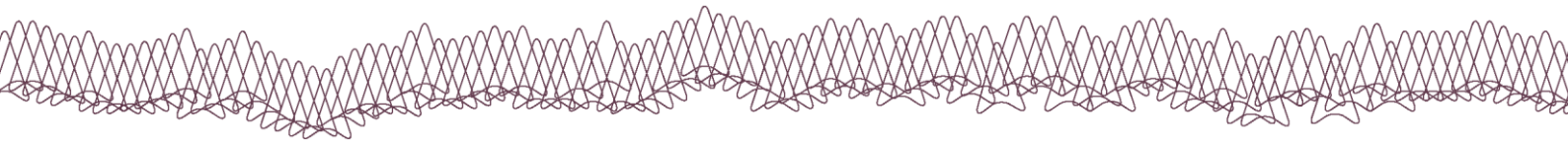
“The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise).” (IPCC, 2014b, pp. 1772–3).

Transformation

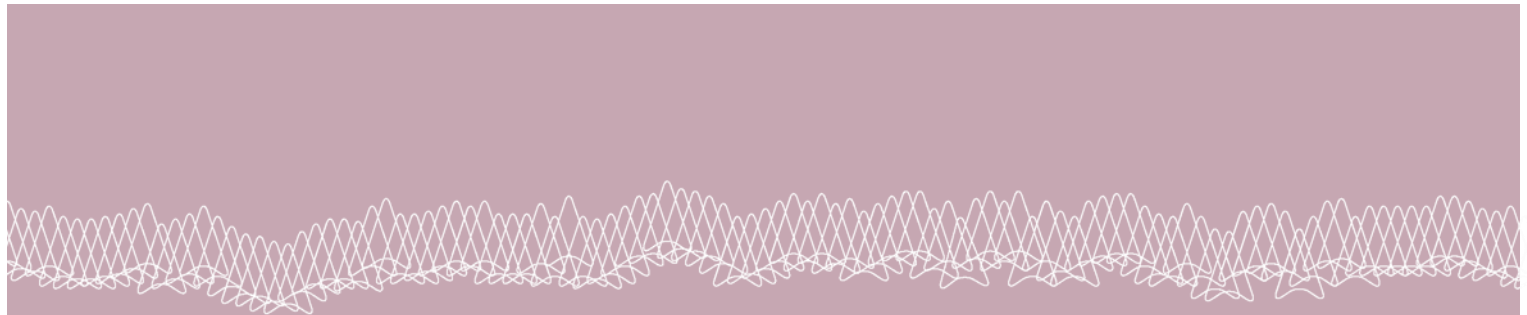
Transformation is “a change in the fundamental attributes of natural and human systems” (IPCC, 2014b, p. 1774).

Transition

Transition is a gradual and continuous process of change that results in a new stable state to a system (i.e., of greater complexity). Unlike transformation, the fundamental structural features of human and natural systems remain unchanged.

**Vulnerability**

“The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.” (IPCC, 2014b, p. 1775).

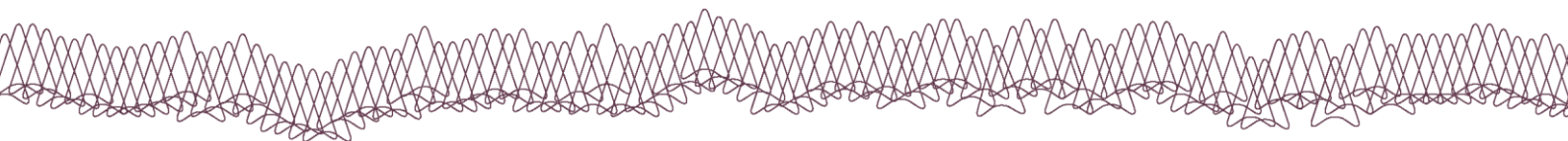


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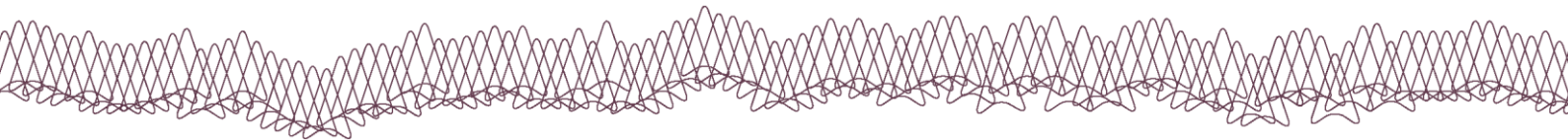


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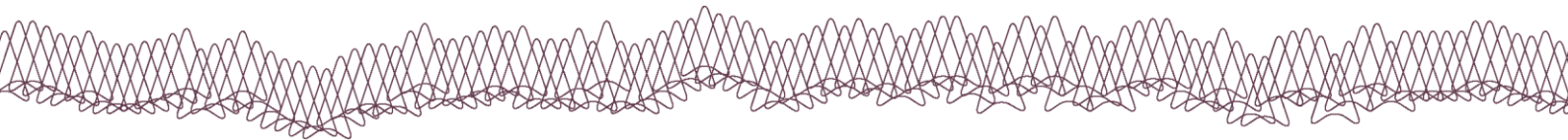
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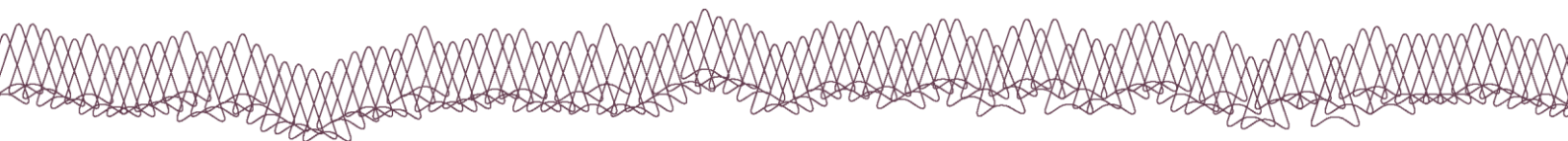
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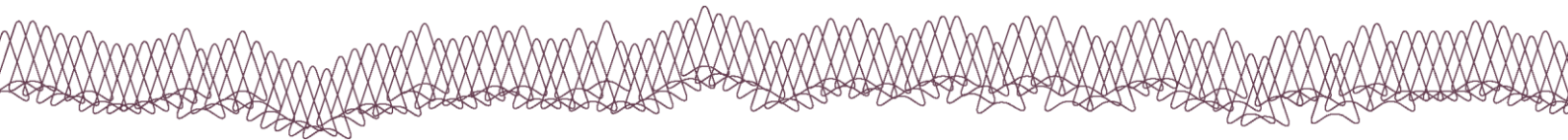
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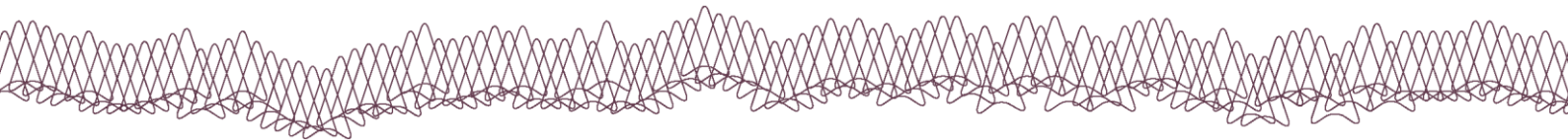
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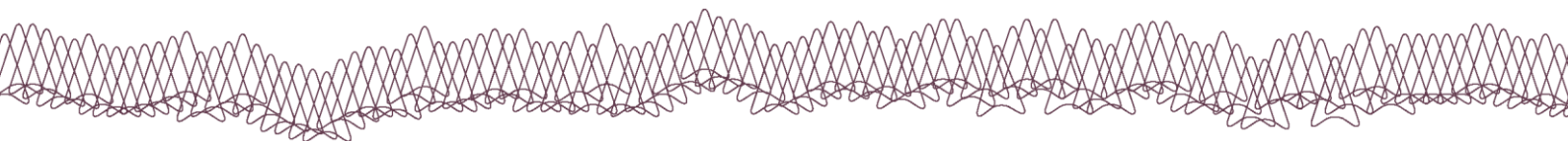
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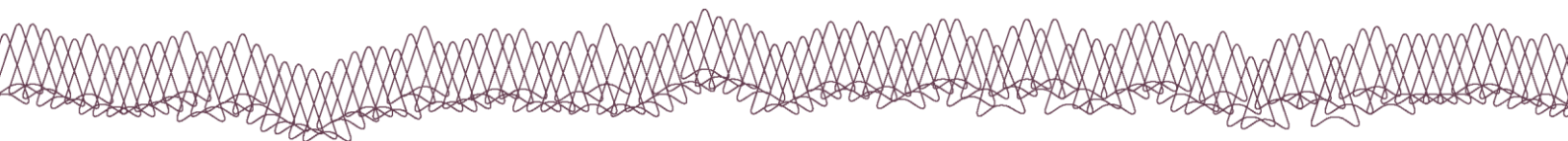
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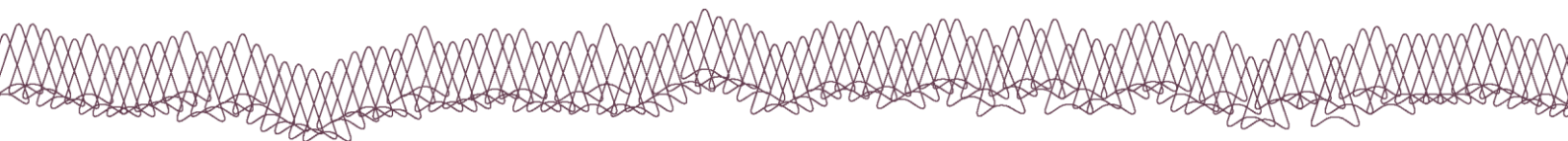
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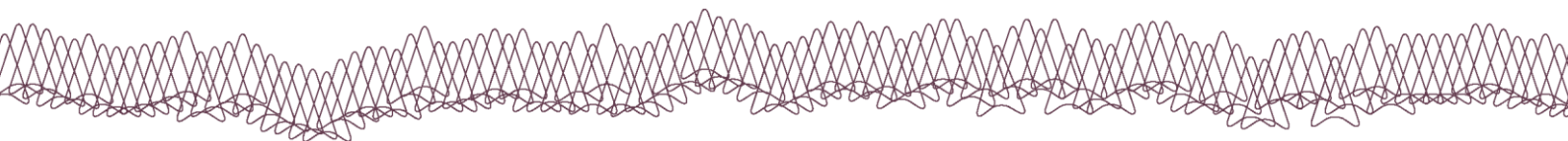
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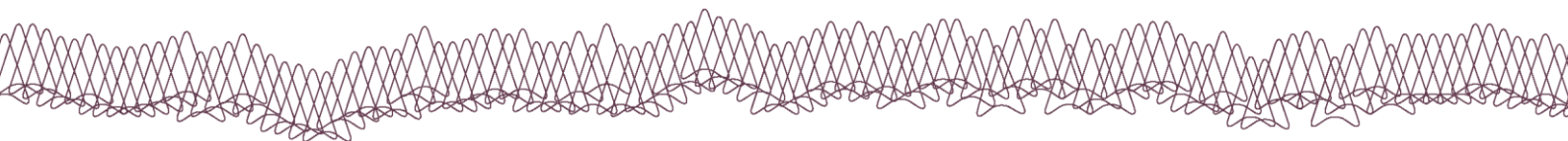
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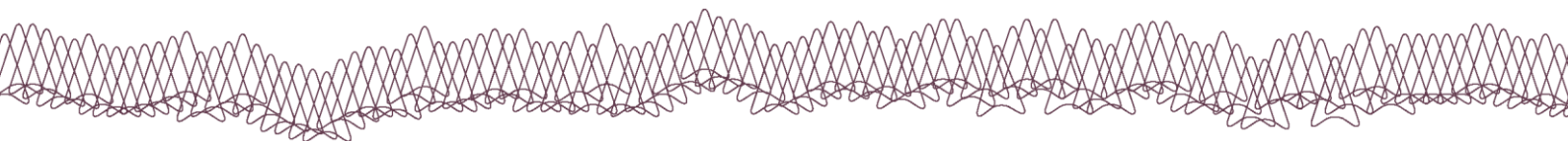
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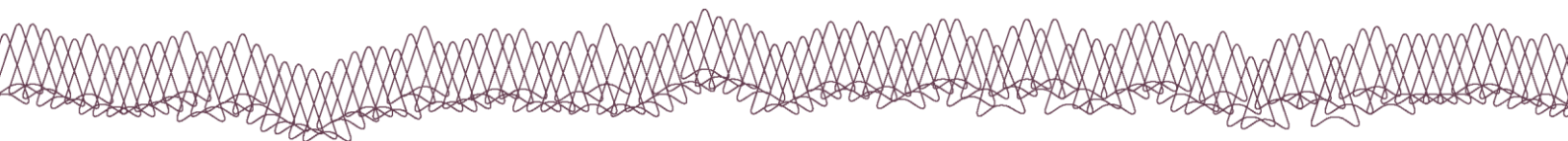
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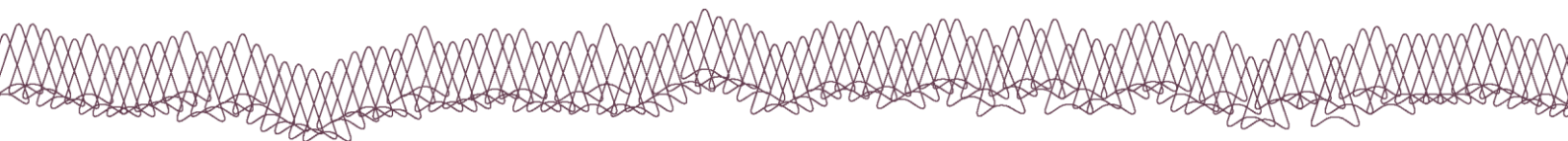
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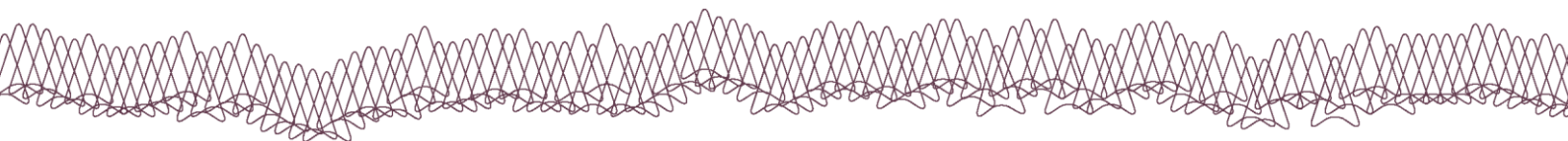
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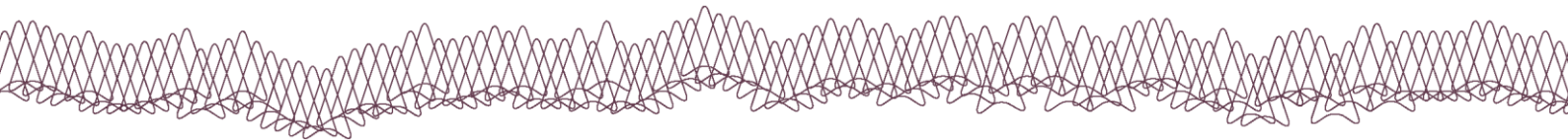
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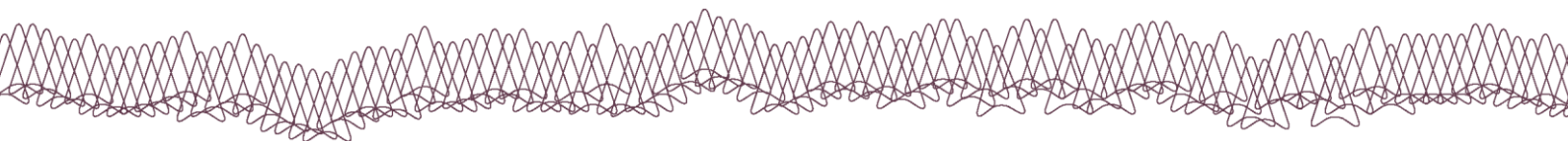
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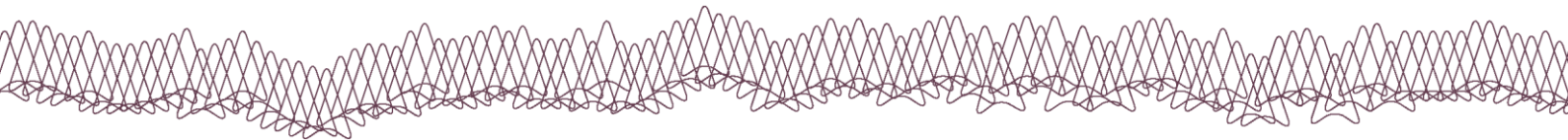
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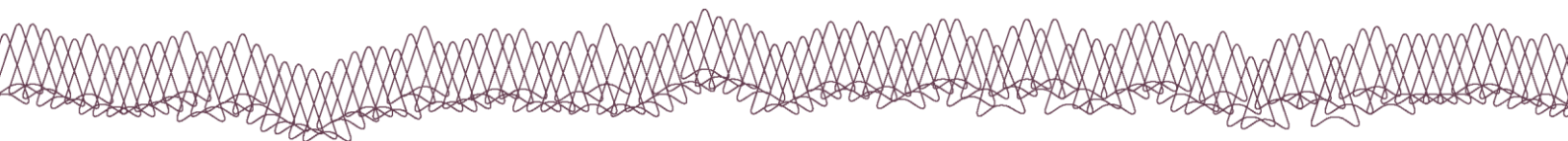
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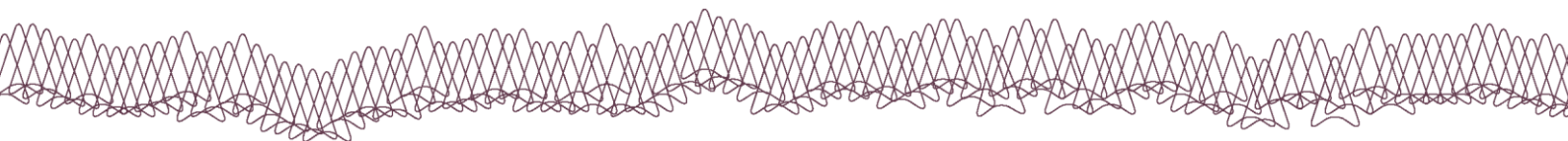
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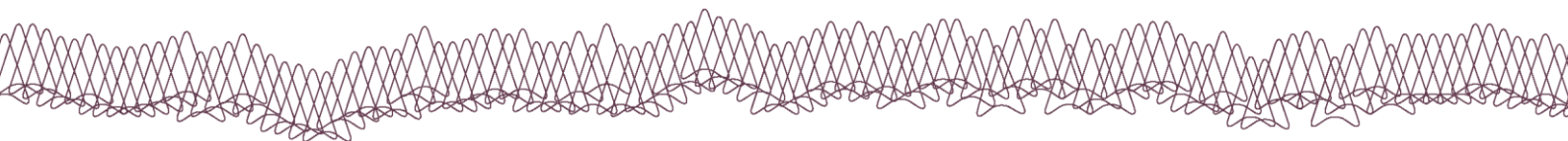
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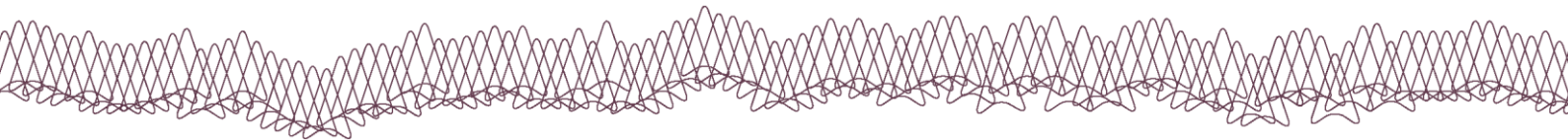
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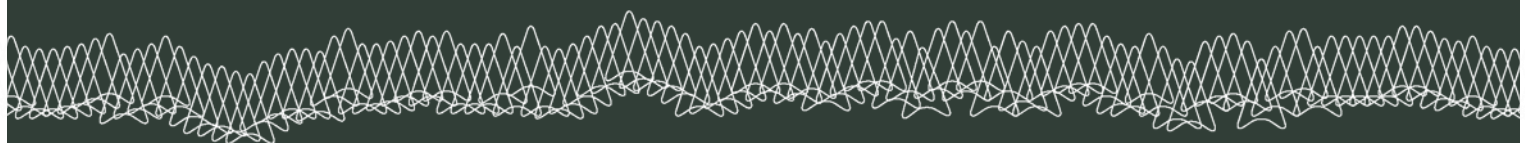
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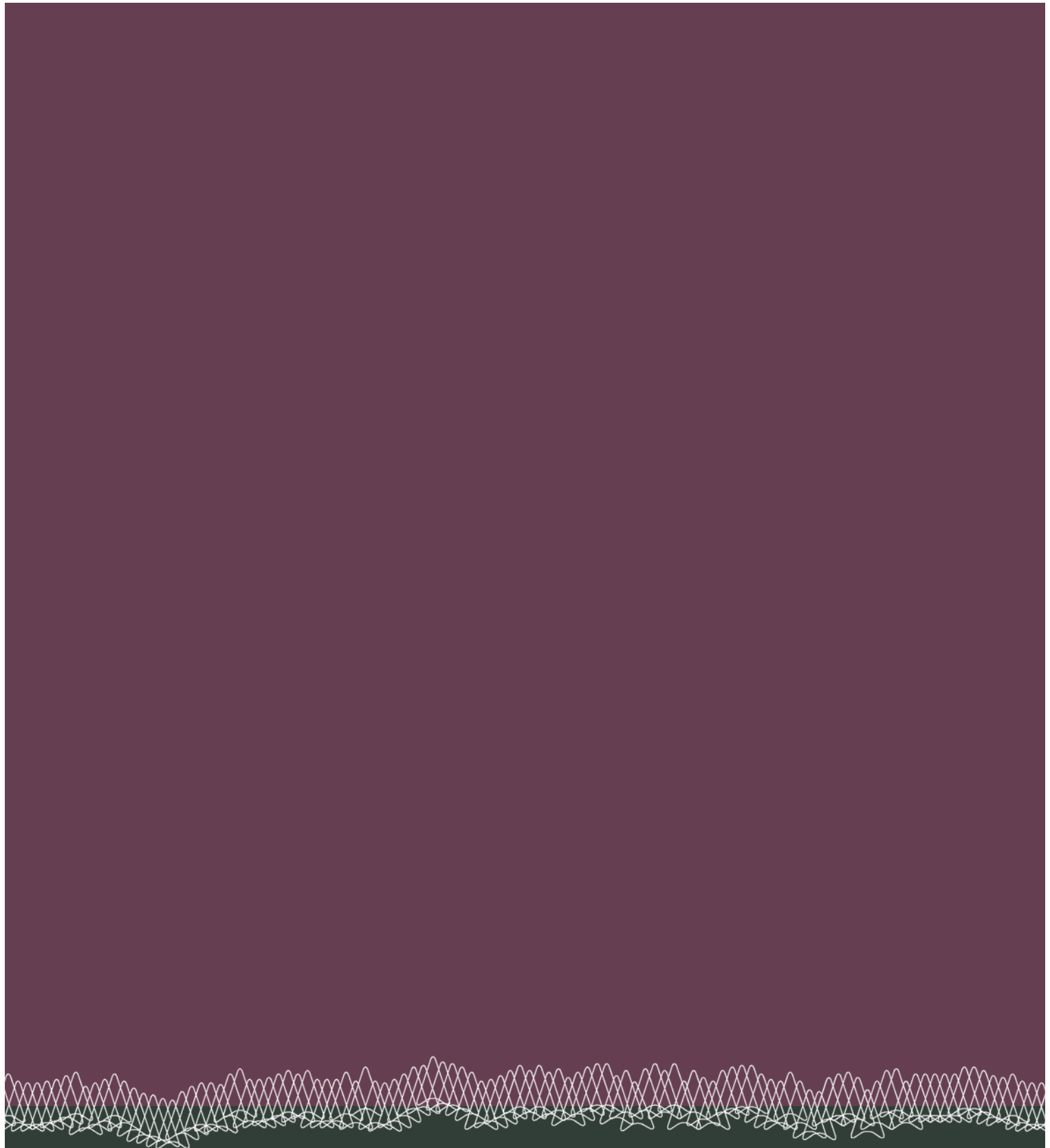


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