CoastAdapt

Building the knowledge base for adaptation action

Information Manual 1

2nd Edition

www.coastadapt.com.au

Published by the National Climate Change Adaptation Research Facility 2017

ISBN: 978-0-9946054-0-5

Please cite this Manual as:

Boulter, S., 2017: Building the knowledge base for adaptation action. CoastAdapt Information Manual 1, 2nd edn, National Climate Change Adaptation Research Facility, Gold Coast.

Acknowledgement

This work was carried out with financial support from the Australian Government (Department of the Environment and Energy).

In this the second edition of this Information Manual, we have updated information and links where resources have changed or new resources have become available since we published the first edition.

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Information Manual 1

2nd Edition

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NCCARF
National
Climate Change Adaptation
Research Facility

Australian Government
Department of the Environment and Energy

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Preface

In 2014, the National Climate Change Adaptation Research Facility (NCCARF) was commissioned by the Australian Government to produce a coastal climate risk management tool in support of coastal managers adapting to climate change and sea-level rise. This online tool, known as CoastAdapt, provides information on all aspects of coastal adaptation as well as a decision support framework. It can be accessed at www.coastadapt.com.au.

Coastal adaptation encompasses many disciplines ranging from engineering through to economics and the law. Necessarily, therefore, CoastAdapt provides information and guidance at a level that is readily accessible to non-specialists. In order to provide further detail and greater insights, the decision was made to produce a set of Information Manuals, which would provide the scientific and technical underpinning and authoritativeness of CoastAdapt. The topics for these Manuals were identified in consultation with potential users of CoastAdapt.

There are ten Information Manuals, covering all aspects of coastal adaptation, as follows:

1. Building the knowledge base for adaptation action
2. Understanding sea-level rise and climate change, and associated impacts on the coastal zone
3. Available data, datasets and derived information to support coastal hazard assessment and adaptation planning
4. Assessing the costs and benefits of coastal climate adaptation
5. Adapting to long term coastal climate risks through planning approaches and instruments
6. Legal risk. A guide to legal decision making in the face of climate change for coastal decision makers
7. Engineering solutions for coastal infrastructure
8. Coastal sediments, beaches and other soft shores
9. Community engagement
10. Climate change adaptation planning for protection of coastal ecosystems

The Information Manuals have been written and reviewed by experts in their field from around Australia and overseas. They are extensively referenced from within CoastAdapt to provide users with further information and evidence.

NCCARF would like to express its gratitude to all who contributed to the production of these Information Manuals for their support in ensuring that CoastAdapt has a foundation in robust, comprehensive and up-to-date information.

Part 1: Introduction to adaptation planning frameworks

1 This manual – the approach and how to use it

1.1 CoastAdapt and the role of the information manuals

This information manual is the first in a series that has been produced by the National Climate Change Adaptation Research Facility (NCCARF). The information manuals have been designed to give more technical detail on key areas of coastal adaptation to climate change. They form part of NCCARF's coastal risk management tool **CoastAdapt**.

1.2 This manual – a guide to the important issues and resources for adaptation planning and decision-making

This manual is an introduction to adaptation planning and decision-making. In it, we focus on two key areas: the **things you should understand** and the **resources to read** if you are thinking about undertaking adaptation planning and implementation in the coastal zone. We include a look at the most important tools and frameworks and describe how you might want to use them and how they have been used in practice. We have highlighted free products, but there are other commercial products and consultant services that you could also consider. Here we focus on empowering you to find information and build your understanding. The manual is a first-pass guide, with links to more information.

We expect this manual will be useful for decision-makers in local government, industry and private business who are thinking about climate change adaptation in coastal areas in particular. The manual has two main parts (see also Figure 1):

- **Part 1** introduces adaptation planning frameworks and tools and how you might use them for your organisation
- **Part 2** looks at the key issues and key resources to support each step in an adaptation planning

Titles of the information manuals developed for CoastAdapt

1. Building the knowledge base for adaptation action
2. Understanding sea-level rise and climate change, and associated impacts on the coastal zone
3. Available data, datasets and derived information to support coastal hazard assessment and adaptation planning
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process such as those considered in Part 1. We have used the six steps in NCCARF's CoastAdapt Climate Change Adaptation Decision Support (C-CADS) adaptation planning framework (Figure 2) to structure this Part. The steps are broadly similar to most adaptation planning frameworks. It should be noted that much of the content of this manual falls under the first step "Identify Challenges" as this is the step where you will be seeking most of the available external information and data. Following that you are likely to mostly be looking for guidance and generating your own information.

Many of the issues in this manual are explored in more depth in the other volumes in this series and within the CoastAdapt website and accompanying case studies and factsheets. These can all be found at http://www.coastadapt.com.au.

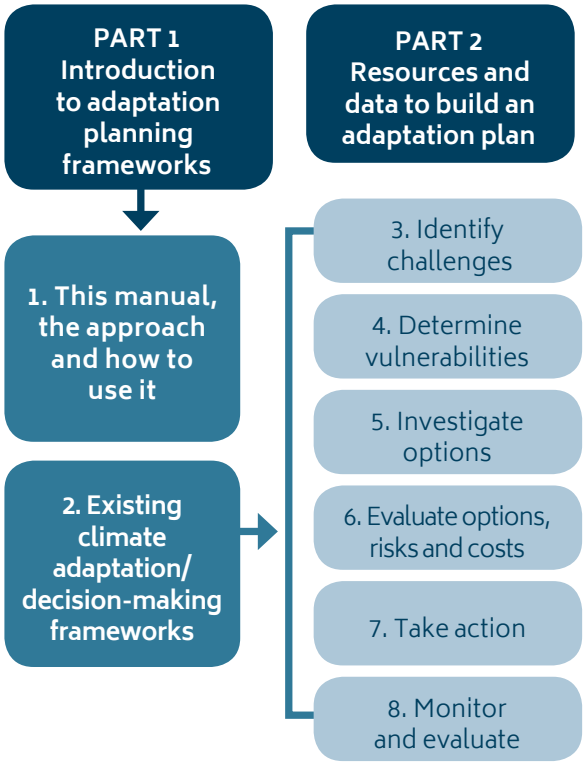


Figure 1: Schematic showing an outline of how the sections of this manual reflect a decision-making framework. Source: © NCCARF 2016.

1.3 How you might use this manual

This manual is intended to give you an initial guide to important topics and information to support your decision-making. You can dip into individual topics of interest to get a brief overview, then you may want to look at the recommended key resources to get more information.

Of course the resources will date; some of the science may go out of date and need revision; and the thinking and understanding of issues will grow. We hope the manual will help you understand technical issues and empower you to access more information by guiding you in where to look for it and how to use it in your adaptation planning.

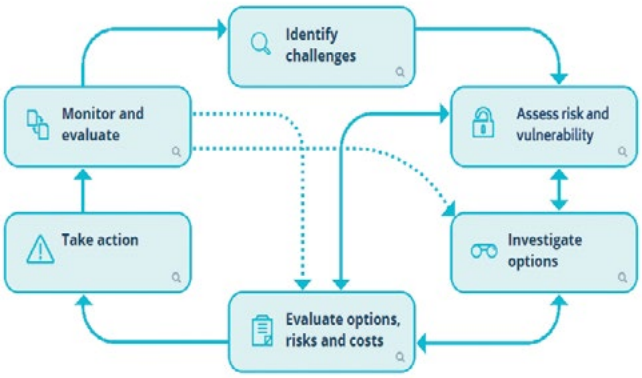


Figure 2: The steps and process of the C-CADS adaptation planning framework used to structure Part 2 of this manual. Source: © NCCARF 2016.

2 Existing climate adaptation/decision-making frameworks

2.1 What do we mean by 'adaptation framework' or 'decision-making framework'?

Decisions about how to adapt to climate change can be informed by a variety of tools, methods and approaches. Many of these make up or fit within the steps of what can be described as an **adaptation decision-making framework**. These steps are currently accepted as good practice in decision-making and as being able to cover the entire decision-making process.

Adaptation decision-making frameworks that are iterative and circular (allowing revision) are considered good practice in recognition of the need for flexibility and adaptive management in addressing climate change risks. This also comes from the understanding that planning for climate change is not going to end with a single decision.

The dynamic and long-term nature of climate change means that decisions need to be nuanced, and they will need to be revisited, or delayed or even replaced in the future as things change and more understanding is gained of the rate of climate change and how society and the environment are responding to it.

Most adaptation decision-making frameworks share common or similar steps. Central to NCCARF's CoastAdapt Tool is an adaptation framework called C-CADS, which steps users through six adaptation-planning steps (Figure 2) that are common to or overlap with several frameworks, making them a useful basis for the structure of this manual. The steps are:

- **Identify challenges** – this step looks at the community's or organisation's values and what you hope to achieve through adapting; and it helps you determine if you need to adapt, gather information, engage stakeholders and ensure your leadership and governance management structures are in place. You may consider the timeframe in which you want to achieve your goals (when are you adapting for), any legal requirements and limitations of adapting, the scope (e.g. geographical, political). It is also the stage at which you need to establish monitoring so you can measure your progress and success. It is where you will be looking for a great deal of external guidance, information and data
- **Determine vulnerabilities** – this step is about assessing your climate risks, vulnerabilities and opportunities under climate change.
- **Investigate options** – this step looks at what steps, projects, activities or changes you could undertake that might help you meet the objectives of your plan.
- **Evaluate options, risks and costs** – this step looks at your adaptation and planning options so you can decide which ones are best for your community or organisation, which ones must be done now and which ones you should prepare for in the future, which ones you have the resources for, which ones you need to gather resources for and what trade-offs each option needs.
- **Take action** – in this step you determine how to undertake your adaptation actions and who will lead and who will support, and you start implementing the actions you have decided to undertake first.
- **Monitor and evaluate** – in this step you will both monitor climate to identify trigger points for action and monitor the effectiveness of these actions so you can correct or change course in your plan.

Other frameworks use variations on this set of steps. Sometimes they undertake tasks at different stages, for example, but the concepts tend to be quite similar and use many of the same principles. Your choice of the best framework for you is likely to be influenced by the target sector of each framework, or your own specific circumstances or a preferred format for your organisation. We developed C-CADS with local governments, industry and businesses in the coastal zone in mind. Even if you do not follow C-CADS strictly, you may find it provides useful ideas and guidance that can be adapted to your circumstances. The same applies for most frameworks.

2.2 What might you do? (e.g. follow an existing approach, test your existing approach)

How you use an adaptation framework or guide will depend on the current state of your thinking about adaptation and your existing planning as well as your geographic location and/or sector. Most planning or thinking about climate change will fit somewhere between those organisations that are not yet explicitly considering climate change adaptation through to those that are undertaking adaptation actions based on a well-established adaptation plan.

Here we consider four stages that might characterise the current thinking in your organisation, and we will see how you could use an adaptation planning framework in each situation.

1. Limited understanding of climate change and how it may affect your organisation. No organisational commitment as yet

You are likely to begin by focusing on building some background understanding of climate change and its potential to harm your organisation. You may also consider what methods and approaches are needed to build organisational understanding and to invest in appropriate governance structures and community engagement. If your organisation is in this situation, you may find that the initial step of an adaptation planning framework, which is usually around identifying your challenges (see section 3) and preparing for embarking on adaptation planning, will offer a useful place to start addressing these needs.

2. An idea about climate change and know it will be a problem. No formal adaptation plan or consideration of climate change in other current strategy. Some initial resources to explore this issue

At this stage, you will want to look at what areas of your organisation and its management responsibilities are likely to be covered by your plan and what process might be most suitable at this point in time for your organisation. You may want to compare a number of frameworks to understand how different approaches may help you, looking for the one that best suits you (see section 2). This can be a difficult choice, but perhaps start with those frameworks designed for an organisation or sector or issue most similar to yours and read through their processes, or you may find a more general framework like C-CADS provides the most flexibility. You may find that one framework in particular resonates well with your challenges, or you may take some guidance from a few additional resources. Given adaptation frameworks are seen as good practice, you may find working methodically through a process, ensuring you have covered off on all suggested tasks, provides a sound basis for your planning. If you already have an assessment of your risk or your vulnerability, this can be used to help build the first steps of an adaptation planning process.

3. No adaptation plan per se, but components of adaptation in some element of organisational management (e.g. land use plan, NRM regional plan, beach erosion management plan, etc.). May have good or poor support internally to create an adaptation plan

If you already have an existing plan in the area of risk you are thinking about with respect to climate change, you may wish to use the adaptation framework approach to review and test your existing plans for their response to climate change. The AdaptNRM Checklist (Snapshot 5), for example, is designed to allow users to test existing NRM regional plans and is a useful starting point to consider how you might approach a revision of your plans. You may also wish to look at more sector-specific resources to understand particular challenges for you.

4. Existing adaptation plan

If you already have an existing adaptation plan, it is worth testing your plan and process against another framework to identify gaps and barriers. For example, do you have good organisational and community buy-in? Are identified adaptation actions being successfully implemented? This testing could be carried out as part of your monitoring and evaluation step and used to evaluate your planning process. You might be able to use alternative approaches to address challenges you have faced developing or implementing your adaptation actions. You may also need to improve mainstreaming the planning approach across your organisation or implementing adaptation actions. You might explore other frameworks and examples of their use to look for ideas on addressing these challenges.

2.3 Which tools and frameworks should you know about? Seven snapshots

There is an ever-growing number of documents and web-based resources that offer some type of adaptation decision-making or planning process or framework. Most have been developed for a specific location or sector in response to a particular need. Despite their specific focus, many have good general applicability. In this section, we review examples of these adaptation frameworks. It's not an exhaustive list, but it will give you a good understanding of what different frameworks offer and, where possible, examples of their use.

For a further review of national and international adaptation tools and information portals visit CoastAdapt (https://coastadapt.com.au/review-national-and-international-adaptation-tools-information-portals).

SNAPSHOT 1: *Climate adaptation: Risk, uncertainty & decision-making*

Author/s: Willows and Connell (Eds.)

Date: 2003

Sector: National adaptation

Type: Framework

Funding agency: UK Climate Impacts Programme

Website: http://www.ukcip.org.uk/wordpress/wp-content/PDFs/UKCIP-Risk-framework.pdf

Description

Developed for the UK's Climate Impacts Programme, the report presents an eight-stage framework and associated guidance material to promote good decision-making where climate change may be a significant factor. Given the broad audience and diversity of applications, both tools are inevitably rather generic. A case study example is described in one of the report's appendices, demonstrating the application of the framework to a decision within the forestry sector. In addition, framework-supporting material can be used by people who are unfamiliar with aspects of risk assessment in general or with risk-based climate change impact assessments in particular.

Why you should know about this resource

This framework is one of the first and one of the best-known adaptation decision-making frameworks. While it was created for a very specific process in the UK, it was developed to apply to a wide range of decisions that may be affected by climate change and does therefore provide a fairly generic framework and set of supporting guidance material.

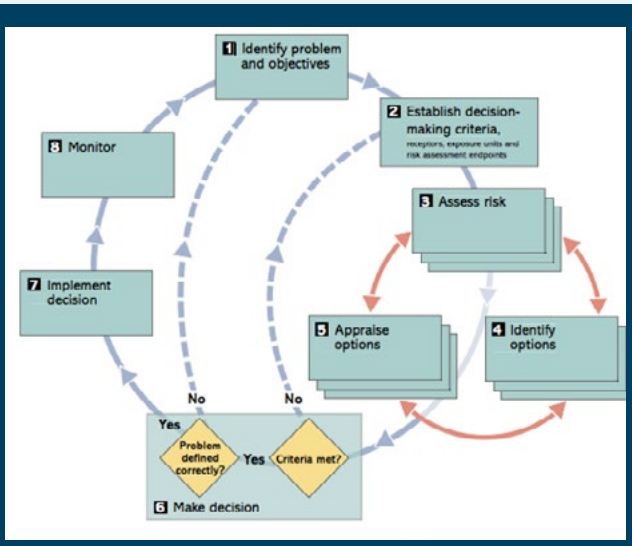
Many more recent frameworks have built on this initial set of guidance principles; although some of the steps have been collapsed into single steps, this provides a good foundational understanding to adaptation decision-making.

At each decision-making stage, the framework provides a set of questions in order to help you understand the key issues particular to that step. It also describes tools and techniques to support you as you work through each step and gives further information and support for each step. These additional resources and the guided exploration of issues may provide you with more information, or information in a different format, so as to emphasise the most important points you need to consider when undertaking adaptation planning.

Example/s of use

The approach adopted by Willows and Connell is fairly typical of an adaptation planning process, although they have included a number of iterative steps. The planning process has been used as the basis for a number of tools that have been developed since by other organisations (e.g. AdaptNRM planning framework).

The framework is the basis of the UKCIP Adaptation Wizard (http://www.ukcip.org.uk/wizard/about-the-wizard/). The wizard provides links to other tools for each step of the framework (http://www.ukcip.org.uk/wizard/tools-portfolio/).



SNAPSHOT 2: *Five steps to managing your climate risks. A guide for public bodies in Scotland*

Author/s: Adaptation Scotland

Date: 2013

Sector: Public sector organisations

Type: Document

Funding agency: Scottish Government, Sustainable Scotland Network, SEPA

Website: http://www.adaptationscotland.org.uk

Description

This booklet provides operational guidance to managing climate for public bodies across Scotland. The guidance takes account of legislative changes and builds on recent adaptation planning successes in Scotland. It advocates a 'resilience approach', which will not only address climate risks, but improve the general business of the organisation as well.

The guide walks organisations through protecting their critical functions and core services; here this refers to some of the primary functions of public bodies. The guide provides practical actions to help build an adaptation plan and provides clear outcomes for each step and a checklist to help guide the user through each step.

It is built on legislative requirements in Scotland but is a useful and practical guide for public sector bodies to consider.

It includes a diverse range of case studies to illustrate each step.

Why you should know about this resource

The guide was created specifically for public bodies and is targeted in its approach to the activities and functions of this type of organisation. Although developed specifically for Scotland's legislative requirements, it gives practical actions and guidance that might provide a useful template for some activities relevant to a broader audience. For example, it provides a template for considering climate risk that could be adapted for your local climate and functions.

It is a simple framework, using just five steps, and in some organisations this approach may be more digestible in the first instance. For example, you could use it as a conversation starter with senior management.

The five steps

Adaptation Scotland have recently revised their website. The site provides considerable resources and case studies to support the use of this framework and specific resources for different sectors. www.adaptationscotland.org.uk

SNAPSHOT 3: *US Climate Resilience toolkit*

Author/s: NOAA and partners

Date: 2014

Sector: Currently federal government

Type: Website

Funding agency: US Federal Government

Website: https://toolkit.climate.gov

Description

The US Climate Resilience website brings together case studies (Taking Action stories), a catalogue of freely available tools, information and access to expertise. It provides a five-step framework to build resilience to extreme climate events. In addition, it has a visualisation tool called 'Climate Explorer', which shows climate stressors and how and when people and assets will become vulnerable to these stressors through maps of the US. The tool has been developed nationally for the US and is focused particularly on extreme events and climate stressors (e.g. drought, sea-level rise, flooding, hurricanes).

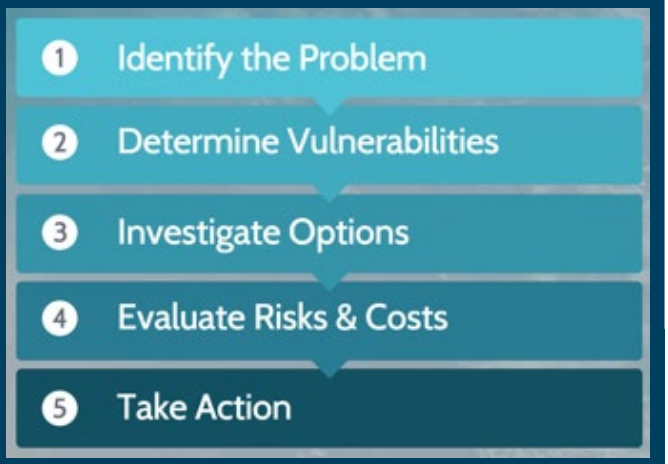
Why you should know about this resource

The website is one of a new generation of online resources. While it provides a simple decision framework, with steps similar to many other document-style frameworks, it also provides a useful platform for exploring more information, with each step providing a short plain language explanation, a glossary of terms used, further resources and case studies. Each case study also links to any tools or resources that are relevant. The website is still growing, with new information being added regularly.

While the focus is on the US and on specific climate stressors, this resource will be useful for you to explore the how and why of adaptation planning if you are looking for more information. Each step has a concise description and will be fairly quick to read through if you are looking for a different explanation of a concept or step to that given in C-CADS or another adaptation planning framework.

New modules are regularly being added to provide information and guidance on specific topics (e.g. built environment).

The five steps of the US Climate Resilience framework



SNAPSHOT 4: *UKCIP risk framework*

Author/s: UKCIP

Date: 2013 (tool accessed 3 March 2015)

Sector: A general framework for all aspects of adaptation decision-making

Type: Web portal and documents

Funding agency: Department for Environment, Food and Rural Affairs

Website: http://www.ukcip.org.uk/wizard/about-the-wizard/ukcip-risk-framework/

Description

The UKCIP website includes a five-step risk-based adaptation framework that is based on the risk framework developed by Willows and Connell (Snapshot 1 Climate adaptation: Risk, uncertainty & decision-making). It is designed to help an individual or business assess appropriate adaptation measures and cost, implement and monitor them.

Each of the five steps has a simple description of the process, a list of tasks to undertake and a link to resources and tools to help with decision-making. The key output of using the framework is an adaptation strategy document that includes a record of the users' vulnerability to current climatic variability, a prioritised list of climate risks, a list of possible adaptation measures to address those risks, an adaptation options appraisal and an implementation strategy.

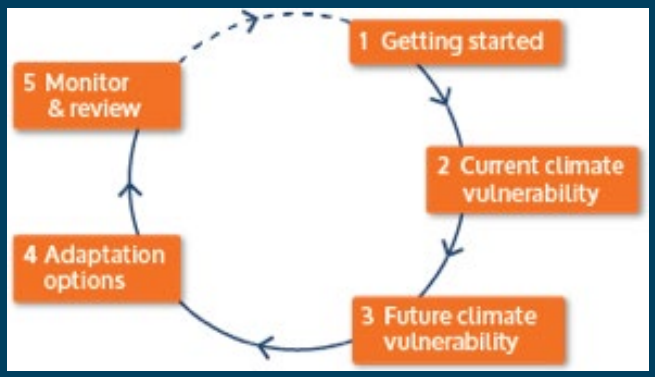
The UKCIP framework includes a tools portfolio with links to a costing methodology – applicable to most sectors and scales – to help calculate the cost of impacts compared to adaptation actions; the adaptation wizard, which helps foster and capture group thinking through prompts for discussion, checklists and space for note taking; and the AdaptME toolkit, which guides the process of monitor and review.

Why you should know about this resource

While designed for the UK and its legislative requirements, the UKCIP website provides a simple framework in an easy-access format. It provides a number of useful resources and decision-support or other tools so you can explore in greater depth to help you understand the steps in adaptation planning and to supplement your planning approach.

The five steps of the UKCIP Climate Wizard

Each step is divided into an explanation of the process for that step, a task list and links to additional resources.



Example of use

The Midlands Co-operative, a large regional business cooperative, reported using the UKCIP Adaptation Wizard methodology to commence their planning for climate change.

http://www.sustainabilitywestmidlands.org.uk/resources/the-midcounties-co-operative-and-ukcips-adaptation-wizard/

SNAPSHOT 5: *The NRM Adaptation Checklist: AdaptNRM*

Author/s: CSIRO, NCCARF

Date: 2014

Sector: Natural resources

Type: Web portal and documents

Funding agency: Department of Environment (Australia)

Website: http://adaptnrm.csiro.au/adaptation-planning/

Description

The NRM Adaptation Checklist is a generalised planning framework developed to help NRM planners organise specific ideas about why and how planning approaches may need to shift to be effective under climate change. The intended outcome is for users to have a clear understanding of how their existing planning process could be improved or extended. The format is based around a checklist designed to allow regional NRM groups to take stock of existing plans to consider their climate-readiness. The guide is not prescriptive; rather, it highlights issues and supports gradual improvement.

The checklist component is built around a decision framework that uses five stages common to adaptive planning: (i) assessment, (ii) strategic planning, (iii) implementation planning and action, (iv) monitoring, and (v) reflection. The checklist is based on a series of questions with resources and ideas attached to a 'yes' or 'no' response. The information is supported by case studies and a website.

Why you should know about this resource

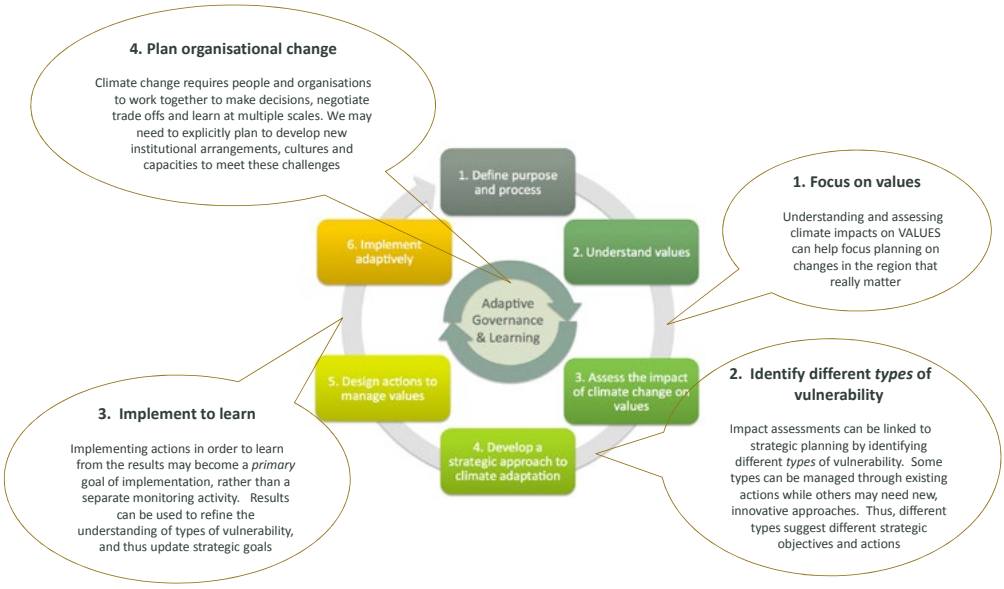
This resource is of interest because firstly, it is focused on natural resources, so considers issues around agriculture, biodiversity, weeds and water; secondly, the guide is useful for testing the robustness of existing planning processes to the risks associated with climate change; and finally, the guide outlines four key challenges for climate change adaptation in NRM planning. These challenges are important for other sectors as well, so the resource provides a useful description of these issues and their planning implications that can be used broadly. The four challenges are: (i) making decisions for multiple possible futures, (ii) employing flexible and adaptive planning processes, (iii) explicitly identifying and preparing for likely future decisions, and (iv) strengthening the adaptive capacity of people and organisations

Example of use

The Murray Basin cluster, an NRM group, has developed a local version of the AdaptNRM planning tool. They have included four additional steps or processes more explicitly in the framework:

- **A focus on values**
- **Identification of different types of vulnerability**
- **Implementing to learn**
- **Planning for organisational change, including adaptive governance and learning.**

https://terranova.org.au/repository/murray-basin-nrm-collection/adaptation-planning-framework



SNAPSHOT 6: *Climate adaptation planning guidelines*

Author/s: Local Government Association of South Australia

Date: 2014

Sector: Councils and regional bodies

Type: Guidelines

Funding agency: LGA Research and Development Fund and the Department of Environment, Water and Natural Resources

Website: http://www.lga.sa.gov.au/webdata/resources/files/LGA%20CAPG%20Final%20Print%20Version.pdf

Description

This guide has been developed to help regional organisations undertake a regional adaptation process. It provides information specific to the South Australian policy background. It sets out an adaptation planning process as a seven-step framework designed to help develop a regional adaptation plan. It also provides an overview of the process as context-setting for high level decision-makers.

The guide explains the process and rationale of each step and provides tasks and activities to consider undertaking, links to more information and resources needed for some activities. In addition, each step includes a checklist to help determine if a step has been explored in sufficient detail. Supporting materials have been developed by a range of players from the LGA and its partners, to governments across the country and researchers.

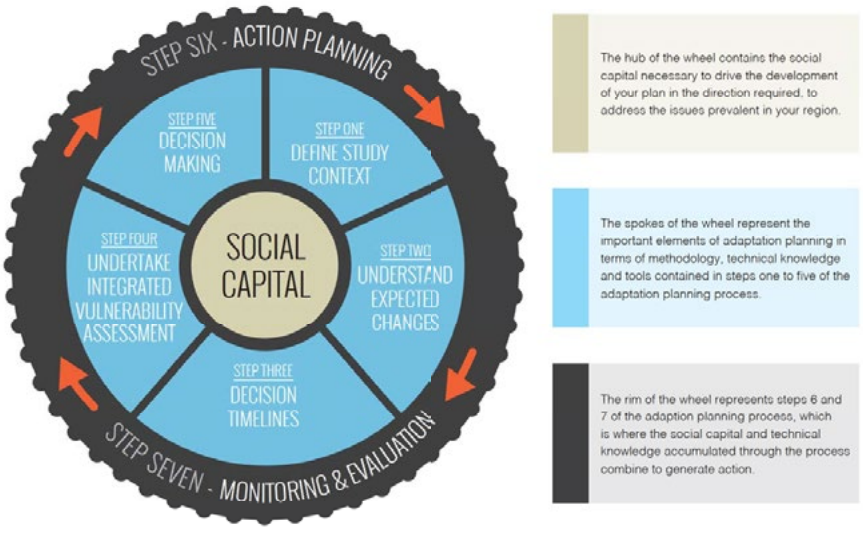
Why you should know about this resource

The guide has been written by an Australian local government association, and while it specifically targets South Australia, the approach is likely to resonate well with other local government and regional bodies. The approach of the guide is to provide very clear instructions; for groups in South Australia in particular, this is a process that can be followed quite precisely to achieve a particular outcome. An explanation of why and how each step should be undertaken is also given, and this backgrounding will help you determine the suitability of this approach to your situation. Note that the guide refers to climate projections from OzClim. This site has now been superseded by Climate Change in Australia: http://www.climatechangeinaustralia.gov.au/en/

The seven steps of the process outlined in the LGASA ***Climate adaptation planning guidelines.***

A strong element emphasised in the process is the role of social capital in driving successful outcomes.

FIGURE 1: WHY SOCIAL CAPITAL IS IMPORTANT TO PLANNING



SNAPSHOT 7: *Climate adaptation manual for Local Government: embedding resilience to climate change*

Author/s: Inglis et al.

Date: 2014

Sector: Local government

Type: Guide

Funding agency: ACELG and City of Canada Bay

Website: http://apo.org.au/node/40378

Description

This two-volume manual is not an actual set of planning guidelines, but rather an effort to guide local councils to embed climate resilience into their organisations and activities. Its intention is to help councils move beyond strategic planning and into taking action. It provides a step-by-step process, a set of case studies of practical examples and resources (toolkits, checklists, systems and processes) that are available to support the process. The case studies illustrate responses to a wide range of issues and the use of a wide range of approaches.

The Australian Centre of Excellence for Local Government (ACELG) closed in 2015 but the manual remains available on the University of Technology Sydney website.

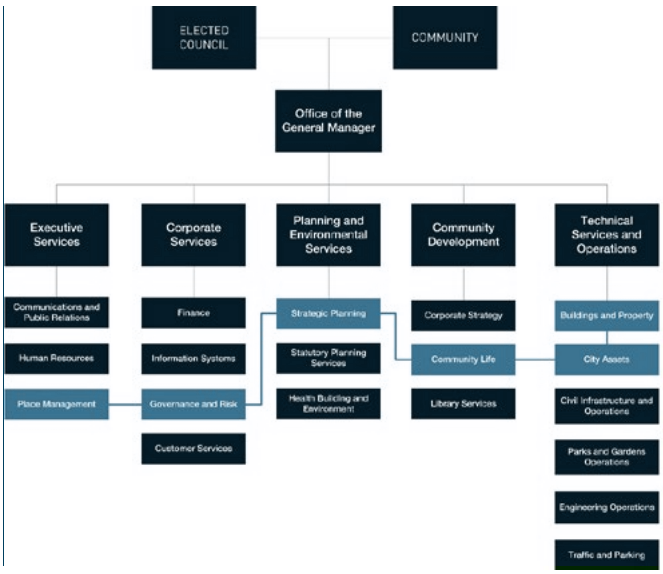
Why you should know about this resource

While not a guide to adaptation planning as such, this guide focuses on the key challenge of mainstreaming or embedding the adaptation response to climate change. This is particularly likely to be useful for those councils (or organisations) that have already undertaken a vulnerability assessment or strategic adaptation plan but are struggling to get action across the organisation, or those who have not yet undertaken much planning but may wish to ensure the idea of embedding adaptation action into the council is considered throughout the planning process.

The manual codes the case studies by:

1. functional area (i.e. corporate services, land use planning, works, assets and engineering, community services, environment and economic development)
2. function (e.g. council meetings, reports, etc.)
3. hazard (e.g. bushfire, heat, severe weather, sea-level rise/flooding)

The guide presents a range of models for embedding climate change: full council approach, issue approach (this is the model shown below, where the issues are the light blue functional roles), department approach, hybrid approach and transformational approach.



Part 2: Resources and data to build an adaptation plan

In this part we look at the **key things you should understand** and the **key resources to read** when undertaking adaptation planning and implementation. We follow the six steps used in the C-CADS framework to organise the part.

3 Identify the challenges

When starting down the pathway of adaptation planning, you are likely to be gathering information and data to understand what lies ahead. You might gain an understanding of what adaptation means, find out what others are saying is a good course of action or will be the challenges you need to consider, collect material about physical impacts and your local environment, think about your community, establish what the existing policy and legislation mean for your plan and get some guidance to start the planning process. The following sections introduce you to some of these ideas and resources to help you.

It is worth noting that some of these resources may not give you enough detail for your specific area, but they should help you with an initial assessment and background so you can identify risks from climate change and start planning for a climate-affected future.

3.1 The scientific literature

Underlying adaptation practice is a growing body of scientific research exploring, testing and reporting on adaptation concepts and planning, as well as on strategic and on-ground actions. In addition, many projects have considered the impacts of climate change in coastal areas.

How adaptation is defined

One of the key challenges of adaptation is knowing when to adapt and how much to adapt. In understanding adaptation, researchers have considered the human ability to adapt to climate variability (something we have always done) and the need for more proactive adaptation and planning. Much of how we do that depends on the lifetime of the decision. Decisions with a short consequence period can be adjusted regularly. For example, choosing a crop variety to plant can be varied annually. Where a decision has a long consequence time, such as building a bridge, a great deal more planning and decision-making is involved, and greater uncertainties must be navigated.

These two aspects of decision-making – Do I need to adapt? and What is the lifetime of my decision? – have prompted researchers to think about adaptation as either incremental or transformational.

Incremental adaptation implies manageable and gradual tweaking of an existing management approach. It is more aligned with what we already know as adaptive management. Gradual change relies on mainstreaming adaptation across the organisation. This is the form we consider most of our adaptation planning will take.

But in some cases this gradual change will not be enough, and researchers have turned their attention to transformational adaptation.

Transformational adaptation:

'a discrete process that fundamentally (but not necessarily) results in change in the biophysical, social or economic components of a system from one form, function or location (state) to another, thereby enhancing the capacity for desired values to be achieved given perceived or real changes in the present or future environment' (Park et al. 2012)

Deciding what transformational adaptation is in practice, however, is tricky; what might be considered transformational at one level may be incremental at another. What is likely to be the most important consideration for adaptation planning is to consider solutions beyond adjustments to 'business as usual' – there needs to be a 'we can't keep going down this path' decision-making moment. While these solutions may not always seem practical, it is worth considering and testing them, as a point may come when they are a good option.

Planning for coastal adaptation

Researchers considering adaptation in the coastal zone in Australia have considered the roles and responsibilities of the different government levels as well as the different planning measures, policies and approaches to adaptation planning.

There is considerable interest in the 'pathways' approach to adaptation planning in the literature. Early adaptation research has developed our understanding of the concept of adaptation, approaches to assessment of vulnerability and adaptation decision frameworks. Yet it was clear that translating these into on-ground action was a stumbling block for many decision-makers. We know there are many barriers to taking action, including uncertainty and lack of resourcing. The pathways approach is a response to this and offers a flexible approach to undertaking decision-making for the future.

A pathways approach to adaptation planning is about keeping options open, reducing unnecessary expenditure and preventing decision-makers being locked into actions that may not be the best solutions in the long-term. Under the approach, rather than determining a final outcome or decision at an early stage, decision-makers are able to build a decision-making strategy that will follow changing circumstances over time as the rate and scale of change become more certain.

A number of research papers consider the pathways approach and how it can be useful. They describe case studies of its application in practice. An overview of the pathways approach, a worked example and case studies of the pathways approach in practice are available through the CoastAdapt website. (https://coastadapt.com.au/pathways-approach).

Adapting to sea-level rise

Options for coastal adaptation considered by researchers can be classified as those measures that protect, those that accommodate and those that involve retreat.

Protect options can include hard or soft measures to maintain coastlines such as seawalls, groynes, dune rehabilitation and other eco-engineering options. Testing of the performance and comparison of the effectiveness of these options feature in a number of studies. Issues associated with protect options include potential impacts on the local foreshore as well as cost and legal issues.

Accommodate options are diverse and represent a range of strategies designed to maintain the use and amenity of coastal areas. These include, for example, building codes, changes in land use, changes in building design and insurance options. Accommodate options present legal risks associated with exposure, with the problem of transferring risk decisions to future decision-makers and with the need to ensure utilities can also be accommodated.

Retreat options involve the abandonment of land and structures in vulnerable areas and the resettlement of inhabitants. Issues associated with a retreat option include legal concepts, planning instruments, the question of compensation and community engagement. There are a number of case studies in the literature that explore some of these issues.

Each of these options has trade-offs, and adaptation planning will be about balancing these trade-offs.

How to access the academic literature

Most research findings are published in academic journals, which means that the research and findings have been reviewed by other experts and are reasonably reliable. However, most journals are not freely available and papers must be purchased, which makes it difficult for many practitioners to access them.

If you are looking for technical information, use journal search engines (e.g. google scholar is free access) and read a short abstract that will help you decide if you want to know more. From there you can use a library service, purchase the article online or try contacting the author, who may be able to send you a free reprint.

Key academic papers

Defining adaptation concepts	**Palutikof, J. P. et al., 2013: The past, present and future of adaptation: setting the context and naming the challenges. *Climate Adaptation Futures*, J. P. Palutikof et al., Eds., Wiley Blackwell, 3-29.** This chapter considers some of the challenges of adaptation, including defining the idea of transformational adaptation, barriers to action and mainstreaming adaptation into practice. **Park, S. E., et al., 2012: Informing adaptation responses to climate change through theories of transformation. Global Environment Change, 22(1), 115-126.** This paper provides a definition of transformational adaptation. The authors use the definition of transformation to construct a framework to support decision-making.
Pathways approach (case study)	**Barnett, J. et al., 2014: A local coastal adaptation pathway. *Nature Climate Change*, 4, 1103–1108.** This paper reports on a study of a coastal community negotiating its adaptation planning. It tests and demonstrates the simple, low-cost adaptation pathway approach that other local governments might adopt.
Pathways approach	**Wise, R. M. et al., 2014: Reconceptualising adaptation to climate change as part of a pathways of change and response. *Global Environmental Change*, 28, 325–326.** This paper represents some of the latest thinking on framing adaptation responses in a pathways approach. It explores how to conceptualise pathways in a way that allows decision-makers to incorporate responsive incremental change with longer term transformational change. The approach is aimed at accommodating different levels of 'willingness' and the need for social change.
Case studies of adaptation	**Palutikof, J. P. et al., 2015: *Applied studies in climate adaptation*, Wiley Blackwell, 496 pp.** The chapters in this book describe the results of research projects funded under the NCCARF Phase 1 program. They present a series of case studies that provide evidence of adaptation practices in a variety of sectors. All case studies are from Australia and give examples for practitioners.
Communicating adaptation	**Moser, S. C., 2014: Communicating adaptation to climate change: the art and science of public engagement when climate change comes home. *WIREs Climate Change*, 5, 337–358.** This paper provides a synthesis of the literature on communicating climate change adaptation. It looks at both the language used and the reception of information. Importantly, it provides a number of recommendations for communicating adaptation information.
Planned retreat	**Abel, R. et al., 2011: Sea level rise, coastal development and planned retreat: analytical framework, governance principles and an Australian case study. *Environmental Science & Policy*, 14.3, 279–288.** The paper explores a framework for use in considering and planning retreat in coastal settlements.
Planning for sea-level rise	**Cooper, J. A. G., and Lemckert, C. J., 2012: Extreme sea-level rise and adaptation options for coastal resort cities: A qualitative assessment from the Gold Coast, Australia. *Ocean and Coastal Management*, 64, 1–14.** This paper provides a worked case study that considers the physical and economic implications of a selection of sea-level rise planning benchmarks for a highly populated coastal town. Although the case study is a theoretical exercise, the paper provides a useful example of the considerations and costings of such planning policies.

3.2 Data on the physical environment

3.2.1 Climate Projections

Australian coastal zones are likely to experience the full range of direct and indirect climate change impacts, including warmer temperatures and extreme heatwaves, increased fire weather, rainfall variability, changes to storminess and raised sea levels.

Climate projections are the most useful tool we have to help us understand the range of possible future risks that climate change brings. You will want to assemble a selection of projections to support your plan.

What are projections, and why is there uncertainty?

Climate change projections are based on complex models, and the outputs of these models can sometimes be difficult to interpret and understand and can include a level of uncertainty. The models are developed to mirror complex natural climate processes; while we are getting better at understanding some of these processes, there are still some things we cannot yet accurately explain, and this creates a measure of uncertainty. The models also need, as an input, information about our expectations of how greenhouse gas emissions will change in the future. This relies on predicting what direction government policies will take and the success of attempts to meet greenhouse gas emissions targets, again introducing considerable further uncertainty.

Globally, projections are assembled through the Coupled Model Intercomparison Projects (CMIPs) and evaluated by the Intergovernmental Panel on Climate Change (IPCC) in its assessment reports. The most recent models are called CMIP5. The CMIP5s are built on four future emission scenarios called the Representative Concentration Pathways (RCPs) (see Figure 3).

In Australia, projections have been produced at both national and regional scales by CSIRO and the Bureau of Meteorology (BoM) and by state governments or their agencies (Table 1).

Choosing projections for planning

Climate projections come in seemingly endless variations: different numbers, different maps, different graphs. Choosing which ones to use can be overwhelming.

In choosing projections, you should first know why they vary. Box 1 outlines the key factors that can be altered for any given projection or set of projections.

Your choice will depend on:

1. what data you need (e.g. if you are thinking about coastal development, sea-level information will be important)
2. your known climate risks (e.g. recent storm impacts might highlight the need to think about storms)
3. the spatial scale you are thinking about (e.g. a local council might look for projections at a finer scale or downscaled projections)
4. the temporal scale you are planning for and the confidence level of projections (e.g. rainfall projections are very variable, so you might want to consider several projections to get the full range of possibilities)
5. your stage of planning (e.g. at the earliest stages, you may want to keep the information simple and high level).

In addition, it is important to choose modelling based on the most recent IPCC evaluation data (CMIP5) where available. This is because climate change models tend to become more sophisticated over time, so the more recent models are the best information we have and are more reliable. Some downscaled data have been built on earlier models (e.g. CMIP3). These may still be the best downscaled data you have and can still be valuable, particularly if you look at more recent broadscale modelling to look for areas of greatest variability in projections. It is important to always bear in mind that these projections are *possible* scenarios of future climate; when you are planning, you should use them as guidance, not as a given.

You will also be able to choose projections in a variety of formats, such as maps, statistics or numbers, graphs and downloadable data for use in another application or simple text descriptions.

Projections are available from a number of sources in Australia, and Table 1 provides a descriptive list of them. A number of the state governments have developed projections and products specifically for their state. You might find this a good place to start exploring projections. The most recent projections (based on CMIP5) come from the Climate Change in Australia project. The projections are both national and regional. The website provides a multitude of ways for different levels of user to access the projection information. More information is provided in Table 1 and a more in-depth guide is provided in Information Manual 3: Available datasets.

Further information:

The Climate Change in Australia website provides guidance on choosing projections:

Common mistakes in using climate models

http://www.climatechangeinaustralia.gov.au/en/climate-campus/modelling-and-projections/using-projections/common-mistakes/

Choosing from multiple sources of models

http://www.climatechangeinaustralia.gov.au/en/climate-campus/modelling-and-projections/multiple-sources/

Deciding what climate data you need

http://www.climatechangeinaustralia.gov.au/en/climate-campus/modelling-and-projections/using-projections/data-needs/

CoastAdapt Information Manual 3: Available datasets provides more in-depth guidance on climate projections.

CoastAdapt also has information on:

- Understanding climate scenarios (https://coastadapt.com.au/how-to-pages/how-to-understand-climate-change-scenarios).

- Accessing climate scenarios (https://coastadapt.com.au/how-to-pages/how-to-access-climate-change-scenarios).

- Using climate scenarios (https://coastadapt.com.au/how-to-pages/how-to-use-climate-change-scenarios-to-evaluate-risk-plan-and-make-decisions).

- Communicating climate scenarios (https://coastadapt.com.au/how-to-pages/how-to-communicate-about-global-climate-change-scenarios).

What are the RCPs?

RCP stands for 'Representative Concentration Pathway'.

To understand how our climate may change in future, we need to predict how we will behave. For example, will we continue to burn fossil fuels at an ever-increasing rate, or will we shift towards renewable energy? The RCPs try to capture these future trends.

Global emissions are following this RCP

They make predictions of how concentrations of greenhouse gases in the atmosphere will change in future as a result of human activities. The four RCPs range from very high (RCP8.5) through to very low (RCP2.6) future concentrations. The numerical values of the RCPs (2.6, 4.5, 6 and 8,5) refer to the concentrations in 2100.

2°C increase in temperature is recognised as the threshold at which climate change becomes **dangerous**

Effort to curb emissions	Energy generation	New technology	Transport		Temperature 2081–2100 (average increase relative to 1986-2005)	Sea level 2081–2100 (average rise relative to 1986-2005)	Extreme weather 2081–2100	Adaptation required
Low	Coal-fired power		Cars, trucks	RCP 8.5	3.7 °C	0.63 m	Large increase	High level at high cost
Medium	Mix		Mix	RCP 6.0	2.2 °C	0.48 m	Moderate increase	Medium level at medium cost
Medium	Renewable		Mix	RCP 4.5	1.8 °C	0.47 m	Moderate increase	Medium level at medium cost
High	Renewable	Emissions capture	Bicycles, public transport	RCP 2.6	1.0 °C	0.4 m	Small increase	Low level at low cost

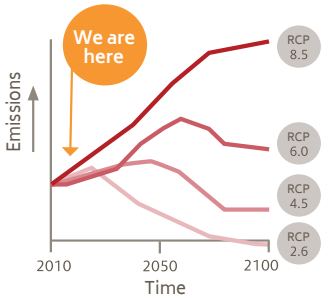
Where do the RCPs come from?

The RCPs were used in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) in 2014 as a basis for the report's findings.

Previous IPCC assessment reports used a set of scenarios known as SRES (Special Report on Emissions Scenarios), which start with socioeconomic circumstances from which emissions trajectories and climate impacts are projected. In contrast, RCPs fix the emissions trajectory and resultant radiative forcing rather than the socioeconomic circumstances.

We can use the RCPs to plan for the future

Scientists use the RCPs to model climate change and build scenarios about the impacts. You can use these scenarios to plan for the future.



If we follow the RCP 8.5 pathway, **more adaptation** will be needed.

If we follow the RCP 2.6 pathway, **less adaptation** is needed.

RCP 8.5 leads to much greater temperature increases, and this means greater impacts and greater costs. To adapt to these changes will also cost more. A balance must be struck between the cost of impacts and the cost of adaptation.

Coastal climate change Infographic series
www.coastadapt.com.au

Australian Government Department of the Environment and Energy | CoastAdapt | NCCARF National Climate Change Adaptation Research Facility

Figure 3: This infographic provides an explanation of the RCPs. Source: © NCCARF 2016.

Box 1: The ways climate projections vary

The models

Fully three-dimensional numerical models that take into account mass and energy transfer and radiant exchange are used to create projections that simulate the climate. They are called General Circulation Models (GCMs) and there are around 40 different models worldwide. While most models perform reasonably well, not one single model is the best or most accurate; some groups of models seem to be more accurate for some parts of the world than others. For this reason, projections may be based on a subset or an ensemble of models (an average of the best set of models for your area). If you need to choose a model, you can compare a number of models or look for information on the performance of models for your area.

The emissions scenario

As mentioned earlier, these are now modelled based on RCPs (Figure 3). Before adopting the RCPs, a set of scenarios referred to as SRES were used, which were based on storylines of social and economic policies. They considered how population might change, what energy technologies were being used and so on. The change to the RCPs recognises that there might be many different ways we can reduce our emissions that are hard to capture in these storylines, so a system that focuses on changes to radiative forcing (see Figure 3) was adopted. You may still find projection data based on SRES, and these remain useful and relevant projections, but there may be more up-to-date projections you could use depending on the scale you are looking at.

The climate

Projections are presented for individual climate elements. For example, you might have a map or set of numbers for average daily temperature or annual rainfall and so on. Climate models can give information on a range of climate measures, including general climate (e.g. mean, minimum or maximum temperature, rainfall, solar radiation, evapotranspiration, wind speed, relative humidity), extreme climate (hottest day/s, coldest night/s, wettest day/s) and marine climate (mean sea level, sea-level allowance, sea-surface temperature and salinity, ocean pH).

How far into the future

Climate projections can calculate projected changes in climate across a number of time periods into the future. We tend to look at time periods up until 2100. It might be clear what time period you are interested in: for example, you may be planning for a bridge that has a life span of 50 years, so you will probably focus on projections up to 50 years into the future. If you are planning more generally (e.g. a local government plan) it makes sense to look at several time periods – including the near future and far future – to help you decide when you need to take certain actions.

Downscaling

Most GCMs model climate at a resolution of 200 km. When you are thinking about your local area, this scale can be quite large. Downscaling is used to generate projections at a local or regional scale (10–100 km). There are two main methods of downscaling climate projections. The first, dynamical downscaling, uses fine resolution climate models (often using regional climate models [RCMs]) to generate projections. They use the same physical process as GCMs and are potentially useful in areas with complex topography (e.g. mountains). The second method, statistical downscaling, involves applying observed statistical relationships between large-scale climate and local synoptic conditions. This is then used to infer or estimate local scale changes in climate.

Table 1: Sources of national and regional climate projections for Australia

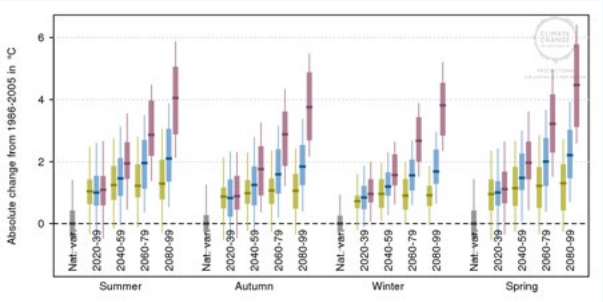
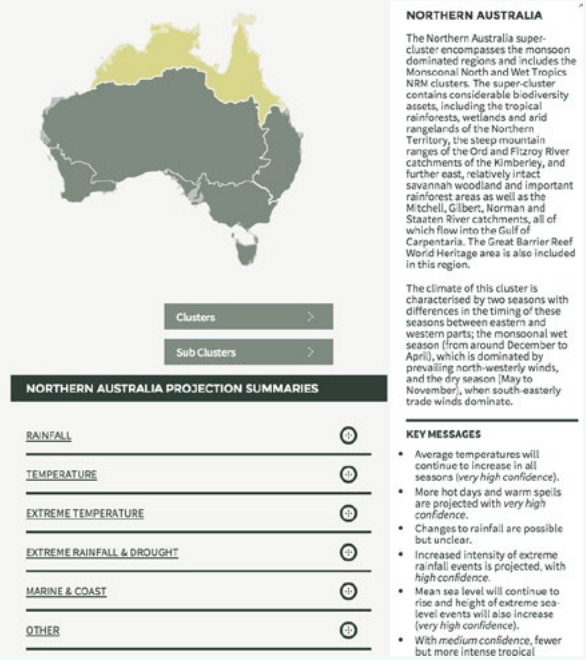
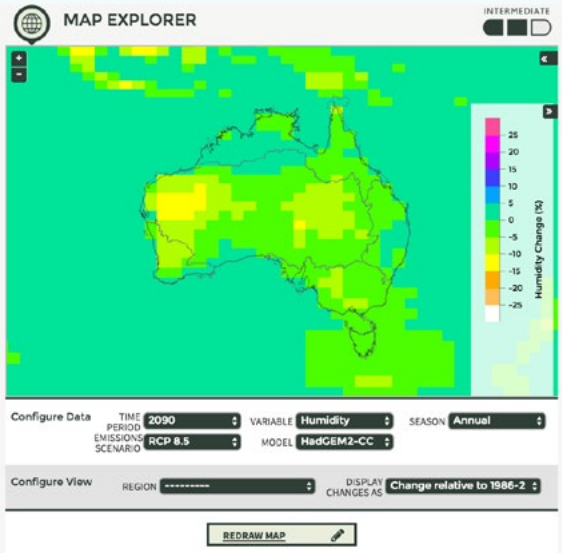
Project	Details	Example outputs
Climate Change in Australia **Agencies**: CSIRO and BoM **Link**: http://www.climatechangeinaustralia.gov.au/ **Description**: The most recent national projection resource. Projections were developed for the Natural Resource Management regions. Extensive website includes several formats for climate projections, with different levels of user in mind (from basic to advanced) including: short descriptions of climate change for regions (Regional Climate Futures Explorer) – basic a map of climate analogues (Analogues explorer) – basic graphs of climate (including extremes information: Summary and Extremes data explorer) – basic an interactive map-based projection generator for coastal and sea climate change (Marine explorer) – basic an interactive map-based projection generator with which you can select many of the variables outlined in Box 1 (Map explorer) – intermediate a tool to produce maps or download threshold data (e.g. days over 35 °C) (Thresholds calculator) – intermediate a guided tool for generating projections data specifically for your application and impact assessment (Climate futures: Projections builder); users must register – intermediate a tool to compare projections and combine emissions (Climate Futures: Compare Projections); users must register – intermediate a guided tool for generating tailored projections and exporting data (Climate futures: Detailed projections); users must register – advanced	**Region**: All Australia **Models**: CMIP5 **Scenarios**: 4 RCPs **Times**: Every five years from 2025 to 2090 **Downscaling**: yes – both dynamical and statistical, depending on location	  

Table 1: Sources of national and regional climate projections for Australia - Continued

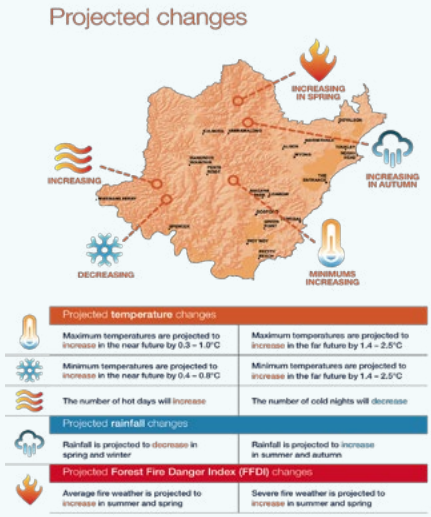
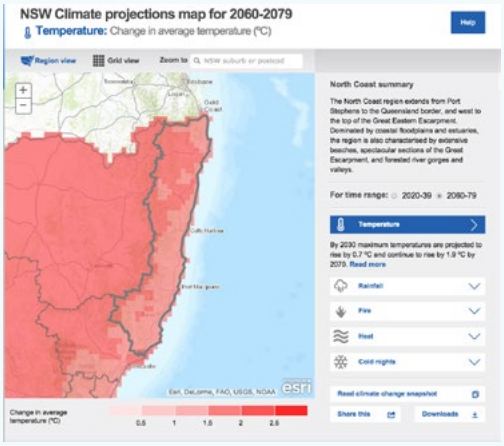
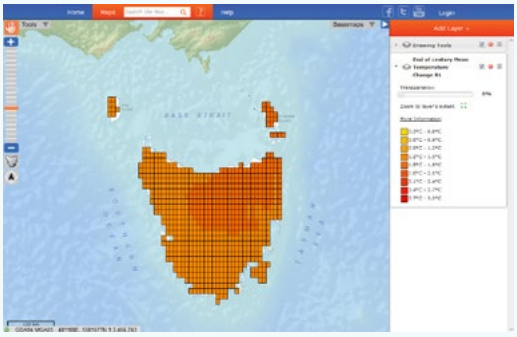
Project	Details	Example outputs
NSW and ACT Regional Climate Modelling (NARCliM) **Agencies**: NSW Government and University of NSW **Link**: http://climatechange.environment.nsw.gov.au/ **Description**: Web-based set of projections for NSW and the ACT. Interactive map based explorer allows users to select a region and one of two time periods for a number of climate parameters. Information for each region is also available as descriptive snapshots.	**Region**: NSW and ACT **Models**: subset of CMIP3 **Scenarios**: SRES A2 **Times**: 2020–2039 and 2060–2079 **Downscaling**: Dynamical downscaling ~10 km	 
Climate Futures Tasmania **Agencies**: ACE CRC and Tasmanian Government **Link**: http://www.dpac.tas.gov.au/divisions/climatechange/climate_change_in_tasmania/impacts_of_climate_change http://acecrc.org.au/climate-futures-for-tasmania/ **Description**: Local climate projections for Tasmania. Projections available on the State's LIST interactive mapping site. Information also available as general summaries of projections, sector reports and technical reports. Information is also available as brief climate profiles for each local government.	**Region**: Tas. **Models**: subset of CMIP3 **Scenarios**: SRES A2 and B1 **Times**: 2010–2039, 2040– 2069 and 2070–2099 **Downscaling**: Dynamical downscaling	

Table 1: Sources of national and regional climate projections for Australia - Continued

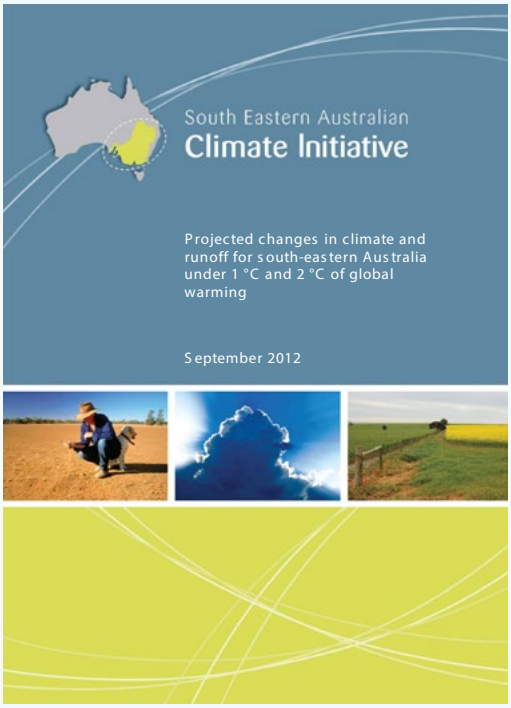
Project	Details	Example outputs
South Eastern Australian Climate Initiative (SEACI) **Agencies**: CSIRO and BoM **Link**: http:/ww.seaci.org/ **Description**: The program was established in 2005 and concluded in 2012. It delivered an updated set of projected changes to rainfall, potential evapotranspiration and run-off across south-eastern Australia under 1 °C and 2 °C of global warming. Projection data are available as downloadable data (following registration) and in technical reports.	**Region**: SA, Vic. and NSW **Models**: CCAM **Scenarios**: SRES **Times**: 2030 and 2070 **Downscaling:** Statistical	
SA Climate Ready **Agencies**: Goyder Institute **Link**: https://data.environment.sa.gov.au/Climate/SA-Climate-Ready/Pages/default.aspx **Description**: A set of projections for South Australia's NRM regions. Data are available for six climate variables (rainfall, temperature maximum, temperature minimum, areal potential evapotranspiration, solar radiation, vapour pressure deficit). The information is tailored specifically for hydrological analysis (e.g. analysis of run-off and river flows).	**Region**: SA **Models**: subset of CMIP5 **Scenarios**: RCPs 4.5 and 8.5 **Times**: 2020–2039, 2040–2059, 2060–2079 and 2080–2099 **Downscaling:** Statistical	 

Table 1: Sources of national and regional climate projections for Australia - Continued

Project	Details	Example outputs
Climate-Ready (Victoria) **Agencies**: CSIRO, BoM and the Victorian Government **Link**: http://www.climateready.com.au **Description**: Provides regional projection information for Victoria.	**Region**: Vic. **Models**: subset of CMIP5 **Scenarios**: RCPs 4.5 and 8.5 **Times**: 2020–2039, 2040–2059, 2060–2079 and 2080–2099 **Downscaling:** Statistical	
Consistent climate scenarios **Agencies**: Long Paddock – Queensland Government **Link**: https://www.longpaddock.qld.gov.au/climateprojections/about.html **Description**: Daily time series suitable for using in biophysical models (e.g. GRASP and APSIM) for periods centred on 2030 and 2050. The project provided daily projections of rainfall, evaporation, minimum and maximum temperature, solar radiation and vapour pressure deficit for individual locations. Projections were also developed on a 0.05 degree (approximately 5 km) grid across Australia. Data from the project are available as a download.	**Region**: All Australia **Models**: subset of CMIP3 **Scenarios**: SRES **Times**: 2030 and 2050 **Downscaling:** Statistical and dynamical	
Indian Ocean Climate Initiative (IOCI) **Agencies**: WA Government, CSIRO and BoM **Link**: http://www.ioci.org.au **Description**: A number of research projects to investigate the causes of the changing climate in WA and develop projections of the future climate in WA. Projections are available in technical reports.	**Region**: WA **Models**: Subset CMIP3 **Scenarios**: SRES B1, A1B, A2 **Times**: 2047–2064, 2082–2099 **Downscaling:** Statistical	

3.2.2 Sea-level rise, coastal inundation and flooding

Projections of sea-level rise

Sea-level rise is caused mainly by thermal expansion of seawater (warming of the oceans) and melting ice from land sources (e.g. glaciers). Most of the impact of sea-level rise is felt as an increasing number of floods from the sea during storms and high tides, leading to coastal erosion and loss of sandy beaches. Climate change is also likely to change run-off from overland flooding (from precipitation), so when looking at flooding and inundation risks it is important to consider coincident event modelling (e.g. 1% rainfall with a 5% storm tide).

Like climate projections, sea-level rise projections are modelled globally, and global projections are provided by the IPCC in their assessment reports.

From these projections, local or regional sea-level rise can be extrapolated. Most sea-level rise mapping uses the simple 'bathtub' method by overlaying projections on the local terrain and elevation mapping to predict inundation, usually using Digital Elevation Modelling (DEM). These maps are useful as a first-pass assessment or communication tool, but do not take account of some more complex processes (e.g. the effect of a seawall, storm surge, erosion, estuaries or other local factors) that can all influence the behaviour of floodwaters.

Australia has projections produced at a national level, with some states and local authorities producing their own sea-level rise mapping or flood mapping that accounts for sea-level rise. In Table 2 we describe the national datasets and tools. More detailed wave and hydrodynamical modelling will be needed for detailed impact and risk assessments (see Information Manual 2: Understanding sea-level rise).

Individual councils or regional groups have commissioned mapping at a more local level. For example, the Yorke Peninsula Sea Flood Risk (SA) mapping project covered several bays and beaches in the Yorke Peninsula. The approach was similar to the simple bathtub approach taken by Geoscience Australia in the OzCoasts product. Other local areas have more detailed stormwater inundation modelling that includes sea-level rise considerations (e.g. the *Stormwater Management Plan: Cities of Holdfast Bay and Marion*).

The tool Canute – the sea level calculator, developed by the ACE CRC, allows users to estimate the likelihood of future flooding from the sea. Users can adjust time scales and scenarios to explore a range of likely futures.

Understanding how sea-level rise projections might impact your coastline.

Sea-level rise is likely to increase the risk of flooding and inundation and alter coastal processes (e.g. erosion).

To understand how sea-level rise will impact these processes, you need to understand the topography, geology, sediments and elevation of your coastline.

Your organisation may already have some of this information in the form of topographic maps or coastal studies.

Landforms and sediments

There are two national sources of some of this information. First, the Smartline Coastal Geomorphic Map of Australia is a detailed map of the coastal landform types or geomorphology of continental Australia and most adjacent islands (excluding the Great Barrier Reef). The maps provide the topography (planform, elevation and shape of the coastal landforms) as well as indicating what the different coastal landforms are made of (i.e. rock types: laterite, coral, sand, mud, boulders, beachrock, etc.). You can explore information from an interactive map (Figure 4).

The second is a national classification of Australia's coastline into 'compartments' based on landforms and patterns of sediment (sand and other beach material) movement. The Sediment Compartments approach is designed to identify management units and to forecast changes in the shoreline through erosion and sand movement processes (Figure 5). The maps are available as a download with an accompanying technical manual.

Both datasets provide a nationally consistent format and classification of coastal landforms. You may find these useful to help understand some of the physical processes happening on your coastline, to give an initial assessment of your risks and to use consistent classifications for any comparisons. CoastAdapt brings this information together into a visualisation tool Shoreline Explorer.

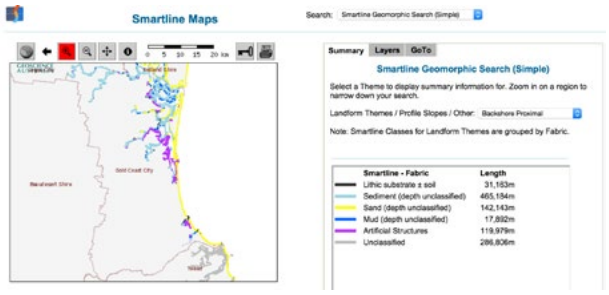


Figure 4: Sample output from Smartline maps. Source: © OzCoasts (Geoscience Australia) 2016.

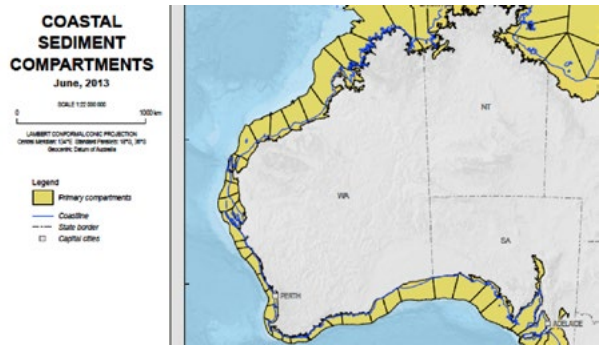


Figure 5: Part of the Coastal Sediment Compartments map for Primary compartments. Source: © Commonwealth of Australia (Geoscience Australia) 2016.

Topography and elevation

Topography and elevation data have generally been captured by states in the form of topographic mapping, and through collection of light detection and ranging (LiDAR) data to develop DEMs, which give a three-dimensional model of the ground surface topography.

At a national level, the National Elevation Data Framework portal collates much of these elevational data. Mid-resolution DEM information is available for the entire coast of Australia, with higher resolution modelling (vertical accuracy better than 1 m) for selected urban areas – primarily the east and south-east coast of Australia. Some local governments have acquired LiDAR data for their region.

Also important for coastal studies are bathymetric data, which include information about the depths and shapes of underwater terrain.

Flooding and inundation

Flooding and inundation can come from either the sea (sea-level rise and storm surge), rivers or from overland sources (rainfall).

Most coastal areas already experience flooding of at least one of these types, and in some cases all types.

Modelling and mapping of flooding risks tend to be undertaken at the local level and often as part of an emergency services preparation and response program. The Australian Flood Risk Information Portal (included in Table 3) assembles flood studies and mapping from various sources around Australia. It was initiated in response to widespread flooding in 2011. Mapping may look at current flooding risks and may include future projections.

A number of states and individual councils have assembled flooding information. Most of these are based on current climate but, increasingly, they are considering a range of climate change scenarios.

Storm-surge mapping exists for specific locations – primarily those with a significant risk (e.g. areas at risk from cyclones or storms). An example of storm-surge mapping that includes consideration of climate change risks is the Busselton Inundation report.

More information

CoastAdapt's Information manuals provide more technical guidance around sea-level rise and its impact, the available datasets and how to use them. Information Manual 2 provides an introduction to climate change and sea level rise and provides a better understanding of the potential impacts of these changes. Information Manual 3 provides a technical description of coastal processes and how they interact with the landscape to impact on erosion and inundation and other climate-related impacts (e.g. rainfall, storms, etc.). It also provides a more in-depth guide to climate projections.

Information Manual 2: Understanding sea-level rise and climate change, and associated impacts on the coastal zone

Information Manual 3: Available data, datasets and derived information to support coastal hazard assessment and adaptation planning

Table 2: Sea-level rise projections and tools available at a national level.

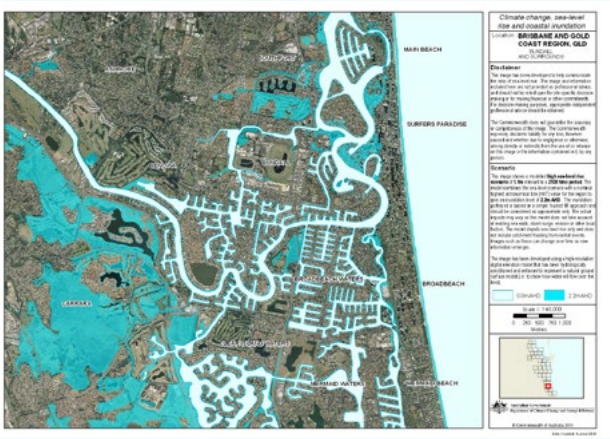
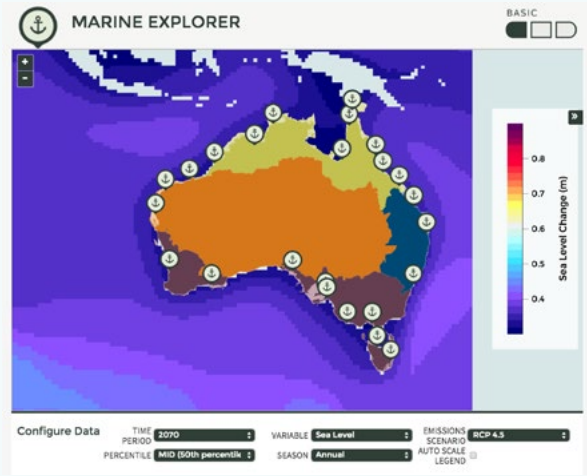
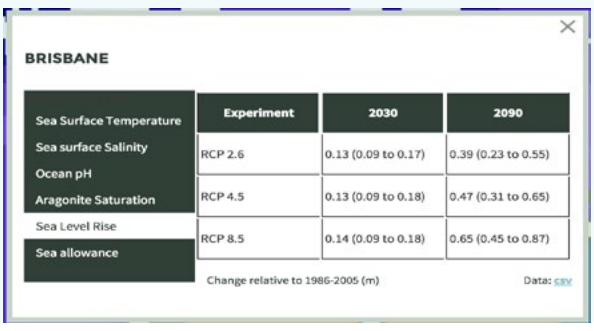
Projections	Details	Sample output
OzCoasts **Agencies**: Geoscience Australia **Link**:http://www.ozcoasts.gov.au/climate/sd_visual.jsp **Description**: sea-level rise maps for six regions: Sydney, Hunter and Central Coast (NSW), Adelaide, Melbourne, south-east Queensland and Perth south to Mandurah. The intention of the maps is to provide a set of examples using simple bathtub modelling and limited considerations (e.g. not coastal protection infrastructure), rather than precisely accurate maps.	**Scenarios**: 0.5 m, 0.8 m and 1.1 m of sea-level rise **Method**: Bathtub **Output**: Downloadable images	
Climate Change in Australia – Marine Explorer **Agencies**: CSIRO and BoM **Link**:http://www.climatechangeinaustralia.gov.au/en/climate-projections/coastal-marine/marine-explorer/ **Description**: Projections are available through an interactive map format, with specific data shown for a series of points around Australia's coast. Users can choose four time points, three RCPs, three percentiles and seasonal or annual projections.	**Models:** CMIP5 **Scenarios**: RCPs (2.6, 4.5, 8.5) **Time:** 2030, 2050, 2070 and 2090 **Output**: Interactive map, downloadable data	 

Table 2: Sea-level rise projections and tools available at a national level - *continued*.

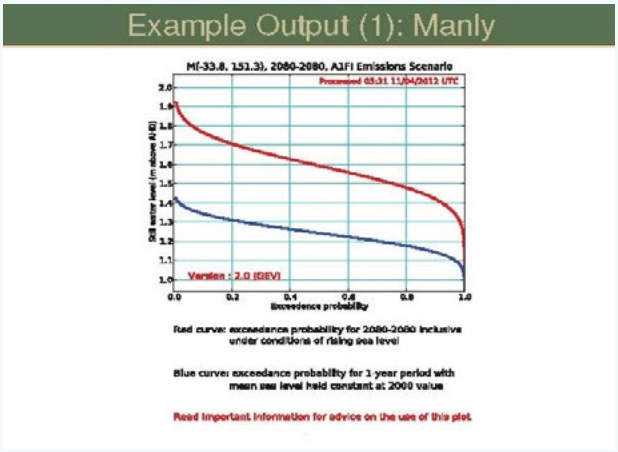
Projections	Details	Sample output
Canute **Agencies**: ACE CRC **Link**: http://canute2.sealevelrise.info/ **Description**: Canute is a tool that allows users to estimate the likelihood of future flooding from the sea. The model combines the frequency of present storm surges and projections of future sea-level rise. The output is expressed in two ways: first as a statistical indication of the probability of experiencing at least one flooding event during the selected period (e.g. 1 event in a 100-year period) or as the expected number of floods in a given period. Users can adjust time scales and scenarios to explore a range of likely futures. The tool also includes a wave setup and run-up calculator, shoreline recession calculators and storm-surge climatologies. Updates to the tool are due for release in 2016.	**Models:** **Location:** All Australia (12,000 data points) **Scenarios**: SRES B1FI, A1B, B1, **Output**: Graphs **Resolution**: 2.5 km **Output:** Plots of sea-level rise projections and probability exceedance	

Table 2: Sea-level rise projections and tools available at a national level - *continued*.

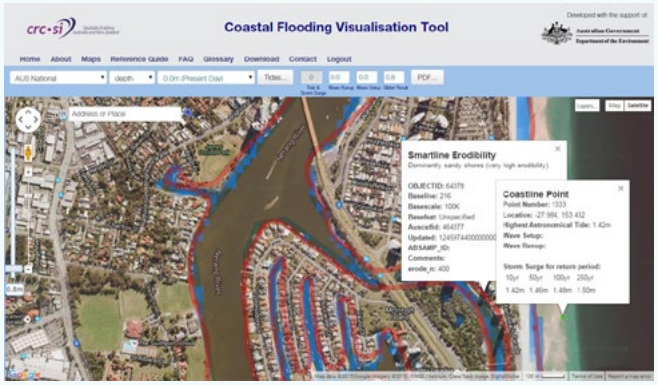
Projections	Details	Sample output
Coastal Risk (previously VisTool) **Agencies**: Spatial Information CRC and Commonwealth Government **Link**: http://www.coastalrisk.com.au/ **Description**: The Coastal Risk tool uses an interactive map interface to give an indication of the likely inundation around Australia under a range of different climate change projections. It uses high-resolution elevation data and bathtub modelling. Users can select a region and a sea-level rise scenario and can explore the impact of tides and storm-surge events. Results are viewable on a map. The tool was formerly known as VisTool.	**Models:** **Location:** All Australia **Scenarios**: SRES B1FI, A1B, B1, **Method**: Bathtub **Output**: Interactive maps **Resolution**: 2.5 km	

Table 3: Other datasets to help understand coastal geomorphology and topography, and their impact on flooding and erosion.

Coastal landforms and geomorphology	**Smartline Coastal Geomorphic Map** **Link**: http://www.ozcoasts.gov.au/coastal/smartline.jsp ***Description***: Presents geomorphic data as a segmented line. The lines are tagged with attributes (e.g. landform types, geology, exposure to wave energy, etc.), and the maps can be queried and analysed using GIS software	***Location***: All Australia ***Date***: 2009 ***Agencies***: Geoscience Australia
Elevation data	**Bathymetry** **Link**: http://www.ozcoasts.gov.au/coastal/smartline.jsp **Description**: Geosciences Australia maintains a compiled record of bathymetric data.	**Location**: All Australia **Date**: From 2009 **Agencies**: Geoscience Australia
	National Elevation Data Framework **Link**: http://www.ga.gov.au/scientific-topics/marine/bathymetry **Description**: A portal of high-resolution elevation data. The available information is audited periodically to build the portal.	**Location**: All Australia **Date**: 2009 **Agencies**: Geoscience Australia
Flooding datasets	**Australian Flood Risk Information Portal** **Link**: http://www.ga.gov.au/flood-study-web/#/search **Description**: This portal holds flood information from different sources around Australia. Individual governments at all levels lodged their flood information so it can be accessed from this one entry point. It includes maps and flood studies.	**Location**: All Australia **Date**: From 2012 onwards **Agencies**: Geoscience Australia

3.2.3 Habitat and ecosystems

The type of information you need about local habitats, and individual plant and animal species will depend on your adaptation plans.

Most information on the distribution and habitat of individual species associated with the coastal zone is likely to be available for local areas or on a species-by-species basis. The majority of research is concerned with the impacts of climate change on habitats and ecosystems. This information is likely to be useful when you are thinking about individual species or ecosystems within your planning area.

In considering climate change impacts on plants and animals, much of the earlier literature considers the potential for changes in the distribution of individual species. Work has been undertaken to develop species distribution models in order to project the likely survival, extinction or colonisation by individual species and is often the basis for adaptation planning of natural ecosystems. Newer approaches include considering a whole-of-biodiversity approach and decision-support models to help understand impacts of climate change on ecosystems.

In addition, several bodies of work have produced principles and guiding information to support adaptation decision-making on the coast.

CoastAdapt's Information Manual 10: Ecosystems provides a stepwise process for developing an adaptive management strategy for coastal ecosystems. The manual looks at how to balance different values.

Key resources

General ecosystem impacts of climate change in the coastal zone	**Marine climate change in Australia: 2012 report card** **Link**: https://www.nccarf.edu.au/sites/default/files/attached_files_publications/Marine_Report_Card_Australia_2012.pdf **Description**: This report provides information on the effects of climate change on marine and coastal ecosystems. It also provides information on policy responses to a range of issues. It will be a useful document to track effectiveness of adaptation options.	**Location:** All Australia **Date**: 2012 **Agencies**: CSIRO, NCCARF, Fisheries Research and Development Corporation (FRDC)
	Coastal ecosystems responses to climate change **Link**: https://www.nccarf.edu.au/sites/default/files/attached_files_publications/Hadwen_2012_Coastal_ecosystems_responses_to_climate_change.pdf **Description:** This report provides a recent synthesis of climate change responses and adaptation pathways for 13 Australian coastal habitats. This report does not provide data or mapping layers, but provides useful information that can be used to support planning for adaptation on the coast.	**Location**: All Australia **Date**: 2012 **Agencies**: NCCARF, Griffith University
Species and ecosystem distribution	**OzCoasts** **Link**: http://www.ozcoasts.gov.au/index.jsp **Description**: OzCoasts collates a range of datasets, including conceptual models of ecosystems and habitat mapping for a range of coastal ecosystems. A number of these habitat maps may provide a useful first-pass assessment of the types of habitat that are present in a particular area and may support decision-making about adaptation options.	**Location**: All Australia **Date**: various **Agencies**: Geoscience Australia
	Climate change adaptation strategies for Australian birds **Link**: https://www.nccarf.edu.au/sites/default/files/attached_files_publications/Garnett_2013_Climate_change_adaptation_strategies_for_Australian_birds.pdf **Description**: The project used climate modelling to determine the effect of climate change on Australian water birds (including estuarine, coastal and marine species). It identifies the most vulnerable species and considers management options.	**Location**: All Australia **Date**: 2013 **Agencies**: Charles Darwin University, NCCARF

Key resources

Species and ecosystem distribution

Implications of climate change for biodiversity: A community-level modelling approach

Link: http://adaptnrm.csiro.au/biodiversity-impacts/

Description: A modelling approach (Generalised Dissimilarity Modelling) that provides spatial information on the potential effects of climate change on key groups of organisms or a whole-of-biodiversity perspective for planning. The project developed a set of maps and spatial datasets that projects the potential shifts in biodiversity in response to climate change.

Location: All Australia

Date: 2014

Agencies: CSIRO

Adaptation measures and guidance

Climate change adaptation strategies to support Australia's estuarine and coastal marine ecosystems

Link: http://frdc.com.au/Archived-Reports/FRDC%20Projects/2011-040-DLD.pdf

Description: The report is the result of a research project that reviews current knowledge, data, tools and processes for developing adaptation strategies to manage Australia's estuarine and coastal marine ecosystems. No single tool was assessed as sufficient to deal with the diversity around Australia's coast, so the report gives a set of general principles to guide adaptation strategies.

Location: All Australia

Date: 2014

Agencies: FRDC

Australia's marine biodiversity and resources in a changing climate: A review of impacts and adaptation 2009-2012

Link: https://www.nccarf.edu.au/sites/default/files/attached_files_publications/Marine%20NARP%20Lit%20Review_2012_FINAL_0.pdf

Description: A critical review and synthesis of the published literature from December 2008 to 2012 relating to climate change impacts and adaptation for Australia's marine biodiversity and resources. The report is organised around a number of themes and questions.

Location: All Australia

Date: 2012

Agencies: NCCARF

NCCARF coastal ecosystems adaptation information manual

Link: http://coastadapt.com.au/information-manuals/climate-change-adaptation-planning-for-protection-of-coastal-ecosystems:

Description: Manual designed to provide stakeholders with the knowledge needed to sustainably manage coastal ecosystems under climate change. It provides a framework to develop a strategy and more detailed resources to support that process.

Location: All Australia

Date: 2016

Agencies: NCCARF

3.3 Economics and insurance

The costs of both adapting and failing to adapt are significant, and considerations of financial exposure, cost of impacts and adaptation measures and quantified benefits should be incorporated into decision-making. A number of tools and techniques are available to help you assess and compare costs.

Cost–benefit analysis

Cost–benefit analysis is one tool that decision-makers are likely to look to for support in their decision-making. The approaches to assessing costs and benefits include traditional cost–benefit analysis, cost-effectiveness analysis, cost minimisation and multi-criteria analysis. Approaches can also range from a self-assessment of the attributes exposed to climate change (e.g. asset values, ecosystems, etc.) through to detailed economic modelling undertaken by an economist.

Economic analyses are useful in understanding and informing trade-offs, for example, development restrictions versus building a seawall. The trade-offs are evaluated on the basis of the value or importance of the resources to individuals and society. The value is a combination of numerous social, environmental, cultural and economic factors, and these must be valued in a way that they can be effectively and legitimately considered in decisions that inevitably result in some benefiting and others losing out. An example of a cost and benefit analysis for coastal communities can be found in the NCCARF report "Costs and coasts" https://www.nccarf.edu.au/sites/default/files/attached_files_publications/Fletcher_2013_Costs_and_coasts.pdf.

Assessment of costs and benefits may need to be done at several stages in the decision-making process, although it is most likely an in-depth analysis will be undertaken when considering adaptation options.

There are a number of challenges to economic analyses under climate change. These include uncertainty, the scale of the problem (in both space and time) and analytical challenges. Valuing things such as the intrinsic value of an ecosystem can be extremely difficult, but a socially unpopular decision about an ecosystem can quickly escalate its political value. It is essential that an analysis of values include not only functional values, but also social and cultural values, and a number of techniques exist to help undertake these assessments.

As with any modelling, the assumptions used greatly influence the outcome of the results. For example, discount rates are used to compare future values to present day costs and make an assumption about how values will change in the future. The rate used will make a significant difference to what is assumed.

Insurance

It is clear that insurance, and potentially markets, will have a role to play, either as drivers of adaptation action and policy or, in the case of insurance, as a financial recovery mechanism.

Presently, sea-level rise is not covered by insurance in Australia, although some policies cover erosion loss and inundation where it is tied to another event (e.g. cyclone).

Insurance premiums are a mechanism by which the 'market' recognises risk, and government intervention (e.g. providing funding for disaster recovery) means the market does not reflect the actual risk. There is some scope for public–private partnerships, and Suncorp Insurance is currently looking to build such a partnership with its Protecting the North initiative (http://www.suncorp.com.au/insurance/protectingthenorth).

Further information

CoastAdapt Information Manual 4 provides more in-depth guidance on costs and benefits analyses. CoastAdapt includes information on the role of insurance.

Information Manual 4: Assessing the costs and benefits of coastal climate adaptation

CoastAdapt: The role of insurance

3.4 Legal liability and litigation

Legal issues, particularly the risk of liability for development decisions, is an important concern for most councils when they are planning to reduce climate change risks. Private businesses may also be concerned that decisions could leave them open to claims of negligence in the future.

Some legal challenges and their decisions (case law) give some guidance around legal liability issues; however, a definite answer about the legal liability of any decision can only be given if it is tested in the courts.

The best course for decision-makers is to ensure they are following the best advice they can and have the best information available to them. In the CoastAdapt Information Manual 6: Legal risk, a guide is given for decision-makers to take a legal reasoning approach. It outlines the key three questions to address to understand the legal risk associated with a decision:

- Do you have the legal power to make the decision?
- Have you taken account of the best possible knowledge that relates to the decision, including the uncertainties (in this case, around climate change and its impacts)?
- Is there any uncertainty in the law?

Most difficult for many decision-makers is ensuring they have the best possible knowledge. As discussed earlier in this manual, information can go out of date quickly (e.g. new CMIP5 climate change projections that supersede models used for downscaled projections). In a legal challenge, it is likely that the courts would take account of what resources the decision-makers had available to them and what was reasonable information to use in decision-making.

A number of reviews have been particularly targeted at local governments responsible for planning decisions, that have discussed the possible risks of acting or not acting in response to climate change risks, particularly in the coastal zone. These provide a good understanding of the potential issues and the way forward for local councils.

Issues considered across the reviews include any legal risks that might arise when a development application is made or in the future as the result of a climate hazard. The reviews also consider whether there is any legal obligation to compensate landholders in different circumstances where development restrictions are imposed because of future risks.

The Western Australian Local Government Association (WALGA) has provided an opinion on the legal risks of releasing risk hazard information (e.g. flood risk mapping). Local councils have expressed concerns that releasing hazard information may expose them to claims of 'pure economic loss' (i.e. decreased property value loss), but the paper from WALGA actually suggests that failure to release 'reasonably accurate hazard information' may be a greater legal risk. Again, the emphasis is on having the best possible information within the resource capacity of a council. http://walga.asn.au/getattachment/Policy-Advice-and-Advocacy/Environment/Climate-Change/Climate-Change-Projects-and-Resources/Disclosing-Hazard-Information-Legal-Issues-Paper.pdf.

3.5 Policy and legislation to address coastal climate risks

In most states, policies about managing climate change risks in the coastal zone are found in non-binding, statewide policy documents rather than in state legislation. Most of these policies are given effect through the land use planning system of each state and territory, where they inform local statutory planning schemes and the assessment of major developments. There is a great difference between the policies of each jurisdiction. (Information Manual 5: Planning instruments, Appendix 1 provides a listing of the different state planning legislation.)

Decision-makers (e.g. planners) have a considerable degree of discretion under these existing approaches, which can result in uncertainty, inconsistencies in decision-making and the possibility of legal challenge. Sea-level benchmarks are a good example: the best science gives us projections of what sea-level rise might do in the future, but there is uncertainty associated with them, so we end up with a range of, rather than definitive, projected values. For example, Australia expects a sea-level rise of 45–82 cm for a high emissions scenario (RCP8.5). Governments must look at what is an acceptable risk and determine if they will set a benchmark and what it will be. While the benchmark can be supported by good science, it also includes an assessment of risk appetite and future emissions. Some states provide no planning benchmark, and local governments have significant discretion in their decision-making.

Across Australia there is little consistency in:

- what is meant by the term 'coast' (e.g. how far inland and how far offshore remains within the defined coast)
- sea-level rise benchmarks (i.e. the sea-level rise projections that any planning must take into account)
- the methods for deciding what is a 'coastal hazard area'.

Despite these issues, there is an increase in state-sponsored design and planning guidelines for foreshore management and coastal development.

Key resources

Information Manual 6: Legal risk. A guide to legal decision making in the face of climate change for coastal decision makers **Link**: http://coastadapt.com.au/information-manuals/legal-risk-guide-to-legal-decision-making-for-coastal-decision-makers **Description**: A manual to help decision-makers self-assess their potential legal risk in decisions that address climate change. Provides an overview of the types of decisions coastal managers are making and how to approach them to reduce legal risks.	**Authors**: Baker-Jones, Barton & Bell **Agency**: NCCARF **Year**: 2016
Information Manual 5: Adapting to long term coastal climate risks through planning approaches and instruments **Link**: http://coastadapt.com.au/information-manuals/adapting-long-term-coastal-climate-risks-through-planning-approaches-and-instruments **Description**: Manual developed to help users planning for the impacts of climate change in Australia. It looks at the broader national context, including jurisdictional approaches to planning; the key approaches and planning instruments that can be employed; and case studies of leading strategies for building coastal resilience.	**Authors:** Norman & Gurran **Agency**: NCCARF **Year**: 2016
Climate change and coastal development law in Australia **Link**: https://www.federationpress.com.au/bookstore/book.asp?isbn=9781862879713 **Description**: Provides a comprehensive analysis of the various legal issues that are likely to arise in Australia as governments adapt to sea-level rise. Explores how legal risks can be managed and what legal approaches can be implemented to reduce the likely economic impacts and spread them across time. Also considers the evolving role of the insurance industry.	**Authors:** Bell **Agency**: Private publisher **Year**: 2014
Local council risk of liability in the face of climate change – resolving uncertainties **Link**: http://alga.asn.au/site/misc/alga/downloads/environment/ALGA%20Consolidated%20Report-v7B-1392955-SYDDMS%20-%20Final.pdf **Description**: Report commissioned by the Australian Local Government Association (ALGA) identifies trends and inconsistencies between the jurisdictions in key legal risk areas and develops recommendations to reduce legal risk. It also considers how councils with limited resources can respond to climate change and legal proceedings resulting from climate change. A set of recommendations is provided.	**Authors**: Baker & McKenzie **Agency**: ALGA **Year**: 2011

Coastal climate change risk – legal and policy responses in Australia **Link**: http://www.environment.gov.au/system/files/resources/68cbcb67-bd6c-41ee-b214-02a5143d90d9/files/coastal-cc-legal-responses.pdf **Description**: Review of the (then) extent and status of state and territory laws and policies addressing coastal climate change risks in Australia. The report maps and analyses relevant laws and policies, reviews risk protection standards and current coastal climate change risk management responsibilities and summarises key coastal climate change–related legislation and policy for each state and the Northern Territory.	**Authors:** Gibbs and Hill (Blake Dawson) **Agency**: Department of Climate Change and Energy Efficiency **Year**: 2011
Disclosing hazard information: The legal issues Agency: WALGA and LGIS **Link:** http://walga.asn.au/getattachment/Policy-Advice-and-Advocacy/Environment/Climate-Change/Climate-Change-Projects-and-Resources/Disclosing-Hazard-Information-Legal-Issues-Paper.pdf **Description:** This paper discusses the legal issues surrounding the disclosure of hazard information. It also considers the options available to councils in releasing hazard information as well as considerations when gathering information.	**Agency:** WALGA and LGIS **Year:** 2016

3.6 The human environment

Adaptation, by its nature, calls for flexibility and adaptive planning. The resilience of communities will depend on their capacity to be adaptive and to learn and respond to change into the future.

Understanding the resilience and adaptive capacity of your community can be challenging. Only a limited number of studies have tried to assess vulnerability or adaptive capacity at the community level.

Knowing some demographics or statistics about your community may help. Consider social and economic information: vulnerability is often associated with age, poverty, chronic health issues, disability and cultural background. However, it is important that when you are looking at climate change projections you should also consider local future demographics (e.g. in 2030 there may be an ageing population in your neighbourhood, which will exacerbate any vulnerabilities). Check with the Australian Bureau of Statistics or your state agency for population projections.

3.6.1 The role of communication and community engagement

Engaging with stakeholders is one method that will help you understand both the community's risk appetite and values as well as its vulnerability and resilience. Genuine engagement builds relationships – and therefore trust – to support decision-making that is equitable and representative of collective social values of the community.

Engagement and communication need to be undertaken at various steps in the planning process, usually starting with this first step of identifying the challenges. Early engagement is likely to build good partnerships and improve the design and progress of planning.

There are a range of manuals, tools and guidance on community engagement and communication. CoastAdapt's Information Manual 9: Community engagement brings together information from a variety of sources to provide a set of examples of how community engagement might be undertaken in your organisation. It outlines lessons about effective engagement:

- It takes time
- It is best done through existing networks
- It considers its target audience plus influencers on that audience
- It is inclusive and values diversity
- It is clearly scoped and resourced.

To engage the community, you need to understand who to engage and how and when to engage them. Part of your engagement strategy may also be to seek guidance on communication, consultation and participation.

Key resources

Community engagement	**Information Manual 9: Community engagement** **Link**: http://coastadapt.com.au/information-manuals/community-engagement **Description**: This manual considers many of the key concepts and approaches to community engagement. It identifies six steps in a long-term cycle of engagement. It also lists state and other engagement guides and describes a series of case studies of engagement approaches.	**Authors**: Smith, Leitch and Thomsen **Agency**: NCCARF **Year**: 2016
	Online community engagement toolkit for rural, remote and Indigenous councils **Link:** http://www.acelg.org.au/rri-toolkit/#tkmenu **Description:** This online website provides nine modules designed specifically for rural, remote and Indigenous councils to undertake community engagement. It provides practical advice for small councils and councils with few resources	**Agency:** ACELG
Communication	**Communication guidelines: coastal hazard adaptation** **Link**: http://lgaq.asn.au/documents/10136/ad5bc50f-4db4-460a-af66-d252cd264d96 **Description:** Guidelines designed to help councils develop communication strategies around planning for coastal hazards. Provides a description of 10 elements that should make up the communication plan and tips and examples to help implement the communication strategy.	**Authors**: SGS Economics & Planning **Agency**: LGAQ **Year**: 2014

4 Determine vulnerabilities

At this point you will have gathered information on the physical environment, including climate projections, will have some understanding of the community and its values and will have established the objects of your plan. Your next step is to analyse this information to understand your vulnerabilities.

This step will include a climate risk assessment, which will identify and assess likely climate change impacts in your local area or for your project and an analysis of adaptive capacity for your region or organisation. Pulling this together will help you understand your broader vulnerabilities.

The IPCC defines vulnerability as 'the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes'. It is usually thought of as your risk of harm from exposure (expected climate change) and sensitivity to stresses (impacts of climate change) associated with environmental and social change and from the absence of capacity to adapt.

You may be familiar with a risk assessment. There is a great deal of overlap between vulnerability assessments and risk assessments, and the terms tend to be used interchangeably.

A range of tools, resources and examples of completed assessments are available to help you conduct risk and vulnerability assessments. We list some of the guides and tools in Box 2. It is worth noting that the NSW government is producing a guide to help coastal managers identify and assess the vulnerability of coastal environmental, social and economic values and evaluate management actions. A draft version has recently been released. http://www.environment.nsw.gov.au/coasts/coastreforms-manual.htm

Interactive tools can also help with this stage of planning. The Coastal Climate Blueprint is an online questionnaire that allows communities to calculate their vulnerability. This interactive approach might be valuable in engaging with the community at this stage.

When your concerns are with infrastructure, you can use AdaptWater, which is an interactive tool developed to quantify climate risks, assess adaptation options and provide economic modelling for investment decisions across a range of utility and infrastructure types, including water, rail, airports and gas suppliers.

Case studies of vulnerability and risk assessments

You might find it useful to see what others have done to assess their risk and vulnerability.

Some examples are the result of a state-mandated process (e.g. councils in the Sydney metropolitan area and outskirts were required to complete a climate change risk assessment under a now-defunct Waste and Sustainability Improvement Payment Program), while others have been undertaken as part of council or organisation business. Many have different levels of data and resources.

The Townsville Hazard Adaptation Strategy Pilot Project is an example of a data-intensive study, in this case focused on coastal hazard rather than broader adaptation for the region. *Climate Change Impacts on Clarence Coastal Areas – Final Report* describes the council's approach of community consultation as well as data assessment in assessing the council's risk.

CoastAdapt provides guidance for undertaking a risk assessment in the coastal zone. The risk assessment is at three levels of increasing depth and resource requirement. It is accompanied by templates to help complete the process. (https://coastadapt.com.au/how-to-pages/how-to-conduct-a-climate-change-risk-assessment).

Box 2: Tools to guide risk and vulnerability assessments

General risk management guidelines:

The intention of these guidelines is to incorporate planning for risk into existing strategies or business plans. You may find these a good place to start if your organisation already undertakes risk assessments. The process will be familiar and will help you get an idea of what you might do.

Australian/New Zealand Standard ISO 31000:2009 – Risk management: principles and guidelines (Standards Australia 2009)

Climate change impact and risk management – A guide for business and government (DEH & Greenhouse Office 2006)

Standards Australia AS 5334-2013 Australian Standard on climate change adaptation for infrastructure (Standards Australia 2013)

Guidelines developed for adaptation planning:

A number of the Australian states have produced their own set of guidelines to help assess climate risk. While they are each developed for a particular state, they have a process that is transferable to most locations.

Climate change risk management matrix: A process for assessing impacts, adaptation, risk and vulnerability (Queensland Government 2011)

Guide to climate change risk assessment for NSW local government (Office of Environment and Heritage 2011)

Guidelines developed for coastal hazard assessment:

A number of Australia's state governments have developed specific guidelines for assessing coastal hazard risk. These guidelines look specifically at the physical risks to coastal communities, infrastructure and business. These will help you process some of the more technical aspects of your vulnerability assessment. Make sure you are also covering off on other risks such as community health, infrastructure or housing at risk from non-coastal impacts (e.g. riverine flooding).

Guideline for preparing a coastal hazard adaptation strategy (Queensland Government 2013)

Coastal hazard risk management and adaptation planning guidelines (Western Australian Government 2014)

Victorian coastal hazard guide (Victorian Government 2012)

5 Investigate options

At this stage of planning you will have a good understanding of your risks and vulnerabilities and will start considering what your adaptation options might be. You will not be looking to rule any of these out yet; you should consider a broad range of options.

There are several categories of adaptation options, including planning options, engineering options, economic options and market mechanisms, and social and education options. For a comprehensive listing of adaptation options visit: https://coastadapt.com.au/adaptation-options.

Planning options for new developments might include:

- creating long-term strategic land use plans to ensure areas of future risk are not zoned for development
- changing planning schemes and development approvals: conditions on development attached to land
- avoiding hazard: development restrictions
- accommodating impacts: conditional development, for example, houses on stilts may be required for areas that experience temporary inundation but are unlikely to be appropriate for areas subject to permanent inundation or erosion
- planning retreat: occupation for limited time or until a trigger event
- defending against inundation or erosion: planning scheme allowance to construct defence structures (e.g. seawall).

For existing developments, planning options might include:

- acquiring property (compulsory or delayed acquisition or voluntary buy-back schemes)
- building defence structures
- accommodating risk (e.g. raising buildings)
- conducting land swaps or transfers of development rights.

Experience from both within Australia and overseas has found that building resilience is a key long-term component of planning for climate change in the coast.

Engineering options tend to address protection or amelioration options. The Engineers Australia report Climate change adaptation guidelines in coastal management and planning considers several categories of protection/amelioration options, and reviews examples of their use and the advantages and challenges of each option. This is also considered in Information Manual 7: Engineering solutions

The Australian Government published a set of adaptation actions for local governments in 2007 that were considered to provide a net economic, social or environmental benefit regardless of the level of climate change that might occur in the future (SMEC Australia 2007). The actions address six local government functions: infrastructure and property services, provision of recreation facilities, health services, planning and development approvals, natural resource management and water and sewerage services. Although these guidelines are now quite dated, they provide a useful description of categories of adaptation actions. A number of the Australian states include information on adaptation actions in planning and hazard assessment guidelines.

Key resources

Planning and development options	**Climate change and coastal development law in Australia** **Link**: https://www.federationpress.com.au/bookstore/book.asp?isbn=9781862879713 **Description**: Provides a comprehensive analysis of the various legal issues that are likely to arise in Australia as governments adapt to sea-level rise. Explores how legal risks can be managed and what legal approaches can be implemented to reduce the likely economic impacts and spread them across time. Also considers the evolving role of the insurance industry.	**Authors**: Bell **Agency**: Private publisher **Year**: 2014
	Information Manual 5: Planning instruments and approaches to enable adaptation to long-term climate risks **Link**: http://coastadapt.com.au/information-manuals/adapting-long-term-coastal-climate-risks-through-planning-approaches-and-instruments **Description**: Manual developed to help users planning for the impacts of climate change in Australia. It looks at the broader national context, including jurisdictional approaches to planning; the key approaches and planning instruments that can be employed; and case studies of leading strategies for building coastal resilience.	**Authors**: Norman & Gurran **Agency**: NCCARF **Year**: 2016
Engineering options	**Climate change adaptation guidelines in coastal management and planning** **Link**: https://www.engineersaustralia.org.au/sites/default/files/content-files/2016-12/climate_change_adaptation_guidelines.pdf **Description**: Guidelines to assist coastal managers considering physical intervention options, under both present day conditions and with climate change. This includes identifying the key issues (coastal values and hazards) and understanding the relevance of local coastal processes and how the coast may respond during extreme events now and into the future with and without intervention. Outlines a range of intervention strategies.	**Authors**: Cummings et al. **Agency**: Engineers Australia **Year**: 2012
	Information Manual 7: Engineering solutions for coastal infrastructure **Link**: http://coastadapt.com.au/information-manuals/engineering-solutions-for-coastal-infrastructure **Description**: Summary of engineering functions and role in coastal management now and in the future. Provides a summary of the guidelines produced by Engineers Australia.	**Authors**: Webb **Agency**: NCCARF **Year**: 2016
General overview	**Climate change adaptation actions for local government** **Link**: http://www.lincoln.ac.nz/PageFiles/6702/4230_localgovernment_s13808.pdf **Description**: Outlines the potential impacts of climate change on local government functions. It provides a valuable toolkit of responses including information on their benefits and costs. The document is no longer available on the Australian Government website, but is still a useful prompt to think about different adaptation actions.	**Authors**: SMEC **Agency**: Department of the Environment and Water Resources **Year**: 2007

6 Evaluate options, risks and costs

This step is largely focused on making decisions. It starts with considering your decision criteria, including community and stakeholder risk appetite, and then moves to evaluating options.

In evaluating your options, you will want to consider the timing of actions (e.g. some options may not be needed for some time), if any options will prevent you from undertaking another option, your resources and the community's values. For the private sector, it will also be about market demand.

A number of decision-support tools are available, and choosing the appropriate one can be challenging for decision-makers.

Decision-making frameworks generally fit into a number of categories. Three of the most recognisable are cost–benefit analysis, multi-criteria analysis and a pathways approach. Each framework has its own set of advantages and disadvantages, and it is unlikely that a single approach will be sufficient to make your decision.

Two of the resources listed below are themselves guides to choosing decision support frameworks. Randall et al. (2013) assists decision-makers to work through a process of choosing and implementing a decision-making framework. Webb and Beh (2013) review a large number of products and tools.

Costs and benefits

A cost–benefit analysis is likely to be one of the key tools for evaluating your options. As highlighted in section 3.3, cost–benefit analysis values a combination of social, environmental, cultural and economic factors in a way that they can be effectively and legitimately considered in decisions.

Multi-criteria analysis

A multi-criteria analysis (MCA) directly incorporates multiple values of stakeholders into the analysis of management alternatives without the need to reduce those values to a standard monetary unit. This means that options can be considered in the context of social, political or environmental criteria as well as economic criteria. The approach provides opportunity for stakeholder participation in the analysis.

A pathways approach

You may also wish to consider using a pathways approach, which is not a decision support system per se, but rather a way of structuring your decision-making process. It helps you identify points or junctures in the future where further decisions must be made or actions taken; it helps you understand how actions and decisions affect other actions and decisions; it maps out the path of adaptation options and helps you avoid undesirable outcomes.

An adaptation pathway process can be characterised as a decision-making strategy that is made up of a sequence of manageable steps over time. Each step is triggered by some change (environmental or social). A wide range of options can be considered, evaluated and left on the table for the future, giving decision-makers flexibility and allowing decisions to be responsive, iterative and transformative.

Key resources

General guide	**Leading adaptation practices and support strategies for Australia: An international and Australian review of products and tools** **Link**: http://www.nccarf.edu.au/sites/default/files/attached_files_publications/Webb_2013_Leading_adaptation_practices_support.pdf **Description**: This report looks at building enhanced climate adaptation support products and tools for use within Australia, and strategies to ensure effective uptake and use of products. As part of the process they review and describe a database with more than 300 adaptation support products.	**Authors**: Webb and Beh **Agency**: NCCARF **Year**: 2013
	Choosing a decision-making framework to manage uncertainty in climate adaptation decision-making: A practitioner's handbook **Link**: http://www.nccarf.edu.au/sites/default/files/attached_files_publications/Randall_2012_Practitioner_handbook.pdf **Description:** Provides guidance on how to select, implement and evaluate a decision-making framework. The handbook discusses the problem of managing risk and uncertainty in climate change adaptation decision-making, introduces a number of the many available decision-making frameworks and suggests a few ways to compare these alternatives.	**Authors:** Randall et al. **Agency:** NCCARF **Year:** 2012
Cost–benefit analysis	**Information Manual 4: Assessing the costs and benefits of coastal climate adaptation** **Link**: http://coastadapt.com.au/information-manuals/assessing-costs-and-benefits-of-coastal-climate-adaptation **Description:** This manual provides readers with information and advice on deciding when, why and how to assess the costs and benefits of adaptation.	**Authors**: Wise and Capon **Agency**: NCCARF **Year**: 2016
Pathways approach	**Eyre Peninsula Regional Climate Change Adaptation** **Link**: http://www.naturalresources.sa.gov.au/eyrepeninsula/projects-and-partners/climate-change **Description:** An example of the application of a pathways approach to build a regional adaptation plan in South Australia.	**Authors:** Siebentritt et al. **Agency**: EPICCA **Year**: 2014
Multi-criteria analysis	**A multi-criteria analysis of coastal adaptation options for local government** **Link**: http://www.sydneycoastalcouncils.com.au/sites/default/files/MCA_of_Coastal_Adaptation_Options_for_Local_Government.pdf **Description:** This report provides a practical example of how to undertake a multi-criteria analysis of coastal adaptation options. It analyses the performance of 15 illustrative adaptation options against 16 criteria spanning governance, financial, social and environmental dimensions.	**Authors:** Preston **Agency:** Sydney Coastal Councils Group **Year:** 2013
Case studies	**Case studies of climate change adaptation tools and application processes used by local government practitioners** **Link**: https://www.nccarf.edu.au/settlements-infrastructure/sites/www.nccarf.edu.au.settlements-infrastructure/files/ACCARNSI_CASE_STUDIES_PORTFOLIO_May2012_Final_0.pdf **Description:** A total of 18 case studies from councils and regional organisations across the states and territories are described. In addition, synopses of adaptation tools and processes commonly used in Victoria, Western Australia, South Australia and New South Wales are outlined.	**Authors:** Booth and Cox **Agency:** NCCARF **Year:** 2012

7 Take action

This step is about implementing your selected adaptation options. There are no specific guides to implementing adaptation actions. Information you are likely to be looking for includes identifying when actions need to be taken and how, thinking about funding mechanisms, assessing how much community buy-in is needed in order to act and learning how to build partnerships (e.g. public–private, regional, research and community). In planning and putting into practice your adaptation actions, you may encounter a number of barriers and look for ideas to overcome these.

A barrier is any type of challenge or constraint that can slow or halt progress on adaptation but that can be overcome with concerted effort. Common barriers include:

- a lack of understanding or knowledge about climate science
- organisational barriers (e.g. lack of funds, organisational culture, lack of leadership)
- lack of capacity (e.g. financial, technical, human resources)
- uncertainty around risks
- limited information
- limited financial resources
- regulatory and institutional frameworks
- legal uncertainty
- lack of organisational buy-in
- community context.

A variety of solutions are needed to overcome these barriers, including good communication and engagement, development of appropriate governance structures, new financial models and development of new information.

To help implement your adaptation actions, you may find it useful to look at examples of coastal adaptation practice by others.

Key resources

Case study collections	**CoastAdapt case studies** **Link**: https://coastadapt.com.au/case-studies **Description**: Within CoastAdapt there are a broad selection of case studies (both long and short) that illustrate many examples of adaptation planning, thinking, decision making and actions.
	NCCARF adaptation good practice case studies **Link**: http://www.nccarf.edu.au/localgov/map/list?type[0]=case_study&field_state_tid=All **Description**: Assembled as part of the Adaptation Good Practice (AGP) project, the collection of sixteen case studies is designed to help practitioners learn from the experience of others. It was designed to provide tangible, practical, real-life examples of adaptation processes or activities that could be used to leverage or model practices in other jurisdictions or organisations.
	The Australian Centre of Excellence for Local Government Climate adaptation manual for local government: Embedding resilience to climate change – Volume 2 case studies **Link:** https://opus.lib.uts.edu.au/handle/10453/42120 **Description:** A collection of case studies designed to assist councils embed climate risk planning into council business.

8 Monitor and evaluate

All adaptation frameworks and processes stress the importance of monitoring and evaluation for adaptation. This might be considered in two ways: firstly, as monitoring climate and impacts to identify trigger points for adaptation action; secondly, as monitoring the effectiveness of adaptation actions themselves.

Measuring elements associated with adaptation is a core component of monitoring and evaluation. Although monitoring and evaluation are often only begun towards the end of a phase of adaptation actions, it is fundamental that it is built into the system at the outset of any adaptation planning. Elements of monitoring and evaluation include resourcing, timing (e.g. set timing and/or trigger-based timing) and determining indicators to measure.

In your monitoring, you might include questions such as, 'Are we achieving the outcomes we set out to achieve?' and 'Are our goals still appropriate, given changes in resources and the cost of actions?'

There are few guides to monitoring and evaluation for adaptation.

The Sydney City Coastal Councils Group has developed a guide, specifically for local government, which promotes the assessment of adaptation planning and adaptive capacity as well as outcomes. You should use the guide early in the planning process to help build good practice in your planning and to set up procedures and processes for monitoring and evaluation. The guide recommends developing criteria, indicators, measures and targets for each adaptation objective of a plan, and it provides a matrix for monitoring and evaluation of the plan.

If you are looking for more information, Bours et al. (2013) undertook a review of tools and approaches to monitoring and evaluation of climate change adaptation. Although the report is largely focused on development applications, the authors provide a useful analysis of the current suite of monitoring and evaluation tools and frameworks.

Key resources

Monitoring and evaluation guidelines	**A guide to monitoring and evaluating coastal adaptation (Second edition, 2014)** **Link**: http://www.sydneycoastalcouncils.com.au/sites/default/files/A-Guide-to-Monitoring-and-Evaluating-Coastal-Adaptation.pdf **Description**: Within CoastAdapt there are a broad selection of case studies (both long and short) that illustrate many examples of adaptation planning, thinking, decision making and actions.
	Monitoring and evaluation for climate change adaptation: A synthesis of tools, frameworks and approaches (Bours et al. 2013) **Link:** http://www.ukcip.org.uk/wp-content/PDFs/SEA-change-UKCIP-MandE-review.pdf **Description:** A review of tools and approaches to monitoring and evaluation of climate change adaptation. Although largely focused on development applications, they provide a useful analysis of the current suite of monitoring and evaluation tools and frameworks and challenges for the future.

9 Additional information resources

In this manual we have looked at specific data portals and information sources for a range of information related to building your adaptation plan.

There are a number of libraries and portals of general information that are relevant addressing coastal management and climate change adaptation issues. Below we list and describe a number of these information portals and libraries.

OzCoasts

An online database designed to provide comprehensive information about Australia's coasts (including its estuaries and coastal waterways). It includes several information and data sub-portals and houses a lot of information from Geoscience Australia. http://www.ozcoasts.gov.au/index.jsp

Coastal Adaptation Resources Database

Arising from a three-year CSIRO-funded coastal cluster project, the site provides links to reports and information on adaptation issues for coastal areas. http://coastaladaptationresources.org/

Coastal Research (CSIRO)

A portal for coastal research projects undertaken on Australia's coasts.
http://coastalresearch.csiro.au/

Marine Report Card

Released in 2012, the latest Marine Report Card includes a number of sections on the impacts of climate change on marine climate and biodiversity.
https://www.nccarf.edu.au/sites/default/files/attached_files_publications/Marine_Report_Card_Australia_2012.pdf

The Long Paddock

Primarily designed to support farmers, this Queensland Government website provides useful climate information for all of Australia. https://www.longpaddock.qld.gov.au/

Terra Nova

A central information hub designed for researchers in the climate adaptation research domain to deposit data, information and resources. https://terranova.org.au/

NCCARF Adaptation Library

A searchable library of research reports, information sheets and links that help support Australian decision-makers prepare and adapt to climate risks.
https://www.nccarf.edu.au/adaptation-library

CoastAdapt

An on-line decision support framework and information portal that helps support adaptation in Australia's coastal regions.

https://coastadapt.com.au/

10 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.
Adaptation pathways	An analytical approach to planning that explores and sequences a set of possible actions that are based on external developments over time.
Adaptive capacity	The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities or to respond to consequences.
Bathtub models	A type of inundation mapping – often called 'single-value surface models' – that has only two variables: the inundation level and the ground elevation.
Climate change	A change of climate that 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.
Climate models (GCMs, RCMs, CMIP)	*General circulation models* (GCMs) are numerical models that represent physical processes in the atmosphere, ocean, cryosphere and land surface that are used for simulating the response of the global climate system to increasing greenhouse gas concentrations. *Regional climate models* (RCMs) are climate models of higher spatial resolution than GCMs. *Coupled Model Intercomparison Project* (CMIP) promotes a standard set of model simulations.
Climate projection	A climate projection is the simulated response of the climate system to a scenario of future emissions or concentration of greenhouse gases and aerosols, generally derived using climate models. Climate projections are distinguished from climate predictions by their dependence on the emission/concentration/radiative-forcing scenario used, which is in turn based on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realised.
Coast	We have an integrated definition of the coast for the purposes of this project. The coast encompasses the area from the upper coastal catchments to the near-shore environment. Our definition includes offshore ecosystems, such as coral reefs and islands, and inland areas that have a direct effect on the coast.
Climate scenarios	A plausible and often simplified representation of the future climate. Representative Concentration Pathways (RCPs) are greenhouse gas concentration trajectories adopted by the IPCC in the fifth assessment. They are used for making projections based on four different twenty-first century pathways of greenhouse gas emissions. The RCPs include a stringent mitigation scenario (RCP2.6), two intermediate scenarios (RCP4.5 and RCP6.0) and one scenario with very high greenhouse gas emissions (RCP8.5).

Downscaling	Downscaling climate data is a strategy for generating locally or regionally (10 to 100 km) scaled data from larger General Circulation Models (GCMs). There are two main methods for downscaling climate projections: dynamical and statistical downscaling. ***Dynamical downscaling*** uses fine resolution climate models (often using regional models – RCMs) to generate projections. They use the same physical process as GCMs but with finer resolution. They are potentially useful in areas with complex topography (e.g. mountains). ***Statistical downscaling*** involves applying observed statistical relationships (between large-scale and local climate) to large-scale changes in climate simulated by models, in order to estimate changes at local scales.
Maladaptation (Maladaptive actions)	Actions that may lead to increased risk of adverse climate-related outcomes, increased vulnerability to climate change or diminished welfare, now or in the future.
Resilience	The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure, while also maintaining the adaptive capacity for adaptation, learning and transformation.
Risk assessment	A systematic process of evaluating the potential risks that may be involved in a projected activity or undertaking.
Social capital	Links, shared values and understandings in society that enable individuals and groups to trust each other and so work together.
Uncertainty	A state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from imprecision in the data to ambiguously defined concepts or terminology or uncertain projections of human behaviour.
Vulnerability	The degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.

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