

PROJECT REPORT

Climate Change Adaptation Guidelines

February 2016

WSA 303 – 2016-v1.2



WATER SERVICES
ASSOCIATION OF AUSTRALIA

Overview of WSAA

WSAA is the industry body that supports the Australian Urban Water Industry

WSAA members provide water and wastewater services to over 20 million Australians and many of Australia's largest industrial and commercial enterprises.

The Association facilitates collaboration, knowledge sharing, networking and cooperation within the urban water industry. It is proud of the collegiate attitude of its members, which has led to industry-wide approaches to national water issues.

WSAA can demonstrate success in the standardisation of industry performance monitoring and benchmarking, as well as many research outcomes of national significance. The Executive of the Association retains strong links with policy-makers and legislative bodies and their influencers, to monitor emerging issues of importance to the urban water industry. WSAA is regularly consulted and its advice sought by decision makers when developing strategic directions for the water industry.

Disclaimer

This Report is issued by the Water Services Association of Australia Limited on the understanding that The Water Services Association of Australia Limited and individual contributors are not responsible for the results of any action taken on the basis of information in this Report, nor for any errors or omissions.

Copyright

This document is copyrighted. Apart from any use as permitted under the Copyright Act 1968, no part of this document may be reproduced or transmitted in any form or by any means, electronically or mechanical, for any purpose, without the express written permission of the Water Services Association of Australia Limited.

© Water Services Association of Australia Limited, 2015

ALL RIGHTS RESERVED

ISBN 1 920760 70 9

First version 1.1 published November 2015.

Second version 1.2 published February 2016.

Table of Contents

Overview of WSAA 2

I.	A message from the project delivery team	5
II.	Acknowledgements	6
III.	About these guidelines	8
1.	Prepare and Commit	13
	Key messages	13
1.1	Understand regulatory drivers and barriers to adaptation	13
1.2	Gain internal support and set direction	14
1.3	Integrate adaptation considerations into governance structure	15
1.4	Define robust decision-making processes	15
1.5	Understand core functions and interdependencies	16
1.6	Source tools, documents and climate science inputs	16
1.7	Allocate resources and consider funding options	17
2.	Assess	19
	Key messages	19
2.1	Undertake scenario planning	19
2.2	Undertake vulnerability assessment across core functions	20
2.3	Decide priority areas	21
2.4	Undertake detailed risk assessment	22
3.	Plan and Respond	24
	Key messages	24
3.1	Develop adaptation options...	24
3.2	Evaluate and prioritise adaptation options	25
3.3	Document adaptation options	26
4.	Embed	28
	Key messages	28
4.1	Determine roles, responsibilities and Measures of Success	28
4.2	Embed adaptation options into investment decisions and relevant business planning frameworks and plans	29
5.	Monitor and Review	31
	Key messages	31
5.1	Monitor and assess changes and revise adaption options as required	31
5.2	Analyse events and review risks and adaptation options	32
5.3	Review adaptation approach	32
	Appendix A Guidance for core functions	35
1.	Source waters and demand ...	36
2.	Built assets	42
3.	Natural environment	48
4.	People and workplace	53
5.	Interdependencies	59
6.	Customer and product delivery	65
	Appendix B Climate data sources, key tools and references	68
	Appendix C Stakeholder engagement	73
	Appendix D Scenario planning, vulnerability assessment and risk assessment	74
	Appendix E Categories of adaptation options and maladaptation	80
	Appendix F Logic and Approach	82
	Appendix G Glossary	88

List of figures

Figure 1: Climate change adaptation decision-framework within a water utility	9
Figure D-1: Risk management process adapted from AS 5534-2013	79

List of tables

Table A-1 Vulnerabilities of source waters to climate change	37
Table A-2: General climate change trends for source waters	38
Table A-3: Detailed modelling of sensitivities for source waters	39
Table A-4: Example adaptive responses for source waters	40
Table A-5: Vulnerabilities of built assets to climate change	43
Table A-6: General climate change trends for built assets	44
Table A-7: Detailed modelling of sensitivities for built assets	45
Table A-8: Example adaptive responses for built assets	46
Table A-9: Vulnerability of natural environment to climate change	49
Table A-10: General climate change trends for the natural environment	50
Table A-11: Detailed modelling of sensitivities for the natural environment	51
Table A-12: Example adaptive responses for the natural environment	51
Table A-13: Vulnerabilities of people and workplace to climate change	54
Table A-14: General climate change trends for people and workplace	55
Table A-15: Interdependencies to consider	56
Table A-16: Example adaptive responses for people and workplace	57
Table A-17: Vulnerabilities to climate change due to interdependencies	60
Table A-18: Examples of general climate change trends and their effect on interdependencies	61
Table A-19: Examples of stakeholder roles in climate change adaptation and event response	61
Table A-20: Vulnerabilities to customer and product delivery	65
Table A-21: Questions to assess sensitivities of customers to climate change	66
Table A-22: Adaptive responses for customer and product delivery	66
Table B-1 Climate data sources	68
Table B-2: Key tools, documents and references	71
Table C-1: Possible objectives of stakeholder communication during the adaptation planning process	73
Table D-1: Resources for scenario planning	74
Table E-1: Categories of adaptation options	80
Table E-2: Characteristics of maladaptation and possible impacts of major water infrastructure projects	81

I. A message from the project delivery team

Humanity will need to act decisively now if the global average temperature rise is to be contained within the 2°C limit agreed to by world governments in Paris. This landmark agreement furthermore called for substantial action to adapt to climate change. Australian and New Zealand water utilities have already had to adapt to harsh changes in their operating environment – from running out of water, to floods, power outages and other disruptions. These disruptions may or may not be linked to climate change, but they are an indication of things to come.

Adaptation to the extreme climate and weather events experienced in Australia and New Zealand has already cost the urban water industry millions of dollars. In some cases, the responses of governments and water utilities to these events have been heavily criticised.

Water utilities can expect the challenges associated with climate change – protecting assets and providing consistency and quality of service – to increase in both frequency and magnitude as warming progresses. Utilities will have to cope with events not previously experienced. It is clear that the past is not a reliable indicator of the future as the probability of extreme events is rapidly changing, making conventional approaches to the estimation risks unreliable. This causes a serious problem for water industry planners and decision-makers.

These guidelines are the urban water industry's first attempt to systematically address these dilemmas, and to alert water utility planners and decision-makers of the need to take climate change adaptation seriously. While the importance of mitigation cannot be understated, the guidelines only focus on adaptation.

Effective leadership from senior management is important in preparing water utilities to respond to the impacts of climate change. Boards and senior executives of water utilities must be prepared to respond in a timely manner to the probable material risks to the businesses they run. It will also be important for water utilities to proactively engage with the community. The key measures of success for water utilities will be continuity of services, building a shared understanding of the issues, and community and political acceptance of the difficult decisions required.

While we have called these 'adaptation' guidelines, we are aiming for a paradigm shift to transformative decision-making. These guidelines should assist water utilities in a systematic, consistent and coordinated approach to addressing climate adaptation dilemmas. We look forward to their widespread adoption into decision-making in urban water utilities around Australia and New Zealand and of course to their progressive improvement over time. We commend these guidelines to you.

The Project Delivery Team

II. Acknowledgements

We acknowledge and appreciate the work and guidance from the project delivery team. Original members included Eleanor McKeough (Melbourne Water, lead), Nicola Nelson (Sydney Water, co-lead), Bob Humphries and Michael Scott (Water Corporation), Alesky Bogusiak (Coliban Water), Greg Greene (WaterNSW), Michael Bartkow (Seqwater) and Jennifer Bartle-Smith (WSAA). Unfortunately, some people in the original team were unable to see the project through to completion because of organisational changes. We also acknowledge and appreciate the input from the following WSAA members who stepped in to fill the gaps - Melita Stevens (Melbourne Water) and Christine Turner (Sydney Water). Bob Humphries continued to participate as a consultant after June 2015.

Utility contributors who made this project possible include:

- ▶ City West Water
- ▶ Coliban Water
- ▶ East Gippsland Water
- ▶ Gippsland Water
- ▶ Gladstone Area Water Board
- ▶ Hunter Water
- ▶ Icon Water
- ▶ Melbourne Water
- ▶ Queensland Urban Utilities
- ▶ SA Water
- ▶ Seqwater
- ▶ South East Water
- ▶ Sydney Water
- ▶ Unitywater
- ▶ Watercare (NZ)
- ▶ Water Corporation (WA)
- ▶ Water NSW

EY developed the guidelines in consultation with the water industry, with support from GHD who provided additional water industry expertise and assisted in the consultation process.

The logic and approach of these Climate Adaptation Guidelines has been strongly influenced by the important paper by Stafford Smith, Horrocks, Harvey and Hamilton *'Rethinking adaptation for a 4°C world'* (2011). See [Appendix F](#) for an overview of this paper.

III. About these guidelines

Purpose

The purpose of these guidelines is to provide the Australian and New Zealand water industry with consistent, clear and authoritative guidance in building climate resilience across all aspects of the water utility business. The guidelines draw upon the experience of the water industry, identify current best practice and provide clear principles to guide the industry forward in a pragmatic and defensible approach to adaptation.

These guidelines are designed to help water utilities with all stages of the adaptation process, from initial appreciation of the issues, through to the implementation, monitoring and improvement of response actions. While these guidelines do not attempt to analyse the science, they do recognise that the impact of climate change will vary significantly from region to region across Australia and New Zealand. For those utilities approaching the issue for the first time, the guidelines will help lay the foundation for a structured organisational strategy and response. Conversely, for those utilities that have appraised their climate risks and are implementing adaptation actions, the guidelines can provide a benchmark for best practice and can facilitate continuous improvement.

These guidelines are informed by the risk management process of AS 5534-2013 *Climate Change Adaptation for settlements and infrastructure - a risk based approach*. They are deliberately non-prescriptive in the core of the document so as to remain easily adaptable to different situations, although they do provide principles to help to achieve a level of consistency across the industry.

Intended audience

Water utilities are the primary audience of these guidelines. As climate change will affect most aspects of a water utility's business, the use of these guidelines is not limited to any specific departments within a water utility. Similarly, it is expected that water industry stakeholders, other industry groups, governments and contractors will be interested in these guidelines.

Structure

For ease of use, these guidelines are structured to allow the reader to examine specific sections as needed, or to be followed in totality. It is acknowledged that adaptation is not a linear process and the support and direction provided in the guidelines should be used on this basis.

Figure 1 provides a graphical representation of climate change adaptation within a water utility and sets the framework for these guidelines.

The guidelines outline three stages, for the major stages of climate change adaptation: 'getting ready', 'adapting' and 'keeping it current.' Within these stages, there are five sections which address the preparation and commitment, assessment, planning, implementation and monitoring of adaptation. Each section begins with major underlying principles and information, before presenting key actions and decisions that need to be made.

The appendices provide further guidance on how to implement elements of the guidelines in the core functional areas of water utilities. They also provide further information and tools for key activities including risk assessments, vulnerability assessments and scenario planning.

Stakeholder engagement is intrinsic to all stages of climate change adaptation (as shown in [Figure 1](#)). Within each section of the guidelines stakeholder engagement is not explicitly highlighted – it is more an expected result of gathering information, knowledge and feedback, and implementation. Water utilities have a number of support mechanisms internally and deep experience in engaging their stakeholders. [Appendix C](#) highlights how different levels of engagement might be used in adaptation planning.

Climate change adaptation decision framework

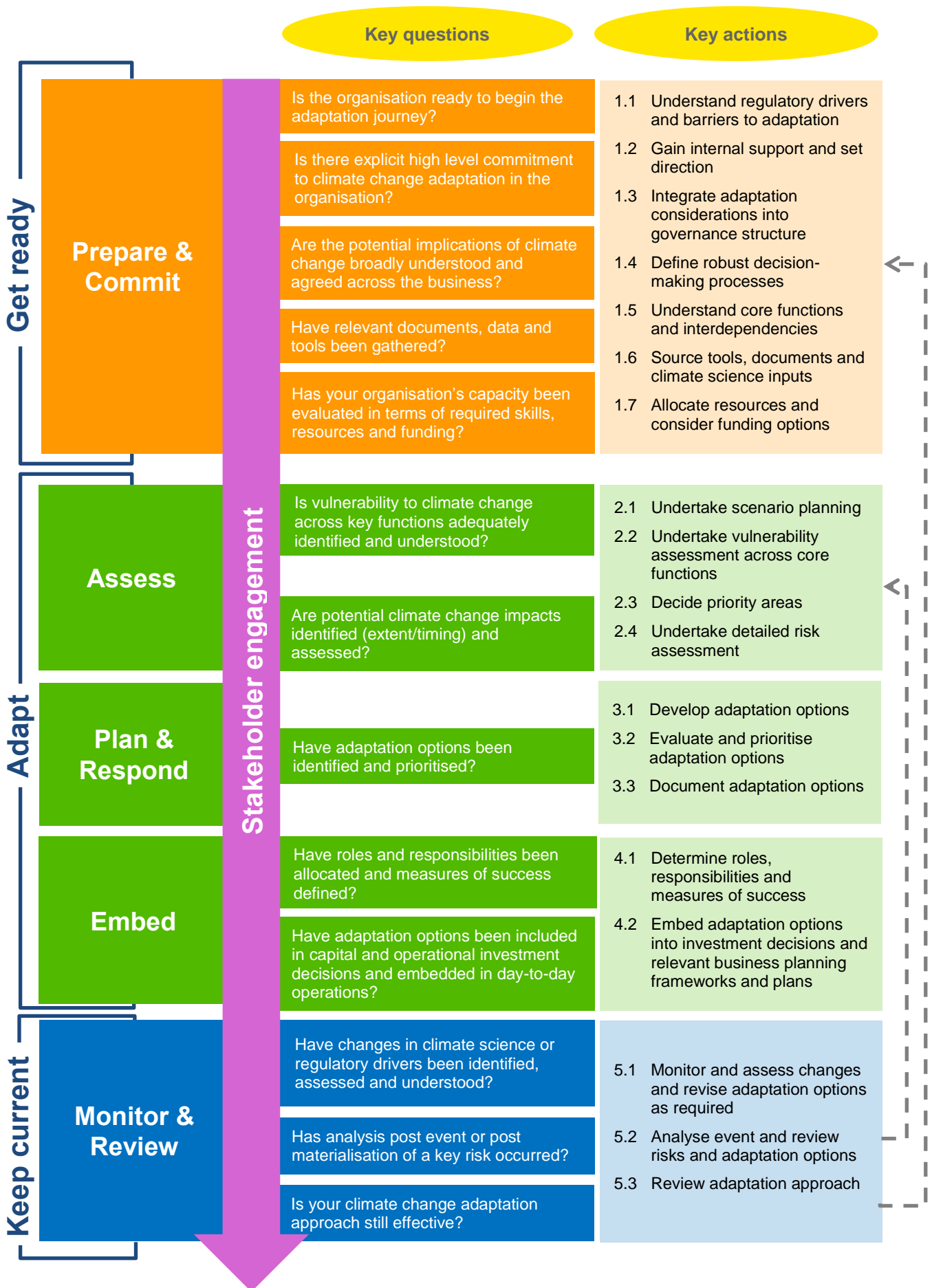


Figure 1: Climate change adaptation decision-framework within a water utility

Get ready

1. Prepare and Commit

Key messages

- ▶ Barriers to adaptation need to be understood so that they can be addressed as part of a comprehensive adaptation strategy.
- ▶ Support for adaptation planning from the Executive and Board of Directors is crucial.
- ▶ Readiness of an organisation is reliant on support from all business areas.
- ▶ Strong governance around climate change will ensure that commitment and momentum are not lost over time.
- ▶ Stakeholder engagement (internal and external) is a critical delivery tool for successful adaptation.
- ▶ Keep climate science knowledge current and use the range of tools and reference materials available.
- ▶ Climate change presents ‘known unknowns’ that require action i.e. decision-making processes need to be able to respond to uncertainty.

This section is about setting a solid foundation for your organisation to adapt to climate change, through preparing and committing to action. It outlines how to identify regulatory drivers and barriers to adaptation inside and outside the water utility. It then outlines the key steps to gain senior managers’ and executive support, discusses organisational structure and governance principles, and emphasises how the uncertainty of climate needs to be factored into the decision-making process. The section then covers how to prime your organisation to commit to climate change adaptation through examination of its core functions and information, skills, resources and funding options.

This section covers the **key actions** required to address the following **key questions**:

- ▶ Is the organisation ready to begin the adaptation journey?
- ▶ Is there explicit high-level commitment to climate change adaptation in the organisation?
- ▶ Are the potential implications of climate change broadly understood and agreed across the business?
- ▶ Have relevant documents, data and tools been gathered?
- ▶ Has your organisation’s capability been evaluated in terms of required skills, resources and funding?

Further detailed support can be found in the Appendices, particularly [Appendix B: Climate data sources](#), key tools and references, [Appendix C: Stakeholder engagement](#) and [Appendix A-4: People and workplace](#).

1.1 Understand regulatory drivers and barriers to adaptation

To understand regulatory drivers and barriers to adaptation, you need to review:

- ▶ the external regulatory environment, including state and federal policy and legislation
- ▶ barriers to adaptation both within your own organisation and the external environment.

These barriers may include:

- ▶ the nature of climate change as a ‘wicked problem’– complex, cross-cutting, and with no easy solutions (see APSC, 2007)
- ▶ the tendency to push back, or deprioritise, adaptation actions because of their long timeframes
- ▶ impediments to working together such as siloed working practices and poor communication
- ▶ budgetary and capacity constraints.

Many barriers will be able to be addressed within your organisation; however, others will require external engagement and support. For example, advocating to regulators may be necessary to move towards a regulatory environment that supports adaptation. The Productivity Commission (2012) provides a broader discussion on barriers to adaptation (refer to [Appendix B](#)).

1.2 Gain internal support and set direction

Careful consideration and insight of how ‘ready’ an organisation is to adapt to climate change will assist in overcoming difficulties as you progress in your adaptation journey. Climate change is a whole of organisation issue, relevant to all business areas, not only the environment. Hence, to aid readiness and ensure whole of organisation buy-in for adaptation planning, you should have:

- ▶ support from your Board, chief executive officer and senior management that climate change is a key risk that needs addressing from a whole of business perspective
- ▶ a policy, position, strategy or direction-setting document, whether existing or new, that provides clear, transparent and ongoing commitment to adaptation planning over the longer term (see, for example, the description of WaterNSW’s Climate Adaptation Strategy in case study 1 below)
- ▶ sufficient resources both financial and non-financial – or in-principle support for provision of these resources – for coordination and input into the adaptation planning process.

Climate change adaptation needs to be embedded into key planning processes and policy documents, appropriate people and resources are critical to its success. It is important to ensure you make the best use of the knowledge and expertise within your organisation. Refer to Case study 1 regarding the implementation of a successful adaptation strategy.

As utilities differ in their internal setup, there is no one-size-fits-all solution to staffing and resourcing. However, the following checklist may help.

- ▶ Formally allocate CEO time to reviewing the implementation and success of adaptation measures.
- ▶ Appoint a champion for climate change adaptation within the board.
- ▶ Allocate responsibility for coordinating adaptation to at least one senior manager.
- ▶ Delegate responsibility within key functional areas to managers. These guidelines use the following six core functions: source waters, assets, environment, people and workplace, interdependencies, customer and product delivery (as determined in consultation with the water industry).
- ▶ Allocate staff to monitor and review progress and effectiveness of adaptation within each of the 6 core functional areas.
- ▶ Create effective internal and external communication and engagement pathways.

Expectations of staff around the adaptation planning process should be clarified, through:

- ▶ Overall internal policy statements and awareness training
- ▶ Inclusion of climate change adaptation responsibilities in position descriptions and performance contracts.

Some of these elements are detailed further in [Appendix A-4: People and workplace](#), and [Appendix C: Stakeholder engagement](#).

Case study 1: WaterNSW Climate Change Adaptation Strategy

The WaterNSW Climate Change Adaptation Strategy looks at the risks of a changing climate and its potential consequences for WaterNSW both in the short and long-term. The strategy is a succinct and directed document that provides context, a prioritised risk assessment, four key focus areas and monitoring and review requirements.

The strategy builds on existing activities and identifies priority actions across multiple business areas, and programs and responsibilities for implementing actions.

WaterNSW identified the following as priority risks:

- ▶ gaps in knowledge on climate projections
- ▶ non-optimal water quality and quantity, and intervention monitoring
- ▶ yield reliability and security
- ▶ responses to extreme events and natural disasters
- ▶ increased frequency of water quality incidents
- ▶ risks to staff and contractors.

Risk reduction responses and adaptation measures have been developed for all these priority risks, and will be incorporated into Water NSW's planning and risk management processes.

1.3 Integrate adaptation considerations into governance structure

To ensure that governance arrangements are in place:

- ▶ Review existing governance arrangements to see if adaptation planning can be integrated into the utility's governance structure.
 - If not, create a governance framework including a steering committee or internal reference group responsible for reporting to the executive or board. Make sure that representation is across the business and includes all key functional areas.
- ▶ Establish communications and engagement channels that best suit the organisation, such as intranet, webinars, blogs, fact sheets, or a regular report to the business on actions taken and by whom.
- ▶ Engage with neighbouring water and other utilities and other agencies to share knowledge and to ensure that approaches are complementary.

1.4 Define robust decision-making processes

Uncertainty is a key characteristic of climate change; a fact that no amount of investigation will alter. However, because the risks of climate change are broadly known, this creates the responsibility to address them. It is important to ensure that decision-making processes can deal with the inherent uncertainties caused by the changing climate.

Decision-making processes need to be critically analysed and changed to:

- ▶ incorporate climate change into all existing decisions, as an additional variable, rather than a discrete issue to be tackled in isolation
- ▶ integrate scenario planning, or planning for extremes, rather than just planning for 'average' conditions
- ▶ plan over multiple planning horizons, taking into account both the time when a risk will reach a critical trigger point and the time-lag required to implement effective responses
- ▶ favour flexible solutions, which may require definition of multiple pathways (see [Section 3.3](#)).

As budgetary constraints are central to long term investment decisions, it is essential to build robust business cases to justify capital and operational expenditure and bring the topic into discussions with Ministers, regulators and other key decision-makers (see [Section 1.1](#)).

1.5 Understand core functions and interdependencies

To gauge your organisation's understanding of the implications of climate change for its business, you need to:

- ▶ identify and define the core functions and associated business areas that are most likely to be adversely affected by climate change; these are termed 'systems at risk'
- ▶ identify key interdependency risks relevant to core functions, such as the continuity of power supplies and telecommunications.

This should be done in collaboration with stakeholders including your supply chain partners.

Defining core functions is the first step in identifying which areas of the water utility's business will be most critically degraded by climate change. It is also a powerful communication tool to engage external stakeholders and to identify interdependencies (that is, where there is mutual reliance between the water industry and another sector that would be adversely affected by climate change, extreme events or by adaptation actions).

The combination of the identification of core functions and understanding the climate science are preparatory steps for the vulnerability assessment described in [Section 2.2](#).

1.6 Source tools, documents and climate science inputs

There are many tools and sources of information that will assist in your preparation for adaptation and decision-making. Similarly, sound and up-to-date climate science is a critical input for undertaking vulnerability assessments. Water utilities should:

- ▶ understand the characteristics of the climate zone in which they operate
- ▶ identify the most reliable and up-to-date information available for this climatic zone
- ▶ obtain access to tools for climate change adaptation, and resources and advice from other utilities and organisations, especially leaders in climate change adaptation
- ▶ document information sources and ensure that a robust monitoring system for updates is in place, recognising that the currently available information will become less relevant or obsolete, and change over shorter timeframes than we are used to-e.g. the changing estimates of what constitutes a 1:100 year flood.

More information on climate data sources is provided in [Appendix B](#). Additionally, state and territory governments, and sometimes local authorities, commission and publish specific relevant work on climate variables and their impacts. Refer also to Case study 2 for adaptation tools.

Case study 2: AdaptWater – A climate change adaptation tool (Sydney Water)

AdaptWater, an online climate change adaptation and asset-planning tool, will allow Sydney Water's Climate Change Adaptation Program to centralise its hazard mapping, identify climate change impacts, and quantify costs of adaptation approaches. This will assist the communication of the impacts and costs of climate change to a range of internal and external stakeholders.

The tool is designed to quantify the risks of climate change and extreme events, and perform cost-benefit analyses of proposed adaptation options. It can quantify the impact of climate hazards on water supply and sewerage assets, and calculate the risk to the utility in both financial and non-financial terms. As well as producing graphical representations, the tool can compare adaption options, enabling the prioritisation of options.

Sydney Water, Climate Risk and WSAA developed the AdaptWater tool in partnership with Melbourne Water, SA Water, Water Corporation, Queensland Urban Utilities and City West Water.

1.7 Allocate resources and consider funding options

Water utilities need to ensure that adequate resources are allocated and supported to deliver successful adaptation responses. Ensuring the availability of resources and funds will be a long-term consideration and will require ongoing decisions and adjustments (e.g. when identified trigger points are reached). Vital components are:

- ▶ allocation of adequate time for the coordination of the climate change adaptation activities
- ▶ allocation of adequate time for working with internal and external stakeholders, particularly those with whom collaboration is essential, e.g. power companies, local government, emergency management agencies
- ▶ building skills and capacity of staff, and ensuring succession planning
- ▶ resources for infrastructure adaptation projects
- ▶ resources for behavioural adaptation projects
- ▶ resources for monitoring climate change and the success or failure of the implementation of adaptation actions.

Some of above may not require specific budget allocations and may be absorbed in 'business as usual' activities through a reallocation of roles and priorities.

Adapt

2. Assess

Key messages

- ▶ Risk assessment processes must be adjusted to incorporate complexity, including the different levels of risk and/or uncertainty over different planning and decision horizons.
- ▶ A vulnerability assessment assists with setting key priority areas; these are further explored in detailed risk assessments.
- ▶ Consider both risks and opportunities when undertaking risk and vulnerability assessments.
- ▶ Open engagement (internally and externally) and broad collaboration will yield the best results for the assessment process.

This section of the guidelines addresses the critical task of assessing climate risks, which will set the foundation for the prioritising and planning adaptation responses. It should therefore not be seen as a one-off exercise, but one that needs to be revisited regularly and as events occur, in a process of continuous learning and improvement.

The assessment process builds on the previous section's foundation work of identifying key functions, information and interdependencies. With this work as a base, the recommended process described in this section for assessing climate risk is to:

- ▶ understand the implications of future climate scenarios
- ▶ carry out a high level vulnerability assessment to define the key climate change adaptation priority areas
- ▶ undertake detailed risk assessments, to identify and rank climate change impacts requiring a response.

This section covers the **key actions** required to address the following **key questions**:

- ▶ Is vulnerability to climate change across key functions adequately identified and understood?
- ▶ Are potential climate change impacts identified in terms of their extent and timing and are they addressed?

This section is supported by all appendices, especially [Appendix A: Guidance for core functions](#), [Appendix C: Stakeholder engagement](#) and [Appendix D: Scenario planning, risk assessment and vulnerability assessment](#).

2.1 Undertake scenario planning

Scenario¹ planning is a method to help organisations broaden their strategic thinking by envisaging plausible, but wide ranging and complex future scenarios. This method can assist in breaking the tendency of people to think only in terms of the status quo, 'average' or 'familiar' conditions and trends and to think that changes will be incremental, and small, rather than large and sudden.

¹ The Intergovernmental Panel on Climate Change (IPCC) defines a scenario as 'a plausible and often simplified description of how the future may develop, based on a coherent and internally consistent set of assumptions about driving forces and key relationships'.

Scenario planning for robust climate change adaptation must embrace complexity, requires systems thinking (i.e. understanding of interdependencies), acknowledges uncertainty and encourages the development of solutions that remain valid over a wide range of future scenarios.

To begin scenario planning:

- ▶ Review the current climate scenarios developed by expert agencies such as CSIRO and the Bureau of Meteorology (BOM).
- ▶ Ensure that all variables relevant to your core functions and supply chain partners are incorporated in the scenarios (such as population trends and water use projections, location of human settlements etc.) and that you are satisfied with the underlying assumptions of the scenarios.
- ▶ Select the most appropriate scenarios from those available, or use up-to-date climate science to create your own set if this is more appropriate.

The scenarios chosen should be examined by a panel of experts to test the underlying basis of the utility's climate change adaptation approach. Once defined, future climate scenarios should be consistently applied across the adaptation planning process, until the need to review and amend them arises.

To find out more about scenario planning (including tools to use), refer to [Appendix D](#) and Case study 3 below.

Case study 3: Scenario planning – *Water Forever* 50-year water security plan (Water Corporation)

In the mid-1990s the Water Authority of Western Australia published its 50-year water plan, *Perth's Water Future*. By the late 1990s it was clear that using historical inflow records to predict future reservoir inflows had failed. A radical re-think of the approach to water security was needed.

Under *Water Forever*, the Water Corporation abandoned the traditional approach of using historical records of rainfall and river flows to estimate the probability of future reservoir inflows. Instead, its water planners developed high, moderate and low demand projections and combined these with dry, average and wet climate futures. The three scenarios were then used to determine the mix of responses for each scenario to ensure water security for the Integrated Water Supply Scheme.

Each response is a complex mixture of demand management, de-rating of non-performing reservoirs and groundwater schemes, new water sources such as seawater desalination, indirect potable reuse of treated wastewater, and others. For more detail see: <http://www.watercorporation.com.au/-/media/files/about-us/planning-for-the-future/water-forever-50-year-plan.pdf?la=en>.

2.2 Undertake vulnerability assessment across core functions

Vulnerability assessments identify areas where the greatest potential for harm lies and define the various factors that may contribute to that harm. When undertaking vulnerability assessments, a water utility should:

- ▶ examine the 'systems at risk' that were defined in [Section 1.5](#)
- ▶ use the climate science information collected under [Section 1.6](#) as inputs
- ▶ acknowledge and incorporate interdependencies with other stakeholders
- ▶ map climate vulnerability for each system at risk by:
 - identifying exposure and sensitivity of each system to climatic events and climate change trends
 - assessing potential impacts on each system
 - taking into account the current adaptive capacity, which increases a system's resilience
 - estimating where the qualitative or quantitative threshold of unacceptable or dangerous impact or consequence might be for this particular system.

- ▶ engage openly with internal and external stakeholders so that they accept each vulnerability and its consequences
- ▶ check for vulnerabilities across systems
- ▶ identify priority areas where the potential for 'greatest harm' lies.

Appendix D provides further information on vulnerability assessments, including definitions of exposure and sensitivity, and examples of vulnerability for the six core functions used in these guidelines: source waters, built assets, natural environment, people and workplace, interdependencies, and customer and product delivery.

The importance of climate science

Most of Australia's water infrastructure was designed using short-term climate records as a base. Yet, scientific reconstructions of the eastern Australian climate over the last millennium have shown that severe droughts such as the Millennium Drought from 1997-2009 are not unusual. Indeed, past droughts may have lasted up to 40 years. Because of this, Vance et al. (2015) note that the water industry in eastern Australia needs to incorporate decadal-scale droughts as a normal feature of the hydrological cycle in their business. This also serves to emphasise that all water utilities should draw on the latest climate science for their area when undertaking vulnerability and risk assessments.

2.3 Decide priority areas

Identifying priority areas focuses the attention of a water utility on the highest risks of service delivery disruption arising from climate change. This focus on priority areas will deliver the best outcomes when undertaking detailed risk assessments (see Section 2.4 and Case study 4).

Priority areas arising from the high-level vulnerability assessment should show:

- ▶ the potential of high or unacceptable harm to the system concerned (infrastructure or people) when all impacts, including cumulative risks, are considered
- ▶ the immediacy of the risk (e.g. heatwaves will be more immediate than sea level rise).

The definition of priority areas can then feed into the detailed risk assessment process described in Section 2.4. Once priority areas are defined by a water utility in consultation with the community and other stakeholders, it should:

- ▶ issue a summary of the outcomes of the vulnerability assessment and rationale for priority areas to internal stakeholders
- ▶ obtain validation from the executive and board on these priority areas and confirm their commitment to providing subsequent resource needs
- ▶ openly communicate the results to all stakeholders.

Case study 4: 2014 Drought Risk Management Plan (Coliban Water)

Following the development of a generic drought risk management plan, Coliban Water is now developing system-specific plans for each of its nine supply systems, a central feature of which will be a vulnerability table. The following is an extract of one of the policy statements from the drought risk management plan:

Any [critical] infrastructure requirements deemed necessary to secure supplies during acute or severe raw water shortages shall be capable of being in place prior to such conditions being experienced. The objective is to minimise the lead-time needed for full implementation. The infrastructure requirements can include design work (from concept to functional and detailed design), planning and/or works approvals, and land acquisition or creation of easements. Any such infrastructure shall be included as 'business as usual' capital expenditure and form part of the corporate planning process.

While here the focus is on drought, a similar process could be undertaken for other climate risks.

2.4 Undertake detailed risk assessment

When priorities are established and validated by management, the water utility should undertake a more detailed risk assessment. The purpose of this assessment is to explore technical aspects and possible impacts on individual assets or systems critical to the delivery of the organisation's core functions.

The first step is to critically analyse the 'normal' risk assessment processes in the utility to ensure their suitability for this type of assessment:

- ▶ If the 'normal' risk management processes are driving effective decisions, they should be updated to manage climate risks and adaptation measures.
- ▶ If your risk management processes are inadequate, they should be strengthened and new, more robust systems put in place.

When it comes to managing climate change, the traditional approach of using the past behaviour of systems (for example, the observed long-term relationship between rainfall and runoff) to predict future system behaviour is not reliable and may lead to ineffective or maladaptive decisions.

The key considerations of the climate risk assessment process are:

- ▶ **Differing time horizons:** applying a single probability or consequence to a risk can lead to over-emphasising or discounting risks that vary over time - e.g. increasing sea surface temperatures lead to an increasing probability of cyclones.
- ▶ **Threshold events:** when particular thresholds are reached the behaviour of natural and human systems will change suddenly. Examples include spontaneous asset failure from excessive heat and bushfire-generated thunderstorms during heatwaves.
- ▶ **Overlapping risks:** risks arising from climate change may reinforce or increase known risks.
- ▶ **Cumulative risks:** heavy rains on catchments that have already been de-vegetated by bushfires cause dramatic effects on raw water quality in storages.
- ▶ **Interdependencies:** water utilities are part of a complex physical and social system, and the operation of critical assets depends on access to other services (including road access and the provision of electricity). It is important that other utilities and the community take account of and adapt to the effects of the same climate-related stressors.
- ▶ **Uncertainty:** risk assessment processes must be sufficiently flexible to embrace the difficulty in predicting the probability and location of a particular climate-related impact. For example, it is certain that the risk of cyclones will increase in some locations, but it is impossible to predict their frequency, their magnitude and when and where they will occur before they begin to form.

The second step is to carry out the risk assessment, which can be qualitative, semi-quantitative or quantitative. This step is not described here, as water utilities have established processes for risk assessment, but the risk assessment should engage both internal and external stakeholders. Standards that guide risk assessment are referenced in [Appendix D](#).

Case study 5: Climate change risk for water supply and demand (Gippsland Water)

Gippsland Water's 2012 Water Supply Demand Strategy incorporated a number of climate scenarios as a risk management measure and to deal with uncertainty. The strategy aims to ensure that the region's water needs can be met and managed over the next 50 years. Using the REALM suite of models and CSIRO data, Gippsland Water examined each of the region's water systems in terms of drought resilience and long term yield and demand projections. Forecasts for dry, medium and wet climates were used, and results were downscaled to a resolution aligning with Victorian River Catchments.

This process showed where there is a risk of shortfall in water supply under various scenarios. The magnitude and timing of the potential shortfalls were then considered in developing the action plan contained in the strategy. For further information, the strategy can be found at:

https://www.gippswater.com.au/application/files/5314/3831/1802/Gippsland_Water_Final_2012_WSDS.pdf.

3. Plan and Respond

Key messages

- ▶ Review the adequacy of existing processes in the planning and response to climate change
- ▶ Establish broad dialogue using the experience of staff, other utilities and knowledge from other agencies dealing with emergencies.
- ▶ Engage and collaborate with internal and external stakeholders.
- ▶ Think ‘outside the box’ and consider innovative solutions.
- ▶ Keep adaptation actions flexible.
- ▶ Beware of maladaptation and over-adaptation, and learn from previous events.
- ▶ Favour multiple pathways over fixed, rigid plans; the most cost effective, successful and efficient adaptation may be a sequence of appropriately timed actions rather than a single intervention.

This section provides an outline of how to develop, evaluate and prioritise adaptation options and actions to support a robust response to climate change for a water utility. [Appendix A](#) offers further guidance specific to core water industry functions. This section is also supported by [Appendix C: Stakeholder engagement](#), and [Appendix E: Categories of adaptation options and maladaptation](#).

This section covers the **key actions** required to address the **key question**:

- ▶ Have adaptation options been identified and prioritised?

3.1 Develop adaptation options

The development of adaptation options should aim to protect the continuity of critical service delivery and systems at risk as identified in the vulnerability and risk assessments in this section. You should encourage creativity and ‘thinking outside the box’ to ensure that cost-effective, innovative solutions are not overlooked and ensure this is supported by extensive stakeholder engagement.

To generate adaptation solutions and to secure acceptance of the adaptation options, water utilities should engage openly with internal and external stakeholders, to encourage the development of collaborative solutions amongst internal work groups and across organisational boundaries. Water utilities are familiar with these processes (see [Appendix C](#)). The following principles are particularly relevant:

- ▶ Identify solutions that address several risks at the same time, as these are likely to give ‘biggest bang for the buck’. This is why developing solutions in inter-disciplinary teams is usually helpful.
- ▶ Identify transformative solutions² as well as incremental ones (See also [Appendix F](#)).
- ▶ Favour points of intervention that reduce the vulnerability of water systems to hazards, build in resilience and enhance the capacity to recover from shocks.
- ▶ Share information with customers, politicians and others in an open and honest manner so they can understand the need for adaptation actions and the consequences for them.
- ▶ Consider different categories of adaptation actions (these are further explained in [Appendix E](#)).

² Transformative solutions are those that fundamentally change objectives or ways of doing things (Stafford Smith et al. 2011).

To build organisational capacity over time, consider developing a register of possible adaptation options. The register should be kept up to date with documentation of the current status of development and the technical, environmental, social and financial viability of each option. This can be part of the continuous improvement process and can also be turned into an industry-wide knowledge exchange and collaborative exercise.

A note on insurance:

Utilities should consider the adequacy and provisions for their insurance reserves as part of climate adaptation planning. This applies equally to those utilities that self-insure or insure externally, as the insurance industry is likely to put limitations on future events claims and/or significantly increase premiums.

3.2 Evaluate and prioritise adaptation options

Evaluate (screen) options

Once a suite of adaptation options has been developed the next step is to evaluate through a first-pass review of the viability and potential benefits or co-benefits of each adaptation option, as well as a broad consideration of expected costs (screening). Screening reduces a large number of options into a shorter list of options that justifies more detailed investigation and prioritisation.

The screening process involves the following steps:

- ▶ **Develop high-level classifications to describe each adaptation option.** Suggested classifications include:
 - no-regrets options - those with little to no cost that do not preclude other options and provide benefit under a wide range of possible climate futures, or options that address a number of issues beyond climate change
 - viable, but further development needed
 - viability unknown - further development needed
 - not viable - redesign required.
 - not viable or 'defer' (the lack of viability is most likely because of excessive costs).

The classification suggested by Stafford Smith et al. (2011) is particularly useful here See [Appendix F](#) for a summary of the paper. Classification based on orders of magnitude of implementation costs may provide an appropriate secondary filter.

Apply the classifications:

- earmark no-regrets options for implementation
- identify supplementary information or work required for other options.
- ▶ **Avoid maladaptation and over-adaptation.** Apply a 'reasonableness' check early on to ensure that the solution envisaged will not lead to maladaptation (through omission of any key elements of the risk context), or over-adaption (by considering a 'worst-case' scenario where a more flexible approach to dealing with uncertainty could be possible). Also consider the experience and lessons learnt by other water utilities and other industry sectors. Further information on maladaptation can be found in [Appendix E](#).

At the end of the screening process, 'suites' of options that logically belong together or complement each other should be able to be formed.

Prioritisation of options

Prioritising the options should be a critical analytical process that examines option robustness and effectiveness under a range of climate futures. Depending on the physical and time scale, and

budgetary implications of the decisions, a simple multi-criteria analysis may suffice or a business case may be required. The process and the assumptions adopted should be transparent and understood and supported by all involved.

Prioritising adaptation options includes:

- ▶ estimating costs, benefits and co-benefits and identifying possible funding sources
- ▶ refining the description of interactions amongst options, such as noting where one action is a prerequisite for another iterative refinement of the investigation for the best options
- ▶ iteratively refining the investigation of the best options
- ▶ developing any required cost-benefit analyses (quantitative or qualitative, but always taking into account uncertainty)
- ▶ considering other business issues and priorities
- ▶ obtaining endorsement by management.

It is important that the selected adaptation options are flexible over time to accommodate uncertainty.

3.3 Document adaptation options

Documentation of actions is critically important as it brings together all the assessment work and formalises decisions made in relation to adaptations options.

Whether in the form of an adaptation plan or otherwise, the document should:

- ▶ include flexible solutions and adaptation pathways to avoid locking the water utility into a one-track adaptation plan
- ▶ link and refer to existing key planning documents, such as assets and corporate plans and other existing business processes
- ▶ include the endorsement of any decision made in relation to climate change adaptation action by senior management and the Board.

The following is a sample structure that could be adopted for an adaptation plan (or similar):

- ▶ **Introduction:** endorsement from senior management and the Board, with a brief contextual statement of the business and how climate change affects it.
- ▶ **What are we adapting to?** A description of climate change trends, and the scenarios on which the plan is based.
- ▶ **Priority areas:** key vulnerabilities and risks identified in [Section 2 \(Assess\)](#).
- ▶ **Responses:** actions that address key vulnerabilities and risk organised by priority area or across core functions (as prioritised in [Section 3.2](#))
 - Actions will need to be detailed over specific timelines, linked to relevant triggers, with a brief rationale for the decision, and assign accountability for the implementation of actions.
 - The responses should be formalised into adaptation pathways that incorporate different actions depending on the triggers set; this is consistent with scenario planning described in [Section 2.1](#), with further resources at [Appendix D](#).
 - Extreme events provide the opportunity to learn, and should trigger the immediate review and revision of all adaptation plans
- ▶ **Governance:** covers any changes in State and Commonwealth laws, changes to international protocols, revisions as a result of extreme events and the next planned revision date for the document.
- ▶ **Appendix:** Detailed action plan, with timelines, responsibility allocations and indicative budgets.

It is useful to have a central document that presents climate-change adaptation actions, such as a specific strategy and action plan. However, as long as actions are appropriately integrated into existing plans and business processes then a separate strategy or action plan may not be necessary.

4. Embed

Key messages

- ▶ Maintain the commitment to change; in a world where climate change is the new norm this must be reflected in your organisation's ethics, processes and behaviours.
- ▶ Define roles and responsibilities to build ownership of and accountability for climate change adaptation actions within your organisation.
- ▶ Engage proactively to build 'communities of common concern' and knowledge hubs for engagement with the community and stakeholders to help gain acceptance of and support for the need for climate change adaptation and the actions needed.
- ▶ Ensure consideration of climate change is comprehensive and does not leave areas of ambiguity.

This section covers the implementation and embedding of climate change adaptation in day-to-day operations and governance processes of the water utility. To embed climate change action within an organisation it is critical to ensure that adaptation actions are adequately resourced and that roles, responsibilities and measures of success are clearly defined. Support for action on an ongoing basis will only be obtained through open and transparent engagement with stakeholders including the community.

The guidance in [Appendix A](#) for core water industry functions provides more specific support for embedding climate change adaptation into a water utility. This must also include significant stakeholder engagement as outlined in [Appendix C](#).

This section also covers the **key actions** required to address the following **key questions**:

- ▶ Have roles and responsibilities been allocated?
- ▶ Have measures of success been defined? In most cases, these could be very different from familiar measures of success.
- ▶ Have adaptation options been included in capital and operational investment decisions and embedded in day-to-day operations?

4.1 Determine roles, responsibilities and measures of success

[Section 1.7](#) discussed the need to ensure that resources are available for climate change adaptation. With their adaptation actions documented, water utilities should allocate roles and responsibilities to the staff and external stakeholders with a part to play in the implementation of the actions. Internal and external stakeholders should be engaged in this process.

Measures of success should be set to drive the ongoing implementation of climate change adaptation. Roles and responsibilities will need to be agreed and embedded into the water utility's performance and governance processes. Water utilities and the staff involved will need to consider how success can be measured. Such measures should include continuity of services, building of community confidence, and political acceptance of the inherent difficulties in adaptation decision-making. The measures of success need to be:

- ▶ measurable– this may include qualitative assessment of outcomes
- ▶ reviewed on a regular basis given the inherent uncertainties with climate change
- ▶ aligned with community goals; for example that they want to know that their water utility is taking climate change properly into account
- ▶ documented and embedded into the organisation's governance structure.

It is important to document existing governance arrangements in an appendix to the adaptation plan (or alternative document) to facilitate review should these change.

Since climate change adaptation is a long-term commitment, water utilities should consider succession planning to ensure skills, knowledge and capability are transferred to others as staff and stakeholders change.

4.2 Embed adaptation options into investment decisions and relevant business planning frameworks and plans

The most cost-effective way of adapting to climate change is to integrate the consideration of climate change into all decision-making processes of the utility. In this way, decisions are made in the context of a changing climate rather than making isolated and additional decisions on climate change (which could lead to maladaptation or over-adaptation).

There is no single formula on how best to embed climate change into decision-making processes. Each water utility will need to determine the best path for it. Key points to cover include:

- ▶ **Seek support from executive management:** This has been addressed in [Section 1 Prepare and Commit](#) and is similarly essential for embedding climate change in the fabric of an organisation.
- ▶ **Include in planning and policy documents:** Water utilities are highly structured and governance-driven organisations and embedding climate change considerations in every planning and policy document is essential.
- ▶ **Use key data and modelling:** The datasets used for the key modelling studies undertaken by a water utility, as well as professional standards such as engineering design guidelines, should consider future climate scenarios.
- ▶ **Engage with decision-makers early:** A specific section has been dedicated on decision-making under uncertainty in [Section 2 Assess](#). Engaging with decision makers early and making sure climate change is front of mind is a good 'catch all' strategy. Conversely, changing minds of critical decision-makers too late in the decision-making process can be difficult, and may even fail.
- ▶ **Demonstrate and share knowledge:** The merits of non-infrastructure based, flexible solutions need to be recognised and demonstrated through case studies or direct sharing of experience, so that staff and others can progressively build confidence and capacity in innovative thinking.
- ▶ **Advocate externally:** As noted in [Section 1 Prepare and Commit](#), engagement with external stakeholders such as regulators and politicians may be important to overcome some regulatory, social or financial barriers.
- ▶ **Educate and build capacity:** Assistance is sometimes required so that people feel confident in doing things differently.
- ▶ **Engage and communicate:** Change management requires communication, internally and externally, to avoid misunderstandings and to ensure stakeholders are aware of their own responsibilities in preparing for climate change.

At the budgeting stage, the same innovative thinking that was needed for developing climate change adaptation responses should apply. For example, it may be possible to find solutions that address climate change risks and other service delivery issues at the same time, and for minimum budgetary outlay. This may require grouping projects or 'piggy-backing' on some planned work (Office of Water, 2014).

Keep current

5. Monitor and Review

Key messages

- ▶ It is important to monitor:
 - climate science as it changes, changing risk management practices and the relevant experiences of other organisations
 - key ‘warning’ thresholds specific to your utility operations and regional climatic conditions
 - regulatory, policy and governance changes.
- ▶ Adaptation is an ongoing, ever-evolving process; reviews must be as frequent as necessary, including after extreme events.
- ▶ The best pathway today might not be optimal in the future.
- ▶ Collaboration and learning from industry experience will improve future outcomes.

This section outlines the important role that monitoring and review play in climate change adaptation. Monitoring and review help to identify when key trigger points are approaching, to measure overall planning or adaptation success, and to provide a benchmark for assessing the effectiveness of actions. [Appendix A](#) provides more specific support for monitoring and review within some core water industry functions.

This section covers the **key actions** to undertake to address the following **key questions**:

- ▶ Have changes in climate science or regulatory drivers been identified, assessed and understood?
- ▶ Has analysis post-event or post-materialisation of a key risk occurred?
- ▶ Is your climate change adaptation approach still effective?

5.1 Monitor and assess changes and revise adaption options as required

Monitoring is fundamental to assess changes in the environment and risk context and trigger the review of adaptation options. Monitoring helps tackle the uncertainty inherent in climate change impact by putting in place warning systems that will indicate when alternative actions are required or when expected climate trajectories do not eventuate.

Examples of changes that may be triggered by the monitoring process include:

- ▶ **Sea level rise:** A ‘retreat’ decision for coastal assets may be needed once the rate of sea level rise accelerates, or when a particular threshold sea level is reached.
- ▶ **Drought and population:** A dual trend of population increase and increase in likelihood of drought may trigger a decision to augment the water supply.
- ▶ **Aquifer recharge rates and state of key systems:** Indicators such as groundwater levels and salinity in extraction bores may trigger decisions to switch to other supply options.
- ▶ **Changing ecology and rising temperatures:** The changing ecology of a reservoir, combined with a rise in average temperatures can trigger adverse water quality incidents.

Water utilities therefore need to:

- ▶ define key variables that need to be monitored (if not defined as part of the planning process)
- ▶ keep abreast of:
 - changes in climate science, including new projections based on improved climate modelling (see the information sources listed in [Appendix B](#))
 - changes in regulatory and policy drivers

- published and unpublished work relevant to climate change adaptation (e.g. revision of the Australian Rainfall and Runoff Guidelines)
- experiences and lessons learnt, including maladaptation and over-adaptation, by other water utilities and by other industry sectors.

Water utilities can maximise their ability to capture such information by:

- ▶ keeping key sources of information up-to-date in a formal database under the responsibility of a staff member and encouraging all staff to locate and share new information
- ▶ collaborating with other water utilities and other stakeholders who may be monitoring the same information and measures of success, thereby reducing cost.

To ensure good governance, reporting on the progress of adaptation measures should be provided at least annually to the board, and whenever a significant climate-related event occurs (for example an extended dry period or severe power outages caused by storms). Regular reporting to the executive is also essential.

5.2 Analyse events and review risks and adaptation options

A structured, periodic review process should lead to ongoing improvement of adaptation plans and actions. However the effectiveness of some adaptation actions will only be able to be gauged when an extreme climatic event occurs. An extreme event should trigger a review of the risks and the adequacy of adaptation approaches adopted. The following actions should be useful in any review:

- ▶ When extreme climate events occur, community members, outside experts and utility staff should be brought together as a panel to identify weaknesses in the climate adaptation responses in place and to recommend improvements. It is wise to establish membership of such groups in advance as part of the utility's adaptation approach.
- ▶ Information from other regions or countries on the success or failure of adaptation responses across a range of utilities will provide valuable insights to inform the panel above.
- ▶ An extreme event is likely to trigger the need for development of new scenarios; the panel of experts should review these scenarios and the 'warning' thresholds for action (see Section 2.1).

The crossing of 'warning' thresholds should also trigger partial or full reviews of the adequacy of the adaptation actions in place using the mechanisms above.

After each review, all essential documentation, particularly the risk register and adaptation options or plans, should be updated.

5.3 Review adaptation approach

Water utilities will need to periodically review climate risk and the adequacy and performance of adaptation actions. This is because of the long timeframes involved and the risk of losing track of the importance of various priority actions.

A formal review of climate change adaptation actions should take place at least annually, and after any extreme event. The outcomes of reviews should be reported formally to senior management with recommendations for corrective actions, followed by the updating of all essential documents.

The scope of the review should address the following questions:

- ▶ **Is the climate adaptation plan being effectively implemented?** The priority placed on implementing adaptation actions may 'slip' or funding may be reallocated because of the discounting of the importance and significance of climate change and because funding and political priorities change. It is important to identify such instances and assess the impact this may have on the overall implementation of the broader adaptation plan (Turner et.al, 2014).

- ▶ **Are the climate adaptation actions in place being successful?** The measures of success may be simple, for example hectares revegetated to a benchmarked density and diversity within the past 12 months, or complex – for example continuity of services during and after a major event, where lots of elements need to operate together to achieve the desired result. Note that a narrow focus on conventional measures of success is unlikely to be successful in the climate change space.

When planned actions are not implemented, governance arrangements and the organisational commitment to climate change adaptation should be revisited. When actions have failed to produce the expected benefit, the reasons for the failure should be determined and corrective measures implemented wherever they are needed, up to and including board level.

It is important to remember that climate change adaptation is both a transformative and an iterative process. It is a new paradigm for making decisions within water utilities, and provides a mechanism for integrating future climate change risks into today's decisions within water utilities.

Appendices

Appendix A Guidance for core functions

The following appendix provides further information for water utilities to assist them in implementing the climate change adaptation actions within core functional areas of their business. The Appendices describe how climate change may impact on each of the core functional areas, and the particular considerations that should be taken into account by the relevant staff when planning for and responding to these impacts.

The Tables listing the vulnerabilities of the six core functions below are not comprehensive, but rather provide a starting point for water utilities to establish their own list of risks and vulnerabilities. Similarly, the climate trends listed are generic and need to be defined for the particular geographic areas of operation for each utility.

The six core functional areas detailed in these appendices were determined through consultation with the water industry. They are illustrated in Figure A-1 and listed below, with the sections of the guidelines for which additional content is provided:

1. Source waters and demand
 - ▶ Assess
 - ▶ Plan and Respond
2. Built assets
 - ▶ Assess
 - ▶ Plan and Respond
3. Natural environment
 - ▶ Assess
 - ▶ Plan and Respond
4. People and workplace
 - ▶ Assess
 - ▶ Plan and Respond
 - ▶ Embed
 - ▶ Monitor and Review
5. Interdependencies
 - ▶ Assess
 - ▶ Plan and Respond
 - ▶ Embed
 - ▶ Monitor and Review
6. Customer and product delivery
 - ▶ Assess
 - ▶ Plan and Respond
 - ▶ Embed

These core functional areas cover the breadth of operations within Australia and New Zealand.

1. Source waters and demand

Introduction

This section describes the process to assess, plan and respond to the impacts of climate change on source waters. Source waters refers to surface water, groundwater, desalination, recycled wastewater, stormwater and rainwater resources that are used to supply urban, rural and environmental water demands. This section covers climate change impacts on source water availability, quality and demand. The section on natural environment covers the environmental elements of water catchments.

Climate change can affect source water planning by:

- ▶ **Changing the average volumes available and seasonal variability of surface water (and possibly groundwater):** Reduced rainfall, higher evaporation levels, and higher runoff through harder, drier ground surfaces can reduce the long-term yield of systems. Runoff usually decreases more rapidly than the corresponding decline in rainfall.
- ▶ **Increasing the average volumes of runoff and groundwater because of increasing rainfall:** While this is not happening in southern Australia, in northern regions such as southeast Queensland and parts of coastal north and central NSW, extreme precipitation has contributed to severe flooding, service disruption and water quality problems.
- ▶ **Reducing the reliability of predictive or stochastic modelling:** This makes long-term planning more difficult, and may mean that current triggers for action are insufficiently conservative.
- ▶ **Increased environmental stress in aquatic ecosystems** from increased temperature and reduced runoff, leading to higher environmental flow requirements.
- ▶ **Increasing demand for water** because of increased temperatures, reduced rainfall and other factors such as population growth.
- ▶ **Degrading the operability of systems because of secondary effects:** For example, if water quality problems increase, this can reduce the availability of source water at a suitable quality.
- ▶ **Reducing water quality from saline intrusion** from higher king tides and sea level rise.

Assess

Do you have a documented understanding of the general climate change trends and vulnerabilities specific to your location?

Assess vulnerabilities to climate change

A number of the commonly identified vulnerabilities of source waters are presented in Table A-1.

Table A-1 Vulnerabilities of source waters to climate change

Vulnerability to climate change impacts		Climate change impacts							
Source water	Vulnerability	Sea level rise	Reduction in seasonal/annual rainfall (incl. leading to reduced stream flows)	Higher intensity rainfall events (severe storms & storm surges)	Increased temperature	Heatwaves (and extreme heat events)	Bushfires (loss of vegetation / loads of sediment, ash & organic material in runoff)	Catchment changes (vegetation cover, species and distribution)	Increased environmental water requirements
Surface water	Decreased or increased yield								
	Increased competition with environmental water								
	Quality: Increased algal blooms and pathogens								
	Quality: Increased turbidity and suspended solids								
Stormwater	Decreased or increased yield								
Rainwater	Decreased or increased yield								
Groundwater	Decreased availability: Lower groundwater tables								
	Quality: Increased salinity								
Recycled water	Quality: Increased salinity								
Desalination	Risk to assets close to coast								
All	Increased peak demands								
	Increased overall demand, including from agricultural sector								

Other key climate change risks affecting source waters may include:

- ▶ Unintended consequences of changes to water supply system operation as additional sources are brought on line and integrated into the system
- ▶ Increased demand from urban and rural customers and for environmental flows.

Review and document general trends from available information sources

The climate change trends for your specific location, to which your source waters are vulnerable, should be documented using climate data sources such as those in [Appendix B](#). Examples of general trends are described in Table A-2.

Table A-2: General climate change trends for source waters

Climate change impact	Source water vulnerability	General trend The following are examples of general trends only. Determine the actual trends in your location.
Reduction in average seasonal & annual rainfall Increased temperatures	Lower surface water yields due to reduced inflows	Seasonal rainfall is expected to decrease by 5-10%, evaporation is expected to increase by 10-20%, and inflows to water storages are expected to decrease by 20-40%, over the next 50 years. There is uncertainty in the climate change models, so both higher and lower inflows than historical could occur under different climate futures. River flows are expected to be more inconsistent, even if total flow remains similar.
Increased environmental water requirements	Lower surface water yields from increased environmental water requirements	As total streamflows decline, environmental flow requirements in key rivers are expected to increase by 25-100% to protect sensitive species.
Increased temperatures and heatwaves	Increased peak demands	Unrestricted peak demands in summer months may be 5-20% higher due to higher urban irrigation demands as a result of increased temperatures and lower rainfall; Restrictions on demands for public and private urban irrigation may not be acceptable to the community due to the need to maintain 'green infrastructure' and manage temperatures in cities (i.e. consider liveability and urban heat island mitigation).
Higher intensity rainfall	Lower surface water yields	Greater frequency of higher intensity rainfall but fewer rainfall days will result in greater spill volumes from storage reservoirs; For reservoirs and dams with dual storage and flood mitigation functions, higher peak flows will result in the need to maintain greater flood storage volumes, thus changing the operational regime.

Have you undertaken sensitivity testing to understand areas where the system is most vulnerable?

Undertake detailed systems/resource modelling to understand areas where the system is most vulnerable

Sensitivity or scenario cases to model might include:

- ▶ a worst case rainfall and temperature scenario
- ▶ a worst case demand scenario (e.g. unrestricted demand, dryer and hotter climate, lot scale rain tanks and stormwater harvesting storages empty at start of analysis period).

Questions to explore might include:

- ▶ What is the system 'failure' point? (e.g. how many very-low-flow years in a row would cause the water supply system to fail?)
- ▶ Is reaching the system failure point possible under the climate trends identified? For example, if a system previously had acceptable reliability in 99 of 100 years, and failure in 1 of 1,000 years, what change in inflows is needed to significantly alter these design objectives?
- ▶ What contingency plans do you have and how would they perform under changed circumstances? For example, are they affected by trends that are influenced by climate change?
- ▶ How will peak, daily and seasonal demands change?

Examples of the types of detailed modelling that might be required to investigate sensitivities are presented in Table A-3.

Table A-3: Detailed modelling of sensitivities for source waters

Vulnerability	Detailed modelling approach	Example
Lower surface water yields from reduced inflows, as a result of reduced seasonal and annual rainfall and increased temperatures	In detailed systems or water resource modelling historical climate data for catchment runoff, rainfall and potential evaporation can be synthetically adjusted using scaling factors, to represent predicted changes in climate for certain climate futures.	In Victoria, the <i>Guidelines Development of Water Supply Demand Strategies: Version 2</i> (Department of Sustainability and Environment, 2011) provide scaling factors for catchment runoff, rainfall and potential evaporation for use in systems modelling for each major catchment in Victoria (e.g. Werribee or Maribyrnong system). For the guidelines, modelling was undertaken to determine the changes to catchment runoff under different climate scenarios. When running a REALM model, for example, the scaling factors for catchment runoff impact the modelled streamflows, whilst the scaling factors for rainfall and potential evaporation are used to model rainfall onto and evaporative losses from storage reservoirs.
Lower rainwater harvesting and stormwater harvesting yields, because of reduced rainfall	Input climate datasets (rainfall, evaporation, evapotranspiration, etc.) to water balance models can be synthetically adjusted using scaling factors to represent predicted changes in climate for certain climate futures.	The <i>Australian Climate Futures</i> free web-tool (CSIRO and Bureau of Meteorology, 2015) provides climate change projections specifically for use in impact assessments such as water balance modelling. This includes projections for different 'averaging periods' (e.g. monthly, seasonal, annual) for a range of climate variables, including rainfall, evapotranspiration, drought, heavy rainfall (99th percentile) and extreme daily rainfall (1 in 20 year event). This tool can be used to determine the location specific climate change projections for use in your impact assessments.
Higher rainfall, more intense storms and runoff; water system disruption from floods	Use of scaling factors in models may assist, but be aware that the behaviour of catchments and waterways may change in unanticipated ways.	

Further points for consideration

Other Interactions: What are the more complex interactions with other competing actors wanting water resources? For example, irrigators may be willing to pay more to get water in the future. If climate change increases the price of food this may lead to competition with urban water needs. Recreational use of water is also an emerging competing demand to also consider.

Case study 6: NSW / ACT Regional Climate Modelling (NARClIM)

A research partnership between the NSW and ACT governments and the Climate Change Research Centre at the University of NSW was formed in 2011 to develop high resolution climate change projections for south east Australia. WaterNSW is using these projections to manage climate change impacts and inform adaptation planning and research.

NARClIM produced an ensemble of regional climate projections within three time periods: 1990 to 2009 (base case), 2020 to 2039 (near future), and 2060 to 2079 (far future). Global Climate Models were dynamically downscaled using Regional Climate Models to 10 km grids including a large area of ocean to capture offshore climate events, such as storms generated from east coast lows. Tools are being

developed using the data to calculate risk of floods, bushfires and other extreme events.

WaterNSW is using the NARCLiM projections in their water source modelling for Sydney's drinking water supplies and will also use the information to assess future water security in the Sydney Basin.

Plan and respond

Have practical and effective adaptive responses been identified?

Practical and effective adaptive responses to climate change impacts should be identified, assessed and embedded into your organisation's planning framework; from catchment to tap.

Investigate feasible responses

Examples of some impacts and possible responses are provided in Table A-4.

Table A-4: Example adaptive responses for source waters

Vulnerability	Possible adaptive responses	Example
Lower inflows leading to reduced availability of water	Implement non-climate dependent water sources to provide diversity and reliability of supply. This could include major recycling schemes that offset potable water use or seawater desalination to augment potable supply.	Cities such as Perth, Adelaide, Melbourne, Sydney and Gold Coast can now provide between 15% and 50% of their potable water from seawater desalination. The WA Water Corporation is currently trialling the injection of highly treated reclaimed wastewater into aquifers to supplement potable supply.
	Manage existing water sources to increase water resource security. Multi-source water supply systems are typically managed to balance interrelated and sometimes conflicting drivers of water security, water quality, water cost, environmental obligations, asset integrity and other factors. In some systems, it is possible to provide increased water resource security through targeted operation of the existing system (often at additional operating cost).	In East Gippsland, water is extracted from the Mitchell River when water levels are high and then injected into the Latrobe Valley Group of aquifers through an Aquifer Storage and Recovery (ASR) scheme. This water is then used to supplement the Mitchell River Water Supply System during times of lower yield thereby increasing the system reliability.
	Manage demand during droughts through water restrictions. Water restrictions have been used across Australia and New Zealand to manage demand during periods of low inflow. However, given community expectations for increased greening to assist in maintaining liveability, use of severe restrictions may be more challenging in future.	Under tightening water restrictions and public awareness campaigns, Melbourne's total water use dropped from around 410 L per person per day in 2000 to 230 L per person per day in 2010. Residential used dropped over the same period from 250 L per person per day to 150 L per person per day.

Vulnerability	Possible adaptive responses	Example
Higher peak inflows to reservoirs leading to increased flooding	<p>Provide alternative water storages and/or sources uncoupled from flood mitigation functions to maintain water supply reliability as flooding risk grows. Solutions could include:</p> <p>Where reservoirs provide both water storage and flood mitigation functions, increased frequency and severity of flooding may drive reservoir managers to increase allocated 'flood volume' thereby reducing the water resource storage allocation.</p> <p>Provision of off stream dedicated water storages or alternative sources to provide a reliable supply.</p>	Seqwater owns and operates the Wivenhoe, Somerset and North Pine dams as key parts of South Queensland's water supply network. Through optimisation studies and community consultation, Seqwater has developed integrated operating procedures for the reservoirs and their other sources (including the Gold Coast Desalination Plant and Western Corridor Recycling Scheme) which balance water supply needs whilst reducing community vulnerability to flooding.
Increased frequency and severity of bushfires leading to poor water quality and reduced yield during regrowth	Manage catchments to reduce the risk of bushfires and building flexibility / capacity into the water supply.	Canberra's Cotter River Catchment was significantly affected by bushfire in 2003. The loss of vegetation immediately following the fires increased the amount of sediment entering the water beyond the capacity of the existing Mount Stromlo Water Treatment Plant. Following the fires, Icon Water upgraded the plant and undertook significant remediation works in the lower catchment to improve water quality and to reduce bushfire risk.

Assess feasible responses (e.g. detailed modelling, options assessment, risk assessment)

The identified responses should be assessed to determine the resilience to climate change impacts that they provide. This may involve:

- ▶ detailed modelling (refer sensitivity testing above)
- ▶ application of an options assessment framework such as a multi criteria analysis or advanced cost-benefit analysis
- ▶ application of a risk assessment framework.

2. Built assets

Introduction

This section describes the process to assess, plan and respond to the impacts of climate change on planning, creating, operating, maintaining and decommissioning built assets. Built assets refers to the civil, mechanical, electrical and telemetrical infrastructure used in all classes of water supply, wastewater treatment and drainage and flood protection services (e.g. storage reservoirs, treatment plants, treatment lagoons, pump stations, pipelines, levees, retarding basins, drains and stormwater treatment wetlands).

Drivers

Climate change can affect the planning, construction, operation and maintenance of built assets by:

- ▶ Changing water quality of raw water inflows to water treatment plants from issues such as increased algal blooms, increased sediment loads and other effects.
- ▶ Driving the relocation or adaptation of assets because they are close to the coast and will be affected by sea level rise, or in positions with heightened flood levels.
- ▶ Reducing asset life or increasing operational complexity when operating assets at increased temperatures and during extreme weather. For example, extreme rainfall may lead to larger and faster inflows, inundating or isolating assets.
- ▶ Increasing frequency and length of peak demand periods during very hot days and in periods of drought.
- ▶ Changing the temperature at which biological (and to a lesser degree, chemical) reactions operate. This could affect the fundamental processes and the materials of which assets are built.
- ▶ Increasing the temperature of water and sewage in distribution and reticulation systems. This is likely to reduce disinfection residuals in water supplies and increase odour generation in sewers.
- ▶ Leading to updated design standards, new construction materials and emerging technologies that can withstand the impacts of climate change.

Assess

Do you have a documented understanding of the general climate change trends and vulnerabilities in your specific location?

Assess vulnerabilities to climate change

A number of the commonly identified vulnerabilities for different asset types in the water sector are presented in Table A-5.

Table A-5: Vulnerabilities of built assets to climate change

Vulnerability to climate change impacts										
Asset class	Asset type	Vulnerability	Sea level rise	Extreme weather events (wind, storms, rainfall, storm surge, heatwave, bushfires)	Increased temperature	Heatwaves (and extreme heat events)	Bushfires and grass fires (loss of vegetation, sediment, ash & organic material in runoff)	Catchment changes (vegetation cover, species and distribution)	Ground movement/cracking (soil drying out / stressed tree roots looking for water)	Declining waterway health
			General infrastructure	All assets	Infrastructure damage/failure					
		Power supply interruptions								
		Operational performance								
Water supply	Reservoirs	Higher peak inflows								
	Water treatment plants	Surface water quality: Increased algal blooms and pathogens								
		Surface water quality: Increased turbidity and suspended solids, pathogens								
		Groundwater quality: Increased salinity								
	Potable water transfer network	Increased chemical dosing								
		Higher peak demands								
Bursts and leaks										
Waste-water treatment	Wastewater treatment plants	Flooding								
		Wastewater quality: Increased salinity								
		Wastewater quality: Increased algal blooms								
		Stringent discharge obligations								
		Increased odours								
	Wastewater transfer network	Breaching hydraulic compliance								
		Increased inflow and infiltration								
		Corrosion of assets								
		Increased odours								
		Leaks, blockages and spills								
Drainage, flooding & storm-water	Drainage network	Corrosion of assets								
	WSUD & stormwater management	Infrastructure damage/failure								
		Stringent quality/flow obligations								

It is important to note interdependencies, such as increased algal blooms occurring during a drought in which sewage loads remain the same but water consumption reduces.

Review and document general trends from available information sources

The climate change trends for your specific location, to which your built assets are vulnerable, should be documented using climate data sources such as those in [Appendix B](#). Examples of general trends are described in Table A-6.

Table A-6: General climate change trends for built assets

Climate change impact	Asset vulnerability	General trend
Sea level rise	Sea level rise will result in flooding, permanent inundation, erosion, corrosion and operational performance failures of coastal assets.	Sea level rise is predicted to be between 0.5 m to 1.0 m over the next 50 to 100 years. This could result in: <ul style="list-style-type: none"> System performance failures, such as drainage systems not draining out to sea because of rising tail water levels, or increased inflow and infiltration to sewerage systems resulting in greater frequency sewage spills and higher salinity sewage Increased storm damage or permanent inundation of wastewater treatment plant assets commonly located close to the coast and discharging to the ocean Increase corrosion of sewerage and water supply pipes due to rising saline coastal groundwater tables.
Increased temperatures	Increased temperatures can impact the operational performance of assets.	Average temperatures are expected to increase from 2° to 4° over the next 50 to 100 years, and peak daily temperatures could increase considerably more during hot months. This may exceed the acceptable working range of temperatures for certain assets and equipment.
Higher intensity storms	Heavy rainfall, strong wind and lightning strikes risk the physical integrity and performance of built assets	Severe thunderstorms are expected to increase in frequency, and the average of extreme wind speeds is also likely to increase. This could result in physical damage to infrastructure from wind, water or fire (caused by lightning strikes). Erosion, particularly of buried assets, may also result.

Have you undertaken sensitivity testing to understand areas where built assets are most vulnerable?

Undertake detailed modelling or other analyses to understand areas where built assets are most vulnerable

Sensitivity or scenario cases to model might include:

- ▶ A worst case rainfall and temperature scenario
- ▶ A worst case sea level rise and rainfall event scenario.

Questions to explore might include:

- ▶ What is the asset 'failure' point? For example, what is the peak maximum temperature at which major pieces of equipment will fail? This is particularly critical for electrical equipment, motors, control systems and switchboards.
- ▶ Is reaching the asset failure point now credible given trends? For example, if an asset previously had acceptable reliability in 99 of 100 years, and failure in 1 of 1000 years, what change is needed to significantly alter these design objectives?
- ▶ What contingency plans do you have and how do they perform? For example, are they affected by trends that are influenced by climate change?

It is important to incorporate interdependencies, such as between built assets and peak demands. Table A-7 gives examples of the types of modelling that might be required to investigate sensitivities.

Table A-7: Detailed modelling of sensitivities for built assets

Vulnerability	Detailed modelling approach	Example
Sea level rise will result in flooding, erosion and/or permanent inundation of coastal assets.	Detailed modelling approaches may include use of 1D and 2D floodplain modelling to understand flood behaviour under climate change conditions, or coastal inundation mapping to understand the potential risks to coastal infrastructure from sea level rise and storm surge.	<p>Melbourne Water's <i>Flood Mapping Projects: Guidelines and Technical Specifications</i> take into account both sea level rise (i.e. tailwater levels) and increased rainfall intensities.</p> <p>Additionally, <i>Melbourne Water's Planning for sea level rise – Guidelines</i>, sets applicable flood levels and minimum floor levels consistent with the sea level rise planning requirements set out in the State Planning Policy Framework. These include a requirement that decision makers should plan for and manage the potential coastal impacts of climate change, including:</p> <p>Possible sea level rise of 0.8 metres by 2100, allowing for the combined effects of tides, storm surges, coastal processes and local conditions such as topography and geology when assessing risks and coastal impacts associated with climate change</p> <p>New developments in close proximity to existing development (infill), an increase of 0.2 metres over current 1 in 100 year flood levels by 2040 is used. For new greenfield developments outside town boundaries, not less than 0.8 metre sea level rise by 2100 is used.</p> <p>Additionally, The Future Coasts Program led by the Victorian State Government developed a Victorian Coastal Inundation Dataset which provides a high level assessment of the potential risks from sea level rise and storm surge at a state-wide to regional scale.</p>
Sea level rise will result in increased inflow and infiltration in sewage systems.	Hydraulic modelling can be run with different groundwater levels and design storms to test the sensitivity of the network to climate change.	<p>There are no standard approaches for modelling changes to rainfall intensities. However, to provide interim guidance, in November 2014 Engineers Australia published the <i>Australian Rainfall and Runoff Discussion Paper: An Interim Guideline for Considering Climate Change in Rainfall And Runoff</i>.</p> <p>The interim guideline notes that 'In the absence of robust research results or national guidance, a number of states and organisations have developed approaches to allow for the impacts of climate change on extreme rainfall' and documents different approaches used in NSW, Queensland, New Zealand and the United Kingdom.</p>

Plan and Respond

Have practical and effective adaptive responses been identified?

Investigate feasible responses

Examples of some impacts and possible responses are provided in Table A-8.

Table A-8: Example adaptive responses for built assets

Vulnerability	Possible adaptive responses	Example
Sea level rise leading to flooding and increased risk of storm damage to built assets	Identify critical infrastructure which is located in areas that will be flooded or have increased risk of storm damage with sea-level rise, and plan for relocation or adaptation of infrastructure	Relocation of basement level switchboards throughout Brisbane after the floods
Higher peak rainfall events leading to increased flooding of built assets	Identify critical infrastructure which is located in areas that will be flooded or have increased risk of flood damage and plan for relocation or adaptation of infrastructure	Improved emergency response approach developed in Newcastle area post flooding
Increased frequency and severity of bushfires which damage built assets	Review assets which are in areas of currently medium fire risk and determine if climate change would create a higher risk	Increased fire resistance and clear zones established around assets at risk in Canberra area post fires
Increased temperatures impacting the operational performance of electrical, mechanical or chemical processes and systems	Identify critical control systems and switchboards that are vulnerable to temperature increases, and decide whether to shade, cool or replace them	None identified yet, but new standards under consideration for specifying new assets in Queensland
	Embed new temperature standards in asset planning	None identified yet
	Review wastewater treatment plant processes to determine where increased temperature will degrade performance	The use of aeration blowers which may need air cooling on the source air
Other	Increased ground cracking and other local issues from increased temperatures and the drying of soil	Planning responses and emergency responses in Auckland

Assess feasible responses (e.g. detailed modelling, options assessment, risk assessment)

The identified responses should be assessed to determine the resilience to climate change impacts that they provide. This may involve:

- ▶ detailed modelling or other relevant analyses (refer sensitivity testing above)
- ▶ application of an options assessment framework
- ▶ application of a risk assessment or asset management framework
- ▶ ensuring water utilities work together for efficiency and effectiveness, particularly where interdependencies exist
- ▶ consideration of updated design standards, and innovative adaptive responses such as new construction materials or emerging technologies
- ▶ Including clauses in contracts and tender documentation directing built asset designers to make allowance for climate change.

Case study 7: Incorporating rainfall projections into stormwater infrastructure design

Following severe storms and flooding in the region in 2005, Tauranga City Council developed future heavy rainfall scenarios incorporating the impacts of climate change. The Council used the New Zealand Ministry for the Environment's Climate Change Effects and Impacts Assessment as a basis for its methodology. The study found many more heavy rainfall events are expected by 2055.

The findings have been fed into design criteria for new and upgraded stormwater infrastructure. Specifically, infrastructure must now be able to withstand a one-in-ten-year flood, as opposed to one-in-five-year floods previously. For more detail see: <http://www.mfe.govt.nz/sites/default/files/tauranga-city-council.pdf>.

3. Natural environment

Introduction

This section describes the process to assess, plan and respond to the impacts of climate change on the natural environment. The term 'natural environment' refers to natural assets that your organisation depends on or has responsibilities or obligations for, in respect to managing their health or condition (e.g. catchment areas, waterways, groundwater aquifers, wetlands) or managing water cycle impacts (e.g. sewage spills, licenced wastewater discharges).

Drivers

Climate change is predicted to have a range of complex interactions with the natural environment, including:

- ▶ Water supply catchments may change over time, leading to reductions in water yield and water quality
- ▶ Bushfires may affect water supply catchments more often
- ▶ Some species may be affected, leading to altered growth rates and behaviour, with potential degradation of source water quality and receiving water quality. This is particularly true for nuisance algae and cyanobacteria.
- ▶ Urban streams and waterways may be affected by changes in ecological behaviour and stream flows, and as a result may become more sensitive to other impacts
- ▶ Receiving environments may become more stressed, leading to more stringent requirements on discharges to land, air and water.

Assess

Do you have a documented understanding of the general climate change trends and vulnerabilities in your specific location?

Assess vulnerabilities to climate change

A number of the commonly identified vulnerabilities for different elements in the water sector are presented in Table A-9.

Table A-9: Vulnerability of natural environment to climate change

Vulnerability to climate change impacts		Climate change impacts							
Elements of or impacts to the natural environment	Vulnerability	Reduction in seasonal and annual rainfall (incl. leading to reduced streamflows)	Increased temperature	Sea level rise	Higher intensity rainfall events (severe storms & storm surges)	Heatwaves (and extreme heat events)	Bushfires (loss of vegetation / loads of sediment, ash & organic material in runoff)	Catchment changes (vegetation cover, species and distribution)	Declining waterway health
		Waterway health	Increased environmental flow requirements						
Reduced streamflows									
Peak flows									
Degraded water quality									
Seawater intrusion to coastal wetlands, estuarine waterways									
Groundwater health	Lower groundwater tables affecting groundwater dependant ecosystems								
	Seawater intrusion to coastal groundwater aquifers								
Urban stormwater runoff impacts	Reduced stormwater quality from degraded system performance								
	Erosion								
Wastewater impacts	Sewer spills to waterways								
	Wastewater treatment plant spills to bay								
	More stringent wastewater discharge obligations								

Review and document general trends from available information sources

The climate change trends (or impacts) for your specific location, to which elements of the natural environment are vulnerable, should be documented, drawing on sources of climate data such as those listed in [Appendix B](#). In addition, the latest approaches to predictive modelling of the interactions of climate change on environmental assets should be reviewed.

Examples of general trends are described in Table A-10.

Table A-10: General climate change trends for the natural environment

Climate change impact	Natural environment vulnerability	General trend
		Note: This is a complex area requiring specific local ecological science. The following are examples of the kinds of impacts that might occur.
Reduction in average seasonal and annual rainfall and Increased temperatures	Increased environmental flow requirements Waterway health	As total streamflows decline, environmental flow requirements in key rivers are expected to increase by 25-100% to protect sensitive species. Streamflow and flow into wetlands and natural water bodies may become more ephemeral and recede to pools or dry out more often, presenting a risk for fish species migration, which could decline as a result.
Higher intensity rainfall	Sewer spills to waterways; increased erosion and sedimentation	Greater frequency of higher intensity rainfall events will lead to increased inflow and infiltration to sewerage systems, leading to increased wet weather flows and more frequent and/or greater volume sewer spills, impacting local waterways.
Sea level rise		This will be compounded in low-lying areas with infiltration to sewerage systems from a rising coastal groundwater table.

Have you undertaken sensitivity testing to understand areas where environmental assets are most vulnerable?

Undertake environmental risk modelling to determine the areas of high vulnerability

Sensitivity or scenario cases to model might include:

- ▶ a worst case rainfall and temperature scenario
- ▶ worst-case increased environmental sensitivity because of the combination of climate change impacts.

Questions to explore might include:

- ▶ At what trigger point would irreversible impacts occur?
- ▶ Which elements of the environmental asset are most sensitive?
- ▶ What contingency plans do you have and how do they perform? For example, are they affected by trends that are influenced by climate change?

Table A-11 contains examples of the types of modelling that may be required to investigate sensitivities.

Table A-11: Detailed modelling of sensitivities for the natural environment

Vulnerability	Detailed modelling approach	Example
Higher intensity rainfall will result in increased inflow and infiltration in sewage systems, leading to greater frequency and/or volume sewer spills to waterways.	Hydraulic modelling run with different design storms to test the sensitivity of the network to climate change.	<p>There is no standard approach for modelling changes to rainfall intensities. However, to provide interim guidance, in November 2014 Engineers Australia published the Australian Rainfall and Runoff Discussion Paper: An Interim Guideline for Considering Climate Change in Rainfall And Runoff. The interim guideline notes different approaches used in state and international jurisdictions 'in the absence of robust research results or national guidance'. These include:</p> <ul style="list-style-type: none"> Sensitivity analyses with rainfall values for increases of 10%, 20% and 30% (NSW) 5% increase in rainfall intensity per °C of global warming (Queensland) Adjustments to rainfall for each 1 °C of global warming for different ARIs and rainfall durations (New Zealand).
Increased environmental flow requirements	Environmental water requirements are typically determined based on historical climate datasets. This approach may not be valid, particularly if reductions in available water are severe.	<p>There is no standard approach for determining environmental water requirements under future climate change. This is considered a knowledge/research gap in the industry.</p> <p>Work by the CRC for Water Sensitive Cities explores this area, and future publications should be followed.</p>

Plan and Respond

Have practical and effective adaptive responses been identified?

Investigate feasible responses

Examples of some impacts and possible responses are provided in Table A-12.

Table A-12: Example adaptive responses for the natural environment

Vulnerability	Possible adaptive responses	Example
Lower annual stream flows and higher peak flows leading to degradation of waterways, and greater variation between low and high stream flows	<p>Increased use of stormwater as a water source, to allow reduced overall withdrawal from rivers, while also reducing peak flows in local waterways</p> <p>Increased reliance on non-surface water sources to leave more water in river systems</p> <p>Increased complexity in river management to provide flow regimes that maintain ecosystems</p> <p>Use of highly treated wastewater to maintain flows in waterways</p>	<p>These concepts are being explored as part of current planning, and have not yet been implemented at a significant scale.</p> <p>Local examples include:</p> <ul style="list-style-type: none"> Lower Werribee River planning in Melbourne Brisbane River Planning in South East Queensland <p>Sydney Water's St Mary's Recycling Scheme was also designed to increase environmental flows.</p>

Vulnerability	Possible adaptive responses	Example
Higher peak rainfall events causing increased spills from sewers and bypasses around wastewater treatment plants into waterways	<p>Increased local and at-plant wet weather storage.</p> <p>Environmental consequence trades, where additional impact is offset with environmental restoration elsewhere.</p> <p>Use of alternative sewer systems such as pressure sewers</p>	Melbourne Water uses wetlands to reduce the impacts on Dandenong Creek from sewage spills from Emergency Relief Structures (ERS) on the Ringwood Branch Sewer.
Climate change stress leading to compromised ecosystems in receiving waters	<p>Increased treatment standards for wastewater discharges</p> <p>Increased large scale recycling could reduce large scale extraction but may increase risks associated with disposal of more concentrated waste</p>	These concepts are being explored as part of current planning studies, and have not yet been implemented at a significant scale

Assess feasible responses (e.g. detailed modelling, options assessment, risk assessment)

The identified responses should be assessed to determine the resilience to climate change impacts they provide. This may involve:

- ▶ environmental risk modelling (refer to sensitivity testing above)
- ▶ application of an options assessment framework
- ▶ application of a risk assessment framework.

4. People and workplace

Introduction

This section describes the process to assess, plan and respond, embed and review the impacts of climate change on water utilities' staff and workplaces. People refers to all staff members of water utilities, including those who will have a direct role in ensuring service continuity during climatic events, and in the recovery process. Workplace refers to the environment in which staff work, including offices, assets and facilities, and in the field or community.

Drivers

Climate change can affect people and workplaces by:

- ▶ Increasing incidence of illness and unplanned personal leave, including from heat stress, inability to cope psychologically and changes to disease patterns (such as tropical diseases increasing their geographical range).
- ▶ Increasing the risk of extreme weather events, including limiting staff mobility and access to assets.
- ▶ Exacerbating the risk that workplace infrastructure may pose, such as flyaway tiles during a storm, an overly hot work vehicle, or black ice on the road.
- ▶ Increasing exposure of staff to UV radiation, air pollutants and bushfire smoke.
- ▶ Causing cumulative impacts, such as increased stress and anxiety levels in staff due to their role in response and recovery to a climatic event, even if they were not affected by the event at first.
- ▶ Rendering existing emergency management systems insufficient if they cannot be scaled up to the projected increase in frequency and intensity of severe events.

Principles

People play a pivotal role in the response to climate change, and the following principles should be taken into account for all parts of this process:

- ▶ People need all the critical information required and be supported to assess and respond to the challenges of climate change.
- ▶ Engagement is vital; it creates a shared understanding of the challenges facing the organisation, builds the knowledge base, and is a means to determine and gain broad consensus for the most appropriate and viable responses.
- ▶ People need to be empowered to take action, as in any change management process; leadership from senior management and champions, training and ongoing communication is crucial.
- ▶ Sufficient resources need to be available, both for effective response and to reflect the importance of the issue.
- ▶ Psychological support to help people deal with fear, loss, injury or other traumas should be available.

Assess

Have climate change trends been assessed as part of your organisation's work health and safety risk assessment?

Assess vulnerabilities to climate change

Assessing vulnerabilities can be done as part of the organisation's routine work health and safety risk assessment process. A number of possible vulnerabilities for people and workplaces of the water sector are presented in Table A-13.

Table A-13: Vulnerabilities of people and workplace to climate change

Vulnerability to climate change impacts		Climate change impacts					
Elements of or impacts to people and workplace	Vulnerability	Higher intensity cyclones and storms (including wind and storm surges)	Increased temperature	Heatwaves (and extreme heat events)	Bushfires	Sea level rise	Higher intensity frost or snow events
Staff health	Increased incidence of illness/leave						
	Changing disease patterns						
	Stress and anxiety						
	Exposure to pollutants						
	Exposure to excess UV radiation						
Mobility and access	Staff mobility reduced						
	Access to assets lost or reduced						
Workplace infrastructure	Loosened objects						
	Unsafe workplace conditions (e.g. flooded, overheated etc.)						
	Outdoor hazards (e.g. increased activity of snakes, poisonous insects, black ice on roads)						

Review and document general trends from available information sources

The climate change trends for your specific location, to which your people and workplace are vulnerable, should be documented, drawing on sources of climate data such as those listed in [Appendix B](#). Staff should be involved to better establish the vulnerabilities they face.

Examples of general trends are described in Table A-14.

Table A-14: General climate change trends for people and workplace

Climate change impact	Staff and workplace vulnerability	General trend
Heatwaves and extreme heat events	Heatwaves and extreme heat events can detrimentally affect staff health and comfort, and reduce operational performance of critical assets.	<p>Days with maximum temperatures over 35°C are expected to increase in occurrence, and heatwaves worsen in length and intensity over the next 20 years and beyond. This could result in:</p> <ul style="list-style-type: none"> Even higher temperatures and risks in built-up areas of the workplace, due to the urban heat island effect Increased risk to staff health, particularly older or pregnant staff or staff with pre-existing health conditions, and consequent increase in unplanned leave Increased dust levels and associated respiratory problems Decreased staff comfort and efficiency System performance failures affecting staff ability to do their work, such as in the case of communication systems failure, or risking their health, such as in the case of disrupted sewerage systems Longer active hours of snakes and poisonous insects to which staff in the field may be exposed
Higher intensity storms	Wind gusts and flooding caused by storms can cause infrastructure damage and restrict access to the workplace	<p>More frequent and severe rainfall events, with associated wind gusts and lightning strikes, may:</p> <ul style="list-style-type: none"> Render existing emergency management systems insufficient due to unexpected scale of event Flood roads and workplace assets, restricting staff getting to or from work, and limiting access to flooded assets Increase the chance of landslides, limiting staff access Increase the risk of bushfires Create projectiles out of loose workplace infrastructure, endangering staff Create stress and anxiety among staff if there are difficulties in responding to the event, such as re-establishing service provision.

Do you actively engage staff around climate change awareness and climate risks in their workplace?

Staff should be involved in the risk assessment process as they are best placed to determine their particular sensitivities to climate change in the workplace. Staff engagement has the additional benefit of raising awareness of climate change risks and hence forming part of the organisation's response.

Undertake scenario planning

Scenario planning can enable people to think about work health and safety issues. Scenario cases (based on the latest science for your area as reviewed in the previous step) to discuss might include:

- ▶ a worst case heatwave and bushfire event
- ▶ a worst case storm and flooding event.

Questions to explore might include:

- ▶ What would this event mean for me personally, my colleagues and my workplace? What risks would we face?

- ▶ How would staff respond to this event? Are current plans and strategies sufficient or do they need to be adapted?
- ▶ Which interdependencies are at play? (See [Appendix A-5](#) for guidance on identifying and assessing interdependencies).

If not experienced in scenario planning, there are various online sources or third party organisations that water utilities may access, such as those listed in [Appendix D](#). It is recommended that relevant stakeholders, such as emergency management agencies, are involved in this process.

The results of assessments made in this stage should be documented both as part of work health and safety risk processes and emergency response processes, and cross-referenced in the organisation's risk registry.

Plan and Respond

Have adaptation responses considered all people and workplace issues related to climate change?

Identify and incorporate interdependencies

Interdependencies can exacerbate climate change risks to people and workplace and hamper proposed responses. Examples of people and workplace interdependencies for a water utility to consider are shown in Table A-15.

Table A-15: Interdependencies to consider

Interdependency	Importance
Communication	The single most important factor influencing people's ability to respond to emergencies is the ability to communicate with others. Ensuring that communications remain operational and that key contacts are known by all involved is critical.
Duration	The length of an emergency is an important risk factor as people become fatigued and people without specialised skills and training may be called upon, possibly increasing risks to staff and the public.
Emergency management agencies	The actions of these stakeholders during and following a climatic event will likely interact with the water utility's response. They will also have a wealth of experience that should be learnt from and drawn upon.
Other water utilities	Collaboration with other water utilities facing similar issues may reduce adaptation costs.
The public	The response of the public to climatic events such as heatwaves or floods (and any resultant disruptions in service provision) may help or hinder the water utility's response to the event and recovery following.

Are staff responsibilities in responding to climate change clearly identified?

Develop an internal engagement plan

As part of a water utility's climate change adaptation planning, roles and responsibilities of staff members, and the support that will be provided, should be clearly identified. An internal engagement plan should be developed, cognisant of climate change risks and prioritised solutions. Possible adaptation actions that could be incorporated into this plan are shown in Table A-16. Staff should be involved in assessing which responses are feasible.

Table A-16: Example adaptive responses for people and workplace

Climate risk/vulnerability	Possible adaptive response
All climate change risks	Awareness training for all staff, including clearly defining roles and responsibilities. Establish key performance indicators on managing people and workplace climate change risks for relevant areas/people within the organisation.
Heatwaves	Implementation of measures that may increase staff safety and comfort during heatwaves, which could include flexible working hours and conditions, alternative work locations, and ensuring that cooling and hydration are available.
Staff in the field more exposed to climate change risks (e.g. bushfire, flood, UV exposure etc.)	Specific training for staff members most exposed, such as those working in the field. Provision and use of personal protective equipment adequate for increased risks, both for common weather conditions (e.g. sunscreen and appropriate clothing), to extreme weather conditions (e.g. emergency equipment, satellite phones and provisions). Development of specific safeguarding processes, such as having staff in the field regularly check in during a period of climatic instability.
Extreme weather events	Adaptation of emergency management policies to ensure people and workplace safety during projected extreme events. Run exercises in disaster response using projected climate scenarios, so that people are aware of their roles and responsibilities. Involve extra staff when dealing with minor emergencies as a training opportunity for when more severe events occur.
Staff with existing health conditions more vulnerable to climate risks	Ensure staff with special requirements or who are at particular risk are known to those responsible for enacting emergency management procedures, and plans established to cater for them.

A note on emergency exercises: The importance of exercises cannot be underestimated, as theoretical training or information has been shown to have little practical value when an emergency strikes. When under stress, people are more likely to remember and act on information acquired during an exercise that builds resilience into the water utility.

Embed

Are people given the means to carry out their responsibilities?

To implement adaptation responses, water utilities will need to build capacity among their people, through provision of sufficient resources and training as outlined in the engagement plan. The leadership of senior management and champions within the organisation will be crucial to embed the engagement plan in day-to-day business.

Water utilities should also ensure that the risks to people and workplace that have been assessed are incorporated into the overall risk register and work health and safety processes, and, where appropriate, as key performance indicators for the organisation.

Monitor and review

Does the organisation track employee resilience in relation to climate change?

Staff awareness and resilience to climate change impacts can be gauged through surveys and other engagement tools. Such monitoring should identify:

- ▶ The effectiveness of actions that have been implemented, even in the absence of emergencies (through scenario training).
- ▶ Changes in workplace conditions, which may mean new or changed climate risks.
- ▶ Changes in the overall level of staff awareness and knowledge of climate change, and their roles and responsibilities (which may be caused by staff turnover).
- ▶ Changes in the sensitivities of staff to climate risks, such as changed mental or physical health or working patterns.

Feedback obtained through staff engagement should then drive a continuous improvement cycle.

Is there a plan to regularly review climate change adaptation plans, actions and key performance indicators?

The implementation of the engagement plan should be monitored to assess the effectiveness of actions, even in the absence of emergencies. Where key performance indicators have been implemented, these could be reviewed through established performance evaluation processes.

In addition, the organisation should monitor the human resources field for approaches and best practices of dealing with climate risks on people and workplace, and feed new information back to staff and into the engagement plan.

5. Interdependencies

Introduction

This section describes the process for assessing, planning and responding, embedding and reviewing interdependencies in climate change adaptation planning.

Interdependencies and climate change

Water utilities are part of a complex system, and depend on the infrastructure and services of others for their operations, just as other infrastructure and service providers depend on water utility services.

The interdependencies referred to here includes the mutual and critical dependencies that core service providers have on each other. These include the services of electricity and gas supply, water services, telecommunications, road and rail, process chemicals, fire-fighting and emergency services and others.

Other factors may also affect the water industry due to climate change, such as population movements, customers' requirements, operating costs and insurance. These are noted in the guidelines but not discussed further here.

Assess

Does your organisation have a clear understanding of its climate change exposure resulting from interdependencies?

Assess vulnerabilities to climate change

To assess vulnerabilities arising from interdependencies and climate change, water utilities should first analyse and document all service providers that support service delivery. Then, with climate change trends for the area in mind, assess how these relationships may be affected by climate change and extreme events, remembering that both parties in a relationship may be affected.

The loss of critical services, such as power and telecommunications, has been found to be among the top threats to water utilities' operations (Sydney Water, 2012), and climate change may make such events more likely. On the other hand, many other service providers rely on the water industry for their operations, and will be detrimentally affected if water services are disrupted during an extreme event or by water restrictions during drought.

As part of this process, the specific vulnerabilities of interdependencies to the impacts of climate change should be documented. A number of example vulnerabilities for water sector interdependencies are presented in Table A-17.

Table A-17: Vulnerabilities to climate change due to interdependencies

Vulnerability to climate change impacts		Climate change impacts				
Sector	Vulnerability of water sector	Stronger storms (high rainfall and wind, including flooding impacts)	Bushfires	Heatwaves (and extreme heat events)	Changes in rainfall patterns, combined with more hot days (drought)	Sea level rise
Energy	Service disruptions, including to critical assets					
	Damaged infrastructure					
	Service reliability compromised					
Telecommunications	Service disruptions					
	Emergency response capacity compromised					
	Damaged infrastructure					
Transport	Damaged infrastructure					
	Loss of access to critical assets					
	Emergency response capacity compromised					
	Disruption in supply chains including fuel deliveries					
Raw Materials (chemicals)	Service reliability compromised					
	Disruption in supply chains					
Bulk water (where not controlled by water utility)	Service provision compromised					

Review and document general trends from available information sources

The climate change trends for your specific location, and the critical, vulnerable interdependencies should be documented in collaboration with other service providers and by drawing on sources of climate data such as those in [Appendix B](#). It is important to involve the critical services that your organisation depends on, as they will have a more detailed understanding of climate change impacts on their own operations, including their likelihood and potential severity.

Examples of climate trends and how they affect water industry interdependencies are shown in Table A-18.

Table A-18: Examples of general climate change trends and their effect on interdependencies

Climate change impact	Sectoral vulnerability	General trend
Changes in rainfall patterns including longer dry periods	<p>Energy: less water is available to meet increasing demand.</p> <p>Emergency management: Drier, hotter conditions may reduce water supply available in emergencies.</p>	<p>Note: This is a complex area, and specific knowledge of interdependencies for your organisation is required. The following are examples of impacts which might occur.</p> <p>Water supply arrangements in dry times may no longer be sufficient to meet or manage demand.</p> <p>The sustainability of water for firefighting may be put under pressure. Water run-off from firefighting may create issues for urban areas and catchments.</p>
Stronger or more frequent extreme events (including storms, floods, bushfires, heatwaves)	<p>Energy: Higher incidence of damaged infrastructure and service disruptions.</p> <p>Telecommunications: Higher incidence of damaged infrastructure and service disruptions.</p> <p>Transport: Heatwaves can soften paved roads and cause disruptions in rail transport. Higher incidence of damaged infrastructure during storms and floods.</p>	<p>Power supply to critical assets impacted more frequently or for longer periods, possibly beyond the coping capacity of existing back-up generators and pumps.</p> <p>Service reliability compromised.</p> <p>Water utilities' ability to respond to emergencies impacted by more frequent or longer disruptions in telecommunications and power.</p> <p>Water utilities' ability to respond to emergencies and access critical assets limited by transport infrastructure damages.</p> <p>Ability for key water supply chemicals to be delivered is reduced.</p> <p>Delays in major works and capacity of interim holding areas to cope.</p>
Sea level rise / saline intrusion	<p>Telecommunications: Over the long-term infrastructure may corrode in coastal areas.</p> <p>Transport: May cause corrosion or flooding of coastal infrastructure.</p>	<p>Telecommunications-reliant systems in coastal systems may need to be adapted.</p> <p>Limited access to coastal infrastructure following an outage or event.</p>

Do you understand the role your stakeholders can play in managing your organisation's long-term climate change impacts or acute climatic events?

Identify and document the role of stakeholders

Once a water utility has a clear picture of the relevant climate change trends, it should identify and document the role of stakeholders that play a role in climate change adaptation and event response. These agencies can greatly influence the actions of interdependent service providers, whether day-to-day – via policies, regulations or memorandums-of-understanding (MOUs) – or during extreme events. Table A-19 provides examples of the stakeholders that should be assessed.

Table A-19: Examples of stakeholder roles in climate change adaptation and event response

Stakeholder	General role (note these may differ by state or locality)	Example
Local and state government agencies	<p>Provide framework, legislation, systems and guidelines for action.</p> <p>Outline roles and responsibilities of stakeholders.</p> <p>Develop contingency plans, including</p>	<p>Victoria's Critical Infrastructure Resilience Strategy established Sector Resilience Networks with key sectors (including water). Fire breaks are strategically planned to protect</p>

Stakeholder	General role (note these may differ by state or locality)	Example
	evacuation and shelter. Assess and plan for climate risks. Promote community awareness and preparedness. Maintain partnerships with critical service providers (including the water industry). Develop state-wide/regional water plans.	such as water supplies catchments in case of bushfire. Queensland has developed regional water supply strategies addressing drought management. Some states and councils have developed water efficiency programs, for example in government buildings, new developments or agriculture.
Emergency management organisations	Manage warning and alert systems. Respond to extreme events. Community education and engagement.	Sydney Water has an MOU with NSW fire authorities for the use of recycled water for firefighting operations. Regional or municipal emergency management committees or working groups often include water industry representatives.
Critical service providers	Manage service provision as per legislation or agreements with government bodies.	Key services include power, gas, road access, telecommunications, key chemicals, etc.
Supply chain	Provide essential chemicals to water utility.	Stock management during critical times of the year.

This analysis will provide an understanding of interconnections between these stakeholders and the water industry, and any arrangements already in place between different parties to manage climate change and extreme events.

Feed information gathered into the climate change adaptation assessment

Information gathered from the stakeholder analysis should be fed into the assessment on climate change vulnerabilities. This will help to determine sensitivities and priorities for action.

Plan and respond

Does your climate change adaptation plan integrate actions by stakeholders?

Engage with stakeholders to develop feasible joint adaptive responses

The first step of planning is to engage with stakeholders and service providers to explore joint adaptive responses. This engagement process should provide a greater understanding of the impacts of certain actions on other sectors and on the utility itself, ensuring only feasible responses are identified, and avoiding maladaptation or over-adaptation. Joint or complimentary measures to include in the adaptation plan could be identified, cognisant of interdependencies.

An example joint measure is water and power utilities working on strategies to reduce both water and power demand in peak periods, such as through water reclamation, use of recycled water or alternative cooling methods in power generation.

Are responsibilities of stakeholders and suppliers unequivocally agreed upon?

Next, the water utility should continue to work with its stakeholders to modify or negotiate MOUs or appropriate agreements to document respective responsibilities applying both day-to-day and during extreme weather events. Day-to-day, for example, stakeholders may share data with the water utility and vice versa, as well as ensure a minimum level of service provision. During a bushfire, a water utility

will usually provide access to a pressurised water system for fire services, but may require emergency management agencies to provide bottled water until a drinking water supply can be re-established.

A number of interdependencies work within and across jurisdictional borders and hence provide opportunities to work with other water utilities on a consistent long-term approach. When necessary, MOUs could be endorsed at state government level.

Case study 8: How an MOU might incorporate climate change

The 2009 MOU between the NSW Department of Water and Energy and the then-State Water Corporation (now WaterNSW) stated that the parties would, 'work cooperatively to find acceptable solutions that balance the impacts and benefits of various flow management scenarios (such as daily river operations, bulk water transfers, and dam and weir release patterns).'

One way climate change could be incorporated into this agreement is to integrate climate change projections into the flow management scenarios.

Integrate contingencies for critical interdependencies

Both your organisation's climate change adaptation plan and emergency management plan should prioritise and incorporate contingencies for critical interdependencies.

For example, alternate back-up power supplies may be required if existing arrangements will not cope with increasing frequency or length of power disruptions. This decision should be made according to local climate change projections, so as not to over-adapt. Similarly, emergency management and supply chain plans might be developed for extreme weather scenarios, including droughts, of greater impact than experienced in the past, that incorporate potential disruptions in transport, telecommunications and other interdependent sectors.

Embed

Are responses from stakeholders integrated into your climate change adaptation plan?

Ensure stakeholder engagement is ongoing

Ongoing collaboration between interdependent service providers is vital and will allow for:

- ▶ More effective implementation of agreements and joint responses
- ▶ The flexibility necessary to address changes in interdependencies due to external pressures, such as in the advent of new policies or a changed operating environment
- ▶ Lessons learned
- ▶ Continual development of best practice in this relatively new policy area for water utilities.

As with adaptive responses that have been developed by the water utility, incorporating frameworks for stakeholder engagement (such as regular meetings or triggers for meetings) will embed climate change adaptation into your planning processes.

Monitor and review

Is there a plan to regularly review climate change adaptation plans and actions in light of interdependencies?

Climate change adaptation responses, and the interdependencies informing them, should be monitored and updated regularly to ensure the latest climate science and best practice adaptive planning approaches are being used. This is particularly so after an extreme event such as a major bushfire or flood. Joint adaptive actions, agreements and MOUs with stakeholders should likewise be monitored, and reviewed as necessary.

6. Customer and product delivery

Introduction

This section describes the process to assess, plan and respond and embed adaptive planning for the impacts of climate change on customer and product delivery. Customer delivery refers to the delivery of water products to residential and industrial users. Product delivery refers to delivery of irrigation water to third parties and broader water reuse schemes.

Drivers

Climate change has the potential to disrupt the feedback system between the need of a product, such as drinking water, irrigation and sewerage services, and the delivery of that product. Drivers of this include:

- ▶ reduced rainfall and streamflow due to a hotter, drier climate affecting water availability
- ▶ extreme weather events causing infrastructure damage and service disruptions.

Assess

Does the organisation understand the requirements of customers, their needs of the utility, and how this might change?

Determine vulnerabilities to climate change

The first step is to determine and document the specific vulnerabilities in the customer and product delivery process. A number of example vulnerabilities are presented in Table A-20.

Table A-20: Vulnerabilities to customer and product delivery

Vulnerability to climate change impacts		Climate change impacts					
Elements of customer and product delivery	Vulnerability of water sector	Extreme weather events (including bushfire)	Longer, hotter droughts	Heatwaves (and extreme heat events)	Sea level rise	Catchment changes (vegetation cover, species and distribution)	Declining waterway health
Potable water	Insufficient water available to meet customer needs						
	Service disruptions						
	Quality reduction						
	Delivery infrastructure damaged						
	Water restrictions						
Sewerage services	Service disruptions						
Recycled water	Less water available for re-use						
	Delivery infrastructure damaged						
	Changing demands						
	Service disruptions						

This step will provide an understanding of how product and service delivery may be affected by climate change in your area. This will be important in determining the particular sensitivities of your customers (residential, industrial and water reuse) to climate change impacts.

Assess customer sensitivity

The water utility should undertake a material assessment of customer needs and review any crossover with climate related aspects, including how customers may be affected if their needs are not met. As part of this, the water utility should engage with product delivery stakeholders around their requirements. Table A-21 provides examples of questions your organisation could address in the survey.

Table A-21: Questions to assess sensitivities of customers to climate change

Climate risk	Questions to assess customer sensitivities
Longer and hotter droughts	<ul style="list-style-type: none"> ▶ What are the requirements of our customers and how will they change? ▶ Will your organisation be able to meet the requirements of its customers? ▶ Will the level of water reuse be affected?
Extreme weather events	<ul style="list-style-type: none"> ▶ Does the customer have alternate access to water in case of service disruption? ▶ Does your organisation provide water to businesses or vital services (such as a hospital) that could fail without water? ▶ Who/where will be affected by a disruption in the sewerage system? ▶ Will some areas be harder to service than others?

The results of this process could be formalised in a customer sensitivity map, and will feed into a more detailed risk assessment and prioritisation process for adaptation planning.

Plan and respond

Does your organisation have dedicated water availability and reuse plans?

Determine operational changes required

Using the sensitivity map and risk assessment, the organisation should determine if any operational changes or adaptive actions are required to address sensitivities in customer and product delivery. Table A-22 provides examples of possible adaptive responses.

Table A-22: Adaptive responses for customer and product delivery

Vulnerability	Possible adaptive responses
Longer and hotter droughts combined with more extreme events threaten dam operation and water supply to customers	<ul style="list-style-type: none"> ▶ Reconsider operational purpose of dam. ▶ Consider alternative sources of water. ▶ Adapt dam operation manual to incorporate climate forecasts. ▶ Negotiate with the local/state government around the level of reliability and service expected and feasible, and for what cost.
Longer and hotter droughts result in less water available for reuse	<ul style="list-style-type: none"> ▶ Work with product delivery stakeholders to manage expectations. ▶ Collaborate with neighbouring water utilities to facilitate regional solutions.
Reduction in water availability or quality	<ul style="list-style-type: none"> ▶ Consider public awareness campaigns to encourage residential users to accept recycled water. ▶ Assess viability of alternate water sources or water treatment processes.

The feasibility of any responses or organisational changes you identify should be assessed, and developed into a dedicated water availability and reuse plan that complements the organisation's climate change adaptation plan.

Case study 9: Alternative water use in South Australia

Adelaide is facing reduced soil moisture levels that have not recovered since the end of the Millennium Drought, and an increasing number of hot days each year. This has led SA Water to place emphasis on the provision of water for both private and public open space, and addressing the increasing urban heat island effect from the built environment. SA Water currently recycles around 30% of its treated effluent through a number of recycled water schemes.

Research has noted the many co-benefits of using recycled water to irrigate open spaces. These include amenity, social interaction, stable property prices, a reduction in air temperature and hence a reduction in energy use for air conditioning, and the holistic benefit associated with a reduction in recycled water discharge to the marine environment.

SA Water is also studying how it might blend stormwater and recycled water on a medium to large scale to better guarantee product supply. This move stems from the popular take-up by councils and other open space irrigators (e.g. golf clubs) of stormwater reuse schemes using Aquifer Storage and Recovery, a method of Managed Aquifer Recharge. These schemes are reliant on rainfall to generate stormwater, and hence SA Water is unable to guarantee supply to customers from these schemes; a problem that will worsen should rainfall patterns change. Blending stormwater with recycled water will enable these alternative water supplies to be climate independent. It will also reduce the salinity of the recycled water, making it more suitable to a greater range of uses, such as increased industrial and commercial use, and use on salt sensitive vegetation.

Embed

Is there an active dialogue with users and authorities governing water availability, quality and reuse?

Ensure stakeholder engagement is ongoing

To implement the plan, the water utility should create a continuous feedback loop, which will serve to strengthen the resilience of both the water utility and community. Customer sentiment, awareness and preparedness can be monitored through surveys and other engagement means, including social media.

Water availability and reuse should be key topics when engaging with governance stakeholders. It is important there is negotiation between the water utility, local government and community around the level of reliability and service expected and feasible, and for what cost.

Seek third party assurance for reports

Water utilities should engage with external parties to continually improve customer reporting, including through quality assurance and control, as well as ensuring information is provided to customers in a relatable way.

As community expectations change so will the response to service delivery, which is where the feedback loop created in this step will come into its own. It will be vital in monitoring and reviewing the water availability and reuse plan.

Appendix B Climate data sources, key tools and references

Climate data sources

Water utilities can draw upon the sources of climate data shown in Table B-1 to assess and review their climate risks and vulnerabilities.

Table B-1 Climate data sources

	Source	Description
Data	CSIRO and Bureau of Meteorology http://www.climatechangeinaustralia.gov.au/en/	Projections are aligned with Australia's natural resource management (NRM) regions. Projections are described for both intermediate and high emissions scenarios, and in relation to rainfall, temperature, extreme temperature, extreme rainfall and drought, marine and coastal impacts, and other elements such as tropical cyclones, fire weather, humidity and evaporation.
	NSW/ACT Regional Climate Modelling (NARCLIM) http://www.ccr.unsw.edu.au/sites/default/files/NARCLIM/index.html	Ensemble data for NSW and the ACT, reflecting various emissions scenarios, and at a resolution of 10 km. Maps for the various regions of NSW and the ACT are provided, showing the projections for particular climate variables (such as number of hot days, rainfall, and forest fire danger) for the time periods 2020-39 and 2060-79. Climate data is available for download, including Australia-wide data at lower spatial resolution (50 km).
	Bureau of Meteorology http://www.bom.gov.au/climate/	Weather observations and climate patterns from all Australian weather stations, in the form of data and graphs. Trend maps are available at state and national level. The Bureau of Meteorology also provides seasonal outlooks on rainfall, temperature, tropical cyclones and the El Niño-Southern Oscillation Index.
	NZ National Climate Database http://cliflo.niwa.co.nz/	Holds weather observation data from 600 weather stations in New Zealand, with the earliest observations from 1850. Can provide raw data or statistical summaries.
	Intergovernmental Panel on Climate Change (IPCC) http://www.ipcc-data.org/sim/gcm_monthly/AR5/	Data from the Global Climate Models (GCMs) used by the IPCC in their latest assessment report (AR5) on climate change. Presented for more experienced users.
Key reports (including water industry-specific)	<i>Climate Change in Australia: Information for Australia's Natural Resource Management Regions: Technical Report</i> (CSIRO and Bureau of Meteorology, 2015) http://www.climatechangeinaustralia.gov.au/en/publications-library/technical-report/	The Technical Report provides detailed information on key climate change projections and guidance on how to use climate change data in impact assessment and adaptation planning. There are also cluster reports for the following NRM regions: <ul style="list-style-type: none"> Central Slopes East Coast Monsoonal North Murray Basin Rangelands Southern Slopes Southern and South Western Flatlands Wet Tropics

Source	Description
<p><i>Fifth Assessment Report (AR5)</i>, (Intergovernmental Panel on Climate Change (IPCC), 2014) http://www.ipcc.ch/report/ar5/index.shtml</p>	<p>The IPCC's Fifth Assessment Report includes a description of climate change science and impacts on the Australasia region.</p>
<p><i>Climate change scenarios for New Zealand</i> https://www.niwa.co.nz/our-science/climate/information-and-resources/clivar/scenarios</p>	<p>A summary of IPCC science on climate change, projections, scenarios and impacts for New Zealand.</p>
<p><i>Southern Slopes Information Portal Report: Climate change adaptation information for natural resource planning and implementation</i> (Wallis, P.J., Harwood, A., Leith, P., Hamilton, L., Bosomworth, K., Turner, S.L., Harris, R.M.B. and Bridle, K., 2015).</p>	<p>The <i>Southern Slopes Information Portal Report</i> aims to inform the development of NRM strategies and plans incorporating climate change adaptation for the south-east Australia region.</p>
<p>Climate change adaptation and the Australian urban water industry. Occasional Paper 27 (Water Services Association of Australia, 2012).</p>	<p>Informed by water industry collaboration, this paper discusses the risks, challenges and adaptation actions underway for three themes: the Build and Social Environment, the Biophysical Environment and Infrastructure.</p>
<p><i>Water Forever: Towards Climate Resilience</i> (Water Corporation, 2009).</p>	<p>The WA Water Corporation's plan for providing sustainable water services to 2060, including a portfolio of options to achieve its desired goals.</p>
<p><i>Climate Change Adaptation Program</i> (Sydney Water) http://www.sydneywater.com.au/web/groups/publicwebcontent/documents/document/zgrf/mdq0/~edisp/dd_044233.pdf</p>	<p>Describes the key project findings and organisational learnings of Sydney Water's Climate Change Adaptation Program that ran from 2009 to 2013.</p>
<p><i>Melbourne Water Climate Change Study: Implications of Potential Climate Change for Melbourne's Water Resources</i> (Howe, Jones, Maheepala, & Rhodes, 2005). http://library.bsl.org.au/jspui/bitstream/1/842/1/Climate_Change_Study.pdf</p>	<p>This study developed climate projections, and discussed implications for Melbourne's water resources and adaptation options.</p>

Key considerations when using climate data

In relation to uncertainty of the climate change projections, it is important to bear in mind that:

- ▶ Information is continually evolving; water utilities will need to keep abreast of new information as it is released.
- ▶ Historical climate data should not be used to forecast future trends without also incorporating climate change projections.
- ▶ The uncertainty surrounding climate projections should not detract from planning. Rather, it makes it essential to find strategies to appropriately integrate uncertainty into planning.
- ▶ Uncertainty typically increases with the time horizon considered; multiple horizon planning will be necessary particularly for long-life assets.

- ▶ Even more difficult to predict than climate trends are possible ‘tipping points’ when a ‘step change’ in climatic events is likely. The relevance of such tipping points for planning is that significant investments may become cost-effective only when the tipping point is reached. This highlights the importance for the water utility to be able to identify when this is the case.
- ▶ As climate forecasting becomes more granular, the greater geographical detail is likely to be useful only for impacts such as sea level rise and flooding, that is, where the topography of the land profile increases the exposure to climatic variables.
- ▶ Indicators of climate change are typically presented separately for clarity and convenience; however there are interdependencies between them that need to be understood.

Key tools, documents and references

The sources in the Table B-2 are those referred to through the guidelines and appendices, and that may be useful for the adaptation planning process in your organisation.

Table B-2: Key tools, documents and references

	Source
Tools to support adaptation planning	<p><i>AdaptWater™ online climate change analysis tool</i>, Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education, 2013</p> <p>A tool, developed by WSAA, Sydney Water and partner utilities, that quantifies the risk associated with climate change and extreme weather events to water and sewage assets, and performs cost-benefit analyses on proposed adaptation options to inform planning and investment decisions.</p>
	<p>Bosomworth, K., Harwood, A., Leith, P., & Wallis, P., <i>Adaptation Pathways: a playbook for developing robust options for climate change adaption in Natural Resource Management</i>, Southern Slopes Climate Change Adaptation Research Partnership (SCARP): RMIT University, University of Tasmania, and Monash University, 2015.</p>
	<p>Climate Change Adaptation toolkit, Net Balance, 2012.</p> <p>Provides a guide and tools to plan for organisations to integrate adaptation into their business and support effective and efficient risk management. Contains three steps: exploring the risk context; developing adaptation actions; and screening for climate change interactions.</p>
	<p>Developing Robust Strategies for Climate Change and Other Risks: A Water Utility Framework, Water Research Foundation, 2014.</p>
	<p>Presents a framework for Robust Decision-making for water managers to identify and manage climate risk, incorporating the inherent uncertainty.</p>
	<p>Economic Commission for Europe, <i>Guidance on Water and Adaptation to Climate Change</i>, United Nations, 2009.</p>
	<p>With a focus on transboundary basins, this report provides advice on assessing impacts of climate change on water quantity and quality, performing a risk assessment incorporating health issues, gauging vulnerability, and designing and implementing appropriate adaptation strategies.</p>
	<p>Rissik, D., Boulter, S., Doerr, V., Marshall, N., Hobday, A., & Lim-Camacho, L., <i>The NRM Adaption Checklist: Supporting climate adaption planning and decision-making for regional NRM</i>, CSIRO & NCCARF, 2014,</p> <p>Aims to support NRM groups plan for climate change adaptation, including in regards to evaluating plans, determining where changes may be needed, and amending plans.</p>
	<p>Stafford Smith, M., Horrocks, L., Harvey, A., & Hamilton, C., 'Rethinking adaptation for a 4°C world,' <i>Philosophical Transactions of The Royal Society</i>, vol. 369, no. 1934, pp. 196-216, 2011.</p> <p>Explains how to address the inherent uncertainty and complexity in climate change adaptation planning through a variety of risk management strategies and tactics, which aim to reduce barriers and better target adaptation actions.</p>
	<p>UKCIP Adaptation Wizard, UKCIP, 2015 (accessed via http://www.ukcip.org.uk/wizard/tools-portfolio/#.Vm4MiK1Mq70)</p> <p>The UKCIP Adaptation Wizard is a five-step process for businesses and organisations to assess their climate vulnerability identify adaptation options to address key risks, and develop and implement a climate change adaptation strategy. This web page provides tools and resources in support of this process.</p>
	<p>Yates, D., & Miller, K., <i>Climate Change in Water Utility Planning: Decision Analytic Approaches</i>, National Center for Atmospheric Research, 2011.</p> <p>Provides guidance to water utilities on how to incorporate climate change into strategic and long-term planning processes through formulating the problem and model, characterising uncertainty and evaluating alternatives. The bulk of the report consists of several detailed case studies from the US context, including on collaborative projects.</p>

	Source
Examples of climate change documentation	Statement of intent: Page 4 in: Enhancing Life and Liveability: Melbourne Water Annual Report 2013-14, Melbourne Water, 2014.
	Program: Climate Change Adaptation Program, Sydney Water, 2014.
	Plan: Water Forever: Towards Climate Resilience, Water Corporation, 2009.
Other literature cited in the guidelines	Allen Consulting Group, <i>Climate Change Risk and Vulnerability</i> , 2005.
	Australian Public Service Commission, <i>Tackling Wicked Problems: A Public Policy Perspective</i> , Commonwealth of Australia, 2007.
	Barnett, J., Graham, S., Mortreux, C., Fincher, R., Waters, E. & Hurlimann, A., 'A local coastal adaptation pathway', <i>Nature Climate Change</i> , no. 4, pp. 1103-1108, 2014.
	Barnett, J. & O'Neill, S., 'Maladaptation,' <i>Global Environmental Change</i> , vol. 20, no. 2, pp. 211-213, 2010.
	Office of Water, <i>Climate Change Adaptation Implementation Plan</i> , United States Environmental Protection Agency, 2014.
	Productivity Commission, <i>Barriers to Effective Climate Change Adaptation</i> , Report No. 59, Final Inquiry Report, 2012.
	Standards Australia, <i>Climate change adaptation for settlements and infrastructure – A risk based approach</i> , Australian Standard 5334–2013, 2013.
	Sydney Water, <i>Benchmarking resilience: Organisational Resilience to Extreme Climatic Events</i> , 2012.
	Turner, S., Moloney, S., Glover, A., & Funfgeld, H., <i>A Review of the Monitoring and Evaluation Literature for Climate Change Adaptation</i> , RMIT University, 2014.
UKCIP, <i>Transformational adaptation: what it is, why it matters & what is needed</i> , UK Climate Impacts Programme, 2015.	
Vance, TR., Roberts, JL., Plummer, CT., Kiem, AS., & van Ommen, TD., 'Interdecadal Pacific variability and eastern Australian megadroughts over the last millennium', <i>Geophysical Research Letters</i> , vol. 42, pp. 129-137, 2015.	

Appendix C Stakeholder engagement

As reflected in [Figure 1](#) of the guidelines, stakeholder engagement is a vital and ongoing process for climate change adaptation planning, helping organisations to build internal capacity, assess interdependencies and collaborate with external entities to develop and gain support for responses.

Engagement around climate change adaptation is important because:

- ▶ It is a collective problem that requires collective solutions
- ▶ Commitment is required to act together, across organisations, over the long-term
- ▶ Uncertainties inherent to climate change need to be understood by all (including external stakeholders) so that they can build their resilience
- ▶ Clear definition and agreement on respective responsibilities for each stakeholder (including customers) is a way for water utilities to manage their liabilities

Water utilities are well practiced in stakeholder mapping and engagement, and so Table C-1 below, rather than discuss engagement techniques, aims to highlight how different levels of engagement (based on the IAP2 Public Participation Spectrum) might be utilised for the climate change adaptation planning process.

Table C-1: Possible objectives of stakeholder communication during the adaptation planning process

Level of engagement	Possible objective – internal stakeholders	Possible objective – External stakeholders
Inform	To ensure a shared understanding of the objectives of climate change adaptation and priorities, and the importance of action	To communicate the adaptation plan when finalised
Consult	To survey staff: Level of awareness of climate change Level of preparedness Willingness to collaborate	To identify: Interdependencies with other service providers, governments and emergency management organisations Customers' expectations in relation to service provision To gain support for the adaptation plan
Involve	To involve staff charged with implementing the plan, to ensure their ideas are incorporated and a level of ownership felt.	To learn and incorporate the concerns of stakeholders into the water utility's climate change adaptation planning, and gain their support for the chosen approach
Collaborate	To work with staff to formulate climate change adaptation responses, incorporating their input to the maximum extent possible	To develop and implement joint adaptive actions or agreements where interdependencies exist, such as with governments, other service providers or emergency management agencies
Empower	To utilise champions within key business units to be advocates for climate change adaptation planning and response and empower the organisation and its staff to fully support and embed the adaptation plan into day-to-day business To empower the relevant staff (such as senior management and champions) to make decisions and guide the adaptation process	To empower and influence stakeholders to make the best decisions, where these are out of the control of the water utility, such as climate change regulations or price determination processes. This could be done by transferring the advanced knowledge gained through the adaptation planning process to stakeholders, and ensuring two-way communication channels remain open.

Appendix D Scenario planning, vulnerability assessment and risk assessment

Scenario planning

The following table presents a few examples of resources that can be used by the water utilities to inform their approach to scenario planning (refer to [Section 5.1](#)).

Table D-1: Resources for scenario planning

Source	Description
<p><i>Scenarios for climate adaptation</i> (Wiseman, Biggs, Rickards & Edwards, Victorian Centre for Climate Change Adaptation Research, 2011)</p> <p>http://www.vcccar.org.au/publication/research-paper/scenarios-for-climate-adaptation-guidebook-for-practitioners</p>	<p>This report (particularly from page 50 onwards) presents a comprehensive review of:</p> <ul style="list-style-type: none"> • Different methods of scenario planning, including the benefits and limitations of each • How to best apply scenario planning to climate change adaptation <p>It also includes various case studies.</p>
<p>Climate Analogues, CSIRO and the Bureau of Meteorology</p> <p>http://www.climatechangeinaustralia.gov.au/en/climate-projections/climate-analogues/analogues-explorer/</p>	<p>The Climate Analogues tool allows the user to find areas where the current climate is similar to the projected future climate in your area. The Climate Futures tool on the same website provides projections for various time periods out to 2090. These scenarios would need to be combined with locally relevant assumptions about demand, evolving stakeholder expectations etc.</p>
<p><i>Climate change scenarios for New Zealand</i></p> <p>https://www.niwa.co.nz/our-science/climate/information-and-resources/clivar/scenarios</p>	<p>This website discusses the potential future scenarios for the New Zealand climate, based on IPCC data. It covers several climate elements (e.g. storms, strong winds, snow, rainfall), and provides country level maps.</p>
<p><i>Decision Support Planning Methods: Incorporating Climate Change Uncertainties into Water Planning</i> (Water Utility Climate Alliance 2010)</p> <p>http://www.wucaonline.org/html/actions_publications.html</p>	<p>This paper explores the use of scenario planning to support robust decision-making under uncertainty within the water industry (coined as Decision Support Planning Model in the paper). In section 2.2, it provides a step by step approach to scenario planning. US case studies are provided in section 3.2.</p>
<p>Shell</p> <p>http://www.shell.com/global/future-energy/scenarios/what-are-scenarios.html</p>	<p>Although not in the water sector, Shell have established themselves as a major advocate of scenario planning and are communicating widely about their approach.</p>
<p>Water industry associations</p>	<p>VicWater, for example, has organised scenario planning workshops in the recent past and is likely to organise similar activities in the future.</p>

Source	Description
Case studies from within the water industry	<p>The following initiatives from Victoria each employed scenario planning:</p> <ul style="list-style-type: none"> Development of water supply-demand strategies, Department of Sustainability and Environment. Resilient Agribusiness for the Future of Sunraysia, Department of Primary Industries. Melbourne Water Sewerage Strategy, Melbourne Water. Melbourne Water Climate Change Study, Melbourne Water, CSIRO. Water Forever: Towards Climate Resilience, Water Corporation.
<p><i>Scenario Planning for Climate Change Adaptation</i> (Low Choy, Serrao-Neumann, Crick, Schuch, Sanò, van Staden, Sahin, Harman & Baum, 2012)</p> <p>https://www.griffith.edu.au/_data/assets/pdf_file/0004/464251/Griffith-University-SEQCARI-Scenario-Report-Oct-2012.pdf</p>	<p>This paper documents a scenario planning exercise on how South East Queensland might be impacted by and adapt to climate change. While not water industry-specific, the report reflects interdependencies, and discusses the need for improved infrastructure design and emergency management, which both relate to the water industry.</p>

Vulnerability assessment

Vulnerability assessments represent a broad-ranging, top-down approach to risk appraisal based on a collaboratively developed understanding of ‘systems at risk’. They identify where the greatest potential for harm lies and explain the various factors that may contribute to that harm.

Vulnerability assessments are well suited for a first step strategic assessment as they take into account risk context rather than delve into the detailed technical aspects of the risks. Even for water utilities that have already undertaken a climate change oriented risk assessment, there is merit in conducting a vulnerability assessment to ensure that complex, compounding or multi-faceted risks are identified.

The process for a vulnerability assessment is typically as follows (although variations are possible):

1. Ensure that the preparatory work has been done.

In particular, this step should ensure that:

- ▶ There is consensus in your organisation around core functions and ‘systems at risks’ that need to be protected
- ▶ The climate change trends in the region have been documented
- ▶ You understand your current capacity to adapt to these climate trends
- ▶ Interdependencies with other stakeholders are well understood.

2. Carry out stakeholder workshops.

The vulnerability assessment usually takes the form of a workshop or series of workshops that define the threshold of unacceptable or dangerous impact for each ‘system at risk’ (see table D-1 below for example of vulnerabilities relevant to water utilities), considering in particular:

- ▶ **Scenario planning** (see [Section 5.1](#)), to manage uncertainty about climate impacts and their interaction with water industry systems and assets.
- ▶ **Upstream interdependencies**, such as energy systems, population change, behaviour change, transport and communications systems, and raw water suppliers.
- ▶ **Downstream dependencies**, including the impact of climate change on customer needs, urban growth, community attitudes, social institutions, industry, urban growth and planning.
- ▶ **Compounding and cumulative risks**, such as heavy rains after bushfires affecting water quality, and floods and sea-level rise combining, resulting in increased inundation severity.
- ▶ **Relevant time horizons and immediacy** of the vulnerability. For example, heatwaves are an immediate risk, as they will increase in frequency with climate change. Sea level rise, while certain, is longer term.
- ▶ **Current adaptive capacity**, that is, where the organisation has in-built resilience or high potential to adapt. This is a strength that can be built upon. For example, multiple sources of water supply that are not rainfall dependent may already be available.

3. Document and validate the assessment.

Document the vulnerability assessment, highlighting the priorities that have been identified and the associated rationale. Validation should be sought from the organisation’s executive and decision makers in each division, so that the agreed priorities can guide the detailed risk assessment.

4. Communicate the assessment.

To help guide further action, and build a shared understanding of challenges faced, the assessment should be communicated within the organisation, and to external stakeholders, as appropriate.

Guidance for vulnerability assessments is available from various open references, some of which are noted in [Appendix B](#). Table D-1 provides key climate risks of core functional areas to consider in the vulnerability assessment.

Table D-1: Key climate change risks for the water industry

Core functional area / System at risk	Key climate change risks
Source waters	<ul style="list-style-type: none"> ▶ Decreased water availability ▶ Higher use of non-climate dependent sources, resulting in higher costs ▶ High peak flows, requiring more flood space in reservoir, and reducing volume in storage ▶ Contaminated runoff from bushfires and reduced yield during regrowth phases ▶ Lower groundwater reserves from reduced recharge ▶ Reduction in aquifer reserves and water quality from seawater intrusion ▶ Increase in algal blooms and reduced effectiveness of some water purification chemicals from increased temperatures.
Built assets	<ul style="list-style-type: none"> ▶ Increased odours from sewerage networks and treatment plants ▶ Increase in extreme weather events causing asset failure, disruption to power supplies and others ▶ Change in hydraulics for sea based infrastructure.
Environmental impacts	<ul style="list-style-type: none"> ▶ Potential increase in breach of obligations and regulations ▶ Lack of water for environmental flows ▶ Increased demand for environmental flows to support waterway health ▶ Changes in catchment vegetation affecting run-off and yields.
People and workplace	<ul style="list-style-type: none"> ▶ Urban heat island effect ▶ Mobility and risk of workforce during extreme events ▶ Access to assets ▶ Changes to disease patterns, such as tropical diseases increasing their range or entering the country.
Interdependencies	<ul style="list-style-type: none"> ▶ Increased insurance costs or refusal by insurers to cover risks ▶ Reduced income/revenue, such as when restrictions are imposed or demand declines ▶ Essential services disruption, including blackouts ▶ Movement of populations

Core functional area / System at risk	Key climate change risks
Customer and product delivery	<ul style="list-style-type: none">▶ Increased challenges to service delivery, including from bushfires, floods and sewer spills▶ Increased stress on the community from acute water shortages, floods and coastal inundation▶ Changing customer expectations▶ Increased peak demand▶ Increased agricultural demand▶ Decreased willingness to bear costs▶ Investment decisions / budget considerations.

Risk assessment

Utilities already manage risk, but sometimes the constraints of the systems do not allow for adequate integration of complex risks with multiple time horizons such as climate change. For this reason, the guidelines recommend critically analysing risk assessment systems (See [Section 5.4](#)).

Figure D-1 outlines the Risk Management Process adapted from AS 5534-2013 *Climate Change Adaptation for settlements and infrastructure - a risk based approach*, which can be referred to for more detailed guidance.

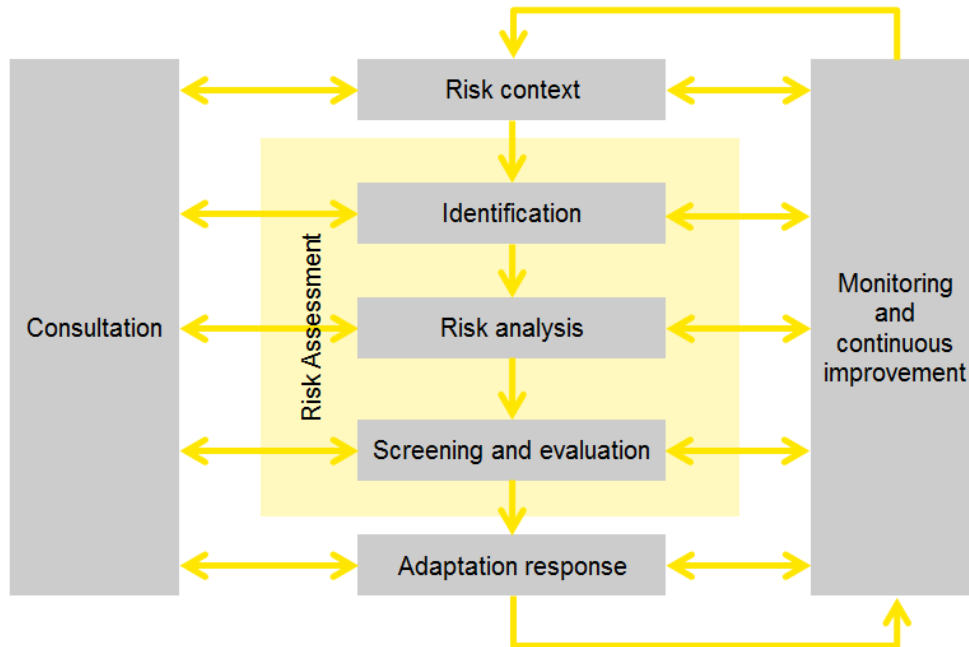


Figure D-1: Risk management process adapted from AS 5534-2013

The elements in this diagram that call for particular attention in relation to climate change risk management are:

- ▶ **Consultation:** More than for non-climate risks, engagement with external stakeholders – customers, local government, emergency response agencies and other community support agencies – is critical as they may wear part of the risk or be part of the response.
- ▶ **Continuous improvement:** Climatic events, crossing of trigger points or warning thresholds must trigger reviews of risk estimations and adaptation responses; this is essential as the organisation will still be in a learning process and uncertainty around impacts and interdependencies is high.
- ▶ **Risk context:** Climate risks have specific characteristics, in terms of time-lag, uncertainty, and cumulative factors (climate events of different nature occurring in rapid succession). This should be explored to support the risk analysis and prioritisation. Useful elements for the risk context will have been defined during the vulnerability assessment.
- ▶ **Risk analysis:** Climate trends are a key input into the analysis. As recommended in the guidelines (see [Section 5.1](#)), scenario planning techniques can be used to avoid being locked into one specific climatic future. It is essential to recognise the inadequacy of using past climatic data to predict future trends without integrating any correction factor for climate change (for specific guidance, see [Section 4.6](#), [Section 5.1](#), and [Appendix B](#) on Climate Data Sources).
- ▶ **Screening and evaluation:** This step can be more complex than for other risks, due to the complex cumulative and interdependent relationships between risks and the various time horizons to consider (see [Section 4.4](#) on decision-making under uncertainty).

The standard AS/NZS ISO 31000:2009 *Risk management – Principles and guidelines*, provides more general guidance on risk management (i.e. not specific to climate change adaptation).

Appendix E Categories of adaptation options and maladaptation

Adaptation options

As referenced in [Section 6.1](#) – Develop adaptation options – there are various categories of adaptation options that a water utility should consider to foster ‘outside the box’ thinking. These are described in Table E-1.

Table E-1: Categories of adaptation options

Category	Description
Incremental solution	Solutions which meet current objectives under changed conditions People will, as a default, tend to think of incremental solutions (Stafford Smith et al. 2011).
Transformative solutions	Solutions which fundamentally change objectives or ways of doing things (Stafford Smith et al. 2011). Transformative and incremental solutions can be compatible.
Accepting impacts and bearing losses	The decision not to act. This can be a valid option, for example where there are sufficient procedures already in place to deal with the risk, or when the relevant assets or systems are not worth the effort or cost associated with protecting them. Stakeholders may accept a reduced level of security of service delivery if the cost of adaptation is too high.
Loss prevention	Reducing vulnerability to climate change, through addressing exposure, sensitivity or adaptive capacity, prior to experiencing the impact. The most extreme form of this would be to move vulnerable populations or systems away from climate change hazards. Of course, this will not always be viable.
Behaviour modification	Eliminating the activity or behaviour that causes the exposure or sensitivity to climate change impacts.
Loss sharing	Spreading the risk of loss among a wider population, such as through insurance or levies.
Exploiting positive opportunities	Recognising benefits of new activities, behaviours, or practices arising out of climate change impacts or adaptation activities. New opportunities may also be exploited by moving activities to a new location to take advantage of changed climatic conditions.
Reducing decision timeframes	Planning or designing for shorter time-frames with more frequent reviews, to reduce exposure to the higher uncertainty inherent in more distant time horizons. For example, cheaper assets could be designed for interim capacity requirements, rather than over-investing in solutions that turn out to be inappropriate for future conditions.
Risk hedging approaches	Spreading risks in space or time. For example, designing for shorter asset lives or utilising multiple water sources and water grids (security through diversity).
Soft fail approaches	Options built into water infrastructure that allows the consequences of peak or intense events to be reduced.

Refer also to [Appendix A](#), which gives examples of climate change adaptation actions for core functional areas of water utilities.

Maladaptation

Maladaptation is ‘action taken ostensibly to avoid or reduce vulnerability to climate change that impacts adversely on, or increases, the vulnerability of other systems, sectors or social groups’ (Barnett and O’Neill, 2010). Major infrastructure projects in the water industry which aim to address water stress issues, such as desalination plants, large dams, or pipelines to move water from distant catchments are sometimes cited as examples of maladaptation. Table E-2 illustrates why these projects may result in maladaptation.

Table E-2: Characteristics of maladaptation and possible impacts of major water infrastructure projects

Maladaptation characteristic	Possible result of major water industry projects
Disproportionately affects the most vulnerable, whether people or ecosystems	Water prices increase, affecting the poorest the most. Regional or indigenous populations may be adversely affected.
Reduces incentives to adapt	Customers return to a mindset of consuming rather than conserving water.
High social, environmental or economic costs relative to alternatives (i.e. high opportunity cost)	Major projects may cost more than alternative measures (such as treating wastewater to a higher standard), in addition to detrimentally impacting the riparian or marine environment through reduced flows or changed chemistry of discharges.
Establishes pathways which limit future options	Large amount of capital expended not available for alternative or complementary measures.
Increases greenhouse gas emissions	Energy intensive both to construct and operate.

Table content adapted from Barnett and O'Neill (2010).

Other maladaptation risks include building assets which do not work, or that are lost or damaged in extreme events shortly after their commissioning.

Hence, it is important to weigh up the short and long-term costs and benefits of different adaptation options (including social and environmental costs and benefits), to determine the best way forward and reduce the level or risk of maladaptation that may occur.

Collaborating with interdependent sectors is also important to avoid maladaptation. For example, managing fertiliser use at its source in the agricultural sector may be more appropriate than the water industry using energy intensive methods to later remove excess nutrients in the system. Similarly, as development on floodplains has intensified, the water industry could advocate for better planning practices to reduce the risk to the community and its operations.

Appendix F Logic and Approach

The logic and approach of these Climate Adaptation Guidelines has been strongly influenced by the important paper by Stafford Smith, Horrocks, Harvey and Hamilton '*Rethinking adaptation for a 4°C world* (2011). The following provides an overview of that paper.

The author's key point is that adaptation and mitigation efforts to date have been inadequate, as has the conceptualisation of the complexity faced in adapting to a diverging and highly uncertain future. They make the point that there will not be some sort of equilibrium climate when the planet warms by 2° C or 4° C, but rather it will be a 'more substantial, continuous and transformative process'. This lack of endpoint equilibrium, combined with the observation that warming is progressing more quickly than predicted, and that many adaptation actions have long time frames makes decision-making extremely difficult. They quote Adger and Barnett (2009):

- ▶ The task is unexpectedly hard and urgent
- ▶ Adaptive capacity won't (necessarily) translate into action
- ▶ Existing maladaptation is widespread
- ▶ Measuring adaptation success is profoundly complex

The challenges of long-term adaptation are well articulated in their paper, which you are strongly encouraged to read. The key messages in this paper have strongly underpinned the thinking behind these Climate Adaptation Guidelines:

- ▶ It is very likely that we will be dealing with 2° C changes from 2030 onwards and up to 4° C by 2060 onwards.
- ▶ Some aspects of climate change are relatively predictable and monotonic, for example increasing atmospheric CO₂ concentrations, increasing global average temperatures, sea level rise and the declining pH of the oceans. By contrast, other elements of climate change such as precipitation and storminess are much more uncertain and largely indeterminate. See Table 1 for more detail on this.
- ▶ Continuous improvement-based adaptation is likely to fail – for the longer term transformational approaches to adaptation will be needed. See Table 1 for a summary of these.
- ▶ Society will need to deal with more than technical challenges – also with psychological, social and institutional barriers. See Table 2 for a summary of these, including adaptive and maladaptive coping strategies and their consequences.
- ▶ The paper defines decision lifetime = lead-time (first consideration of a decision to its execution) + consequence time (when the outcomes of a decision emerge). Decisions should be mapped with respect to their lifetime – both their lead time and consequence:
 - Short lead + short consequence period (which wheat cultivar to plant)
 - Short lead + long consequence (building a house)
 - Long lead + short consequence (breeding a new crop, development of a new drug)
 - Long lead + long consequence (location of new suburbs e.g. servicing Western Sydney, building a new seawater desalination plant)

- ▶ The key point of the paper is how to improve long-term decision-making in the face of uncertainty. Uncertainty shouldn't be reason for inaction, but rather the driver to get the best possible decision-making framework in place. Table 1 summarises rational responses to decision-making over short- and long timeframes.

Figure 1 illustrates these points well.

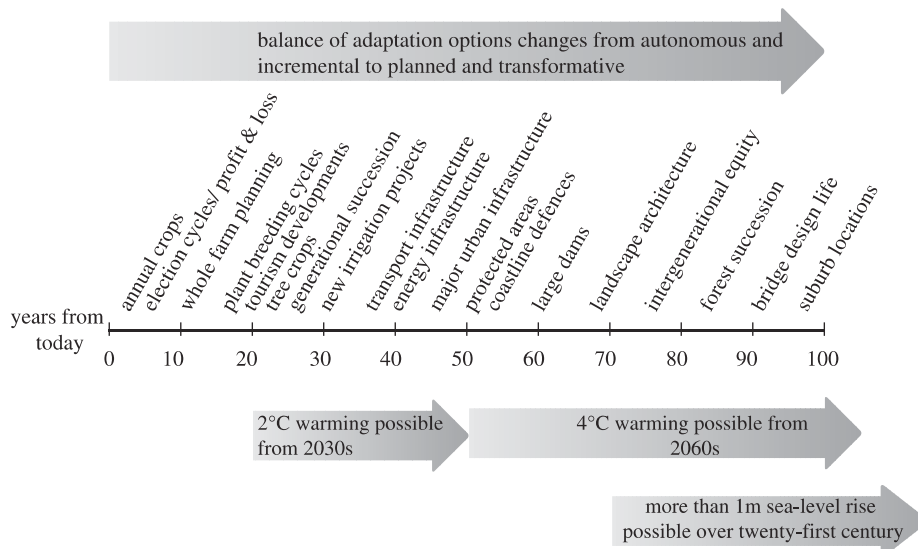


Figure 1. The timeframes of decisions (from Stafford Smith et. al., 2011).

Short lead-time, short consequence decisions often don't need to take account of climate change, but long lead-time decisions need to factor in climate change risks now. Figure 2 illustrates how to respond rationally to diverging futures by adopting transformational rather than incremental approaches to decision-making, and Table 1 outlines the implications of different combinations of decision lifetimes, driver uncertainty type and adaptation response types for decisions under diverging climate futures.

Hallegatte (2009) proposes five ways to reduce risk:

1. Select 'no regret' strategies that work even in the absence of climate change.
2. Select reversible and flexible options.
3. Buy 'safety margins' in new investments.
4. Promote 'soft' adaptation options (e.g. demand reduction).
5. Reduce the time horizons of decisions.

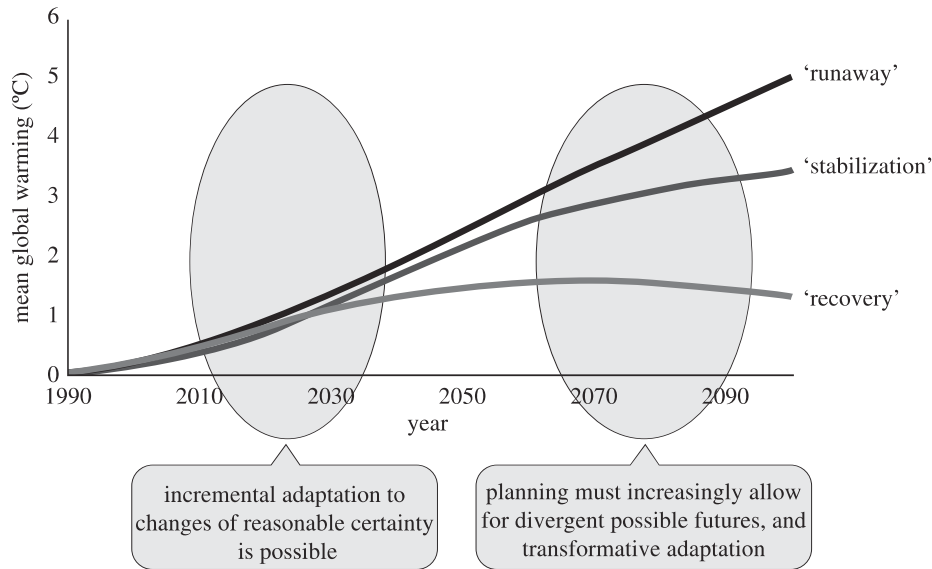


Figure 2: Responding rationally to divergent futures (from Stafford Smith et. al., 2011).

Bates et al (2010) make a key reinforcing point regarding the changing nature of uncertainty under conditions of climate change. They show that the time series data relied upon for estimating the probabilities of events important to water utilities are changing their statistical distributions as climate change progresses. This is known as statistical non-stationarity. Loosely speaking, a stationary process is one whose statistical properties do not change over time.

The problem caused by the non-stationarity of time series data such as rainfall and river flows (including flood frequencies) is that it becomes impossible to reliably estimate the probabilities of future events such as the 1 in 100 year storm or flood. Most water utility infrastructure design is based on the statistics of events. For example, reservoirs are designed to reliably capture and yield a certain volume of water over an averaging period of a few years, and their spillways sized to bypass floods above a certain size.

Table 1: Implications of different combinations of decision lifetimes, driver uncertainty type and adaptation response types for decisions under diverging climate futures. (Modified from Stafford Smith et. al., 2011)

Decision Lifetime	Driver Uncertainty Type	Type of Adaptation Response	Type of Decision-making about Risk
1. Short- or long-term	Monotonic or indeterminate	Same type and extent under all scenarios.	'No regrets'; BAU to implement cost-effectively.
2. Short-term (easily reassessed)	Monotonic or indeterminate	Little scenario divergence in short-term – one set of responses OK.	Ongoing, incremental adaptation in line with direction and pace of change.
3. Long-term (50-100 years)	Monotonic	Same type but different extent for different scenarios.	Precautionary risk management – use Cost-Benefit Analysis to determine best response now.
4. Long-term (50-100 years)	Monotonic	Different type and extent for different scenarios.	Risk-hedging against alternative futures (gradual transfer of resources as uncertainty diminishes).
5. Long-term (50-100 years)	Indeterminate	Same type but different extent for different scenarios.	Robust decision-making in the face of uncertainty about direction of change.
6. Long-term (50-100 years)	Indeterminate	Different type and extent for different scenarios.	Risk-hedging against alternative futures (gradual transfer of resources as uncertainty diminishes); delay acting if possible.

Table 2. Analysis of psychological strategies for responding to the prospects of severe climate change (after Hamilton and Kasser, 2012)

Types	Strategies	Brief Description
Denial strategies	Active denial	Actively rejects the science
	Casual denial	Avoids exposure & dismisses discomfort by raising scientific uncertainty.
Maladaptive coping strategies	Reinterpreting the threat	By making scale smaller or timeframe distant.
	Diversion	Appropriate responses replaced by trivial actions – e.g. low energy light bulbs.
	Blame-shifting	Avoids responsibility by blaming others – e.g. ‘China isn’t doing anything’.
	Indifference	Deliberate apathy - short-term pressure; but with a high future cost.
	Wishful thinking/unrealistic optimism	Benign fictions - predict what we want to see; and refuse to respond to evidence.
Adaptive coping strategies	Expressing and controlling emotions	Expressing emotions is healthy - but being ‘stuck’ in them is not.
	Problem-solving	Knowledge - action; collaboration and sense of control.
	New values orientations	Considered reflection on death promotes less materialistic, more pro-social responses.

References

Adger, N. & Barnett, J. 2009. Four reasons for concern about adaptation to climate change. *Environ. Plan. A* **41**, 2800-2805.

Bates, Bryson C., Chandler, Richard E., Charles, Stephen P., and Campbell, Edward P. 2010. Assessment of apparent nonstationarity in time series of annual inflow, daily precipitation, and atmospheric circulation indices: A case study from southwest Western Australia. *Water Resources Research* 46, W00H02, doi: 10.1029/2010WR009509, 2010.

Hallegatte, S. 2009. Strategies to adapt to an uncertain climate change. *Glob. Environ. Change Hum. Policy Dimens.* **19**, 240-247.

Hamilton, C. & Kasser, T. 2009. Psychological adaptation to the threats and stresses of a four degree world. In *Fours degrees and beyond*. Environmental Change Institute. Oxford, UK: Oxford University Press.

Stafford Smith, M.; Horrocks, L.; Harvey, A. & Hamilton, C. 2011. Rethinking adaptation for a 4°C World. *Phil. Trans. R. Soc.* **369**, 196-216. <http://rsta.royalsocietypublishing.org/>

Appendix G Glossary

Absorptive capacity	The ability of an organisation to recognise the value of new information and apply it.
Adaptation	Adjustments in state, form or structure in response to a modified environment.
Adaptation option	Strategies or solutions to manage climate change risks
Adaptation pathway	A sequence of linked strategies to adapt to climate change, in which initial decisions can have low regrets and preserve options for future generations (Barnett et al. 2014).
Adaptive capacity	The ability of an organisation to adjust to climate change to mitigate potential risks, take advantage of opportunities or to cope with the impacts.
Climate	A statistical description in terms of the mean and variability of relevant indicators, such as those relating to temperature and rainfall, over a period of time. The World Meteorological Organisation defines this period as three decades.
Climate change	A long-term shift in regional and global weather patterns, in particular the shift evident from the mid-20 th century onwards and beyond natural variability and attributed to anthropogenic forces.
Climate hazards	Risk, threat or problem that is climate induced.
Climate risk	Chance of loss or change due to the climate.
Climate variability	Natural fluctuations in climate such as seasonal variability.
Co-benefit	When addressing a risk in one area has a corresponding benefit in a separate area.
Extreme weather	An extreme weather event as rare or rarer than the 10 th or 90 th percentile of a climate variable.
Interdependency	Where two things (e.g. organisations) are mutually reliant on each other to function successfully.
Mitigation	The process of making a condition less severe or controlled.
Maladaptation	When action taken to reduce vulnerability to climate change has a flow on adverse impact on other systems, sectors or social groups.
NARClIM	The NSW and ACT Regional Climate Modelling Project.
No-regrets options	Adaptation options that provide immediate economic, environmental or social benefits regardless of future climate conditions as well as improving resilience to the potential impacts of climate change.
Over adaptation	Over responding to an inherent risk.
Resilience	The capacity to adapt to stress and adversity.
Risk assessment	Process for evaluating potential risks.
Robust	Durable and resilient.
Scenario	A projected event.
Tipping points	A tipping point is reached when global climate changes from one stable state to another stable state. After the tipping point has been passed, the transition to a new state occurs.
Transformative adaptation	Solutions that fundamentally change objectives or ways of doing things (Stafford Smith et al. 2011; UKCIP 2015); transformative and incremental solutions can be compatible.
Transformative	The ability to organisationally move with change.

capacity

Trigger points

Set points or thresholds to which an action is required.

Vulnerability

The degree a system is unable to cope with the adverse effects of climate change.

Vulnerability assessment

The process of identifying, quantifying and ranking vulnerabilities in a system.

Weather

Short-term state of the atmosphere.