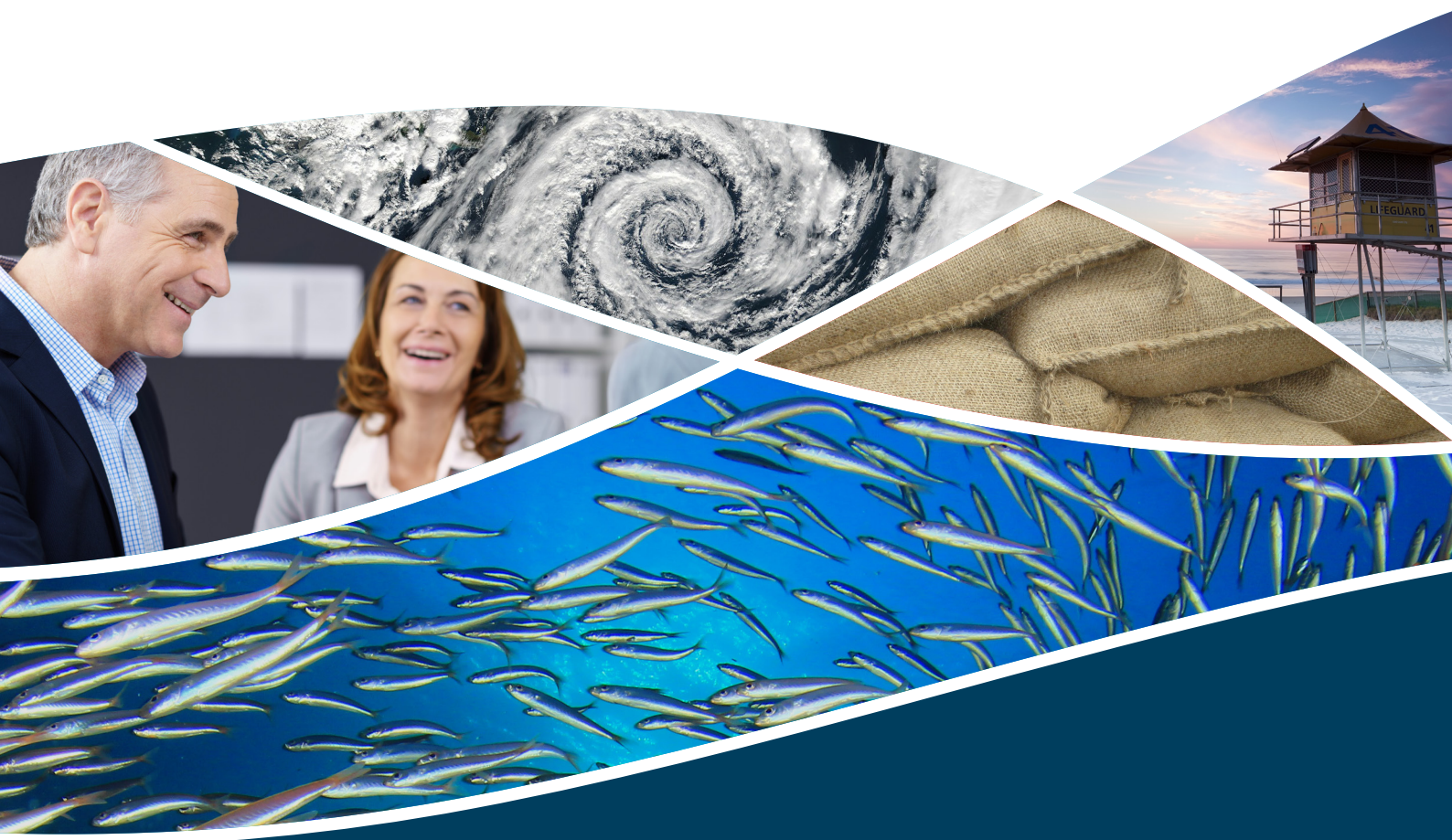


A local government framework for coastal risk assessment in Australia



Final Report

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Disclaimer

The views expressed herein are not necessarily the views of the Commonwealth or NCCARF, and neither the Commonwealth nor NCCARF accept responsibility for information or advice contained herein.



Executive Summary

Background

This report presents a framework for coastal risk assessment by local government in Australia. The work was funded by the National Climate Change Adaptation Research Facility (NCCARF) under a targeted program of research in support of the development of NCCARF's coastal climate risk management tool *CoastAdapt*. The focus for the work was to provide guidance to Australian coastal councils that have decided to consider adaptation planning and are just beginning the process of assessing their exposure to climate change risks. The work deals specifically with those risks that are uniquely experienced by coastal councils, including risks related to climate change processes such as projected sea-level rise and increased coastal storminess. The report does not deal with adaptation strategies and options and we note that substantial guidance is to be provided by *CoastAdapt* and is already available elsewhere.

The framework outlined in this document was designed to be incorporated into *CoastAdapt*. It deals with risk assessment in particular, and provides guidance on the identification of 'hot-spots' for more detailed follow up analysis.

Framework Development Context

In Australia, local government is on the front line of providing an adequate planning and adaptation response to climate change. In comparison, individual state and territory governments provide the legislative and policy direction, funding and technical support, within which coastal management and planning for coastal climate change is undertaken.

Initially, our framework development effort focussed on the identification and assessment of past case studies of coastal climate change risk assessments. It was decided to limit case studies to Australian experience to compare the similarities and differences between the approaches of different state and territory governments, in setting the context for coastal risk assessment.

Across Australia, the concept of *Ecologically Sustainable Development (ESD)* and its underpinning principles have been endorsed by government. While the principles may be expressed differently in different documents, ESD broadly refers to the conservation and balanced use of resources to maintain ecological processes and increase the total quality of life, both now and into the future. The achievement of ESD is seen as being in the public interest; in practice, coastal management, including the consideration of climate change, is heavily influenced by ESD principles across Australia.

At the present time, there are variations in the approach of different state and territory governments and the legal and policy environment. This variation is significant enough that advice on the specific methods, for example, that should be applied for risk analysis cannot be considered appropriate for all jurisdictions. Much of the advice contained herein, including the framework contained in Chapter 7, is

necessarily broad. This high level advice is consistent with the purpose of the framework.

Ideally, different state governments would develop their own guidelines to expand upon the skeleton guidance provided by the framework. Depending on the advice available from state government, local government agencies may consider following the guidance provided by the *CoastAdapt* online tool, which is broadly consistent with the framework presented here.

Applicability and Limitations of the Research

The broad ideas expressed within this research report and resulting framework may be applicable to other climate change risks which, while important to some coastal councils, are not specifically coastal in nature. Examples include risks related to changes in bushfire intensity and frequency, caused by an overall drying climatic trend. We note, however, that these risks are not unique to coastal councils and it is likely that better guidance for assessing these risks can already be found elsewhere.

To remain consistent with the overall adaptation focus of NCCARF and *Coast Adapt*, this report deals with risk assessment in the context of planning for adaptation. While coastal councils have a complementary interest in emergency/disaster risk management, the focus of the present work is not on the reactive management of hazards but to encourage a smoothly planned, adaptive transition to minimise the risks arising from climate change affected emergencies and disasters.

Furthermore, within Australia, Queensland is the only jurisdiction where local government has responsibility for coordinating emergency planning and the multi-agency response to emergencies as they are occurring. Some of these emergencies are uniquely coastal in nature. For all other jurisdictions agencies have been established at the state level to deal with particular emergencies (e.g. the State Emergency Services in New South Wales, Tasmania and South Australia). In keeping with the focus on local government across Australia, this document does not deal with emergency/disaster risk management. Again, more relevant information can be found on assessment of these types of risks elsewhere, such as through Emergency Management Australia (EMA) in the federal Attorney Generals department.

Approach of this Research Effort

The work undertaken for this project relied heavily on a review of available literature from the past 10 years. Pursuing the aim of identifying best-practice risk assessment, our literature review has focussed on Australian case studies of coastal risk assessment, within the context of coastal adaptation.

Prior to identifying and undertaking the case study assessment, it was necessary to provide a concise summary of what risk assessment is, and to clearly define a variety of standard terms that are used to describe the risk assessment process. Herein, we have adhered closely to the definitions outlined in the international standard for risk management, ISO 31000, and associated publications from the International Standards Organisation. Based on our experience and review of case studies, it is critically important that clear language is used. Universal adoption of the standard's

terminology makes the integration of coastal risk assessment outputs into the broader risk management environment of a local council much smoother (e.g. inclusion in an over-arching risk register).

Our study of practice in Australia initially focussed on the review of 28 different case studies of coastal climate change risk assessment. Based on the requirements of ISO 31000, the study team developed an assessment table as a means of methodically considering each of these case studies. The assessment table method and weightings was provided to NCCARF for review with a progress report and subsequently adopted in the review. While the process adopted is significantly qualitative, the method was sufficient to provide an understanding of the approaches and limitations of historical coastal climate change risk assessment in Australia.

Each study was assessed in terms of its consistency with the requirements of ISO 31000 with respect to:

- establishing the context
- risk identification
- risk analysis in term of likelihood and consequences
- risk evaluation
- communication and consultation.

Many of the risk assessment efforts reviewed were found to be inconsistent with the standard, most notably through the lack of a clearly defined context for the risk assessment and an apparent lack of effort in clearly identifying and describing risks. To date, most relevant studies have been undertaken in a very strategic, 'high level' manner.

Follow up Interviews and Key Findings

Follow up interviews with organisations responsible for three short-listed best-practice studies indicated that a high level of compliance with ISO 31000 tends to correlate with positive, lasting impacts and ongoing adaptation actions. In particular, reported evidence of high levels of communication and consultation seem to translate to good outcomes. Aspects which also seem to contribute to successful risk assessment and follow up actions include clear guidance from state government and clear funding pathway opportunities. Conversely, absence of these elements can be detrimental to the success of the risk assessment and follow up activities.

One particular area of concern is where the risk assessment is taken at a broad scale, potentially covering up to half a dozen different local government areas. This is problematic, as decision making inevitably needs to be made by individual local government areas, based on their own particular requirements. While this broad scale approach may provide value in a *strategic* sense, the process would typically need to be replicated at a smaller scale to become meaningful for an individual council. This is not abnormal; it is common for the risk assessment process to iterate, cascading into more focused, but detailed studies with each iteration.

Ultimately, our findings regarding elements of best practice for coastal climate change risk assessment are unsurprising; they are consistent with what is regarded as good risk assessment practice and closely adhere to ISO 31000. Key findings include the following.

- Councils should be proactive and have a clear understanding of their own objectives and their role and overall responsibilities for risk management. This includes assuming a primary role to clearly understand the context, including the geographical extent, time frames, legal environment, hazards to be considered and the expected level of assessment of deliverables. Many aspects of the coastal risk management context are more sensibly established at state government level in Australia.
- Broad, continuing consultation is very important and deserves significant attention. However, it is recognised that there is a need for some information prior to entering the necessary conversations with stakeholders. In particular, the context needs to be established and would likely involve some up-front, preliminary study of the possible extent of hazards and the assets that would be affected.
- Best practice risk assessment makes genuine attempts to address uncertainty. This will require significant effort and goes above and beyond many of the qualitative approaches that have been made in the past. As much as possible, a probabilistic approach to assessing the likelihood of risks is strongly recommended. The adoption of benchmarks and scenarios with no assessed likelihood does not result in best practice risk assessment.
- Care is needed in applying available guideline documents to ensure that they are consistent with standard risk assessment practice and relevant for coastal climate change. The *CoastAdapt* tool aims to provide access to data and advice alongside relevant state government level guidance is unavailable. One particular issue with different guideline documents is the adoption of nomenclature which differs from that applied in standard practice.
- The key influencing factor of coastal climate change risk is sea level rise although changes to storminess are also important. Sea level rise will combine with changes to storminess to exacerbate coastal erosion, inundation and flooding with consequences to various assets such as infrastructure, settlements, beaches and ecological communities.

A Local Government Framework for Coastal Risk Assessment in Australia

The framework presented in Section 7 of this document comprises scaffolding for a step by step approach. Based on our research, the approach should enable the development of more specific guidance to risk assessment that provides the best chance of achieving successful adaptation outcomes. The framework presented is not intended to be a handbook for coastal risk assessment and will need to be considered and adapted/extended for application in different jurisdictions.

Key aspects of the framework include the development of a dedicated coastal risk committee comprising a broad range of stakeholders and chaired by local government, which would be responsible for ensuring that the context for the risk assessment is clearly outlined and understood. Continuous and genuine stakeholder involvement is encouraged throughout the process.

In most cases, local governments are unlikely to have the required high level risk analysis skills, required to probabilistically assess risk likelihoods and robustly examine the consequences. Engagement with third parties such as private consultants, universities, CSIRO or Geosciences Australia would be required in most cases. Even so, it is important that the coastal risk committee has a pro-active role in setting the scope and briefing any external studies, to ensure that the results are consistent with the requirements of the overall risk assessment process.

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1 Introduction

1.1 Background

This report presents a framework for coastal risk assessment by local government in Australia. The work was funded by the National Climate Change Adaptation Research Facility (NCCARF) under a targeted program of research in support of the development of NCCARF's Coastal Climate Risk Management Tool *CoastAdapt*. The title of the project was *Methodologies for vulnerability, impact and risk assessment, including methods to identify at-risk hot spots* and the work was undertaken by staff from the School of Environmental and Life Sciences at the University of Newcastle, New South Wales.

The focus for the work was to provide guidance to Australian coastal councils that are just beginning the process of assessing their exposure to climate change risks. The work deals specifically with those risks that are uniquely experienced by coastal councils, including those risks related to climate change processes such as projected sea-level rise and increased coastal storminess.

The framework laid out in this document was designed to be incorporated into the online *CoastAdapt* tool of NCCARF. It deals with risk assessment in particular, and provides guidance on the identification of hot-spots for more detailed follow up analysis.

In Australia, local development planning and consent is the responsibility of local government. Local government needs to plan for future climate change and incorporate climate change considerations in development consent decisions. In comparison, state and territory governments provide the legislative and policy direction, funding and technical support, within which coastal management and planning for coastal climate change is undertaken. Coastal councils have responsibility for land use planning decisions adjacent to, or in close proximity of, the coast. Some of these decisions should involve the consideration of risks relating to those processes and attributes that are of importance to the coastal zone, which may impact on settlements and infrastructure sited therein.

At the present time, the approach of different state and territory governments and the legal and policy environment varies. This means that specific advice, for example, on methods that should be applied for risk analysis cannot be considered appropriate for all jurisdictions. Much of the advice contained herein is broad and high level; consistent with the purpose of developing a framework.

Of particular concern to coastal local councils is the uncertainty of how the coast will evolve in future decades (and, in some cases, centuries), particularly under the influence of sea-level rise. This evolution will impact upon coastal societies, environments and economies.

The uncertainties associated with risks considered in this report arise from the following.

-
- The uncertain amount of sea level rise that will occur over different time frames, and its interaction with ongoing climatic variability. Our study considers sea level rise to be the quantifiable variable of most concern.
 - Future changes to storm behaviour and subsequent storm surge characteristics are uncertain. As the scientific evidence increases it will become easier to provide reasonable estimates at the scale required for planning by local government. The framework developed by this study can incorporate estimates.
 - The uncertain geomorphological response of the coastline with rising sea levels and changes to storms.
 - The uncertain extent, nature, resilience and value of assets that may be threatened by sea level rise, noting that asset values may be environmental, social or economic; tangible or intangible.

Due to the prominence of uncertainty, risk management has emerged as a preferred approach to coastal planning (Department of Environment and Heritage Protection, 2013; Department of Sustainability and Environment, 2012; OEH, 2013). In Australia, risk management is occurring in a fragmented manner with a number of competing approaches to risk assessment presently being applied.

The aims of this report are to review the approaches, summarise best practice and develop a commensurate framework for applying coastal climate change risk assessment. An analysis of historical case studies was undertaken. Case studies were limited to Australian experience so as to consider the similarities and differences between the approaches of the various state and territory governments.

The first step was to establish a baseline understanding of risk and how it will be described in this report. Comparing risk assessments can be confounded by the adoption of different definitions for words such as “vulnerability”, “sensitivity”, “hazard” and even “risk” itself. A framework for discussing risk is outlined in the next chapter.

1.2 Scope

In developing this framework, the following tasks were completed:

- 1 Establishment of a baseline framework and nomenclature for discussing risk within this report, acknowledging that there are many terms interpreted in different ways by different people when assessing risk (Chapter 2).
- 2 Development of a methodology to assess the adherence of a number of case studies against standard risk management principles (Chapter 3). The developed methodology is significantly qualitative but sufficient to provide an understanding of the approaches and limitations of historical coastal climate change risk assessment in Australia.

-
- 3 Preliminary literature review of a large (but not exhaustive) selection of case studies which have incorporated risk assessment for coastal land use planning and development approval decisions across Australia (Chapter 4).
 - 4 Selection of a small number of case studies which performed well against the criteria established in Item 2 (Chapter 5).
 - 5 Follow up of selected studies through detailed examination and targeted interviews to acquire feedback on the outcomes of the risk assessment process and to assess medium term adoption, barriers to progress through to risk management and overall performance of the risk assessment process (Chapter 5).
 - 6 Formulation and documentation of a recommended methodology for coastal risk assessment, given the findings of prior stages. This culminates in the development of guidance in applying a framework for identifying at-risk coastal hotspots and more detailed risk assessment (Chapters 6 and 7)

The framework is not intended to be a handbook for coastal risk assessment and will need to be considered and adapted or extended for application in different jurisdictions.

2 Risk Assessment and Nomenclature

2.1 Key Points

- The international standard for risk management (ISO 31000) was adopted as the basis for this work.
- Standardisation of the approach to coastal climate change risk assessment, and across the different functions of local government will make it easier to compare competing risks from different areas.
- Within ISO 31000, risk assessment comprises three components: (i) risk identification; (ii) risk analysis; and (risk evaluation), and these three areas are the focus for the present study and framework.
- Risk assessment needs to take account of the objectives of various stakeholders involved in coastal management, and the overall decision making environment of local government. Therefore, the risk management processes of ‘establishing the context’ and ‘communication and consultation’ are also important for successful risk assessment.
- In risk management, confusion arises from the varied and inconsistent use of language. For this reason, we have adhered closely to the nomenclature adopted by ISO 31000.
- A significant change in nomenclature between ISO 31000 and the preceding Australian Standard (AS4360:2004) is redefinition of risk as *‘the effect of uncertainty on objectives’*. Accordingly, coastal climate change risks may have either positive or negative consequences. Furthermore, risks should be determined with reference to the overriding objectives of local government.
- Robust risk assessment should involve significant effort to define levels of uncertainty. The purpose of risk management is to make justifiable decisions in the face of uncertainty.

2.2 ISO 31000: The International Standard for Risk Management

AS/NZS ISO 31000 (Standards Australia, 2009; henceforth 'The Standard') is the present international standard for risk management. Its introduction in 2009 aimed to normalise a standard approach to risk management (including risk assessment), replace a large range of national standards and to extract a common underlying approach to risk management that could theoretically be applied to any industry. Over the latter decades of the 20th century, a number of distinct, industry specific risk assessment methods had evolved and these were inconsistent, meaning that risks from different industries could not be compared.

For organisations, including all tiers of government in Australia, it is common to have a number of 'silo-centric' divisions or departments which would have historically approached risk management in different ways. When the results filter to the organisational levels where decisions are made, this would result in an 'apples and oranges' situation, confounding a clear comparison. The Standard aims to eliminate these inconsistencies, enabling fairer comparison between the competing demands from different branches of an organisation.

Purdy (2010) summarises the above:

“Decision makers are uncomfortable about resolving pieces of apparently similar but fundamentally different information, obtained from different processes and different assumptions, that are described using the same words but that have different meanings”

ISO 31000 is globally accepted and was derived over a period of four years, through seven drafts and involving the input of hundreds of risk management professionals from 28 countries around the world (Purdy, 2010).

Movement towards the standard approach continues, and the approach outlined in ISO 31000 has been adopted as the basis for comparing risk assessment methods within this research study. Those methods which adhere more closely to the standard can be viewed as less likely to become redundant over time and more likely to remain consistent with assessments from different sectors that make up the overall decision making environment for government in Australia.

2.3 The Standard Risk Management Process

The process of risk management outlined in The Standard is as shown in Figure 1.

Risk Management Process

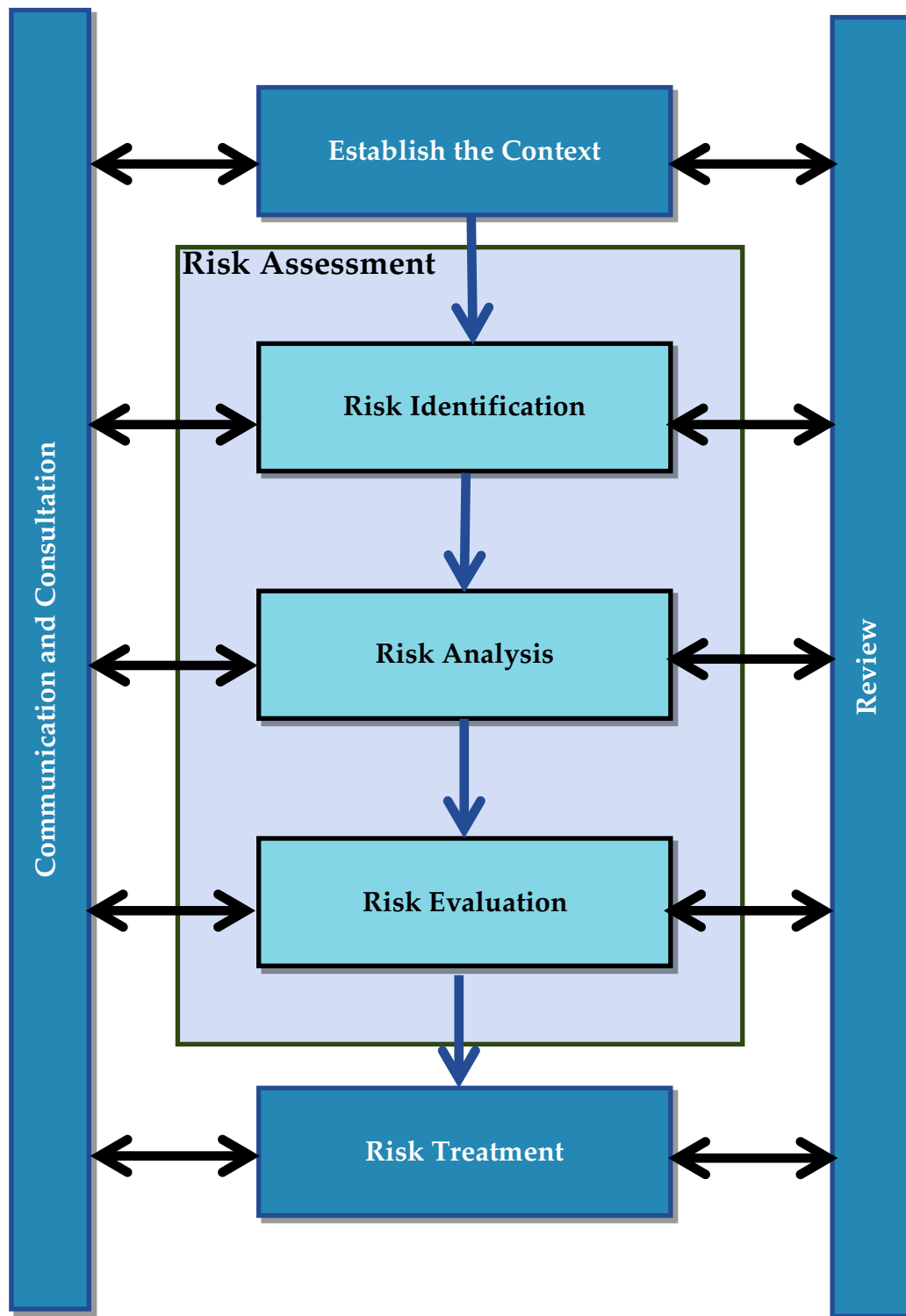


Figure 1 Risk management process from ISO 31000

The risk assessment process, with which this study is primarily concerned, is a subset of the risk management process (Figure 1), which is itself a continuous process involving ongoing review, communication and feedbacks. Strictly, risk assessment contains the following consecutive steps:

- risk identification
- risk analysis
- risk evaluation.

It is not possible to undertake rigorous risk assessment without understanding the decision making context. For that reason, the present study has also considered the decision making environment within which local government works in Australia.

2.4 Standard Risk Management Nomenclature

There are ongoing difficulties with language as industries adjust to The Standard's nomenclature, noting that this may differ from that which has been applied for decades in certain fields. Key definitions are discussed here, beginning with a discussion of 'risk' itself and followed by supplementary terms of importance to risk assessment.

2.4.1 Definition of Risk

The Standard has fundamentally defined risk as the:

"effect of uncertainty on objectives"

...which is somewhat obscure and warrants discussion.

Organisations (companies, government departments, governing bodies, community groups etc.) are established for a particular reason or suite of reasons. Even if these reasons are obscure, or poorly defined, a set of *objectives* relating to those reasons will normally exist for any active organisation.

Organisations typically operate in an environment (governed by factors which may be external or internal to the organisation itself) subject to uncertain events. Whether or not these events occur, and the magnitude of those events, may have an effect on whether the goals of an organisation are achieved or how well they are achieved. The Standard is clear that positive risks may arise from an organisation's operating environment. Risk treatment may attempt to maximise the likelihood of these positive risks, while minimising the likelihood of negative risks.

Purdy (2010) highlights the nature of risks as defined by the standard:

"risks are not events or just consequences. They are descriptions of what could happen and what it could lead to in terms of how objectives could be affected"

This quote points towards a need to comprehensively explain or describe a risk, noting that a full description should include (i) what could happen; (ii) what it could lead to; and (iii) how objectives could be affected.

Over time, a number of methods have evolved to help organisations properly identify and describe risks. A simple pictorial representation follows the shape of a bow tie as, shown in Figure 2.

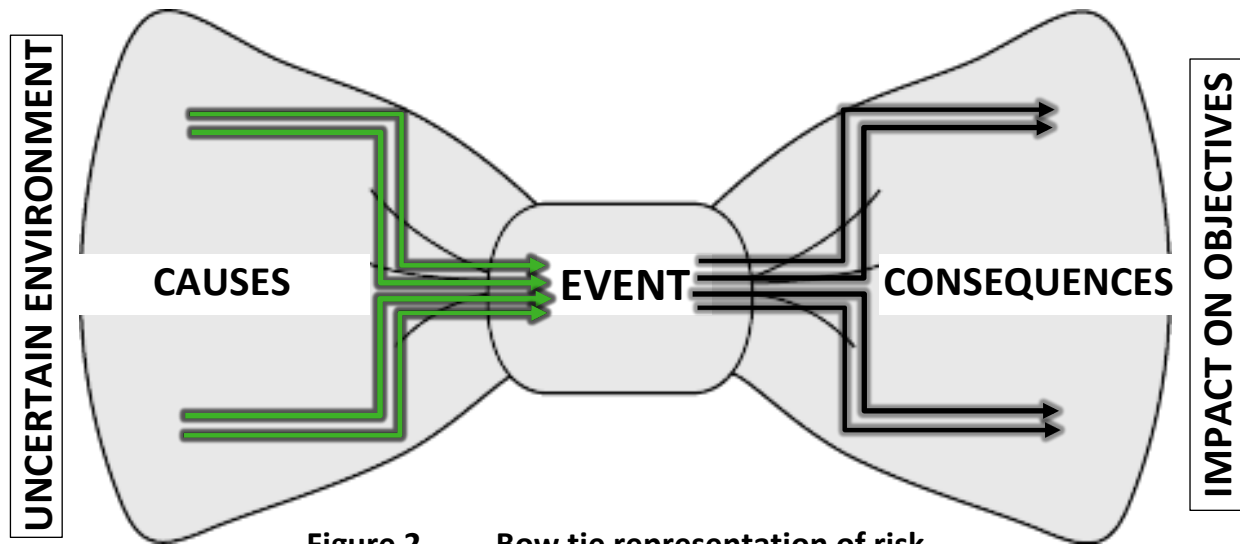


Figure 2 Bow tie representation of risk

The Bow Tie model, in its simplest form, centres on an event. That event is precipitated from one or a number of causes that arise from an uncertain environment. Those causes will have a certain likelihood of occurring. Occurrence of the event has consequences that could potentially impact on the objectives of an organisation. The magnitude and nature of the event (and its causes) will affect the magnitude and nature of the impact.

To undertake successful risk assessment, it is important to completely describe the risk (or effect) on an organisation's objectives. To do so, it is necessary to also describe the way in which causes arise from the environment, how they precipitate the event, and the nature of the consequences and how they impact on the objectives of the organisation.

Utilising tools such as the Bow Tie, it is tempting to think in terms of a cause followed by an effect (i.e. from left to right). This approach prompts initial efforts focussing on the uncertain environment, causes and events. In the coastal context, this would traditionally involve a 'coastal processes' or 'coastal hazard definition' study. Subsequently, a management study would be undertaken to examine the consequences, determine the impacts and the mitigative actions required.

However, The Standard prompts us to approach risk assessment from the 'objectives' side (i.e. right side of Figure 2) from the very beginning. This has a number of advantages including:

- it focuses the risk analysis on those processes and areas of importance to objectives, restricting the scope of potentially costly process studies to that which is of importance to the organisation undertaking the risk assessment

-
- it encourages involvement of stakeholders at a very early stage, and should help to assist in the final acceptance of the risk management outcomes.

A wide range of stakeholder involvement should be sought in identifying risks. When considering climate change, it is important to realise that the degree of understanding of climate change science among different stakeholders will vary significantly. There is still some genuine debate over finer points relating to the reliability of models in predicting particular variables, the reasonableness of future scenarios adopted for projection and the degree to which existing climate variability (particularly at the local scale) is understood. This can confuse decision makers and stakeholders, who may misinterpret minority views as being more representative than they actually are.

Early involvement helps stakeholders and decision makers to be more aware of the balance of scientific opinion along with the fact that uncertainty remains and the nature of that uncertainty. For risk assessment to be successfully completed in accordance with The Standard, there is a need to grapple explicitly with uncertainty.

2.4.2 Supplementary Definitions

These supplementary definitions have been drawn from key references (ISO/IEC, 2009; Purdy, 2010; Standards Australia, 2009), paraphrased where appropriate to highlight their relevance to risk assessment. These definitions will be used in the subsequent assessment presented within this study report.

Communication and Consultation: "Continual and iterative processes that an organisation conducts to provide, share or obtain information, and to engage in dialogue with stakeholders regarding the management of risk". This can be used to gain information on the likelihood, significance or evaluation of a risk. The process is two-way, enabling stakeholders to have a role in influencing decisions. However, it is not a process of joint decision making.

Establishing the context: "define the external and internal contexts of risk management for the organisation". This includes setting the scope for risk management and the risk criteria. The external context is noted to include the "cultural, social, political, legal, regulatory, financial, technological, economic, natural and competitive environment" within which an organisation exists and the ongoing trends operating in that environment. Certain standards and guidelines will likely set parameters within which an organisation must operate. Also important are the perceptions, values and relationships of external stakeholders. The internal context includes governance, organisational structure roles and accountabilities, policies, objectives and strategies, available resources and knowledge, culture and relationships between internal stakeholders.

Risk criteria: These are the metrics against which the significance of a risk will be assessed, and will relate to the context and objectives of the organisation. Those criteria may be derived from requirements such as those present in law, standards or policies.

Risk Assessment: Within The Standard, this involves three components: (i) risk identification; (ii) risk analysis; and (iii) risk evaluation.

Risk Identification: Ideally, this is a systematic process to identify and describe risks. Description should involve the identification of the causes leading to an event, the event itself and the consequences of that event. The consequences should be described in terms of their impact upon the objectives of the organisation.

Risk Description: A formulaic statement of risk containing sources (elements that have the intrinsic potential to give rise to risk, including hazards: which have the potential to harm), event (occurrence or change of a particular set of circumstances, also 'incident' or 'accident') and consequences.

Risk Analysis: A process to determine the magnitude of a risk (i.e. risk estimation). This process will normally result in a more thorough understanding of the nature of that risk and will feed, at a later stage of risk management, into the development of risk treatment options and decision making. Classically, it involves evaluating the likelihood of a risk arising and the consequences of that risk occurring.

Likelihood: The probability, frequency or chance of something happening over a given time period. This can be objective / quantitative, or subjective / qualitative.

Exposure: Extent to which an organisation or stakeholder is subject to an event.

Consequence: Outcome of an event which has an impact on the objectives of an organisation. The impact may be positive or negative and may be expressed quantitatively (i.e. \$ value) or qualitatively (moderate, severe etc.). Consequences can be complex and interrelated.

Probability: Quantitative measure of the chance of occurrence, expressed as a number between 0 and 1, where 0 is impossibility and 1 an absolute certainty. Note that this is a narrower, more mathematically constrained term than 'likelihood' in The Standard.

Vulnerability: An intrinsic property of something, resulting from those characteristics which determine its susceptibility to a risk source, and any subsequent events which may lead to a consequence.

Risk Matrix: A tool for quantifying, ranking and displaying risks by defining two axes comprising ranges for consequence and likelihood.

Level of Risk: The magnitude of a risk, often derived through use of a risk matrix. This may be a qualitative magnitude (low, medium, high etc.) or a \$ value (calculated by *likelihood of risk event* (0-1) \times *\$ value of event consequences*)

Risk Evaluation: The process of comparing the level of risk (from risk analysis) with the risk criteria, to determine whether the risk is acceptable or tolerable to the organisation. The level of tolerance will be expressed in the risk criteria and will stem largely from the culture, resilience, capabilities and nature of the organisation.

3 Assessment Methodology and Case Study Selection

3.1 Key Points

- A key, required outcome of NCCARF was the identification of case studies of best-practice application of risk assessment techniques. We reason that best-practice is represented by coastal climate change risk assessment studies that have resulted in well formulated actions that have been subsequently followed up. In other words, the risk assessment has proven a useful basis for further work and decision making.
- A first step in this process was a methodical desktop literature review of past climate change studies. Our review was limited to the past application of coastal climate change risk assessment in Australia, driven by our desire to ultimately identify where useful follow up activity has occurred. The approach is qualitative, but considered suitable for this purpose.
- The risk assessment sections of ISO 31000 were reviewed to identify the elements of an idealised risk assessment study. A series of questions, based on those elements, were derived to assess case studies of coastal climate change risk assessment in Australia.
- The questions were weighted and organised into an assessment table to enable studies to be ranked in terms of compliance with the requirements of ISO31000.
- The weights were based on the experience and discussions among study team members and then forwarded to NCCARF for comment before proceeding. There are significant qualitative aspects to the assessment, but the methods followed process was sufficient to provide an understanding of the approaches and limitations in an Australian context.
- Following the lead of the literature review in NCCARF (2015) an internet search for Australian risk assessment studies on coastal climate change adaptation and sea level rise was undertaken to identify case studies.
- A sample of 28 risk assessment studies were identified and reviewed, although not all studies covered all risk assessment stages.

3.2 Assessment Methodology

An assessment methodology was derived primarily by reviewing The Standard and associated documents, as outlined in the previous chapter. From that review, questions were formulated that could be used to determine how well a risk assessment activity compared against The Standard.

These questions were subsequently re-ordered in accordance with the stage of risk assessment to which they refer.

- Establishing the context, while strictly not a part of the standard Risk Assessment process, it is essential that this is done well to focus the study appropriately. The best risk assessment methods available are likely to achieve nothing unless they are warranted by an appropriate consideration of context.
- Risk identification
- Risk analysis, typically including ‘likelihood’ and ‘consequences’
- Risk evaluation
- Communication and consultation, while strictly not a part of the risk assessment process, is important for the overall effectiveness of risk management. Suitable levels of consultation and communication are necessary to gain the confidence of stakeholders.

The adopted assessment table is presented in Table 1. The categorised questions are presented, along with the weighting that was applied to each question (and stage) of an idealised assessment. Overall, ‘establishing the context’ and ‘communication and consultation’ were seen as being very important but, as they are not strictly part of The Standard’s definition of risk assessment, were given a total weighting of 30% (15% each). Considering the remaining aspects of risk assessment, we note that ‘risk analysis’ often comprises the majority of effort required to complete the risk assessment and detailed, rigorous studies require a high level of detailed and specialised expertise. Furthermore, risk analysis is likely to be revisited at a later stage of the management process when risk treatment options are being formulated and assessed. Accordingly, risk analysis was weighted particularly highly, and this was divided into two parts; likelihood and consequences (25% each). In comparison, ‘risk identification’ and ‘risk evaluation’, while necessary parts of the process, take less effort and can be achieved relatively easily, provided that a structured approach to these tasks is taken. These two components of risk assessment were each weighted at 10% of the total.

The weightings were discussed among study team members and forwarded to NCCARF for concurrence, prior to the assessment of any case study reports.

Broadly, analysis has progressed in two stages. Initially, keeping in mind the questions outlined in Table 1, all identified risk assessment studies were reviewed. A descriptive assessment corresponding to the questions presented in Table 1 was prepared for each study. Once these descriptive assessments had been prepared for

all studies, the weightings in Table 1 were applied and scores were assigned for each aspect of the subject study, resulting in an overall score out of 100.

3.3 Literature Search and Case Study Selection

3.3.1 Methodology

A detailed assessment of the existing science and regulatory framework was documented by NCCARF as part of a state-of-play report (NCCARF, 2015). The report has been used as the foundation for identifying studies that could be considered as part of the present research effort. The State-of-Play report divided its findings into the stages of a basic adaptation framework;

- establishing the context
- analysing the problem and making decisions
- implementation, monitoring and evaluation.

Our consideration was limited to the first two points.

The approach of NCCARF (2015) involved a search through *Web of Science* to identify the academic literature relating to adaptation and coastal management in Australia. That review was current at April 2015. For this study, we have replicated the Web of Science search to update the list of relevant studies using the following search terms:

- “coast* AND climate change adaptation AND Australia”
- “coast* AND sea level rise AND adaptation AND Australia”.

The list of search results was limited to those dealing with risk, and addressing the risk management stages relevant to the present study. The results from those searches were combined with the journal article abstracts presented in Section 4.1 of NCCARF (2015).

All of the abstracts were reviewed and those of limited expected use to the present study have not been considered further. Generally, the peer reviewed literature did not contain the detailed case study information required for us to undertake our assessment. However, there were a number of papers that are of some interest in terms of emerging analysis techniques that may be consulted to inform selection of an appropriate method. The list of papers is presented in Appendix A (Table A1).

Table 1 Assessment Table for Risk Assessment Projects

Risk Assessment Stage	Relevant Questions	Weighting	Stage Weighting
Establishing the context	Has the scope of the risk assessment been adequately defined, including the time frame and geographic extent?	2.5	15.0
	Have stakeholders been identified?	1.5	
	Have the relevant legal requirements, standards and policies been identified?	1.5	
	Have relevant risk criteria been established at the outset of the study, including establishment of the way in which risks will be evaluated, including consideration of whether quantitative or qualitative measures might be applied?	2.5	
	Were stakeholders appropriately involved in the determination of risk criteria as part of context setting exercises?	2.0	
	Prior to Risk Assessment being undertaken, were suitable efforts made to understand the <i>external</i> context and environment for the risk assessment?	1.5	
	Prior to Risk Assessment being undertaken, were suitable efforts made to define the <i>internal</i> context and environment for the risk assessment?	1.5	
	Does the method incorporate an up-front focus on the objectives of local government and have those objectives been well defined?	2.0	
Risk identification	Was a systematic method used to identify the risks?	3.0	10.0
	Have the views of stakeholders been appropriately incorporated into the risk identification process?	4.0	
	Are risk descriptions presented, including consequences, their impact on objectives, the risk sources and how they arise from the environment, along with the central event itself?	3.0	
Risk analysis: likelihoods	Has the best available information been used to assess likelihoods and is use of the data justified?	8.0	25.0
	Have suitably robust methods been used to assess the likelihood, given the available data and study constraints, and has use of those methods been justified? Is uncertainty explicitly addressed?	12.0	
	Has the scale of likelihoods been determined sufficiently in a way that is consistent with well defined “risk criteria”?	5.0	
Risk analysis: consequences	Has the best available information been used to assess consequences and is use of the data justified?	8.0	25.0
	Have suitably robust methods been used to assess the consequences, given the available data and study constraints, and has use of those methods been justified?	12.0	
	Has the scale of consequences been determined sufficiently in a way that is consistent with well defined “risk criteria”?	5.0	
Risk evaluation	Has risk evaluation been undertaken?	5.0	10.0
	Is the method of risk evaluation consistent with the established risk criteria and the likelihood and consequences assessments?	3.0	
	Has the risk evaluation clearly indicated those risks that need further consideration?	2.0	
Communication and consultation	Have stakeholders been informed of the methods used in risk analysis and are they aware of the justification for use of those methods?	4.0	15.0
	Was the knowledge of stakeholders leveraged to obtain information on the likelihood and consequences of risks?	7.0	
	Have the outcomes of the risk assessment been adequately communicated (i.e. quality of reporting).	4.0	

Grey literature of relevance were identified in Section 4.2 of NCCARF (2015). These included numerous frameworks, guides or manuals incorporating aspects of coastal risk assessment. While these are not case studies that demonstrate application of coastal risk assessment, they are of background importance to understanding Australian practice in the field of coastal risk assessment. The list of identified guidance documents is presented in Appendix A (Table A2). Similar to the journal articles, these documents were referenced, in the study.

The grey literature review of NCCARF (2015) identified a number of geographically specific case studies incorporating elements of risk assessment. These are of most interest to our present study. The review of NCCARF was augmented with studies identified by the present study team, based on our own experience working in this area and a standard Google web search (using the terms ‘oastal’ and ‘risk assessment’ and limiting results to the Australian top level domain). The studies identified are presented in Table 2, and it was these studies that were carried forward for assessment.

NCCARF (2015) also provided numerous references to information, such as data sources, which are of relevance to the consideration of best practice. However, data availability and its overall quality is very fluid at the present time, and any definitive advice on the best data sources to adopt is likely to become outdated rapidly. The Bureau of Meteorology, the IPCC, CSIRO and Geosciences Australia have historically provided reliable and defensible information and a proposed function of *CoastAdapt* is to provide access to up to date data. Care is needed to ensure that information from any source is up to date. It will remain the responsibility of individual practitioners to investigate the most appropriate data to use when undertaking a risk assessment and whether there are data gaps that need to be filled.

Table 2 List of case study literature identified for assessment

Case Study Author and Title(2012)

Marsden Jacob Associates (2010a) Coastal Councils - Climate Change Adaptation Plan (for HCCREMS)

and

Marsden Jacob Associates (2010b) Potential Impacts of Climate Change on the Hunter, Central and Lower North Coast of NSW

SEA Systems Engineering (2010) High Resolution Storm Tide and Climate Change Impacts Study

S. Martin, D.Moore and M.Hazelwood (2014) Coastal Inundation Modelling for Busselton, Western Australia, Under Current and Future Climate

Flocard et al (2013) Future Coasts- Port Fairy Coastal Hazard Assessment

Climate Adaptation in Coastal Caravan Parks: 3 Reports

Blackwell, Boyd (2012) Report 1: Economic Value and Equity Literature Review

Walker C, Blackwell B and Rolf, John (2012) Report 2: Economic Value and Equity Research Report

Tsioulos, C (2012) Report 3: Economic Value and Equity Decision Support Framework

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

Australian Government: Department of Climate Change and Energy Efficiency (DCCEE, 2011) Climate Change Risks to Coastal Buildings and Infrastructure

Cockburn Sound Coastal Alliance (Coastal Zone Management et al., 2013) Reports have been prepared for the “Coastal Vulnerability” and “Coastal Values and Risk Assessment”.

ACIL Tasman, (2012) Climate Change Adaptation Options Assessment: Developing Flexible Adaptation Pathways for the Peron Naturaliste Coastal Region of Western Australia

Case Study Author and Title(2012)

URPS and Seed Consulting Resilient South Regional Climate Change Adaptation Plan (Cities of Holdfast Bay, Marion, Mitcham and Onkaparinga)

Plus 2 Additional Reports

URPS and Seed Consulting (Resilient South, 2014a) Resilient South Climate Change Risks, Opportunities and Vulnerabilities in the Southern Region

URPS and Seed Consulting (Resilient South, 2014b) Resilient South IVA Technical Report

GHD Australia (2009) Climate Change Risk Management and Adaptation Action Plan for the Southern Metropolitan Councils

GHD Australia (2012) Townsville Coastal Hazard Adaptation Strategy :Appendices A (Vulnerability and Risk Assessment) and B (Economic Assessment)

Central Local Government Region of South Australia (2011) Central Local Government Region Integrated Climate Change Vulnerability Assessment – 2030

Jones, R & McInnes, K (2004) A Scoping Study on Impact and Adaptation Strategies for Climate Change in Victoria

BMT WBM (2009) Port Stephen Council – Local Adaptation Pathways Program for Climate Change Assessment

SGS Economics and Planning Pty. Ltd. and Water Research Laboratory, University of New South Wales (2008) Climate Change Impacts on Clarence Coastal Areas

Coastal Zone Management Pty. Ltd. (2009) Mandurah Coastal Zone Climate Change Risk Assessment and Adaptation Plan Report

Ku-ring-gai Shire Council (Unknown) Climate Change Adaptation Strategy – Ku-ring-gai Shire Council

Marsden Jacob and Broadleaf (2009) Climate Change Risk Assessment and Adaptation Plan

Heyward, Oliver; Graham, Katrina; Green, Graham (2013) Latrobe Council Corporate Climate Change Adaptation Plan. Southern Tasmanian Council's Authority

Climate Risk Pty Ltd (2010) Climate Change Risk Assessment: Kempsey Shire Council

Case Study Author and Title(2012)

Royal Haskoning (2014) Coastal Zone Management Plan for Collaroy-Narrabeen Beach and Fishermans Beach

Lake Macquarie City Council: Coastal Zone Management Plan

BMT WBM (2015a) Swansea Channel Hazard Study and Risk Management Assessment

BMT WBM (2015b) Lake Macquarie Coastal Zone Hazard and Risk Assessment

Woodroffe, C et al (2012) Approaches to risk assessment on Australian coasts

Ped et al (2011) Risk Assessment of Impacts of Climate Change for Key Marine Species in South Eastern Australia

SKM (2012) Coastal Climate Change Vulnerability and Adaptation (for the Great Ocean Road Coast Committee)

NACC, Curtin University and West Australian Planning Commission (Northern Agricultural Catchments Council et al., 2015) Irwin Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) Literature Review

AECOM (2012) Bayside Climate Change Strategy – A Plan for Council’s Operations

Gurran et Al (2011) Planning for climate change adaptation in Coastal Australia: State of Practice

AECOM (2012) Climate Change Risk Assessment and Adaptation Planning: Tiwi Island Shire Council

Coastal Zone Management Pty Ltd (2008) Vulnerability of the Cottesloe Foreshore to the Potential Impacts of Climate Change

BMT WBM (2011) Kakadu-Vulnerability to climate change impacts.

Australian National University (2009) Implications of climate change for Australia’s World Heritage Properties: A Preliminary Assessment.

Water Technology (2014) Western Port Local Coastal Hazard Assessment

3.3.2 Case Study Evaluation Process

Each of the studies in Table 2 was reviewed, with particular focus paid to the summaries, conclusions and sections that dealt specifically with aspects of risk assessment. A review sheet was established for each study, containing the questions presented in Table 1 and a space for recording observations of relevance against each question. These observations were essentially qualitative in nature. No scoring was undertaken at this point in time.

Once each study had been reviewed in this way, the answers to each individual question were collated for comparison. Identifying information was removed. By grouping the statements next to each other, it was simple to assign scores relatively in accordance with Table 1 to each individual response. The relative score given to each study was therefore consistent across all studies. Some questions were not relevant to some studies. For example, in some instances, it was clear that only hazards were being considered, meaning that questions relating to the consequences of those hazards were irrelevant to that particular study. In this case, they were assigned a value of 'N/A' for subsequent filtering. In some cases, studies effectively had no relevance in terms of risk assessment. This has occurred, for example, where a study was initially identified, but the authors had adopted a meaning for the term 'risk assessment' which was not similar to the standard definition in ISO 31000.

The scores assigned across the board are presented in Appendix A. Note that the study names are not presented; they have been replaced with a number. It was not considered necessary to report on those particular studies which were assessed as performing particularly poorly or well. The purpose of this study is to consider performance as a whole, such that areas where poor performance is common could be focussed upon as part of the framework for best practice which is the key outcome of this study.

The tabulation of all scores has been further summarised into the six risk assessment stages of Table 1. Where any single question pertaining to a risk assessment stage was assigned a value of 'N/A' for a particular study, that study was assigned an overall value of 'N/' for that stage. This reduced the size of the sample for each stage, but enabled statistical examination of the scores.

In summary, 35 individual studies (or projects where multiple studies were available) were considered. Of these, seven were false positives meaning that they had limited relevance in the context of ISO 31000. These were eliminated, leaving 28 studies in total. Of those, not all claimed to deal specifically with all risk assessment stages, meaning that the sample size for most stages was less than 28. The sample sizes are presented in Table 3.

Table 3 Sample size of studies specifically dealing with the different risk assessment stages (Total 28)

Risk Assessment Stage	Sample Size
Establishing the context	20
Identifying risks	23
Risk analysis – likelihoods	27
Risk analysis – consequences	25
Risk evaluation	21
Communication and consultation	28

4 Outcomes of Case Study Assessment

4.1 Key Points

- The identified case studies were assessed.
- In 'establishing the context' studies tended to identify the geographical extent and hazards of concern to the study. However, consideration of the internal risk environment, legal/regulatory environment and overriding objectives of local government were often not reported.
- Overall, it was common that there was limited evidence of systematic 'risk identification' to provide clear descriptions of each risk of concern. Where efforts were made, it was common for only staff from the local council to be involved, whereas broader stakeholder involvement could have achieved better outcomes.
- The analysis of risk likelihoods has commonly been limited by, for example, adoption of a preferred climate scenario or set of scenarios without clear attempts to assign likelihoods to the scenarios. Accordingly, the likelihoods reported are 'conditional'. Generally, this approach has been either advocated by state government policy, or alternatively, more robust assessment of likelihood was not possible due to a lack of available information
- The analysis of risk consequences was typically completed in a methodical, albeit cursory, qualitative manner. There were stand out examples where detailed analysis of the value of assets fed into a robust consequences assessment
- Risk evaluation was most typically completed using the guidance of a risk matrix, combining consequence and likelihood to assign a qualitative risk level (high, very high, low etc.). While methodical and consistent with the high level approach of many of the studies reviewed, such an approach does not support more advanced analysis of adaptation options, such as cost benefit analyses.
- In some instances, communication and consultation efforts appear to have been limited.

4.2 Outcomes of Past Study Review

4.2.1 Establishing the Context

The average score for assessed studies was 7.8 out of a possible 15 (sample size 20) and was slightly negatively skewed. No study scored perfect marks. The highest score was 13/15. A histogram of results is presented as Figure 3.

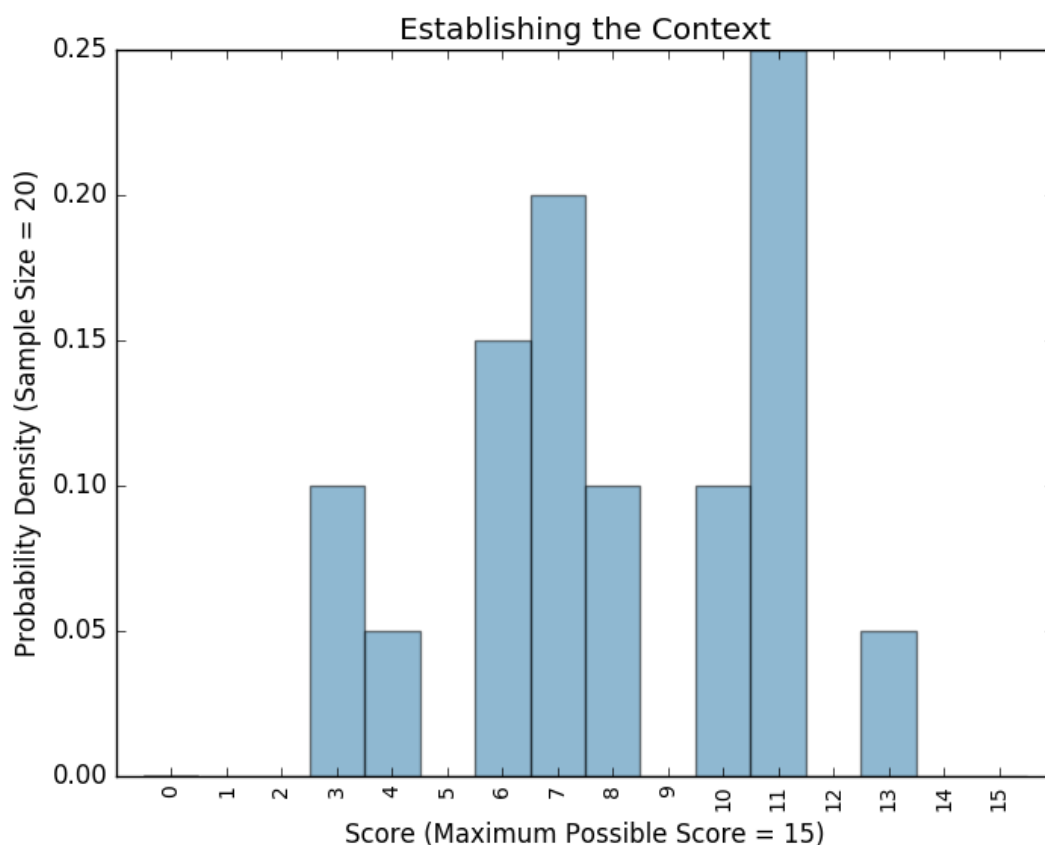


Figure 3 Histogram of Study Results for ‘establishing the context’

While The Standard does not include establishing the context as part of a risk assessment, it makes sense that study reports should have a background summary of the reasons why and context within which the report is being undertaken. This understanding is essential as a base for justifying the scope and approach taken during risk assessment.

For the most part, studies tended to document the subject geographical extent and outline the hazards of concern as part of the introduction to the report. However, while this establishes the scope, issues such as internal risk environment and the objectives of local government were poorly considered. These issues are fundamental in affecting the willingness and ability of local government to adequately manage risk. Furthermore the legal / regulatory environment which establishes the various responsibilities of local government was often either not documented or poorly understood.

It could be argued that some of these contextual issues are inherently understood and that the risk assessment can be completed in isolation with no need to document the context. However, this approach is inappropriate for reports that are destined for scrutiny by the general public and a wider range of community groups and government stakeholders that may not otherwise have a clear picture of the objectives and scope of responsibilities of local government. Furthermore, without setting a firm foundation for the remaining risk assessment, it is easy for remaining stages of the study to become derailed. For example, it is impossible, without understanding the objectives of local government, to identify those risks that are of concern to local government.

Finally, one area where mixed results were achieved was that of risk criteria. Many of the studies reviewed were completed using funding from the former Department of Climate Change and Water, under the Local Adaptation Planning Pathways (LAPP) program. One of the criteria for that program was that the methodology outlined in guidelines published by the (then) Australian Greenhouse Office (Broadleaf Capital International and Marsden Jacob Associates, 2006) be applied to the risk assessment. That document provided clear guidance on the risk criteria to be applied and a number of studies performed well in that regard. In the absence of those guidelines, it was not uncommon for very limited attention to be paid to these criteria for success at an early stage. These need to be considered and documented up front during the risk management process. The alternative of waiting until risk analysis is completed can result levels of acceptance of risk being influenced by a desirable outcome which is determined by factors that are not of primary relevance to the risk assessment process (such as political objectives or ideological beliefs).

In short, establishing the context is critical for successful risk assessment. It appears that, for coastal management around Australia, it has rarely been well executed. There is certainly a need to provide clear guidance for this stage of risk assessment.

4.2.2 Risk Identification

The average score for assessed studies was 3.9 out of a possible 10 (sample size =23) and was noticeably positively skewed. A histogram of results is presented as Figure 4.

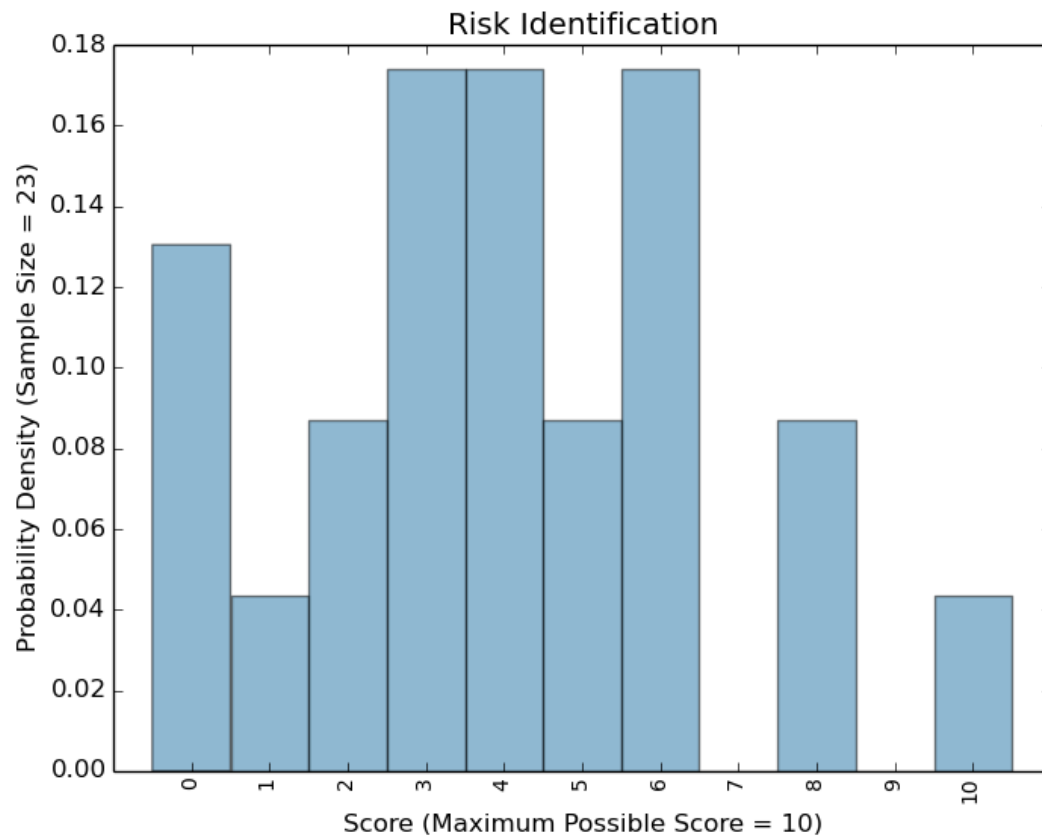


Figure 4 Histogram of results for ‘risk identification’

Risk identification was generally completed poorly. The overall scores were lower than for establishing the context, although two studies did score full marks. Those studies which reasonably addressed this stage of the process were undertaken as part of the LAPP program. The relevant guidelines (Broadleaf Capital International and Marsden Jacob Associates, 2006) provide specific guidance on holding a workshop, brainstorming and providing clear descriptions of risks. Of note, however, is that those guidelines were based on the 2004 Australian Standard for Risk Management (Standards Australia, 2004), and defined a risk as:

“The chance that something happening that will have an impact on the organisations objectives”

...which focuses on chance (or *likelihood*) only and is somewhat inconsistent with risk being evaluated as a combination of both likelihood and consequences. While the more recent international standard is based on the previous Australian standard, this anomaly has been corrected with the more consistent definition presented in Section 2.4.1.

Even though risks were identified at a workshop as part of these studies, it was common that the assessment only involved facilitators and staff from the local council. While it is reasonable for council staff to make up the majority, a more diverse composition for the workshop would have been desirable. It is true that risk assessment should focus on the objectives of local government. However, local councils do not act in isolation from their community or other tiers of government.

In Australia, local government is effectively an agent of state government which exerts control over the way in which local government is to operate. Therefore, it seems imperative that such workshops should involve representation from state government agencies. Similarly, local communities are a primary stakeholder. Ideally, risk identification should be more inclusive, including councillors, broad community representation and local government stakeholders.

4.2.3 Risk Analysis – Likelihoods

The average score for risk analysis for assessed studies was 13.6 out of a possible 25 (Sample Size = 27) and was negatively skewed. A histogram of results is presented as Figure 5.

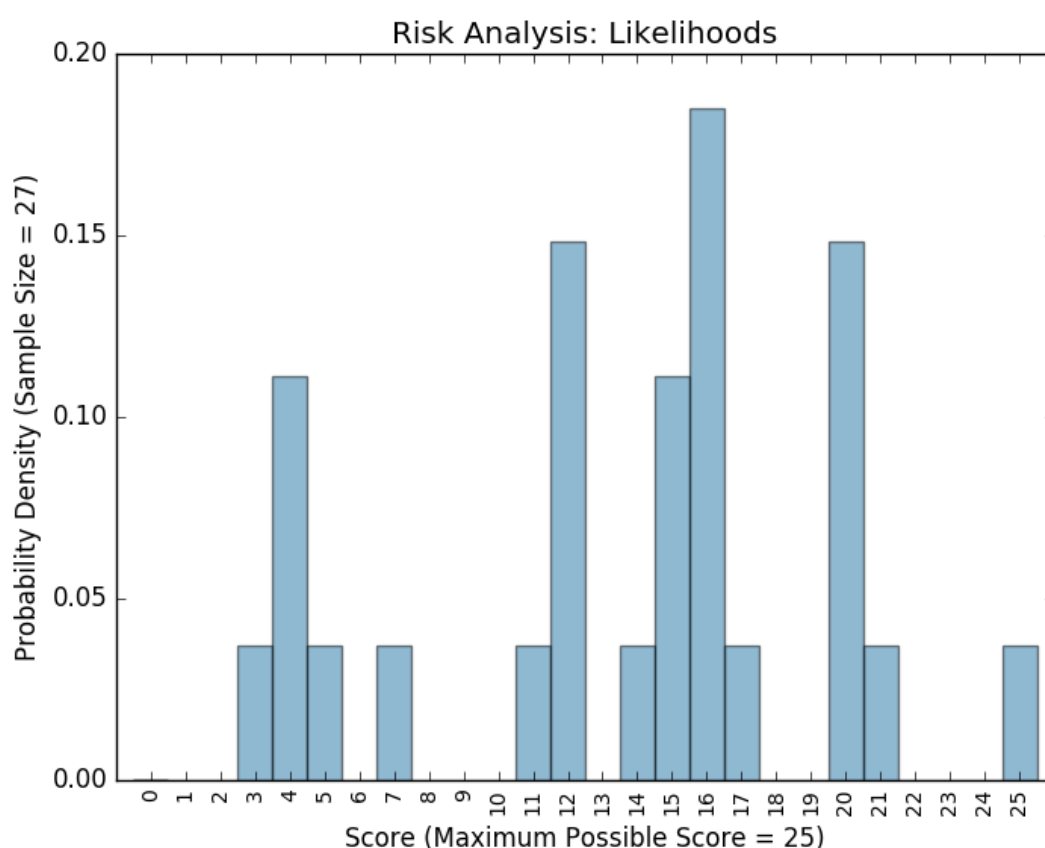


Figure 5 Histogram of results for ‘risk analysis - likelihoods’

Associating likelihood with a particular level of climate change is a particularly vexing issue. The studies reviewed as part of this study were primarily completed prior to the release of AR5 (IPCC, 2013) and therefore informed by the findings of AR4 (Pachauri, 2007). Considering sea level rise (probably the most important coastal climate change variable), Hunter (2010) noted that the 5 to 95% ranges that could be derived from AR4 were measures of the uncertainty in the distribution of model estimated sea level rise, and not the distribution of possible future projections. In other words, AR4 provided a measure of how much model results were spread, but it was not considered that this was representative of actual likelihoods.

In AR5, the authors have taken the additional step of equating the 5 to 95% of model results with the 'likely' range (~17 --83%) of foreseeable outcomes (Wainwright et al., 2014). It has therefore become possible to attribute meaningful likelihoods to particular levels of sea level rise at different points in time. However, those likelihoods are still conditional on the adoption of a particular Representative Concentration Pathway (RCP) of which four are provided in AR5. No guidance on the likelihood of any particular RCP is provided in AR5, but all are considered 'plausible' and 'illustrative'.

In the absence of more rigorous advice, councils are therefore led to either consider them to be equally likely, or to undertake independent assessment of the individual likelihoods of different RCPs. This is a task that local councils may be asked to consider, but it is unreasonable to expect them to have the resources necessary to do so in a meaningful manner. Selective use of any given RCP is likely to be qualitative and influenced by ideological concerns.

Aside from the limits to which the results of AR5 could be applied, practitioners are asked to assess risk likelihoods when, at a state level, it is common for a particular projection or benchmark of levels at particular points in time to be specified by state governments. Those benchmarks have often been set without any indication of likelihood although they tend to sit, understandably in the absence of a rigorous risk assessment, towards the conservative end of ranges published by the IPCC. There are local policies and guidelines which advocate, for example, that planning decisions are made with due regard to the precautionary principle in terms of sea level rise (for example NSW Government, 1997).

Being cautious in selecting a benchmark could be interpreted as 'precautionary' in line with the principles of ecologically sustainable development (ESD) and adherence to ESD principles is considered to be in the public interest. Therefore adoption of a high benchmark may be considered a prudent approach. However, selecting a particular sea level rise projection (derived for example, from one of the RCPs in AR5, adjusted to local conditions) effectively makes the risk assessment 'conditional' and therefore transparent risk-based decisions become more difficult.

From a risk assessment point of view, a more robust approach is to consider a wider range of projections, but to be more risk averse when selecting a tolerable risk level.

Effectively, the present regulatory environment for sea level risk planning in Australia has not allowed for a meaningful assessment of likelihood. The most common approach has been to apply benchmark values, and possibly undertake a sensitivity analysis on consequences for higher and lower values, with those values commonly being provided from modelling by specialised organisations, such as the CSIRO. There was one study which scored full marks for likelihood assessment, as it managed to place meaningful likelihoods onto different sea level rise projections, using the results of AR5. In discriminating between other studies, consideration was given to the rigour applied in transferring sea level rise information to a coastal hazard (such as erosion, shoreline recession or inundation).

A myriad of methods are available for coastal hazard assessment, ranging from simplistic methods such as the Bruun Rule for recession, or the bath tub method for

inundation assessment, to sophisticated numerical modelling. The applicability of different methods is governed largely by the scope of the assessment and the availability of suitable data. In most instances, studies had access to high quality data such as detailed tide records and LIDAR elevation data. However some aspects of coastal processes are still poorly understood.

4.2.4 Risk analysis – consequences

The average score for assessed studies of risk analysis was 16.7 out of a possible 25 and was strongly negatively skewed. A histogram of results is presented as Figure 6.

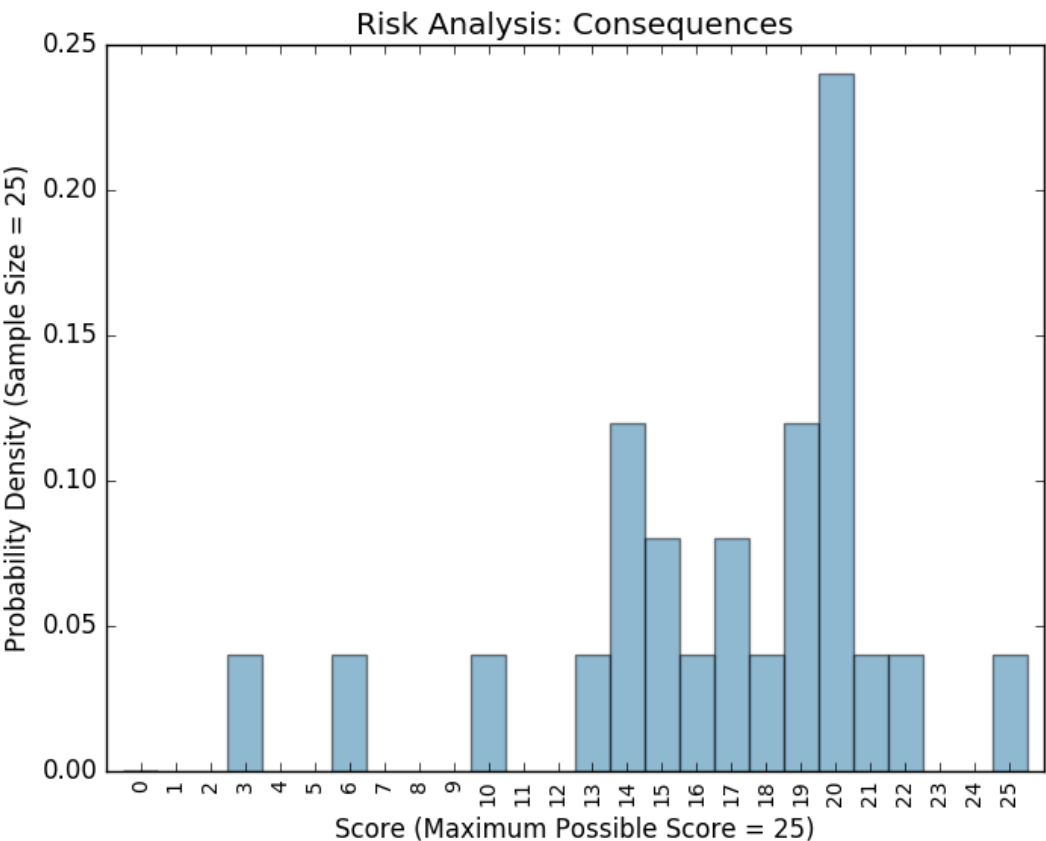


Figure 6 Histogram of results for ‘risk analysis - consequences’

The consequences side of risk analysis was completed relatively well, although there are notable poor examples which tend to arise from studies that purport to be full risk assessments, but are primarily hazard assessments. In the context of the responsibilities of a coastal council, the consequences assessment is largely a geographical/spatial problem. Once the extent of hazards for a given likelihood are determined (e.g. elevation when considering inundation or horizontal extent when considering shoreline recession) it is a matter of determining the assets that are spatially affected, their ability to withstand or recover from that hazard, and the value of the asset.

In this discussion, the assets could come from a range of different types (e.g. infrastructure, private property, public facilities, environmental) and there are many different ways in which values can be assigned. Ideally, a dollar value is assigned,

but this is difficult when considering the value of environmental assets and more intangible aspects like beach recreational values.

Even so, there are established methods for assessing these, and to facilitate decision making, it is important that values are expressed in a common way to enable a fair comparison of risks.

The majority of studies that actually completed a consequences assessment did so in a fairly cursory and qualitative manner. This was a common approach for studies funded by the LAPP program. There were, however, stand out examples where significant effort was placed on assigning dollar values on intangible aspects of assets.

4.2.5 Risk Evaluation

The average score for assessed studies on risk evaluation was 8.4 out of a possible 10 and was strongly negatively skewed. A histogram of results is presented as Figure 7.

Our review indicates that most studies completed this in a competent manner. We expect this arises from the availability of a standard risk matrix in order to combine likelihood and consequences with relative ease.

Unfortunately, the results that are produced from risk evaluation, typically assigning levels of 'very high', 'high', 'medium' or 'low' to each identified risk, can very effectively hide limitations in other aspects of the analysis. In the absence of rigorous analysis and the development of suitable criteria for evaluation, the risk evaluation can be reduced to a qualitative assessment which returns results that are in line with expectations that were present from the outset of the risk assessment process. As the outcome of the process meets the expectations, there is lesser tendency for the results to be scrutinised.

Such an outcome defeats the purpose of the entire exercise. Ideally, it should tease out and evaluate risks which would otherwise have been unexpected and highlighting where the consequences relating to those are unacceptable.

The entire process needs to be undertaken with an open mind, for the final risk evaluation to be valid. For this reason, the inputs from a range of stakeholders with different interests and backgrounds are important, as discussed in Section 4.2.2.

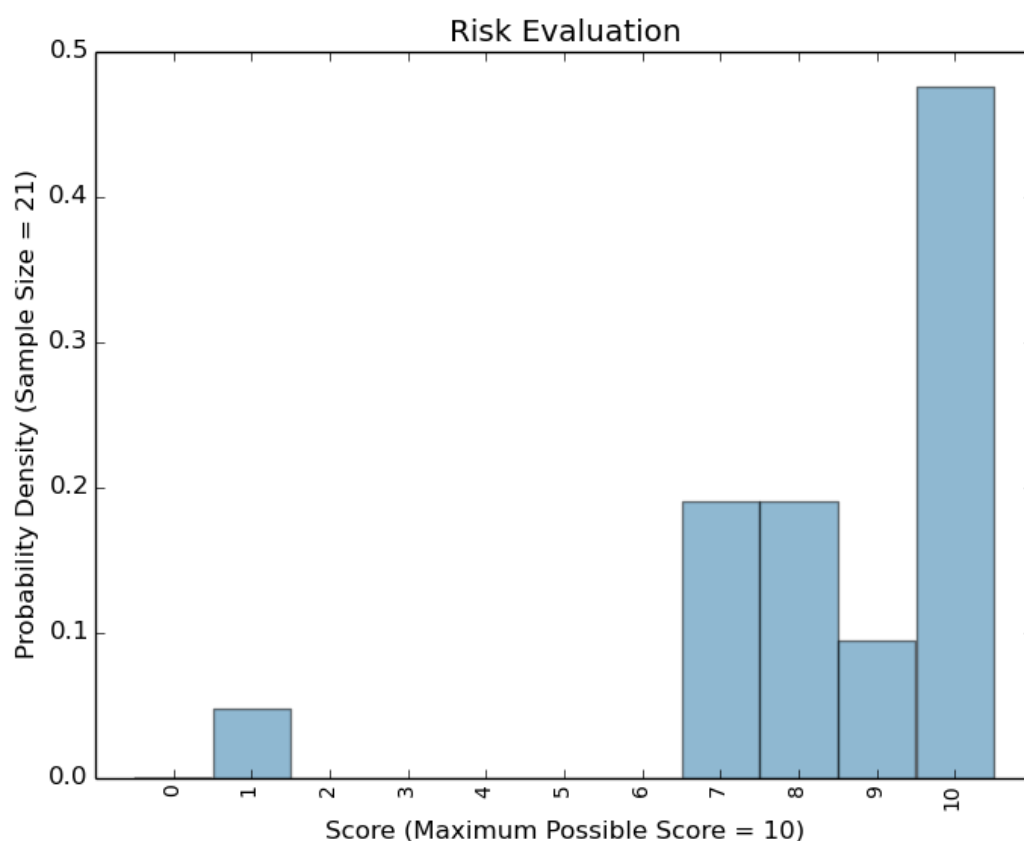


Figure 7 Histogram of results for ‘risk evaluation’

4.2.6 Communication and consultation

The average score for assessed studies on communication and consultation was 8.8 out of a possible 15 with a very slight positive skew. A histogram of results is presented in Figure 8.

The results here reflect the quality of reporting (given the reports were the primary basis of our analysis at this stage). However, higher marks were awarded where it was clear that efforts were made to consult with stakeholders and the community prior to and following the main risk assessment phase. It was very rare that we could find evidence of communication and consultation following the model demonstrated in Figure 1. Therein, reporting and feedback with stakeholders is indicated at every step of the process, including having inputs to risk identification and the methods that are to be used for risk analysis.

Generally, there was limited evidence that stakeholders were actively engaged when deciding the appropriateness of different methods that would be used throughout the process, including those used in analysing risks.

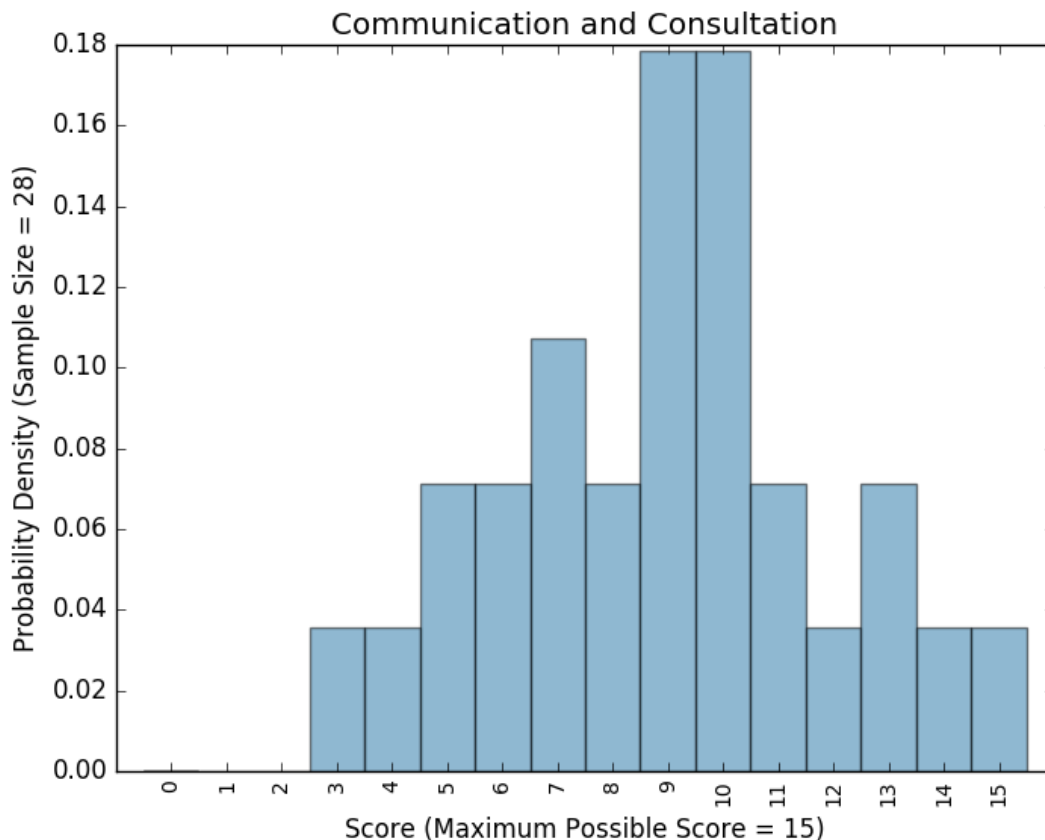


Figure 8 Histogram of results for 'communication and consultation'

4.3 Overall Observations

The utilisation of formalised coastal climate change risk assessment is relatively recent in Australia, having only been applied over the past decade in the experience of the authors. Risk assessment is eminently suitable for assessing climate change impacts, given the present significant uncertainty in how the future will unfold. However, our review of a sample of reports undertaken across Australia over the past decade indicates that:

- risk assessment is typically not undertaken to a high standard
- the regulatory framework often makes it difficult to undertake a genuine risk assessment as, for example, a benchmark amount for sea level rise is commonly established, with no corresponding likelihood
- the efforts made to establish the context and involve stakeholders are often lacking.

Finally, different authors will tend to focus on their particular area of expertise. For example, a specialist risk assessment professional will provide a thorough coverage of the standard process, but the detailed technical effort required for best practice risk analysis may be lacking. Similarly, an economist may focus almost exclusively

on the tasks required to evaluate assets and perform a risk assessment based on scientific or engineering information that they do not understand. Lastly, an engineer or scientist may undertake an analysis of coastal processes and hazards without consideration of the overall objectives and risks of concern, and only a cursory consideration of consequences. It is clear that a more coordinated, multi-disciplinary approach is required which gathers together skills from a wide variety of areas in order to achieve a best practice outcome.

5 Investigation of Best Practice Outcomes

5.1 Key Points

- Follow up interviews were carried out to determine whether those studies which showed relatively high consistency with ISO31000 also resulted in identifiable and ongoing risk management outcomes.
- The interview questions aimed to identify if the risk assessment activity had proven useful, whether it had resulted in follow up actions, and whether there were barriers to implementing study recommendations.
- The questions were geared to clarify some of the key research concerns of NCCARF, broadly identifying the key aspects of a 'successful' coastal climate change risk assessment.
- Six studies were shortlisted based on the assessment presented in Chapter 0. Follow up contact was made with the relevant organisations, resulting in three interviews. In some instances, the staff responsible for commissioning / carrying out the study were no longer available, or no response was received after numerous contact attempts.
- A common characteristic of the shortlisted studies was high scoring against communication and consultation. This highlights the apparent importance of that aspect of risk management in influencing the overall performance throughout the risk management process.
- The interviews were carried out face to face, or via tele conferencing.
- Key factors for success appear to be:
 - clear policy and guidance from state government
 - clear opportunities for funding implementation
 - effective communication and consultation.
- An identified barrier to success, in addition to absence of those success factors, was the completion of risk assessment at too broad a scale (i.e. regional multi council scale) necessitating rework to enable decision making at a local scale.

5.2 Identification of case studies to participate in follow up interviews

The overall aim of this chapter is to assess how well the initial risk assessment was received by local council and if/how the recommendations have been translated into action (such as adaptation plans, policy actions, planning instruments etc.). These are considered a key measure of success of the risk assessment studies that cannot be garnered from the desktop scoring of the reports in isolation.

Our assessment focused on the risk assessments that scored highly in our analysis of Chapter 4. The 28 studies were ranked according to their overall score and the best six (all of which scored 70 or above out of 100) were shortlisted for further review. The studies represent a wide geographical spread across Australia (one study each from Queensland, New South Wales, Victoria, Northern Territory and two from Western Australia).

The stage scores for each of the six case studies varied across the risk assessment categories (Figure 9). For example, all of the studies scored highly in terms of 'risk evaluation' (with the exception of case study 5) and most scored above the group average for 'establishing the context', 'risk analysis: likelihoods', 'risk analysis: consequences'.

A number of the shortlisted case studies effectively carried out the risk identification process (which was otherwise carried out poorly on average across the wider group). However, even some studies that were shortlisted fell short of the mark in this aspect.

Interestingly, all six case studies scored highly (relative to the wider group) on the 'communication and consultation' aspect of the study. This is likely related to why these projects were also more successful in other aspects of the risk assessment.

These aspects were followed up through further direct contact with the councils involved, via telephone or face to face interview. Initial contact was made with all six shortlisted local councils (or groups of councils) to determine their willingness to participate in an interview connected with this study to further elucidate how successful activities following from the risk assessment had been and what could still be improved.

Of the six Councils contacted, three were interested in participating in an informal interview. It is important to note that some of the shortlisted studies were completed quite some time ago (up to 10 years ago, during the first round of the Local Adaptation Pathways Program) and the individuals originally connected to the study no longer worked for the particular council involved. This has hindered the interview process, but some assessment was still possible.

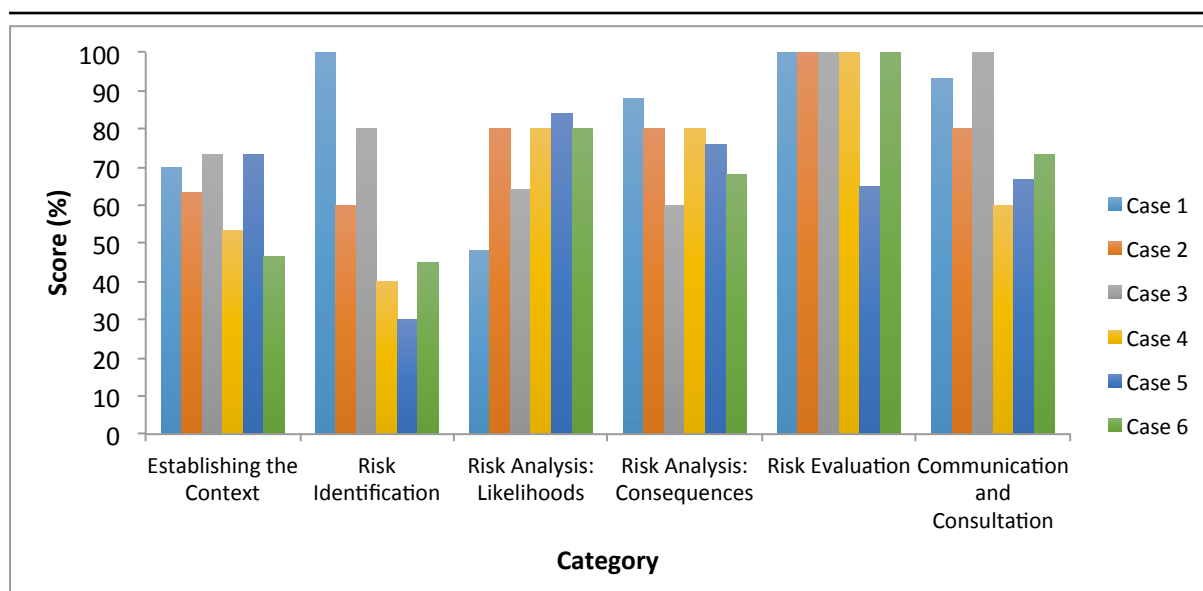


Figure 9 Individual scores for the six studies shortlisted

The interview centered on the following themes, although broader issues were also discussed:

1. Overall, how well did the climate change risk assessment meet the needs of the Council?
2. What were the key components that made the project a success / what were the key components that were missing that could have improved the study?
3. What was the level of engagement between the team that carried out the study and the stakeholders (including Council) during project initiation and throughout? How was communication of the project results addressed and what was the success/failure in this regard?
4. Were the results of the study transferred into action plans that were compatible with current Council risk management strategies/approaches?
5. Where attempts were made to transfer results and recommendations into action, (i) how readily were the action plans implemented and (ii) how successful were the action plans?

5.3 Summary of findings

The questions listed above prompted broad discussions with the interviewees. Following review of the interview notes, we have summarised the key issues that arose from the interviews, which have not been already highlighted during previous chapters. These sometimes surprising issues have assisted in developing the risk assessment framework presented in Chapter 7.

5.3.1 The Influence of State Government on Local Government Risk Assessment

Risk assessment by local councils is commonly conducted within frameworks established by state government. That is, risk assessment is guided by legislation and manuals established at the state level. Therefore, to obtain funding for risk studies (from the state), the spatial boundaries tend to be restricted to assets or hazards (e.g. estuaries, beaches etc.) identified by, and of interest to the state government. However, this may not match the objectives at the local level. For example a particular beach or foreshore may not have issues of state significance, but may be of particular importance for a local council.

State guidelines for coastal development overlap with flood management planning regulations and some funding derives from those sources. Much of the flood management planning has been developed to deal with floodplains and estuaries of larger inland rivers, as opposed to coastal estuaries and urban flooding (both of which are critical issues for coastal councils). Accessing external funds to carry out risk assessment and adaptation studies for such sites can therefore be problematic.

This issue appears to be state specific however, with one interviewee commenting that they use a bottom up approach, where the local council first determines the hazard(s) they wish to assess, which is then followed up by an application for funding to the state government.

Funding from state government level, while most common, is not the only way funds may be acquired. One interviewee noted that their funding rarely came from the state government and most climate change related funding was obtained through the National Disaster Resilience Program (NDRP). This highlights an issue with attempting to develop a national framework for risk assessment, when councils obtain funding from different sources with different interests and having varying degrees of control over the process.

5.3.2 Funding provided on an ad-hoc basis

Federal, state and local governments all operate on different funding cycles. Local government tends to operate on an annual cycle, while state and federal funding can be heavily influenced by the political cycle. Funding related to climate change and coastal risks is very much tied to these political cycles and therefore naturally results in funding being released on an ad-hoc basis. One interviewee noted that they were provided funding to conduct a storm tide study for only a partial section of their coastline and had to wait a number of years to obtain funding to complete the study for their remaining region of interest. They commented: “they know exactly what their hot-spots are but it is difficult to obtain funding to address these issues”. The ad-hoc nature of funding for coastal climate risk studies needs to be addressed if we are to empower coastal councils who are just starting on their journey of climate risk assessment and adaptation planning.

5.3.3 Risk assessment at an appropriate scale

Scale is a critical issue when it comes to risk assessment. The initial hazard identification stage may be carried out at a broad scale (across the LGA region) but this should primarily be used as a way to identify issues/regions/assets of critical importance that require a detailed risk assessment. This tends to be driven by

consequence (what represents a major consequence, as opposed to what we can accept/deal with) and importantly, assists to identify the most appropriate use of funds.

The scale at which the risk assessment is carried out can also influence the uptake and implementation of findings. For example, one interviewee described how a risk study conducted under the LAPP across multiple coastal councils identified risks that weren't necessarily specific (or relevant) to individual councils. As a result the study had varying degrees of impact on the way climate related risk have been dealt with. For example, one council within the group used the broader risk study as a tool to 'set the context' for a more detailed hazard assessment and adaptation plan, while other councils have yet to utilise the findings in a proactive manner. The issue of scale was again highlighted when the study team interviewed another coastal council who had commissioned a very similar risk study but with much greater success (in terms of implementation and uptake). The success appears to be driven by a number of factors, one of which was that the original risk study was conducted across a single coastal council and there was a continuation of the involvement of dedicated staff subsequent to the study. The findings were directly tailored to their needs and resources.

However, the same council also commented that being a small council meant that their access to funds to deal with important issues such as climate change was limited and that strict adherence to risk assessment procedures can be a costly task. Therefore, while risk assessment ultimately needs to be conducted at the local scale, it also needs to be carried out in a cost effective manner in an environment with limited funding avenues.

5.3.4 Setting the baseline risk

During the communication process it is important for stakeholders to understand their current risk and how this then may change in the future. One interviewee explained how they had produced maps of future flood risk, however didn't present the 'natural' or 'current' risk. This meant that stakeholders could not place the future risk in perspective. For example, did the maps represent an increase in flood risk for their property? Did they need to adjust their insurance to deal with this? Is this an entirely new risk they haven't had to consider before? Setting an appropriate baseline of risk is an important aspect to the assessment given that in most instances it is the change in risk that is important to the stakeholders.

5.3.5 Communicating uncertainty

This was identified as an issue that requires improvement with respect to the risk assessment process and in particular community consultation. However, there are many studies on how to deal with communicating uncertainty (, for example).

Stakeholders may find traditional expressions around uncertainty hard to deal with in their thinking around actions on climate change (e.g. "...A likely range of global

¹ <https://www.nccarf.edu.au/content/bridging-user-needs-and-science-capability> for a review and subsequent recommendations

mean sea level rise for 2081 – 2100 compared with 1986 – 2005, depending on emissions (0.40 [0.26–0.55] m for RCP2.6, 0.63 [0.45–0.82] m for RCP8.5), can be projected with medium confidence, including the contribution from ice - sheet rapid dynamics. “)

Stakeholders seek firm numbers, at clear time points and fine spatial scales about the amount of warming and the associated effects on other climate variables such as rainfall, sea level rise and windstorms. This is not something that science can currently deliver. As discussed by Verdon-Kidd et al. (2013), the absence of this precision can provide a justification for inaction. However, this desire for certainty as a prerequisite for action is unnecessary, and at odds with principles of ecologically sustainable development, given that we have always been able to make decisions and plan for the future in the context of uncertainty in fields as diverse as defence, finance and insurance. It is simply a matter of changing the way uncertainty is communicated.

5.3.6 Public engagement

Dealing with climate risk assessment is considered a complex problem, as is the question of when to engage stakeholders in this process. As one interviewee said “when do we open the can of worms?” If this occurs too early in the process it can make it difficult to set boundaries on the study (as each stakeholder will have a different idea of what is important to them), however if it occurs too late in the process stakeholders will feel disempowered. One interviewee noted the lack of community interest (community disengagement) in their climate change risk assessment and adaptation planning activities and attributed this partially to attempting to engage too late in the process (at the adaptation stage). The interviewee also noted that the lack of historical or current management issues (e.g. a big storm event that caused flooding/erosion) in the region had created an additional roadblock. That is, “people don't think it will happen unless they have seen it in their lifetime”. This issue was confirmed by a further interviewee who noted that residents were reluctant to accept future risk maps without having directly experienced a similar event (e.g. coastal erosion, flood event) first hand.

The most appropriate course of action may be to first identify the boundaries of the study (what regions are we looking at and why, what assets, what timeframe) and then invite stakeholder consultation to identify the consequences (and therefore the risks). Importantly, engaging stakeholders at this stage of the project will assist in building trust in the project outcomes and ultimately increase the acceptance and uptake of the recommendations. It is important that council first identifies what they are responsible for internally to identify their corporate risks (set the boundary) before “the can of worms is opened”.

5.3.7 Legacy Issues versus Future Planning

Applying the risk assessment and management process when siting new development is relatively easy, when compared to risk assessment in already

² In particular, the precautionary principle which in one form includes the statement that “...lack of scientific certainty should not be used as a reason for postponing action”

developed areas, where it becomes much more problematic. Legacy issues can be dealt with through a 'watch and wait' approach. Council may have plans in place to deal with consequences if/as they occur (e.g. building a sea wall to protect houses or buy back of coastal properties). Given the inherent cost involved (and problems with public perceptions) councils find that a monitoring approach is more palatable to stakeholders.

The issue of fairness and equality in future planning can also be a difficult one to overcome. Dealing with changes to land use planning as a result of future risk is challenging, as residents can perceive they are being unfairly treated through time (for example, one resident is required to build on a 30m set back due to a recently conducted coastal hazard assessment, yet their neighbours who built the previous year were allowed to build much closer to the beach).

5.3.8 Integration of coastal risks into councils risk register

Risk identification needs to be undertaken by council on a periodic basis. Most councils maintain a list or register of risks, and schedule regular reviews of that register. These reviews take such things into account as changes in the Council's services and operating environment and identify all risks that impact on the council's activities, regardless of whether or not the risks are under the council's control. This register of risks therefore represents a useful tool in which climate change/coastal risk can be integrated within councils overall risk related activities. To date, most climate/coastal risk studies have been carried out opportunistically (when funding is available) and in a separately from this overarching process. Integrating climate/coastal risk assessment in the risk register would therefore most likely improve the effectiveness and uptake of such studies.

Of the three Councils interviewed, only one had integrated the findings of the climate change risk assessment into their risk register. This has resulted in the risks associated with climate change being integrated in the cross section of daily council operations (from infrastructure planning right through to fleet efficiency, procurement and purchasing services). That is, climate change related risks are "embedded in business as usual" which has resulted in a "changing organisational mindset". This approach therefore appears quite successful as it means the entire organisation is engaged rather than just a specific group/team of isolated individuals.

6 Aspects of a Best Practice Framework for Coastal Risk Assessment and ‘Hot Spot’ Identification

6.1 Key Points

- Prior to developing a recommended framework for coastal risk assessment (Chapter 7), the key findings of our case study assessment and subsequent interviews have been grouped, summarised and discussed in more detail within this section.
- Many of the findings are unsurprising, being largely in line with the recommendations of ISO 31000 and accepted elements of good risk assessment practice.
- Local government is the front line tier of government responsible for coastal climate change adaptation planning in Australia, with local councils commonly engaging a third party (consultant, CSIRO) to undertake detailed studies.
- Risk assessment should meet the needs of Council as the primary risk owner. Council should be pro-active and involved in appropriately establishing the context for any detailed studies. This should include geographical extent, time frames, legal environment, hazards to be considered and the expected level of assessment and deliverables. Some of this context is more appropriately established by State Government.
- As an entry to the risk assessment process, it is recognised that at least some risk information needs to be prepared to open a conversation with the full range of stakeholders. A scoping preliminary study, which also doubles as a means for hot-spot identification, is recommended.
- Broad, continuing consultation is very important. This requires significant effort and can be uncomfortable.
- Genuine attempts should be made to address uncertainty. This will take significant effort to complete successfully. We recommend that a probabilistic approach, with appropriate likelihoods assigned to different climate change scenarios be adopted. The use of ‘benchmark settings without consideration of likelihood is not considered best-practice.

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- Extra care is needed when using terms such as sensitivity, hazard, exposure, vulnerability and adaptive capacity. Wherever possible, nomenclature should adhere to that of ISO 31000.
 - Numerous guideline documents exist to undertake risk assessment. These are often generic and not of direct applicability to coastal climate change risk assessment nor the needs of local government. In the absence of a directly applicable guideline document, the NCCARF *CoastAdapt* Tool aims to provide relevant assistance to Local Government in Australia.

The key driver of coastal climate change risk is sea level rise although changes to storminess are also important. Sea level rise will exacerbate coastal erosion, inundation and flooding with consequences to various assets such as infrastructure, settlements, beaches and ecological communities.

6.2 Introduction

Our suggested framework for coastal risk assessment is presented in Chapter 7. The present chapter is designed to act as a bridge between our assessment findings (Chapters 0 and 5) and that framework. The key findings carried forward from those assessments are summarised in Section 6.3.

Section 6.4 discusses important precursors to successful risk assessment. This broadly encompasses the key questions that need to be answered in ‘establishing the context’.

Acknowledging that risk management, as defined by The Standard is a continuous, iterative process, some initial idea of the risks that are of concern is necessary to provide an entry point to risk management. We recommend that a formal scoping preliminary study be undertaken as an entry point to the process, and guidance for this study is presented in Section 6.4.3. In this way, more detailed risk assessment and analysis can be properly targeted and funded.

6.3 Lessons Learned

6.3.1 Introduction

Our overall assessment of coastal risk studies undertaken around Australia during the past decade is that they have not been particularly well executed, with notable exceptions. The assessed poor execution is not necessarily a reflection of the quality of analysis or level of skill demonstrated by the study report. Often, the limitations are caused by the framework within which councils are forced to undertake risk assessment studies, including pre-determined guidelines on methodology and / or a lack of reliable data to properly complete the assessment. In some cases, the way in which organisations are instructed to undertake the risk assessment may actually result in risk assessment of a lower quality than could otherwise have been achieved.

Within the following sections, we have expanded on the key lessons learned as part of our research activities.

6.3.2 The Primary Role of Local Government

The primary role of local government was well expressed by Bell (2014):

“despite calls for national consistency, regulation of coastal development still occurs at the State and local government levels....all State governments provide some degree of policy direction, with local governments left to implement these policies into their planning schemes and often to make decision regarding individual development approvals”

The model for funding and executing coastal risk assessment studies appears to commonly follow:

- 1 state, or sometimes federal, government money is made available for studies

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- 2 a local council applies for a grant to undertake a coastal risk assessment
 - 3 if successful, the council engages a consultant to undertake the coastal risk assessment
 - 4 a consultant undertakes the risk assessment and prepares a report, which may also include a plan of action arising from the assessment.

A problem that seems to arise from this model is where a council acts primarily as an intermediary of the funding organisation, engaging consultants on behalf of the funding organisation. It may also be the case that the scope of study is already defined in state management guidelines. This can act to focus the risk assessment on areas of state or federal concern, which may not always match the particular priorities of local government. In a worst case scenario, this can disconnect the risk assessment process from the primary risk owner, reducing the relevance of the assessment and any subsequent management actions that are suggested by that assessment.

Again, there are examples where the local council (or group of councils) has taken a very pro-active role in guiding and coordinating the activities of consultants engaged to undertake the study. A positive side effect of this is that the council tends to engage directly with the community and stakeholders, developing relationships that will prove important to ongoing activities that continue well beyond the involvement of a consultant.

Key message: Best practice risk assessment requires that a local council is pro-active and involved, undertaking up front work to establish the context of any detailed risk assessment. This will help to target specialised studies (thus reducing costs) and to maximise the chances of successful implementation.

6.3.3 Avoiding Future Pain: Stakeholder Involvement

It was typical for there to be at least some level of stakeholder consultation and communication as part of the coastal risk assessments reviewed. Indeed, the most successful studies (based on our score card methodology) rated highly in the communication aspects of the study. The relative roles and responsibilities of different stakeholders need to be ascertained early.

Generally speaking, the key stakeholder is the local council. However, in Australia this can be confounded by the source of government funding (federal or state) and the status of local governance as a constitutional power of the states and territories. State governments are responsible for the establishment of local councils and the setting of geographical boundaries of different governance areas (LGAs). Effectively, local councils are controlled by the relevant state government and local government acts as an arm of the state government.

This means that the objectives, directions and requirements of state governments constrain the context within which local councils can act, while state government bodies can also be seen as important stakeholders. The responsibilities and objectives of local councils are influenced largely by the legislative and policy framework constructed by the state government and should normally reflect the

responsibilities and objectives of state government. The situation can be made particularly complex when the apparent objectives of different state government bodies conflict!

In comparison, local governments also bear a responsibility to the local community, in providing infrastructure (e.g. roads, lighting, parks), services (e.g. water, sewerage, garbage collection) and property services relating to planning and development control. In turn, the local community pays rates, and elects councillors.

Therefore, there is a political imperative for local councils to consider the desires of the local community when making decisions. It is important that a range of views from the local community are considered when making important decisions about coastal planning in the face of sea level rise and other climate change related phenomena. Further, it is better to involve the community in the process early on (e.g. to identify values that might be impacted by climate change). Based on the findings of Chapters 4 and 5, early stakeholder involvement increases the likelihood of uptake and implementation of the findings.

Effective consultation requires balance. Participation in a consultative process by individuals or groups with particular interests does not necessarily mean that their point of view will be adopted when a decision is made. This is clearly impossible when different groups have conflicting points of view and interests. However, effective consultation needs to make sure that a variety of points of view are heard and the basis for any subsequent decision is clear, even when it conflicts with a particular point of view. Effective consultation will assist in educating the community about the issues at hand.

Key message: Coastal risk assessment should involve consultation with relevant state government bodies and the local community; in addition to representatives from local government. This is difficult and conflict will inevitably arise. Even so, it should be conducted early in the process to maximise the chances of overall success

6.3.4 Conditional Risk

Risk assessment aims to explicitly deal with uncertainty. This makes it suitable for application in planning for problems that will arise from future sea level rise and other climate change driven risks. The sources of uncertainty around climate change can be divided roughly into two categories:

- uncertainty around the way in which global economic growth will unfold in future, and the way this will affect concentrations of greenhouse gas emissions
- uncertainty in the amount that this will affect the combined natural earth systems.

These uncertainties are underlain by an incomplete understanding of the natural climate variability, presently characterised in reference to a number of large-scale climate modes such as the El Nino Southern Oscillation or Interdecadal Pacific Oscillation/Pacific Decadal Oscillation (ENSO or IPO/PDO respectively).

6.2.4.1 Example for Sea Level Rise

Following AR4, it was commonplace across Australian states to specify a benchmark value for sea level rise planning. This has encouraged application of benchmark values in a deterministic manner and has thwarted the effective application of a risk management process, by eliminating consideration of the level of uncertainty associated with the key coastal climate change variable: sea-level rise.

With the release of AR5, justifiable probabilities of different global average sea level rise amounts can be adopted, providing that a particular RCP (of which there are four) is adopted. A best practice assessment of sea level rise can now be derived for a location using the following steps

- For each of the four RCP's, take the spatially averaged projections (reported as 16.7 and 83.3 % exceedance values over time, assuming a normal distribution).
- Adjust those values to reflect relative sea level rises for the location being considered (e.g. projected changes to ocean current patterns, ongoing isostatic rebound and/or changes to the earth's gravitational field caused polar ice loss).
- Reconstruct a local normal distribution at a suitable resolution of exceedance values (say 5% intervals) and time frames (say decadal).

At the present time, this process will yield four sets of curves (relative sea level rise versus time for each of four RCP's) of different projected likelihoods of exceedance. A decision then needs to be made on how each of the RCP's is to be treated. This is difficult as there is limited advice on how to assign a probability to any given RCP. The information provided in AR5 indicates that all RCP's are scenarios that are plausible and illustrative and the language here reflects the difficulty in grappling with assigning probabilities to future emissions scenarios in the face of an extremely uncertain geopolitical future.

In the absence of further consideration, we believe that the most pragmatic and sensible approach for decision makers would be to assume that all four RCPs are equally likely (i.e. each has a 25% chance). Even so, decision makers should ensure that they remain abreast of ongoing knowledge about emissions scenarios as the future unfolds (e.g. if the lower bound becomes less likely as we move forward into the future). For example Fuss et al. (2014) indicated that, in 2014, the net annual global CO₂ emissions for RCP2.6 (the lowest emissions scenario) would have been surpassed and that the world was tracking the scenario represented by RCP8.5. However, with recent signing of the 2015 *Paris Agreement*, it could be expected that, with a promise to "*aim to reach global peaking of greenhouse gas emissions as soon as possible*" a global peak in emissions could be reached within the next few decades.

Local councils should determine how to combine different RCPs in light of the most rigorous, readily available and widely accepted information available at the time. The sets of curves need to then be appropriately weighted and combined. Care is then required in weighting the sets of curves corresponding to the RCP's in a statistically appropriate manner.

The description presented above may appear complicated and it is for this reason that adoption of benchmark, often conservative, values for sea level rise could seem

far more attractive. In reality, the process described above is simple and rapidly achievable using freely available tools on a standard desktop or laptop computer. As described above, adoption of a particular set of benchmark values without consideration of the uncertainty cripples the ability to produce meaningful outcomes from a risk assessment.

We note that benchmarks are still commonly set by state governments across Australia. We understand that these are often prescribed to guide local councils in taking a precautionary approach to planning when deliberating on the effects of sea level rise. This is driven somewhat by the recognised public interest value in adhering to the principles of Ecologically Sustainable Development (ESD), particularly in ensuring that planning decisions are not made that could place unnecessary burden upon future generations.

However, from a risk management point of view, adoption of benchmark values is non-standard. More appropriate and transparent application of a degree of caution should occur at the stage of establishing a risk tolerance. Decisions that may detrimentally affect future generations or overall future biodiversity would therein adopt a lower threshold of acceptable risk.

The adoption of a pure risk assessment based approach is not a small matter. The approach genuinely expects that decision makers are involved and cognisant of the likelihood and consequences of risks to be considered. Inevitably, some degree of subjective decision making is required from a local council, and these subjective assessments are unlikely to be consistent with those of all stakeholders. Conflict is inevitable and a clearly documented and justifiable rationale for decisions about risk tolerance will provide the best defence to any potential legal challenge that may arise in future.

It is attractive for local councils to plan to a given set of benchmark values stipulated at state level. This makes justification of decisions much simpler and also provides a sense of apparent fairness in decision making. However, as noted above, this does not explicitly take account of uncertainty and defies a real assessment of the magnitude of risks that need to be managed. Accounting for this uncertainty comes at a cost; detailed risk studies are not necessarily cheap, and councils need to have the requisite skills to understand the concepts arising from different likelihoods and consequences and how this will feed into decision making. The framework developed here aims to reduce that complexity as much as possible, although it is not possible to completely eliminate the need for some understanding or subjective reasoning in making decisions.

Key message: the use of benchmarks for sea level rise (or any other climate change related risk) is unsuitable for use within The Standard risk assessment framework and is an oversimplification of present scientific understanding. It is recommended that a set of probability curves (one for each RCP) be developed for each hazard (e.g. sea level rise) and subsequently weighted according to best available science. In the absence of other reliable and widely accepted information, it is recommended that equal weighting be applied to the RCPs.

6.3.5 ‘Vulnerability’ and its Relationship to Risk Assessment

In our review of coastal risk studies, we also found the occasional confusion of terms. A common issue was a tendency to interchanging the terms ‘vulnerability’ and ‘risk’. For good reason, ISO 31000 provides a specific definition of vulnerability; repeating from Section 2.4.2:

“An intrinsic property of something, resulting from those characteristics which determine its susceptibility to a risk source, and any subsequent events which may lead to a consequence”

As an example, a sandy shoreline may be considered vulnerable when compared to a sea cliff comprising hard rock. Its vulnerability is a factor which contributes to the erosion hazard and, using the bow tie analogy sits on the causes (c.f. likelihood) side of the risk equation (Figure 2). Vulnerability may be present but not be of concern because:

- the likelihood of climate change interacting with that vulnerability is negligible
- the consequences of climate change interacting with that vulnerability are minimal (i.e. value of the asset potentially at risk is not of concern)

Accordingly, vulnerability in itself is not a robust indicator of risk, but studies of vulnerability may be an important precursor for determining the extent of a hazard (of a certain likelihood).

Similarly, terms such as ‘exposure’ and ‘sensitivity’ can be confused with risk as specified by ISO 31000. As an example, Schröter et al. (2005) presented an eight step approach to assessing vulnerability, broadly classifying vulnerability as a function of three elements: exposure, sensitivity and adaptive capacity.

The method of Schröter et al. (2005) is broadly consistent with the ‘causes’ side of the bow tie. Exposure, sensitivity and adaptive capacity can all be considered causative factors leading to an event that would result in the loss of value of an asset at risk. However, their paper implies that vulnerability assessment is sufficient to enable decision makers to make decisions about “options for adapting to the effects of global change”.

This apparently implies that the asset at risk has intrinsic value that must be conserved. Unfortunately, councils may face a future where preservation of all assets of value is simply not possible. A degree of triage is likely to be essential, whereby councils will need to weigh the relative values of environmental, social and economic assets in order to make decisions. A complete risk assessment would enable this to occur.

In comparison, the present Australian Standard for the *Adaption of infrastructure and settlements to climate change* (Australian Standards, 2013), which relies heavily on the international Standard for direction, includes definitions for vulnerability (to climate change):

“Degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change including climate variability and extremes.”

..and sensitivity (to climate change):

“Degree to which a system is affected, either adversely or beneficially, by climate-related stimuli”

Again, these definitions point towards the overall vulnerability as being indicative of the cause side of the bow tie model. As is common throughout risk management literature, the introduction of different definitions for the same term, or overlapping terms for the same concept is likely to lead to confusion.

Finally, The Standard is careful to point out that risks can have both negative and positive consequences for an organisation. Terms such as ‘sensitive’, ‘expose’ and ‘vulnerable’ tend towards negative connotations, raising the possibility that positive impacts may not be given the attention they deserve. While the impacts of sea level rise and climate change may be predominantly negative, it is still sensible to exploit and maximise any positive consequences as much as possible.

Key message: For our purposes, we have elected to adhere to the nomenclature of ISO 31000. Different models of risk analysis, whether comprising methods referred to variously as studies of sensitivity, hazard, exposure, vulnerability, adaptive capacity (etc.) or combinations of those should be accessible within our framework. However, regardless of the model of risk analysis adopted within our framework, it is essential that they provide results that relate a level of likelihood with a corresponding impact extent.

6.3.6 The Importance of Study Clarity

For successful risk assessment to be undertaken, the purpose and scope of the risk assessment study (or component studies) needs to be made clear. This can be achieved by expending up-front effort in establishing the context of the study. Our overall assessment of reports reviewed as part of this study indicates that this was often lacking, both overall, and within separable parts of the risk assessment effort.

To establish a basis for successful coastal risk assessment, the following should be identified:

- Required geographical extent.
- Objectives of the local council and the assets related to those objectives. Note that assets may include infrastructure, settlements, environmental or cultural assets and the relationship between these. In some instances, we note that the risk assessments undertaken in the past have tried to cover all assets with a single risk assessment exercise. We question whether this is optimal, and suggest that councils may be better served by focused separate studies on particular classes of assets.

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- The expected time frames (or life cycle) of those assets of concern, to provide guidance on how far into the future risk assessment will need to project. It is still quite common for risk assessment to be projected to 2050 and 2100, years that were established circa 2000 to represent 50 and 100 year timeframes. Coastal risk assessment should probably now be looking beyond 2100. In addition, more critical, imminent time frames (e.g. 10-15 years) need to be considered. There is far more certainty in projections over this time frame and the need for adaptive actions may be imminent in those locations.
 - Legislative and legal framework, noting that these will strongly influence the objectives of the local council,
 - Hazards, threatening processes or trends which are to be considered as part of the risk assessment. As we are dealing with coastal risk assessment and climate change, the key considerations here are those climate change variables that are of particular concern to coastal councils, but not necessarily of concern to inland councils,
 - A definite and clear way of describing risks which, in turn helps to make decisions regarding appropriate means of risk analysis (e.g. qualitative vs. quantitative; cursory vs. detailed),
 - Clear language: we recommend that the nomenclature of The Standard be strictly adopted to avoid confusion,
 - Clarity regarding the adoption of particular scenarios or combinations (RCP's in the parlance of AR5) and the way in which likelihoods of those scenarios are determined. Without this crucial step, any likelihoods are contingent, will lack transparency and may ultimately prove unjustifiable,
 - Clarity regarding the justification for choosing particular means of analysis. Methods adopted should, ideally, be generally accepted among professionals involved in the work being undertake and have been subject to publication and critical peer review.

In Australia, much of this clarity would be most suitably, and cost effectively specified by state government as part of its overarching role in guiding the functions of local government. A suitable state guideline document which establishes and clarifies much of this background context would help to place future risk assessments on a path to success. It is not enough to specify that a risk assessment approach 'should' be taken. State governments should aim to provide much of the background framework to ensure that the nature of that risk assessment approach is well understood.

With this state level guidance, a local council issuing a brief for risk assessment can fill in the gaps with particular details regarding, for example, the particular asset class and geographical extent that is to be subject to a given risk assessment exercise.

Context setting is an essential precursor to developing a clear brief for response by consulting organisations. A local council will need to ensure that analysis methods

specified will give them results that enable the risks of coastal climate change to be incorporated into a broader corporate risk management strategy, enabling for more transparent decision making.

Intrinsic to this approach is that councils will take an overarching role of the risk assessment process. It is possible that a number of individual studies will be commissioned, recognising that different aspects of the risk assessment process (e.g. consultation, coastal process assessments, valuations) require organisations with different skill sets if they are to be carried out to the required high level that best-practice requires.

Key message: Overall clarity of purpose and boundaries for the risk assessment process should feed into clearer reporting and communication to stakeholders, which will in turn provide the highest likelihood of acceptance and success for follow up adaptation actions. The framework that has been developed as the key outcome of this research effort suggests ways in which this clarity can be achieved.

6.4 Groundwork for Successful Outcomes

6.4.1 What Guidance is Available?

Internationally, there are numerous guidelines available that deal with coastal risk assessment (NCCARF, 2015). Clearly, these can provide useful guidance, although there are limitations in applying them in an Australian context.

Throughout the present study, we have used The Standard (ISO 31000) as a starting place for our analysis, and it follows that The Standard has also been used as the fundamental basis for the framework we have subsequently developed. The Australian Standard for *Climate Change Adaptation for Settlements and Infrastructure* (AS 5334: Standards Australia, 2013) has also been used where it provides additional information. Some of the principles contained within Section 5 of AS 5334 are of relevance to risk assessment for coastal councils:

Principle (a): *The effects of climate change are not contained within jurisdictional boundaries; adaptation may require policy, planning and action at national, state, regional and local levels.*

When undertaking coastal risk assessment, much of the relevant context will be established at a state level. However, the interconnectivity of coastal sediment compartments and ecosystems means that some cooperation is warranted between adjacent coastal councils. Studies involving coastal geomorphology are best undertaken at a regional scale and some aspects of coastal ecological studies may also warrant a regional approach.

Principle (b): *Climate change risk management needs to be an integral part of decision making concerning settlements and infrastructure.*

Principle (c): *The risk from climate change and the requirement for adaptation needs to be considered for all stages in the lifecycle of settlements and infrastructure.*

These principles point towards the setting of appropriate time scales for risk assessment. Perhaps most difficult is establishment of a suitable time frame for the assessment of settlements. While individual dwellings may have a design life of 50-60 years, the act of subdividing land for settlement comprising development (residential and/or commercial) and its associated infrastructure can be viewed as having a much longer design life. Associated with this is a public perception of ongoing private property rights of land threatened by sea level rise and the remaining legal uncertainty surrounding these issues. In depth discussion of these legal aspects can be found in Bell (2014). Local government is presently grappling with the issue of coastal settlements that are already threatened and the potential need to abandon those settlements at some future time. When subdividing coastal land, councils are faced with the need to set an appropriate design life for new settlements. While 100 years appears to be the commonly adopted standard, it could be easily argued, based on past experience, that this is insufficient.

One limitation of the widely applied AGO guidelines (Broadleaf Capital International and Marsden Jacob Associates, 2006) was its reliance on a 25 year timeframe. It is true that this time frame is suitable for businesses – one of the target audiences for that document. However, 25 years is at the shorter end of the timeframes that local government works with. As noted above, much longer time frames need to be considered when dealing with subdivision of land for the purpose of settlement.

Principle (d): *Climate change risk management and adaptation requires the involvement of stakeholders in settlements and infrastructure*

The framework developed here encourages the broad and continual involvement of stakeholders

Principle (e): *When managing the risk from climate change, organizations need to use the best available authoritative and relevant information.*

The most authoritative source for future climate change information internationally is the Intergovernmental Panel on Climate Change. In an Australian context, authoritative bodies providing advice are the CSIRO and Bureau of Meteorology. At a local scale, studies will generally have to be commissioned by local councils to examine impacts of climate change along the coast and to assess the values of assets threatened by those impacts. As context for the risk assessment process, local councils will need to determine the best available data to underpin those local studies at the time that they are commissioned.

Principle (f): *When information about climate change is updated, the specification and performance requirements for settlements and infrastructure need to be reconsidered*

The framework should incorporate flexibility that enables a relatively rapid update of performance requirements in the face of new information. Specific guidance that is of relevance to the framework developed here is presented in Section 7.3 of AS 5334, and aspects of that section of the standard have been customised to reflect the particular needs of coastal councils.

Again, the other notable guidance document which has been utilised as background to our framework is the guideline document produced for the Australian Greenhouse Office and subsequently used to underpin the majority of LAPP studies reviewed as part of this research effort (Broadleaf Capital International and Marsden Jacob Associates, 2006). That document provided particularly clear guidance to local government in a process that is broadly consistent with, albeit predating, the present international standard. In our review of existing studies, however, we note that the risk assessment process using those guidelines has rarely extended beyond the “initial strategic assessment” stage, which was essentially a qualitative exercise.

Key message: The present framework aims to take coastal councils beyond that initial strategic assessment, towards more quantitative assessment. Such quantitative assessment requires risk analysis techniques (likelihood and consequences) which should be undertaken by professionals with a high level of skill and expertise. There are a wide range of methods that can be used to undertake these assessments, each with drawbacks and advantages. The present study does not aim to compare and assess these different analysis techniques. The techniques come from rapidly evolving fields of research and it is necessary for a local council, along with relevant stakeholders, to make a clear, documented and justifiable decision on the analysis methods to be adopted at the time that various analytical studies are commissioned.

6.4.2 What are the Risks of Concern?

The focus of the present document is coastal climate change risk assessment. Accordingly, the risks of concern here relate to climate change impacts that are specific to the coast. We acknowledge that other impacts (e.g. bushfire, heat waves) may also be of concern to coastal councils, but these are not specifically coastal problems. A review of the coast specific risks indicates that they can mostly be expressed in terms of the bow tie diagram presented as Figure 10.

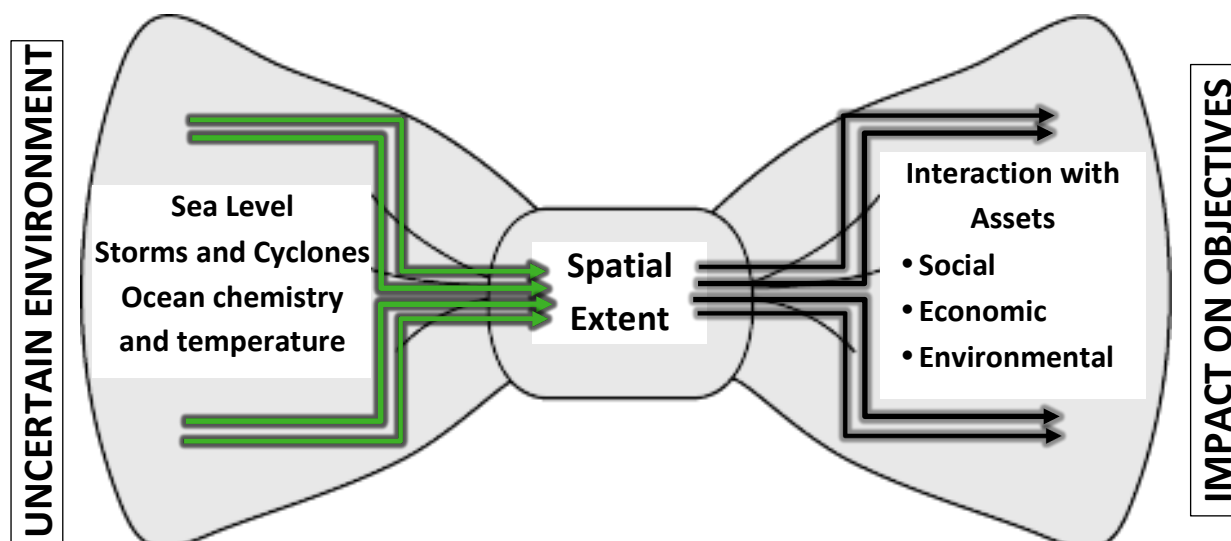


Figure 10 Bow Tie of coastal specific risks

We have opted to place the concept of a spatial extent as the ‘event’ in our bow tie analysis. We consider that consequences will arise from a spatial extent being reached, for example:

- Sea level rising to such an extent that regular ‘nuisance’ inundation is occurring to the extent that residence within an area is no longer feasible.
- Ocean chemistry and temperature changing such that the extent of given limiting condition inside estuaries and along the coast changes. This may impact on particular ecosystems.
- Open coastline recession, caused by changes in mean sea level and storminess, occurring to such an extent that existing infrastructure or development is no longer feasible and needs to be abandoned (in the absence of intervention).
- Local councils determining a seaward extent of allowable development, resulting in community concerns regarding property rights and values, and potential legal challenges.

Therefore, the causative factors of the risks can be effectively defined by changes to physical extent. Risk analysis would involve two parts:

- Determination of a physical extent (or, more correctly, a range of extents with assessed probabilities at a range of future times).
- An assessment of the corresponding value (economic, social, environmental) lost (related to impacted key assets that are important to a council’s objectives) in the absence of actions to adapt or ameliorate those impacts. This assessment may require examination of a chain of consequences and there may be uncertainties associated with the consequences side of the risk analysis as well.

These analyses are predominantly spatial in nature. The use of GIS software and maps to undertake the analysis and facilitate communication with stakeholders is highly recommended.

6.4.3 A Preliminary Study – ‘Hot Spot Identification’

Detailed studies are not needed at every location along the coast. As part of our framework, we recommend that a ‘Level 1’ or scoping or preliminary study be undertaken as the first step in risk assessment. This is a broad brush, conservative, upper extent assessment that can be undertaken prior to any further risk assessment work. The following steps are recommended:

Step 1: Collate data

Basic data needs to be collated and reviewed. Core information includes previous studies relating to the effects of climate change on coastal processes, including ecological processes where appropriate. Importantly, a robust ground elevation data set is required. LiDAR data is normally available for coastal areas in Australia.

Step 2: Identify an upper limit projection

One purpose of the initial study is to set a maximum extent for possible consideration in future studies. Therefore, an ‘upper bound’ condition should be established as a catch all for all possible impacts that could be of concern for a local council. At the present time, we recommend that the equivalent of a 95% likelihood limit on the highest readily available and widely accepted scenario (or projection – RCP8.5 at present) be adopted over a future time frame of up to 200 years.

Step 3: Undertake initial spatial analysis of impacts

Utilising the selected projection, determine the spatial impact of changes to physical variables arising from climate change. At this stage – coarse methods of analysis are acceptable. For example:

- Bath tub analysis of the extents of sea level rise inundation, combined with flooding; and
- Bruun Rule analysis for coastal recession.

Conservative assumptions (resulting in larger extents of impact) should be adopted throughout, considering that the primary focus is identifying an upper, extremely unlikely, limit of possible impact so that a spatial boundary can be set for future consideration of risks.

As much as possible, information from background studies should be utilised. Where insufficient information is available to make a conservative assessment, this should be flagged as a data gap and further consideration given as to whether that gap needs to be filled.

Step 4: Identify assets potentially impacted

Spatial information on all assets of concern to council should be acquired and all assets which fall within the geographical boundary established during Step 3 identified. Care is required here to also consider flow on impacts that may occur beyond these boundaries. For example, changes in an estuary may affect the migratory patterns of some fish species and, if those patterns are important for the

functioning of upstream freshwater ecosystems, the environmental asset of concern (upstream of the estuary) may well fall outside the boundary established during Step 3. Similarly, changes to inundation levels of parts of a road network, may hinder the evacuation of other places during extreme flooding events.

The extents and assets established during Steps 3 and 4 will form the spatial context and potential scale of impact to assist briefing subsequent risk assessment activities.

Step 5: Identify hot spots

A hot spot assessment is designed to identify areas that require imminent attention. Many of these hot spot locations will already be familiar to the local council, as assets of concern are likely to have been threatened in the recent past and the subject is likely to be dealt with in reports collated as part of Step 1.

For hot spot identification, we recommend that Steps 3 and 4 be repeated, but in this instance, adopt a time period of more imminent concern than 200 years (we suggest a 25 year period or less). The analysis should be used for the following two purposes:

- To broadly validate the process, noting that any pre-identified hot spots should have been captured by the analysis. If this is not the case, the process will need to be revisited and adjusted, if necessary, to capture known hot spots.
- To identify those areas that may need fast tracked risk assessments and adaptation planning.

Step 6: Report

A report on the preliminary study outcomes needs to be prepared, as background into the potential geographical scale, nature and distribution of threats from climate change that need to be considered as part of future risk assessment. The report needs to be worded carefully and clearly.

- It should be worded carefully to not cause unnecessary alarm. The scenario being considered is designed to be extremely unlikely, and projected a long time frame in the future;
- It should be worded clearly and simply so that it can be understood by a broad range of stakeholders with different levels of background understanding of the processes being considered. This report will provide the first point of contact with many stakeholders and an introduction to establishing the context prior to subsequent risk assessment studies.

The preliminary study could feasibly be undertaken at the state government level to identify priorities for funding. The preliminary study can be undertaken prior to making extensive contact with stakeholders although some is likely to be necessary to acquire data. The preliminary study should be seen primarily as a basis for opening a conversation on risks and their associated uncertainty, and setting boundaries on the scope of works for subsequent studies. The preliminary study is not envisaged to be a reasonable basis for land use planning or development consent decision making.

7 Framework for Coastal Climate Change Risk Assessment

7.1 Key Points

- A step-by-step framework for coastal climate change risk assessment is presented.
- The framework is not a practice guideline but provides suggestions as to what a good guideline document should contain
- Understanding the context of the risk assessment process is of primary importance. 'Establishing the context' deserves considerable effort.
- The underpinning of successful coastal climate change risk assessment comprises broad stakeholder involvement (communication and consultation) and a high level of commitment from individuals driving the process.
- Establishment of a dedicated coastal risk committee is recommended. That committee should be responsible for outlining the context for the risk assessment process
- Subsequent studies associated with risk identification, the likelihoods associated with hazard events of various magnitudes (or extents), the consequences corresponding to those hazard events (values of threatened assets) and risk evaluation should be undertaken under the guidance of the coastal risk committee

7.2 Keeping an Eye on the Real World

The framework presented here acknowledges that bounds need to be set on risk assessment, primarily by 'establishing the context'. The risk assessment process operates in a world full of uncertainties beyond the boundaries thus established. Figure 11 illustrates the step-by-step framework within the context of a broader environment of unknowns, required decisions and allocation of limited resources. For the framework to be effective there needs to be at least some clear guidance and commitment from both state government level and from senior management within the council undertaking the assessment. Organisations need to contend with a number of additional risks encompassing social, political, economic and legal uncertainties beyond those which arise from projected climate change effects. Even so, it is important that climate change risks are taken seriously.

Furthermore, the parameters which define all of these risks, including those related to climate change, may change dramatically with time. This cannot be ruled out. In such an environment, continual monitoring and review is required to ensure that our understanding increases with time, and continual communication/consultation are required with stakeholders and the community for the purposes of transparency and to foster trust in the overall process. Both of these aspects of risk management will help local government to adjust to unforeseen changes which may arise.

Another important feature of Figure 11 is the exclusion of other risk management activities from our framework: such as adaptation planning and implementation activities. The response of an organisation to the assessment of risk is beyond the scope of the framework; although the studies and approach recommended as part of the framework should prove invaluable as background and input to the development of subsequent adaptation options and their assessment.

7.3 Overall Approach

Figure 12 lists the steps of the framework. In reality, there are numerous possible feedback loops and potential iterations of different steps as part of the process, and the steps presented here are intended as an idealised guide to introduce those aspects we have assessed as being important for achieving successful risk management outcomes. A broad scale risk assessment may indicate the need for a more detailed risk assessment for particular assets, or groups of assets.

The first step of the process is the preliminary study which is outlined in Section 6.4.3. The study is a rapid pass assessment of extreme upper bounds of climate change spatial extents and the assets and values impacted. A shorter (< 25 year) time frame is also examined to identify those assets which may be impacted in the foreseeable future (i.e. to identify hot spots) and need early attention.

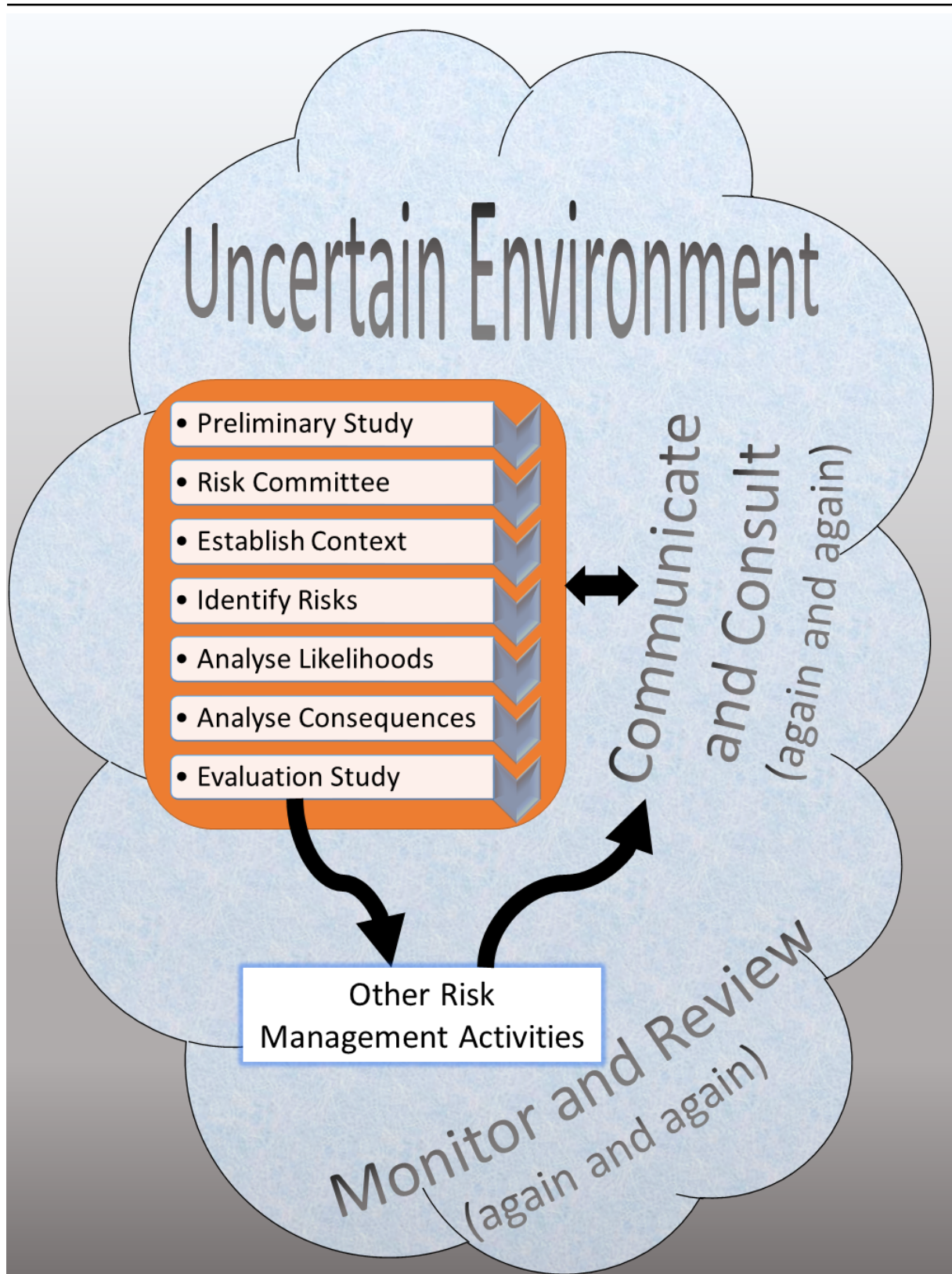


Figure 11. Risk assessment framework within an environment of uncertainty



Figure 12 Steps in the risk assessment framework

The following two steps, involving the formation of a committee and establishing the context do not strictly fall within the definition of ‘risk assessment’ in ISO 31000. However, our review of the overall process, backed up by our review of studies from around Australia, indicates that these steps are important to increase the overall chances of success.

7.4 Coastal Risk Committee

The single qualitative factor that appears to correlate to good risk management outcomes is a high level of commitment of individuals or a group of individuals in the process. The commitment is long term and extends beyond the involvement of any individual risk assessment activity. The reason for this appears to be that those individuals remain aware of key tasks that sit outside the risk assessment process, such as establishing the context and keeping an eye on the overall aims of risk management and the objectives of the local council in question.

These aspects are critical. The most sophisticated, robust and innovative methods may be applied in a risk assessment activity that turns out to be worthless if it is not grounded in the overall purpose of risk management, to maximise the likelihood that a local council will achieve its objectives.

Bringing together a group of committed people during the early stages, by forming a Coastal Risk Committee, is a key early step in achieving good outcomes. The membership should be broad to encourage free dissemination of outcomes to stakeholders as the risk assessment process evolves. At this point, it is important to acknowledge a degree of climate change scepticism that may persist in the community. Although the overwhelming majority of scientists involved in analysing climate change and sea level rise accept the reality and significance of anthropogenic effects on climate change, some will still dispute this mainstream view. If this is not acknowledged and addressed at an early stage, the issue has the potential to cause problems that derail later parts of the risk management process.

In some cases, a pre-existing committee may suitably take on the role of the coastal risk committee. The committee should be chaired by the local council. Membership should draw significantly from state government departments with representation also from local interest groups, recreational groups, business and property owners and, potentially, academic experts with ties to the local area.

7.5 Establish the Context

A clear context for risk assessment is essential and is the responsibility of the coastal risk committee. Without a clear context, it is not possible to clearly define the requirements of different risk assessment activities. An idea of spatial extent and the hot-spots that are likely to require most attention will have been gained from the preliminary study.

In practice, aspects of the context will be provided by state government in Australia. Elements of the context will be set by legislation and state government policy, which varies from state to state. Ideally, state governments should clearly summarise those aspects which are set at state level, and those that can be determined locally.

Guidance in the form of a manual of practice that applies to all coastal councils in a given state appears to be a suitable way to achieve this. The different elements of context that need to be defined to appropriately constrain the risk assessment are described in the following sections.

7.5.1 Legal Requirements / Legal Environment

As noted above, the legal responsibilities and legislative framework within which councils operate will vary from state to state (and from year to year). With local government acting as an arm of state government throughout Australia, it makes most sense that state government establishes guidelines that can be followed by local government in order to discharge their responsibilities under law.

7.5.2 Objectives and Key Assets

ISO 31000 gives prominence to the objectives of an organisation. While the role of local government in Australia has changed over recent decades, the most common overriding objectives (or roles) of local government include:

- the provision of physical infrastructure (roads, drainage, sewerage and water)
- municipal services, including the maintenance and operation of infrastructure and collection of rubbish
- community services, such as libraries, cultural facilities, parks and recreation, encouraging tourism and local economic growth
- planning services, including assessment of development applications and the creation of overriding land use planning and development controls, incorporating environmental considerations.

The committee should identify, using outputs from the preliminary study, those assets of importance to the achievement of a council's objectives of concern and how they could be impacted by changes to coastal climate variables.

7.5.3 Hazards of Concern

This framework is limited to those climate variables that are of unique concern in the coastal environment. A preliminary list of hazards is as follows.

- Sea level rise causing intermittent but regular inundation (e.g. inundation during high spring tides).
- Sea level rise exacerbating extreme flooding, including additional overtopping of coastal barriers.
- Sea level rise affecting normal tide levels, which may affect the operation of waterside infrastructure.
- Sea level rise affecting erosion and sedimentation patterns inside estuaries.

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- Changes to weather/storminess affecting coastal erosion. At the present time, we note that outputs from climate models tend to show variations in storm tracks that may either increase or decrease the amount of coastal erosion. Careful consideration of available research is required.
 - Changes to storminess exacerbating extreme flooding due to modifications in the scale and characteristics of coastal storm surge.
 - Changes to the potential location of water chemistry thresholds (e.g. limiting salinity).
 - Changes to location of water temperature thresholds (e.g. temperature too high for species to survive).
 - Changes to groundwater levels along the coast (may affect below ground services and facilities, or bearing capacity of footings and roads).

The above list may be added to or subtracted from as necessary for a given location. To make the hazards consistent with the way risk is described under this framework, each of the hazards should be posed in a way that links the outcome of the hazard to a spatial extent.

Broadly, these hazards can be grouped into the following categories:

- inundation hazards
- erosion and morphological hazards
- water physico-chemical hazards
- groundwater hazards.

Each category roughly corresponds to a particular set of skills for analysis, and they could be considered separately as part of different analytical studies. However, there are interactions and it is important to understand how hazards will eventually manifest as a risk. For example, while sea level rise is most likely to occur gradually, the storm events which significantly elevate coastal water levels and cause severe erosion tend to occur infrequently. The impact of sea-level rise may not manifest until such time as an extreme storm event occurs *on top of* that underlying rise in mean sea level.

7.5.4 Time Frames of Concern

The time frames of concern will vary depending on the decisions to be made and the assets involved. As time progresses the actual year in the future which needs to be considered for different decisions will change. The time frames provided in Table 4 are put forward for consideration in coastal risk assessment.

Table 4 Example time frames for planning and design

Consideration	Applicable time frame
Requiring imminent attention	Up to 15 years
Design of minor infrastructure (landscaping etc.)	25 years
Generational changes	35 years
Design life of normal infrastructure (e.g. roads, drainage)	50 years
Design life for residential buildings	50-60 years
Major & critical infrastructure (e.g. hospitals, schools, bridges)	100+ years
Residential subdivision	100+ years

7.5.5 Risk Tolerance and Success Criteria

For the assets of concern, a level of tolerance needs to be identified for the applicable time frame. Care is required, as there are likely legal implications that guide councils towards adopting a more conservative (i.e. risk averse) approach. There are circumstances in which councils owe a duty of care to the community and this should be demonstrated in the selection of an appropriately risk averse level of tolerance. Furthermore, in Australia there are precedents for the need to consider principles of ecologically sustainable development in the public interest (Bell, 2014). Therefore in considering issues relating to intergenerational equity, there is a need to adopt the precautionary principle in the maintenance of biodiversity.

Again, the degree and formality with which these issues are dealt with may vary on a state by state basis and therefore requires an understanding of the legal environment (Section 7.5.1).

Related to the concept of tolerance is the concept of risk criteria. These criteria are the way in which risks are categorised following analysis. A certain classification of risk will be assigned using these criteria and based on the analysis of likelihood and consequences. That classification would then be compared against the established levels of tolerance to determine whether the risk is acceptable or needs to be treated.

Different levels of tolerance may apply to different assets, depending on their importance to different objectives. More consideration of this is discussed under risk evaluation (Section 7.9). Similarly, the criteria for assessing likelihood and consequence are described in Sections 7.7 and 7.8. While these scales are more closely related to the risk assessment tasks of analysis and evaluation, it is timely for councils to consider these for the sake of transparency. In other words, the aim is to prevent scales being adjusted at a later stage of the risk assessment to try and achieve a more politically or ideologically ‘palatable’ outcome.

7.5.6 Climate Change Projections to be Adopted

The use of benchmarks, or a single assumed trajectory for sea level rise (or any other climate change related parameter) is inconsistent with risk assessment as specified by The Standard. In the most recent assessment report from the IPCC (AR5), probabilities are associated with a variety of climate change parameters.

At this point in time, it is recommended that a set of trajectories (for the variable of interest) be determined for each RCP. Each set would include trajectories corresponding to likelihoods determined for assessment, as described in Section 7.5.5. These should subsequently be weighted according to the best available information at the time. In the first instance, equal weighting is recommended.

Variation from the above weighting is likely to be justified as new information comes to hand. For example, when the IPCC releases a new report, a new set of projections may be adopted. Similarly, high level political agreements, and emerging patterns of greenhouse gas emissions may be used to give more weight to a particular RCP.

7.6 Key Risk Identification

Prior to identifying risks, a broad examination of the extents and distribution of assets threatened should be made. To facilitate systematic risk identification, it is recommended that assets be subdivided into logical groupings based on the purpose and scale of the risk assessment. For example, it may make sense to divide geographically (deal with different estuaries and coastal embayments separately), or via classification (e.g. infrastructure, settlements, environmental assets, recreational assets, public safety risks).

Formal risk identification can be undertaken in workshop / brainstorming sessions, armed with the results of the preliminary study and providing descriptions of:

- 1 a potential effect on a council's objectives
- 2 the events that would lead to that impact (or consequence)
- 3 what would cause the event (of unknown likelihood at the present time)?

Herein, the council's objectives are considered the primary entry point to formally identifying risks. This ensures that focus remains on the particular issues that council is concerned with, reducing the identification of false positive and dead end risks.

Under the framework, risks are considered to revolve around a *spatial extent* where the spatial extent is the parameter that has a level of likelihood attached to it.

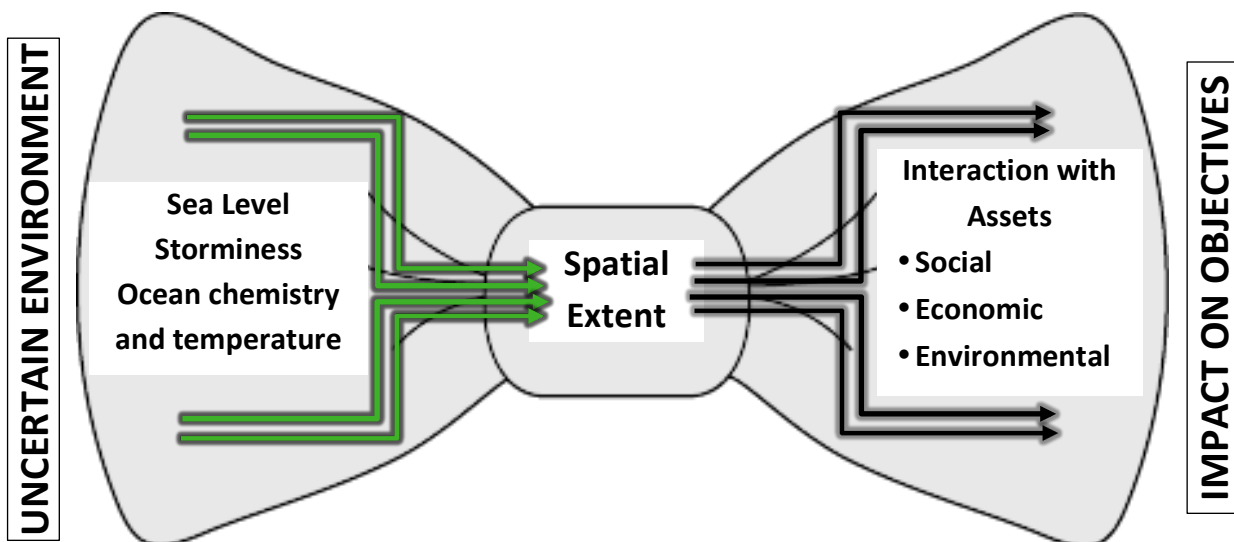


Figure 13 An uncertain spatial extent is the central event of risk descriptions

All risks should be identified, including those over which the council has limited control. In addition to the above, the adaptive capacity of different assets and existing controls may be identified, as a precursor to considering adaptation options at a later stage of the risk management process.

The presence of complex risks, involving cascading and cumulative factors must also be considered. This may affect how subsequent hazard studies are undertaken.

It is envisaged that risk identification would be undertaken by the coastal risk committee, potentially with external help to facilitate the exercise and the involvement of external experts as necessary. To optimise the participants' time in a workshop, a briefing paper should be issued to outline the context and explain the risk identification exercise. The outcome of the exercise will be a list of clear risk descriptions of the cause, event, consequences and impact on council's objectives. Following completion of the risk identification process, it will be necessary for the committee to identify areas where more detailed analytical studies are required to provide the information necessary to analyse and evaluate the risk.

The separation of different analysis studies into particular skill sets is highly recommended. For example, some analyses are best completed by a coastal geomorphologist, some by an engineer and others by ecologists. Similarly, detailed valuation studies of environmental or recreational assets may need the input of a specialised economist. In some cases (for example the interaction of coastal and catchment inundation and erosion) multiple skill sets may be required and the coastal risk committee should carefully consider an appropriate scope for each study to be commissioned.

7.7 Likelihood Studies (Including Hazard Extents)

A review of risk analysis studies undertaken during development of this framework indicates that there is no overriding standard approach to assessing likelihoods of hazards reaching a particular spatial location. The studies reviewed spanned from

around 2004 to 2014 and typically adopted either benchmark values, or ranges of unspecified likelihoods in climate change parameters. Furthermore, the studies were often based upon a limited consideration of one or two SRES (previous IPCC) scenarios and the outputs were therefore conditional on the occurrence of those particular scenarios.

The differences in approach to assessing likelihoods and hazards indicate that this area is a field of rapid research and development. The committee needs to have a broad understanding of the methods available for hazard (likelihood) analysis and needs to select a method or prepare a brief to recommend a method accordingly. Although it appears uncommon in Australian practice to date, we consider that best practice would utilise methods that are peer reviewed and widely accepted. This framework does not recommend any particular method of hazard analysis. Analysis during this risk assessment stage should assume existing controls—or business as usual—which may act to mitigate or exacerbate the consequences, remain unchanged. Actions to mitigate risks should be considered at a later stage.

Best practice for hazard and likelihood analysis would output results which, for a variety of required time frames, provide a snapshot of spatial locations and associated probabilities. While best practice suggests determination of a numerical probability, it may be adequate to deal with this in a more qualitative manner. If the qualitative path is chosen, it is important that the overall criteria for risk analysis and tolerance thresholds are adjusted accordingly. Qualitative assessment needs to be clearly justified. Existing guidance on qualitative assessment, where the likelihood scale ('almost certain', 'likely' etc.) is linked to a descriptor (e.g. may occur about once per year) is provided in a number of publications that have been applied in industry (Australian Standards, 2013; Broadleaf Capital International and Marsden Jacob Associates, 2006)

An alternative approach is to present outputs for a range of values (i.e. a sensitivity analysis) for the important climate change variables. For example, the situation with a sea level rise of 0.1, 0.2, 0.4, 0.7 and 1.0m might be mapped. The advantage of this approach is that the future time frame and probability is not fixed. Should new information indicate, for example, that the probability distribution of future sea level rise changes, these spatially consistent snapshots can be re-used, eliminating the need to recomplete costly analysis studies.

Following completion of significant hazard studies, the results should be presented to the broader community, in order to keep them abreast of the broader risk management / risk assessment process.

In reporting the results of likelihood studies, a clear description of the assumptions, limitations and overall confidence in the methods used should be provided. This is needed to allow informed evaluation of the risks.

7.8 Analyse Consequences (Including Study of Asset Values)

The ultimate aim of the consequence analysis is to spatially map the values of all assets of concern. Theoretically, these studies can be undertaken in parallel and independently from the likelihood and hazard studies. There is some value in

maintaining independence between these two, to ensure that fears of concerning outcomes from the overall risk evaluation do not adversely affect judgement when assigning values (or the extent of impact associated with a particular likelihood level).

It is highly likely that there will be substantial data gaps at the outset, particularly when looking to evaluate recreational values and environmental assets. One particular area where there may be a lack of data is how the nature of exposed built assets will change over time. For example, future patterns of coastal development in the face of a receding shoreline will be affected in complex ways by social, economic and political factors extending beyond the life of any existing plans of land development. The likely life cycle of assets prior to replacement (and possible relocation) may require consideration. These factors add further uncertainty to the analysis and that uncertainty should be made clear to decision makers and addressed where possible within the analysis.

It is likely that a significant amount of community and stakeholder consultation will be required as part of the process of gathering additional value information. The best practice standard is considered to be assigning a dollar value to all assets, such that impacts can be balanced against each other in subsequent risk evaluation, adaptation strategy considerations and benefit cost analyses.

The methods that can be used to assign values are numerous and vary depending on the nature of the asset being considered. As for the likelihood analysis we do not advocate any particular method over another, and it is up to the committee to consider the approach that best suits the situation being considered. Again, peer reviewed methods that have a demonstrable track record are preferred. A clear decision and agreement on the method to be adopted should be made prior to commencement of the study.

In some instances, complex interactions may occur that require special consideration. For example, seagrasses may be of importance to a particular species of fish during its juvenile stage of development. Subsequent migration to a different environment in its adult stage means that impacts affect values of a geographically dispersed fishery. Therefore, it can be stated that seagrasses (or saltmarsh, or mangrove wetlands) are of broader geographical significance to fisheries.

It is imperative that care is taken in consultation at this point in time. Values of most assets are intrinsically related to the desires of the community and the way in which they view the future. Broad contact with a wide range of stakeholders and ordinary community members is appropriate at this stage.

It is possible that less detailed or qualitative assessment is justifiable. In this case, to work in the present framework, only the location and extents (areas, quantities, elevations etc.) of different assets need to be defined.

In reporting the results of consequence studies, a clear description of the assumptions, limitations and overall confidence in the methods used should be provided. This is an important aspect which is needed to enable evaluation of the risks.

7.9 Evaluation Study.

Risk evaluation is displayed conceptually in Figure 14. Initially, the suite of risks being analysed should be appropriately grouped. For example, risks may be classified depending on the asset threatened (infrastructure, environmental, recreational, cultural etc.). Further subdivision will also be warranted. For example, infrastructure may be divided in to sub-groups including roads, drainage and water supply.

The idea of setting risk criteria and tolerance levels was introduced in Section 7.5.5. These concepts relate to Figure 14 and a 'risk tolerance' relationship of the form shown is required for each asset grouping determined in accordance with the preceding paragraph. Furthermore, multiple time frames may be required for some assets groupings, meaning that a relationship needs to be derived for each time frame.

As an example, the committee may determine that they are willing to accept a 10% chance that \$20,000 would be lost over a 50 year time frame, whereas they are willing to tolerate a 90% chance of a \$2,000 loss over the same time frame. By determining the levels of acceptability (or tolerance) for a range of probability levels, a risk tolerance curve would be constructed. As noted above, this is best undertaken as part of the process described in Section 7.5.5, prior to risk analysis activities.

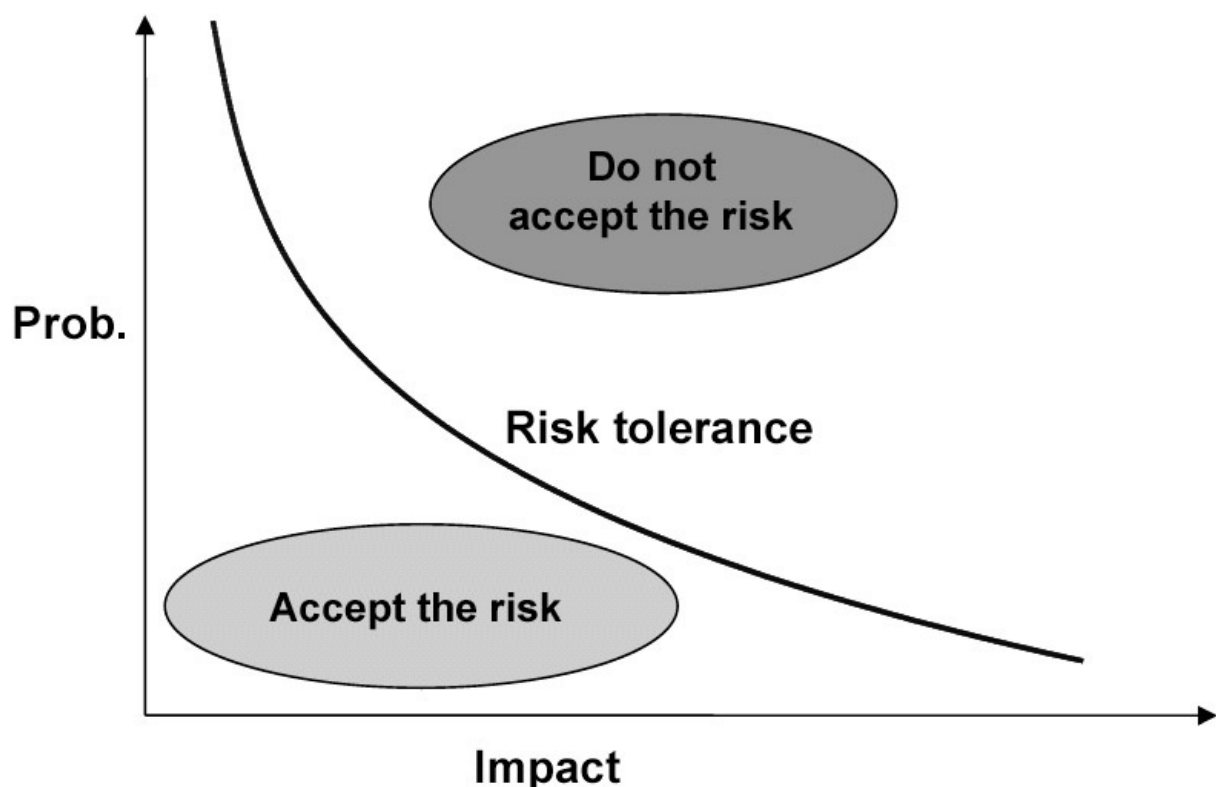


Figure 14 Conceptual representation of risk evaluation

Best practice evaluation methods would involve a set of probabilities (from 0 to 1) along the vertical axis, and dollar values along the horizontal axis. For each of the probabilities specified for use in hazard studies, a spatial extent will have been determined for each time frame of concern. From the values study a corresponding

value of assets affected by that probability can be determined using geographical information systems (GIS) software or other suitable means.

By plotting these ordinates (value, probability) for each of the asset classes and comparing with the appropriate risk tolerance curve, a decision on whether to 'accept the risk' (not requiring treatment) or 'do not accept the risk' (requiring treatment) would be made. Those risks that plot significantly above the line would represent the risks that need to be treated with a higher priority, whereas those that sit only marginally above the line would represent those with a lower priority. From this point, cost-benefit analyses could be undertaken to determine the viability of a range of strategies while developing a climate change adaptation plan.

At risk evaluation stage, it is also important to consider the levels of confidence reported by analyses of likelihoods and consequences. Generally, accepted practice in risk management is to lower the level of tolerance (i.e. be more risk averse) if the quality and confidence of information used in the evaluation is lowered.

Figure 14 is a graphical representation of the standard qualitative risk matrix type approach which has been commonly applied in Australian coastal risk assessment practice over the past 10 years. The qualitative approach can still provide value and may remain justifiable in some instances when undertaking detailed coastal risk assessment.

Information is now available to assign a reasonably robust quantitative probability to a given spatial hazard extent. However, assigning dollar values to recreational and environmental assets can be contentious. The qualitative guidance for impact (or consequence) assessment provided in AS5334 (2013) is presented in Table 5, and from Broadleaf Capital International and Marsden Jacobs (2006) in Table 6 and Table 7.

Alternative tables exist in other publications, however these should be considered carefully to ensure they are appropriate for use by a local council and are tailored to cover the types of risks being considered. For example, guidance provided by the National Emergency Risk Assessment Guidelines (Australian Government Attorney Generals Department, 2015) may prove of value, particularly when the risk assessment is dealing with rapidly emerging emergency situations.

It is suggested that a local council could start with one of these tables and add a column expressing a dollar value against each of the consequence descriptors. For example, in the context of a particular local council, the loss of \$5,000 might be considered insignificant, whereas the loss of \$50 million might be considered catastrophic to the objectives of that council. Consideration can then be given to what the acceptable probability of a catastrophic event would be. Over the life' of the decision being made, is it 1%, 0.1% or less? These are questions that are best determined by workshopping with appropriate individuals as part of the procedure outlined in Section 7.5.5.

Once percentages are determined, these dollar values could be used, in the absence of better information, to transfer from the qualitative statements in other columns to an equivalent dollar value. The values thus applied would be specific to the

particular council undertaking the assessment and would be highly influenced by the size of that council's budgetary constraints. They may, however, be inconsistent with the values of other stakeholders, such as state government.

We envisage that the risk evaluation would act as a precursor to establishing risk treatment and adaptation options. It seems premature to consult broadly with the community at this stage, before considering options for risk management. However, once the risks have been evaluated, a preliminary consideration of their importance and potential ranking of the risks could be undertaken with the risks entered onto Council's overarching risk register.

Risk evaluation is the final stage of risk assessment which, if undertaken in the manner described, should provide a transparent assessment that has a high chance of evolving to an implementable and successful adaptation plan.

Table 5 Qualitative consequences risk criteria (Table B1 from AS5334)

Consequence Descriptor	Adaptive capacity (see Note 1)	Infrastructure, service	Social/cultural	Governance	Financial (see Note 2)	Environmental (see Note 3)	Economy (see Note 4)
Insignificant	No change to the adaptive capacity	No infrastructure damage, little change to service	No adverse human health effects	No changes to management required	Little financial loss or increase in operating expenses	No adverse effects on natural environment	No effects on the broader economy
Minor	Minor decrease to the adaptive capacity of the asset capacity easily restored	Localised infrastructure service disruption No permanent damage Some minor restoration work required Early renewal of infrastructure by 10% - 20% Need for new/modified ancillary equipment	Short-term disruption to employees, customers or neighbours Slight adverse human health effects or general amenity issues	General concern raised by regulators requiring response action	Additional operational costs Financial loss is small <10%	Minimal effects on the natural environment	Minor effect on the broader economy due to disruption of service provided by the asset
Moderate	Some change in adaptive capacity Renewal or repair may need new design to improve adaptive capacity	Limited infrastructure damage and loss of service Damage recoverable by maintenance and minor repair Early renewal of infrastructure by 20-50%	Frequent disruptions to employees, customers or neighbours Adverse human health effects	Investigation by regulators Changes to management actions required	Moderate financial loss 10-50%	Some damage to the environment, including local ecosystems Some remedial action may be required	High impact on the local economy, with some effect on the wider economy
Major	Major loss in adaptive capacity Renewal or repair would need new design to improve adaptive capacity	Extensive infrastructure damage requiring major repair Major loss of infrastructure service Early renewal of infrastructure by 50-90%	Permanent physical injuries and fatalities may occur Severe disruptions to employees, customers or neighbours	Notice issued by regulators for corrective actions Changes required in management Senior management responsibility questionable	Major financial loss 50-90%	Significant effect on the environment and local ecosystems Remedial action likely to be required	Serious effect on the local economy spreading to the wider economy
Catastrophic	Capacity destroyed, redesign required when repairing or renewing asset	Significant permanent damage and/or complete loss of the infrastructure and the infrastructure service Loss of infrastructure support and translocation of services to other sites Early renewal of infrastructure by > 90%	Severe adverse human health effects, leading to multiple events of total disability or fatalities Total disruptions to employees, customers or neighbours Emergency response at a major level	Major policy shifts Changes to legislative requirements Full change of management control	Extreme financial loss >90%	Very significant loss to the environment May include localised loss of species, habitats or ecosystems Extensive remedial action essential to prevent further degradation Restoration likely to be required	Major effect on the local, regional and state economies

Table 6 Qualitative consequences scale for a local authority (Table 8 from Broadleaf Capital International and Marsden Jacob Associates, 2006)

Rating	Public safety	Local economy and growth	Community and lifestyle	Environment and sustainability	Public administration
Insignificant	Appearance of a threat but no actual harm	Minor shortfall relative to current forecasts	There would be minor areas in which the region was unable to maintain its current services	No environmental damage	There would be minor instances of public administration being under more than usual stress but it could be managed
Minor	Serious near misses or minor injuries	Individually significant but isolated area of reduction in economic performance relative to current forecasts	Isolated but noticeable examples of decline in services	Minor instances of environmental damage that could be reversed	Isolated instances of public administration being under severe pressure
Moderate	Small numbers of injuries	Significant general reduction in economic performance relative to current forecasts	General appreciable decline in services	Isolated but significant instances of environmental damage that might be reversed with intensive efforts	Public administration would be under severe pressure on several fronts
Major	Isolated instances of serious injuries or loss of life	Regional stagnation such that businesses are unable to thrive and employment does not keep pace with population growth	Severe and widespread decline in services and quality of life within the community	Severe loss of environmental amenity and a danger of continuing environmental damage	Public administration would struggle to remain effective and would be seen to be in danger of failing completely
Catastrophic	Large numbers of serious injuries or loss of life	Regional decline leading to widespread business failure, loss of employment and hardship	The region would be seen as very unattractive, moribund and unable to support its community	Major widespread loss of environmental amenity and progressive irrecoverable environmental damage	Public administration would fall into decay and cease to be effective

Table 7 Qualitative consequences scale for a public utility (Table 9 from Broadleaf Capital International and Marsden Jacob Associates, 2006)

Rating	Service quality	Service delivery	Interaction with other providers	Administration	Community confidence
Insignificant	Minor deficiencies in principle that would pass without comment	Minor technical shortcomings in service delivery would attract no attention	Minor unnecessary overheads arising from relations with other providers but no material effect	There would be minor areas of concern but they would not demand special attention	There would be minor concerns but they would attract no attention
Minor	Services would be regarded as satisfactory by the general public but personnel would be aware of deficiencies	There would be isolated instances of service delivery failing to meet acceptable standards to a limited extent	Unnecessary overheads in dealing with other providers would absorb some effort but the public would be unaware of this and would not be affected	There would be some administrative shortcomings demanding attention but they would not be regarded as serious failures	There would be some concern about our capacity to serve the community but it would not be considered serious
Moderate	Services would be regarded as barely satisfactory by the general public and the organisations personnel	There would be isolated but important instances of services being poorly targeted or delivered late	Unnecessary overheads arising from relations with other providers would be a drain on resources but the public would be unaware of this	Administrative failings might not be widely seen but they would cause concern if they came to light	There would be isolated expressions of concern about our capacity to serve the community
Major	The general public would regard the organisation's services as unsatisfactory	There would be isolated instances of services being incorrectly targeted, delivered late or not delivered at all	The effort of managing relations with other providers would drain resources and badly degrade service delivery	Administration of the organisation would be seen to be deficient and in need of external review	There would be serious expressions of concern about our capacity to serve the community
Catastrophic	Services would fall well below acceptable standards and this would be clear to all	Services would be incorrectly targeted, delivered late or not at all in a large number of cases	The organisation would be in conflict with other providers and this would directly affect services	Administration of the organisation would be seen to have failed and in need of external intervention	There would be widespread concern about our capacity to serve the community

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Appendix A Supplementary Literature

Table A1 Identified Supplementary Literature of Relevance, Including Journal Articles

Peer Reviewed Article Author and Title	Year
Button, C., Harvey, N., Vulnerability and adaptation to climate change on the South Australian coast: a coastal community perspective.	2015
Metcalf, S.J., van Putten, E.I., Frusher, S., Marshall, N.A., Tull, M., Caputi, N., Haward, M., Hobday, A.J., Holbrook, N.J., Jennings, S.M., Pecl, G.T., Shaw, J., Measuring the vulnerability of marine social-ecological systems: a prerequisite for the identification of climate change adaptations.	2015
Watson, J., 2015. Practical precautions, reasonable responses: How South Australia's planning regime adapts to the coastal impacts of climate change.	2015
Serrao-Neumann, S., Harman, B., Leitch, A., Choy, D.L., Public engagement and climate adaptation: insights from three local governments in Australia.	2015
Bryan, B.; Harvey, N.; Belperio, T.; et al. Distributed process modeling for regional assessment of coastal vulnerability to sea level rise.	2001
Catford, Jane A.; Naiman, Robert J.; Chambers, Lynda E.; et al. Predicting Novel Riparian Ecosystems in a Changing Climate.	2013
Saintilan, Neil; Wilson, Nicholas C.; Rogers, Kerrylee; et al. Mangrove expansion and salt march decline at mangrove poleward limits.	2014
Serrao-Neumann, Silvia; Di Giulio, Gabriela M.; Ferreira, Lucia C.; et al. Climate change adaptation: Is there a role for intervention research?	2013
Zander, K.K., L. Petheram and S.T. Garnett Stay or Leave? Potential climate change adaptation strategies among Aboriginal people in coastal communities in northern Australia.	2013
Cechet, R. P.; Skene, D.; Arthur, W. C.; et al. (2009). Assessment of potential climate change impacts on coastal infrastructure assets.	2009
de Freitas, D. M.; Smith, T. and A. Stokes Planning for uncertainty: Local scale coastal governance.	2013

Peer Reviewed Article Author and Title	Year
Dutta, Dushmanta; Wright, Wendy and Philip Rayment. Synthetic impact response functions for flood vulnerability analysis and adaptation measures in coastal zones under changing climatic conditions: a case study in Gippsland coastal region, Australia.	2011
Finlayson, C. M.; Davis, J. A.; Gell, P. A.; et al. The status of wetlands and the predicted effects of global climate change: the situation in Australia.	2013
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Harvey, N. and C. D. Woodroffe. Australian approaches to coastal vulnerability assessment.	2008
Lin, Brenda B.; Khoo, Yong Bing; Inman, Matthew; et al. "Assessing inundation damage and timing of adaptation: sea level rise and the complexities of land use in coastal communities.	2014
McInnes, Kathleen L.; Macadam, Ian; Hubbert, Graeme; et al. An assessment of current and future vulnerability to coastal inundation due to sea level extremes in Victoria, southeast Australia.	2013
Pecl, Gretta T.; Ward, Tim M.; Doubleday, Zoe A.; et al. Rapid assessment of fisheries species sensitivity to climate change.	2014
Pratchett, Morgan S.; Bay, Line K.; Gehrke, Peter C.; et al. Contribution of climate change to degradation and loss of critical fish habitats in Australian marine and freshwater environments.	2011
Preston, B. L.; Abbs, D.; Beveridge, B.; et al. Spatial Approaches for Assessing Vulnerability and Consequences in Climate Change Assessments.	2007
Runting, Rebecca K.; Wilson, Kerrie A. and Jonathan R. Rhodes (2013). Does more mean less? The value of information for conservation planning under sea level rise.	2013
Sano, M.; Golshani, A.; Splinter, K. D.; et al. A detailed assessment of vulnerability to climate change in the Gold Coast, Australia.	2011
Rogers, Kerrylee; Saintilan, Neil and Craig Copeland. Modelling wetland surface elevation dynamics and its application to forecasting the effects of sea level rise on estuarine wetlands.	2013
Stevens, H. R. and A.S. Kiem. Developing hazard lines in response to coastal flooding	2014

Peer Reviewed Article Author and Title	Year
Tonmoy, F. N. and A. El-Zein. Vulnerability of infrastructure to Sea Level Rise: A combined outranking and system-dynamics approach.	2014
Tran, Da B.; Dargusch, Paul; Moss, Patrick; et al. An assessment of potential responses of Melaleuca genus to global climate change.	2013
Wang, X., Y. B. Khoo and C. H. Wang. Risk assessment and decision-making for residential housing adapting to increasing storm-tide inundation due to sea level rise in South East Queensland, Australia.	2014
Gibbs, M & Hill, T Coastal Climate Change Risk – Legal and Policy Responses in Australia (Includes Annexure A)	2011
Bell, J Climate Change and Coastal Development Law in Australia	2014
Dowdy, A. et al East Coast Cluster Report, Climate Change in Australia, Projections for Australia's Natural Resource Management Regions	2015
Gibbs, M Pitfalls in Developing Coastal Climate Adaptation Responses	2015

Table A2 List of Identified Published Guidelines and Frameworks Incorporating Coastal Risk Assessment Techniques

Guidance Document Author and Title	Year
Marsden Jacob Decision Support for Coastal Adaptation – The Handbook (Literature Review and Consultation Paper and Discussion Paper available for Download, full report apparently only available for purchase)	2013
Local Government Association of South Australia. Climate Adaptation Planning Guidelines	2014
Western Australian Local Government Association. Risk Assessment (Part of the online Climate Change Management Toolkit) http://www.walgaclimatechange.com.au/risk-assessment-and-management.htm	Undated.
Victorian Centre for Climate Change Adaptation Research. Climate change Adaptation Navigator (online tool contains sections on “Risk Assessment” within “Assessing the Effects of Climate Change”) http://www.adaptation-navigator.org.au/	
Australian Centre of Excellence for Local Government. Climate Adaptation Manual for Local Government. Embedding resilience to climate change. (2 volumes, Report and Case Studies)	2014
Blackwell, Boyd Dirk; Raybould, Mike and Neil Lazarow Beaches as Societal Assets: Council Expenditures, Recreational Returns, and Climate Change, Chapter in Handbook of Tourism Economics: Analysis New Applications and Case Studies.	2013
NSW Office of Environment and Heritage Guide to Climate Change Risk Assessment for NSW Local Government	2011
NSW Office of Environment and Heritage Guide to Integrated Regional Vulnerability Assessment (IRVA)for Climate Change	2013
West Australian Planning Commision and Department of Planning Coastal Hazard Risk Management and Adaptation Planning Guidelines	2014

Guidance Document Author and Title	Year
Williams KJ, Prober SM, Harwood TD, Doerr VAJ, Jeanneret T, Manion G, and Ferrier S (2014) Implications of climate change for biodiversity: a community-level modelling approach, CSIRO Land and Water Flagship, Canberra	2014
Hawden, W.; Capon, S.; Poloczanska, E. et al Coastal Ecosystems Responses to Climate Change - A synthesis report	2012
Baker & Mackenzie Local Council Risk of Liability in the Face of Climate Change Resolving Uncertainties	2011
QLD Department of Environment and Heritage Protection Guideline: A Risk Assessment Approach to Development Assessment in Coastal Hazard Areas	2013
QLD Department of Environment and Heritage Protection Coastal Hazard Technical Guide. Determining Coastal Hazard Areas	2013
QLD Department of Environment and Heritage Protection Preparing a Shoreline Erosion Management Plan	Unknown
QLD Department of Environment and Heritage Protection Preparing a Coastal Hazard Adaptation Strategy	2013
Victorian Government Department of Sustainability and Environment Victorian Coastal Hazard Guide	2012
Tasmanian Government: Department of Premier and Cabinet Community-Based Coastal Adaptation Planning – Module 1-4 (Online Resource at: http://www.dpac.tas.gov.au/divisions/climatechange/adapting/local_government_resource_portal/coastal_adaptation_planning)	-
Grainger, K. Disaster Risk Assessments for Local Governments: A Practitioner's Guide	2014
Australian Government: Department of the Environment and Heritage, Australian Greenhouse Office Climate Change Impacts and Risk Management: A Guide for Business and Governments	2006

Guidance Document Author and Title	Year
New South Wales Government: Department of Environment and Climate Change Floodplain Risk Management Guideline: Practical Consideration of Climate Change	2007
Engineers Australia Climate Change Adaptation Guidelines in Coastal Management and Planning	2012
SMEC Australia Climate Change Adaptation Actions for Local Government	2007
Randall, A.; Capon, T.; Sanderson, T. et al. Choosing a decision-making framework to manage uncertainty in climate adaptation decision-making: A practitioner's handbook	2013
UK Department for Environment, Food and Rural Affairs Appraisal of Flood and Coastal Erosion Risk Management: A DEFRA Policy Statement	2009
New Zealand Ministry for the Environment Climate Change Effects and Impacts Assessment: A Guidance Manual for Local Government in New Zealand	2008
Adaptation Scotland and Sniffer Consulting Five steps to managing your climate risk. A Guide for Public Bodies in Scotland	2013
Russell, N. and G. Griggs Adapting to Sea Level Rise-A Guide for California's Coastal Communities	2012
Local Government Association of Queensland Adapting to Climate Change - A Queensland Local Government Guide	2007
NSW Government NSW Coastal Management Manual Part B, Stage 2 Detailed studies of vulnerabilities and opportunities	2015

Appendix B Coastal Risk Study Assessment Scores

