ASSESSMENT OF IMPACTS OF CLIMATE CHANGE ON AUSTRALIA'S PHYSICAL INFRASTRUCTURE

REPORT OF A STUDY BY THE AUSTRALIAN ACADEMY OF TECHNOLOGICAL SCIENCES AND ENGINEERING (ATSE) 2008

ASSESSMENT OF IMPACTS OF CLIMATE CHANGE ON AUSTRALIA'S PHYSICAL INFRASTRUCTURE

This study, by the Academy of Technological Sciences and Engineering, concludes that the impacts of current climate change projections have the potential to significantly challenge the capacity of elements of Australia's physical infrastructure and that action needs to be taken at the national level to ensure that appropriate adaptation measures can be implemented to meet these challenges.

REPORT OF A STUDY BY THE AUSTRALIAN ACADEMY OF TECHNOLOGICAL SCIENCES AND ENGINEERING (ATSE) 2008

ASSESSMENT OF IMPACTS OF CLIMATE CHANGE ON AUSTRALIA'S PHYSICAL INFRASTRUCTURE

ISBN 1 875618 96 1

Publisher

The Australian Academy of Technological Sciences and Engineering (ATSE)

Ian McLennan House

197 Royal Parade

Parkville, Victoria 3052

(PO Box 355, Parkville, Victoria 3052)

Telephone +613/03 9340 1200

Facsimile +613/03 9347 8237

Website www.atse.org.au

Author: Emeritus Professor Len Stevens AM FTSE

This work is also available as a PDF document on the ATSE website, www.atse.org.au

Funded by the Australian Research Council

– via a Linkage Learned Academies Special Projects grant

Design and production: Coretext, www.coretext.com.au

Printing: FSG Print Management, www.fsg.com.au

Date of Publication: July 2008

Cover: This recent storm surge on Queensland's Gold Coast indicates the threat of climate change to Australia's infrastructure – CSIRO photo

Executive Summary

1 The Academy of Technological Sciences and Engineering (ATSE) has conducted an assessment of the impacts of climate change on Australia's physical infrastructure. This assessment was an initial scoping study, with the aim of identifying the important impacts of climate change on Australia's physical infrastructure and to provide broad recommendations for future action. The purpose of this report is to stimulate discussion and to induce action by relevant authorities.

2 The ATSE study involved a qualitative assessment of risk of the impact of climate change on Australia's physical infrastructure. The assessment also considered how existing physical infrastructure could be adapted to the effects of climate change; some consideration was also given to the requirements for future infrastructure. It considered generic categories of existing infrastructure in several geographical regions across Australia; the study did not consider individual infrastructure at specific locations. This study included a literature survey of the current status of the relevant disciplines, an electronic survey of fellows of the Academy, two workshops, and teleconferences involving fellows and other experts in particular fields of infrastructure.

3 The ATSE risk assessment study has identified that major potential impacts on physical infrastructure often arise from combinations of projected climatic events. These include, for example, the impact of drought, bush fires and extremes of temperature on energy generation and distribution systems, or extreme rainfall, or sea-level rise and storm surge on low-lying coastal developments. In addition, critical examination will need to be given to drainage, storm water and sewerage infrastructure where significant rainfall intensity is projected.

As a result of this study the Academy is of the view that impacts from climate change, arising from either natural causes or from greenhouse gas emissions, can provide significant challenges for the future physical security and operation of various categories of Australia's physical infrastructure. This is the view of a very substantial majority of those who participated in the ATSE study. The study concluded that further intensified research and related studies are required for these critical areas of infrastructure.

4 The existing generally comprehensive frameworks of codes, regulations and planning authorities, the general level of scientific and technological expertise and resources, have all contributed to Australia being well placed to undertake these risk assessments. These existing frameworks provide a sound basis for coordinated future studies. The study has shown that significant initiatives have already been taken by the Australian, State, and Territory Governments, and their agencies, in research to develop information on climate change scenarios and projections which are specifically related to Australia's climatic regions. Other initiatives span the development of guidelines and frameworks for the assessment of impacts of climate change, involving the application of established risk management techniques, and the assessment of adaptation strategies to cope with potential impacts.

5 While this report has identified significant challenges arising from the effects of climate change for security and operation of various categories of Australia's physical infrastructure, it must be acknowledged that most of Australia's physical infrastructure has been designed to resist the effects of climatic loading effects. Accordingly, there is intrinsic capability in such infrastructure to resist the additional effects imposed by climate change.

6 On the basis of this study, there is a prima facia case for relevant authorities to request/require more comprehensive risk assessment studies be undertaken for specific installations of existing critical infrastructure categories that are considered vulnerable to the effects of climate change. Adaptation

strategies should be implemented, as required, for specific infrastructure installations that are deemed vulnerable to the effects of climate change.

7 The study identified also the need to develop comprehensive strategic planning controls for future specific installations in critical infrastructure categories that are considered vulnerable to the effects of climate change. Comprehensive risk assessment methodologies should be implemented to support the design of such infrastructure. This initiative must be supported by reviewing existing design codes, particularly loading codes.

8 In supporting these particular risk assessment studies, emphasis should be given to providing information which includes detailed statistical information in the form of probability density functions of climate change events so that more accurate comparative studies may be made of risks and adaptation requirements.

9 The Academy study points to the need for strengthened research efforts to improve the modelling of small-scale events such as extreme rainfall, hail, storms and tropical cyclones, for all Australian regions where current studies have identified potential risks. Information in the form of probability distributions, specific to Australian conditions, is essential to supplement the more broadly based global IPCC scenarios and projections which may not necessarily be suitable for application locally. In addition, information in the form of probability distributions is required for the capacity of infrastructure components after adaptation.

10 Adaptation strategies should take into account the consequences of the impact of climate change, which may range from discomfort, inconvenience, economic loss caused by interruption of services, property damage, threats to health, to injury and death. Decision on actions to be adopted should be made with a clear understanding of the assumptions on which the scenarios are based and upon which the assessed consequences depend.

11 Adaptation strategies may include a range of options, including no action, action to modify the capacity of infrastructure components or deferral of action pending new information, reliance on insurance to cover damage and improved emergency services as well as retrofitting or replacement of infrastructure elements.

12 In essential national sectors, such as the generation and distribution of electrical energy, the implementation of adaptation strategies may require intervention by Government to ensure that planning is fully integrated. It must be recognised that important legal liability issues may arise from actions taken (or not taken) as a result of studies into the impact of climate change. This should be a subject of specific studies and research.

13 As a result of the study, the Academy recognises the need to develop further the expertise of persons and organisations capable of both undertaking assessment of the potential impacts of climate change and developing adaptation strategies which are soundly based. The need to develop and improve professional skills in this discipline area must be recognised in order to ensure that the information and techniques for assessment are applied with a full understanding of the scientific, technological, regulatory, economic, societal and legal issues involved.

14 The Academy has gained a broad understanding of the challenges arising from the impacts of climate change in this and other exercises. As a result of the surveys, workshops and teleconferences, it has access to members and other individuals with a wide range of knowledge in infrastructure and expertise in assessment procedures. For this reason the Academy offers to make this

expertise available to governments and their agencies, as appropriate, including in the form of advisory roles on research and policy and in the peer review of proposals.

15 Given the complexity of the issues involved, and the imperative for national coordination, and as a further development of the "National Climate Change Adaptation Framework", there is an urgent need to establish national guidelines for the evaluation, design and planning of infrastructure subject to the effects of climate change. These guidelines would represent appropriate policy solutions to climate change adaptation by considering the expected consequences of climate change and would be assessed within a risk assessment framework. Due consideration should be given to financial, legal, social, environmental and emergency management matters.

NOTES

A This study adopted scenarios and projections for future climate change that were published by the Australian Greenhouse Office# (AGO) and the CSIRO in May 2006, using earlier published material. These projections incorporate a range of quantifiable uncertainties and are based on models consistent with those adopted by the IPCC and Australia's CSIRO and Bureau of Meteorology. It is recognised that the AGO 2005 report (see Literature Review, Section 2.3) contains a number of limitations, including climate change scenarios to 2030 and projections that have a limited focus on extreme events, such as wind speed. More recent projections have been published for climate change in Australia* (2007) which contain more comprehensive projections to 2030, 2050, 2070 and 2100 and hence have greater relevance to the assessment of infrastructure. However, this information was published too late for it to be used in the ATSE risk assessment study which used the climate change projection data available at the time. Nevertheless, the observations and recommendations in this report continue to be valid.

B The issue of emission controls is not within the scope of this study. It should be noted, however, that the outcomes of future emission control measures may significantly affect climate change, particularly in the longer term, leading to consequential changes in scenarios and the associated projections. Furthermore, consideration of climate change effects on natural systems, health and agriculture did not lie within the scope of the study, except where they are associated with the physical infrastructure.

As a result of recent administrative arrangements implemented by the Australian Government, the Australian Greenhouse Office is now the Department of Climate Change.
* http://www.climatechangeinaustralia.gov.au/resources.php

Recommendations

As a result of this study, the Academy makes a number of recommendations to mitigate the impacts of climate change on Australia's physical infrastructure:

RECOMMENDATION 1

The Australian Council of Governments (COAG) should convene a National Climate Change Adaptation Taskforce (NCCAT) to produce Guidelines which would represent appropriate national policy solutions to climate change adaptation by considering the expected consequences of climate change. These Guidelines will be based on a risk assessment framework and will be applied to relevant planning and design codes in a nationally consistent manner.

RECOMMENDATION 2

In producing these Guidelines, NCCAT should be supported, as appropriate, by the Department of Climate Change and the National Climate Change Adaptation Research Facility. It is further recommended that NCCAT would be responsible for identifying the need for, and facilitating the conduct of, the necessary research to support the development of these planning and revised design codes, particularly loading codes.

RECOMMENDATION 3

Under NCCAT guidance, relevant authorities should be requested/required to:

- undertake comprehensive risk assessment studies for specific installations of existing critical infrastructure categories that are considered vulnerable to the effects of climate change using the NCCAT Guidelines; adaptation strategies should be implemented, as required; and
- implement comprehensive strategic planning controls for future specific installations in the case of identified critical infrastructure categories considered vulnerable to the effects of climate change.

RECOMMENDATION 4

NCCAT should focus its initial attention on those authorities that are responsible for those categories of infrastructure that have been identified in this study as most vulnerable to the effects of climate change, namely:

- energy distribution and supply;
- low-lying coastal areas; and
- drainage (in areas where a significant increase rainfall intensity is projected).

RECOMMENDATION 5

Further research efforts should be conducted by the Bureau of Meteorology and the CSIRO to improve data collection and modelling of local events such as extreme rainfall, hail and tropical cyclones for all Australian regions where current studies have identified potential risks. Probability distributions for local climatic events are required, specific to Australian conditions to supplement IPCC global scenarios. In addition, the Academy recommends that further research efforts should be conducted by universities and CSIRO to improve probability distribution information on the capacity of infrastructure components after adaptation.

RECOMMENDATION 6

Education must be provided in the emerging discipline areas of assessing the impacts of climate change and in the development of adaptation strategies. NCCAT should facilitate procedures to ensure that information and techniques for assessment are applied by professionals with a full understanding of the scientific, technical, economic and societal issues.

RECOMMENDATION 7

NCCAT should be responsible for facilitating the study of important legal liability issues to arise from actions taken, or not taken, as a result of studies into the impact of climate change.

Acknowledgements

The Academy is most grateful to the contributions made by the author of the report and the Steering Committee established to oversee the conduct of the project.

A brief background of the author of the report is given below:

Professor L K Stevens AM FTSE

Len Stevens is Emeritus Professor of Civil Engineering at the University of Melbourne. He has had wide experience in the theory and practice of engineering with direct involvement in large infrastructure projects. He has taken a leading role in the development of structural engineering codes and standards with particular reference to extreme events such as tropical cyclones and earthquakes.

This project was overseen on behalf of the Academy by a Steering Committee:

- Dr Vaughan Beck FTSE, Technical Director, ATSE
- Mr Ian Carruthers, Department of Climate Change
- Dr Peter Crawford AM FTSE
- Mr Peter Laver AM FTSE, Vice President, ATSE
- Dr Max Lay AM FTSE
- Dr Mike Manton FTSE, Monash University
- Associate Professor Priyan Mendis, University of Melbourne
- Dr John Nutt AM FTSE, Vice President, ATSE
- Dr Greg Scott, Geoscience Australia
- Professor Len Stevens, AM FTSE, University of Melbourne

Prior to the current phase (commencing February 2006) of the project that led to the publication of this report, two Project Leaders had been previously appointed:

- Mr Brian Sadler FTSE
- Dr Subramania Ramakrishnan FTSE

The project was established and managed for ATSE by:

- Professor Ian Rae FTSE, Technical Director (to February 2006), and
- Dr Vaughan Beck FTSE, Technical Director (since February 2006).

Dr Beck also contributed to the development of the project and the report. The production of this publication was overseen by Mr Bill Mackey, Communications Director, ATSE.

The Australian Academy of Technological Sciences and Engineering, ATSE, gratefully acknowledges:

1. Funding provided by the Australian Research Council (ARC) under the Linkage Learned Academies Special Projects program to support the conduct of this project.
2. Resources provided by the ARC Research Network for Secure Australia to assist in the completion of the project. This process was facilitated by Associate Professor Priyan Mendis of the University of Melbourne.

Contents

1 Introduction

1.1 OVERVIEW

The Australian Academy of Technological Sciences and Engineering (ATSE) was awarded an ARC Project titled *The Impact of Natural Hazards on Australia's Infrastructure*. Project documentation, based on a risk assessment methodology, was produced and a scoping survey was conducted to assess the impact of natural hazards on infrastructure.

Following a review of the project in 2006, it was decided to focus the remainder of the project on an assessment of the risks arising from the effects of climate change on natural hazards to major infrastructure. A qualitative risk assessment approach was proposed to be adopted for the remaining stages of work consistent with the Australian and New Zealand Standard 4360:2004 Risk Management and HB436 Risk Management Guidelines (AS/NZS 4360:2004 Risk Management). In addition, an assessment would be made of the adaptive capacity of the infrastructure to respond to the risks imposed by climate change.

The revised approach was endorsed in discussions with the then Australian Greenhouse Office (now the Department of Climate Change) and approved by the ATSE Project Steering Committee.

It was intended, as the final part of this study, to conduct a preliminary scoping investigation that would identify those generic types of infrastructure that may be most at risk and require significant adaptation to the effects of climate change. It was intended that vulnerable pieces of infrastructure, identified in this study, would then form the basis of more detailed investigations that would be conducted in subsequent projects.

1.2 METHODOLOGY

The assessment and recommendations of this report result from the review of the topic by a number of experts and the aggregation of their views.

These were gained through a survey of ATSE Fellows and other leading experts in the fields of infrastructure and climate change, supported by two workshops and a number of telephone conferences.

2 Review of Literature

Recent publications on the effects of climate change have identified probable likelihoods, consequences and risks of the effects of climate change, as well as the capacity for adaptation, on international and regional scales. There have also been publications on how risks and adaptation capacity can be assessed. A selection of issues raised in these publications are summarised in the following sections. This is done in general terms for the broader issues relating to climate change but is given in more detail where considered particularly relevant to the proposed ATSE study assessments of impacts of climate change.

2.1 IPCC WORKING GROUP 2

Climate Change 2007: Impacts, Adaptation and Vulnerability[1]

The Intergovernmental Panel on Climate Change (IPCC) identified "key vulnerabilities of industry, settlement and society as most often related to (a) climate phenomena that exceed thresholds for adaptation, related to the rate and magnitude of climate change, particularly extreme weather events and/or abrupt climate change, and (b) limited access to resources (financial, human, institutional) to cope, rooted in issues of development context."

2.2 STERN REVIEW

The Economics of Climate Change[2]

The Stern Review examined the possible economic consequences of climate change and concludes that ignoring climate change will eventually damage economic growth. The emphasis in the Review is on the measures that will need to be taken to control and reduce the emission of greenhouses gases which are identified as being responsible for climate change. However, the Executive Summary concludes with the statement; "At the same time, given that climate change is happening, measures to help people adapt to it are essential. And the less mitigation we do now, the greater the difficulty of continuing to adapt in future."

2.3 AUSTRALIAN GOVERNMENT I

Climate Change: Risk and Vulnerability[3]

This report by the Australian Greenhouse Office (AGO – now the Department of Climate Change) explores the risks to Australia from impacts of climate change over the next 30 to 50 years. A risk management approach is used to identify sectors and regions that have the highest priority for adaptation planning.

It is noted that "adaptation and mitigation are related because the success of mitigating greenhouse gas emissions will determine the magnitude (possibly the nature) of changes to which we must adapt".

The belief that "expectations of future climate are implicitly, or explicitly, based on a continuation of past patterns" is firmly rejected and it is concluded that, for an adaptation strategy to be effective, it must result in climate risk being considered as a normal part of decision making allowing governments, businesses and individuals to reflect their risk preferences."

It is also concluded that: "Adaptation strategies therefore involve the identification of sectors/systems/regions vulnerable to change and an examination of the scope to increase the coping capacity of these systems – their resilience – which in turn will decrease their vulnerability."

1 IPCC Working Group II, *Climate Change 2007: Impacts, Adaptation and Vulnerability*, Cambridge University Press, 2008. http://www.ipcc.ch/ipccreports/ar4-wg2.htm

2 Stern, N., *The Economics of Climate Change: Stern Review*, Cambridge University Press, 2006 http://www.hm-treasury.gov.uk./independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm

3 Allen Consulting Group, *Climate Change: Risk and Vulnerability*, Australian Greenhouse Office, March 2005 http://www.greenhouse.gov.au/impacts/publications/pubs/risk-vulnerability.pdf

2.4 AUSTRALIAN GOVERNMENT II

Climate Change Impacts and Risk Management, a Guide for Business and Government[4]

The stated purpose of this document is as "a guide to integrating climate change impacts into risk management and other strategic planning activities in Australian businesses and organisations to adapt to climate change. It is not concerned with policy and other actions aimed at mitigating climate change."

The guide adopts the Australian and New Zealand Standard AS/NZS 4360:2004 Risk Management to provide a framework for assessing risk from a consideration of the likelihood and consequences of climate change impacts. It does not give assessments of any particular sectors or regions.

2.5 AUSTRALIAN GOVERNMENT III

Climate Change Scenarios for Initial Assessment of Risk in Accordance with Risk Management Guidance[5]

Regional scenarios for climate changes, which had been prepared by CSIRO for use in the initial assessment of risks in accordance with the Guide described in Section 2.4 above, have been simplified to provide climate change projections for 10 Australian climatic regions to 2030. Ranges of uncertainty for each region are expressed, based on both low and high global warming scenarios, which enable the assessment of events to be estimated for use in the Guide. Some general observations on possible consequences have been offered but these are not specifically targeted on infrastructure sectors.

There are a number of limitations with this report, including climate change scenarios to 2030 and projections that have a limited focus on extreme events, such as wind speed.

2.6 AUSTROADS STUDY

Impact of Climate Change on Road infrastructure[6]

This study into the impacts of climate change on Australian roads was prepared for Austroads by the Bureau of Transport and Regional Economics using CSIRO projections of Australia-wide climate change for the next 100 years. It included assessments of the likely impacts on patterns of demography and industry as related to road infrastructure demand, the effects on existing road infrastructure, particularly pavements, and possible adaptation measures and reported on policy implications.

The climate change emissions scenario chosen by CSIRO was for 'A2', one of the higher IPCC emissions scenarios published in 2000, in order to provide for a 'strong contrast' with current conditions. This scenario is based on a global population of around 15 billion in 2100 and has no special status as a likely future occurrence. Under the A2 scenario, the rate at which carbon dioxide is released into the atmosphere grows steadily over the next 100 years, increasing nearly fourfold. (It is noted in the Study that this assumption has been criticised as being based on unrealistically high assumptions for long-term economic growth, particularly for developing countries.)

The key findings relate to direct and indirect impacts on road infrastructure. Direct impacts are due to the effects on the environment. Rainfall changes alter moisture balances and influence pavement deterioration and temperature can affect the seals that represent more than 90 per cent of sealed roads. More frequent reseal treatment will ameliorate the problem, but at a cost to road agencies for maintenance.

Flood heights and frequencies are important considerations for the location and design of roads and bridges and sea level rise and increased occurrence of storm surges will affect roads in coastal areas.

High water tables can reduce the structural strength of pavement subgrades, and salinity can cause rusting of steel reinforcement in concrete pavements.

4 Broadleaf Capital International and Marsden Jacob Associates, *Climate Change Impacts and Risk Management, a Guide for Business and Government*, Australian Greenhouse Office, 2006 http://www.greenhouse.gov.au/impacts/publications/pubs/risk-management.pdf

5 CSIRO, *Climate Change Scenarios for Initial Assessment of Risk in Accordance with Risk Management Guidance*, Australian Greenhouse Office, 2006 http://www.greenhouse.gov.au/impacts/publications/pubs/risk-scenarios.pdf

6 Bureau of Transport and Regional Economics, *Impact of Climate Change on Road Infrastructure, AP-R243/04*, Austroads, March 2004 http://www.onlinepublications.austroads.com.au/script/Details.asp?DocN=AR0000048_0904

The indirect impacts of climate change on roads are due to the effects on the location of population and human activity altering the demand for roads.

An understanding of the expected impacts could engender considerable cost savings in the long term.

There is no indication so far as to any action arising directly from these findings.

2.7 ENGINEERS AUSTRALIA

Infrastructure Report Cards[7]

Engineers Australia commissioned and published a series of Report Cards on the adequacy of Australia's infrastructure to meet the current and future needs of the Australian economy and community expectations. The Reports examine the key infrastructure sectors of the states, evaluates the status of the assets and planning processes and assigns a rating. The assessments do not consider the possible impacts of climate change or extreme natural hazards but concentrate on operational issues related to current and future requirements assuming stationary climate scenarios.

2.8 AUSTRALIAN GOVERNMENT HOUSING STUDY

An Assessment of the Need to Adapt Buildings for the Unavoidable Consequences of Climate Change[8]

This report only became available after much of the study included in this project had been completed. It covers some of the research into a particular area in much more detail than that attempted in the ATSE study.

It is a comprehensive investigation into the likely effects of climate change on Australia's current building stock and the implications for the design of future buildings.

The study is based on climate projections for 2030 and 2070 provided by CSIRO, and similar to those presented in the AGO 'Climate Change: Risk and Vulnerability' study reviewed above, and assessed in accordance with the AGO Risk Management Guidelines. The following are relevant extracts from the Executive Summary of the Report:

"This study draws three broad conclusions about the resilience of Australia's new building stock to the likely impacts of climate change:

- new buildings are reasonably resilient to expected changes in average climate conditions, but may not be as resilient to changes in extreme events such as storms and flooding;
- some recent changes to building codes and practices, while not designed to address the impacts of climate change, have increased the resilience of new buildings. For example, higher energy efficiency standards mean that buildings are better able to cope with more frequent hot spells; and
- there is considerable scope to improve the resilience of new buildings although further research may be required before specific measures can be formulated. Options are discussed below under 'possible adaptation measures'.

The resilience of Australia's older building stock to the likely impacts of climate change is more difficult to assess, partly due to lack of information about the stock of buildings.

Good maintenance and, where appropriate, upgrading is the key to resilience for older buildings. Deciding whether to upgrade older buildings to increase resilience to climate change will depend on a combination of considerations including the expected life of the building, significance of the building, cost and risk. There would be merit in developing some guidance on whether older buildings should be modified."

Possible adaptation measures are discussed including consideration of the case for reviewing building codes and standards with possible merit in updating design criteria for cyclones, storms and high winds

[7] Hardwicke, L., *Australian Infrastructure Report Card*, Engineers Australia, 2005 http://www.infrastructurereportcard.org.au/downloads/AustralianReportCard.pdf

[8] BRANZ Ltd, *An Assessment of the Need to Adapt Buildings for the Unavoidable Consequences of Climate Change*, Australian Greenhouse Office, 2007 http://www.greenhouse.gov.au/impacts/publications/pubs/buildings-report.pdf, http://www.greenhouse.gov.au/impacts/publications/pubs/buildings-appendices.pdf

to take into account future increases in high wind events but no specific examples of structural reliability analyses are provided to quantify the impact on actual safety. Those homes not built to satisfy the current standard for bushfire risk may need to be retrofitted. The link between building standards and planning decisions is explored with particular reference to flooding.

2.9 RISK ASSESSMENT FOR VICTORIA

Infrastructure and Climate Change Risk Assessment for Victoria[9]

It is stated that the "report examines the likely impacts of climate change on Victoria's infrastructure, establishes the categories of infrastructure most at risk and outlines opportunities for adaptation responses. The report also details the current governance structures associated with each infrastructure type".

The sections in the report relevant to the ATSE study are summarised in the following:

Climate Change

The climate change projections used in the report are based on CSIRO modelling underpinned by the work of the IPCC.

It is stated that the precise effects of climate change are uncertain.

The report has used the best available data with projections from several models for up to the year 2070 presented for different climate scenarios.

The assessment is based on no adaptation responses to climate change. Results are presented as low and high ranges rather than as a single value.

In assessing the risks of climate change, the report assumes a worst case scenario – that is, the impacts of climate change are assumed to be at the upper level of presented ranges and this approach is used because of the level of investment in infrastructure and the economic risks and implications associated with failure of infrastructure projects.

Infrastructure

The infrastructure types examined include water, power, telecommunications, transport and buildings.

Risk Assessment

The Australian Standard for the identification and assessment of risk, AS/NZS 4360:2004 Risk Management, is adopted for the infrastructure risk management assessment process.

Governance Arrangements

Attention is drawn to a conclusion that the identified risks represent a significant challenge for infrastructure owners, managers and decision makers, compounded by the variety of disciplines, the long life span of infrastructure and the limited ability to modify existing infrastructure. Attention is also drawn to the legal issues with the prospect of liability for negligence because of a failure to properly address the risks arising from climate change. Insurance is also identified as an area where climate change risks are already an important issue.

Assessments Arising from Analyses

Risk assessments have been carried out for each of the infrastructure sectors with the analyses included in an extensive set of Appendices. No analyses have been made of any specific infrastructure element in a specific location so the results are necessarily of a broad nature.

The main conclusions from the assessments are summarised below.

[9] CSIRO, Maunsell and Phillips Fox, *Infrastructure and Climate Change Risk Assessment for Victoria*, Australian Greenhouse Office, 2007 http://www.dpi.vic.gov.au/CA256F310024B628/0/2021C307264A6473CA2572DD00055CBB/$File/Climate+change+and+Infrastructure+Final.pdf

Water

The main risks are the potential for increases in extreme daily rainfall events affecting the capacity and maintenance of storm water, drainage and sewer infrastructure. In addition, acceleration of the degradation of materials and structural integrity may occur through increased ground movement and changes in ground water. Water shortages may occur due to greater demand and decrease in annual rainfall.

Energy

The potential for increased frequency and intensity of extreme storms may cause significant damage to electricity transmission infrastructure and service.

Coastal and offshore energy infrastructure is potentially at risk of significant damage and increased shut-down periods from increases in storm surge, wind, flooding and wave events, especially when combined with sea level rise. Extreme heatwave events are likely to increase in frequency, generating an increase in peak demand for electricity as well as reducing the efficiency of transmission due to reduction of conductivity.

It is noted that Victoria's electricity and gas industries are fully privatised with private companies owning the assets used for production, transmission and distribution. This has implications for the management of the infrastructure and price regulation through the Essential Services Commission.

Telecommunications

Increased frequency and intensity of extreme wind, lightning, bushfire and extreme rainfall events may cause significant damage with increases in maintenance and increased length of outages and disruption.

Transport

Increased frequency and intensity of extreme rainfall events may cause significant flood damage to road, rail, bridge, airport, port and especially tunnel infrastructure. Rail, bridges, airports and ports are susceptible to extreme wind events. Ports and coastal infrastructure are particularly at risk when storm surges combine with sea level rise.

Buildings

Increased frequency and intensity of extreme rainfall, wind and lightning events is likely to cause significant damage to buildings and urban facilities. Buildings and facilities close to the coast are particularly at risk when storm surges are combined with sea level rise. Accelerated degradation of materials, structures, and foundations of buildings and facilities may occur through increased ground movement, changes in ground water, and increases in temperature and solar radiation. The accelerated degradation of materials may reduce life expectancy of buildings, increasing maintenance costs and leading to potential structural failure during extreme events.

It is noted that the building infrastructure sector has the greatest diversity in ownership, which presents challenges regarding communication of risk to owners and in ensuring that the risks are incorporated into decision making.

Estimates of extreme events used in the analyses of risk

The estimates of extreme events used in the Report are of particular interest for the ATSE study which has adopted the high 2030 scenarios given in the AGO 2005 Report.

Table 1 (overleaf), using information extracted from the Report, shows the 2070 low and high scenarios that were used to assess the risks.

TABLE 1 'LOW' AND 'HIGH' 2070 SCENARIOS

	Low scenario 2070	High scenario 2070
Drought frequency	Increase by 20% to 40%	Increase by 40% to 80%
Heat wave (days > 35º)	Increase by 3 to 5.5 days pa	Increase by 13 to 42 days pa
Bushfires	Greater severity and frequency	Greater severity and frequency
Daily rainfall	Increase of 40% in intensity	Increase of 40% in intensity
Sea level	Rise of 7cm	Rise of up to 52cm
Extreme wind speed	Increase by 3% to 9%	Increase by 9% to 18%

Note: the actual values are not given, but in Section 2.9 of the Risk Assessment for Victoria Report it is stated that projected changes in extreme daily wind speed were based on daily 99th percentile values determined by ranking daily wind speeds within a window of three years centred on the year of interest. It has not therefore been possible to relate these quoted extreme wind speeds to the Australian design wind speeds used for structural design. These are typically the 500-year return period of the maximum 3-second gust. Such information is required if the structural integrity of a structure is to be properly assessed for the assumed conditions. It is also stated in Section 2.9 of the report that there is significant uncertainty about changes in extreme wind speed over Victoria as a result of climate change.

Climate Change Impacts on Infrastructure Adaptation Framework

The report introduces the IPCC concept of adaptation strategies which aim to increase the resilience of human and natural systems to possible changes in climatic conditions, whilst taking account of the social dimensions of distributing losses. A climate change adaptation framework for Victoria is envisaged with key stakeholders in infrastructure policy, planning, investment, insurance, design, construction, management, operation and maintenance.

No attempt has been made in the report to assess the investment required to provide for any required adaptation capacity, although expectations of increases in costs in certain areas are indicated.

Several adaptation responses are suggested. These include changes in material selection, in design standards, in technology, in culture, and in planning.

Summary

The report is a comprehensive study of the possible impacts of climate on Victoria's infrastructure considered on broad sectorial bases. The report has used the most recent climate change projections for the Victorian regions and has considered a range of scenarios. In assessing the risks of climate change, the report assumes a worst case scenario.

Risk management assessments made in accordance with AS/NZS 4360:2004 Risk Management have been demonstrated to be applicable for assessment of impacts of climate change on infrastructure sectors. Risks have been assessed for all of the major infrastructure sectors for up to the year 2070.

The Report demonstrates that the objective of the ATSE study of carrying out an Australia-wide assessment of the impacts of climate change has been shown to be achievable on a smaller regional scale. It also shows that the risk management approach proposed for the ATSE study is appropriate for such an investigation.

2.10 CLIMATE CHANGE IN AUSTRALIA

Climate Change in Australia[10]

The ATSE study adopted the scenarios provided by the report by the Australian Greenhouse Office (AGO) *Climate Change Scenarios for Initial Assessment of Risk in Accordance with Risk Management Guidance* (2006) for the assessment of risk and adaptation capacity (see Section 2.5).

The report *Climate Change in Australia* was released in October 2007 and was therefore not available during the period when the ATSE study was being carried out. Some major advances beyond the AGO 2005 Report have been made which are relevant to the ATSE study. The most relevant of these for the ATSE study are summarised in the following:

[10] CSIRO and Bureau of Meteorology, *Climate Change in Australia*, Technical Report, Australian Greenhouse Office, 2007 http://www.climatechangeinaustralia.gov.au/resources.php

- Projections are provided for the years 2030, 2050, 2070 and 2100 which are more appropriately aligned with the design life of much of Australia's physical infrastructure.
- The 10 regions into which Australia was divided in the AGO Report have been replaced by much more detailed maps enabling a more accurate identification of projections for local regional areas.
- Projections are provided, rather than scenarios, with the inclusion of some probabilistic information. This is seen to be essential for the proper assessment of likelihood in the risk analysis process.
- The Report includes guidance on the application of climate change projections by a formal risk assessment process. Examples are provided and caution is advised in the assessment of likelihood with a full recognition of the underlying assumptions and a warning to avoid under and over confidence in the outcomes.
- More specific information is included relating to climate events. The most important for the ATSE study include sea level rise, temperature, drought, fire extreme days, extreme daily rainfall intensity and tropical cyclones.
- Recent trends in sea level rise, with an average of 1.2mm a year, are reported with an expectation that this will continue. Central estimates of rises from 1990 to 2100 vary from 28 to 43cm with ranges of 18 to 38cm and 26 to 59cm respectively, dependent on the emissions scenario adopted. This should be compared with the AGO 2030 scenario estimate of 17cm used in the ATSE study.
- Two studies especially relevant to the ATSE study relate to the combined effects of sea level rise and storm surge in areas already known to be vulnerable under current circumstances. A study of Victorian Gippsland local coastal areas using selected projections for 2030, concluded that the total areas subject to inundation could be doubled by a combination of high tide, storm surge from extreme wind, and sea level rise, with significant impact on the constructed infrastructure in the affected areas. A similar study for Cairns in Far North Queensland used a randomly selected population of projections for tides, sea level rise and tropical cyclones to model a possible increase of the area of inundation from 32km^2 for the current climate, to 71km^2 in 2050, with the potential to seriously disrupt much of the road network for the city. Such results are indicative of the types of assessment which can be made on a probabilistic basis by the application of the now available projections to specific elements of infrastructure. Interpretation must however be made, keeping in mind the emissions assumptions which underlie the projections which have been adopted.
- Projections for rainfall confirm current observed trends of longer dry spells interrupted by heavier precipitation events. It is expected that there will be increases in frequency of extreme daily rainfall in most wet tropical areas with decreases in frequency in the south-east, south-west and east-central coast, although significant increases in intensity are expected. A map provided for one of the lower emission scenarios confirms the AGO 2005 qualitative scenario for Victoria for moderate increases in extreme daily rainfall intensity, but does not give sufficient detail to confirm the quantitative estimate of a 70 per cent increase in daily intensity.
- With respect to tropical cyclones, the projections are stated to be subject to the current sources of uncertainty inherent in climate change projections based upon modelling of small scale events. The IPCC 2001 projections, in which peak intensities may increase from five to 10 per cent are restated, but it is emphasised that there is a need for much more work in this area to provide more robust results. More recent work relevant to Australia is reported, but this does not appear to have resolved the uncertainty about both frequency and intensity. However, there appears to be some limited consensus among local research workers that there may be an increase in the frequency of long-lived eastern coast tropical cyclones but a decrease for the Western Australian coast. It is noted that three recent Australian model studies have suggested a marked increase in the proportion of Category 3 to 5 storms but there is no further reliable information on likely increases in extreme wind speeds.

- Projections for climate change effects on temperatures, drought, hail and bushfires are generally consistent with those in the AGO 2005 scenarios which have been adopted in the ATSE study.

In summary, there is no information in this 2007 report which invalidates the processes developed in the ATSE study and the conclusions based on the scenarios adopted. The additional information will enable further studies to extend the time scale to cover design life of infrastructure, and to apply more rigorous probabilistically based information in the assessment of likelihood and hence consequence, risk and adaptation capacity.

2.11 CLIMATE CHANGE ADAPTATION FRAMEWORK

National Climate Change Adaptation Framework[11]

The Council of Australian Governments requested the development of a National Adaptation Framework in February 2006 as part of its *Plan of Collaborative Action on Climate Change*, with an implementation plan to be developed in 2007.

The Framework outlines the future agenda of collaboration between governments to address key demands from business and the community for targeted information on climate change impacts and to fill critical knowledge gaps which inhibit effective adaptation.

The long-term goal of the Framework is defined as being to position Australia to reduce the risks of climate change and realise its opportunities. It has a medium five to seven-year term goal of targeted strategies to build the capacity to deal with climate change impacts and to reduce vulnerability in key sectors and regions.

Adaptation is identified as the principal way to deal with what are described as the unavoidable impacts of climate change.

It is described as a mechanism to manage risks, adjust economic activity to reduce vulnerability and to improve business certainty.

The first priority area is stated to be to build understanding and adaptation capacity to be undertaken through a proposed 'Australian Centre for Climate Change Adaptation', which will deal with the diverse and varied nature of the expected climate change impacts which are of particular concern to Australia. The importance of integrated multi-disciplinary studies for the assessment of impacts and vulnerabilities is emphasised.

The second priority area is to reduce vulnerability in key sectors and regions with particular attention to "water resources, biodiversity, coastal regions, agriculture, fisheries, forestry, health, tourism and settlements".

It is acknowledged that there is an existing Australian base of information about how climate is changing and the broad physical impacts these changes may have. However, there is seen to be a need for improved information in the projections of climate change, particularly for extreme events, social and economic trends that affect vulnerability, and the social and economic impacts.

It is intended that the Centre should develop tools for adaptation planning tailored to user's requirements, with decision support tools such as methods for assessing the costs and benefits of adaptation strategies, and guides for risk management.

The areas in which the Centre's interest coincides most closely with the ATSE study are those concerned with the physical infrastructure sector and only these are considered in the remainder of this review.

Water is identified as being an area in which climate change will present significant additional challenges and the importance of addressing key knowledge gaps is emphasised.

Coastal zone vulnerability to a combination of climate change impacts is also identified as requiring detailed assessment. "Settlements, infrastructure and planning" are grouped together. This is seen as an

[11] COAG, *National Climate Change Adaptation Framework*, Council of Australian Governments, 2006 http://www.coag.gov.au/meetings/130407/docs/national_climate_change_adaption_framework.pdf

area likely to be affected by climate change, especially by changed frequency of extreme weather events. Additional information is seen to be needed about the vulnerability of major infrastructure in order to develop adaptation strategies, which may include revision and development of codes, standards and guides to increase resilience to climate change.

Summary of issues pertinent to the ATSE study

The National Adaptation Framework and the tasks proposed for the 'Australian Centre for Climate Change Adaptation' are relevant to the objectives of the ATSE study where the physical infrastructure is concerned. The outcomes of the ATSE study should provide additional guidance to the Centre in identifying climate change events which may have a significant impact and in assessing vulnerability and adaptation capacity requirements. This information should be useful in assisting in the selection of priority areas for further investigation, research and development.

The ATSE study is considered to be consistent with the National Climate Change Adaptation Framework's objectives and proposed mode of operation and is complementary in every aspect.

2.12 CLIMATE CHANGE IN AUSTRALIA: REGIONAL IMPACTS AND ADAPTATION

Climate Change in Australia: Regional Impacts and Adaptation, Managing the Risks for Australia[12]

This report was prepared by an independent working group for the Prime Minister's Science, Engineering and Innovation Council (PMSEIC).

The report accepts that there is overwhelming evidence that Australia's climate has been changing and will continue to change over the foreseeable future driven by global greenhouse emissions.

The Working Group strongly supports the proposed establishment of the Australian Centre for Climate Change Adaptation and the National Research Flagship on Climate Adaptation (as discussed in Section 2.11).

Adaptation is seen as being one of the most effective options open to Australia to help manage the risk of climate change, helping us to cope with effects in the short to medium term while other longer-term mitigation measures can take effect and help reduce our greenhouse footprint. The report does not address the other principal focus of Australia's response to climate change by the reduction of emissions since this was outside its terms of reference.

The report uses IPCC and other modelling, which have already been discussed, to construct two scenarios for global emissions, one optimistic and one challenging, for 2030 and 2070. The optimistic scenario assumes that concentrations stabilise toward the end of the current century while, in the challenging scenario, they continue to rise. Both scenarios assume no policy interventions to reduce emissions.

Assessments have been made of the impact of these scenarios on temperature, rainfall, and oceans, together with the implications of more climatic extremes. It is noted that emission scenarios for 2030, and therefore the projected temperatures, vary only slightly, but that by 2070, climate projections reflect a much wider range in the emissions scenarios. The conclusions are generally in agreement with those given in the CSIRO Report *Climate Change in Australia* reviewed in Section 2.10 of this Literature Review.

The main focus of the Working Group report is on what can be done to adapt to climate change in six sectors; cities and coastal communities, water, infrastructure, health, agriculture, and natural systems. The first three of these are relevant to the current study and the conclusions are briefly reviewed below.

[12] PMSEIC Working Group *Climate Change in Australia: Regional Impacts and Adaptation, Managing the Risks for Australia*, Prime Minister's Science, Engineering and Innovation Council, 2007
http://www.dest.gov.au/NR/rdonlyres/CE5D024E-8F58-499F-9EEB-D2D638E7A345/17397/ClimateChangeinAustraliareport.pdf

Cities and coastal communities

The major impacts include effects on the provision of services, particularly in tropical and south-east Queensland, increased coastal inundation and erosion, exacerbated by coastal developments. Potential adaptive responses include revision and enforcement of building codes, consistent planning and regulatory measures taking into account sea level rises. The need to inform and educate the public about the impact of climate change is also included as an adaptive measure.

Water security

Impacts are identified for cities and industry, particularly for southern and eastern Australia.

Adaptation responses suggested include desalination, increasing regulation and restrictions for water use, expanding water markets and encouraging trading in rural areas, construction of new and interconnecting pipelines, and moving settlements to reduce population pressure.

Major infrastructure

Impacts include the likelihood that the current design criteria for extreme events may be exceeded by floods and storm surges and that increased damage is likely for buildings, transport structures telecommunications, energy services and water services. Adaptation responses suggested include development of guidelines for infrastructure design such as Possible Maximum Precipitation estimates, encouragement of cost effective adaptation through full life cycle estimates, early planning for long-term infrastructure and management of urban sprawl by zoning and regulation.

Examples of planned adaptation

Examples are given of planned adaptation measures for tropical cyclones involving national, regional, local and individual responsibilities. It is concluded that there is evidence that adaptation works from the experience following cyclone Tracy after which building codes were reviewed. This has revealed that structures built to meet post-1980 standards have fared much better when exposed to potentially damaging tropical cyclone than those constructed before 1980. This is confirmed by a study of the effect of building codes on the size of insurance claims for the Far North Queensland cyclonic region.

Several case studies are included and some examples are given of potential strategic adaptation options for certain general classes of infrastructure.

Summary of issues pertinent to the ATSE study

The report includes issues directly relevant to the ATSE study relating to the impacts of climate change and adaptation.

The sections on infrastructure in the PMSEIC Report provide confirmation of the relevance of the objectives of the ATSE study and give valuable additional information for the assessments of impacts and adaptation capacity.

2.13 SUMMARY OF LITERATURE SURVEY

As a result of the Literature Review, it is concluded that there is need to assess the impact of climate change on Australia's physical infrastructure on a regional basis by using risk assessment methods and information sources outlined in this Review.

The survey undertaken by ATSE, and described in the following section, was devised to enable fellows of the Academy and other experts (in business, governments and research institutions), to provide overviews of the likelihood, consequence, risk and adaptation capacity of Australia's physical infrastructure by sector and region using well established risk management strategies and available data.

3 Risk Assessment Methodology

It was decided to attempt to develop a qualitative method for the assessment of both the risk and adaptive capacity of generic types of infrastructure to the effects of climate change, including long-term average trends as well as transient extreme events. The following process was adopted:

- assess the risk to the infrastructure from the effects of climate change by evaluating both the likelihood and consequences; and
- assess the adaptive capacity of the infrastructure to respond to the effects of climate change.

3.1 INFRASTRUCTURE

The scope of work is to make qualitative assessments on generic types of existing infrastructure. The possible types of infrastructure that are to be considered in the study include:

- transport – road, rail, airports, sea ports;
- energy – gas, electricity, oil and coal – production and distribution;
- mining;
- built environment – domestic housing, institutional, industrial, essential services, agriculture production and coastal facilities;
- water – storage capacity, distribution, irrigation, industrial, waste treatment, drainage capacity;
- communications – fixed line and wireless; and
- other.

It was not intended to examine any specific piece of infrastructure or individual infrastructure element.

Assessments were to be solely on issues related to the effects of climate change on Australia's current existing physical infrastructure. The assessment of climate change on future infrastructure is beyond the scope of this project.

3.2 CLIMATE CHANGE

The project was intended to consider a number of events that can be subject to the effects of climate change, including:

- tropical cyclones and major storms;
- sea level rise;
- floods;
- hail;
- average temperature effects;
- extreme temperature effects;
- bushfires;
- drought; and
- other events.

In order to quantify the magnitude of climate change effects, reference was made to the Australian Greenhouse Office publication, *Climate Change Scenarios for Initial Assessment of Risk in Accordance with Risk Management Guidance*.[13]

[13] CSIRO, *Climate Change Scenarios for Initial Assessment of Risk in Accordance with Risk Management Guidance*, Australian Greenhouse Office, 2006. http://www.greenhouse.gov.au/impacts/publications/pubs/risk-scenarios.pdf

This publication quantifies climate change according to scenarios for 10 regional areas of Australia. It is recognised that these scenarios are not predictions, but projections based on emission scenarios for CO_2 adopted by IPCC and CSIRO modelling. It was considered that the "High Global Warning Scenario" for each of the 10 regional areas should be adopted as a basis for assessment. This would be in accordance with established engineering design practice, where the most severe likely estimate should establish the design criteria. It was recognised that the "Global Warming Scenarios" in the AGO publication are applicable for the year 2030 and that this might not cover the life of the infrastructure being considered. Nevertheless, this was best information available for the study.

3.3 RISK ASSESSMENT

An internationally recognised method of risk assessment was sought for the evaluation of impact and adaptation capacity of infrastructure.

The process adopted for the assessment of risk is consistent with the standard AS/NZS 4630:2004[14] and the Australian Greenhouse Office publication *Climate Change Impacts and Risk Management, a Guide for Business and Government*.[15]

The following three terms are the essential elements of the methodology:

- L – Likelihood;
- C – Consequence; and
- R – Risk.

These terms, which are consistent with the definitions adopted in AS/NZS 4360:2004 Risk Management, were used in the development of the method for the assessment of risk.

3.3.1 Likelihood, L

The Likelihood Levels, L, for the event under investigation, are based on the Risk Management Guidelines[16] for AS/NZS 4360:2004 Risk Management using the following levels: A, 'Almost Certain' to E, 'Rare', as in Table 1.

Table 1: Likelihood Descriptors

Level	Descriptor	Description	Indicative Frequency (expected to occur)
A	Almost Certain	This event will occur at least on an annual basis	> Once a year
B	Likely	This event has occurred at least several times in your career	Once in every 3 years
C	Possible	This event might occur a few times in your career	Once in every 10 years
D	Unlikely	This event does occur somewhere from time to time	Once in every 30 years
E	Rare	Heard of something like the event occurring elsewhere	Once in every 100+ years

3.3.2 Consequence, C

Five Consequence Levels for the interaction between the event and the infrastructure being considered, are defined in Table 2, and range from:

- Level 1, 'Insignificant', a level that would attract no attention or resources; to
- Level 5, 'Catastrophic', the level that would constitute a complete failure.

14 AS/NZS 4360:2004 *Risk Management*, Standards Australia and Standards New Zealand, 2004

15 Broadleaf Capital International and Marsden Jacob Associates, *Climate Change Impacts and Risk Management, a Guide for Business and Government*, Australian Greenhouse Office, 2006
http://www.greenhouse.gov.au/impacts/publications/pubs/risk-management.pdf

16 This table is consistent with that given in Table 6.4 of *Risk Management Guidelines, Companion to AS/NZS 4360: 2004*, Handbook HB 436:2006, Standards Australia and Standards New Zealand, 2006. (The number of levels has been reduced from 7 to 5).

Table 2: Consequence Descriptors

Level	Descriptor
1	Insignificant
2	Minor
3	Moderate
4	Major
5	Catastrophic

Respondents to the ATSE survey were requested to assess which Consequence Level is relevant according to three Description Matrices given in an AGO document, *Climate Change Impacts and Risk Management, a Guide for Business and Government*[17]. These matrices are applicable to:

- Local Authority (AGO Table 8, page 35);
- Public Utility (AGO Table 9, page 36); or
- Commercial Business (AGO Table 10, page 37).

3.3.3 Risk, R

Four levels were used to characterise risk, and are given in Table 3.

Table 3: Risk Descriptors

Level	Risk Descriptor
1	Low
2	Medium
3	High
4	Extreme

The level of risk applicable to the generic type of infrastructure under consideration is defined according to both the Likelihood Level and the Consequence Level, as given in Table 4[18].

Table 4: Risk Level Determination

Likelihood Level	Consequence Level				
	1 Insignificant	2 Minor	3 Moderate	4 Major	5 Catastrophic
A Almost Certain	Medium	Medium	High	Extreme	Extreme
B Likely	Low	Medium	High	High	Extreme
C Possible	Low	Medium	Medium	High	High
D Unlikely	Low	Low	Medium	Medium	Medium
E Rare	Low	Low	Low	Low	Medium

17 Broadleaf Capital International and Marsden Jacob Associates, *Climate Change Impacts and Risk Management, a Guide for Business and Government*, Australian Greenhouse Office, 2006
http://www.greenhouse.gov.au/impacts/publications/pubs/risk-management.pdf

18 This table is taken from: Broadleaf Capital International and Marsden Jacob Associates, *Climate Change Impacts and Risk Management, a Guide for Business and Government*, Australian Greenhouse Office, 2006
http://www.greenhouse.gov.au/impacts/publications/pubs/risk-management.pdf
This table is consistent with that given in Table 6.6 of *Risk Management Guidelines, Companion to AS/NZS 4360: 2004*, Handbook HB 436: 2006, Standards Australia and Standards New Zealand 2006

3.4 ADAPTATION CAPACITY ASSESSMENT, A

The IPCC and AGO concept of adaptation capacity, which assesses the prospects for an effective response or resilience to climate change, has been adopted for this study to enable an assessment to be made of how effectively generic forms of infrastructure can be expected to adapt to climate change risks. Adaptation capacity is generally related to the IPCC Assessment concept of the resilience or the ability of the infrastructure to recover from an event or to be managed or amended to mitigate the effects.

Thus, following the assessment of risk, it is then necessary to assess the ability of the infrastructure to be adapted to the impact of climate change event under consideration, as in Table 5.

Table 5: Adaptation Capacity Assessment

Level	Descriptor	Example Descriptions
1	No action required	
2	Minor investment required	< 5% of the capital cost of infrastructure
3	Significant investment required	< 20% of the capital cost of infrastructure
4	Major investment required	> 20% of the capital cost of infrastructure
5	External initiatives required	Emergency preparedness or emergency management (including evacuation)
6	Combination of #5+#1 (or #2)	
7	Combination of #5+#3 (or #4)	

4 Method of Collection and Presentation of Assessments

In order to provide a framework for the collection and presentation of results of assessments, it was decided that a matrix form of representation would be most suitable. It was considered that a matrix framework had the advantage of providing for a structured approach which might improve the consistency of assessment between different sectors and would provide a convenient summary which could be readily used for comparative purposes. It also had the advantage of drawing attention to possible interactions between the sectors and events.

The matrix which was developed is shown in Figure 4.1.

The Sectors and Events which were described in Section 3 were arranged in the form of an Excel spreadsheet which was designed so that results could be entered and processed electronically or used for a manual return. The electronic entry was simplified by drop-down panels which were activated when an entry was to be made to one of the elements in the spreadsheet. Instructions for the electronic entry of assessments are included in Appendix D.

The matrix was designed to be applicable to any particular climate change region and relates the major elements of Australia's physical infrastructure by sector with a selected climate change scenario.

Figure 4.1

Infrastructure/Climate Risk Assessment Matrix		L:	C:	R:	A: Adaptation
Region	Date	A: Almost Certain B: Likely C: Possible D: Unlikely E: Rare	1: Insignificant 2: Minor 3: Moderate 4: Major 5: Catastrophic	1: Low 2: Medium 3: High 4: Extreme	1: No Action 2: Minor Investment 3: Significant Investment 4: Major Investment 5: External Initiatives 6: #5 + #1 (or #2) 7: #5 + #3 (or #4)
Respondent Name	Email				

Sector/Event			Tropical Cyclones Major Storms				Sea Level Rise				Floods				Hail				Average Temperature				Extreme Temperature (+) (-)				Bushfires				Other Drought			
Assessment Description			L	C	R	A	L	C	R	A	L	C	R	A	L	C	R	A	L	C	R	A	L	C	R	A	L	C	R	A	L	C	R	A
Transport	Road																																	
	Rail																																	
	Airport																																	
	Seaports																																	
Energy	Gas	Production																																
		Distribution																																
	Electricity	Production																																
		Distribution																																
	Oil	Production																																
		Distribution																																
	Coal Production																																	
Mining	Mineral Production																																	
Built Environment	Domestic Housing	Designed																																
		Undesigned																																
	Institutional																																	
	Industrial																																	
	Essential Services																																	
	Agriculture Production																																	
	Coastal Facilities																																	
Water	Storage Capacity																																	
	Distribution																																	
	Domestic																																	
	Irrigation																																	
	Industrial																																	
	Waste Treatment																																	
	Drainage Capacity																																	
Communication	Fixed Line																																	
	Wireless																																	
Other																																		

5 Collection of Assessments

Assessments were collected by three separate methods:

1. By a survey of Fellows of the Academy and other selected individual leading experts in the fields of climate change and Australia's physical infrastructure.
2. By workshops in Melbourne and Sydney with participants drawn from a range of leaders in relevant disciplines in these cities.
3. By a series of telephone conferences with leading national figures with expertise in the major infrastructure sectors.

Details of the assessments collected are provided in Appendices A, B and C.

6 Conclusions

Conclusions reached from this ATSE study of the impact of climate change on Australia's physical infrastructure are, by necessity, of a broad-brush nature given the detail of the available regional and local climatic information and the extremely varied forms of infrastructure. The study has been mainly directed at existing categories of infrastructure, but many of the conclusions also apply to the planning and design of future elements of infrastructure.

6.1 CLIMATE CHANGE INFORMATION

The Literature Review has demonstrated a rapidly increasing level of confidence in the statistical information obtained from a wide range of models and emission scenarios from which projections have been derived. The IPCC Reports, the Stern Review and the Australian Government reports provide general background information, while the most recent report by CSIRO and the Australian Bureau of Meteorology, *Climate Change in Australia* (2007), gives the most comprehensive summary of the information which is relevant for Australian conditions.

Measurements clearly show that there has been a global warming trend over the past 100 years. The mean worldwide temperature has risen by an average of 0.13°C per decade since 1900, while Australia's mean annual temperature has increased by about 0.9°C since 1950. Sea levels have also risen by 1.8mm per year over the past 100 years.

In its *Fourth Assessment Report* (2007), the Intergovernmental Panel on Climate Change (IPCC) concluded that most of the increase in global average temperatures in the past 60 years was probably caused by the increase in greenhouse gas (GHG) concentrations in the atmosphere. These gases are released by human activities, according to this report.

The increase in global average temperature is projected to accelerate over the next century from the effects of GHGs already in the atmosphere and from future emissions. The IPCC's *Fourth Assessment Report* presents projections of global mean temperature rises of 0.1°C to 0.7°C by 2020 and 1.1°C to 6.4°C by 2100. It has projections of sea level rise by 2100 of 18cm to 59cm, with a possible additional contribution from melting ice sheets of 10cm to 20cm. The wide range in the forecasts can be attributed to both scientific uncertainty and uncertainty over how effective policies will be at reducing future GHG emission levels.

Modelling has indicated that stabilising GHG levels below 490 parts per million (ppm) – the most ambitious target that was assessed by the IPCC – 'would require global carbon emissions to peak by 2015 and to fall to 50 to 85 per cent of 2000 levels by 2050'. This could limit global mean temperature increases to 2°C to 2.4°C above pre-industrial levels – an improvement on the range of 2.8°C to 3.2°C that is projected to occur if GHGs stabilise below 590ppm.

Climate change projections, based on various scenarios for GHG emissions levels, have been accepted as the basis for the development of strategies for impact assessment and adaptation measures for Australia's physical infrastructure. The currently available information is sufficiently compelling to support the need for action now to prepare for the impacts from projected scenarios for the next 25 to 100 years. However, further additional information of a detailed statistical nature is desirable if assessments are to be made for specific infrastructure locations with sufficient confidence to enable strategic decisions to be made. In addition, further research is required to improve the level of confidence for local events such as rainfall, floods, drought bushfires, hail and storms and tropical cyclones.

6.2 PROCESS OF ASSESSMENT

The assessment of impacts of events, where there are levels of uncertainty in their likelihood and their consequence, requires a methodology which enables risk to be determined in a systematic and scientifically based manner.

Such an approach is available in the risk management process provided by the Australian Standard, AS/NZS 4360:2004 Risk Management.

This Standard was adopted and developed as a guide for application specifically for the assessment of climate change impacts. A detailed description of these guidelines is provided in the publication, *Climate Change Impacts and Risk Management, a Guide for Business and Government*.[19]

The methodology has been tested in a number of practical applications and has been shown to provide useful guides for the assessment of risk for specified scenarios. Caution is advised in the assessment of likelihood, since it must be must recognised that the scenarios are projections based upon a range of models and future emissions assumptions. It is recommended that both optimistic and challenging scenarios should be examined as an aid to assessing actions which may need to be taken. More recent studies have included more of the detailed information of a statistical nature in climate change scenarios, which is needed to provide confidence in the assessment of likelihood.

Assessment of adaptation capacity and development of appropriate adaptation strategies have recently been given increased attention by governments. In particular, the Council of Australian Governments initiated the development of a National Adaptation Framework and a report by the Prime Minister's Science, Engineering and Innovation Council, *Climate Change in Australia: Regional Impacts and Adaptation*.[20] These documents provide a valuable basis for the development of consistent methodologies for assessment of adaptation and implementation strategies.

The ATSE matrix questionnaire was designed to be answered electronically by individual respondents. Difficulties were experienced with some aspects of the ATSE matrix questionnaire, particularly in assessing the likelihood of an event. This led to a greater than expected variation in the responses for the likelihood assessment. Nevertheless, the responses gave valuable information on consequences and adaptation assessments and provided guidance for the planning of the workshops and the teleconferences which followed.

The matrix questionnaire was used as a basis for discussion at the workshops. The workshops again highlighted the problems of the determination of likelihood for the scenarios used in a risk management process. However, the interaction between participants and groups provided much more consistent outcomes.

The teleconferences benefited from the experiences of the questionnaires and workshops. They were organised, using the matrix questionnaire as a basis, to assess both the consequences and adaptation capacity for each major sector of infrastructure for defined scenarios for specific climatic regions. The participants were experts in the particular infrastructure sectors and were able to bring the necessary levels of theory and practical knowledge to the assessment of consequences and adaptation capacity required.

The framework for each of the ATSE assessments was provided in the form of a matrix questionnaire, relating climate change events to each infrastructure sector with inputs for likelihood, consequence, risk and adaptation capacity. Matrices were provided for each climatic region and were intended for use with a specified scenario. This framework ensured that all combinations were able to be readily identified and provided a consistent basis for assessment. Similar matrix presentations have also been used in studies by other organisations and have been found to be effective in obtaining detailed outcomes for particular elements of infrastructure in regional localities, as well as for the more broad brush regional assessments sought in the ATSE study.

The assessment of adaptation capacity requirements provided for responses, from no action to major investment, dependent on assessment of consequences ranging from discomfort, inconvenience, economic loss through disruption, societal concerns and property damage – which should be clearly differentiated from damage causing injury and loss of life.

Future adaptation actions include the adoption of a holding position pending the emergence of new data, no immediate action with the acceptance of increased future maintenance costs, immediate or

[19] Broadleaf Capital International and Marsden Jacob Associates, *Climate Change Impacts and Risk Management, a Guide for Business and Government*, Australian Greenhouse Office, 2006
http://www.greenhouse.gov.au/impacts/publications/pubs/risk-management.pdf

[20] For reference details, see Section 2 of this report

deferred retrofitting, or replacement of infrastructure elements.

The possibility of legal liability arising in the future relating to adaptation actions taken, or not taken, should also be a matter for serious consideration.

There are existing methodologies by which the assessment of the impacts of climate change can be made using established risk management processes.

Frameworks for the assessment of adaptation capacity of infrastructure and implementation strategies are also being developed. These should provide consistent guidelines for decisions regarding future actions to take into account the impacts of climate change.

6.2.1 Assessment of impact of climate change on infrastructure sectors

The assessments given in the following subsections have been arrived at from a consideration of the published material covered in the ATSE studies; namely, the matrix questionnaire, workshops and teleconferences (for details see the Appendices).

The results obtained from these sources reflect a range of opinions but, in general, a reasonably high degree of agreement was found on major issues. It is acknowledged that there are dissident views, some of which are strongly held.

Although the study concentrated on the impacts on existing infrastructure, many of the conclusions are relevant to the design and planning of future infrastructure. It is important that design and planning decisions are made in a manner which will facilitate future modification or retrofitting, which may become necessary as a result of more recent data and information. The possible need to strengthen regulatory controls, to ensure that long-term strategic planning can be undertaken and implemented, must also be considered.

Only the sectors for which the impacts, consequences and risks are considered significant are reviewed in this section; details for the full assessments applicable to all infrastructure sectors are provided in the Appendices to this report.

6.2.2 Water infrastructure sector

The most significant impact from the climate change scenarios is drought in the more southern regions of Australia. The capacity of storages and the effectiveness of distribution systems required to survive extended periods of drought are seen as a high to extreme risk with effective adaptation capacity requiring major investment and national strategic planning. Consideration of cost-effective alternative supply sources including desalination and recycling and community education for reducing use are included in the adaptation measures to be considered. The possible negative effects of the increased emissions from the use of fossil fuels to provide power for desalination processes must be considered. Coupling desalination installations with thermal power stations may be worthy of consideration.

The risk of increased local flooding in those areas of Australia where increased rainfall is projected is recognised as producing potentially serious consequences, particularly when associated with sea level rise and storm surge. Developments in low-lying coastal areas, which are currently at risk from inundation and erosion, will become increasingly vulnerable. Assessments for such areas require specific physical information and local climate change projection scenarios based on modelling at the small geographical scale. Consideration of adaptation strategies needs to taken into account analyses of economic and societal impacts.

A high priority needs to be given to the development and rigorous implementation of planning procedures for these critical areas.

6.2.3 Energy

The electricity production and distribution sector was identified as having a very high degree of vulnerability to climate change. This is particularly seen to be critical in the southern areas of Australia which are currently put under pressure from a combination of climatic factors which may occur simultaneously. For example:

- drought affects the generation capacity by limiting hydroelectric power generation and the supply of cooling water for thermal plants;
- high temperatures increase the demand while also reducing efficiency of generation and distribution; and
- bushfires may interfere with distribution and interrupt communication.

Adaptation to cope effectively with these situations is expected to require major investment with integrated, high-level strategic planning.

Other elements of the energy sector are less critical, but strategic planning for energy infrastructure is required by taking an integrated holistic approach for the provision and management of all elements of the system. There are potential problems in providing for the implementation of such strategic national planning, particularly in the electricity sector, because of the intensely commercially competitive nature of the industry and diverse private ownership, much of which is offshore. Government intervention may be necessary to achieve the required outcomes.

6.2.4 Transport infrastructure sector

The impact of climate change on established transport systems which have been designed and maintained to current design standards are generally considered to be from minor to moderate, with adaptation requiring minor to moderate investment. Action is likely to be needed for specific elements in local areas where, for example, there may be a need to cope with possible increased severity of flood damage to roads and bridges. Airports situated in low-lying areas may be increasingly vulnerable to combined effects of sea level rise, flooding and storm surge, with serious disruption to services.

Increases in temperature and the effects of drought, affecting the subgrade moisture content and salinity, may reduce the durability of pavements with consequent increase in costs of future maintenance programs.

Assessments of adaptation strategies should be made from a consideration of the costs and benefits of investment, having regard to the consequences arising from accessibility restrictions imposed by loss of transport links.

6.2.5 Mining infrastructure sector

The major impacts of climate change on the mining sector appear to be mainly related to the interruption to transport services from storms and tropical cyclones, which particularly affect the export of minerals. In consideration of possible adaptation strategies, it will be necessary to consider the costs and benefits of proposed actions on the broader transport system.

Mining generally requires large quantities of water and adaptation strategies need to consider alternative sources and effective recycling processes.

6.2.6 Built environment sector

This sector includes a wide variety of construction which is subjected to markedly different climatic conditions.

Structures which have been designed, constructed and maintained in accordance with the Building Code of Australia and associated Australian standards have been found to perform well under current extreme climatic events such as storms, tropical cyclones and bushfires. These codes and standards provide a very sound basis upon which any responses to climate change impacts can be developed in a logical manner. For such structures, adaptation requirements to cope with climate change may require minor to significant investment but decisions require cost benefit analyses of specific elements for local areas.

Decisions regarding amendments to design requirements in codes and standards should also be subject to careful cost-benefit studies based upon the best available projections for Australian conditions. These projections may not align with the more general global IPCC projections. For example, the most recent projections given in the CSIRO *Climate Change Report* are stated to be subject to uncertainty about the intensity of tropical cyclones for Australia's north-east and north-west tropical regions, although there is some degree of agreement on the frequencies of their occurrence. More research with detailed small-scale modelling of these events is needed to obtain statistical information which can be used to provide design wind speeds for the return periods deemed to be appropriate for the design of structures in these regions.

Structures which have not been designed or constructed to the above codes and standards may already be vulnerable to current climatic conditions. This has been repeatedly demonstrated by their lack of performance in tropical cyclones over recent years. Adaptation strategies for such a collection of buildings, with their widely ranging structural capacities, must be arrived at by consideration of various classes of construction to determine the most cost effective action. This may range from no action, with reliance on emergency services and insurance, to retrofitting or replacement. Careful consideration must be given to consequences which may result in injury or loss of life as well as property damage.

Damage to buildings in low-lying and coastal areas from flooding and erosion from intense rainfall, possibly combined with sea level rise and storm surge, is likely to be exacerbated by climate change. Adaptation strategies must be developed for specific situations and may require from minor to major investment dependent on the extent of development. The need for long-term planning and enforcement of regulations for development in such areas is essential to mitigate the potential future impacts of climate change.

The energy efficiency of newer buildings, which have been designed to satisfy more recent regulations and guidelines (with a focus on improved sustainability), have increased resilience to the impacts of temperature arising from climate change, particularly in southern regions of Australia. However, the development of appropriate adaptation strategies for older buildings will require further detailed study of specific classes, including consideration of costs and benefits of possible retrofitting or replacement.

Given the existing resources of scientific and engineering expertise in Australia, the regulatory frameworks which are already in place or proposed, and the available economic resources, the built environment sector is generally considered to be well placed to respond to potential challenges arising from climate change and to provide advice on adaptation strategies. Action is needed to ensure that these resources are maintained, and expanded where necessary, to ensure that this advantage is maintained. Regulations and guidelines should be kept under review as a result of further research on climate change and the development of practical adaptation measures.

6.2.7 Communications sector

An effective communication infrastructure is an essential element for the successful operation of all other infrastructure sectors. Instant, reliable communication is particularly important in the coordination of elements of the energy sector when decisions have to be taken to cope with combinations of extreme temperatures, increase power demands, drought, and bushfires. Consideration should be given to the need for alternative networks or modes of communication to cope with local failures under extreme conditions.

The potential consequences of climate change on the sector is considered to be from minor to moderate with adaptation measures requiring from minor to moderate investment. The life cycles of different elements of the sector need to be taken into account in determining adaptation strategies.

In general, the communications sector is considered to have a high degree of resilience to the possible effects of climate change and is well placed respond by the development of appropriate adaptation strategies.

Appendix A: Results of Assessments

Analysis of Responses to Survey from ATSE Fellows and selected individuals.

A.1 GENERAL

The survey form described in Section 4 was sent in electronic form to Fellows of the Academy and non-members selected from a broad range of scientific, engineering and business expertise connected with the main sectors of Australia's infrastructure. The intention was to obtain the views of persons familiar with the technical operation and the practical management of infrastructure elements. Climate change experts were also included to ensure that the interpretation of the information provided was tested.

However, it was not intended that the survey should debate the validity of the AGO 2005 climate change scenarios, but that it should consider how the selected scenarios could be employed in a practical manner to identify those sectors of Australia's infrastructure as being 'key vulnerabilities' for specified climate change impacts.

A.2 REACTION TO THE MATRIX PROCESS

The electronic response generated 16 responses, the majority of which were for the Victorian region. Several respondents provided additional comment, while others chose to submit manual returns.

Many respondents noted the process of completing the matrix return in the electronic form was complex and several respondents suggested that such an approach was more suitable for a detailed examination by an experienced consultant of a specific infrastructure element.

Respondents generally considered that the methodology and the presentation in a matrix format were suitable for ensuring that infrastructure categories and events were subject to scrutiny and enabled possible interactions to be recognised.

The methodology was generally considered to be appropriate for the assessment of specific elements of infrastructure in a localised region for which detailed climate change scenarios were available. However, it was felt that it was only suitable for a very general overall assessment of risk and adaptation capacity for the broad infrastructure sectors which had been requested.

Climatology experts strongly urged that care be taken in distinguishing between the natural variability in current extreme events and the additional effects with their own associated variability, which are attributed to climate change, whether from natural causes or as a result of human activity. It was also suggested that a distinction needed to be made between the climate change terms, such as temperature, and consequential 'climate change events', such as sea level rise.

Several respondents suggested there should be reference to drought as a specific event, rather than relying on reference to rainfall projections in the scenarios. The lack of inclusion of drought as a specific event is accepted as a serious deficiency since it led to many respondents neglecting to include any assessment of the effects of a reduction in the availability of water on the ability of a wide range of infrastructure facilities to function effectively. Drought was therefore added as a separate event in later amendments to the matrix.

A.3 ELECTRONIC MATRIX RETURNS

Many respondents made their own assessments of likelihood of the scenarios/projections without regard to the AGO scenarios and projections which had been provided as a given for use in the assessments. This probably reflects the general spread of opinion on the acceptance of climate change, whether from natural or anthropomorphic causes.

Interpretation of the likelihoods of events from the scenarios was the most contentious issue with respondents giving assessments, which ranged from rare to very likely for the same event. For example, the scenario provided for Victoria makes no mention of any increase in storm intensity for Victoria, but the returns show likelihood assessments for increase in storm impacts varying from likely to rare. This suggests that either the respondents did not read the instructions or that they had formed their own subjective views on the likelihood. (It has been noted elsewhere that the 2006 AGO scenarios do not treat extreme events in a detailed statistical manner.) This emphasises the importance of having scenario information in a probabilistic form so that likelihood can be assessed on a more rigorous scientific basis.

It was also apparent that the process for determining risk from likelihood and consequence was not always followed and there was a wide variety in the assessments of the investments required to achieve the necessary adaptation capacity.

As a result of the limited number of responses and the misinterpretation of likelihood from the scenarios, it was concluded that there would be little value in attempting to carry out any meaningful statistical analysis of the results. However, it was still considered to be useful to consider the consequences which had been attributed to these assumed likelihoods, as a means for assessing general opinions of the vulnerability of infrastructure sectors.

If extreme assessments were neglected, it was clear that the results for likelihood, consequence, risk and adaptation capacity were generally clustered about a consistent level. These 'cluster values' have therefore been adopted for developing consensus views, while recognising that there may be a number of significantly divergent opinions. On this basis the general conclusions that can be drawn from the electronic matrix returns included the following reactions to events.

A.4 GENERAL CONCLUSIONS

Tropical cyclones and major storms

Since the scenario for Victoria, and all other areas except the tropical regions, did not indicate any increase in the intensity of major storms, the validity of returns which assumed likelihoods between 'likely' to 'rare', and clustered about 'possible' must be questionable.

However, consideration of the consequences based on an assumed 'possible' likelihood of increase in intensity, showed that these were assessed as minor with an adaptation capacity requiring minor investment, with some exceptions. The consequences for both oil and electricity production were assessed in the range from minor to moderate, but the adaptation capacity was assessed as requiring only minor investment. The consensus view for the consequences for un-designed domestic housing was assessed as major, with an adaptation capacity requiring between minor and major investment.

Sea level rise

Despite a scenario projection of 17cm, the likelihood estimates clustered around 'unlikely', except for sea ports and coastal facilities where the estimate was 'likely'. This again indicates that respondents had difficulty in interpretation of likelihood. The assessments of consequence reflected this difficulty with all the consequences rated as minor or less, except for seaports and coastal facilities which were assessed as moderate, with adaptation capacity requiring significant investment in both instances.

Floods

Likelihood was assessed as between 'likely' and 'possible', with the consequences generally minor, except for the built environment and drainage capacity where the consequences were assessed as moderate. The adaptation capacity for the built environment was assessed as requiring minor investment while major investment was seen as necessary for drainage capacity.

Hail

Assessments of likelihood of increased impacts were widely spread with a consensus value between 'unlikely' and 'possible'. In no case was consequence assessed at more than insignificant, except for the built environment where minor consequences were assigned to domestic housing and moderate consequences to agricultural production facilities. The adaptation capacity assigned to these latter cases was between no action and minor investment.

Average temperatures

The consensus assessments was much less scattered than for other events with likelihood consistently between 'almost certain' and 'likely'. Consequence for all physical infrastructure sectors was consistently assessed as insignificant and no action was seen as necessary for adaptation capacity.

Extreme temperatures

The assessments were again less scattered compared to other events, with a likelihood between 'almost certain' and 'possible'.

Consequence was generally assessed as minor, except for gas and electricity energy production, presumably from expected increases in peak demand, where the consequences were assessed as moderate. As well, un-designed domestic housing had a consequence assessed as moderate.

The consequences for water infrastructure, including storage, distribution capacity, domestic supply, and irrigation demand, were assessed as moderate. In all cases, where the consequences were assessed as moderate, the adaptation capacity was assessed as requiring between minor to moderate investment.

Bushfires

There was a strong consensus that the likelihood was 'almost certain' for southern regions.

Consequence was assessed as 'moderate' for roads with an adaptation capacity requirement of 'minor' investment.

Consequence was assessed as 'moderate' for electricity production with an adaptation capacity requiring between 'minor' to 'moderate' investment.

Consequences for domestic housing, both designed and un-designed, were assessed identically as being between 'moderate' and 'major', with adaptation capacity requirements between 'minor' to 'significant' investment.

Essential services consequences were assessed as between 'moderate' to 'major', with adaptation capacity requiring 'minor' to 'moderate' investment.

Consequence for water storage capacity was assessed as being between 'minor' to 'moderate', presumably because of effects of bushfires on run off, erosion and salinity. Requirements for adaptation capacity were assessed to be from 'minor' to 'significant' investment.

Consequence for the communications sector was assessed as being between 'minor' to 'moderate' with adaptation capacity requiring between 'minor' to 'significant' investment.

Other events – drought

Drought was not specifically included in the original matrix but was identified by several respondents as a result of rainfall scenarios. It was pointed out that effects of drought have an interactive effect with other events. These issues are further discussed in the subsection on Written Responses that follows

A.5 WRITTEN RESPONSES

It was pointed out by one respondent that it should be recognised that climate change scenarios were based on the UNFCCC definition of climate change, with impacts arising only from the human induced component without allowance for the input of natural variability on the occurrence of extreme events. Such natural variability has already been factored in to the design of many elements of important infrastructure.

Several submissions pointed out that significant consequence and adaptation deficiency could arise in the impacts generated by interaction between climate events, such as drought, high temperatures and bushfires, particularly on the energy infrastructure sector, with electricity demand, generating capacity and supply being the most vulnerable.

The built infrastructure was considered to be less vulnerable, provided the elements had been designed to current standards (which tend to involve conservative design provisions). Domestic dwellings not designed to these standards ('undesigned'), which were already vulnerable to extreme events such as high wind, bushfires and flash flooding, could be expected to suffer serious consequences from climate change where such events were included in the scenarios for the particular regions.

While there were again varying interpretations of the assessments of likelihood arising from the AGO scenarios, it was pointed out that there was a need to have scenarios that provided more specific statistical information about extreme events over the expected life cycle of the infrastructure elements if meaningful assessments were to be made of consequences, risks and adaptation capacities

The importance of retaining natural vegetation protection of coastal zones against sea level rise and storm surge and wave action associated with tropical cyclones was seen as an important adjunct to adaptation capacity strategies.

Some wider ranging regional overviews were provided by several respondents and these are included in the following section.

A.6 REGIONAL OVERVIEW

Victoria

Road and rail transport was considered too vulnerable to inundation due to increased severity of local flooding but the adaptation capacity investment requirement was assessed as minor.

Electricity production and distribution were seen to be vulnerable to extreme temperatures resulting in increased electricity demand, drought with lack of water for thermal and hydro power generation, reduction in transmission capacity and interruption from bushfires.

Adaptation capacity requirements were rated as requiring 'significant' investment.

Domestic housing was seen as vulnerable to flooding and bushfires with adaptation capacity requirements of 'minor' investments.

Water drainage capacity was seen as being vulnerable to increases in local flood intensity with adaptation capacity requiring 'minor' investment.

Water storage capacity was seen as vulnerable to drought with adaptation capacity requiring 'major' investment.

New South Wales

The vulnerability of infrastructure in NSW was assessed as being generally similar to that for Victoria, but with an increased impact of bushfires on water storage inflows and quality resulting from increases in the frequency of bushfires.

South-eastern Queensland

The vulnerability of infrastructure in South-eastern Queensland was assessed as being generally similar to that for Victoria and NSW.

North-eastern Queensland

The tropical zone scenario, with substantially more hot days, increases in extreme wind speeds, increased rainfall as well as droughts, led to assessments of increased vulnerability for electricity and generation and distribution with minor investment required to improve adaptation capacity.

Transport was seen as vulnerable to extreme winds from tropical cyclones and flooding, with airports requiring 'minor' investment to improve adaptation capacity

Domestic housing was seen as vulnerable to tropical cyclone extreme wind speeds with 'undesigned' housing requiring 'minor' investment. Domestic housing was also seen as vulnerable to floods and extreme temperature, with the requirement of 'minor' investment to improve adaptation capacity.

Communications were assessed as vulnerable to extreme winds requiring 'minor' investment to improve adaptation capacity.

Top End of Northern Territory

The vulnerability of the Top End was assessed as being generally similar to that of North-eastern Queensland.

North-western Australia

The vulnerability of North-western Australia was assessed as being generally similar to that of North-eastern Queensland with the addition of the impact of tropical cyclones producing interruptions to offshore gas and oil production and mineral exports from ports. 'Minor' investment was considered to be necessary to improve adaptation capacity.

South-western Australia

The vulnerability of South-western Australia was assessed as being generally similar to that of Victoria, with drought exacerbating the conditions for electricity production and water storage, both of which were considered to require 'significant' investment to improve adaptation capacity.

South Australia

The vulnerability of South Australia was assessed as being very similar to that of South-western Australia and Victoria with similar investments required to improve the adaptation capacity.

Tasmania

The vulnerabilities of infrastructure in Tasmania were assessed as being generally similar to those for Victoria although with less vulnerability in the water infrastructure sector.

A.7 SUMMARY OF SIGNIFICANT CONCLUSIONS FROM THE MATRIX SURVEY

Conclusions from the submissions made by respondents to the matrix survey are summarised below:

- The proposed survey process provides a logical framework for the broad qualitative assessment of risk and adaptation capacity for Australia's physical infrastructure.
- The survey process provides a sound basis for the quantitative assessment of individual elements of infrastructure. However, this will require much more detailed local probabilistic information for the assessment of likelihood than is provided in the AGO 2005 scenarios. It will also require the respondents to acquire a high level of skill in the application of the technique.
- It is unrealistic to expect respondents who are not already skilled in risk management techniques and the preparation of electronic returns to devote the time and effort required by the survey process. Such skills could only be expected to be provided by specialist consultants, rather than voluntary respondents.
- The greatest vulnerability is seen to result from climate change effects relating to combination of events, particularly drought, extreme temperatures and bushfires. This applies particularly to the electricity generation and distribution sectors where it is expected that there will need up to major investment to improve adaptation capacity dependent on the region. Another major vulnerability is the impact of drought on water storage and supply where major investment is expected to be required to improve adaptation capacity.
- In most other sectors, if the AGO 2005 scenarios are applied on a regional basis to infrastructure designed to satisfy current standards, the consequences are considered to be generally minor, with minor investment required to improve adaptation capacity. It should however be noted that the required design life of most infrastructure is from 50 to 100 years and the AGO 2005 scenarios only extend to 2030. It is evident that further study is needed to cover the full design lives of important infrastructure elements with estimates extending to 2100.

Appendix B: Workshops

B.1 WORKSHOP IN MELBOURNE

The workshop was attended by 21 participants (see Appendix E) invited from industry, government, research and academic sources to give a general representation of major infrastructure sectors. Members were mainly from Victoria and it was intended that attention should be mainly focused on this region.

It was generally agreed that the matrix presentation provided for a broad view to be formed for most regions and could help to identify specific sector elements in local regions that required detailed further study.

The AGO scenarios were the subject of detailed discussion and it was emphasised by climate experts that these should not be regarded as predictions but as projections based on modelling with assumed possible future emissions of CO_2.

There was considerable uncertainty about how likelihood should be interpreted from the AGO scenarios. It was suggested that scenarios in which information was provided in a probabilistic form was necessary for a rigorous risk analysis but, in its absence, both the high and low emissions scenarios should be used in assessments.

It was generally agreed that assessments of consequences should be made by experts in particular infrastructure sectors, accepting particular AGO scenarios in order to obtain conclusions which could be used for comparative purposes. It was emphasised that consequences should include loss of life and societal as well as economic impacts.

There appeared to be little difficulty in assessing risk from likelihood and consequence by following the AGO risk management guidance methodology.

It was agreed that adaptation capacity needed to take into account the life cycle of the infrastructure element. In some cases, infrastructure designed for current extreme events would not necessarily require adaptation to cope with the expected changes.

Particular areas which were identified as possibly critical and worthy of further study included:

- Combinations of events and their interactions needed to be considered; for example, the interaction between drought, high temperatures and bushfires, in conjunction with increased electricity demand putting severe pressure on distribution and electricity generation infrastructure.
- Extreme rainfall expectation for parts of Victoria may cause severe flooding with serious impact on infrastructure, particularly dam spillways, roads, bridges, housing and electricity generation in the Latrobe Valley.
- It was noted that increase in hail storm activity could be a threat to some horticultural infrastructure.
- Sea level rise was identified as possibly critical for coastal areas with implications for damage from flooding, rising water table and salinity with the potential to damage pavements.
- Non-engineered housing was already at high risk from bushfires and high winds and that climate change would exacerbate these problems.
- It was important to include redundancy and robustness in the design of infrastructure. This was particularly important for domestic housing where the opportunity for failure through the weakest link was noted as a current research topic at James Cook University.
- It was stated that the Australia Building Codes Board has the question of the impact of climate change under review. It was noted that any change to the Building Code of Australia requires an economic evaluation to demonstrate economic benefit for any change to its provisions.

- The matrices that were returned at the workshop were far from complete and included some which ignored the AGO scenarios, or assumed likelihood values not consistent with them; for example, with regard to storms in Victoria for which the scenario showed no increase in extreme wind speed.

B.2 WORKSHOP IN SYDNEY

The workshop was attended by 20 participants (see Appendix E) invited from industry, government, research and academic sources to give a general representation of major infrastructure sectors. Many of the deliberations of the Sydney workshop were similar to those at Melbourne, but the experience there helped to focus the discussion more closely on the issues.

It was agreed that the matrix provided a good general framework for discussion and the identification of local hot spots. The matrix survey was considered to be too complicated for general use in the electronic form originally contemplated for the survey of Academy members.

There was a need to consider the wider international interactions arising from the fragile nature of the environments and economies of our neighbouring nations and their lack of adaptation capacities.

The assessment of likelihood from the scenarios was a matter of the same sort of uncertainty which arose at the Melbourne workshop. Not all members were prepared to accept the AGO scenarios and introduced their own, or anecdotal assumptions about likelihood. There were serious reservations about whether the scenarios were appropriate for the exercise with some insistence that storms and storm surges should be included in the NSW scenario.

It was observed that:

- Water and temperature are the basic ingredients in climate change impacts.
- The impacts should be extended to include war and terrorism but this was considered to be beyond the scope of the project.
- There are less direct ways of adaptation than by adjusting the infrastructure, if people can be encouraged to change their habits.
- The impact of climate change on coastal areas can only be assessed for specific locations and infrastructure elements.
- The database we have for current extreme events is limited historically and extrapolation from this base needs to recognise this limitation.
- The direct and indirect impacts of consequences and the effects of interaction need to be taken into account in assessments of risk. An example was the interaction between temperature, wind and fire and their impacts on water supply, electricity and sewage treatment failures following major bushfires in Canberra in 2003.
- Future population growth and relocation as a result of climate change needs to be considered as a significant interaction effect.
- The demand for electricity, and its supply and generation under conditions of drought, flood, high temperature and bushfires is a potentially highly critical risk area and is in need of detailed study for its adaptation capacity in specific cases.
- There is a need to ensure that the Building Code of Australia and its associated standards are responsive to assessed risks in an appropriate manner. It was suggested that progress would be made by establishing small focus groups of infrastructure specialists to define more clearly potential hotspots.
- The insurance industry was suggested as an industry source of possibly useful data.
- Matrix returns were variable and did not always follow the AGO scenarios. Potential hot spots were identified, which included sections of the built environment, energy production, tourism, mining and irrigation infrastructure.

As a result of the discussion at both workshops about the uncertainty relating to the assessment of likelihood from the AGO scenarios, it was decided to eliminate this assessment from the next phase of the project to be conducted as teleconferences as described in the following section.

Appendix C: Teleconferences

Telephone and direct interview conferences were conducted with the intention of obtaining expert informed opinion on each of the major infrastructure sectors separately. It was decided that likelihood would not be assessed but the discussions should focus on the assessment of consequences and adaptation capacity using the AGO 2005 scenarios.

C.1 WATER TELECONFERENCE

C.1.1 General

It was generally accepted that the methodology for assessment would be appropriate for use with given scenarios for the determination of consequences and adaptation capacity for specific subregions and infrastructure sector elements. Application for the defined regions and infrastructure categories could only be expected to produce general qualitative 'first order' results which would, however, be valuable for identifying 'hot spots' for further detailed study.

Some concern was expressed about the form of the information in the scenarios for use in risk management studies, for which information presented in a probabilistic form would be more effective for the assessment of likelihood and hence consequence and risk.

It was also noted that much of Australia's water infrastructure is expected to have a long life cycle and that scenarios were required which covered periods beyond 2030 if more meaningful assessments are to be made.

It was pointed out that for the assessment of consequences it was necessary to recognise that 'tipping points' in responses to events are often critical. Non-linear response with the consequences disproportionate to the changes could be a factor in assessing impacts of climate change.

It was also pointed out that there are complex interactions which must be taken into account of the impacts on interrelated sectors.

C.1.2 Issues specific to the water sector infrastructure

Storage capacity infrastructure

The most likely critical issue for southern areas, including Western Australia and South Australia, was not capacity but rainfall and catchment run off. The key issue was average annual river flows and evaporation. Adaptation needs to focus on the demand side of the equation but catchment management is an area requiring study specific to climate change, for example, having regard to interactions with effects of bushfires. The impacts of bushfires on water quality and increased silt levels are significant, while catchment yield is a complex issue with possibly quite opposing effects over time and in particular catchments. These are areas requiring detailed specific studies.

The situation in the northern tropical regions was much less critical.

The need to develop alternative sources of supply was an essential adaptation strategy. Groundwater sources were already under stress in many regions and the main credible adaptation alternatives were the extension of current desalination and recycling initiatives. These may require significant additional resources for some regions.

The effects of flooding on storage capacity, was considered to be of relatively minor consequence for storage capacity for most regions of Australia including the tropical north. Spillway capacity to deal with excess flows from floods was not likely to be a short to medium-term problem, noting that the ANCOLD design requirements were based on long return periods.

Distribution infrastructure

Distribution was seen as already being a critical current issue which climate change would exacerbate as a result of changes in rainfall. It was considered that there would be an increased need to integrate the water distribution infrastructure in many southern areas including Western and South Australia, where communities were relatively isolated.

The impact on distribution varied within regions depending on the activities in local areas. Adaptation measures such as recycling, rather than drawing on other supplies could be more relevant to industries where water quality was of lesser importance, such as electricity generation, mining and some manufacturing activities.

The impacts of sea level rise combined with storm surge on pumping installations in low-lying coastal areas were identified as possibly of consequence requiring adaptation with localised minor investment. The problem is not region-specific, but could be more severe in some tropical localities.

The impact of bushfires was identified with the possible loss of power for pumping with adaptation requiring probably minor enhancement of back-up capacity.

Domestic infrastructure

Some of the issues covered under 'Distribution' were relevant to this section and are not repeated here.

Critical to the domestic scene were the impacts of the increase of extreme rainfall intensity in some southern regions which, in combination with sea level rise could have serious consequences for flooding and damage to domestic infrastructure by erosion of foreshores. (This was also an issue considered by the Built Environment study group)

It was pointed out that some infrastructure, such as gardens and sports grounds, had significant societal and tourism implications and that the supply of water to maintain such facilities should be taken into account.

The most significant domestic impact is the control of demand, which is already a feature of the current situation in most southern regions and which will increase in importance with climate change.

Irrigation infrastructure

The climate change impact of drought in southern regions on irrigation infrastructure will exacerbate the current critical situation, putting more pressure on the need to improve the efficiency of both the distribution and irrigation practices.

Climate changes leading to higher average and maximum temperatures will lead to drying out of subsoils with lower water tables. This will result in increased loss of water through unlined channels and by evaporation. Impacts on current salinity problems are complex and interact with the drainage infrastructure.

Adaptation measures include extension of the current proposals for sealing open channels and piping with better education in irrigation practice.

Industrial infrastructure

A reduction in the supply of water to industry in southern regions could be critical, but most industries should have the capacity to adapt by improving efficiencies, by using lower quality water and by recycling. The possible impact of bushfires on the interruption of water supplies will require minor increases in back up facilities.

The impact of sea level rise and storm surge on industries located on low lying flood prone areas may require some additional protection above that already necessary.

Waste treatment infrastructure

Several interactions impacting on waste treatment operation were identified.

Bushfires can interrupt treatment by cutting off electricity supplies leading to inability to carry out activities which have a high power demand. This could increase the threat to health due to contamination of domestic water supplies by effluent discharge. Effects of flooding from intense rainfall, together with sea level rise and storm surge, could also exacerbate current critical situations in coastal communities which include rapidly expanding tourism areas in the north eastern tropics. Adaptation measure would be expected to require minor additional investment.

A positive contribution could be achieved by the expansion of recycling with application of the recycled products to achieve economic benefit.

Drainage infrastructure

A significant impact could be expected on the capacity of existing drainage systems to cope with increased local flash flooding in some southern areas, together with sea level rise and storm surge in more northern areas. This could have significant consequences for large tracts of low-lying land in areas of high population which, in many cases, are still in the process of development.

It was agreed that effective drainage was an essential requirement for the protection of property and health, but that this was difficult to achieve when planning control was not effectively exercised. It was recognised that development investment strategies did not always consider such issues in sufficient detail and that property values were often determined with a short-range profit vision by virtue of current society and local government attitudes. It was considered that an integrated long-term investment and planning strategy was essential for future development of coastal communities particularly if the expected population growth in these areas was to be achieved.

Reference was made to the ATSE *30/50 Report*[21], where a study, carried out for the Scanlon Foundation, reviewed the possibility of an Australian population of 30 million by 2050. It concluded "that there were no insurmountable engineering, scientific or environmental barriers to 30/50, assuming that thorough analysis and planning occur and that leadership is exercised, especially by governments."

Adequacy of current standards

It was generally considered that the current Building Code of Australia, and Australian Standards provided a sound basis for addressing the impacts of climate change but they will need to be reviewed and amended as more specific information becomes available in suitable forms. standards such as ANCOLD also provided a sound basis for the long-term assessment of dam safety.

A particular instance was cited regarding standards for the design of slab-on-ground concrete floors for housing where the requirement to recognise sea level rise may need to be included.

It was also agreed that revisions of standards and associated planning controls should proceed in parallel.

C.1.3 Summary

The elements with the most significant consequences and requirements for investment in adaptation capacity were identified to be in the storage capacity and irrigation infrastructure resulting from reductions in rainfall in most southern regions and in local drainage arising from increases in daily rainfall intensity.

[21] ATSE, *30/50 – The Technological Implications of an Australian Population of 30 Million by 2050*, Australian Academy of Technological Sciences and Engineering, 2007.
http://www.atse.org.au/index.php?sectionid=128

C.2 ENERGY TELECONFERENCE

C.2.1 General

It was agreed that the identification of 'hot spots' for consequences arising from climate change could be accomplished on a broad scale by the proposed methodology but that the assessment of specific items of infrastructure would need more detailed statistical information on climate change projections.

It was noted that new information was now being released by CSIRO and the AGO that may assist. It was agreed to use the AGO higher global warming scenarios for 2030 for the purpose of establishing comparisons.

It was agreed to proceed by examining the Victorian region initially for significant consequences and adaptation capacity. The more northern regions would then be considered with the identification of any significant differences arising from the scenarios.

C.2.2 Issues specific to energy infrastructure

VICTORIA

Gas infrastructure

No significant consequences arising from climate change were identified due to climate change impacts for production and distribution, but it was noted that the scenario did not include any reference to storm intensities in Bass Strait which could affect gas production. Production infrastructure was considered to already to be robustly designed and able to cope with minor changes. The possible impact of increased demand for gas for electricity generation to meet extreme demands for air conditioning due to increases in temperature was seen as an area for detailed further consideration.

Electricity infrastructure

Interaction between events such as drought, high temperatures, bushfires and increased demand for the power required for reverse osmosis desalination plants was seen as likely to have significant consequences for both the generation and distribution of electricity. The vulnerability of overhead transmission lines to bushfires and storms was identified as having possibly serious consequences. An effective adaptation strategy would be to place the cables underground requiring significant investment, which was probably already justified to meet current conditions

Shortage of cooling water was already a significant factor electricity generation in the Latrobe Valley and this would be exacerbated by climate change. The proposed use of desalinated sea water and recycled water from distant Melbourne waste treatment plants was noted, but the opinion was strongly held that there was a need to introduce new technology to replace wet cooling by dry cooling systems. Such systems have already been demonstrated to be effective overseas. There was also criticism of the apparent lack of coordinated total design and planning with reverse osmosis desalination plants being proposed in isolation from base load generating plants, the waste heat from which could be efficiently utilised in alternative flash distillation desalination processes.

Flooding of the brown coal pits from intense rainfall was recognised as a potential problem for the generation of electric power, but it was considered that current protection was robust and that storage capacity would probably be sufficient to minimise delays in production. *(This belief in the robustness has been brought into question by more recent events)*. Relatively little adaptation would be necessary to meet the consequences of increased flooding due to climate change.

Oil infrastructure

No significant impacts from climate change were identified for the elements of the Victorian oil infrastructure in the absence of any indications included in the scenario for increases in the intensity of storms in Bass Strait. These structures were also considered to be robust and to have been designed conservatively.

Coal infrastructure

The major coal infrastructure is associated with the Latrobe Valley electricity production and the issues have already been covered.

In a general observation it was noted that elements of the energy infrastructure located in some coastal regions were potentially at risk from tsunamis for which effective design measures may not have been considered. However, the additional direct impact of climate change with the scenario sea level rise would not be significant.

NEW SOUTH WALES

Gas infrastructure

No significant differences from Victoria were identified.

Electricity infrastructure

Similar issues as were identified for Victoria were considered to be relevant for NSW with similar consequences and opportunities for adaptation.

In addition it was noted that many generating stations were located in low lying coastal areas and could be susceptible to the effects of sea level rise, local flooding and storm surge arising from climate change. Specific detailed studies would be needed for such stations.

It was noted that timber poles and other structures were still widely used for many power distribution systems and that many were of considerable age. Their capacity to resist any additional impacts imposed by the effects of climate change would need to be assessed. The design of the steel transmission towers carrying high voltage cables was considered to provide adequate robustness to cope with climate change impacts but it was agreed that underground cables would reduce their vulnerability to bushfires.

It was also noted that the efficiency of transmission was reduced by higher temperatures and that a review of the strategy regarding high voltage transmission may be warranted. Overhead cables also sagged more in high temperatures, reducing clearances.

It was expected that there would be major changes in the patterns of power generation in the future with moves towards increases in the generation of electricity from distributed stations relying on renewable sources such as wind and solar. It was noted that wind-generated energy was susceptible to changes in wind patterns and that both high and low speeds restrict the energy output. These factors will increase the need for improved interconnected grids and integrated control to balance the inputs and demands.

It was noted that adaptation measures should take into account changes in community attitudes which are taking place as a result of increasing public awareness of issues arising from demand for electricity. The capacity of the community to adapt should not be overlooked.

Oil infrastructure

No significant differences from the issues for Victoria were noted.

Coal infrastructure

There were no significant issues identified for production.

The export of coal was identified as having existing problems due to shipping being delayed by storms. It was also noted that the delivery of coal to ports relied on tightly controlled timetables and that the storage of coal to be exported should be under cover. Although the AGO NSW scenario shows no increase in storm intensity or frequency, any increases due to future climate change could exacerbate the problems. It was an issue which should be noted for further study.

SOUTH-EASTERN QUEENSLAND

Gas infrastructure

No significant differences from those for more southern regions were identified but it was noted that the development of extraction of coal seam methane would improve the supply situation in the future.

Electricity infrastructure

The region was considered to be expected to experience similar problems as Victoria and NSW as a result of climate changes affecting rainfall, temperature, drought, flash flooding and bushfires.

The increases in temperature in conjunction with population growth will increase the demand for electricity. Drought will limit the production of wet-cooled generating plants and adaptation by the adoption of dry cooling should be considered. The expectation of greater fire risk, in a region not previously seriously threatened, needs to be recognised by protecting distribution and by improving emergency services. The need to improve the interstate linkages to cope with regional demands was seen to be made more critical by climate change projections.

The increased demand for water which is proposed to be met by reverse osmosis plants could probably be better met by integrating flash distillation plants with thermal power stations and by recycling.

It was emphasised that holistic strategic planning would be essential to meet the future needs of the region having particular regard to population growth areas, which will create problems that will be further exacerbated by the climate change scenario.

Oil infrastructure

No significant difference, in the case of the more southern regions, was identified.

Coal infrastructure

The dependence on rail transport of coal to the coastal regions for both electricity generation and export was already a significant problem due to interruptions to service by extreme weather events. This would be exacerbated by climate change. Adaptation measures could include upgrading of the services and increased storage provisions to increase reserves.

NORTH-EASTERN QUEENSLAND

Gas infrastructure

No additional impacts to those for the more southern regions were identified. It was noted that a proposed gas pipeline from Papua New Guinea would traverse coastal regions, which may be subjected to increased tropical cyclone intensity and frequency but construction to current design practices should ensure its robustness to function under the conditions in the scenario.

Electricity infrastructure

The issues were similar to those identified for South-eastern Queensland, but the increased wind speeds in tropical cyclones could be a more serious problem for aging timber poles and structures. Above-ground transmission lines will become more susceptible to damage from airborne debris and from local extreme wind forces from tornadoes embedded in tropical cyclones. Protection of overhead cables from these actions is difficult to ensure. Placing cables underground would be an effective and practical adaptation measure if continuity of supply distribution is considered to be necessary.

An associated problem of the region is the very large areas with sparse population densities with the problem of providing an interconnected grid with the capacity to cover local interruptions to distributors.

The opportunities for the local generation of hydro-electric power should be considered as an adaptation measure since there is still expected to be substantial water available in most areas despite the small possible decrease in the annual average rainfall given in the AGO scenario.

Oil infrastructure

No additional impacts to those identified for the more southern regions were identified.

Coal infrastructure

No additional impacts to those identified for South-eastern Queensland were identified.

C.2.3 Summary for energy infrastructure

The energy infrastructure sector has special requirements which need to be recognised in discussing effectiveness to cope with current issues and the possible consequences of future climate change. The sector has significant vulnerability to climate change and major investment and planning may be required to provide the required adaptation capacity.

- The management of the generation and supply of electricity requires an integrated efficient and reliable communication system across all sectors and between all regions to ensure that operational decisions can be made expeditiously. The sector cannot operate if the communications are disrupted.
- Planning for the future energy infrastructure of Australia will require a totally integrated holistic approach to the provision and management of the operation of the elements of the sector. This applies particularly to electricity generation and distribution where there are existing problems to achieving such an outcome. These include two potential conflicts in attempting to impose the required planning control: first, the intensely competitive nature of the market with diverse ownership of the elements of infrastructure; and second, the international ownership of much of the generation and the distribution facilities.

The above are not technical issues, but must be recognised as important issues which will have to be faced if future planning for all contingencies, including climate change, are to be effectively addressed. The need for governments to intervene to secure the authority to act appropriately may be necessary.

C.3 BUILT ENVIRONMENT TELECONFERENCE

C.3.1 General

It was agreed that the matrix form was a suitable framework for the proposed assessments of consequences and adaptation capacity in a qualitative manner for the given scenarios, but that specific studies would require scenarios with more statistically based information for periods consistent with the design life of the sector element.

Mark Edwards had previously submitted matrices for all regions in which he had made assessments for events and sectors which he considered most critical. It was agreed to use these returns as a framework for discussion.

C.3.2 Issues relating to the built environment

It was agreed to identify critical issues for Victoria as a starting point, then move to the northern regions to determine if significant differences arose as the tropics were approached.

VICTORIA

Domestic housing

It was noted that the Australian Greenhouse Study on the impacts of climate change on housing was useful in assessing the vulnerability of housing in specific areas for the assumed scenarios and was a relevant reference document.

In the Victorian region, it was agreed that flooding from of low-lying land, from intense rainfall combined with sea level rise, was likely to cause significant impact on housing. Adaptation measures included the use of more flood resistant materials in construction, review of the soil classifications for slab-on-ground and the application of tighter planning controls.

It was pointed out that decisions to build in what are currently recognised as flood-prone areas will need to take into account the future likely consequences of climate change. Such decisions must take into account the costs and benefits of continuing to use such land in situations where the community has been prepared to accept the threats of flooding with the possibility of insurance covering the costs of rehabilitation.

It was also noted that the threat from flooding of housing was related to property damage and should not be assessed in the same way as for situations where loss of life is an issue. This is reflected in the current acceptance of a design flood with a 100-year return period in comparison with structural design return periods of 500 or 1000 years.

The impacts of climate change on bushfires were seen as having major consequences, particularly for houses which do not meet the design requirements of the 1999 Australian Standard AS 3959. Adaptation for housing built to the current Standard should require no action or only minor investment, but un-designed housing may require significant investment to reduce the threat. Victoria's long exposure to bushfire threat provides a basis for future adjustments with the need for specific studies for vulnerable localities.

The increase in average and maximum temperature has consequences for electricity demand for air conditioning of domestic housing, with a consequential interaction with the electricity generation and distribution capacity. Requirements for meeting energy rating of housing with additional insulation were seen as helping to provide adaptation capacity.

Reduction in annual rainfall and increases in evaporation could lead to reduced soil moisture content with implications for the construction of slab-on-ground concrete floors on reactive soils. The impact needs to be considered for specific localities with possible review of the application of the Standard AS 3959.

Institutional buildings

It was agreed that most institutional buildings could be expected to have been designed to generally satisfy current requirements of building standards and codes and were not likely to suffer significant consequences from the given scenarios. It was pointed out that the design life of such buildings was usually 50 years or more so there was a need for more statistical information for a more appropriate assessment of structural reliability

It was considered that the normal refurbishment cycles for institutional buildings could be integrated with adaptation requirements for climate change.

Industrial buildings and essential services facilities

It was considered that the issues for industrial buildings and essential services facilities would be similar to those for institutional buildings.

Coastal facilities

It was considered that coastal facilities designed to satisfy current standards and codes should not be vulnerable to the effects of sea level rise and flooding for the given scenario, but that such facilities usually have a design life extending beyond 2030.

NEW SOUTH WALES

It was agreed that the impacts for New South Wales could be expected to be mostly similar to those of Victoria for the assumed scenario.

It was noted that there was a much lower expectation for increase in the extreme daily rainfall intensity for NSW. However, this did not reduce the need for assessment of the consequences of the impact of climate change on flooding for specific localities.

There was some discussion on hail damage although this does not feature in the scenario for NSW.

Hail damage was already a current feature of many parts of the region and an increase in thunder storm activity could exacerbate the problems. It was an issue that needed to be kept under review with attention being given to the selection of appropriate roofing materials and roof drainage provisions.

SOUTH-EASTERN QUEENSLAND

Significant impacts and adaptation actions were seen as generally similar to those in NSW with domestic housing being vulnerable to flooding from extreme weather events and sea level rise. It was noted that there was an increased likelihood of bushfires and that the consequences of this could be significant for a region in which bushfires have not had the same sort of impact experienced regularly by Victoria and NSW. This is an issue which should be the focus of further study, including the development of public awareness of the impact of bushfires in urban communities.

It was noted that the Gold Coast was currently recognised as a locality where low-lying land had extensive housing and tourism development which was vulnerable to effects of flooding causing property damage as well as erosion. This vulnerability will be exacerbated by the effects of climate change in the assumed scenario. Information for the longer term is needed to assess the consequences of climate change for this and other similar locations in South-eastern Queensland.

There was discussion on the possibility that tropical cyclones may extend their southern boundaries as a result of climate change but insufficient reliable information was available on this possibility to assess impact. It was suggested that wind speeds associated with cyclones that did penetrate into the South-eastern Queensland region would not be any more severe than storms arising from the east-coast lows which are currently experienced. However, fully developed cyclones could contribute more severe storm surges which, with sea level rise, could exacerbate local flooding. These possibilities should be reviewed if more information became available.

NORTH-EASTERN QUEENSLAND

A significant difference in the scenario for North-eastern Queensland compared with those for the more southern east coast regions is the increase in extreme wind speeds in tropical cyclones of 10 per cent, given in the AGO scenario.

This increase in wind speed could increase storm surges significantly and, in association with sea level rise, local flooding would increase the current existing problems of property damage and coastal erosion in low-lying areas. Reference was made to an Australian Government publication which has specifically addressed the issues relevant to coastal facilities. It was agreed that additional action needed as a result of the assumed climate changes in the scenario would probably require only minor investment and that it would be essential to carry out cost-benefit studies to justify significant investment when property damage, which may be able to be covered by insurance, was the major issue.

It was observed by one member at the conference that the design wind speeds given in current loading standards were based on models which took into account the uncertainties of projections of extreme events based upon limited historical data. The design values were intended to result in robust structural designs with low probabilities of failure. The magnitudes of the values of increases in cyclone wind speeds and the uncertainties in the projections included in the assumed scenarios were considered to be such that no changes in current values to take into account the impacts of climate change were warranted at this time. More reliable assessment of the consequences of climate change will need more detailed statistical information and determination of adaptation measures should be made as a result of specific cost benefit studies commensurate with the design life of the facility.

It was noted that current extreme wind speeds in all tropical cyclone regions were subject to ongoing review and that it was recognised that the cyclonic regimes in the northern regions of Australia appeared to exhibit markedly different characteristics. The need for continued monitoring of the characteristics of tropical cyclones and review of design wind speeds, irrespective of climate change, of was endorsed.

The rises in temperature together with population increases in the region could be expected to put additional pressure on electricity generation and distribution. Adaptation measures could include improving the energy ratings of buildings, particularly for new and retrofitted commercial facilities.

C.4 TRANSPORT CONFERENCE

C.4.1 General

It was agreed to proceed by commencing with issues relate to the scenario for the Victoria region initially, and then to consider any significant differences for the more northern regions.

The Austroads study[22] of the effects of climate change, published in 2004, was accepted as a useful guide for identifying possibly significant consequences, but it was noted that the projections adopted were for the year 2100 and had been deliberately chosen to represent an extreme situation in order to highlight possibly critical areas.

VICTORIA

Roads

Sea level rise was not seen as having a significant effect.

The 70 per cent increase given for the extreme daily rainfall intensity scenario could have a significant consequence on the short term accessibility for some local regions, but it was considered that the adaptation strategies would not require major expenditure. Decisions on priorities for upgrading particular elements should only be made after a full consideration of the costs and benefits. The importance of maintaining adequate emergency services responses for any changes, including the provision of temporary bridges, was emphasised.

It was recognised that there was a need to consider the interaction of flooding with other events. Bushfires before heavy rain could accelerate run off and could also contribute to the debris load in flooded streams with subsequent damage to bridges by blockage. Such damage would however be expected to apply to older bridges which have not been designed to current design codes. Victoria has comparatively few remaining timber bridges which would be exposed to greater risk of damage by an increase in the number of bushfires.

The effects of increase in drought severity on pavements included subgrade deterioration and possible salinity problems but the consequences were not considered to be of major significance for well designed and properly maintained systems. The main responsibility will continue to be the provision of effective and adaptable maintenance programs.

Rail

No major consequences arising from climate change were identified. It was pointed out that the effects of interacting effects of climate change on electricity production and generating capacity resulting from drought, high temperature and bushfires cold have serious short-term effects on the capacity of the electrified rail system to operate. Bushfires could also disrupt the signalling system which is vital for the safe and efficient operation of the whole rail system.

Rail buckling due to climate changes on extreme temperatures should not be a significant problem for systems which satisfy current design codes.

The effects of sea level rise were not considered to be significant for the given scenario, but substantially greater rises could be of concern for rail systems servicing docks in low-lying estuarine river systems which were also subject to flooding. It was felt that the likely consequences for the rail systems serving major seaports in Victoria was not significant.

[22] Bureau of Transport and Regional Economics, *Impact of Climate Change on Road infrastructure, AP-R243/04*Austroads, March 2004 http://www.onlinepublications.austroads.com.au/script/Details.asp?DocN=AR0000048_0904

Airports

The consequences of climate changes to major airports in Victoria were not considered to be significant since these we were designed to meet current extreme events.

Rural airports may be significantly affected by increases in the severity of extreme events, including flooding and bushfires with the interacting effects on communications. It was noted that these airports are often expected to play a critical role in emergencies and the consequences of their unserviceability needs to be carefully considered for particular locations.

Airstrips with unsealed surfaces and inadequate subgrade preparation may require substantial upgrading of maintenance to counter the effects of drought and flooding on their serviceability.

Seaports

No significant consequences were anticipated for major seaports which are expected to have been designed for current extreme events. No increase is projected in the scenario for storms or wind speeds for Victoria and the sea level rise should be within the design limits already adopted.

Minor seaports may be threatened by the effects of drought and flood where access is through dredged channels already subject to effects of siltation. Adaptation measures would require increased commitment to regular dredging.

NEW SOUTH WALES

It was noted that the most significant difference from Victoria was in the six per cent increase in coastal areas in the extreme daily rainfall intensity, compared with 70 per cent for Victoria. This should reduce the effects of flooding damage to bridges by obstruction but it was considered that the local conditions of larger rivers with wide estuaries made the situation more serious with respect to scouring around supporting structures. It was considered that the there were probably proportionately more timber bridges in rural areas which would be more susceptible to bushfire damage but that accessibility should be able to be readily restored and that attention would be given to ensuring the provision of appropriate emergency services.

No significant differences in the effects of climate change for rail, airport and seaport infrastructure were identified beyond those for Victoria.

SOUTH-EASTERN QUEENSLAND

No significant differences of consequences as a result of the scenario for South-eastern Queensland were identified beyond those already considered above. It was noted that the increased likelihood of bushfires in a region for which this has not previously been considered to be a major extreme event should be a matter for review of the relevant emergency services.

The increase in the existing threats to transport links in urban developments and ports in low lying areas along the coast was noted as a potential future problem from the interaction of sea level rise, flooding and storm surge.

NORTH-EASTERN QUEENSLAND

The increase in tropical cyclone wind speeds was a significant difference from the more southern regions. There was also an increase of 25 per cent in the extreme daily rainfall in an area with an already high expectation. The consequences of these effects were identified as mainly in the reduction in accessibility rather than an increased threat to the integrity of structures which had been designed to current codes. The combination of increased storm surge, flooding and sea level rise could be significant for all transport links in low lying regions with urban, industrial and seaport developments which may already be at risk from current extreme events.

Similar adaptation strategies to those required for more southern regions would be appropriate.

It was noted that the extensive rural road system in large areas of the interior was in the black soil country where the reactive clays provided an unstable subgrade for pavement construction. Changes in the present regime of soil moisture could have significant impacts on the performance of these pavements with the consequence of possibly significant increases in maintenance costs.

C.4.2 Summary

It was not considered necessary for any changes to be made to current design codes at this stage, but that planning of future development should consider be made with due considerations of the climate change projections. Assessments should be made of the costs and benefits having regard to the consequences arising from accessibility restrictions imposed by loss of transport links. The impacts on maintenance programs for transport infrastructure elements, and on the required capacities of emergency services, needs to be assessed for specific areas.

C.5 COMMUNICATIONS TELECONFERENCE

C.5.1 General

It was noted that the objective of project is to look at impact of climate change on major infrastructure – not natural hazards *per se*, but the super-positional effect. A qualitative risk assessment approach is being used to identify 'critical infrastructure categories' that will form the basis of recommendations for further study. Both 'consequences' and 'adaptation' capacity were to be considered within the risk assessment framework.

Two areas of infrastructure were identified for discussion – fixed line and wireless – and four climatic regions in Australia (temperate through to tropical cyclone areas) were considered.

It is important to note there are intersections in the communications area with other infrastructure areas such as power/energy, transport, and so on. For example, if energy supply fails, there will be a direct impact on the communication systems.

C.5.2 Fixed line

VICTORIA

Tropical cyclone and major storms

No change expected by climate change. Hence, no assessment required.

Wind speed

No change perceived (noted that water more than wind can cause problems).

Sea level rise

- 17cm projected, but no impact perceived.
- Could cause local outages, but no widespread impact.

Floods

- Extreme daily rainfall intensity to increase to +70 per cent.
- This would lead to widespread localised effects
- Would lead to increased fault rates, but as some infrastructure is subject to the effects of flooding, no major impact is perceived.
- Nationwide infrastructure would assist a particular state if local infrastructure was rendered inoperable.

Hail

- No perceived change.

Temperature

- Increase of 1.1°C was seen as minor.
- This will not cause additional failures that will have any major impact – can be handled through current infrastructure.

Extreme temperature

- Increase in average number of days greater than 35°C, is projected to be +20 days inland and +10 days coastal.
- Network is currently built for local conditions, and thus it is not envisaged that extreme temperature effects will have a major impact.

Bushfires

- There is some bushfire-critical infrastructure – for example, radio towers, transcontinental optic fibre repeater stations.
- In the event of bushfires, there is usually a dramatic increase in the amount of mobile phone usage – for example, emergency services, people calling relatives in a potentially reduced service capacity.
- If a fixed line tower is shut down through fire, it will affect the efficiency of emergency services/communications. If a wireless tower is affected, then the impact will be even greater.
- Other modes of communication could be affected, for example, blogs, satellite photos – but the resultant capacity should still be sufficient.
- If part of the network is damaged, there are alternative routes with fixed line (for example, inland/coastal rerouting is possible and there is the potential to use wireless if it is not affected). Major regional areas (for example, Ballarat) have access to alternative routes, though some small towns (such as Bright) may not have dual access.
- When one line is removed, the transmission capacity will be down on other lines because of redirection of communications and the greater use of communication (data and voice) during an emergency.
- Consequence agreed – moderate.

Drought

- Can produce stress in optical fibres through relative movements in the soil.
- Consequence agreed – minor.

NEW SOUTH WALES

- No expectation for major increase in storms. Floods should be less.
- Extreme temperature and bushfire similar pattern to Victoria.
- As in Victoria, the network has been built to accommodate localised outages.

SOUTH-EASTERN QUEENSLAND

Wind speed and sea level rise

- No impact.

Floods

- Increased extreme daily rainfall events are expected. However, as Queensland already has large rainfall levels, then no real effect is anticipated, apart from an increase in localised outages (as in Victoria).

Hail

- No impact.

Temperature

- Similar impact to Victoria.

Extreme temperature

- Number of days greater than 35°C: +5 days near the coast and +50 days inland.
- Similar impact as for Victoria – hence, can be accommodated with current infrastructure.

Bushfires

- It was noted that normally radio towers were normally built with the potential of bushfires in mind; for example, high fence, gravel/concrete base.

NORTH-EASTERN QUEENSLAND

- Increase in tropical cyclone winds by 10 per cent.
- This would have limited impact on fixed line network
- Hence, the consequences will be minor.

C.5.3 Wireless network

The wireless network is composed of base stations connected into the rest of network by cable. So the considerations that are applicable for fixed lines must also be taken into account for the wireless network.

VICTORIA

Seal level

- No problems perceived.

Floods

- Less impact.

Temperature

- In the case of external plant, the greater number of hot days will cause increased failures. But not catastrophic – more of a maintenance issue.

Bushfires

- The issue will be the damage caused to towers.
- If the mobile phone network goes down in a particular area, it is possible to bring in portable networks (mobile units). However, this can take around two days to transport, install and set up.
- Alternatively, bushfire fighters and emergency services have access to a radio trunk network (shared talk channel) – requires radio infrastructure. This is independent of the mobile network.
- The emergency services network could have towers located in towns and hence less susceptible to bushfires. However, some of the towers will be located on hill tops.
- Repeater stations have own energy/power supply. They are diesel generators and are not normally backed up by solar. These diesel generated power units are vulnerable to the effects of bushfires.
- Adaptation capacity – mobile units can be transported to establish new mobile network.
- Consequence – moderate in terms of infrastructure and high in terms of loss of life.

NSW AND SOUTH-EASTERN QUEENSLAND

- Similar to Victoria.

NORTH-EASTERN QUEENSLAND

- Cyclones: increased wind speed and rain – towers are built to withstand strong winds. However there is obviously a limitation. Possible small increase in faulty transmissions.
- Radio transmission – radio waves are disrupted by very intense rain. Coverage of mobile phone network would be diminished.
- Consequences – minor (localised and temporary).

C.5.4 Summary

It was noted that in relation to communications infrastructure, there is a high degree of resilience in the system that can, in general, accommodate the potential impacts of climate change.

Flooding has the capacity to render part of a network inoperable and cause more disruption, but it will be generally localised and temporary. The impact of bushfires is the most significant area and should be the focus of further study and research.

Appendix D:
Instructions for Completion of the Questionnaire

1. Open the attachment and if an Excel dialog box appears, then click 'Enable Macros'.
2. Before completing details on the Information box, click 'Tools', click 'Macros', click 'Security' and then click 'Medium' level of security. Before starting to complete details in the information box, it is recommended to close the Attachment and then reopen the attachment with the above instructions – without going to 'Tools'.
3. Complete details of the respondent, identifying area of expertise by ticking one or more boxes. If required, other information may be added.
4. Tick the climate change region(s) for which the assessment is to be made. Separate Excel spreadsheets will be generated for each region ticked. Ten regions are identified according to the AGO; refer to the AGO document *Climate Change Scenarios for Initial Assessment of Risk in Accordance with Risk Management Guidance* (http://greenhouse.gov.au/impacts/publications/pubs/risk-scenarios.pdf).
5. Now go to the Excel spreadsheet matrix and assess both risk and adaptation. Adopt the following sequence:
6. Select a climate change region. Refer to the Australian Greenhouse Office publication, *Climate Change Scenarios for Initial Assessment of Risk in Accordance with Risk Management Guidance*[23] to quantify the magnitude of climate change effects.
7. Select an infrastructure sector and a climate change event.
8. Assess the Likelihood (L) on an alphabetical scale from A to E ('Almost Certain' to 'Rare') in accordance with Table 1 (Section 3.3.1) of the event occurring.
9. Assess Consequences, C (of the interaction between the event and infrastructure) on a numerical scale from 1 to 5 in accordance with the Table 2 (Section 3.3.2). Reference will need to be made to the AGO document[24] Section B 4.5, Tables 8, 9 and 10 that are relevant to Local Authority, Public Utility and Commercial Business perspectives.
10. Denote the level of Risk, R on a numeric scale from 1 to 4 ('Low' to 'Extreme') in accordance with Table 3 (Section 3.3.3). The assessment of risk *must* be done in accordance with Table 4.
11. Assess the Adaptation Capacity, A on a numeric scale of 1 to 7 in accordance with Table 5 (Section 3.4), taking into account the assessed Risk, R and your judgement of the resilience of the infrastructure in the defined climate change region to recover from an event or to be managed or up graded to mitigate the effects of the impact.
12. Repeat steps 2 to 6 for different combinations of infrastructure type and climate change event.
13. Repeat the above process for a different climate change region.
14. Add any further comment or information in space provided for 'additional comment'.
15. Save the Excel spreadsheet file and return it to Vaughan Beck (vaughanb@atse.org.au).

If you have any queries regarding completion of the matrix, please contact Len Stevens (l.stevens@civenv.unimelb.edu.au) or Vaughan Beck (vaughanb@atse.org.au).

[23] CSIRO, Climate Change *Scenarios for Initial Assessment of Risk in Accordance with Risk Management Guidance* Australian Greenhouse Office, 2006 http://www.greenhouse.gov.au/impacts/publications/pubs/risk-scenarios.pdf

[24] Broadleaf Capital International and Marsden Jacob Associates, *Climate Change Impacts and Risk Management, a Guide for Business and Government*, Australian Greenhouse Office, 2006 http://www.greenhouse.gov.au/impacts/publications/pubs/risk-management.pdf

Appendix E: Workshop Attendees

Melbourne Climate Change Workshop attendees

Associate Professor Pryian Mendis	University of Melbourne
Professor John Wilson	Swinburne University
Associate Professor Kevin Walsh	University of Melbourne
Dr Lam Pham	CSIRO
Mr Ian McKenzie	Beveridge Williams
Dr Michael Manton	Monash University/ATSE
Mr Anant Gupta	University of Melbourne
Professor Colin Duffield	University of Melbourne
Dr Bob Leicester	CSIRO
Mr Peter Laver	ATSE
Mr Sean Sweeney	Department of Infrastructure
Professor Paul Grundy	Monash University
Mr Muhammad Afzal	University of Melbourne
Mr Reg Hobbs	Flagstaff Consulting
Professor John Zillman	ATSE
Mr Michael Nolan	Maunsell Australia
Professor Brian Cherry	Monash University/ATSE
Mr Tim Gosbell	URS Corporation
Mr Bob Meggs	URS Corporation
Professor Len Stephens	University of Melbourne/ATSE
Dr Vaughan Beck	ATSE

Sydney Climate Change Workshop attendees

Professor Len Stevens	University of Melbourne/ATSE
Professor Vaughan Beck	ATSE
Professor Peter Crawford	Sydney Water
Dr John Nutt	ARUP/ATSE
Mr Richard Kell	Cardno International
Professor Bruce Thom	Wentworth Group Coast Council NSW
Mr Jack Knight	SKM
Mr Ken Conway	GHD Pty Ltd
Mr Alan Chappel	Hunter Water Corporation, Connell Wagner Consulting
Professor Harry Poulos	Coffey Ltd
Mr Paul Sloman	ARUP
Professor Wiji Ariyayatne	RTA
Mr Angus Gordon	Manly Hydraulics Laboratory
Professor Mike Dureau	Warren Centre, University of Sydney
Dr Geo Walker	AonRe Insurance
Associate Professor Ron Cox	University of NSW
Professor Garry Willgoose	University of Newcastle
Mr Greg Kane	Sydney Water
Mr Dragan Hranisavljevic	Sydney Water
Dr Doug Treloar	Cardno International

Appendix F: Teleconference Participants

Teleconference contacts

AREA	NAME	AFFILIATION
Water	Mr Brian Sadler PSM FTSE	Chair IOCI/Water Policy Services and Uni of Notre Dame Australia
	Dr Bruce Thom FTSE	Wentworth Group Coast Council NSW
	Dr Jim Gill FTSE	WA Water Corporation
	Dr Vaughan Beck FTSE	ATSE
	Professor Len Stevens AM FTSE	University of Melbourne/ATSE
Built environment	Mr George Walker	Aon Australia
	Dr Lam Pham	CSIRO
	Mr Mark Edwards	Geoscience Australia
	Dr Vaughan Beck FTSE	ATSE
	Professor Len Stevens AM FTSE	University of Melbourne/ATSE
Transport	Dr Max Lay AM FTSE	SKM
	Mr Peter Balfe	Leightons
	Mr David Hudson FTSE	Barclay Mowlem Construction
	Professor Len Stevens AM FTSE	University of Melbourne/ATSE
	Dr Vaughan Beck FTSE	ATSE
Communications	Mr John Ellershaw	University of Melbourne
	Mr Dan Credazzi	Leightons
	Dr Hugh Bradlow FTSE	Telstra Corporation
	Dr Vaughan Beck FTSE	ATSE
Energy	Dr John Sligar FTSE	Sligar and Associates
	Mr Martin Thomas AM FTSE	Dalhunty Power Ltd
	Professor Mike Dureau FTSE	University of Sydney, Engineering
	Dr John White FTSE	Global Renewables
	Professor Len Stevens AM FTSE	University of Melbourne/ATSE
	Dr Vaughan Beck FTSE	ATSE

ATSE – in brief

The Academy of Technological Sciences and Engineering (ATSE) is an independent, non-government organisation, promoting the development and adoption of existing and new technologies that will improve and sustain our society and economy.

ATSE consists of more than 750 eminent Australian Fellows and was founded in 1976 to recognise and promote the outstanding achievement of Australian scientists, engineers and technologists.

ATSE provides a national forum for discussion and debate of critical issues about Australia's future, especially the impact of science, engineering and technology on quality of life.

ATSE links Australia with leading international bodies and worldwide expertise in the technological sciences and engineering.

ATSE fosters excellence in science, engineering and technology research and the critical education systems that underpin Australia's capacity in these areas.

ATSE tackles many of the most difficult issues governing our future, by offering fresh ideas, practical solutions and sound policy advice – and putting them on the public record.

COVER PHOTO: This recent storm surge on Queensland's Gold Coast indicates the threat of climate change to Australia's infrastructure – CSIRO photo

Assessment of Impacts of Climate Change on Australia's Physical Infrastructure

The Australian Academy of Technological Sciences and Engineering (ATSE)

ATSE Office
Ian McLennan House
197 Royal Parade
Parkville VICTORIA 3052
AUSTRALIA

Mail address
PO Box 355
Parkville VICTORIA 3052
AUSTRALIA

Phone
(03) 9340 1200 (National)
(613) 9340 1200 (International)

Fax
(03) 9347 8237 (National)
(613) 9347 8237 (International)

Email
vaughanb@atse.org.au
billm@atse.org.au

Websites
www.atse.org.au
www.crawfordfund.org
www.cluniesross.org.au