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The Secretary
Standing Committee on Climate Change, Water, Environment and the Arts
House of Representatives
Parliament House
PO Box 6021
CANBERRA ACT 2600

30 May 2008

Dear Ms Holmes

Re: Inquiry into climate change and environmental impacts on coastal communities

We thank you for the opportunity to provide comments on the above inquiry. Our detailed responses to the Terms of Reference are attached.

The environmental and climate change challenges facing coastal communities are significant and include the complexity of human decision-making, institutional structures and governance arrangements. Science is able to assist managers and policy-makers understand many of the consequences of action or inaction, as well as how to monitor the results of management decisions. Science can also provide scenarios of decision outcomes resulting from any adjustments to policy and management approaches using measured environmental, economic and social responses (adaptive management approach).

In our submission, we provide comments on the basis of our extensive expertise and ongoing research at CSIRO in the area of climate change adaptation and environmental management, particularly as it pertains to coastal communities. We look forward to the opportunity to discuss any aspect of our submission further with the Committee.

Please do not hesitate to contact me should you require anything further.

Sincerely

Andrew Johnson
CSIRO Group Executive - Environment

CSIRO

Climate Change and Environmental Impacts on Coastal Communities

CSIRO Submission 08/282

May 2008

House of Representatives Standing Committee on Climate Change, Water, Environment and the Arts

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EXECUTIVE SUMMARY

The environmental and climate change challenges facing coastal communities are significant and include the complexity of human decision-making, institutional structures and governance arrangements. Some of these issues can be solved by science, others cannot. Science, however, is able to assist managers and policy-makers understand many of the consequences of action or inaction, as well as how to monitor the results of management decisions. Science can also provide scenarios of decision outcomes resulting from any adjustments to policy and management approaches using measured environmental, economic and social responses (adaptive management approach).

Coastal environments will continue to be attractive places to live and work, but local and regional demands on coasts and their ecosystems will increasingly exceed their capacity to supply environmental and economic goods and services. Population growth and development need to be limited in vulnerable areas and concentrated elsewhere. In most cases the actions required to reduce or mitigate human impacts are known. However, uncertainty over economic, social and environmental consequences of these actions has led to institutional inertia. To overcome this inertia evidence based management systems and planning tools are needed to help inform decision-making and to assist in evaluating and monitoring the impacts of these decisions. In particular, a nationally consistent coastal information system is required to support planning and management decisions and policy development by providing scenarios which incorporate the potential impacts of different population growth projections, climate change and changes to economic conditions.

Climate change will have significant impacts on coasts and coastal communities, particularly through the combined effects of sea level rise, extreme weather events and coastal inundation. In assessing the impact of climate change on coastal areas, and developing strategies for adaptation a systems approach is required, taking into account the interactions between a range of biophysical, social and economic drivers and impacts.

To reduce some of the uncertainties in adapting to climate change, better understanding of the biophysical impacts of climate change on coastal areas is required. In particular, narrowing the uncertainties associated with sea level rise projections, obtaining a greater understanding of extreme storm surge events and a capability to operationally predict their impact, and improving inundation models to better predict flooding impacts from the interaction of extreme rainfall events, storm surges, and sea level rise associated with climate change. While it may take some time for research to reduce these uncertainties, risk management approaches and tools need to be put in place now to inform decision making in the areas of urban planning and development, flood management, infrastructure and disaster management.

With the combined stresses of population growth, coastal development and climate change, a transformation is needed in the way our coastal environments are perceived. Many of the changes in coastal ecosystems are irreversible - a fish species may become extinct; a reef or a dune system may be destroyed in a storm; the pH of the sea may decrease with significant implications for biota. Predicting these irreversible changes is not always possible, no matter how much research is done. Moving to adaptive governance of coastal environments is therefore essential in overcoming the current institutional barriers to integrating science with management to develop holistic approaches to managing Australia's coasts.

1. INTRODUCTION

Australia's coasts are central to Australian society and culture. They are the source of diverse values, and our life styles and economy depend on them. Despite having laws, policies, agencies and investments for managing our coasts, degradation occurs and its many and varied values are threatened. Pressures on our coasts will increase in the future as populations and resource use grow and towns and cities spread. These pressures are expected to increase as our climate changes and the sea rises and acidifies. There is recognition that Australia lacks both the knowledge and the governance capacity to meet the threats and take the opportunities that are already apparent. The problem is exacerbated by deep uncertainty about the future.

In this submission we define the coast as the combined land and sea regions where the sea and the seafloor are vulnerable to substantial influence from the land and vice versa. Thus, the coast includes the land which delivers water, silt and pollutants to the streams, estuaries and aquifers that discharge into the sea. It also includes the atmosphere that transports pollutants, aerosols and dusts onto both land and sea. The effects of the sea on the land include the obvious such as storm surges and coastal erosion but also the less obvious such as saltwater intrusion into estuaries and aquifers and nuisances such as smells and airborne irritants associated with algal blooms. The coast is not the land above the high tide line, nor should it be defined as a strip of fixed width on land and sea.

We do not aim to give a comprehensive overview the state of Australia's coasts but rather to reflect on the opportunities and pressures affecting them, and the mechanisms that are needed to balance sustainable environmental, social and economic outcomes.

1.1 CSIRO's expertise in relation to the Inquiry's Terms of Reference

It is essential that the management of Australia's coasts is based on reliable information, with clear articulation of uncertainties. CSIRO has core strengths in marine, atmospheric, terrestrial and climate science and in the cross-scale, interdisciplinary approaches needed to address climate change adaptation and coastal governance, and to develop transformation options and pathways. CSIRO is also the best equipped R&D organisation to provide whole-of-system analyses and decision-relevant technologies and information to support Australia's governments, coastal communities, policymakers and regional bodies in their adaptation to climate and population change. Coastal research in CSIRO is concentrated in three of its National Research Flagships - Wealth from Oceans, Climate Adaptation, and Water for a Healthy Country. Key strengths include:

- National coverage, capacity to undertake interdisciplinary science and to transfer and apply knowledge developed in different contexts,;
- Strong linkages to industry practitioners, policymakers, community leaders and the general research community and our commitment to undertaking relevant, credible and legitimate science enhancing prospects for achieving impact;
- Whole-of-system analysis capability, including climate science, biophysical, economic and social impacts and the likely responses of resource users to policy changes. CSIRO does not have the vested interests of a particular jurisdiction or industry. Its ability to connect climate, marine, agricultural, social and economics sciences, ICT, mining, energy and water R&D release it from the narrowness of analysis imposed by use of a single discipline;

- A long history of participative research with governments and communities undergoing or preparing for social and environmental changes in cities, rural regions and along our coasts.

2. RESPONSE TO THE TERMS OF REFERENCE

In responding to the Terms of Reference, CSIRO has integrated the first and fifth terms of reference, so that the existing policies and programs relating to coastal zone management, and governance and institutional arrangements for the coastal zone are dealt with together.

2.1 ToR 2 – The Environmental Impacts of Coastal Population Growth and Mechanisms to Promote Sustainable Use of Coastal Resources

Recommendations:

As coastal populations are likely to continue to grow:

1. Coastal zone management needs to be integrated on a whole of catchment approach
2. Management systems need to focus on learning and dealing with uncertainty
3. Growth needs to be limited in vulnerable areas and concentrated elsewhere whilst reducing or mitigating its impacts.
4. Infrastructure development should limit downstream consequences and preserve important ecosystem service providers such as wetlands, coastal dunes, salt marshes and mangroves.
5. Often these environments are not valued for the free services they provide, and so one mechanism to assist in their preservation is to consider the value of ecosystem services when making development decisions that liquidate natural capital.
6. It is desirable to spread peak level flood discharges by temporarily retaining water in floodplains rather than by rapid flood discharge using channelization of streams. Consequently, uses of inundation prone areas need to be zoned appropriately.
7. Better erosion control, riparian habitat restoration and the maintenance of environmental flows will reduce stress in rivers, estuaries and seas.
8. A national target for coastal parks and reserves in terms of proportion of coastline (not land area) will help with the maintenance of amenity values, keeping in mind that the demand will be greatest in areas of population concentration.
9. Whole of catchment management is particularly important in ensuring that reserves are able to maintain their biophysical and amenity values.

2.1.1 Impacts of coastal population growth

The dynamic nature of Australian coasts reflects the historic and continuing interaction of four drivers of biophysical change, including:

a) natural climate variability;

b) climate and sea-level change induced by global climate change;

c) natural geomorphic-ecologic progression and threshold regime-shifts related to sedimentation and erosion and other biogeochemical processes; and

d) human-induced changes to catchments, estuaries and coastal environments linked to population growth, land use changes and engineering modifications of rivers and foreshores.

The relative importance of each of these biophysical drivers changes over time and differs from place to place. There is increased concern over the risks facing coastal zone assets, both natural and human, from the potential impact of global warming, and these issues are examined in depth in section 3 below. However, any assessment of national or regional changes to coastal conditions must involve consideration of all four drivers.

Importantly, these biophysical changes are occurring within a dynamic economic, social and institutional context. This context creates three additional drivers for coastal change, these being:

e) population and demographic change associated with urban and peri-urban settlement, including the "Sea Change" phenomenon;

f) economic restructuring and the ensuing impacts on the sustainability of employment in areas of coastal growth; and

g) the growing necessity for a higher level of integrated decision making between overlapping and competing jurisdictions within and between various levels of government.

The following examples illustrate some of the diversity of Australian coastal and marine environments affected by the range of drivers:

- The pressures of recreation, urbanisation and population growth in NSW and SE Queensland
- Urbanisation and land use practices in the catchments adjacent to the Great Barrier Reef (GBR) are the source of water quality and ecological problems in the GBR lagoon.
- A distinct set of problems are manifest on the remote Australian coast where there are problems of failed governance with consequential issues associated with the security of coastal borders.
- Other coastal areas, such as the Pilbara and Kimberley coasts are subject to pressures associated with capital intensive industrial development.
- Multiple and competing values and users of these systems and the resources they contain

- Negotiation of coastal-marine resource rights and allocations constitutes a critical dynamic that will shift in response to predicted coastline and coastal environmental changes.

- Coasts in many parts of Australia offers a fulcrum for Indigenous people's lives, cultural identity and Country. In comparison, the beaches are of profound cultural importance to other Australians as sites of recreation and tourism.

It is highly unlikely that the coasts will cease to attract Australians as desirable places to live, work and for recreation. In an export-oriented, commodity-intensive economy, coasts will continue to be a dominant focus of economic activity. This is further reinforced by the importance of the coasts in both domestic and international tourism, and the value and opportunities of marine-based resource industries. Consequently, none of these drivers is expected to ease in future, and many will intensify. The pressures and drivers are not self limiting and even if all the human uses were well managed when considered independently, we may still have unsatisfactory coastal management because the uses will have overlapping demands for ecosystem services and natural capital.

Natural capital is the stock of natural resources and forms much of the "infrastructure" needed to supply ecosystem services. The Millennium Ecosystem Assessment (2005) defines ecosystem services as the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services, such as nutrient cycling, that maintain the conditions for life on Earth.

The local and regional demands placed on our coasts often exceed their capacity to supply. The central problem of management is to determine the level of impacts that are consistent with acceptable environmental, social and economic outcomes. However, this is a difficult problem, because in most cases we cannot predict the relationship between levels of human activity and the consequent impacts on natural systems. In many cases there is evidence of systems that can absorb a certain level of impact until they reach a threshold after which they collapse into an undesirable state from which it is very difficult to return. Toxic algal blooms in estuaries and bays are a well known example.

Sustainability must therefore represent the fundamental aim for the wide variety of coastal management plans currently in existence, and as such may also be seen as a means by which the 'success' of those plans may be measured. So far, however, this measurement has proved elusive.

The elements of sustainability are:

- Utility/welfare does not decline over time

- Resources managed to maintain production opportunities for the future

- Renewable resources and services are managed for sustainable benefits

- Natural capital does not decline over time

- Environmental, social and economic resilience maintained

- Sustainable development builds capacity and consensus

Liquidating natural capital may reduce the supply of some ecosystem services and often we have to replace natural capital with infrastructure. For example, flood control provided by a wetland is an ecosystem service. Draining the wetland leads to inundation elsewhere and so capital needs to be invested in flood control engineering. If the economic and social return from the drained wetland exceeds the cost of the engineering solution then it is a reasonable choice. The problem is however, that often the cost of replacing the services provided by natural assets is not counted in cost benefit analyses. Often it is not even recognised that the decision to drain the wetland will incur a cost to someone else (an externality) and often the consequences will not become apparent until later or even be linked to the decision to drain the wetland.

As well as natural capital and ecosystem services, coasts provide recreational opportunities and amenity benefits which will increasingly need to be taken into account in future planning, given the competing demands that come with increased population. There is an urgent need for Australia to examine in detail how coastal planning can be more effective in maintaining "sense of place" and amenity and derive the associated economic and environmental benefits. This will be a fundamental issue for developing high quality urban areas.

2.1.2 Mechanisms to promote sustainable use of coastal resources

The direct mechanisms available that can limit or modify the levels of human impact on coastal resources include:

- Remediation - allowing a degraded location to recover by either passive (removing impacts) or active measures (removing impacts and reintroduction of missing biota). An example of mitigation is a no net loss policy for mangroves, where clearing in one location is mitigated by re-planting nearby.

- Substitution - replacement for some ecosystem service or natural asset in a different form. For example, replacing one of the services provided by coastal dunes in preventing inundation might be substituted by building seawalls.

- "End of pipe" - reduction of discharges to the environment, either by using technologies to capture pollutants or to convert them into a benign form.

- "Source reduction" - reducing the amount of pollutants by modifying the processes or materials used in making goods or providing services.

- Doing nothing - the level and types of human activity in a given locality will be affected by the decision to do nothing.

So the central question is how to set and vary the direct-effect mechanisms to meet management goals efficiently and effectively. These rely on indirect-effect governance mechanisms outlined in section 2.4.

Since population growth in the coasts is unlikely to be limited in general, it needs to be limited in vulnerable areas and concentrated elsewhere while reducing or mitigating its impacts. Infrastructure development should limit downstream consequences and preserve important ecosystem service providers such as wetlands, coastal dunes, salt marshes and mangroves. These environments are not valued by markets, are often publicly owned or not valued by their owners if on private land, yet they provide valuable free services. Non market valuation surveys can establish their value to the public to prior to development decisions that liquidate natural capital. Peak level flood discharges can be spread by temporarily retaining water in floodplains rather than by rapid flood discharge using channelization of streams. Consequently, uses of inundation prone areas need to be zoned appropriately. Better erosion control, riparian habitat restoration and the maintenance of environmental flows will reduce stress in rivers, estuaries and seas. A national target for coastal parks and reserves in terms of proportion of coastline (not land area) would help with the maintenance of amenity values, keeping in mind that the demand will be greatest in areas of population concentration. Whole of catchment management is particularly important in ensuring that reserves are able to maintain their biophysical and amenity values.

In most cases the actions required to reduce or mitigate human impacts are known. The key management question is; How much and what mix of actions are needed to be applied to have a given result? However, this cannot be predicted with certainty, which leads to a key institutional barrier to implementation. Uncertainty leads to different groups with different values and interests contesting proposed actions, requesting more certainty (which is generally not feasible) and then to "paralysis by analysis". Management systems need to be developed that avoid this pitfall by expanding their capability to experiment with different actions and evaluate the relationships between actions and outcomes.

One of the significant weaknesses in coastal zone management is the lack of effective evaluation and systematic compilation of our cumulative experience. Although considerable efforts are made with the resources available to plan appropriately, and often monitoring programs are set up when plans are implemented, more effort needs to be put into research to learn how the original plans worked, and what lessons can be applied to similar decisions elsewhere or in the future.

2.2 ToR 3 – The impact of climate change on coastal areas and strategies to deal with climate change adaptation, particularly in response to projected sea level rise

Recommendations:

1. In assessing the impact of climate change on coastal areas and developing strategies for adaptation. a systems approach is required, taking into account the interactions between a range of biophysical, social and economic drivers and impacts.
2. To reduce some of the uncertainties in adapting to climate change, better understanding of the biophysical impacts of climate change on coastal areas is required, in particular:
   a) Robust regional to local scale climate projections and impacts on sea level rise, wave conditions and storm surges. Understanding of the impact of climate change on the intensity and frequency of severe storm events and tropical cyclones.
   b) Continuous satellite and in situ observations of the ice sheets are required, closely linked to climate modelling activities to lead to a narrowing of projections of future sea-level rise.
   c) A greater understanding of extreme storm surge events and their impact, and a capability to operationally predict their impact, is required.
   d) Inundation models need to be improved to better predict flooding impacts from the interaction of extreme rainfall events, storm surges, and sea level rise associated with climate change.
3. Even though there are considerable uncertainties associated with climate change, approaches and tools need to be put in place now to inform decision making in the areas of urban planning and development, flood management, infrastructure and disaster management.

2.2.1 Drivers of Climate Change Impacts in the Coastal Zone

The coastal zone is a complex environment at the interface of the land, ocean and atmosphere. There are a number of physical drivers of climate variability change and downstream consequences in the coastal zone, which interact with socio-economic trends and trajectories to determine the risk of adverse outcomes for Australia's environment and communities.

- **Sea-level Rise and Variability.** Globally averaged sea level increased at a rate of 1.7 mm/year during the 20th century. The rate of rise has increased during the 20th century and satellite measurements indicate that since 1993 sea level has been rising at over 3 mm/year (Church and White, 2006). The Intergovernmental Panel on Climate Change (2007) projected future sea-level rise of 18–79 cm by the end of the 21st century, yet more recent analyses have indicated the potential for much higher rates of sea-level rise of up to 1.4 metres by 2100 (Rahmstorf, 2007; Horton et al. 2008), depending on the dynamical processes associated with ice sheets. For Australia, rates of sea-level rise of 10 cm above the global mean are projected along the East Coast due to strengthening of the East Australian current (CSIRO and BOM, 2007). These long-term trends in the average sea level will be punctuated by significant variability arising from natural tidal variations, as well as wind-driven storm surge and wave action. The combination of the mean sea-level rise, particularly at the upper end of these projections, combined with these extreme events will have very significant impact on coastal regions around Australia and also internationally.

- **Catchment Rainfall and Rainfall Variability.** Stream flows of coastal catchments influence the delivery of water, sediments and nutrients to estuaries and coastal wetlands. Catchment rainfall and runoff is therefore a significant regulator of coastal ecosystem structure and function. Reductions in seasonal and annual rainfall and runoff are projected for many parts of coastal Australia, particularly the Southeast and Southwest (CSIRO and BOM, 2007). In contrast, the far North may experience increases in rainfall. Extreme rainfall events and the associated runoff may deliver large quantities of water to coastal areas, resulting in high nutrient loads and the inundation of adjacent land. Such inundation may be exacerbated if extreme rainfall is coincident with storm surge events.

- **Sea-Surface Temperatures.** Increases in atmospheric temperatures will drive increases in ocean temperatures, particularly the surface ocean. Temperatures around Australia are projected to increase by 0.4-1.4°C by 2030 and 0.6-1.5°C by 2070 (CSIRO and BOM, 2007). This may, in turn affect ocean productivity and biogeochemical cycling.

- **Ocean Acidification.** The oceans represent a major sink for atmospheric carbon dioxide. Future increases in atmospheric carbon dioxide will increase the dissolution of CO_2 in the surface ocean increasing its acidity, with subsequent implications for productivity, biogeochemical cycling and biodiversity. The largest declines in ocean pH are projected for the mid- to high-latitudes (CSIRO and BOM, 2007)

- **Catchment Demographics.** Most Australians live near the sea with as many as 30%, or about six million people, within 2 km of the coast and about 6.0% of Australian addresses situated within 3 km of shorelines in areas with elevations below 5 m (Chen and McAneney, 2006). Rapid growth in population, which in some regions such as Southeast Queensland is occurring at a rate of 3% per year, will increase this exposure and, subsequently, socio-economic vulnerability to climate variability and change.

2.2.2 Impacts of climate change in the Coastal Zone

Table 1 below outlines the biophysical and socio-economic drivers and climate change impacts in the coastal zone. While each of these drivers in isolation presents significant issues, they are not independent and planning to deal with them requires a systems approach, taking into account their interaction with each other and cumulative impacts on the coastal zone.

Table 1. Biophysical and Socio-Economic Impacts Associated with Key Climatic and Non-Climatic Drivers in the Coastal Zone

Driver	Biophysical Impacts	Socio-Economic Impacts
Sea-level rise	• Increase in inundation of coastal lands and wetlands • Increased salt water intrusion into estuaries and coastal aquifers • Reduced return intervals and higher storm surge heights • Coastal erosion, particularly of iconic sandy beaches.	• Increased risk of property damage and loss without adequate adaptation measures • Impairment of water quality • Degradation of coastal amenity and recreational opportunities • Loss of culturally significant sites and locations
Rainfall	• Changes in freshwater flows to estuaries and coastal wetlands • Impairment of wetlands and nursery areas • Changes in species composition and abundance • Increased risk of harmful algal blooms	• Impairment of fisheries • Increased risk of coastal flooding during extreme rainfall events • Degradation of recreational opportunities • Loss of tourism revenue
Sea Surface Temperatures	• Changes in the distribution and abundance of fish species • Changes in ocean productivity and biogeochemical cycling • Increased frequency/intensity of coral bleaching events • Increased risk of harmful algal blooms	• Impairment of fisheries • Degradation of recreational opportunities • Loss of tourism revenue
Ocean Acidification	• Reduction in rate of calcification in corals and other planktonic organisms • Reduced resilience of coral communities	• Impairment of fisheries • Degradation of recreational opportunities • Loss of tourism revenue
Coastal Demographics	• Increased coastal development and demand for coastal facilities and amenities • Increased pressure on climate-exposed coastal resources and assets	• Increased risk of property damage and loss • Increased disruption of local business and commerce • Degradation of recreational opportunities • Loss of tourism revenue

2.2.3 Adapting to the major threats: severe weather and sea level rise

An increased frequency of severe weather events and sea level rise are two climate change impacts to which Australia's coastal zone must adapt.

Severe Weather

Coastal areas of Australia, especially the urban areas of the east coast, are affected by severe weather events such as tropical cyclones, extreme rainfall events and damaging thunderstorms. Insurance losses from the major climatic catastrophes affecting Australia show that one third of the losses are due to floods, 30% from severe storms and 28% from cyclones. Climate change is projected to affect the intensity and frequency of severe weather events such as tropical cyclones, extreme rainfall events and damaging thunderstorms.

The impact of climate change on tropical cyclone frequency is the subject of considerable debate but there is growing consensus that the storms will be more powerful producing increased damages due to increased rainfall rates and flooding, stronger winds and increased storm surge levels. In addition to increased damage, changes in tropical cyclone frequency will impact water resources in the tropical and sub-tropical parts of the country. Australian modelling studies suggest that tropical cyclones occurring off the Queensland coastline will move further south in the future, and thus will be more likely to impact the Brisbane and Gold Coast regions. A greater understanding of the impact of climate change on the intensity and frequency of tropical cyclones is required.

Some of the most flood-prone regions of Australia occur along the east coast of the continent and are those that are experiencing the greatest population growth. Thus there is an increasing exposure of the community to extreme rainfall events. The scientific community has the capability to address the issue of climate change and extreme rainfall in small, focused studies but is lacking the capacity to "scale-up" and address this issue from a national perspective. The relationship between extreme rainfall and extreme sea levels needs to be addressed so that these coincident events may be considered in planning future developments in the coastal zone. There is a need to develop conceptual frameworks and tools using risk management principles to include climate change in flood planning and management. Stakeholders acknowledge the importance of climate change but at present lack methods to include it in their mainstream business.

Severe thunderstorms are a major cause of weather-related damage along the east coast between Brisbane and Sydney. The development of projections for the impact of climate change on the frequency and intensity of damaging thunderstorm is problematic because these phenomena are too small to be explicitly represented in global and regional climate models. Thus other techniques are used to infer changes in the frequency of severe thunderstorms and have been developed for Australia. However, these techniques do not account for changes in intensity (i.e. hail size, damaging winds, flash flooding). At present, Australia has essentially no capacity to provide climate change projections of changes in the intensity of severe thunderstorms.

Sea Levels

The current wide range of projections of global averaged sea-level rise, and the almost complete absence of understanding of its regional distribution, makes it extremely difficult to plan cost-effective adaptation measures. There is an urgent need to narrow the current broad range of global averaged sea-level rise and to begin understanding of its regional distribution. This requires continuing global and regional observations of sea levels (and land motion) as well as observations of global and regional ocean thermal expansion, one of the main contributions to sea-level rise. Perhaps the largest uncertainty, particularly on longer time scales, is the response of the Greenland and Antarctic Ice Sheets to climate change. Continuous satellite and in situ observations of the ice sheets are required. These observational programmes need to be closely linked to climate modelling activities to lead to a narrowing of projections of future sea-level rise.

The impact of sea-level rise will be felt most acutely during extreme events, such as Hurricane Katrina and Cyclone Nargis. Particularly important is how these extreme events could change in frequency and magnitude. A more than doubling in the frequency of high sea-level events of a given magnitude has already been observed on the Australian east and west coasts. For a number of Australian locations, a 50 cm sea-level rise (a not extreme value) could see the current one in 100 year event occur several times per year! A greater understanding of these extreme storm surge events and their impact and a capability to operationally predict their impact is required.

Sea-level rise will also be felt through coastal erosion, particularly of iconic sandy beaches. While Australia has excellent capability to understand coastal erosion, we are currently lacking capacity to address the issue. We need to collect and compile information on past coastal erosion, to develop ongoing monitoring and to develop and apply coastal erosion models. These studies need to be connected with a quantitative understanding of regional sea-level rise, changes in wave conditions and storm surges.

Inundation models also need to be developed linking extreme rainfall events to changes in sea levels. Of course these are critically dependent on robust climate change projections at regional scales. At present, Australia has essentially no capacity to do climate change predictions for the next few decades at the regional to local scale and to verify the accuracy of the predictions.

Adaptation strategies

As the previous two sections have highlighted climate change will expose many of the 85% of Australians who live along the coastal fringe to sea-level rise and more extreme weather events. However, urban and coastal development is proceeding rapidly, often in areas vulnerable to climate change impacts; infrastructure damage as a result of weather-related disasters has been increasing exponentially, with extreme weather events likely to increase in the future.

A systematic approach to climate adaptation is required; one that explicitly includes other drivers e.g. demographic change as well as the risks posed by climate change. Two major approaches are required to addressing the challenge posed by climate change:

1. Building adaptive capacity in policy, communities and industry

Adaptive capacity underpins effective climate change responses across all economic and social sectors as well as from the scale of the individual through to communities, industries, or government. Adaptive capacity is enhanced through learning and hence a proactive and participatory, co-learning approach to ensure that learning happens in the critical areas of all social systems that are affected by climate change.

Five key steps are required in building adaptive capacity: 1) identifying socio-economic patterns and trends for the region to put climate change into context; 2) regional synthesis of vulnerabilities to climate change; 3) identifying the key attributes and determinants of, as well as threats to adaptive capacity; 4) refining sectoral level understanding of and ability to manage adaptive capacity through institutional and empirical data analyses; and 5) designing cost effective strategies to enhance adaptive capacity.

a) Adaptation solutions

There are a range of possible adaptation options to deal with climate change and these will assume different priority depending on location and vulnerability. Examples of adaptation options include:

- Improved design criteria for critical infrastructure including roads, bridges, buildings, storm water and sewerage systems. Some of these options will require a major re-think on building infrastructure whilst some options are relatively easy and cost-effective to introduce e.g. shifting the cyclone building code further south to adapt to projected southward movement in tropical cyclones
- Changes in emergency services planning and response procedures to deal with major climate related events e.g. ensuring evacuation routes in low-lying coastal areas are above flooding and storm surge projections
- Providing a comprehensive flood risk assessment at the scale of the street address to help with local government planning and insurance
- Provision of policy and management decision tools to urban planners to incorporate climate change risk into local government and development approvals
- Development of strategies that build the capacity of disadvantaged groups to respond to social and economic climate impacts e.g. improved social networks
- Development of strategies for the tourism, insurance and finance sectors to enable them to better understand and respond to a changing climate

Development of adaptation options needs to be done in partnership with policy makers, industry and communities to avoid perverse outcomes. The costs of adaptation will in many instances be significant, and uncoordinated or inappropriately targeted adaptation will consequently cost the economy severely in inefficiencies, costs of missed opportunities and downside risk. The development of a common and consistent conceptual approach to adaptation across agencies, tiers of government and in the research community will greatly reduce these costs.

2.2.4 Knowledge Gaps and Research Needs

Despite an extensive history of both climate change assessment and coastal management in Australia, significant knowledge gaps persist with respect to understanding the trajectory of future climate changes relevant to coastal areas, the dynamics of coastal biophysical and socio-economic impacts and the mechanisms for overcoming barriers to coastal climate adaptation. Governance issues are outlined in S2Section 2.3, whereas Table 2 below focuses on biophysical impacts.

Table 2. Knowledge Gaps and Related Research Needs for Australian Coastal Adaptation

Knowledge Gap	Associated Research
Significant uncertainties regarding future rates of sea-level rise, particularly that associated with dynamical ice sheet processes. The wide range of current projection makes planning adaptation measures difficult.	Improved understanding of global averaged sea-level rise, including particularly ocean thermal expansion and the response of ice sheets to global warming. Improved understanding of the regional distribution of sea-level rise.
Significant uncertainty of the amount of coastal erosion that would occur.	Collection and compilation of data on historical coastal erosion. Improved quantitative models of beach erosion and their linkage to improved estimates of global-averaged and regional sea-level rise. Improved knowledge of changes in ocean wave conditions and how they impact on coastal erosion. The relative contribution (in different regions) across the frequency spectrum from tidal periods and weather related events to decadal changes
Significant uncertainties regarding the fate of El Nino Southern Oscillation dynamics under anthropogenic climate change	Continued exploration of ENSO behaviour within coupled global climate models as well as improvement in ENSO forecasting and prediction systems.
Potential implications of coincident events on coastal systems, such as combined effects of storm surge, wave action, extreme rainfall on coastal erosion and flooding	Analysis of changes in the frequency of extreme events. Quantitative methods linking sea-level rise, storm surges, ocean waves and coastal erosion.
Access to high quality, high resolution topographic and bathymetric data for coastal modelling of biophysical and socio-economic impacts	Increased acquisition, integration and dissemination of high resolution data sets
Decision-support systems for the incorporation of climate information into coastal zone management	Evaluation of stakeholder needs with respect to critical decisions currently constrained by knowledge gaps, followed by development and trialling of one or more decision-support tools to address these challenges.
Awareness of the institutional arrangements, relationships and tensions that underpin coastal management in Australia	In-depth study of existing institutional relationships and decision-making processes associated with coastal management, emphasising identification of potential adaptation barriers and opportunities of better harmonisation of effort

2.3 ToR 1 and 5 – Governance and institutional arrangements for the coastal zone, including comments on existing policies and programs related to coastal zone management, taking in the catchment-coast-ocean continuum

Recommendations
1) Coasts are non-linear systems with multiple thresholds, some of which are not reversible, and the consequences of changes in climate, population and other drivers are largely unpredictable.

2) Because many of the consequences for our coasts of climate and population change are unpredictable, coastal governance should be adaptive. This includes:

- scanning the future;
- taking lessons from the past and other places;
- seeking ways to better integrate and coordinate governance;
- rescaling governments to suit the scales and distributions of the threats and opportunities from climate change and population increase;
- allocating resources to match the levels and locations of the potential threats and opportunities;
- making rules, such as property rights and development approvals, adaptable to new circumstances;
- using incentives for behavioural change, as well as regulation;
- building and maintaining options, redundancy and reserves; and
- instituting better approaches to risks, uncertainties and cumulative impacts.

2.3.1 Introduction

This section responds to the first and last terms of reference of the Inquiry by evaluating existing policies and programs and the governance and institutional arrangements for the coastal zone.

In 'governance' we include the social norms and formal rules that govern society and its resource uses. It therefore includes institutional arrangements: legislation, regulations, plans, policies, programs and the organisational structures and processes that implement them. We have restricted our analysis and proposals to public governance at Commonwealth, state, territory and local government scales, and have not addressed governance in the private sector, though this will be an important part of adaptation.

Other sections in CSIRO's submission to the Inquiry discuss the impacts that climate and population change may have on our coasts, and mechanisms to promote sustainable coastal communities. Those sections outline the challenges to which governance must respond. In this section we evaluate how well prepared coastal governance is to respond. We assume that the purpose of governance is maintaining the delivery and distribution of multiple, at times contradictory values to diverse social groups, while maintaining the assets that generate those values, and options for future generations. The threats and opportunities that climate change will bring demand that governance will be adaptable, highly aware of thresholds, and able to navigate away from them. In this section we offer criteria for evaluating adaptability, and apply them to current coastal governance. The criteria are drawn from CSIRO's own research, from other Australian research, and from studies of coastal adaptation in

Europe and the USA. The criteria are: learning from the past and other places; scanning the future; integration and coordination; governing at the right scales; resourcing and the capacity to self-organise; the ability to change rules and incentives; building and maintaining options, redundancy and reserves; and dealing with risks, uncertainties and cumulative impacts.

In this section we first evaluate current coastal governance against the criteria, and then conclude with a discussion of pathways to improved coastal governance. The World is now in a century where both climate and population changes will demand adaptation to shocks and opportunities, including energy and other resource scarcities, new technologies, the emergence of new markets and the decline of old ones, geo-political conflicts and other pressures as yet unknown. Building the capacity of governments to adapt to change will, we propose, also enhance their adaptability to threats and opportunities from a wide range of sources.

2.3.2 Learning from the past and from other places

Governance of our coastal regions has developed since the colonisation of Australia on the assumption that the future will be the same as the past. Organisations, laws, regulations, social norms and mental models, information flows, monitoring and learning, and investments in private and public infrastructure have all been shaped by this equilibrial view of our coasts. Climate and population change and other global drivers may bring both threshold changes and rapid trends that make it dangerous to cling to that view. There are multiple examples from Australia and overseas where regions have been surprised by hurricanes and tsunamis, industry closures and other shocks and have shown varying capabilities to respond (Adger et al. 2005). Failures and successes both carry lessons, and they have informed our selection of the other criteria we apply to governance.

2.3.3 Scanning the Future

Australian governments, industries, regional bodies (CMAs and similar organisations) and researchers are already using scenarios of climate and other changes to identify potential threats and opportunities (e.g. Hennessy 2006). We advocate greater use of scenarios in governance, coupled with a greater emphasis on thresholds of potential concern. It is increasingly apparent that an equilibrial view of societies and ecosystems is not valid because many important changes in both of them are non-linear, and the rate of change may increase suddenly as the threshold is approached. Some non-linear processes are effectively irreversible. Effective governance in these circumstances may be best achieved by identifying the critically important thresholds that would, if crossed, harm key assets, and monitoring the risk of crossing the threshold. Although the risk of crossing a particular threshold may be definable, a greater and less easily definable risk is that crossing of one threshold may cause others to be crossed in a cascade of irreversible changes (Kinzig et al. 2006). Sustainability, within this concept, is about keeping key assets on the desired side of the critical thresholds, so that Australians can continue to enjoy the range of values and options our coasts generate.

2.3.4 Integration and coordination

Coastal governance should seek to maintain a flow of multiple values from multiple natural and built assets, across several scales, to diverse stakeholders, including future generations. Integrated governance is about doing this successfully within a system comprising three levels of government, each with its own electorate and jurisdictional boundaries. There are seven constitutions, eight legal systems, and a variety of coastal environments, economies, population densities and dynamics. The states and the Northern Territory govern coastal waters, while the Commonwealth has jurisdiction over the ocean. Native Title claims have been made on some coasts, and some have been successful. The consequence of this variation is that each coastal region faces different challenges and opportunities from climate change. Meanwhile, overlapping, unclear or juxtaposed jurisdictions across local, state and Commonwealth governments do hamper integrated and coordinated responses (Morrison 2007). Given the diversity and values of uses of the coastal zone, and the sectoral administration of State and Commonwealth Governments, there are additional problems of fragmentation and lack of coordination across government agencies. This issue has bedevilled environmental management in recent years; tables 3 and 4 show the results of a brief analysis of the multitude of Government agencies involved in decisions that will or may affect coastal Australia. Research which identifies where fragmentation is perverse and how to ensure integration is a critical part of improving how we manage our coasts (Cash et al. 2006).

Table 3: State and Commonwealth agencies involved in coastal management

Commonwealth:	**State agencies:**	**State agencies:**
DEWHA Dept of the Environment, Water, Heritage and the Arts	NSW-EPA NSW Environmental Protection Authority	TAS-DPIWE TAS Dept of Primary Industries, Water and Environment
DAFF Dept of Agriculture, Fisheries & Forestry	NSW-DECC NSW Dept of Environment and Climate Change	TAS-EPA TAS Environmental Protection Authority Tasmania
AGO Australian Greenhouse Office	NSW-DP NSW Dept of Planning	TAS-PWS TAS Parks and Wildlife Service
EA Environment Australia	NSW- DWE Dept of Water and Energy	TAS-DIER TAS Dept of Infrastructure, Energy and Resources
RET Resources, Energy And Tourism	NSW-NPWS NSW National Parks and Wildlife Service	TAS-EDT TAS Economic Development and Tourism
AFMA Australian Fisheries Management Authority	NSW-DPI NSW Dept of Primary Industries	TAS-HC TAS Heritage Council
AQIS Australian Quarantine Inspection Service	NSW-HC NSW Heritage Council	
GA Geoscience Australia	NSW-RTA NSW Roads and Traffic Authority	VIC-VCC Victorian Coastal Council
NWC National Water Commission	NSW-CMA NSW Catchment Management Authorities	VIC-DSE VIC Dept of Sustainability and Environment
LWA Land & Water Australia	NSW-M NSW Maritime	VIC-EPA VIC Environment Protection Authority, Victoria
DOD Dept of Defence	NSW-SW NSW Sydney Water	VIC-HS VIC Human Services
MDBC Murray Darling Basin Commission	NSW-HW NSW Hunter Water	VIC-PCD VIC Planning and Community Development
	NSW-SPC NSW Sydney Ports Corporation	VIC-PI VIC Primary Industries
State & Territory agencies:		VIC-T VIC Transport
ACT-DUS ACT Dept of Urban Services		VIC-WC Various VIC Water Corporations (e.g. Melbourne, Lower Murray, North East Regional, South Gippsland, etc
ACT-DTSM ACT Dept of Territory and Municipal Services	NT-NREA NT Natural Resources, Environment and The Arts	VIC-CMA Various VIC Catchment Management Authorities
ACT-PLA ACT Planning and Land Authority	NT-PWC NT Power and Water Corporation	VIC-EAC Environmental Assessment Council
ACT-DHCS Dept of Disability, Housing and Community Services	NT-DIPE NT Dept of Infrastructure, Planning and Environment	WA-DEC Dept of Environment and Conservation (DEC)
ACT-DT Dept of Treasury		WA-AWA Agriculture WA
QLD-EPA QLD Environment Protection Agency		WA-DPI WA Dept of Planning and Infrastructure

QLD-DPI QLD Dept of Primary Industries		WA-EPA WA Environmental Protection Authority
QLD-DME QLD Dept of Mines and Energy	SA-EPA SA Environmental Protection Authority (SA)	WA-DIR WA Dept of Industry and Resources
QLD-NRW QLD Dept of Natural Resources and Water	SA-DEH SA SA Dept for Environment and Heritage	WA-OE WA Office of Energy
QLD-PCQ Ports Corp Queensland	SA-DWLBC SA Dept of Water Land and Biodiversity Conservation	WA-WRC WA Water and Rivers Commission
QLD-WC QLD Water Commission	SA-SAP Planning SA	WA-PC WA Planning Commission
QLD-DIP QLD Dept of Infrastructure and Planning	SA-DAC SA Development Assessment Commission	WA-W WA Dept of Water
QLD-BSA QLD Building Services Authority	SA-TEI Dept for Transport, Energy and Infrastructure	WA-PTA Public Transport Authority
QLD-DH QLD Dept of Housing	SA-DPIR Dept of Primary Industries and Resources	WA-WC WA Water Corporation
QLD-LGSR QLD Dept of Local Government, Sport and Recreation		WA-WP WA Western Power
QLD-DMR QLD Dept of Main Roads		WA-SRT Swan River Trust (formerly Water and Rivers Commission)

Table 4: Summary of drivers and impacts in coastal regions, and the State, Territory and Commonwealth agencies involved in approvals, management and environmental impact assessments. *Note: Local council, and in some cases, regional councils are involved in each of the drivers below.*

		Ocean	Freshwater	Terrestrial	Estuarine	Intertidal	Beach	Catchment
Drivers, Pressures, Effects	**State & Commonwealth Management Agencies**	**Domains**						
Vegetation clearing/ removal/ disturbance Direct effects: less vegetation, aesthetics, cultural; Indirect effects: erosion, sedimentation, siltation	**All states:** EPA, PWS, Water catchment authorities; **ACT**: US, PLA; **QLD**: NREW; DPI, BSA; **NSW**: DECC, NPWS, DPI; **NT**: DIPE, NREA; **SA**: DEH, DWLBC, SAP, DPIR; **TAS**: DPIWE, DIER; **VIC**: DSE, PCD, PI, EAC; **WA**: DEC, DPI; **C'wealth**: AGO, DEWHA, DAFF, EA, GA, RET, LWA, DOD, MDBC		X	X	X		X	X
Pollution – point and diffuse sources	**All states:** EPA, Water Commission/Corporations, Water catchment authorities, Ports Corps; **ACT**: US, PLA, DTSM; **QLD**: NRW, DIP, DPI; **NSW**: DECC, NPWS, DPI, M; **NT**: DIPE, NREA; **SA**: DEH, DWLBC, SAP, PIR; **TAS**: DPIWE; **VIC**: DSE, VCC, PCD, PI; **WA**: DPI, EPA, DEC, WRC; **C'wealth**: AGO, DEWHA, DAFF, EA, GA, NWC, MDBC	X	X	X	X	X	X	X
Coastal erosion	**All states:** EPA, PWS, Water catchment authorities, Ports Corps; **ACT**: US, PLA; **QLD**: DIP, NRW, BSA, DH; **NSW**: DECC, NPWS, HC; **NT**: DIPE, NREA; **SA**: DEH, DWLBC, SAP, DAC; **TAS**: DPIWE, DIER, HC; **VIC**: DSE, EAC, PCD, VCC; **WA**: DEC, DPI; **C'wealth**: DEWHA, DAFF, EA, GA, LWA, DOD		X	X	X	X	X	
Recreation, ecotourism and recreational fishing	**All states:** EPA, PWS; **ACT**: US, PLA; **QLD**: DPI, DNRW, DIP, LGSR; **NSW**: DECC, NPWS, HC, M; **NT**: DIPE, NREA; **SA**: DEH, DWLBC; **TAS**: DPIWE, EDT, DIER, HC; **VIC**: DSE, VCC, DE, PCD, PI; **WA**: DEC, DPI, PC **C'wealth**: AGO, DEWHA, DAFF, EA, GA, NWC, LWA, AFMA	X	X	X	X	X	X	X
Water catchment management – floods, inundation, channelization, drainage practices	**All states:** EPA, Water Commissions/Corporations, Water catchment authorities; Health departments in disasters; **ACT**: PLA, US, DTMS; **QLD**: DNRW, DIP; **NSW**: DECC, CMA; **NT**: DIPE, NREA, PWC; **SA**: DWLBC, SAP, TEI, PIR; **TAS**: DPIWE, DIER; **VIC**: DSE, EAC, PI, PCD, VCC; **WA**: DEC, DPI; **C'wealth**: AGO, DEWHA, DAFF, EA, GA, NWC, LWA		X	X	X	X	X	X
Coastal engineering – seawalls, groynes, dredging, reclamation, artificial reefs	**All states:** EPA, Ports Corps; **ACT**: US, DTSM, **QLD**: EPA, DNRW; **NSW**: DECC, NPWS, **NT**: DIPE, NREA; **SA**: DEH, EPA, DWLBC; **TAS**: DPIWE; **VIC**: DSE, EAC; **WA**: DEC, DPI, EPA **C'wealth**: AGO, DEWHA, DAFF, EA, GA, LWA, DOD	X	X	X	X	X	X	
Biosecurity – invasive and introduced species	**All states:** EPA; **ACT**: US; **QLD**: DPI, NRW; **NSW**: DPI, DECC, NPWS; **NT**: NREA, DIPE; **SA**: DEH, SAP, DPIR; **TAS**: PWS, DPIWE, PWS, DIER; **VIC**: DSE, EAC, PI; **WA**: AWA, DPI, DEC; **C'wealth**: AQIS, AGO, DEWHA, DAFF, EA, GA, LWA	X	X		X	X	X	X
Resource extraction - commercial fishing,	**All states:** EPA, Natural Resources, Mining & Energy; **ACT**: PLA, US; **QLD**: DNRW, DPI,	X	X		X	X	X	X

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		Ocean	Freshwater	Terrestrial	Estuarine	Intertidal	Beach	Catchment
oil and gas, sand, seabed resources	DME, DIP; **NSW**: DECC, NPWS, DPI, HC; **NT**: DIPE, NREA, PWC; **SA**: DEH, DPIR, DWLBC, SAP, TEI; **TAS**: DPIWE, IRER, DET, HC; **VIC**: DSE, EAC; **WA**: DPI, DEC; **C'wealth**: DEWHA, DAFF, EA, GA, AFMA, LWA, DOD, MDBC							
Sedimentation / siltation – land-use practices	**All states:** EPA, Natural Resources, Water catchment authorities; **ACT**: US, PLA; **QLD**: DME; **NSW**: DECC, DP, DWE, DPI; **NT**: DIPE, NREA; **SA**: DAC, DEH, DPIR; **TAS**: DPIWE, DIER; **VIC**: DSE, EAC, VCC, PI; **WA**: AWA, DPI, EPA, DEC, WRC; **C'wealth**: DEWHA, DAFF, EA, GA, LWA	X	X	X	X	X	X	X
Urban/peri-urban development (sea change) Direct effects: clearing or infilling of mangroves and tidal mudflats	**All states:** EPA, Water catchment authorities; **ACT**: US, DTSM, PLA DHCS; **QLD**: NRW, DIP, BSA, DH, DMR; **NSW**: DP, DECC, DWE, RTA; **NT**: DIPE, NREA; **SA**: DEH, DWLBC, SAP, DAC, TEI; **TAS**: DIER, DPIWE,; **VIC**: DSE, PCD, T, EAC; **WA**: DPI, DEC, PC, PTA; **C'wealth**: DEWHA, EA, GA, LWA		X	X	X	X	X	X
Industrial development	**All states:** EPA, Water catchment authorities; **ACT**: US, DTSM, PLA, DT; **QLD**: BSA, DIP, DPI, NRW, DMR; **NSW**: DECC, DP, DPI, DWE, RTA; **NT**: DIPE, NREA; **SA**: DEH, DWLBC, SAP, DAC, DPIR; **TAS**: DIER, DPIWE, EDT; **VIC**: DSE, EAC, PCD, PI, VCC; **WA**: DPI, DEC, PC; **C'wealth**: DEWHA, DAFF, EA, LWA;			X	X	X		
Rural development	**All states:** EPA, Natural Resources, Primary Industries, Water catchment authorities; **ACT**: US, DTSM, PLA, DT; **QLD**: DIP, NRW; **NSW**: DP, DWE; **NT**: DIPE, NREA; **SA**: DEH, SAP; **TAS**: EDT, DIER; **VIC**: DSE, EAC, PCD, VCC; **WA**: AWA, DEC, DIR, PC; **C'wealth**: DEWHA, DAFF, EA, LWA		X	X	X	X		X

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Drivers, Pressures, Effects	**State & Commonwealth Management Agencies**	**Domains**						
		Ocean	Freshwater	Terrestrial	Estuarine	Intertidal	Beach	Catchment
Vegetation clearing/ removal/ disturbance Direct effects: less vegetation, aesthetics, cultural; Indirect effects: erosion, sedimentation, siltation	**All states:** EPA, PWS, Water catchment authorities; **ACT**: US, PLA; **QLD**: NREW; DPI, BSA; **NSW**: DECC, NPWS, BG, DPI; **NT**: DIPE, NREA; **SA**: DEH, DWLBC, SAP, DPIR; **TAS**: DPIWE, IER; **VIC**: DSE, PCD, PI, EAC; **WA**: DEC, DPI; **C'wealth**: AGO, DEWHA, DAFF, EA, GA, RET, LWA, DOD, MDBC		X	X	X		X	X
Pollution – point and diffuse sources	**All states:** EPA, Water Commission/Corporations, Water catchment authorities, Ports Corps; **ACT**: US, PLA, DTSM; **QLD**: NRW, DIP, DPI; **NSW**: DECC, NPWS, BG, DPI, M; **NT**: DIPE, NREA; **SA**: DEH, DWLBC, SAP, PIR; **TAS**: DPIWE; **VIC**: DSE, VCC, PCD, PI; **WA**:	X	X	X	X	X	X	X

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		Ocean	Freshwater	Terrestrial	Estuarine	Intertidal	Beach	Catchment
	DPI, EPA, DEC, WRC; **C'wealth**: AGO, DEWHA, DAFF, EA, GA, NWC, MDBC							
Coastal erosion	**All states:** EPA, PWS, Water catchment authorities, Ports Corps; **ACT**: US, PLA; **QLD**: DIP, NRW, BSA, DH; **NSW**: DECC, NPWS, BG, HC; **NT**: DIPE, NREA; **SA**: DEH, DWLBC, SAP, DAC; **TAS**: DPIWE, DIER; **VIC**: DSE, EAC, PCD, VCC; **WA**: DEC, DPI; **C'wealth**: DEWHA, DAFF, EA, GA, LWA, DOD		X	X	X	X	X	
Recreation, ecotourism and recreational fishing	**All states:** EPA, PWS; **ACT**: US, PLA; **QLD**: DPI, DNRW, DIP, LGSR; **NSW**: DECC, NPWS, BG, HC, M; **NT**: DIPE, NREA; **SA**: DEH, DWLBC; **TAS**: DPIWE, EDT, IER; **VIC**: DSE, VCC, DE, PCD, PI; **WA**: DEC, DPI, PC **C'wealth**: AGO, DEWHA, DAFF, EA, GA, NWC, LWA, AFMA	X	X	X	X	X	X	X
Water catchment management – floods, inundation, channelization, drainage practices	**All states:** EPA, Water Commissions/Corporations, Water catchment authorities; Health departments in disasters; **ACT**: PLA, US, DTMS; **QLD**: DNRW, DIP; **NSW**: DECC, CMA; **NT**: DIPE, NREA, PWC; **SA**: DWLBC, SAP, TEI, PIR; **TAS**: DPIWE, IER; **VIC**: DSE, EAC, PI, PCD, VCC; **WA**: DEC, DPI; **C'wealth**: AGO, DEWHA, DAFF, EA, GA, NWC, LWA		X	X	X	X	X	X
Coastal engineering – seawalls, groynes, dredging, reclamation, artificial reefs	**All states:** EPA, Ports Corps; **ACT**: US, DTSM, **QLD**: EPA, DNRW; **NSW**: DECC, NPWS, BG, **NT**: DIPE, NREA; **SA**: DEH, EPA, DWLBC; **TAS**: DPIWE; **VIC**: DSE, EAC; **WA**: DEC, DPI, EPA **C'wealth**: AGO, DEWHA, DAFF, EA, GA, LWA, DOD	X	X	X	X	X	X	
Biosecurity – invasive and introduced species	**All states:** EPA; **ACT**: US; **QLD**: DPI, NRW; **NSW**: DPI, DECC, NPWS, BG; **NT**: NREA, DIPE; **SA**: DEH, SAP, DPIR; **TAS**: PWS, DPIWE, PWS, IER; **VIC**: DSE, EAC, PI; **WA**: AWA, DPI, DEC; **C'wealth**: AQIS, AGO, DEWHA, DAFF, EA, GA, LWA	X	X		X	X	X	X
Resource extraction - commercial fishing, oil and gas, sand, seabed resources	**All states:** EPA, Natural Resources, Mining & Energy; **ACT**: PLA, US; **QLD**: DNRW, DPI, DME, DIP; **NSW**: DECC, NPWS, DPI, HC; **NT**: DIPE, NREA, PWC; **SA**: DEH, DPIR, DWLBC, SAP, TEI; **TAS**: DPIWE, IRER, DET; **VIC**: DSE, EAC; **WA**: DPI, DEC; **C'wealth**: DEWHA, DAFF, EA, GA, AFMA, LWA, DOD, MDBC	X	X		X	X	X	X
Sedimentation / siltation – land-use practices	**All states:** EPA, Natural Resources, Water catchment authorities; **ACT**: US, PLA; **QLD**: DME; **NSW**: DECC, DP, DWE, DPI; **NT**: DIPE, NREA; **SA**: DAC, DEH, DPIR; **TAS**: DPIWE, IER; **VIC**: DSE, EAC, VCC, PI; **WA**: AWA, DPI, EPA, DEC, WRC; **C'wealth**: DEWHA, DAFF, EA, GA, LWA	X	X	X	X	X	X	X
Urban/peri-urban development (sea change) Direct effects: clearing or infilling of mangroves and tidal mudflats	**All states:** EPA, Water catchment authorities; **ACT**: US, DTSM, PLA DHCS; **QLD**: NRW, DIP, BSA, DH; **NSW**: DP, DECC, DWE, RTA; **NT**: DIPE, NREA; **SA**: DEH, DWLBC, SAP, DAC, TEI; **TAS**: DIER, DPIWE, IER; **VIC**: DSE, PCD, T, EAC; **WA**: DPI, DEC, PC, PTA; **C'wealth**: DEWHA, EA, GA, LWA		X	X	X	X	X	X

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		Ocean	Freshwater	Terrestrial	Estuarine	Intertidal	Beach	Catchment
Industrial development	**All states:** EPA, Water catchment authorities; **ACT**: US, DTSM, PLA, DT; **QLD**: BSA, DIP, DPI, NRW; **NSW**: DECC, DP, DPI, DWE, RTA; **NT**: DIPE, NREA; **SA**: DEH, DWLBC, SAP, DAC, DPIR; **TAS**: DIER, DPIWE, EDT, IER; **VIC**: DSE, EAC, PCD, PI, VCC; **WA**: DPI, DEC, PC; **C'wealth**: DEWHA, DAFF, EA, LWA;			X	X	X		
Rural development	**All states:** EPA, Natural Resources, Primary Industries, Water catchment authorities; **ACT**: US, DTSM, PLA, DT; **QLD**: DIP, NRW; **NSW**: DP, DWE; **NT**: DIPE, NREA; **SA**: DEH, SAP; **TAS**: EDT, IER; **VIC**: DSE, EAC, PCD, VCC; **WA**: AWA, DEC, DIR, PC; **C'wealth**: DEWHA, DAFF, EA, LWA		X	X	X	X		X

States hold the constitutional responsibility for coastal planning and management, some of which are devolved to local governments. The current system is dominated by the state government and sectoral decision-making processes, even though all states have a coastal policy or equivalent. Coordination of policy can be poor and lacking integration, while roles and responsibilities are generally not well defined and often conflicting. Governance around indigenous use of resources is particularly poorly integrated, involving as it does intersections of customary and mainstream governance arrangements with Indigenous organisations and laws, such as the Land Councils, Native Title bodies, and various Indigenous natural resource management and service delivery agencies (Orchard et al. 2003). It will be difficult to build adaptive capacity into these arrangements without first simplifying them, but the possibilities need to be explored. CSIRO has been building its capacity to do research with Indigenous peoples on resource use and governance.

An integrated approach to climate change has been sought by the previous Commonwealth Government through the National Climate Change Adaptation Program. The Council of Australian Governments and the Natural Resource Management Ministerial Council have also identified the coasts as a priority for climate change adaptation. Integration has also been sought at national scale through the Inter-Governmental Coastal Advisory Group, which manages the implementation of the Framework for a National Cooperative Approach to Integrated Coastal Zone Management. Members of the Advisory Group represent the State and Northern Territory governments, and the Australian Local Government Association. The predecessor to Integrated Coastal Zone Management, Coastcare, was a Federal Labor government coordination initiative that invested in community-based approaches, but failed in the view of some researchers because it was not integrated with the various levels of government. There has been a significant shift in the way governments and communities engage with planning and management for natural resources and approaching complex and uncertain problems such as responding to climate impacts. Integrated Coastal Management represents current best practice in Australian efforts to plan and manage coastal environments. Recent initiatives in the Great Barrier Reef such as the Reef Water Quality Protection Plan recognise the interconnectivity of marine ecosystem conditions with land-based management practices and seek to adopt a mixture of partnership, regulatory and incentive based strategies in response. A critical research challenge is to inform the development of a governance framework which builds upon the positive elements of Integrated Coastal Zone Management.

The Federal Coastal Catchments Initiative contributes to integration across jurisdictions and regional bodies (Catchment Management Authorities and their equivalents) in the improvement of coastal water quality. Their water quality improvement plans are intended to identify the most cost-effective and highest priority projects for funding by the three levels of government, and community and environmental groups. The plans are consistent with two other Federal integration initiatives, the Framework for Marine and Estuarine Water Quality Protection, and the National Strategy for the Management of Coastal Acid Sulphate Soils. Given the extent of marine pollution from agriculture, and the large areas of acid sulphate soils that could potentially be released by land drainage, there is some question whether the current levels of resource allocation from governments and agricultural and tourism industries will be sufficient to control these threats.

The policies and programs described above seek to integrate across jurisdictions, thus across scales, but they are primarily aimed at biophysical problems. A greater challenge to integrated governance is integration across economic sectors, across stakeholders' values, and across the built and natural assets that produce them. This is attempted by each of the three levels of government at their respective scales. Commonwealth and state governments seek integration through sustainable development, and through Indigenous, biodiversity conservation and whole-of-government policies. There are often real tensions between maintaining ecosystem health and development pressures.

Local governments are likewise responsible for integrating development with environmental management, have the authority to achieve a balance, and because they plan land use and control development are vitally important in coastal management. In many cases development takes precedence over ecosystem health due to the varying pressures of electorate demand, revenue requirements (via rates), and housing and employment needs. The consequence is that local governments can have a limited perspective on coastal management, eschewing long-range planning and an interdisciplinary approach in favour of short time frames and a focus on physical structures and facilities. While considerable improvements have been made in the approach of some local governments to coastal planning and management, there remain concerns about the limited capacity and parochial focus of others.

2.3.5 Governing at the right scales

Governance is likely to be more adaptive to challenges and opportunities when it operates at the right social and spatial scale, because it is more closely connected to the communities, economies and ecosystems that it seeks to govern (Lovell 2002). As a general principle, to be adaptable, aspects of governance should be only be centralised if they are shown to be ineffective at their current scale of operation (Marshall 2005). Arguments to centralise based only on cost savings are not economically valid – the benefits as well as the costs of centralisation must be compared with the decentralised alternative if a sound decision is to be made.

The persistence of our federal system is assumed, but under the threats and opportunities of climatic and population change it is useful to examine governance at finer scales, and to look in particular at regional bodies and local governments, and their roles in adaptation.

While much of the focus on climate change mitigation and adaptation has focused on the international and national levels, there is a great need for research which explores the effectiveness of policy responses at finer scales. The previous Federal Government established regional bodies so as to link local, national and international policies and actions (Keogh et al. 2006). Although they are expected to take development needs into account, it is clear that regional bodies were established primarily to influence natural resource management and biodiversity conservation at catchment scale. They do not have regulatory powers over development, and are not able to implement zoning policies except by persuasion and cooperation with local governments. They are not legitimated by an electoral process, nor do they have statuary authority over any other sector, and they are not sufficiently well resourced to govern at catchment scale even had they the legal authority to do so (Robbins and Dovers 2007).

Local governments, on the other hand, are elected, and do have the authority to govern at shire scale. However, they are not well enough resourced to practice integrated governance (Wild River 2007). It would be useful to examine the roles of local governments and regional bodies in preparation for climatic and population change, and explore the possibilities of constituting the regional bodies as a level of governance at catchment scale.

2.3.6 Resourcing and the capacity to self-organise

Resourcing and the ability to self organise in response to a challenge or an opportunity is closely related to the need to govern at the right scale. A coastal community that relies on a remote city for decisions, resources, services and information is less able to anticipate, cope with and respond effectively to a challenge, a disaster or an opportunity. Effective coastal adaptation to change is therefore likely to require investment in leadership, skills, knowledge, and adaptable infrastructure so that communities can self organise and respond quickly and effectively (Robbins and Dovers, 2007; Wild River 2007). This does not mean that help should not be offered from a higher level of governance to enable recovery or take an opportunity; rather it means that if there is a constant need for resources from governments at lower levels, it is better to devolve those resources permanently (Abel et al. 2006).

Regional bodies tend to lack financial and human resources and would not have the capacity to support major changes in resource use or infrastructure, nor to cope with the complexities of integrated coastal management. Regional bodies rely heavily on funding from federal NHT/NAP funding (now 'Caring for Our Country'). There is uncertainty, however, in regard to how these funds will be distributed in future, adding to insecurity that already affects the long term planning and investments of the regional bodies. Increasing the amounts and the security of resources for the regional bodies would be highly beneficial to adopting an adaptive strategy to coastal management. That said, there may be cases around Australia where climate change makes continuing occupation too costly for society to bear. Should such cases arise, a triage approach will be necessary, and disinvestment as well as investment criteria should be applied within an adaptation strategy.

Self organisation is a property of natural as well as social systems. Our developed coasts display a propensity to replace native ecological communities with engineering works to control floods, currents and waves. Damage to and obsolescence in these structures requires costly replacement. Natural defences, such as reefs, dunes, mangroves and marshes, on the other hand, are either resistant to hydrological forces or recover from them naturally while affording some protection to humans. Climate and population change may require a shift towards self organising defences in natural as well as in social systems.

CSIRO's expertise in formal natural resource management planning processes, adaptive management in marine and fisheries environments and in science-based initiatives to build community capacity to manage regions as systems mean that we can contribute rigorous and innovative thinking to novel partnerships for managing change in the coastal zone. Such partnerships could focus on:

- building technical foundations, including knowledge and data to enable stakeholders to better understand the key drivers of change and explore and monitor it accordingly;
- building capacity for participation to achieve collective thinking and learning;
- developing integration and coordination across scales and government boundaries.

2.3.7 Rules and the ability to change them, and incentives

By rules we mean laws and regulations, in which we include property rights over land and marine resources. Rules and the assurances they give to economic and social transactions are of course a necessary basis for a functioning society, and for the sustainability of resource use. However, when circumstances change but rules do not, social, economic or ecological dysfunction may result (Ostrom 1990). Irreversible rules, such as permissions for development, can limit our ability to experiment with adaptive management approaches and require a more stringent application of the precautionary principle (below). Precaution applies both with respect to environmental harm, but also with respect to civil liability if permissions have to be revoked or lead to catastrophic outcomes, for example building collapses due to unanticipated coastal erosion. Adaptive coastal governance under climate change may require new forms of land tenure and other property rights - leasehold rather than freehold, for example, in the case of land, and for shorter rather than longer periods, or instead with resumption of rights by a government with levels of compensation that are predetermined in the lease, for example. Similarly planning permission could be made conditional and the nature of those conditions could be framed to allow for reversibility or the transfer of certain risks to the developer. The options need research. Similar approaches could be taken to fishing licenses and permits to abstract or pollute coastal water. Australia could take advantage of the policy experiments offered by our multi-jurisdictional country and try different systems in different jurisdictions – research is needed here too.

Regulations are changeable rules supported by laws, which are more perennial. Mediation of relations between people, and between people and the environment have in the past relied fairly heavily on laws and regulations. However, increased use of incentives may in some circumstances be more cost-effective, and encourage a faster and more cooperative response from resource users. The National Market Based Instruments Pilot Program (http://www.daff.gov.au/natural-resources/vegetation/market-based), and CSIRO's Markets for Ecosystem Services research (www.ecosystemservicesproject.org/) and other research initiatives offer examples, some of them coastal, of the kinds of incentive schemes that are being tried in partnerships among resource users, local governments, regional bodies and researchers. They include instruments that affect resource user's behaviour by: changing taxes, introducing levies or providing subsidies; changing property rights or obligations, as in a cap-and-trade scheme, or tradable shares in fisheries; or by making existing markets work better, through research, information, eco-labelling, and revolving funds for nature conservation, for example. Market based approaches may generate innovative solutions to resource management problems, rather than innovative ways of avoiding the regulations. They can also have lower transaction costs, but these potential advantages depend on circumstances. CSIRO has developed practical guides for appraising the potential for and designing market based instruments (Reeson et al. 2007, Whitten et al. 2007).

2.3.8 Building and maintaining options, redundancy and reserves

CSIRO has been involved in research on social and ecological resilience over the past decade (Walker at al. 2006). Resilience is the capacity of a system to absorb disturbances and recover without changing 'state' – in this context, without irreversible loss of values. Maintaining options increases resilience because more choices are available when circumstances change. For example not developing a coastal wetland into a marina means that the opportunity to make a marina still exists, but so does the opportunity for ecotourism or fishing. Maintaining options should, we propose, be a governance goal, along with the maintenance of redundancy.

Redundancy, that is having spare capacity, will be important for both environmental and social/economic resilience too. Thus a drive for efficiency in government departments and local councils can leave them operating at low cost, but extremely vulnerable to staff losses. This is already happening, particularly at local government level.

Resilience is also increased by having reserves that can be drawn upon to enable recovery or the adoption of a new opportunity (Walker and Abel 2002). Governing our coasts for resilience should therefore be about maintaining a wide range of resource uses, while building and maintaining reserves and redundancy. This is inimical to short-run economic efficiency. This is the dominant resource use paradigm at present (Anderies et al. 2006), but climate change is likely to encourage a paradigm shift.

Government initiatives to establish terrestrial and marine reserves and national parks on our coasts already help maintain diversity and options, and provide reserves for stocks of fish and other biota that are important economically or because of their functional roles in ecosystems. We therefore endorse and encourage the expansion of the Commonwealth's Marine Bioregional Planning program, the National Reserve System program, and the various state initiatives that have created marine and coastal terrestrial parks and reserves.

2.3.9 Dealing with risks, uncertainties and cumulative impacts

The precautionary principle, as defined in the 1992 Australian Inter-governmental Agreement on the Environment, holds that where there are threats of serious or irreversible environmental damage, uncertainty should not be a reason for postponing measures to prevent environmental degradation. In the application of the precautionary principle, public and private decisions should be guided by careful evaluation to avoid where possible serious or irreversible harm to the environment; and an assessment of the risk-weighted consequences of various options. Some governments already apply the precautionary principle, or claim to do so, but climate change may demand a more rigorous application. It may also encourage a switch from an engineering view of the world, where resources are invested in making systems fail-safe, to a resilience view where instead 'safe-failure' is advocated. To illustrate the difference, an engineering view of coastal erosion is to use concrete and steel to stop it happening except in the most unlikely circumstances – say a tsunami. A resilience view would advocate measures that reduce the impact of the tsunami when it does happen.

Application of the Precautionary Principle hinges on whether there is a risk of environmental or social harm. At a local scale many routine activities are environmentally harmful, but those activities would not individually be harmful on a regional scale. On the other hand, some impacts are not harmful at a local scale, but if the same impacts are occurring over a broad region, the regional consequences – water quality in a river as a result of multiple small impacts across the catchment for example – may be severe. Similarly, a one-off decision to permit an industrial of development activity may have a small effect, but an accumulation over time of such decisions may have serious consequences. Our developed coasts are already beset by the consequences of such cumulative decisions, and adding the pressures of climate change along with those from intensifying coastal development is highly likely to drive systems across thresholds into states where values are depleted.

2.3.10 Pathways to improved coastal governance

To build the adaptive capacity of coastal governance Australia needs to address the criteria we used to evaluate the current arrangements. The prior step is, however, a transformation in the way we perceive our coasts. They are non-linear systems with multiple thresholds. Some of these are not reversible – a fish species may become extinct, a reef or a dune system may be destroyed in a storm, or the sea level rises, or the pH of the sea decreases. Predictions about many threshold changes are not possible, no matter how much research is done. Moving to adaptive governance is therefore an imperative, not an option. It is founded on the criteria we have explored. The pathway towards it must be carefully chosen, and exploring it soon should, we propose, be a high priority of the Commonwealth, state, Northern territory and coastal local governments. We suggest that the criteria we have used are also a good starting point for this exploration: taking lessons from the past and other places; scanning the future; seeking ways to better integrate and coordinate governance; examining options for rescaling governments to suit the threats and opportunities from climate change; comparing levels and distributions of resources to the levels and distributions of potential problems and opportunities; examining rules, such as property rights, and the ability to change them; exploring the role of incentives for behavioural change; priorities for building and maintaining options, redundancy and reserves; and instituting better approaches to risks, uncertainties and cumulative impacts.

2.4 ToR 4 – Mechanisms to promote sustainable coastal communities

Recommendations:

1. Integrated R&D is required to underpin development of adaptive and resilient communities.

2. A nationally consistent coastal information system is required to support planning and management decisions and policy development by providing scenarios which incorporate the potential impacts of different population growth projections, climate change and changes to economic conditions

3. Scenario development and management strategy evaluation (MSE) should be used to underpin robust decision making for sustainability in coastal communities

4. A range of knowledge gaps should be filled by R&D to facilitate such scenario development.

Reconciling management conflicts in the coastal zone at a time of rapid population growth and climate change presents substantial challenges to governments and communities. Leadership is required to promote sustainable coastal communities in Australia. Many mechanisms for promoting sustainability are outlined below in section 2.1.2 which deals with governance.

In this section, we focus on non-governance mechanisms and how CSIRO can contribute by providing the research and development to support evidence based leadership in the coastal zone.

Integrated research and development (R&D) is required is to inform Australians decision makers about pathways to adaptive and resilient communities. Many of the research questions that need to be addressed are the same regardless of whether the driver is climate change, population change or industrial development.

2.4.1 Stakeholder priorities

CSIRO has identified a number of stakeholder priorities by participating in workshops, by both providing and listening to presentations at conferences, by attending meetings of federal, state and local government officials (e.g. Intergovernmental Coastal Advisory Group, Planning Officers Group – Local Government and Planning Ministers Council), and by consulting with assorted Non Government Organisations and academic interests. Through these interactions we have gained a deep understanding of the challenges of coastal zone management and identified five basic stakeholder priorities for coastal zone R&D, these being:

1. The need for a National Coastal Information System (NCIS) which will deliver decision-support information and tools to coastal managers and planners, communities and the private sector;

2. The need to define vulnerability and constraints facing coastal communities in relation to the seven drivers of coastal change;

3. The need to improve coastal ecosystem and catchment conditions;

4. The need to offer coastal communities a better understanding of the aspirations, values and influences on behaviours of those who live, work and recreate in coastal areas; and

5. The need to provide models of what constitutes sustainable communities to assist planners and managers confronting the challenges of coastal Australia at various spatial and temporal scales.

These priorities are consistent with those identified by others, such as the National Sea Change Task Force. In addressing these priorities, CSIRO partners with other R&D providers, notably with Geoscience Australia, the Australian Institute for Marine Science, several CRCs and many universities. The "adopters" of the R&D are integrated into R&D programs in order for the research outcomes to be tuned to their needs. This participatory approach is important for effective delivery of R&D to governments, industry and the wider community.

2.4.2 Principles needed to underpin future coastal zone management

The following pillars are needed to support coastal zone management decision making of the future:

1. Coastal systems are subject to effects that are not simply additive as population growth generates impacts on a range of key environmental terrestrial and marine assets, processes and feedbacks; the dynamics of such systems must be understood in terms of both resilience to change and existence of thresholds leading to different biophysical states (e.g. eutrophication of a coastal lake following urban expansion in a catchment).

2. Coastal systems involve complex interactions among a spectrum of natural and human forces as well as "disturbances" at various temporal and spatial scales. Capability to assess and model the risk associated with the resulting hazards and impacts is required in order to plan and act to avoid, mitigate or adapt to adverse consequences (e.g. impacts of different levels of sea-level rise or a rapid population influx).

3. For a knowledge system to be valuable nationally to coastal societies there is a need to develop information infrastructure that will facilitate access to data and tools that can consistently display and up-date information and knowledge needed by governments, industry and communities. Such a system could build on existing national, state and local databases (e.g. Ozestuaries) and test the adaptation to Australian conditions of those used overseas (e.g. CVAT by NOAA in the U.S.A.), or those developed regionally within Australia (e.g. Comprehensive Coastal Assessment in NSW).

4. Planning and management tools and practices vary both between and within Australian states. Research is needed to adapt models and tools that encapsulate best practices to address the range of environmental, social, public policy and economic issues that prevail in coastal communities. Such research could identify more robust and consistent application of science-based inputs to planning practices and instruments to better manage constraints, risks and opportunities for new urban settlements, as well as how best to accommodate growth in established non-metropolitan growth centres (e.g. development of more adaptive urban design and planning guidelines, or application of decision support tools such as multiple criteria analysis in settlement planning).

2.4.3 Data and tools required

In order for improved coastal management and planning to take place based on these four pillars, it is vital that existing and new scientific knowledge underpin practical decision-making for application now and into the future. This will require:

- Development of a nationally consistent coastal information system to support planning and management decisions and policy development by providing scenarios which incorporate the potential impacts of different population growth projections, climate change and changes to economic conditions;

- Development of planning and management tools that can be used at national, state and local levels of government to address end-user needs including land use planning, urban design, assessment of development proposals and the need for improvements to natural environmental conditions; and

- Building the capacity of stakeholders in all levels of government, in industry (legal entities, insurance, planning and engineering consultants), in research and teaching organisations, and in communities around Australia to understand and apply knowledge and information for the better management and planning of the coast.

  To support this broad agenda, research is needed on:

- **Assessing and monitoring coastal systems.** Advances can be made in coastal observing system design, data assimilation methods for ecosystem forecasts in catchment-river-estuary-coastal and the trial implementation of a coastal zone observation program. The latest airborne and satellite hyperspectral and lidar data sets can also be used.

- **Material fluxes and transformations.** Existing modelling work on catchment-river-estuarine-near shore interactions could be deepened and operationalise, focusing on transformations in channels, wetlands and floodplains.

- **Ecological functions and response in coastal environments.** The key functional components of coastal ecosystems need definition and key gaps in estuarine and coastal zone biogeochemistry require investigation. Novel approaches to measuring ecosystem health and function and sustaining coastal wetlands are also required.

- **Climate impacts and coastal vulnerability.** (see sections 2.1 and 2.2)

- **Institutional and Governance Research.** Institutional analyses are needed to clarify what types of management approaches are supported by current arrangements. Further research can suggest a range of potential improvements in institutional arrangements.

- **Social.** In order to create sustainable management especially in metropolitan and peri-urban areas there is an urgent need for the development and application of regional recreational systems analysis which can incorporate issues of carrying capacity and substitutability of sites to underpin regional planning. While there have been promising methods developed in differing disciplines such as choice modelling in economics and complex systems network analysis in the social sciences there has yet to be an integrated application of these and other techniques in this context.

- **Science for sustaining quality of life in rapidly changing coastal environments.** Identifying the social and economic drivers and consequences of the Sea Change process, undertake measurement and modelling "quality of life" in coastal communities, will enable us to develop tools to sustain ecosystem services in coastal environments through market-based incentives and planning controls. Economic analysis should focus on several interlinked aspects:

a) predicting pressures on coastal zone resources due to changing human demands;

b) identifying the economic consequences of planning decisions in terms of regional employment and economic activity both for approvals but also the opportunity costs of not allowing certain types of development;

c) developing industrial ecology / urban metabolism methodologies for applying to regional scale, long term analysis of the impacts of population growth on the coastal zone under different patterns of settlement;

d) improving our capacity to track economic and social change in the communities that make up the urbanising coastal zone; and

e) applying complex systems science methods to understanding the interplay between drivers and consequences or urbanisation in their social, economic, environmental and institutional context.

- Integrated approaches to the science and management of coastal systems. Multi-decadal coastal scenarios are required to enable us to prioritise issues, evaluate coastal development and management strategies across regional and local scales; and best practice in community engagement and capacity building.

- There is a rapidly growing capacity to carry out cost-effective coastal research because of opportunities that arise through several exciting science and technology trends:

- Advances in software for spatial data sharing and presentation (e.g. Google Earth), founded on new approaches in data interoperability.

- New observing technologies (remote sensing coupled to networks of smart sensors) that can provide information with unprecedented spatial and temporal coverage and resolution.

- Biophysical models that couple catchment, estuarine and marine models, integrating physics, biogeochemistry and ecosystems, complemented by powerful new data assimilation method.

- The convergence of economic and psychological sciences in the application of experimental economic methods and development of agent-based modelling approaches that enable prediction of individual and collective responses to institutional and environmental change.

- The integration of macro-economic modelling technologies such as computable general equilibrium models with infrastructure, urban metabolism/industrial ecology and biophysical models to enable "top down" policy impact assessment.

CSIRO experience has shown that; (1) a systems approach is essential for effective sustainable resource management, (2) activity research must be integrated for a systems approach to be realised.

Management decisions are made in the face of incomplete information and considerable uncertainty, and so the key questions are:

f) How do we make best use of what we already know?

If what we know is not sufficient, what research is likely to have the best payoff?

In order to break the cycle of making decisions based on inadequate knowledge the following questions must be answered:

g) How do we monitor the outcomes from current decisions to provide cumulative knowledge so that we are better prepared for similar decisions in future?

h) What inventory of knowledge should we aim to build on national, regional and local scales to support future management decisions?

One of the common observations about rapid change in the coastal zone at the local government and community level is that once rapid development or other social transitions (for example the front-of-exploitation associated with some tourist development in the coastal zone moving on to more pristine environments) has occurred, it is all but too late to manage. Tools are required to enhance capacity within such communities to access information about economic and social drivers of change and interpret that data locally through developing and exploring scenarios and trajectories of change.

This presents the prospect of a significantly enhanced knowledge-base for evidence-based planning and policy in the coastal zone. To have impact this information will need to be accessible to and adopted by Federal, State and local Governments for their respective responsibilities in managing development to maximise social benefit. It will also need to be accessible to investors, developers and design practitioners in the private sector who drive development.

Managers need tools to help them make decisions that make the best use of the available information. A management tool is generally a way of looking at the world to see how it may be affected as a result of making a particular decision. The tool may take the form of a model – in which scientists attempt to represent the interrelationship between environmental factors such as water quality, food webs, human activity and so on to build models that can predict environmental, social and economic consequences through a causative chain of events. Alternatively, it may be based on empirical observations of how the world has responded to similar decisions elsewhere – for example, a high nutrient loading frequently leads to an algal bloom.

Managers also need tools to engage stakeholders to find management outcomes that are acceptable to various groups of interests. These tools need to be capable of showing the possible outcomes from management decisions in terms that are intuitively understandable to a general audience.

CSIRO research has developed qualitative modelling tools that can be used with stakeholders to clarify their knowledge about the key properties of relatively complex systems. A complementary tool is under development to allow managers and stakeholders to conduct their own simulated management of the systems as they define them. CSIRO intends to increase research in this area, first by surveying managers to determine what additional tools they identify as needed. Moreover, considerable tools development is intertwined with the development of whole management simulation approaches.

Once managers have assembled available knowledge, and have acquired or developed whatever tools may assist them in making a decision, they still have to decide on a management approach. This may include:

- Setting the objectives
- Deciding whether a given decision is a routine planning decision unlikely to lead to major environmental or social impacts

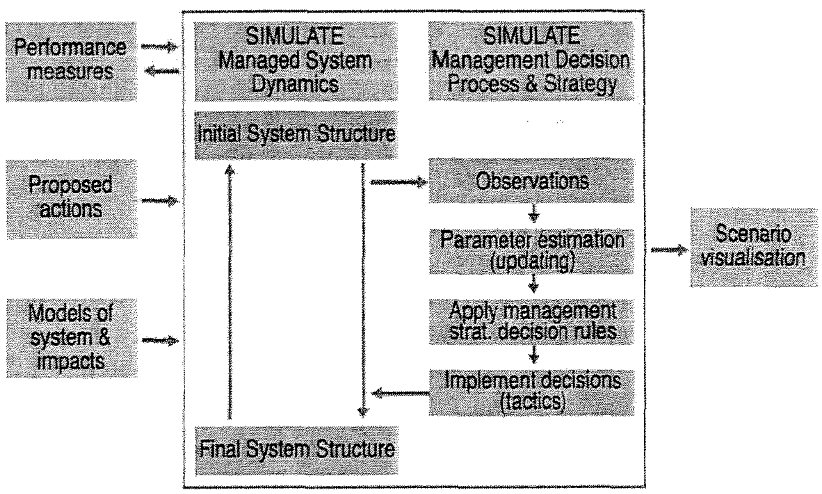
- Determining whether this decision is likely to trigger changes in environmental thresholds

- Identifying trade-offs and compromises.

CSIRO research supports the development of management approaches through whole of system simulation; known as management strategy evaluation (MSE). MSE combines knowledge, tools and approaches to form a "flight simulator" for managers. CSIRO is developing MSE tools through several case studies. The recently launched Northwest Shelf Joint Environmental Study (NWSJEMS) was the prototype. Now the approach is being improved and extended through the Ningaloo Cluster, the Southeast Queensland Healthy Waterways Partnership, and in the Derwent Huon (INFORMD) study. Management strategy evaluation is about testing what our management system can deliver towards usually multiple and conflicting goals.

To do this we use computer simulations of the complete management system – the regulatory system, the human activities, the environment, and the information we collect about all of these. We can try out (evaluate) various management strategies and see how well we achieve both human and environmental outcomes. And we know how well we did because in our simulated world, unlike the real one, we know everything.

General Framework for
Monitoring/Management Strategy Evaluation



Typical management thinking usually begins with objectives. However, in complex environmental management, objectives are often aspirational and mean different things to different people and it is virtually impossible to define and commit to measurable objectives when the consequences are not understood.

MSE is a way of informing stakeholders of the likely consequences of choosing certain objectives, the costs and benefits, how much it will cost to improve the results and what further research is likely to have a good payoff. So MSE is an iterative process of showing stakeholders the art of the possible, helping them to formulate objectives and make trade-offs between them and repeating until, hopefully, there is a general agreement among stakeholders on how to proceed.

MSE breaks the loop of "paralysis by analysis" by changing the question from can we precisely predict the future (we cannot) to; can we design management approaches that help us learn what we need to know over time and not too late to make course corrections? Hence the method helps choose what future data to collect, how to use it to make future decisions, and what those future decisions may look like.

It is also a process for dealing with uncertainty. We don't make one artificial world model, it will certainly be wrong. We make multiple world models that incorporate alternative hypotheses about how the world might work, or might work in the future. These we usually term scenarios and they are one of our two ways of dealing with uncertainty. Our aim is to find, if we can, management strategies that work acceptably under a wide range of scenarios.

We use scenarios to tackle questions that cannot be resolved by practical research, often because the uncertainties are about the future, or because the research is simply unaffordable or would take too long. The second form of uncertainty is the statistical uncertainty which arises when we estimate the value of some quantity used in a management tool or decision. We can take this uncertainty into account directly by incorporating standard statistical methods into the MSE. This enables us to decide how well the variables need to be estimated to meet management objectives and which improvements will be the most cost effective.

One of the key roles of science is in developing the scenarios. Which environmental, future climate and socio-economic models and parameters are plausible, which ones can we rule out? We need to develop practical theory of multiple use management taking into account real-world institutional problems such as multiple agencies and limited resources and the need to reduce complexity to manageable levels.

Management implementation will often be piecemeal and incremental – management is required that builds on current knowledge and arrangements. The most likely approach is to treat multiple use management as a hierarchical control system. This involves delegating control to "local" control systems, and creating distributed control to create as much independence as possible between sub-systems. Where subsystems cannot be made independent requires a higher level (supervisory) control system to manage their interaction. Research is needed on the basic science to develop and apply hierarchical systems theory to integrated coastal management and on the types of institutional and governance arrangements needed to make such an approach feasible.

2.4.4 Complexity and the role of science:

The challenges are complex, and include the complexity of human decision-making, institutional structures, governance arrangements (much discussed at the recent 2020 summit). Hence some management issues can be solved by science, others cannot. But science is able to help managers understand many of the consequences of acting or not acting, how to monitor the results of management decisions and to suggest adjustments to management approaches based on measured environmental response – adaptive management.

While management itself may be considered an art, it requires a broad scientific foundation to be effective, cost-efficient and for us to know into the future that the many decisions we have to make have a cumulative effect that is an acceptable balance between environmental, social and economic outcomes. CSIRO provides this science to support environmental and socially sustainable development of Australia's coastal regions.

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APPENDIX A – TERMS OF REFERENCE

Terms of Reference

Inquiry into climate change and environmental impacts on coastal communities

The committee will inquire into and report on issues related to climate change and environmental pressures experienced by Australian coastal areas, particularly in the context of coastal population growth. The inquiry will have particular regard to:

1. Existing policies and programs related to coastal zone management, taking in the catchment-coast-ocean continuum

2. The environmental impacts of coastal population growth and mechanisms to promote sustainable use of coastal resources

3. The impact of climate change on coastal areas, and strategies to deal with climate change adaptation, particularly in response to projected sea level rise

4. Mechanisms to promote sustainable costal communities

5. Governance and institutional arrangements for the coastal zone

The inquiry was referred to the committee by the Hon Peter Garrett, AM MP, the Minister for the Environment, Heritage and the Arts, and Senator the Hon Penny Wong, the Minister for Climate Change and Water, on 20 March 2008.

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