Storm water runoff from town roads is retained in Lake Jabiru, in the town lease area. This pond operates seasonally as a wetland retention area thus reducing discharge of urban runoff into Magela Creek. It is the policy of the Jabiru Town Council not to fertilise parklands abutting the lake.

Water is supplied from town bores approximately 20 km from Jabiru along the Arnhem Highway, outside the catchment of Magela Creek. Additionally, there are bores within the townsite that are used for non-domestic purposes.

4.4.4 Tourism and recreation

Jabiru provides the focal point for servicing the tourism industry in Kakadu National Park, providing essential facilities and services. Tourist visitor numbers to Kakadu National Park have increased significantly since the park was declared—150 000 in 1985, and averaging 230 000 in the 1990s (Kakadu Board of Management & ANCA 1996).

Tourist resources provided within the park include hotels, chalet accommodation and camping grounds. Tourist access is controlled through the plan of management. Nevertheless, numbers are expected to increase in future and will increase the pressure for access to be provided to areas not currently used for tourist and recreational purposes, as well as for increased levels of accommodation.

The Jabiru Tourism Development Plan (Market Equity 1995) has been prepared by the Jabiru Town Council and submitted to Parks Australia for consideration in preparing the fourth Kakadu Plan of Management. This Development Plan recommends formation of a Tourism Task Force to devise action plans for funding, promotion and monitoring of tourism in the park. The plan has as its theme Jabiru as the Heart of Kakadu, thus making it the acknowledged destination area for tourists within the ARR. It is noted, however, that the main Parks Australia visitor facilities are not located within the Jabiru townsite.

5.0 Issues

Six broad issues were identified through the issue scoping process outlined in Section 2.1. Measures to be taken towards resolving each issue are indicated. The areas of issue and their implications are summarised below.

5.1 Perceptions and values

Societal perceptions and values are manifest in both the level of awareness of the possible effects of climatic and associated changes as well as in the attitudes held with regard to the hazards and threats to the environment resulting from climate change. Although closely interrelated, these issues need to be considered separately.

5.1.1 Awareness

Awareness of possible responses to the expected changes is an important factor to be considered when determining how governments and communities perceive the range of responses that could be necessary to manage the change process. Awareness of change is a difficult concept to come to grips with when dealing with climate related matters because there are few benchmarks from which governments, communities or individuals can measure change. Time series data are usually not generated and few people have access to the available information. Likewise, there are few examples available of GIS or other forms of spatial documentation that show how shorelines have moved or areas of specific habitat have expanded or contracted in response to climate or any other factor. This is specialist

information, and what is required is material for public consumption that will help people develop their own benchmarks from which they can start to appreciate the variability of natural systems.

The difficulties in raising awareness with regard to climate change are compounded by circumstances in which basic information describing historical change is lacking. In the absence of such information people apparently find difficulty in accepting that change is a real and continuing process This situation is compounded by theoretical predictions that are couched in uncertainty for the layperson. Thus, many people believe that there is nothing they can do in response to naturally occurring environmental change. Alternatively, they adopt an uninformed position that environmental change will not have deleterious effects within their lifetime or the lifetime of their children. Hence, raising awareness of the implications of climate change is a most important first step in changing governmental and community perceptions as to what climate change may mean and can be done.

Lack of awareness of the natural variability of coastal wetland ecosystems and the changes that are already in progress is no different for the ARR than for other coastal places in Australia. Information is available on environmental change in the region and mechanisms need to be found to disseminate it.

5.1.2 Attitudes

Raised awareness will lead to changes in attitudes with regard to the responsibility for responding to change processes. Alteration of attitudes is essential when it comes to government allocation of resources and to alteration of administrative arrangements that will be necessary for managing effects arising from environmental change. Change in community attitudes will in turn lead to restructuring of values with regard to those components of the environment that are changing due to natural or human induced factors. The variation in value judgement needs to be from the personal and community level to government, as well as from government policy to individuals in the community, in order that responses to environmental change are recognised as being needed and can be implemented. That is, adjustment of community attitudes to natural and other changes in the environment is a two-way process between government and the community.

5.1.3 Environmental values

Wetlands are considered as valued components of the natural environment (CSIRO 1994). Wetland habitats are recognised as being important for their biological diversity, as sanctuaries for migratory and resident bird populations, and for their contribution to estuarine and marine productivity. These values have been nationally and internationally acclaimed for the ARR, as attested by the World Heritage status accorded to Kakadu National Park. Binninj have long recognised the importance of wetlands in their annual hunting and gathering cycle.

5.2 Hazard and risk

Hazard and risk are viewed as key areas of issue as they relate to physical impacts on the natural and built environment. These terms are often applied to assessments of the effects of extreme events, be they natural or human induced. For example, there are hazards arising from tropical cyclones and other storm events which may place property and people under varying degrees of risk depending on the nature of the event and the locational circumstances of the property or person. In turn, hazardous conditions place property, people and plant and animal communities at risk. That is, life and location at risk in a hazardous situation have a probability of being lost, destroyed or damaged.

In the context of climatic and associated changes, hazards may be related to circumstances occurring during extreme weather events, flooding, inundation by storm surge and coastal erosion. Areas where the level of risk is high may be designated as hazard zones. The parameters used to define such zones could be exposure to storm paths and wind damage, areas subject to storm surge, flood prone areas, and places where the coast is markedly affected by erosion or accretion of the shoreline. From a socio-political perspective, liability is becoming the major issue of concern to government and the general public. In short, there are questions of responsibility and accountability which need to be addressed when changes due to the hazard disrupt orderly use of coastal resources for habitation, industry and commerce, recreation and conservation. Where these are threatened, matters relating to insurance and compensation may arise. Determination of payments may relate to who carries what responsibility for determining whether human activities should be carried out within those areas and at what level of actuarial risk.

5.2.1 Natural hazards

From the perspective of climate and associated change, the main natural hazards of the ARR include:

- extreme weather events, such as tropical cyclones, tropical depressions, heavy rainfall, extended Wet seasons, excessively high temperatures and prolonged droughts;
- flooding, channel avulsion and bank erosion;
- inundation of coastal plains by storm surge; and
- coastal erosion, shoreline retreat, chenier migration and saltwater intrusion.

The morphology and stratigraphy of the coastal wetlands outlined in the literature indicates that the environment has absorbed natural hazards over the Holocene Period, although with change in the distribution of landforms and vegetation communities. Present risks are therefore largely related to a perception that the status quo will be maintained in the immediate future, and that the freshwater wetland ecosystems are adequately represented and conserved in Kakadu National Park.

Evidence of contemporary change throughout the ARR indicates that the coastal wetlands are undergoing very substantial alteration due to shoreline retreat (Woodroffe & Mulrennan 1993), changing estuarine hydrodynamics (D Williams pers comm), and saltwater intrusion (Woodroffe & Mulrennan 1993). The physical causes and extent to which these changes represent a serious risk to maintenance of the freshwater ecosystems requires urgent investigation. The severity of the problem has been recognised for the Mary River system (Sessional Committee on the Environment 1995) and engineering solutions to the problem have been recommended despite a lack of detailed knowledge of contemporary oceanographic, hydrodynamic and geomorphic processes underlying environmental change. In the broader region it is imperative to determine the extent to which the freshwater systems are at risk from the natural hazards, and whether they are adequately represented in the conservation estate.

5.2.2 Built environment

In the context of climate and associated change, risks to human use of the environment include the possibility of an increase in the frequency of recurrent damage to buildings, roads, bridges, culverts and other infrastructure. A large proportion of roads in the area are unsealed and prone to damage during wet conditions. At present, Dry season access tracks are closed during the Wet season to prevent unacceptable damage during the wet. There is also an added

risk to human life that may be associated with damage to infrastructure. Currently, such issues are not considered in the management of the region (ANPWS 1991), although there are building codes and standards (Jabiru Town Council) that need to be met to minimise the risk of damage by tropical cyclones in the region. The possibility of greater damage to the built environment needs to be taken into account in future management plans for the region.

5.2.3 Cultural and heritage

Cultural and heritage values of the coastal wetlands could be at risk if it is perceived by people that the total loss of habitat due to catastrophic events, or more subtle environmental change, leads to irreversible alteration of the conditions that initially gave the area its status. This can be viewed from a Binninj and Balanda perspective. The fixed value system of the latter makes it more difficult to accommodate change, and there is a tendency to want to preserve the status quo of Binninj attitudes as they move to reflect those of the Balanda. These difficulties will expand.

5.2.4 Environmental health

Changes to the level frequency, persistence and extent of wetland inundation that could be expected to accompany the predicted 20% increase in summer rainfall is likely to extend conditions conducive to the breeding of mosquitos and other insect pests. These may be host to infectious diseases and hence affect the health of resident communities and recreational visitors. The risks associated with such changes need investigation.

5.2.5 Insurance and compensation

Environmental damage resulting from natural hazards is currently indemnified by the land user. This encompasses liability issues arising from insuring private property and personal indemnity. There is no direct governmental responsibility, other than political commitment, that links land tenure to insurance and compensation.

5.3 Governance

There are issues of governance within the ARR that are a microcosm of conditions found elsewhere in Australia. Problems of coordination and integration are common, as are issues relating to relations between government and the wider community, particularly with regard to the development and implementation of management plans.

The need for improved inter- and intra-governmental relations so that management of environmental change arising from climatic and other associated factors is focused by shared goals and, if possible, shared resources is the major issue confronting governance (DEST 1995). Achieving ecologically sustainable use of the coast is beyond the capabilities of one jurisdiction. Effective management of the coast requires that there be a shared purpose and cooperation between all three spheres of government, industry and the community. Cooperation and integration are prerequisites to the ecologically sustainable development of the wider region. As agents of the Commonwealth, Parks Australia and ***eriss*** seek to promote cooperation between all spheres of government and the wider community in the management of coastal resources of the Van Diemen Gulf Region.

5.3.1 Governmental relations

Governmental relations for the ARR encompasses the Commonwealth agencies, the Northern Territory Government, the Jabiru Town Council and the Associations representing Binninj. Although the Jabiru Town Council does not have jurisdiction in the coastal margins of the region it is located in the catchment of the Magela Creek and people from the community

utilise the estuarine and coastal resources of the area. Currently, there are no mechanisms to adequately integrate the roles of the various stakeholders in environmental management. Mechanisms are required because there is a need for effective governmental relations in order that the responses to environmental change are owned and implemented by all concerned.

5.3.2 Institutional arrangements

Parks Australia has established mechanisms for the preparation and provision of new management plans for Kakadu National Park (ANPWS 1991). These entail calling on the wider community for submissions on the manner in which the Park should be managed in future, as well as holding extensive consultations with the Binninj Associations. There is no equivalent mechanism for dealing with the management of coastal wetland areas abutting the western flank of the Park, although a Landcare Committee has been established and integrated catchment management is being implemented. Management of the wetlands east of Kakadu National Park rests with the Northern Land Council.

Institutional arrangements will need to be developed to meet the governmental and community requirements for integrated management of the coastal wetlands. Current arrangements tend to focus on the specific issues confronting individual agencies or departments within a specific sphere of government. The intra- and intergovernmental dimensions of the issues identified for the coastal wetlands require a more innovative approach because of the scale of the problems, and because they cross jurisdictional boundaries. New institutional arrangements should include all three spheres of government, the Binninj Associations, Northern Land Council, and industry and community representatives. Resolution of the issues will require flexible and dynamic processes which are appropriate to the geographic diversity of the region, the jurisdictional arrangements, and the cultural context as related to Binninj and Balanda interests.

5.3.3 Funding

Funding is always a vexed issue, particularly in remote areas where the rate base is low or non-existent, and there is only limited acknowledgment that monies should be made available for environmental management. Innovative measures will need to be developed to ensure that the management of a rapidly changing environment in a remote region is adequately funded. The level of funding required can best be obtained through joint-applications that are targeted at priority problems as identified and agreed by government and the communities of interest. Such applications should be directed at as wide a range of Commonwealth policy initiatives and catchment and coastal management areas as possible. Policy initiatives specific to the coastal environment are listed in DEST (1995).

5.4 Strategic management

Strategic management has two interrelated components, regional development and resource conservation. The latter encompasses natural as well as cultural resources. Regional development can not be viewed in isolation from resource conservation because development of the region in social and economic terms is based on the natural and cultural resources. The need to blend regional development and resource conservation may be obvious, but it is an extremely difficult task.

5.4.1 Regional development

Regional development has strong economic connotations and raises questions about the best use of wetland areas. For example, the areas on the western flank of Kakadu National Park are considered as important areas for seasonal pastures and measures have been proposed to

prevent saltwater intrusion (Woodroffe & Mulrennan 1993). In contrast, representatives from the fishing industry consider that the wetlands need to be retained as natural systems that support recruitment of commercial fish species. There is clearly a need for the broad community to resolve such conflict within the context of a regional development strategy. Such a strategy will need to accommodate potentially conflicting objectives of resource development and resource conservation.

5.4.2 Resource conservation

Resource conservation must be viewed in a wider regional context when the potential for climate change is taken into account. Specifically, there is a need to consider what the possible loss of freshwater ecosystems might mean for the conservation of aquatic birds, and whether the areas remaining as freshwater systems will sustain bird populations at or near current levels. The implications of this are important when considering what value is placed on waterbirds as a tourist attraction, and hence as a generator of income for the region, the Northern Territory and the Nation. This raises questions of the adequacy of the conservation estate in its biophysical regional context.

Cost benefit analysis have not been developed for placing a monetary value on natural resource areas and the conservation estate. An economic value needs to be placed on the natural resources to be conserved at an equivalent level to exploitable natural resources.

5.5 Acquisition and custodianship of information

> Data is essential for planning development, managing assets and for the designing and building of structures in the coastal zone. It is an investment for the future (Institution of Engineers Australia, 1993).

Lack of appropriate data and information causes poor decision making and contributes to inappropriate management of coastal resources. It has become increasingly apparent that the recent emphasis on short-term economic returns is having an adverse effect on environmental management. An investment must be made in data and information with the object of reducing uncertainty, improving decision making, enhancing management capability and ensuring that unnecessary funds are not spent on ill conceived and poorly researched projects aimed at remedying environmental change. Acquisition and custodianship of information has been recognised as a key area of issue within the ARR. It could impinge on:

- the strategic management of the responses to climate and other environmental change;
- research and monitoring needed to document the processes of change; and
- evaluation of the effectiveness of any management measures taken.

A wide range of specific questions arise under this area of issue. They include:

- the value of existing and future data sources;
- accessing of data sources; and
- custodianship of data and information pertinent to climatic and other environmental change (Institution of Engineers Australia, 1993).

Coordination of data and information acquisition has been identified as a key component of information management. The need to immediately develop a meta-database is seen as being paramount for the information management process.

5.5.1 Existing data sources

Existing data sources include literature sources, unpublished results of field research and spatial information in the form of remote sensing images, aerial photographs and maps. Sources of information relating to a number of issues being confronted in the coastal wetlands of the Darwin and Alligator Rivers Regions are contained in Appendix 1. Although a considerable array of material is available, there has been no systematic audit of the material to determine whether it can be applied to questions arising from the issues relating to environmental change and the management of the ARR. The bibliography and the listing of additional data sources in Appendix 1 are being developed into databases to aid the auditing process.

The material is being included in a meta-database (CM Finlayson pers comm 1995), but should also be incorporated in a spatial bibliography to facilitate access. The meta-database is needed urgently to provide a coordinated reference system for the wide range of research publications and unpublished data that has accumulated for the ARR over the past 25 years. Compilation of a spatial bibliography requires coupling of a knowledged based system with a geographic information system (GIS). The GIS can then be used to define the area of interest for which the reference material applies. Information loss has been a major administrative and research concern for ***eriss*** and other authorities in the region. Development of the meta-database and the spatial bibliography are viewed as key tools for reducing information loss.

The spatial data currently available is incomplete and includes a GIS for the ARR under development by ***eriss*** as well as the E-RMS data for Kakadu National Park held by Parks Australia. The former uses ARC/INFO software which has vector and raster capability whereas the E-RMS is a specialist software package for raster display only. The ***eriss*** system has full GIS capability, as is demonstrated by the mapped material (maps 6a and 6b) as well as a description of the system presented in Appendix 1.1. Other spatial data includes hard copies of satellite images (1:500 000) and aerial photography (1:25 000). Lists of the satellite imagery and the aerial photography available are included as Appendix 1.2 and 1.3. Although there are time series of the remotely sensed records they are not held in digital format.

Other forms of spatial data include a wide range of maps prepared for different research and reporting purposes. No common standards have been used in the compilation of the maps. Hence the integrity of the information for incorporation in a GIS is open to question. There is a need for standards to be established for future mapping in the ARR. Consideration should be given to the georeferencing of information by the application of differential Global Positioning System technology for future fieldwork.

5.5.2 Access, custodianship and coordination

Information on the ARR is held by a number of governmental authorities, as well as ERA-Ranger uranium mines. Currently there is no directory to the custodians of the data to facilitate ease of access. Although there is good deal of will, and a high level of cooperation between information holding bodies, access pathways are not always clear, and there is a need to update contact points through a directory system. Also, a number of issues relating to ownership and custodianship of the information will need to be resolved if material is to be more easily accessed and, where appropriate, incorporated into a GIS for the region.

5.5.3 Further information requirements

Inquiries into coastal management have repeatedly found that there are serious deficiencies in the knowledge available for the management of coastal resources (DEST 1995). Also, there are serious problems for access to information by managers working in coastal environments,

specifically in accessing information that is difficult to locate. These specific difficulties have been identified for the ARR and measures are at hand to remedy them.

Sound management of coastal areas requires that people with an interest in the coast have access to a diverse range of information encompassing cultural, social, economic, ecological, biophysical and geophysical attributes of the environment. Managers in the ARR have recognised the need for these types of information and a range of research projects have been undertaken to provide material for Park management and monitoring of the effects of uranium mining. Some of this material can be directly applied to addressing management issues specific to the coast of the region. However, information deficiencies have been identified and future research should seek to fill key gaps in knowledge of the various environmental attributes of those ares that are vulnerable to the effects of natural and human induced change. Targeting of research will require that there be greater coordination of research effort so that research programs can yield information that can be applied to addressing more than one set of management or monitoring questions.

The Commonwealth established a National Marine Information System (NatMIS) to provide, in cooperation with the States and Territories, environmental information for the Ocean Rescue 2000 Program and the wider community (DEST 1995). A number of Commonwealth agencies collate natural resource data and have assembled information that is directly applicable to coastal management. Among them are the Environmental Resource Information Network (ERIN), the National Resource Information Centre (NRIC), CSIRO Institute of Environment and Natural Resources, Australian Geological Survey Office (AGSO), Australian Survey and Land Information Group (AUSLIG), Australian Oceanographic Data Centre (AODC), Australian Hydrographic Service, Bureau of Meteorology, and the Australian Maritime Safety Authority. Efforts to obtain information from these sources suggests a need for capacity building and further data gathering in the Van Diemen Gulf region of Northern Australia. The work already undertaken in the region by ***eriss*** and Parks Australia should make a very positive contribution to NatMIS.

5.6 Environmental research and monitoring

Environment is defined under the Commonwealth *Environmental Protection (Impacts of Proposals) Act 1974* as being the total surroundings and activities of humans whether as individuals or in their social groupings. As such, the Commonwealth legislation provides an anthropogenic focus and places people in their physical, biological, social, economic, cultural and political settings. This definition provides a far broader aegis for research and monitoring than the more narrowly based perception of the environment as being the land, air, water and biota.

Environmental research and monitoring is required in the ARR to provide data and information for:

- further understanding of the processes and extent of environmental change;
- development of management strategies and action plans;
- implementing management prescriptions;
- auditing the effectiveness of management actions; and
- assessing performance of the overall management processes.

5.6.1 Environmental research

Research should be broad in scope and include examination of social science questions, particularly those associated with the raising of awareness and attitudinal change in relation to natural variation in the environment of the ARR. Natural systems research is needed to document the processes of change and their effects on the biophysical environment. Both areas of research endeavour will require a high level of innovation in order to integrate the cultural implications of change for Binninj and Balanda. ***eriss*** has approached this task and has based its wetland research direction on key local issues (see Finlayson 1995) under an umbrella of national interest in ecologically sustainable development.

5.6.2 Monitoring

Management of coastal wetlands requires that effective monitoring programs are implemented and that the results are effectively utilised. Monitoring of ecological change in wetlands can be undertaken at several levels and with vastly different techniques. Satellite imagery, often linked to a GIS, aerial photography, flora and fauna surveys at the species and community levels, physico-chemical analyses, ecotoxicological testing, and biomonitoring in stream and bankside all have particular advantages and disadvantages. These have been reviewed by Finlayson et al (1994). The choice of technique is dependent on the objectives of the monitoring program and the nature of the site.

Monitoring also encompasses social, economic and cultural dimensions of change in the coastal zone of the ARR. Social science survey techniques are needed to monitor levels of awareness and community attitudes to the effects of environmental change. Such work should be undertaken in a cross cultural context to ensure that Balanda biases do not overwhelm all community interests., as well as to ensure that there is a high level of community involvement in ongoing assessment of environmental change.

Apart from monitoring to assist with maintenance of the intrinsic values of the region, there is a need to provide national and international benchmarks from which to measure changes in wet-dry tropical environments. The ARR, and especially Kakadu National Park, provides an excellent opportunity for the establishment of a National Environmental Reference Station for the wet-dry tropics. The circumstances that make this region special are that it has a sound history of research, and that there is considerable body of material that could be collated and synthesised to provide baseline descriptions of the essential characteristics and attributes of change in this type of environment. ***eriss*** has a considerable infrastructure already in place to facilitate continuous measurement of climatological and hydrological parameters, and a number of permanent sampling stations have already been established. Additionally, there is a substantial aerial photographic record.

6.0 Management responses

> In the Northern Territory context, for example, I believe that one metre rise of sea level in 100 years or so would turn the South Alligator plains and wetlands to mangrove, samphire, and salt flat from the coast through to a zone about 20 km south of the Arnhem Highway, and that other parts of Kakadu National Park would be similarly affected. We should understand this matter now so that appropriate monitoring can begin and the costs or remedial action can be considered, before any such change is upon us. (Chappell 1988)