

2.0 Approach

2.1 The assessment framework

Environmental management in the context of predicted future climate change is a ‘wicked problem’ (Kenchington 1994) in which management policies must be determined and implemented in a context of uncertainty, ignorance and indeterminacy. In these circumstances, policy and technical solutions for one aspect of the wicked problem are highly likely to generate further difficulties rather than providing effective long-term solutions. The approach followed in this report has sought to accept the uncertainty implicit in best guessing future climate. It focuses on the range of environmental changes in the ARR that are associated with climatic variability and human influences. The changes are reviewed in the light of available scientific information, current predictions of future climate change and responses suited to the capabilities of the management authorities operating in the region. This approach provides a more holistic procedure and the policy frameworks necessary to maintain long-term sustainability of the natural resources and the inherent biodiversity of the region.

Following the Intergovernmental Agreement on the Environment (Commonwealth of Australia 1992: Section 3.5), policy decisions are to be made according to the *precautionary principle*. This is a pseudo-legal principle which requires that where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental damage. Its objective is to ensure the establishment of Ecologically Sustainable Development (ESD) principles in circumstances where environmental information is lacking. The onus is on the developer or development agency to demonstrate that the proposed development will not damage the environment. Here, the precautionary principle needs to be applied in recommending responses to changes that occur naturally in the ARR. A complication arises in its application because the contribution of natural versus exotic processes is not always clear.

The approach taken in this case study for assessing the vulnerability of the coastal wetland areas of the ARR to climatic and other changes has been broadly guided by:

- the conclusions drawn from the 1993 IPCC Eastern Hemisphere workshop (McLean & Mimura 1993);
- recommendations made by the World Coast '93 Conference (IPCC 1994);
- the findings of Kay and Waterman (1993) and Kay et al (1995) with regard to the application of the IPCC Common Methodology (IPCC 1991) to Australian conditions;
- suggestions made for assessing natural and human induced impacts in the Australian coastal zone in general by DEST (Waterman 1996) and for the wet-dry topics by Waterman (1995).

This approach recognises that changes to the environment of the coastal wetland areas of the ARR are a product of natural forces and human induced factors. These factors and environmental impacts can be identified and a range of responses determined from first principle

The assessment framework incorporating these forcing factors, effects and responses is shown in figure 1. Based on this framework a systematic process was undertaken which covered the following activities:

- Scoping the issues relating to climate and other changes currently affecting the physical, sociological, cultural, social and economic components of the environment of the ARR, Kakadu National Park and the lower Magela Creek floodplain. As well, this activity

examined the scope of issues relating to perceptions of the problem and responses to climate change, environmental values, information requirements and management, and strategic management, as well as research and monitoring requirements. These issues were reviewed in the context of environmental change, in which climate change is one factor.

- Identification of the natural, cultural, social and economic resources of the area which could be affected by climatic and human induced change. The resources were examined in the context of the processes of change and not simply as inventory items. Attention was given to those natural resource elements that would indicate temporal and spatial dimensions of change. Physical and biological, as well as social and cultural processes were identified and briefly explained. Governmental processes used to respond to change were considered in the context of the biophysical region and for Kakadu National Park.
- Description of the biophysical change processes in terms of climatic scenarios, predicted sea level rise, hydrological and hydrodynamic conditions and the geomorphic processes currently affecting the coastal margins, the rivers and the floodplains. Changes to floral communities and fauna habitats have been included in the descriptions. Also, the processes impinging on the cultural, social and economic conditions of the study area have been described as they relate to change.
- Assessment of the significance of the changes using a framework which reviewed the possible directions of the dimensions of change. This was done in terms of either increasing or decreasing pressures, eg increased number of storm events, higher rainfall. The implications of the significance of change were evaluated in terms of the application of the results of the assessment to the management processes and the practices commonly used in the ARR and Kakadu National Park.
- Determination of the range of responses to natural and human induced change in the ARR in general, Kakadu National Park, and with a specific focus on the Magela floodplain. The responses encompass strategic and regulatory mechanisms which relate to the management of Kakadu National Park and the discharge of excess water from the Ranger uranium mine onto the Magela floodplain. Research and monitoring capability of both governmental agencies and the community are covered by the range of possible responses. As well, governmental and community capacity and capability to deal with environmental change was addressed in the context of the possible responses.
- Actions to be implemented were determined in terms of both governmental structures and community investment. The type of actions involving government include resourcing the implementation of appropriate management plans and programs. Monitoring is seen as being an integral part of management and it entails auditing both compliance and performance.

2.2 Scoping the issues

Three techniques were used to develop the scope of issues relating to possible effects of climatic and other changes on the coastal margins of the ARR. The techniques used were a literature and information review, consultations and workshops. The issues are discussed in Section 5.

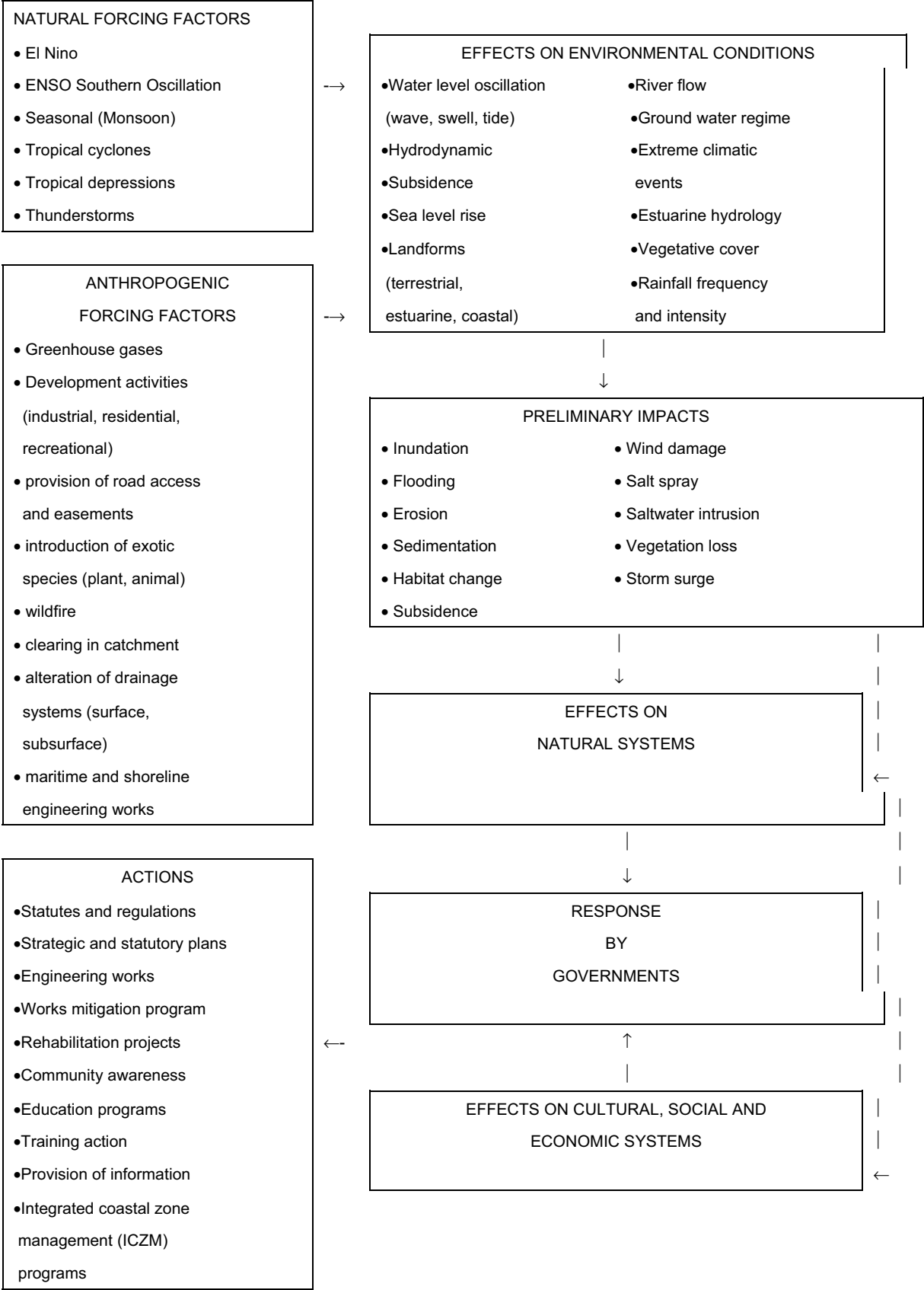


Figure 1 Framework for the assessment of coastal vulnerability in the Alligator Rivers Region of the Northern Territory

2.2.1 Literature and available information

Literature sources by way of published scientific papers, reports and unpublished reports were collated. Key references were used to:

- identify climatic and other changes that are pertinent to the assessment of the vulnerability of coastal and wetland areas of the ARR and to Kakadu National Park;
- review the methods and approaches used to assess the vulnerability of coastal areas to natural and human induced change;
- develop summary scenarios for climate and other changes that can be related to the ARR and Kakadu National Park in general, and the Magela floodplain in particular;
- provide background descriptive information of the areas that could be affected by change by way of natural, cultural, social and economic resources of the areas;
- review the specific and cumulative effects of the change processes identified in the case study area;
- assist in the development of an assessment framework and highlighting the dimensions, possible significance and the potential implications of the changes;
- gain an understanding of types of responses to change that would be relevant to the ARR and Kakadu National Park;
- provide a bench mark for determining the actions most suited to implementation across the case study area.

A bibliography of published and unpublished literature sources has been compiled (see Bibliography). The Bibliography includes documents of a general nature relating to climatic and other changes as well as background material on the ARR and Kakadu National Park. Compared with other areas there is a considerable body of information and knowledge on the physical, biological and cultural attributes of the environment of the Region. Additional sources of information relating to the ARR that are considered to be relevant to the vulnerability assessment are listed in Appendix 1.

The key sources of information identified are:

- the ARR Geographic Information System (Appendix 1.1);
- the Environmental Resource Mapping System (E-RMS) for Kakadu National Park;
- satellite imagery for the ARR and Kakadu National Park highlighting specific environmental characteristics (Appendix 1.2);
- aerial photography for the region (Appendix 1.3);
- thematic maps of the natural resources of the area;
- meteorological, hydrological and tidal prediction data;
- quantitative results of the monitoring programs (water quality, vegetation, biological indicators).

Although a range of information is available, there has been considerable information loss in terms of missing copies of scarce reports, data from field investigations and memoranda outlining results of research. The losses have been due to a variety of management problems. As a result, information management is viewed as an issue in its own right and is to be rectified through the development of a meta-database and appropriate tools at *eriss* to electronically capture and store data.

A review of the requirements for information management is being undertaken to rectify the problem of information loss and to provide a system that will encompass textual, numerical and spatial materials. As part of an information management process a meta-database will be developed and the capability of the Alligators Rivers Region Geographic Information Systems (ARRGIS) expanded. The current status of ARRGIS is outlined in Appendix 1. At present ARRGIS holds some data sets for the lower Magela floodplain area. Topographic and remote sensing information, together with digitised thematic coverages for Kakadu National Park and adjacent areas, including material currently held in the E-RMS operated by Parks Australia, is accessible by *eriss* and may eventually become incorporated into ARRGIS.

2.2.2 Steering committee and consultations

A Joint Steering Committee was established in May 1995 to guide both the policy input into the vulnerability assessment and the consultation process for both of the Northern Territory case studies. Membership of the Steering Committee was drawn from departments of the Northern Territory Government, agencies of the Commonwealth Department of the Environment, Sport and Territories (DEST) and the Northern Land Council. The participating bodies and members of the Committee are listed in Appendix 2.1.

As structured, the Joint Steering Committee was an important vehicle for both inter- and intra-governmental consultation. Additionally, members of the committee provided contacts to be consulted with regard to obtaining information and advice on technical aspects of the vulnerability assessment process. Members of the Steering Committee provided personal insight into issues arising from the possible effects of climatic and other changes on the two regions under investigation in the Northern Territory.

Using the Steering Committee as a consultative tool enabled each case study to be viewed in a broader context. By reviewing issues within a common geographic framework, some of the wider policy issues, which encompassed both of the studies, could be analysed more fully. For example, the community based question of land tenure which has major implications for the Aboriginal people who have an interest in some eighty-five per cent of land in the coastal zone of the Northern Territory as well as nearshore and offshore areas. Equally, the implications of tenure are important for lease holders of pastoral land as well as those having freehold over sites that are within zones which could be affected by unusual storm surge events, flooding or saline intrusions.

Through contacts made during the consultative process, the community dimensions of the implications of climatic and other changes were examined in terms of:

- information needed to provide baseline descriptions of existing conditions so that people can more fully comprehend potential hazards and risks to land, property and ecosystems as well as appreciate the significance of the natural changes occurring in the coastal zones of the Darwin Planning Region and the floodplains of the Van Diemen Gulf area which encompasses the ARR;
- long-term monitoring information that could be generated and used by government and community-based groups which would be simple, have immediate use in the coastal management processes, and have maximum utility in terms of answering questions of the vulnerability of the natural systems and the impacts of ongoing human activities (residential, industrial, recreational, cultural);
- requirements for strategic planning and environmental management plans for land areas under the control of government, private land holdings (freehold, pastoral lease, Crown lease) and Aboriginal communities (Kakadu National Park and Arnhem Land).

Consultations are an ongoing component of the management process. These will continue at both governmental and community levels. Intragovernmental consultations, especially within DEST, are necessary to ensure that all Commonwealth resources that can be utilised in the research and management processes are focused on resolving key issues and are coordinated so that their use is optimised. Intergovernmental consultations are essential to resolve cross-boundary strategic management issues relating to natural and cultural resource conservation. It is essential that intergovernmental consultations, leading to resource sharing, continue so that specific problem areas such as weed infestation, feral and pest animals, and saltwater intrusion can be addressed in an integrated and coordinated manner.

Community consultations need to continue and encompass processes involving the Northern Land Council, the Associations representing the Binninj (Aboriginal people) resident in the Park, ERA Ranger uranium mine and the Jabiru Town Council. As necessary, the consultative process should involve Parks Australia as the management authority and *eriss* for the considerable scientific expertise they can bring to bear on problem solving. Both agencies represent the portfolio interests of DEST and are key players in the implementation of the Commonwealth's Coastal Management Policy in the region.

2.2.3 Workshops

Workshops were undertaken as an integral part of the Vulnerability Assessment process. A technical and a public workshop were conducted through the Joint Steering Committee and held in Darwin in July and August 1995. Workshops were also conducted by *eriss* personnel and their consultants in Darwin and Jabiru.

The purposes of these workshops were to scope the issues specific to Kakadu National Park and the wetland areas of Van Diemen Gulf, determine information requirements, evaluate management options that could be implemented in the region and review progress of the vulnerability assessment.

The first was aimed at a technical level with the purpose of exploring issues relating to climatic and other changes, and exploring the information requirements to address the issues in a broad regional context as well as for specific problems within the study area. A summary of the proceedings of the Technical Workshop, and the results of the issue and information assessment undertaken at the Workshop, are given in Appendix 2.2. Participants at the Technical workshop were from:

- departments of the Northern Territory Government;
- agencies of Environment Australia (Bureau of Meteorology, *eriss* and Parks Australia);
- Centre for Tropical Environmental Studies, Northern Territory University;
- Department of Geography, University of Western Australia;
- Australian Institute of Marine Science (AIMS);
- Northern Land Council.

The second Darwin workshop had as its first purpose informing members of community based organisations and the general public of the Vulnerability Assessment process and the initial findings of the case studies undertaken for the wet-dry tropics. As its second purpose, the public workshop sought to obtain input from the participants on the implications of climate and associated change, as well as comment on the findings with regard to management of the natural, cultural and recreational resources of the coastal zone of the Darwin Planning Region and the ARR. Appendix 2.3 contains a summary of the outcomes of the public workshop.

2.3 Delineation of affected areas and resources

2.3.1 Affected areas

Areas that could be affected by climatic and other changes were determined using a combination of topographic, geomorphologic and biogeographic evidence. Determination of that part of the coastal zone that could be affected by change was carried out at three scales: for the biophysical region, the ARR and the floodplain of the Magela Creek. The biophysical region encompasses catchments of all rivers draining into Van Diemen Gulf

The biophysical regional context is shown in map 3, whereas the regional and locality area is shown on map 4. The areas that could be affected by climate induced changes at all scales encompass the full length of the shoreline of the region and the floodplains of each of the rivers draining into Van Diemen Gulf.

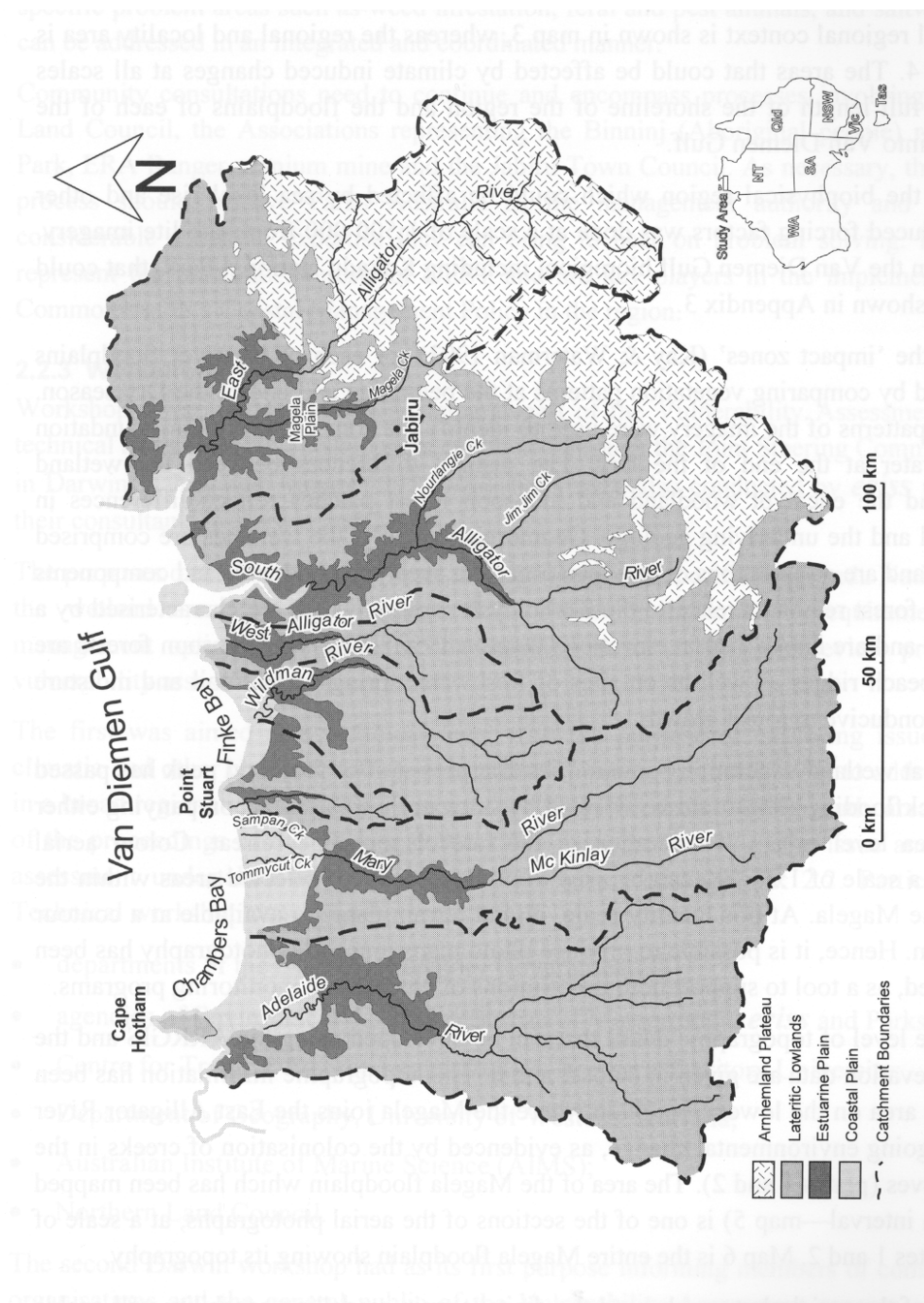
Delineation of the biophysical region which could be affected by sea level rise and other climatically induced forcing factors was done at a scale of 1:500 000 from satellite imagery. The areas within the Van Diemen Gulf bioregion, including Kakadu National Park, that could be affected are shown in Appendix 3.

Boundaries of the ‘impact zones’ (Kay & Waterman 1993) for each of the river floodplains were determined by comparing vegetation patterns at the beginning and end of the Dry season. Changes in the patterns of the imagery were used to identify the zones of maximum inundation and residual water at the end of the Dry. The distinct differences between the wetland communities and the eucalypt woodland and monsoon forest patches reflect differences in topography, soil and the underlying geology. Geomorphologically, the wetlands are comprised of riverine silts and are at elevations of less than 5 m. The eucalypt woodlands and components of the monsoon forest remnants relate to the Koolpinyah surfaces which are characterised by a laterised profile and are above 5 m in elevation (Wasson 1992). Remnant monsoon forests are also found on beach ridges as well as on sites of freshwater springs where soil and moisture conditions are conducive to forest growth.

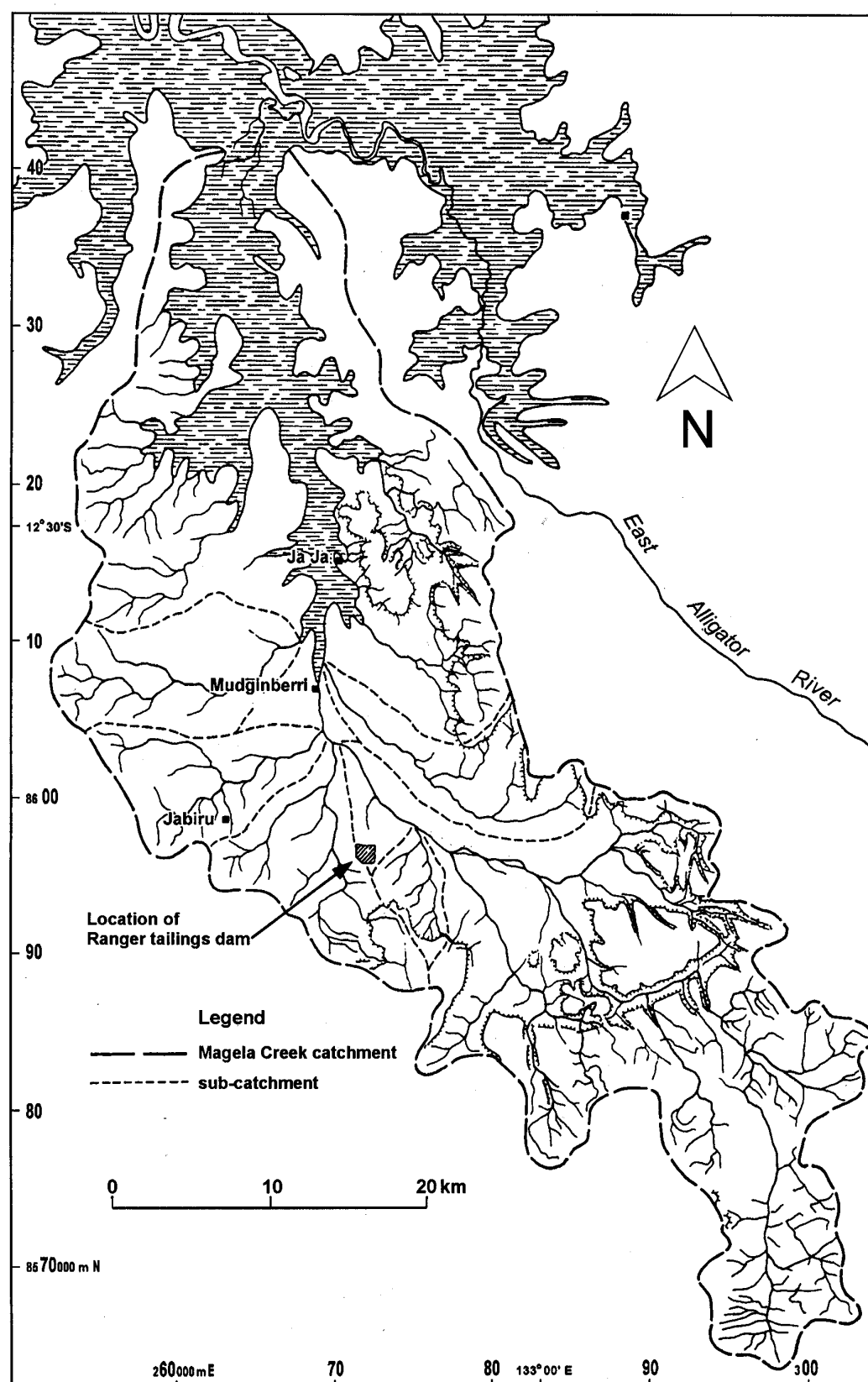
It is assumed that wetland vegetation communities that persist after the flood peak has passed or are in the backflooding zone could be affected by saltwater intrusions accompanying either a rise in the sea level or any acceleration of the rate of shoreline retreat. Colour aerial photography at a scale of 1:25 000 can be used to produce maps of selected areas within the catchment of the Magela. At this locality scale, digital terrain data are available at a contour interval of 0.2 m. Hence, it is possible to produce photo maps, once the photography has been digitally rectified, as a tool to support both descriptions of change and monitoring programs.

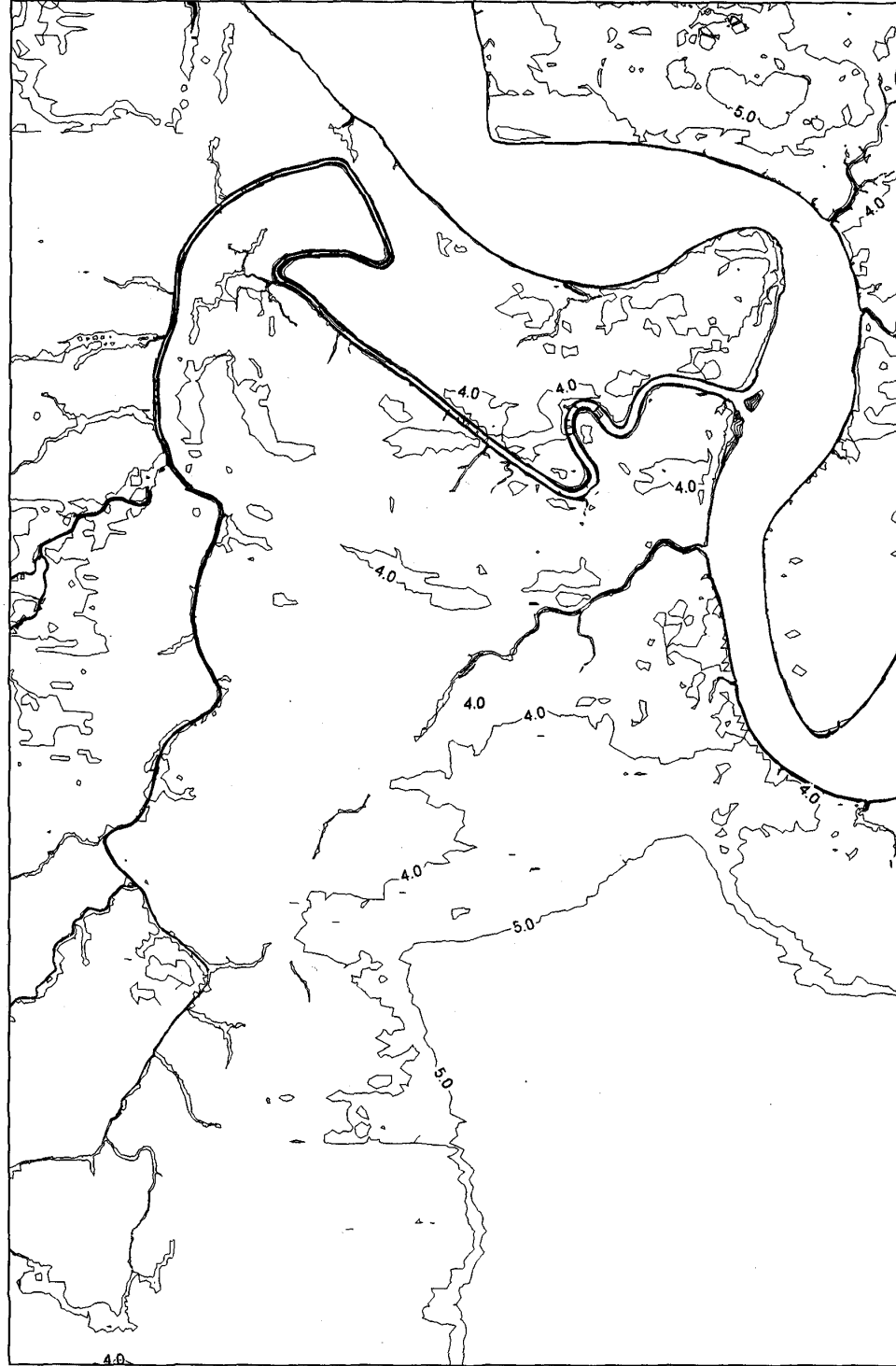
Examples of the level of topographic detail that can be developed using the ARRGIS and the detailed land elevation data are given in maps 5 and 6. This topographic information has been prepared for an area on the lower floodplain where the Magela joins the East Alligator River which is undergoing environmental change, as evidenced by the colonisation of creeks in the area by mangroves (plates 1 and 2). The area of the Magela floodplain which has been mapped in detail (20 cm interval—map 5) is one of the sections of the aerial photographs, at a scale of 1:25 000, in plates 1 and 2. Map 6 is the entire Magela floodplain showing its topography.

A combination of the aerial photography and the digital terrain modelling capability will enable detailed thematic maps to be prepared for the locality under specific attention for vulnerability assessment. This capability can be extended for the whole of the ARR with mapping and digital terrain models using 1.0 m contour interval data that are held by Parks Australia. Delineation of impact zones at map scales of 1:25 000 and contour intervals of 1.0 m is considered to be suitable for analysis of the effects of climatic and associated changes at the regional scale (map 3).



Map 3 The biophysical regional catchments (adapted from Woodroffe & Mulrennan 1993)





Map 5 Confluence of Magela Creek and the East Alligator River
(contours 5 m, 4 m, 3 m, 2 m and less)



Map 6 Contour maps of the Magela Creek floodplain derived from the *eriss* digital terrain model. (a) Map containing 0.2 m contours between elevations of 3.0 m and 4.0 m AHD. This shows that most of the present floodplain lies in this range and could be affected by large increases in sea level. (b) Map containing 0.2 m contours between elevations of 0.0 m and 3.0 m AHD which are potentially inundated by present spring tides.



Plate 1a Aerial photography of the confluence of Magela Creek and the East Alligator River in June 1975. Scale: 1:25 000. Aerial Photographs supplied by Parks Australia: Alligator Rivers 22-6-75 Run 8 No 2888.

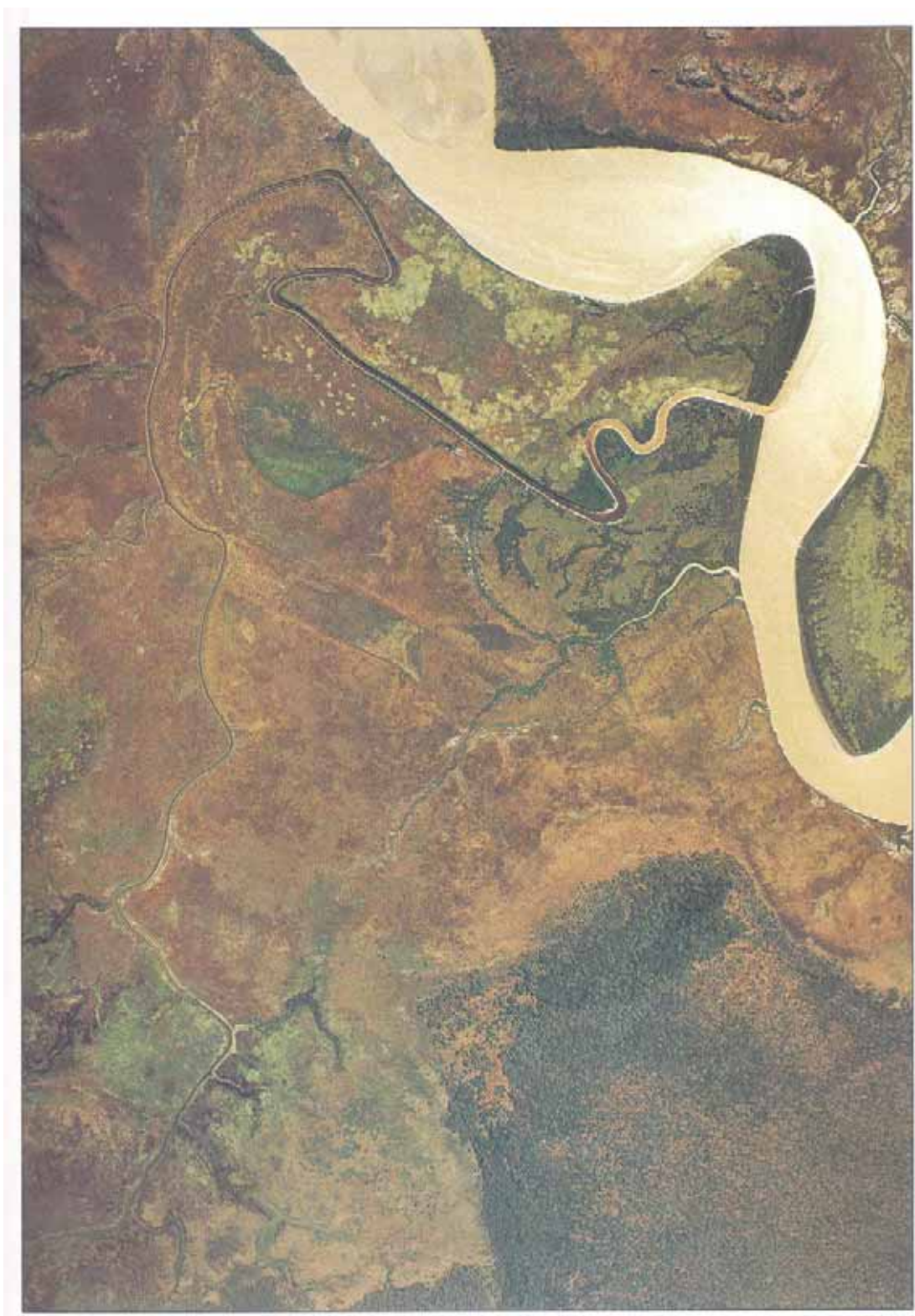


Plate 1b Aerial photography of the confluence of Magela Creek and the East Alligator River in May 1991.
Scale: 1:25 000. Aerial photographs supplied by Parks Australia: Kakadu National Park May 1991
Run 6 No 163.



Plate 2a Aerial photography of the confluence of an unnamed creek, to the north of Magela Creek, with the East Alligator River in June 1975. Scale: 1:25 000. Aerial Photographs supplied by Parks Australia: Alligator Rivers 22-6-75 Run 7 No 2932.



Plate 2b Aerial photography of the confluence of an unnamed creek, to the north of Magela Creek, with the East Alligator River in May 1991. Scale: 1:25 000. Aerial Photographs supplied by Parks Australia: Kakadu National Park May 1991 Run 5 No 092.

The Magela Creek floodplain areas were selected as the specific locality for assessment. This locality within the East Alligator River catchment on the eastern flank of Kakadu National Park has been subject to changes as a result of:

- excavations, stockpiles, tailings dam constructions and other infrastructures relating to the mining and milling of uranium ores at the Ranger uranium mine;
- clearing and accessing for prospecting and mineral exploration at Jabiluka;
- development of the town of Jabiru and associated infrastructure to support the mining and tourist activities;
- the provision of road infrastructure to support tourist and recreational activities;
- broadscale clearing for agricultural and pastoral activities at Mudginberri Station;
- seasonal burning as a past pastoral and ongoing land management practice; and
- invasion by pest animals and exotic plant species.

The floodplain of the Magela Creek has been subject to considerable research (Finlayson et al 1990a & b; Finlayson & Woodroffe 1996; Wasson 1992). This area is viewed as being vulnerable to long-term effects of climatic change as the tailings dam and other mine site features are broken down by acceleration of natural processes (Wasson 1992). Also, the floodplain is vulnerable to saltwater intrusion in response to changes in the fluvial regime of the East Alligator River, as well as to sea level rise and shoreline retreat.

2.3.2 Identification of resources affected

Across the biophysical region the natural, cultural, social and economic resources could be affected by climatic and other changes. Specifically, sea level rise, shoreline erosion and saltwater intrusion would combine to remove both the salt and freshwater wetland resources. This would be manifest in:

- a reduction in some components of the mangrove fringe on the coast line;
- loss of *Melaleuca* (paperbark) stands on the margins of some wetlands;
- colonisation of mangrove species along creek lines as an accompaniment to the salt intrusion; and
- replacement of freshwater wetlands with saline mudflats.

With changes in the wetland communities and habitats there would also be changes in animal populations; particularly noticeable would be the bird species found in the freshwater wetlands. As well, there would be changes in morphology of the streams and in the composition of the fish and other aquatic species. Changes in the natural vegetation and faunal resources may have cultural, social and economic consequences for the Binninj and Balanda (non-Aboriginal people) living or visiting the area. The cultural resources have both social and economic resource values as they relate to the plants and animals used by the Binninj. In turn, it is these resources which give social and economic importance to Kakadu National Park as a site of natural and cultural heritage importance to all people.

The cultural, social and economic resources that could be affected by any accelerations in the change process are discussed in section 4. This discussion should be viewed as indicative of the breadth of factors to be considered, rather than exhaustive. Nonetheless, it serves to indicate the extent of possible changes to the resources of the region.

2.4 Assessing the significance of change

The IPCC (1990) identified three principles of coastal management to be applied under conditions of sea level rise. These are applicable in the broader context of environmental change and provide a basis for vulnerability assessment in the ARR. They are to:

- avoid development in areas that are vulnerable to inundation;
- ensure that critical natural systems continue to function naturally; and
- protect human lives, essential properties and economic activities.

2.4.1 Assessment of environmental change

The assessment of the possible significance of environmental changes due to climatic and other factors covered the following topics:

- climatic variability by way of increases and decreases in the intensity and frequency of storms, cyclones, rainfall, monsoons and other climatic events;
- rise and fall in sea level due to climatic or tectonic factors;
- hydrologic and hydrodynamic vulnerability in terms of increases and decreases in tidal activity, fluvial discharges and groundwater discharges;
- flora by way of climatic effects on indigenous and exotic vegetation;
- fauna in terms of climatic effects on indigenous and introduced species;
- cultural factors in terms of enhancement and/or lessening of heritage values;
- social factors as measured by increases and decreases in population;
- economic factors as related to increases and/or decreases in material resource development, urban and industrial development, and tourism and recreational development;
- governmental considerations by way of acceptance or non-acceptance of international treaties and obligations, greater or less statutory and regulatory intervention, and increased or decreased community involvement in coastal management.

The assessment processes using the topics listed above as a checklist provided:

- guidance for the delineation of potentially affected areas;
- an indication of the limits for the directions of change by recognising that there can be increases or decreases resulting from factors such as rainfall, temperature, and population;
- a sound basis for the interpretation of the effects of change;
- an initial check on research and information requirements to address the issues raised under each topic;
- a focus on the management actions requested to remediate or facilitate the effects of changes.

2.4.2 Implications

All physical, cultural, social and economic systems are changing. Change is continuous and one key factor to be considered is whether change can be perceived as having effects which have adverse impacts on natural and human systems. Perception is important because this dictates the type of response taken to change. On one hand, a heightened perception of change can result in an increased activity to identify, record and implement measures to deal with the changes. On the other hand, a diminished perception of change can result in relaxing measures used in the past to address the negative effects of change. For example, this latter situation is seen over

successive years following extreme climatic events (cyclones) or bushfires, wherein, there are gradual cuts in budgets and reductions in resources to deal with the hazards. This wind down of resources is often paralleled by relaxation of building codes and planning standards. It is accompanied by a lowering of awareness of the implications that the events or changes can have in terms of hazards, risks, lifestyles—human safety as well as the costs and who pays.

A range of implications arise in relation to the climatic and other forcing factors, which may change the environmental conditions of the coastal zone of the wet-dry tropical areas such as the ARR. Some of the implications relate to the type of impacts resulting from the effects of the forcing factors on the dependent conditions and the subsequent environmental impacts as shown at figure 1.

Other implications are manifest in effects on the natural, cultural, social and economic systems and the responses by governments to them. The government responses are in the form of a range of actions targeted at the anthropogenic (human) forcing factors with the intention of changing the effects on environmental conditions and thus the type of impacts that are occurring (fig 1).

2.5 Determining responses and implementing actions

Overall, the responses to changes arising from the effects of natural and human forcing factors on the environmental conditions of the ARR and Kakadu National Park should focus on the actions that can be taken by the Commonwealth Government, and the Binninj and Balanda resident in the park. For the wider bioregion, focus needs to be on the range of possible actions that can be taken by:

- the Northern Territory Government and land users for the Mary and Wildman River localities; and
- the Northern Land Council for the coastal zone areas of Arnhem Land that abut Kakadu National Park either within or outside the catchment of the East Alligator River.

For this case study the range of responses identified included the following:

- Enhancing the research and monitoring capability of *eriss* to make timely input into the management process for Kakadu National Park. This will entail the installation of new monitoring stations and the re-establishment of selected hydrological and climatic monitoring stations used in the past. Additionally, it will entail instituting quantitative measurements of past changes as well as monitoring programs to document changes to the ocean shore, river and creek systems as well as the vegetation communities and faunal habitats of the wetlands.
- Clearly delineating strategic and regulatory responsibilities to enable both *eriss* and Parks Australia to contribute to the long-term management of Kakadu National Park in general and the Magela floodplain in particular. Special attention will need to be given to components of the ecosystem, such as the freshwater plant communities, that may be affected by the change processes. This may require that special regulatory responses are promulgated to deal with the situations created by the long-term breaking down of the material stockpiled and contained within the tailings dam at the Ranger uranium mine.
- Improve the capacities of governments and communities that will be affected so that they can understand the significance of the natural variability inherent in the systems that are changing and to appreciate that change is inevitable. In particular, this means that awareness of change must be maintained and that the attitudes of the communities of

interest must become fully attuned to the implications of the change processes. For example, if the freshwater systems of the ARR are to become saline, then people must understand that the change will bring with it another set of environmental conditions that are not necessarily inferior to those they replace.

- Empower and resource governmental bodies and community organisations so that they can take an active role in the management process. This will require an integrated approach that would result in the Northern Land Council, the Binninj Associations of the Region, Jabiru Town Council and ERA Ranger uranium mine being involved in catchment and coast care programs. Conduits will need to be established to enable those community groups that wish to become part of the management process to be coordinated and resourced.

Government will need to implement actions that will provide management structures and procedures that can persist for the responses to have long-term benefits. The management mechanisms will also need to accommodate the full range of environmental changes (physical, biological, cultural, social, economic) that are occurring. Further, government must involve the wider community in the direct management and monitoring of the natural, cultural and recreational resources that could be affected by climatic and human induced changes.

The management responses arising from this vulnerability assessment are outlined in Section 6. Overall, they provide a framework for the following:

- The ongoing evaluation of the significance of changes to the natural and human systems of Kakadu National Park and the floodplain of Magela Creek. This process will take a more holistic approach and use resources from within and outside the region.
- The long-term integrated management of the ARR in terms of control and organisation arrangements, management plans, implementation mechanisms and community involvement.
- Monitoring programs which encompass baseline and reference stations to produce data and information which can be used immediately in the management process by *eriss*, Parks Australia, the Northern Land Council, and the Binninj and the Balanda who reside in and use the park. This would include both processes for data and information management (spatial, textual, numerical) as well as mechanisms for the dissemination of intelligence (or knowledge) which document the rate, effects, and implications of change.
- Auditing the management processes needed to deal with environmental change in the ARR. This could include management reviews as well as independent compliance auditing. Auditing is viewed as an extension of the monitoring process. It is intended to evaluate the effectiveness of management procedures being used as well as assess the achievement of performance objectives set within management plans and monitoring programs.

3.0 Environmental change

Environmental problems in the ARR include the introduction of exotic flora (eg *Mimosa pigra* and *Salvinia molesta*) and fauna (eg buffalo, pigs and potentially cane toads), saltwater intrusion into the freshwater wetlands of the coastal plains, and increasing use of the region for tourism. During the past two decades scientific research and monitoring related to these problems, as well as to issues associated with establishment of the ERA Ranger uranium mine, have established a regional capability to assess environmental change as well as providing a significant record of change. Science strongly underpins the management of Kakadu National