Buntine-Marchagee

Natural Diversity Recovery Catchment



RECOVERY PLAN: 2007 – 2027

Conservation Commission
WESTERN AUSTRALIA

Department of Environment and Conservation

Buntine Marchagee Catchment

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SUPPORTING INFORMATION

The document *Buntine-Marchagee Natural Diversity Recovery Catchment Supporting Information to the Recovery Plan 2007-2027* includes detailed information on physical characteristics of the catchment. The separate supporting information document, referred to in this plan as appendices, also develops and explains important issues that would otherwise need significant diversions in the recovery plan. The intent is to improve the readability of this document. Attachments are included as part of this recovery plan.

Terminology: The text contains many technical terms and uses a number of common words in particular ways. These are defined in the glossary (Attachment 1).

1 The Department of Environment and Conservation (Western Australia) 'the department' was established on 1 July 2006 with the merger of the Department of Environment (DoE) and the Department of Conservation and Land Management (CALM).

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Buntine Marchagee Catchment

SUMMARY

This recovery plan describes the biodiversity values threatened by altered hydrology, particularly salinity, in the Buntine-Marchagee Natural Diversity Recovery Catchment (BMNDRC) and explains management actions that will guide the conservation of these values for the next 20 years. The plan is a source of information and management guide for catchment managers, landholders and interested community members.

Natural Diversity Recovery Catchments are a State Government commitment under the Salinity Strategy and are one response to secondary salinity, a major threat to the biodiversity of the South West Agricultural Region. South-Western Australia is an important global biodiversity hotspot because of very high plant diversity, species endemism and the extent of land clearing. The generally small patches of remnant native vegetation and wetlands that remain are threatened by increased salinity and other changes brought about by altered hydrology caused by extensive clearing of native vegetation. This is contributing to species extinction and a decline in ecosystem condition. Recovery catchments provide a focus for government and community actions to protect regionally significant, high priority biodiversity assets, especially wetlands that are threatened by altered hydrology. Natural diversity recovery catchments are managed by the Department of Environment and Conservation, which has a statutory responsibility for managing biodiversity in Western Australia.

While the primary goal of recovery catchments is biodiversity conservation, they are also important for investigating and implementing solutions to salinity throughout the South West Agricultural Region. This secondary goal recognises that to manage recovery catchments requires research and development of sustainable forms of agriculture which are both environmentally sensitive and profitable. With 95 per cent of the BMNDRC in private ownership, successful implementation of the recovery plan depends on landholder support. In turn, this requires that management actions on private property for biodiversity conservation must simultaneously meet landholders' economic and other goals. Although there are varying degrees of support for biodiversity conservation, broad support exists for the recovery catchment and local catchment groups have been active in land conservation for decades.

This recovery plan and associated planning processes presents an opportunity for landholders to access new knowledge about salinity management, better access to funds for on-ground work, and the chance to collectively contribute to developing solutions to land degradation and new agricultural industries as well as conserving biodiversity for future generations.

The BMNDRC was identified in 1999 as the fifth of currently six natural diversity recovery catchments. Selection was based on the judgement of experts involved in the wheatbelt biological survey of the inland agricultural region. They identified and recommended for action major, high priority public assets at risk from salinity where significant and ongoing investment in asset recovery and protection was warranted. These recommendations were endorsed by the Western Australian Environment Minister, Conservation Commission of Western Australia and the State Salinity Council (now State Natural Resource Management Council).

The BMNDRC is the first natural diversity recovery catchment with a braided, naturally saline channel wetland system which supports a significant proportion of regional invertebrate fauna, especially salt-adapted species. The catchment covers an area of 181,000 ha, and straddles two biogeographic regions – the Geraldton Sandplains and the Avon-Wheatbelt. Vegetation associations and fauna species linked with these regions are well represented and there are significant areas of remnant vegetation that support good examples of upland vegetation such as the Buntine Nature Reserve. The recovery plan focuses on the high diversity of wetland types and terrestrial vegetation associations (particularly those on valley floors), which are at risk from altered hydrology including rising water tables, waterlogging and salinity. These areas also include a number of Declared Rare and Priority Flora and Priority Fauna.

Although the aspirational goal for the catchment is to conserve the areas full range of biodiversity, a feasibility analysis conducted during the planning process and described in the plan showed that this is not currently achievable, and thus the steering committee adopted an operational goal for planning. This is to:

> *'For the next 10 years, maintain the 2007 richness, distribution, abundance and condition of a representative sample of biodiversity assets threatened by salinity in the BMNDRC.'*

It was also agreed that, among the wide range of cultural values achieved by conserving biodiversity, three are particularly important in BMNDRC and are key drivers for conservation management. These values are: ecosystem services, which contribute to maintaining the catchment and downstream environment; intrinsic/spiritual/

philosophical values, which operate at a State and local level and include the strong sense of place provided by biodiversity; and opportunity values for future generations including the potential for using genetic resources and water. These are consistent with the values used to select biodiversity assets as part of the State's Salinity Investment Framework. Recreation, amenity, and other values were considered, but not identified as priority values.

A comprehensive description of the catchment's biodiversity provides the basis for identifying priority biodiversity assets – those threatened by altered hydrology that are most important for delivering the operational goal and cultural values. Most native biota threatened by salinity occur in valley floor assemblages and a significant proportion live in or are associated with wetlands. There is currently not enough information to identify all areas at risk. Hence, a preliminary assessment of salinity risk has been based on landscape position. The assumption is that areas of highest risk are located near the valley floor or on lower-slopes where the altered hydrology is creating secondary salinity.

Management will focus on the biodiversity assets which are most threatened by salinity and considered to be of highest value in terms of delivering the aspirational goal (framed as an operational goal) and priority cultural values. These assets include species of significance (threatened species and others covered by legislation) and the wetland and terrestrial assemblages that best represent the range of taxa in the valley floor. This includes biota associated with a variety of wetland types including primary saline wetlands and channels, gypsum lakes, fresh/brackish wetlands, bentonite wetlands and freshwater claypans.

Finally, the report discusses how threats to priority biodiversity assets will be addressed. The most significant issues for management are:

- changed biogeochemical processes – in particular altered hydrology and climate change
- environmental weeds, diseases, introduced and problem native animals
- physical disturbance such as fire, cyclones, flood, drought and erosion.

Management actions that respond to these and all other identified threats to priority biodiversity assets are set out in a series of tables. These describe the on-ground activities and products that will be produced, provides a schedule for their delivery and documents the expected outcomes of management.

Key actions include: strategic revegetation and extending surface water management works to better protect priority biodiversity assets, more detailed investigation of priority assets, mapping salinity risk across the catchment, completing a catchment monitoring network for surface and groundwater, developing water balance and ecological models, protecting remaining remnant vegetation, investigating acidity, nutrients and erosion and associated tolerances of biota, and researching potential climate change impacts. A communication strategy will also be developed and implemented as part of this recovery planning process.

Work to date has focused on hydrological assessments and biological survey work to provide the basis for effective management planning. At the same time, on-ground works have been undertaken that will contribute to management of altered hydrology. In particular, this has included a major project on surface water management and revegetation for hydrological control that also provides ecological resources (shelter, corridors, increased food supplies) for biota in remnant vegetation. Building an appropriate culture to support biodiversity conservation has also been an important area of work including the activities of the Steering Committee and landholder surveys.

A framework for monitoring and evaluation has been established as part of this recovery plan to measure progress and evaluate performance during implementation. Monitoring and evaluation will initially focus on the five priority wetlands selected as representative biological communities. Progress towards achieving the operational goal for the catchment will be measured against resource condition targets. These are physiochemical and biological measures which indicate the status of the richness, distribution, abundance and condition of priority biodiversity assets. These criteria and measures, especially physiochemical measures, will be further developed with improved understanding of the systems being managed. Assessing the achievement of the priority cultural values, particularly ecosystem services, also requires the development of additional criteria to assess whether these values are being maintained or improved. These criteria will become part of the recovery plan and reporting process once they are developed and tested.

This plan will be implemented through annual operational planning and works by the recovery catchment team in partnership with the catchment community. It will include annual reporting on expenditure and outputs and progress reports against achieving resource condition targets. This will be complemented by periodic major reviews.

ATTACHMENTS

TABLES

FIGURES

PERSONAL COMMUNICATIONS

Coates, D. *Senior Principal Research Scientist, Science Division, Department of Environment and Conservation (DEC)*, May 2007.
Fowler, B. *Coorow Farmer.* Anecdotal information provided to DEC staff in 2006.
Keighery, G. *Principal Research Scientist, Science Division, Department of Environment and Conservation*, 2006.
Lyons, M. *Research Scientist, Department of Environment and Conservation (DEC)*, 2005.
Roberts, J.D. *Professor Faculty of Natural and Agricultural Sciences – School of Animal Biology, UWA*.
Toser, Dr. P. *Economist, Department of Agriculture and Food (DAFWA)*, July 2005.

1. SALINITY, BIODIVERSITY AND THE ROLE OF RECOVERY CATCHMENTS

INTRODUCTION

Secondary[2] (or dryland) salinity is threatening the biodiversity of the South West Agricultural Region, including the Buntine-Marchagee catchment area (Attachment 2). The catchment has been designated a Natural Diversity Recovery Catchment as part of a program to focus government and community actions to protect regionally significant, high priority biodiversity assets, especially wetlands, threatened by salinity.

This report outlines the threat of salinity to biodiversity, sets goals for biodiversity conservation, describes the catchment area and identifies the high priority assets which have been selected for management. It explains how management priorities have been set to deliver specific cultural values of biodiversity conservation to the community, and identifies what resources – knowledge, technical expertise and community and political support – are needed for success.

Finally the report discusses how threats to priority biodiversity assets will be addressed. A series of management actions is proposed which describes and schedules what will be delivered and identifies expected outcomes of management. This includes a framework for monitoring and evaluation to measure progress and review performance through an adaptive implementation and reporting process. This report is designed to communicate the planning and priority setting process used and serves as a guide for implementation for catchment managers, landholders and the community.

THE THREAT OF SALINITY TO BIODIVERSITY

Secondary salinity is changing significant areas of the Australian agricultural landscape. It is a serious threat to biodiversity as it affects the survival of native species and biological communities. One State Government response to the threat of salinity was the development of the Western Australian Salinity Action Plan (Agriculture Western Australia et al. 1996) which identified salinity as one of the State's most critical environmental problems. McFarlane et al. (2004) in a review of the extent and potential area of salt-affected land estimated that Western Australia has the largest area of dryland salinity in Australia and is at greatest risk of further salinisation over the next 50 years. In 2001, the Land Monitor project estimated that, based on 1996 satellite-remote sensing data, the area of the State affected by salinity was about one million hectares and increasing at 14,000 hectares a year. The area with salinity hazard (that is, areas which may develop water tables close to the surface and thus at risk from salinity) amounts to about 5.4 million hectares. Most of this (81 per cent) is on cleared agricultural land but it also includes very important public assets including biodiversity, water resources and built infrastructure.

The south-west of Western Australia is recognised as one of the world's 34 biodiversity hotspots based on a combination of very high terrestrial (mainly plant) diversity, species endemism and the extent of land clearing (Mittermeier et al. 2005). Much of the south-west agricultural region is highly cleared, with remnant vegetation fragmented into small patches. It is upon this backdrop that increased salinity and other changes brought about by altered hydrology[3] are directly contributing towards species extinctions and a decline in ecosystem condition. Salinity is therefore a critical issue for biodiversity conservation.

A key project funded through the *WA Salinity Action Plan* was the wheatbelt[4] biological survey (1997-2004), which documented biota and the extent to which it was threatened by salinity (Keighery et al. 2004). The results of this survey revealed that salinity has already had a significant effect on the native plants and animals of the wheatbelt, particularly those living in wetlands. There has been a 50 per cent decrease in the number of waterbird species using wetlands and current estimates suggest that 450 plant species and 400 invertebrate species in the wheatbelt are threatened with global or regional extinction (Keighery et al. 2001). Of particular concern is that most wheatbelt wetlands have already been severely degraded. These changes have gone largely undocumented[5]. The wheatbelt biological survey substantially increased our knowledge of the impacts of salinity on biodiversity.

2 *Secondary salinity* (also known as dryland salinity) develops following widespread replacement of perennial native vegetation with annual crops and pastures. The consequent altered hydrology causes a cascade of environmental effects in Australian landscapes, including secondary salinity. Primary salinity is naturally occurring salinity, such as in some salt lakes, that pre-dates European settlement. The use of the term salinity in this report refers to secondary salinity.

3 *Altered hydrology* is used in this report to encompass all the hydrological changes arising from development of the agricultural region. Increasing salinity of surface soils and waters is just one possible effect of changes to hydrological regimes. Understanding altered hydrology and its impacts on hydrological processes at local and catchment scales is a critical part of recovery planning. From a biodiversity perspective it includes appreciating tolerances and thresholds of biodiversity assets to the impacts of altered hydrological regimes.

4 Refers to where wheat is the main cereal crop. The wheatbelt biological survey is also known as '*A biodiversity survey of the Western Australian agricultural zone*'.

5 A broad picture of changes due to salinity is provided by the oral history work of Sanders (1991) and the depth and salinity monitoring studies by Lane et al. (2004).

NATURAL DIVERSITY RECOVERY CATCHMENTS

Natural Diversity Recovery Catchments (NDRCs) provide one focus for government and community actions to manage the impact of salinity on biodiversity. They conserve representative biological communities and the related physical diversity together known as natural diversity[6]. The NDRC program was a commitment by the Government arising from the WA Salinity Action Plan, which aimed to ensure that:

> *critical and regionally significant natural areas, particularly wetlands, are protected in perpetuity.*

The subsequent review of the 1996 WA Salinity Action Plan, the Western Australian Salinity Strategy (State Salinity Council 2000), saw recovery catchments as:

> *based on the identification of major, high priority public assets that are at risk from salinity and warrant significant, ongoing investment in their recovery and protection.*

Reviews of the Government's salinity programs over the last six years have re-confirmed the importance of the NDRC program and, where appropriate, have proposed expansion of the program (State Salinity Council 2000, Frost et al. 2001, Wallace 2001, Government of Western Australia 2002).

The broad objective of NDRCs is to protect high priority biodiversity assets, particularly those associated with wetlands that are threatened by salinity and that are regionally significant within the south-west agricultural region. To achieve this broad objective, the focus of the program has been on selecting and managing biodiversity assets that represent the range of biodiversity threatened by salinity.

PRIORITY SETTING FOR SALINITY ACTIONS

Governments allocate significant resources to protect high value assets where they are threatened by salinity. To guide public investment in salinity management initiatives, the State Salinity Council commissioned development of the Salinity Investment Framework (SIF) in 2000. This study recognised that given the extent and consequences of salinity, and the very high costs of management, it is crucial to have a rigorous framework for ranking salinity investments by government. This approach to priority setting is described in two reports (Department of Environment 2003; Sparks et al. 2006). The goal of this approach is to ensure that the most important public assets are protected from salinity. The assets assessed were biodiversity, land, water and public infrastructure. NDRCs are one of three types of recovery catchments, the others being Water Resource Recovery Catchments (potable water resources) and the Rural Towns Program (infrastructure). With respect to biodiversity assets, there has been an emphasis throughout this work on conserving representative biological communities threatened by salinity, although threatened and protected species and threatened ecological communities are also considered.

SELECTION OF RECOVERY CATCHMENTS

Some of the key biodiversity assets threatened by salinity in the agricultural region were identified in six NDRCs before completion of the wheatbelt biological survey. This was because in the first few years of the salinity program it was important to select and begin management of recovery catchment areas where sufficient value could be identified. This was a deliberate approach to select important and representative samples of biota and ecosystems which created an opportunity to develop generic solutions for salinity in a range of biogeographic settings. It is important to note that while biological values are the primary criteria for identifying recovery catchments, other criteria such as local community support are also very important. Apart from the first three catchments, selections were based on preliminary results from the biological survey in addition to expert opinion. As an interim measure, a set of criteria was developed for identifying recovery catchments (Appendix 1).

Three NDRCs were established by the department in 1996 under the Western Australian Salinity Action Plan: Lake Warden, Toolibin Lake and Muir-Unicup Wetland Complex. A further three NDRCs have been identified since the inception of the salinity program: Lake Bryde, Buntine-Marchagee and Drummond.

The Buntine-Marchagee Natural Diversity Recovery Catchment (BMNDRC) was identified in 1999 and is the fifth NDRC established by the department. The interim criteria satisfied in the selection process were:

- biodiversity values at risk (from salinity)
- biogeographic representation.

This was based on the expert judgement of scientists undertaking the wheatbelt biological survey. The nomination document for the catchment (CALM 1999a) is at Appendix 2. Subsequently, the selection of the BMNDRC was endorsed by the Conservation Commission of Western Australia, State Salinity Council (now the State Natural Resource Management Council) and Environment Minister. The BMNDRC was formally established in 2001.

6 This document is concerned with the conservation of natural biodiversity rather than domestic species and other biodiversity brought about by human action.

Selection of potential recovery catchments is now structured around a more quantitative approach. A more formal analysis using data generated by the biological survey of the WA Agricultural Zone has been used to determine what other areas of the wheatbelt might best complement the existing NDRCs (Walshe et al. 2004).

CATCHMENT OVERVIEW

The catchment has a high diversity of wetland types including primary saline playa lakes, fresh and brackish wetlands and special sub-strata wetlands such as gypsum, bentonite and granitic rockpools. It is the first NDRC with a braided, naturally-saline channel wetland system which supports a significant proportion of regional invertebrate fauna, especially salt-adapted species. Of the estimated 1000 aquatic invertebrate species found in the wheatbelt, 273 species (27 per cent) occur in the BMNDRC. This recovery plan focuses on the biodiversity assets associated with braided naturally-saline channels which are threatened by altered hydrology including rising water tables, salinity and waterlogging.

In addition to important wetland assets, other key biodiversity assets potentially threatened by salinity include: terrestrial vegetation associations (particularly those on valley floors), 45 threatened plant taxa, three species of plants that are uncommon or have commercial value, eight species of threatened and priority fauna and four species of conservation significance.

The recovery catchment straddles two biogeographic regions, the Geraldton Sandplains and the Avon-Wheatbelt. Vegetation associations and fauna species linked with these regions are well represented and there are significant areas of remnant vegetation that support good examples of upland vegetation such as the Buntine Nature Reserve. Eleven per cent of pre-European settlement vegetation is intact. This is relatively high compared with the highly cleared local authorities in the central agricultural zone where four to five per cent is more common (Shepherd et al. 2001).

PLANNING PROCESS

This recovery plan follows a number of important steps in managing for biodiversity conservation which are summarised in Figure 1. While in theory there is a logical and linear sequence to this approach, in practice it is an iterative and interactive process. The planning process also involves significant input from the community, particularly through the BMNDRC Steering Committee.

The Steering Committee is the main forum to facilitate work with the catchment community. Representatives from key stakeholder groups, predominantly local landholders, make up more than half of the committee.

Other members, past or present, include:

- government agencies – DEC, Department for Agriculture and Food Western Australia (DAFWA), Department of Water (DoW) representatives;
- educational institution – Murdoch University;
- local government – Councillors from Shires of Coorow and Dalwallinu;
- research – CSIRO Sustainable Ecosystems;
- catchment groups – representatives from Land Conservation District Committees (LCDCs) for Coorow, Waddy and Latham and the Marchagee Catchment Groups;
- private industry – Liebe Production Group and a private landcare consultant; and
- regional natural resource management group – Northern Agricultural Catchment Council (NACC).

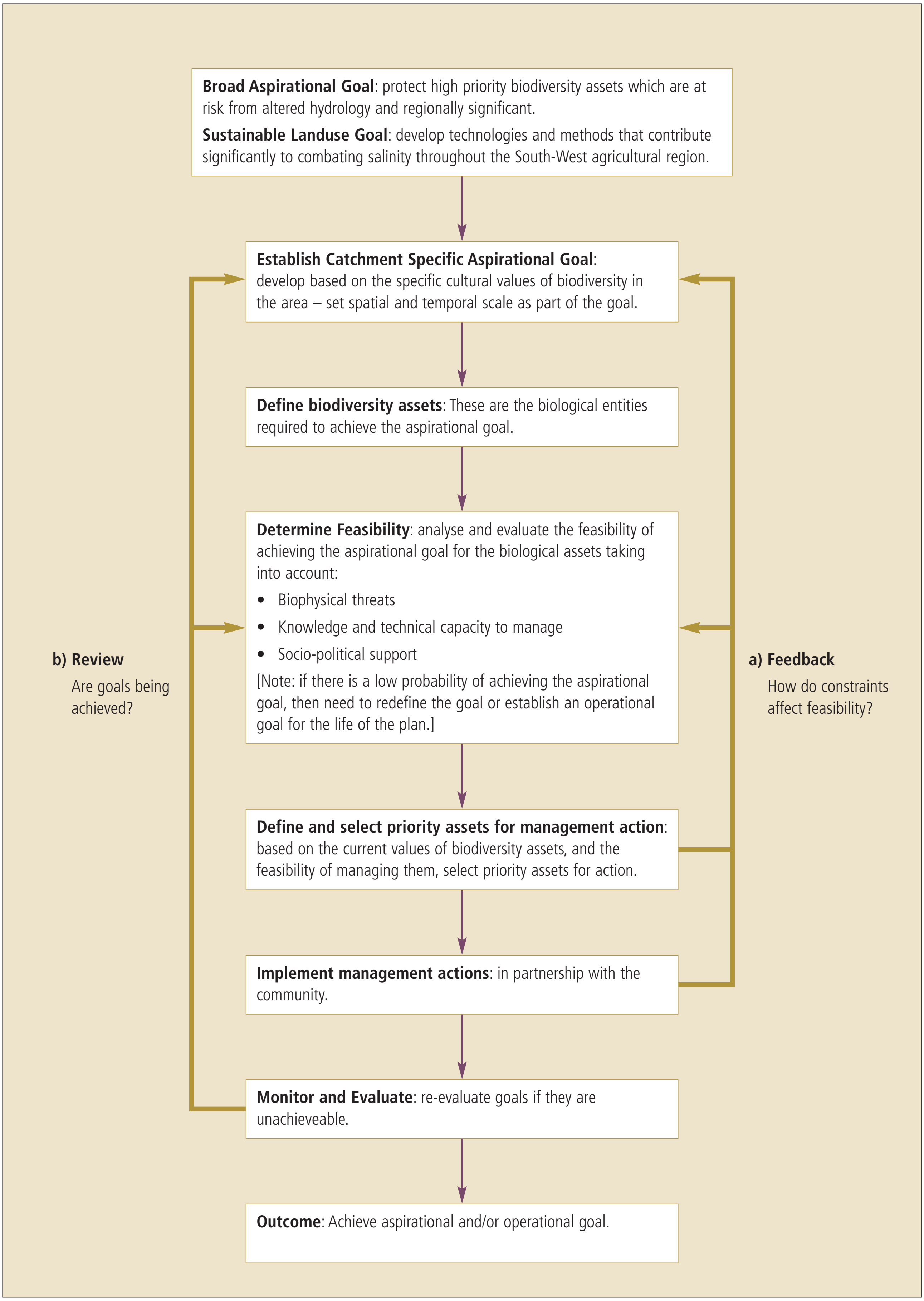
The Steering Committee met twice in 2002 and again in March 2006, to discuss progress and seek input on development of the recovery plan. The meetings in 2002 set out and revised objectives and strategies which led to an information gathering phase which has been used to develop this recovery plan. This work included:

- defining catchment biodiversity values and assessing the threat salinity posed to these values;
- installing several baseline monitoring programs:
  - catchment groundwater and surface water monitoring network
  - vegetation transects
  - aquatic invertebrate surveys;
- conducting a landholder survey to develop an understanding of perceptions to land degradation issues and management.

Within DEC, planning guidance has been provided through a Technical Advisory Group (TAG). This represents DEC senior management, scientists and recovery catchment officers. One of the roles of this committee is to provide technical and management advice on the development and implementation of recovery catchment plans. This includes advising the management team on planning and feasibility of management actions. A wide range of other stakeholders has also been involved. These are listed in *Appendix 3*.

The process for review and approval of recovery plans includes internal review by the DEC TAG as well as input from the project management team and the Steering Committee. This process is iterative and assists in refinement of recovery catchment goals and actions and the development of an evaluation and monitoring plan. Community input and support has been sought for this recovery plan through the Steering Committee prior to publication and release.

Figure 1: The planning and management process for Natural Diversity Recovery Catchments.



RECOVERY PLAN OUTLINE

This plan builds on early works and investigations. Where knowledge is adequate, specific management actions are outlined for particular biodiversity assets. However, given the comparatively early stage of work in the catchment, extensive investigations and monitoring are also proposed as a basis for developing further management actions. There will also be a review process at five and 10 years to evaluate progress and monitor whether goals are being achieved during the life of the plan. Six sections of the Plan cover the following:

Section	Content
Section 1	Introduces the threat posed by salinity to biodiversity and background to the natural diversity recovery catchment program, including selection and overview of the BMNDRC. Also outlines priority setting for salinity action, planning process and describes the structure of the recovery plan.
Section 2	Sets out the aspirational goal of the BMNDRC and explains the link between cultural values and biodiversity conservation goal setting. The importance of sustainable land use as a secondary goal in recovery catchments is highlighted in terms of responsibility and ownership of goal implementation.
Section 3	Provides a description of the planning area, physical and socio-economic characteristics, and an overview of the biodiversity assets of the BMNDRC. The emphasis is on selecting representative assets threatened by altered hydrology.
Section 4	Considers priority setting for management. This includes how biodiversity assets will deliver priority cultural values, an assessment of biophysical threats to assets and the feasibility of asset protection; an appraisal of the knowledge, technical capacity; and the socio-political support to manage for biodiversity conservation. This leads to the definition of an operational goal for the BMNDRC.
Section 5	Discusses management issues and the associated strategies and actions for managing threats and threatening processes to biodiversity assets. This includes what further work is required, the outputs and performance indicators for management and summarises progress to date.
Section 6	Outlines the phases of implementation of the Plan including the monitoring and evaluation framework.

2 THE CATCHMENT GOAL SETTING PROCESS

CULTURAL VALUES AND BIODIVERSITY CONSERVATION

To set goals for biodiversity conservation it is essential to determine the values that drive support for conserving biodiversity in the BMNDRC. That is, why is biodiversity important at Buntine-Marchagee and for what purposes are we conserving it?

How biodiversity contributes to values can be described in a number of ways. A description and examples of the eight categories of cultural values[7] used here is based on Wallace (2006) and described in Appendix 4. These values underpin the aspirational goal for the catchment and assist in defining the biodiversity assets that need to be conserved to achieve the goal. They also support the criteria used in decision-making for management actions.

To determine their relative importance, the cultural values of biodiversity in the catchment were ranked in order of priority by the Steering Committee at a meeting in March 2006. Members ranked the categories of cultural values according to:

- a personal view
- a perceived view of the catchment community
- the stakeholder group which they represent.

The rankings based on the stakeholder groups that members represented were taken to characterise the broader community position relevant to the catchment and its key users. The Steering Committee agreed to a ranking of priority values of biodiversity for which the BMNDRC will be managed. These biodiversity values, in order of priority, along with examples of how these relate to the catchment are:

1. **Ecosystem service values** are values that contribute to maintaining the catchment and downstream environment. Flood mitigation, nutrient stripping and salt storage are examples of important ecosystem services in the catchment, particularly in relation to managing altered hydrology.
2. **Intrinsic/spiritual/philosophical values** of biodiversity resources are a strong driver for biodiversity conservation at the State and local level. From the perspective of the catchment community, the local desire to maintain local biodiversity for the strong sense of place it provides and its contribution towards people's spiritual and physical wellbeing were identified as important.
3. **Opportunity values** of biodiversity are those that provide a range of potential future opportunities. For example, the potential for future use of genetic resources and opportunities for water use and salt harvesting were identified for BMNDRC.
4. **Knowledge and educational values** include a focus on scientific investigations that advance our knowledge of the management of salinity and contribute to education and training.
5. **Leisure/recreational values** include opportunities for tourism or recreational use by locals for activities such as bushwalking, picnicking and bird watching.
6. **Consumptive use values** are plants and animals harvested for domestic use that do not pass through a market and are not sold or purchased. Examples are the use of kangaroos for local pet meat and collection of seeds from native plants for on-farm landcare work.
7. **Amenity values** contribute to aesthetics and scenic values. Catchment landholders place a high value on maintaining the biodiversity of the catchment to deliver aesthetic and scenic values. These contribute towards maintaining a sense of place.
8. **Productive use values** are commercially harvested plants and animals. For example biodiversity resources in the catchment are used to provide materials such as harvesting of kangaroos for commercial gain.

For planning purposes, the first three priority values identified above were taken as the primary purposes of management. These are consistent with the primary values used for guiding work on biodiversity assets under the Salinity Investment Framework (Department of Environment 2003). That is, the State and more local community values are in agreement.

THE ASPIRATIONAL GOAL OF THE BMNDRC

The aspirational goal of the BMNDRC aims to deliver the three priority values described above, and is:

> *For the next 20 years, to maintain the 2007 richness, distribution, abundance and condition of biodiversity assets threatened by salinity[8] within the Buntine-Marchagee catchment.*

This overarching goal is written as an 'aspirational goal' – the desired state that we aspire to while acknowledging that salinity and other threats to biodiversity assets are well established and often increasing in intensity. Halting degradation will take time, in some cases decades.

7 *Cultural values* is used here in a very broad sense to include all our national community's cross-generational values including production values such as agriculture.

8 Biodiversity assets threatened by salinity are defined in section 3.

Therefore, it is expected that some of the targeted biodiversity assets in the catchment will continue to decline in the short to medium term until management actions take effect.

The aspirational goal is linked to specific spatial and temporal scales so that it is clear what area is being managed and over what timeframe goal achievement will be measured. The spatial scale of the goal is described in Section 3 (see Planning Area) and mapped in Attachment 2. The temporal scale for the goal and the broad planning horizon for this document is 20 years. This planning scale is a compromise between the long duration of some natural cycles (in some cases over 100 years) and our ability to plan with reasonable certainty. In addition, it is expected that while positive outcomes from recovery works will be achieved in the short term, major achievements will occur over longer timescales, but within the next 20 years. This is consistent with the approach of regional natural resource management groups.

While the State Salinity Strategy goal for NDRCs referred to biological and physical diversity, the aspirational goal for the BMNDRC is directed only at biological values. This is because the Steering Committee expects that the actions required to conserve biological assets threatened by salinity will also protect physical diversity. For example, sedimentation threatens the physical diversity of wetlands as well as the biodiversity assets associated with them. Therefore actions to protect biodiversity are also expected to conserve the physical diversity of wetlands.

SUSTAINABLE LAND USE GOAL

Work in recovery catchments provides an opportunity to develop and test methods for combating salinity throughout the south-west agricultural region. It is important to recognise that successfully managing recovery catchments to protect biodiversity requires research and development of solutions to achieve environmentally sensitive, profitable and sustainable agriculture. This principle has been recognised in the departmental review of salinity programs (Wallace 2001) and as part of the Toolibin Lake Recovery Plan where three of the principal goals recognise sustainable land use. This acknowledges that the most economical way of achieving biodiversity goals is to undertake works on farmland to address hydrological and other threats to conservation values. Ultimately for an agricultural solution to be adopted it must also be economically viable.

Thus a secondary goal in recovery catchments, including BMNDRC, is:

> *To contribute to the development of technologies to combat salinity throughout the agricultural region.*

Nonetheless, in the management of NDRCs, the primary goal of protecting biodiversity assets threatened by salinity always takes priority and provides the key focus for management actions. While the primary goal of maintaining biodiversity assets may not be a major focus for many landholders in the BMNDRC, an area of mutual interest is the development of technologies to combat salinity that can be used on a broad scale basis to support a more sustainable, economically viable agriculture. For example, limiting the spread of saline and waterlogged areas will benefit agriculture and biodiversity conservation. Sustainable land use will also contribute to delivering priority values for biodiversity conservation. Another example is that improved surface water management contributes to the maintenance of ecosystem services by reducing erosion, waterlogging and improving the quality of stream water flows.

There are already research and management activities underway in the BMNDRC which will protect biodiversity, develop technologies to combat salinity and provide immediate benefits to catchment landholders. These activities contribute to on-farm water and stock management and include:

- a surface water management demonstration site implemented in 2005-2006 which involves five farming properties;
- continuing work on the development of new commercial industries based on mallee eucalypts in the catchment and elsewhere in the south-west; and
- fencing for the protection of native vegetation and revegetation of areas for conservation, including highly erosion-prone areas and sites generating waterlogging on farms.

In turn these activities are expected to contribute to:

- our understanding of important principles and experience in implementing water management in similar landscapes and soil types;
- development of economically viable solutions for water management which also benefit biodiversity conservation;
- increasing agricultural productivity across the BMNDRC; and
- delivering the priority cultural values for which biodiversity is being managed in the BMNDRC.

RESPONSIBILITIES AND OWNERSHIP OF GOAL IMPLEMENTATION

Implementing management actions to achieve the goals of this recovery plan is primarily the responsibility of the Department of Environment and Conservation (DEC), which has a statutory responsibility for managing biodiversity in Western Australia and is the lead agency in the NDRC program. This is reflected in State Government policy such as the WA Salinity Strategy. The department is accountable, through the Western Australian Environment Minister, to the WA community for delivering biodiversity conservation outcomes. The BMNDRC Steering Committee has an advisory role and does not have statutory responsibility for implementation of the recovery plan, although it has strong ownership of the goal and management actions described in this plan.

There are a number of factors that affect ownership and implementation of recovery plan actions:

- **Support of private landholders** Most of the land (95 per cent) in the BMNDRC is held as private property and recovery actions may only be undertaken with the approval of the relevant freehold landholders. Management of the catchment's altered hydrology, in particular, requires significant action on private lands. Achieving the goal of the plan depends on the support of most catchment landholders.
- **Primary management goals of landholders** Most of the management actions proposed for farmland will need to be consistent with the economic needs of landholders. The department acknowledges that while many landholders support the aspirational goal for the BMNDRC, the primary management goal of landholders may differ and economic viability remains of paramount concern. It is therefore important that management actions proposed for farmland meet the primary needs of farm managers as well as those of the BMNDRC. Management actions that meet the goals of all partners will best integrate land use and recovery catchment activities.
- **Landholder support for biodiversity conservation** The BMNDRC Landholder Survey (CALM & Colmar Brunton 2005) revealed that attitudes towards wetlands and their assemblages vary. Some wetlands, such as fresh water wetlands with fringing vegetation, are valued for their amenity and productive use values. Others, for example saline playa lakes, are valued more for their recreational opportunities such as water skiing and/or their landscape amenity values. Generally, landholders feel limited affinity for the wetlands of the BMNDRC. This may be attributed to several reasons, for example a focus towards agricultural production and/or a lack of understanding of the nature conservation values and the wetlands' contribution to human quality of life.

Nonetheless, in selecting this catchment there was widespread local community support for the BMNDRC project. Local catchment groups have been proactive in implementing conservation works for several decades. The results of the BMNDRC Landholder Survey confirmed this commitment, with landholders providing numerous examples of their actions to mitigate land degradation issues and indicating their willingness to be involved with the BMNDRC project. Most recently, the Steering Committee has identified and prioritised the cultural values from biodiversity conservation in the BMNDRC that will be delivered through the implementation of the recovery plan.

OPPORTUNITIES FOR ENGAGEMENT

Management strategies in this plan have been developed with an understanding of the above factors. The activities undertaken as part of this recovery plan acknowledge local needs and allow landholders to further their aims for economically viable, sustainable land use. While accountability for implementation rests with the department, achieving the aspirational goal for the recovery catchment requires actions which bring together a diverse set of land use issues, a number of landholders, community groups and agencies in a collaborative and focussed way.

For landholders, the BMNDRC project provides a unique opportunity:

- for priority access to new knowledge relating to salinity management;
- for better access to funds for on-ground works that integrate the needs of sustainable agriculture and biodiversity conservation;
- to collectively contribute to defining and implementing solutions to land degradation problems;
- to participate in the development of new industries for agricultural lands that provide a range of environmental benefits; and
- to conserve the biodiversity of the catchment for future generations.

3 DESCRIPTION OF THE BMNDRC

PLANNING AREA

The Buntine-Marchagee Natural Diversity Recovery Catchment is a sub-catchment of the Moore River and is located in the northern wheatbelt of Western Australia – approximately 280 kilometres north-east of Perth and 130 kilometres inland (Attachment 2). It covers 181,000 hectares extending 60 kilometres from east to west and 40 kilometres north to south. It is part of the Northern Agricultural Region[9] and includes the townsites of Buntine and Wubin, while Coorow, Dalwallinu, Marchagee and Watheroo are all in the vicinity of the catchment[10] (Attachment 2). The boundaries of the catchment and land tenure are shown in Figure 1 of *Appendix 5*, and Table 1 provides an overview of the planning area.

DEC manages 2,225 hectares of public land or 1.2 per cent of the catchment. This land, vested with the Conservation Commission of Western Australia, comprises six nature reserves. Buntine Nature Reserve is the largest at 1,921 hectares (this does not include the western half managed by the Water Corporation), followed by three unnamed reserves (157ha, 120ha and 114ha), Jocks Well Nature Reserve (40ha) and Nugadong Nature Reserve (10ha). The remaining land (3.8 per cent) includes various shire reserves, road reserves, unallocated Crown land (UCL) and other tenure types. Eight landholders have voluntary nature conservation covenants on their properties, which provides a level of protection for a further 745 hectares of remnant vegetation (CALM & Colmar Brunton 2005).

Table 1. Overview of the BMNDRC planning area.

Percentages shown are the proportion of the catchment in a particular administrative region.

Local Government Shires (4)	Dalwallinu (60%) by area Coorow (31%) Moora (8%) Perenjori (1%)
DEC Administrative regions (2)	Wheatbelt Region (Avon-Mortlock District – 59% by area) Midwest Region (Moora District – 40% by area and Geraldton District – 1% by area)
Land tenure	Freehold (95%) – 84 landholders with an average property size of about 2,400ha DEC managed land (1.2%) Other tenure (3.8%)

SOCIAL, ECONOMIC, CULTURAL AND PHYSICAL CHARACTERSITICS

An overview of the BMNDRC including:

- **Social and economic characteristics** which describes community and economic profile and infrastructure
- **Cultural heritage** which outlines Indigenous and non-Indigenous cultural heritage and recreational use
- **Physical characteristics** which briefly describe climate, regional geology and geomorphology, soils, land capability and surface and groundwater hydrology

is provided at Attachment 3 which also provides links to additional supporting information in the appendices.

DRYLAND SALINITY AND ALTERED HYDROLOGY

Dryland salinity (or secondary salinity) is just one of the many effects of altered hydrology in the Australian landscape that poses a threat to biodiversity. Altered hydrology has resulted from changed water balance due to the removal of native vegetation (high water users) for widespread adoption of annual crops and pastures (low water users). Along with the changes in extent and magnitude of salt-affected areas, other impacts of altered hydrology may include:

- **Hydroperiod changes** including the area, distribution and timing of inundation, can cause negative environmental impacts independent of water quality. Such changes may pose a significant threat to biodiversity assets.

9 The Northern Agricultural Region covers 7.5 million hectares and has a population of 60,000 people. The regional centre is the City of Geraldton which, with the associated Greenough urban areas, accounts for approximately half of the region's population. The region extends northwards from Gingin to Kalbarri, and eastwards to Kalannie.

10 The catchment boundary is defined by a polygon bounded by the following coordinates: NW –29.8828° lat, 116.0819° long; NE –29.8615° lat, 116.7015° long; SE –30.3124° lat, 116.7078 long; SW –30.3070 lat, 116.0810 long.

- **Waterlogging** through increases in soil water content, regardless of the quality of the water, can also cause negative impacts. Vegetation found higher in the landscape and fringing wetland vegetation may be affected.
- **Acidity changes** including elevated levels of acidity (low pH) can cause many negative environmental impacts. While acidity itself can cause condition decline/mortality of flora and fauna, metals and other pollutants that are also associated with acidic water can also have negative environmental effects. It should be noted that increases in alkalinity (high pH) can also have undesirable effects, although this is less common.
- **Erosion increases** causing the loss of topsoil and development of deeply incised channels in drainage lines. Potential undesirable impacts of increased erosion include poor slope stability and high rates of vegetation mortality in drainage lines due to exposure of roots.
- **Sedimentation increases** as a by-product of excessive erosion, can result in accelerated sediment deposition rates downstream. This can alter flow regimes. Typically, increased sedimentation also creates areas of waterlogging in drainages as surface water cannot flow away as easily.
- **Water composition changes** to ionic ratios and concentrations of various components including acidity and salt (NaCl) can cause negative impacts. Increased input of the nutrients phosphorus and nitrogen may lead to algal blooms and eutrophication. Decreases or depletion in ions such as potassium, calcium or magnesium can also cause environmental conditions to become intolerable to some biota.[11] For example, native aquatic snails cannot survive where chemical conditions prevent them from producing shells.

The term dryland salinity commonly implies that salt is the only problem. Altered hydrology is, therefore, a better way to describe the complex set of processes which can result in the loss of biodiversity in the wheatbelt. All of the impacts of altered hydrology described above can threaten the survival of native species, biological communities and ecosystems. It is therefore important to understand the physical characteristics of an area, as well as the tolerances and thresholds of plants and animals to hydrological and associated changes (both increase and decrease).

BIODIVERSITY ASSETS

The aspirational goal for the BMNDRC is couched in terms of maintaining current natural biodiversity which is described here as biodiversity assets. A biodiversity asset is a living entity – such as a single organism, a population of organisms, or a living assemblage – that is considered important to humans in the terms of the values described in Section 2.

Attachment 4 provides a comprehensive description of what is currently known about the biodiversity assets of the BMNDRC. However, it should not be considered definitive, as each new biological survey collects new information. As work in natural diversity recovery catchments is focused on conserving representative biological communities of native biota threatened by salinity the emphasis of this report now shifts to the assets that are threatened by altered hydrology including salinity.

BIODIVERSITY ASSETS THREATENED BY SALINITY

Not surprisingly, nearly all the native biota threatened by salinity occurs in assemblages on valley floors. A significant proportion of the biota either lives in, or is associated with, wetlands. Other valley floor assemblages, for example those associated with salmon gum and morrel communities, are also highly threatened by salinity in the BMNDRC.

Based on their occurrence low in the landscape, 11 plant taxa (of 45 threatened plant taxa) are considered to be threatened by salinity. These comprise assemblages characterised by *Eucalyptus loxophleba* over *Melaleuca thyoides* and *Halosarcia doleiformis*, *Allocasuarina campestris* thickets and medium woodlands of *Eucalyptus loxophleba* and *Eucalyptus salmonophloia*. A baseline survey of littoral (wetland-fringing) vegetation in the BMNDRC was conducted in 2004 (Richardson,et al. 2005). Wetlands were most commonly fringed with samphire and a variety of herbaceous species, with an overstorey of *Melaleuca* spp. or *Casuarina obesa*. Seven of the 27 surveyed wetlands supported aquatic vegetation at the time of sampling and a total of eight species of water plants were collected[12].

The condition of fringing plant communities ranged from almost pristine to heavily impacted, according to the influence of groundwater rise and land management regimes in the vicinity. Vegetation of wetlands higher in the landscape tended to be consistently in better condition, with granite rock outcrops maintaining the most intact natural suite of flora.

There is currently not enough information available on the altered hydrology of the BMNDRC to specifically identify all areas at greatest risk of salinity. However the preliminary assessment of salinity risk presented here is

11 Precipitation of gypsum ($CaSO_4$) due to increased input of SO_4 from drainage can deplete a water body of calcium and impact on macroinvertebrates or gastropods. Chemical reactions such as precipitation can cause this. Plants are also susceptible to changes in the ionic content of water.

12 It should be noted that describing aquatic vegetation was not the principal aim of this survey and so the methodology employed does not provide a comprehensive coverage of these wetlands.

based on landscape position and the assumption that areas of the BMNDRC at the highest risk from secondary salinity are located near the valley floor or lower-slope landscape positions. As areas low in the landscape are most likely to be impacted by altered hydrology, wetlands and valley floor assemblages are the primary focus of current investigations and planning. Areas located in mid- to upper-slope positions, particularly in deep sands without sub-surface impediments (such as dolerite dyke intrusions), are considered to be at a lower threat from salinity. Attachment 5 is a summary list of taxa and assemblages considered to be threatened by altered hydrology and the effects of secondary salinity.

PRIORITY BIODIVERSITY ASSETS

Although under the aspirational goal conservation of all biodiversity assets threatened by salinity is the aim, it is important to focus attention on those assets of highest biodiversity value threatened by salinity. These may be separated into three groups.

- **Species of significance** threatened by salinity, often threatened species and others covered specifically by legislation.
- **Wetland assemblages**, particularly those which best represent the range of taxa and community types threatened by salinity, together with any newly identified occurrences of known TECs that are threatened by salinity.
- **Valley floor assemblages**, again, specifically those which best represent the range of taxa and community types threatened by salinity, together with any newly identified occurrences of known TECs that are threatened with salinity.

Each of these groupings is discussed further below.

Species of significance

A list of those species threatened by salinity is being collated[13] from the following sources: Storey et al. (2004a,b); Lynas et al. (2006); Western Australian Museum FaunaBase records; Huggett et al. (2004); Keighery et al.(2004); Burbidge et al. (2004); Short & Parsons (2004); CALM (1999a); Kitchener et al. (1979); Dell et al. (1979); Davies & Ladd (2000a,b); Threatened Flora Database records, DEC Species and Communities Branch; and Western Australian Herbarium records.

It should be noted that individual species with a formal threatened status – such as Declared Rare Flora – are dealt with through an existing recovery planning process. In addition, other species of significance threatened by salinity – such as geographic outliers and taxa of phylogenetic interest – will generally form part of the communities that are the focus of this plan. That is, most of these taxa will be managed as part of the assemblages covered below.

Wetland assemblages

The BMNDRC contains more than 1,000 discrete individual wetlands. The majority (69.5 per cent) of these occur low in the landscape along valley floors. Many key biodiversity assets are associated with wetlands because these areas are associated with much of the native vegetation remaining in the catchment and provide important habitat for many of the remaining fauna. Consequently, wetland assemblages contain most of the important, representative samples of biodiversity threatened by salinity in the catchment. They have therefore been the major, initial focus for recovery action.

The water chemistry and physical characteristics of wetlands strongly affect the range of biota that lives within them. These characteristics are often used by biologists to classify wetlands into those that will carry different assemblages of plants and animals. Work undertaken in the BMNDRC has identified specific biological communities associated with six wetland types[14]. Refer to *Appendix 10* for a description of the wetland characterisation process used and *Appendix 11* for rationale of prioritisation.[15] One of these wetland types, granite rock pools are not threatened by salinity within the catchment, and is thus not considered further in this plan. The remaining five types and the specific wetland assets selected as being representative are described at Table 2 and the locations of these assets are at Attachment 6. These are the priority representative assets that will be the focus of further investigation and monitoring.

Valley floor assemblages

Remnant vegetation of the valley floor is a major component of the biodiversity in the BMNDRC and is used here as a primary surrogate (a substitute measure) of biodiversity. The vegetation associations mapped by Huggett et al. (2004) have been used as the basis for a preliminary analysis of the priority status of remnant

13 A database of taxa threatened by altered hydrology will be created and used to help evaluate management success in the context of the operational goal. This database will be a work in progress and will be updated as new data is collected. This database will also help assess how representative the biological communities being managed are and identify species that require special management.

14 The wetland characterisation process will be reviewed following the first round of wetland investigation and monitoring work in the BMNDRC. It will also take into account the results of work on wetland classification being undertaken in the Avon catchment in the south-west of Western Australia. The Avon work is due for broad area testing in the Avon during winter 2007.

15 The BMNDRC Steering Committee considered and supported this selection and ranking process at their March 2006 meeting. All wetland assemblages will eventually be ranked.

Table 2. Wetland types and representative assets selected
(note that bold items are those that will be focussed on first)

Wetland type	Description	Representative assets
Primary saline wetlands and channels	These make up a braided chain of wetlands rich in biodiversity assets along the lowest point of the landscape in the valley floor. They comprise mostly broad, shallow basins that experience seasonal or periodic inundation and include numerous meandering river channels.	**W004** W061 **W070** SPS203
Gypsum wetlands	These lakes result from a particular regime of salinity which favours the precipitation of gypsum by evaporation and the leaching of sodium chloride. Seasonal streams rich in calcium and sulphate ions and low in detrital materials such as sand and clay appear to provide the appropriate conditions for gypsum lake formation (GSWA 1990). Of the few examples identified all appear to be isolated from the main drainage lines. The precise salinity threat is unknown but considered moderate to high due to their low position in the landscape.	**W001** There are two other known gypsum lakes in the east of the catchment; north of Bailey Road and adjacent to the main drainage line.
Fresh/brackish wetlands	These are seeps (expressions of the water table) that have formed on sandy soils in the west of the catchment. They are generally fresh to brackish, occur at the lower to mid point of the landscape and many are considered moderate to highly threatened by altered hydrology.	W009 **W011+W012 + 109** **W015 + W016** W020
Bentonite wetlands	A small number of basins have this unique substrate type. The floors of bentonite wetlands support a distinctive suite of vegetation. The precise threat of altered hydrology is unknown, but is considered relatively low as they typically occur high in the landscape and depth to groundwater post 2006 investigations is relatively large (URS 2007).	**W057 + W058 + W059**
Freshwater claypans	Shallow, rain-filled, ephemeral wetlands that are known to contain species not found in other wheatbelt wetlands, and as such represent a habitat type that is now highly restricted. One freshwater claypan has been identified within the BMNDRC. Being situated in the upper part of the landscape the threat of altered hydrology is considered moderate to low.	W074 This wetland is highly modified. Further work is required to identify whether there is a better representative of this wetland type.

vegetation biodiversity assets. About 30 per cent (6,757ha) of the remnant vegetation in the catchment is within the 'existing' or 'at risk' area of secondary salinity – according to Land Monitor categories (DEC 2007). Of this 30 per cent, it is estimated that 20 per cent (1,351ha) are areas with a low gradient directly adjacent to the main drainage line of the BMNDRC. There are also 11 Declared Rare and Priority taxa known to occur in close proximity to the valley floor (Refer to Table 10, *Appendix 7*, or Attachment 3).

The methodology used here to analyse remnant vegetation and to identify and prioritise remnants was a three step process which is set out in detail at *Appendix 12*. In summary, there were three steps to the analysis:

1. An assessment of:
   - the extent and representativeness of vegetation remnants using the principles of the Comprehensive, Adequate and Representative (CAR) reserve system process which is used at a national level
   - areas with a potential or existing salinity risk
   - size, condition, connectivity and shape of remnant vegetation.
2. Allocating remnants to high, medium and low priority classes by taking into account their associated salinity risk
3. Overlaying of biodiversity assets of priority wetlands with flora priorities as determined in the catchment flora analysis.

The analysis (as of June 2007) has progressed to the point of identifying priority remnants of valley floor assemblages associated with representative wetland types (see Table 2 above). However, there are some limitations in the analysis and further work is needed to better prioritise and select a representative sample of terrestrial vegetation assemblages in addition to those associated with wetlands.

The limitations are:

- Wetland associated vegetation mapping (particularly along drainage lines) has not been completed and was not part of the CSIRO work described in Huggett et al. (2004).
- A review of vegetation types on Koobabbie Farm is required as it was not included in the Huggett et al. (2004) survey.
- Broad scale pre-European vegetation extent of Beard (1980) does not distinguish non-mallee woodlands.
- The generic mapping of areas at risk of developing shallow water tables lacks refinement in terms of valley floors. Mapping of other areas potentially at risk in the landscape is needed to have a complete coverage of salinity risk.

The future work proposed to address these constraints is:

- map the vegetation of the main drainage line;
- map areas with evidence of pre-existing vegetation types;
- consult aerial photography and historical records of the J.S. Battye Library;
- map the vegetation of Koobabbie Farm using the same methods as Huggett et al. (2004);
- investigate the feasibility of mapping salinity risk in other areas (besides valleys) of the BMNDRC;
- select a primary set of assets threatened by salinity (i.e re-run steps 1 and 2 of analysis);
- assess the feasibility of protecting these assets;
- develop a work program for priority terrestrial vegetation assets (integrating this, where possible and appropriate, with work on priority vegetation associated with wetlands).

The priority biodiversity assets of the BMNDRC identified here are the wetland and terrestrial vegetation assemblages and protected species threatened by salinity. These are considered to be representative of the biodiversity of the BMNDRC and will be the focus of the recovery plan.

4 SETTING PRIORITIES FOR MANAGEMENT

BIODIVERSITY ASSETS – MEETING THE ASPIRATIONAL GOAL AND DELIVERING PRIORITY CULTURAL VALUES

The full range of biodiversity asset types in the BMNDRC described in the previous section identified two main groupings – species and biological communities threatened by salinity. Of these, wetlands and valley floor assemblages were considered the priority biodiversity assets threatened by salinity which best represent the biodiversity of the BMNDRC. Consequently, these assets are the focus for this recovery plan. Individual species with a formal threatened status are dealt with through existing recovery planning processes. Actions undertaken as part of this plan will complement existing management of threatened species where overlap occurs. In addition, other species of significance threatened by salinity – such as geographic outliers and taxa of phylogenetic interest – will generally be covered by actions to protect the biological communities that are the focus of this plan.

To meet the aspirational goal for the catchment we now need to consider specifically which of these assets and how much of them will be needed to deliver the priority cultural values identified in Section 2, and thus meet the expectations of the State, regional and local communities. The links between cultural values, the result of recovery actions, and biodiversity assets is summarised in Table 3.

It is clear from this table that all the current biodiversity assets threatened by salinity need to be conserved to achieve the key cultural values, and this is consistent with the goal. However, to achieve some ecosystem services will require recovery of some biodiversity assets in addition to conservation of existing ones. For example, Short et al. (2006) identified that human-induced sedimentation is occurring in the catchment, especially in the low-lying areas. Thus revegetation of some areas degraded by salinity is needed to achieve the required level of nutrient stripping and sediment-trapping services. It should be noted that management of priority wetlands and their biota as identified in Section 3 will also contribute directly to these services and provide the knowledge to extend management to other wetlands and thus further deliver services.

The critical question that now needs to be addressed is whether it is feasible for management to conserve and recover the biodiversity assets to achieve the goal and deliver the cultural values. This is dealt with in the next section.

Table 3. Linking recovery achievements to priority cultural values and related assets.

Priority cultural value	In relation to the cultural value, management in BMNDRC will deliver the following outputs:	Related assets
Ecosystem service values	Improve or maintain the medium-term capacity of wetlands to: • buffer downstream salinity by safely storing and releasing salts; • reduce downstream nutrient loads through helping to manage nutrient losses from farmland, and maintaining or improving the capacity of wetlands to 'strip' nutrients; • contribute to flood mitigation by safe storage and discharge of water (includes management of sediments to maintain buffering capacity of wetlands); and • reduce downstream sediment loads by helping to manage sediment losses from farmland, and maintaining or improving the capacity of wetlands to safely store and discharge natural levels of transported sediments.	*Wetlands and associated biodiversity assets* To fully deliver this value, the aspirational goal at a minimum would need to be achieved. Recovery of additional assets and related ecosystem processes is also likely to be required. In the interim, the management of priority wetlands and their biota identified in Section 3 will directly contribute to these services, plus provide the knowledge to extend management to other wetlands and thus further deliver these services. Note that improved management of surface water (including revegetation), as in the current demonstration site, will make an important contribution to delivering these services.
	Improve or maintain the medium-term capacity of remnant vegetation to: • buffer some hydrological change in the catchment; • mitigate wind and soil erosion; and • sequester carbon, and thus mitigate climate change.	*Remnant vegetation assemblages* The management of all remnant vegetation, particularly priority vegetation assemblages and their biota, will directly contribute to these services. Knowledge gained from managing priority areas can be extended to management to other remnants.
	Undertake catchment revegetation that contributes to all the above services. Note that these services will also assist in the protection of a range of biodiversity, land and water values.	*Revegetated areas* Areas that are revegetated as part of recovery management works will, particularly where native species are used, help deliver most of the services listed, as well as provide additional habitat for native biota.
Philosophical/intrinsic/ spiritual values	Protect important, representative assemblages and thus make an important contribution to this value by, for example, maintaining the local identity (sense of place) for those living in, or regularly visiting the catchment.	Genetic, taxonomic and assemblage diversity, as represented in the above assets, will be better conserved through recovery actions.
Opportunity values	Through the protection of representative assemblages and their biota, ensure that future opportunities for economic development of germplasm, leisure opportunities, and other cultural values presently underutilised are protected for future generations.	Genetic, taxonomic and assemblage diversity, as represented in the above assets, will be better conserved through recovery actions.

FEASIBILITY OF MANAGING KEY BIODIVERSITY ASSETS THREATENED BY SALINITY

Feasibility in salinity management is defined in Sparks et al. (2006) as the extent to which an asset can be protected from salinity. It requires assessment of:

- biophysical threats (Refer to Appendix 13 for a full range and description);
- technical capacity and knowledge to manage the asset in light of the biophysical threats (including an assessment of the costs to manage);
- socio-political will/capacity to apply adequate resources to achieve the goal for an asset; and
- confirmation of the goal or assets in question given the outcomes of the feasibility analysis – for example, it may prove necessary to amend goals if it is not currently feasible to achieve them.

Although altered hydrology is the main process threatening biodiversity assets identified for recovery under this plan, a management feasibility analysis must review all the known and potential biophysical threats. This is because one or more threats may have a significant effect on management outcomes. For example, while it may be feasible to manage the threat of altered hydrology to a wetland biodiversity asset, it may be much more difficult to prevent an invasive weed from destroying key elements of wetland biodiversity. Therefore, the feasibility of managing both threats needs to be determined to evaluate whether management is practicable.

BIOPHYSICAL THREAT ANALYSIS

The threat analysis technique used here is based on Wallace et al. (2003). It is a way to account for all biophysical threats in relation to goals for biodiversity management[16]. The process of estimating probabilities was completed by an expert panel at a planning workshop held in December 2003. The temporal scale (20 years) and spatial scale (biodiversity assets threatened by salinity) of the analysis reflects the aspirational goal and all the assets threatened by salinity described in Section 3.

The expert panel estimated the probability of goal failure due to each biophysical threat, and the results are described in Table 4. The first probability shown is that of goal failure if no resources are applied (i.e. the 'do nothing' option). This analysis proposes that a probability of greater than 0.25 needs careful consideration as to whether management would be feasible.

The second column of probabilities is an assessment of the probability of goal failure if resources are applied (i.e. if effective management action is taken). For each of the management issues a probability of 0.2 or less is taken here to represent an acceptable level of risk.

The expert panel assessment did not estimate the probability of goal failure due to climate change. Although acknowledging its importance, the panel did not have adequate data on which to base an assessment. In addition, the panel recognised that key recovery actions to counter salinity, particularly revegetation, presented the most important opportunity for the department to act in relation to mitigating climate change and its effects. However, climate change is clearly a threat that needs to be investigated further in relation to this recovery plan. Addressing climate change as a biophysical threat in this plan will be considered as part of the response to changed biogeochemical processes, specifically, as part of the response to the threat of altered hydrology and insufficient resources to maintain viable populations.

16 To undertake a quantitative threat analysis, a detailed understanding of spatial and temporal trends of hydrological, physio-chemical and other ecological trends is required. Given the lack of quantitative data in the BMNDRC, an alternative decision support tool which estimated the probability of threats leading to goal failure was used.

Table 4. Probability of specific threats causing goal failure in the BMNDRC with and without management

Aspirational goal: *'For the next 20 years, maintain the 2007 richness, distribution, abundance and condition of biodiversity assets threatened by salinity within the BMNDRC.'*

Threat category	Management issue	Probability that threat will cause goal failure, existing management[1]	Probability that threat will cause goal failure, with extra management[2]	Assumptions underlying initial probability assessment
Altered biogeochemical processes	Hydrological processes, particularly salinity	1.0	0.3*	Assumes a feasibility assessment would confirm this. Further degradation of valley floor wetlands may be limited with surface water management.
	Nutrient cycles, including eutrophication	0.6	0.1	Assuming effective farm management of stock and fertiliser use.
	Carbon cycle and climate change	-	-	**Probability not estimated but see comments in text.** Will be addressed through future work on altered hydrology and climate change.
Impacts of introduced plants and animals	Environmental weeds	0.6	0.05	Assumes resources available to remove major problem species (e.g. introduced Typha and Juncus).
	Feral predators	0.2	0.05	Assumes effective fox and cat control to maintain low numbers. Assumes introduced mice are not a problem.
	Preventing new introductions of damaging species	0.1	0.001	Assuming state and federal management.
	Herbivory by introduced species	0.2	0.05	Assumes effective rabbit control.
	Competition for food and shelter (other than as above, and includes habitat damage by pigs)	0	0	Assumes no pig or goat introductions.
Impacts of problem native species	Parrots	0.2	0.001	Assumes effective parrot control to enable effective revegetation.
	Defoliation by scarabs, lerps, etc.	0	0	No known issues.
Impacts of disease	Dieback (*Phytophthora spp*)	0	0	No known issues.
	Armillaria	0.01	0	Assumes effective management of heavy equipment.

* Note that this score contributed towards reassessment of this goal (see page 27).

Table 4. Probability of specific threats causing goal failure in the BMNDRC with and without management continued…

Threat category	Management issue	Probability that threat will cause goal failure, existing management[1]	Probability that threat will cause goal failure, with extra management[2]	Assumptions underlying initial probability assessment
Detrimental regimes of physical disturbance events	Fire regimes	0.06	0.06	Assumes one significant fire within four years burnt one asset threatened by salinity. Therefore 0.25 probability of assets threatened by fire and 0.25 probability that a single fire results in a local extinction of species is (0.25 x 0.25 = 0.0625).
	Cyclones	0	0	Probability of cyclones causing goal failure assessed to be zero – however the possible impact of tropical lows and extreme events in general will be addressed through future work on altered hydrology and climate change.
	Drought	-	-	Probability not estimated. Will be addressed through future work on altered hydrology and climate change.
	Erosion (wind and water, includes sedimentation, acid water and heavy metals)	-	-	Probability not estimated. Need to investigate if deep drainage is having a critical impact on biodiversity assets.
	Flood	0.2	0.1	Assumes surface water management and related revegetation will manage excessive inundation.
Impacts of pollution	Herbicide/pesticide use and direct impacts	0.2	0.1	Assumes that relevant guidelines are being followed. Assumes no major broad scale control of locusts required during next 20 years.
	Pesticide surfactants and impacts	0.001	0.001	Assumes that relevant guidelines are being followed.
	Oil and other chemical spills	0.001	0.001	Assumes that relevant guidelines are being followed.

Table 4. Probability of specific threats causing goal failure in the BMNDRC with and without management continued…

Threat category	Management issue	Probability that threat will cause goal failure, existing management[1]	Probability that threat will cause goal failure, with extra management[2]	Assumptions underlying initial probability assessment
Impacts of competing land uses	Recreation management	0.001	0.001	
	Agricultural impacts (other than as already dealt with above)	0.1	0.01	
	Consumptive uses	0	0	
	Illegal activities	0.1	0	Assumes contaminated sites guidelines are followed and enforced.
	Mines and quarries	0	0	Assumes neither bentonite nor gypsum are mined.
Impacts of community values	Food, water, shelter, oxygen, access to mates	0.2	0.1	Assumes that the department effectively identifies and explains the biodiversity values of the catchment to the community.
Insufficient ecological resources to maintain viable populations		-	-	Probability not estimated. Calculating minimum viable populations is a difficult issue that needs to be addressed by research beyond the capacity of this project.

1 Probability that threat issue will cause goal failure with current management inputs: The question being asked here is that, without additional management to that currently occurring, what is the probability that the specific threat-issue will result in non-achievement of the goal?

2 Probability that threat issue will cause goal failure with additional management inputs: In comparison with (1) above, the question being asked here is that, if resources are applied what is the probability that the specific threat-issue will result in non-achievement of the goal?

Scores are on the basis of threat of goal failure to any aspect of all biodiversity in the catchment. The threat to a specific component of biodiversity may vary from this general score.

The key biophysical threats with potential to cause goal failure (without management intervention) are changed biogeochemical processes and impacts of introduced plants and animals. The main management issues associated with these threat categories are:

- hydrological processes (particularly salinity and negative impacts of drainage such as waterlogging and inundation);
- nutrient cycles (including eutrophication);
- environmental weeds; and
- feral predators.

The most significant changes in probability estimates of goal failure are also associated with these main management issues. That is, this expert-based assessment suggests that additional management actions for the main management issues are expected to have the greatest effect on reducing the chances of goal failure by minimising the impact of threatening processes. However, as these are only estimates of probability it is important that the next two components of the feasibility assessment are carefully considered.

TECHNICAL CAPACITY AND KNOWLEDGE TO MANAGE

Having identified key biophysical threats to biodiversity assets in the context of the aspirational goal, the next step is to ensure that there is sufficient knowledge and technical capacity to manage these threats. The costs to implement management provides a valuable check on whether our level of knowledge is sufficient to effectively implement recovery action. That is, if the costs to manage are very high, this suggests that our knowledge and technical capacity is inadequate to manage the assets and achieve the stated goal.

The threats to biodiversity posed by altered hydrological processes – salinity, waterlogging and inundation – have been identified as the most significant threatening processes for the BMNDRC. An analysis of feasibility of managing biodiversity assets threatened by salinity was undertaken as part of the Salinity Investment Framework II (Sparks et al. 2006). The costs to government of managing the hydrology of the BMNDRC for the next 30 years was estimated through a desk-top calculation at $89.21 million. This was based on generic information about the catchment and its biophysical characteristics. These costs were recalculated as part of the same study, using more information. This increased the estimated costs for engineering and revegetation in the immediate vicinity of biodiversity assets by 88 per cent to $167.07 million[17].

While both estimates should be treated with caution given the paucity of data on which they are based, they do provide an indication of the level of resources required to protect all biodiversity assets in the catchment.

This translates into an annual cost for management of about $3 million per year, and potentially nearly doubles if the recalculation based on more detailed information is considered a more accurate estimate. These costs can only be reduced by research and development that makes the perennial revegetation component of recharge control economically attractive, and by significantly reducing the costs of discharge management. In this regard, it is interesting to note that if the revegetation component of salinity management is economically driven, the costs to governments may be reduced by nearly 50 per cent (Sparks et al. 2006). The implication of the current assessments of recovery costs is that further knowledge and technology development are critical to achieve the BMNDRC's aspirational goal efficiently. The only alternative to meeting these costs through additional funding is to change the goal, or reduce the scope of the goal. This issue is considered below in terms of an operational goal for the BMNDRC. However, the third component of the feasibility assessment – socio-political support – is considered first.

SOCIO-POLITICAL SUPPORT

Achieving conservation goals for biodiversity assets requires sufficient community support at all levels. In particular, this includes the local (particularly landholders in the catchment), regional and State communities; however, support at the national level is also important. Broad support is required to ensure that adequate resources are available for management. This is not simply a matter of funding – management will not succeed, or at least will be extremely difficult, without landholder support for management actions. In the BMNDRC, local landholder support is particularly important given the majority of land is privately owned.

Assessing what socio-political support exists for biodiversity conservation is largely through a process of consultation. The feasibility analysis of SIF II provided a timely and useful check of management costs at a State-wide and regional level for the biodiversity assets that have been identified as being threatened by salinity. It is considered that these estimated costs are significantly in excess of that which would attract socio-political support at the State and regional (and probably local) levels. That is, the funding level required to protect all the biodiversity assets is not considered socially or politically feasible given current knowledge and technical capacity.

17 There are a number of limitations to the methods used to assess the technical feasibility of managing representative landscapes that was used in the SIF II. A critique of these is provided in the SIF II report (Sparks et al. 2006).

At a local level, evidence of community support from the BMNDRC has been formally sought through the Landholder survey in 2003 (CALM & Colmar Brunton 2005) which attempted to gauge perceptions and attitudes of landholders to biodiversity conservation. The BMNDRC Steering Committee also provides a means for seeking community views and support for proposed management actions for the catchment. Agreement on an aspirational goal for the catchment has received broad support from the Steering Committee and is one measure of the support of the local community.

Varying individual landholder support for wetland values as biodiversity assets is, however, an interesting issue. BMNDRC landholders have varying attitudes towards wetlands and their assemblages (CALM & Colmar Brunton 2005). For example fresh water wetlands with fringing vegetation are valued for their amenity and productive use values. Others, such as saline playa lakes, are valued more for their recreational opportunities, such as water skiing and/or their landscape amenity values.

Establishing cultural values and their priority for the conservation of biodiversity was set out in Section 2. In general, the landholder survey has revealed that landholders' interest in the conservation of wetlands within the BMNDRC is unlikely to support the level of funding required to protect all biodiversity assets in the catchment.

In summary, consultation with a range of experts and stakeholders underlines that the projected costs of managing all the biodiversity assets threatened by salinity is unlikely to gain widespread socio-political support.

AN OPERATIONAL GOAL FOR THE BMNDRC

The priority setting exercise described above led to four conclusions:

1. To achieve the priority cultural values that are the goal of management, all the existing biodiversity assets threatened by salinity need to be conserved at a minimum. It was also noted that conservation of key assets threatened by salinity would partially achieve the cultural values.
2. A wide range of biophysical threats need to be effectively managed to achieve the aspirational goal for the BMNDRC. However, feasibility of management and the level of threat posed varies between management issues.
3. While we currently do not have enough knowledge of hydrological issues, there is sufficient knowledge and technical capacity to provide a high probability of success in threat management.
4. With current knowledge and technology, there is a very high cost to manage the hydrology of the catchment to achieve the goal for all biodiversity assets threatened by salinity. Given the predicted level of socio-political support, it is simply not feasible to achieve the aspirational goal for all the biodiversity assets threatened by salinity in the BMNDRC at this point in time.

The consequence of these conclusions, particularly the last point, is that there are three alternative options:

a) Recognise that we cannot achieve the aspirational goal, and shift the resources to a more feasibly managed catchment elsewhere, or set of sub-catchments within the BMNDRC.

b) Amend the goal for the BMNDRC to something that is more achievable. For example, an alternative goal would be 'to slow the current rate of decline of the richness, distribution, abundance and condition of biodiversity assets threatened by salinity within the Buntine-Marchagee catchment.'

c) Amend the goal to achieve the same outcomes, but for a smaller group of assets.

The BMNDRC Steering Committee decided to take a combined approach of (a) and (c) (CALM 2006). As a consequence, the focus of management effort will be on assets considered to be of highest value in terms of delivering the aspirational goal (rewritten as operational goal) and cultural values articulated above.

The operational goal reflects the decision to focus on a smaller sub-set of biodiversity assets. (These are the priority representative assets of wetland and valley floor assemblages which were identified in Section 3). The **operational goal** is:

> *'For the next 10 years, maintain the 2007 richness, distribution, abundance and condition of a representative sample of biodiversity assets threatened by salinity in the BMNDRC.'*

The immediate focus for the BMNDRC is therefore on priority representative biodiversity assets threatened by salinity, namely the most important wetlands and terrestrial vegetation assemblages identified in Section 3. Additional assets will be brought into intensive management as resources allow. That is, while this operational goal is one of containment for a sub-set of biodiversity assets, the intention would be to proceed to recovery if successful and sufficient resources are available. In addition, a minimum level of resources will continue to be applied outside the key assets to help maintain landholder engagement in the recovery process and at least slow the rate of decline of biodiversity assets outside those selected for immediate attention. It is also acknowledged that to achieve the ecosystem service values listed in Table 1, *Appendix 4*, it is important to facilitate a range of management activities throughout the whole catchment.

5 MANAGING THREATS TO REPRESENTATIVE BIODIVERSITY ASSETS

APPROACH

Conservation personnel manage ecosystem processes to sustain biodiversity and, through achievement of goals, maintain specified values. For efficiency, management effort is only directed at processes that distinctly threaten goal achievement. Consequently, management actions in the BMNDRC focus on threatening processes[18], particularly those that most put at risk the operational goal identified in Section 4. The issues dealt with here are those arising from:

- changed biogeochemical processes, particularly altered hydrology and climate change
- environmental weeds, disease, introduced and problem native animals
- regimes of physical disturbance
- an appropriate culture
- ecological resources to maintain viable populations

For each issue, activities are outlined below that significantly increase the probability of achieving the operational goal for the priority biodiversity assets identified in Section 3. With increased knowledge the required actions will be more accurately specified.

MANAGEMENT TERMINOLOGY

There is an overabundance of terms – such as goals, objectives, strategies, outputs, outcomes, performance indicators – available to describe planning. For clarity, the terms used here were chosen to mirror those used by regional natural resource management groups and therefore draw on the definitions in the *National Framework for Natural Resource Management Standards and Targets* and the *National Natural Resource Management Monitoring and Evaluation Framework* endorsed by the Natural Resource Management Ministerial Council in 2002 (Department of the Environment and Heritage 2003).The terms 'activity' and 'outputs' provide a common link into DEC planning processes[19].

The hierarchy of terms used is described in Figure 2 and the terms are defined in the glossary. These provide the framework to describe management actions including monitoring and evaluation methods explained in Section 6.

CHANGED BIOGEOCHEMICAL PROCESSES

Changed biogeochemical processes, which result largely from land clearing, present the most complex set of management issues of all threat categories. They are brought about by changes in the physical environment and associated physiochemical processes. The result of these alterations includes increased: frequency and extent of flooding and inundation, salinisation, acidification, erosion and sedimentation, eutrophication and waterlogging. Climate change is another mechanism which can alter biogeochemical processes both directly (e.g. changes in temperature, humidity, rainfall and evaporation) and indirectly by further affecting hydrology. Consequently, biogeochemical processes are discussed here separately for altered hydrology and climate change.

Altered hydrology

The potential impacts of altered hydrology were described in Section 3 and are summarised in Table 5. Many species and biological communities identified as key biodiversity assets in Section 3 are significantly threatened by altered hydrology.

The altered hydrological processes that threaten biodiversity assets in the BMNDRC affect the occurrence, quantity and quality of water in the landscape. To manage these processes it is essential to understand them, then to remediate existing and prevent future (where possible) negative impacts on biodiversity assets.

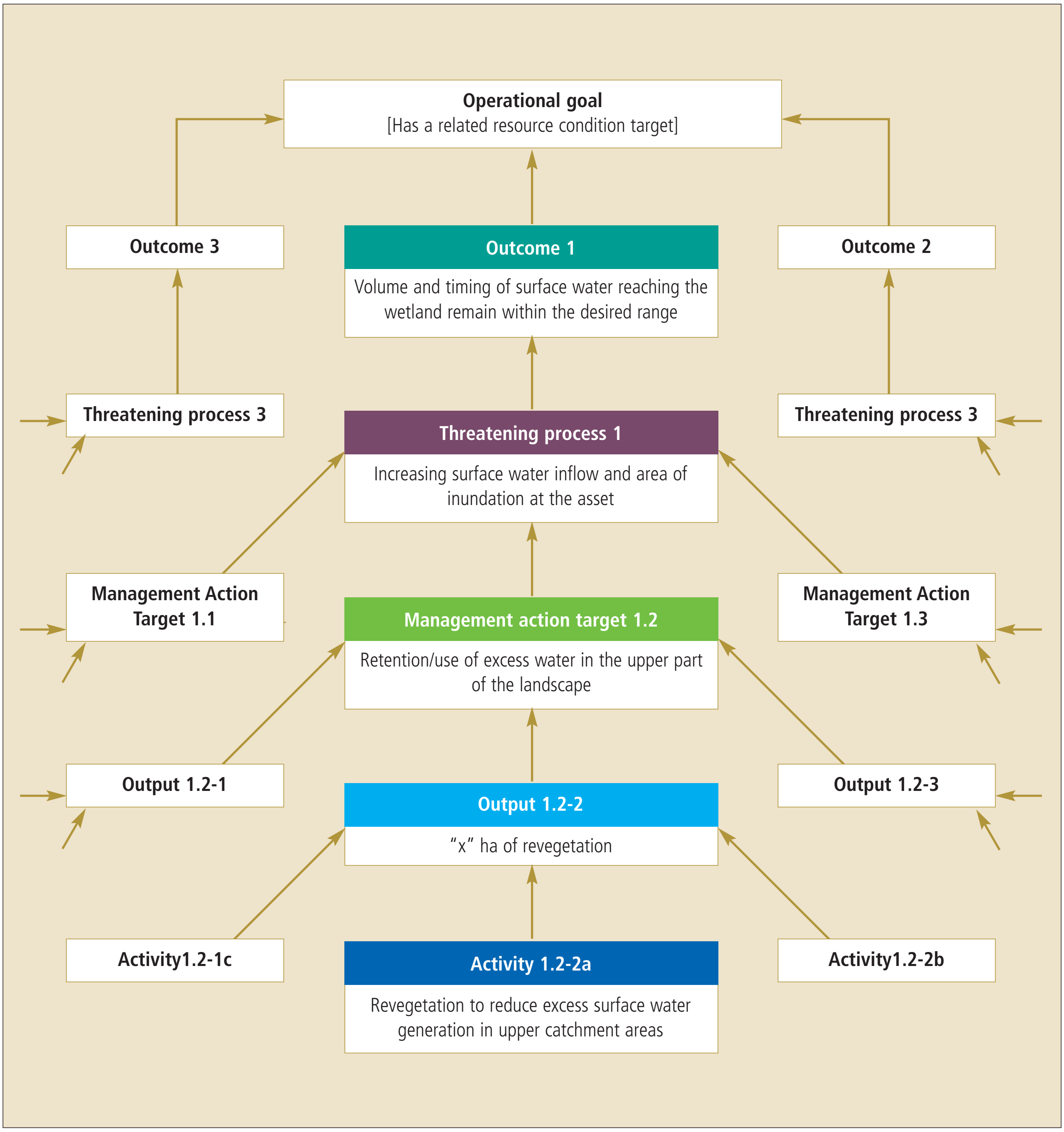
Predicted changes in climate patterns in south-west Western Australia and the impact on hydrology is discussed separately in the section on 'Hydrology and climate change' below and in Table 6 (IOCI 2005).

18 The range of biophysical threats is listed under the biophysical threat analysis in Section 4. A full description of threats is in *Appendix 13*.

19 It should be noted Management Action Targets (MATs) are quantified wherever possible. However, as setting targets is an iterative process and some of the work is in its early stages, some outputs will need to be delivered in order for their respective MATs to be framed as specific, measurable, achievable, realistic and time-bound.

Figure 2: Hierarchy of planning terms used in the recovery plan.

Includes examples for each level of the hierarchy for one sequence. Note that multiple outcomes are required to achieve the operational goal.



This recovery plan focuses on the four most significant management issues identified in the biophysical threat analysis. Each of the corresponding threat categories for these issues is considered separately below, along with the management activities required to address them.

Table 5. Summary of threats to biodiversity assets posed by altered hydrology

QUANTITY Surface water (hydrology)	QUANTITY Groundwater (hydrogeology)	QUALITY Waterborne (surface or groundwater)
• waterlogging resulting from slow or restricted surface water movement • erosion (soil, drainage line stream banks) • flooding, inundation and associated damage • altered wetland hydroperiod • soil and wetland salinisation	• waterlogging of vegetation root zone from rising groundwater • soil and wetland salinisation • increases in extent or flow rate of seepages • increased recharge, rising groundwater levels	• sedimentation and turbidity • nutrient cycle changes and excess quantities • eutrophication • spread of weeds • pesticides • acidification • salinisation • other contamination or deficiency

Figure 3 shows the complex, interconnected character of surface water and groundwater systems, with waterborne threats typically resulting from the interaction of water quantity and quality processes. Figure 4 schematically describes these underlying processes as they operate in the BMNDRC. Linkages between water quantity and quality are shown as dashed lines. Solid lines indicate cause and effect relationships in physical processes and products. For example, rising groundwater levels is a process which may result in increased soil moisture which leads to increased surface water flows as a product. This diagram also identifies threats where remediation is currently possible (bold boxes), and threats where initial activities will need to initially focus on filling knowledge gaps (double line boxes). It should be noted that water and waterborne outflows are not shown but an understanding of them is essential for modelling water and solute balances.

To understand the water and salt balances at either a catchment or sub-catchment scale, we need to measure water quantities and quality at multiple points in the landscape. This allows us to quantify the relative contribution and interaction among the various pathways (Figure 3) followed by water as a basis for designing targets for discharge and recharge management. The design and construction of various models is a key part of the analysis phase during which remedial measures are explored.

Water quality is strongly linked to water balance. For example, there are a number of waterborne impacts of altered hydrology, including increased salinity, which require an understanding of the water balance in terms of quantity, quality, and timing. To conserve the biodiversity values of the BMNDRC also requires an understanding of the water requirements (tolerances and thresholds) of plants and animals to changing ecosystem conditions, that is, their ecological water requirements (EWR). These are water requirements to sustain the ecological values of water-dependent ecosystems (including key biota) at a low level of risk (ANZECC and ARMCANZ, 1996). EWRs are effectively a subset of ecological condition indicators which reflect other characteristics of the environment besides hydrology. As a first step EWRs will be used as targets for management and modelling of altered hydrology (refer to activities relating to tolerances and thresholds in Table 7).

The complexity of interactions shown in Figures 3 and 4, and the year-to-year variability of climate in the south-west, underline that long-term data are critical to effective, landscape-scale management of biodiversity assets threatened by altered hydrology. With regard to the length of time required to typify a climate regime, changes therein and interactions with the physical environment, Lane et al. (2004) reviewed a number of authors and concluded that 'a period of at least several decades, perhaps more, does seem warranted'.

However, even with the current, modest level of knowledge concerning BMNDRC, it is clear that there is a range of on-ground actions that may be implemented to significantly improve the outlook for biodiversity assets. Detail on progress to date and the current level of investigation is given at the end of this section. A framework for monitoring and evaluation and an implementation plan is provided in Section 6.

Figure 3 Main components and schematic interrelationships of components of the water balance in a cleared landscape.

Note: Surface outflows not shown from the valley floor wetland, but an understanding of them is essential to develop a water balance.

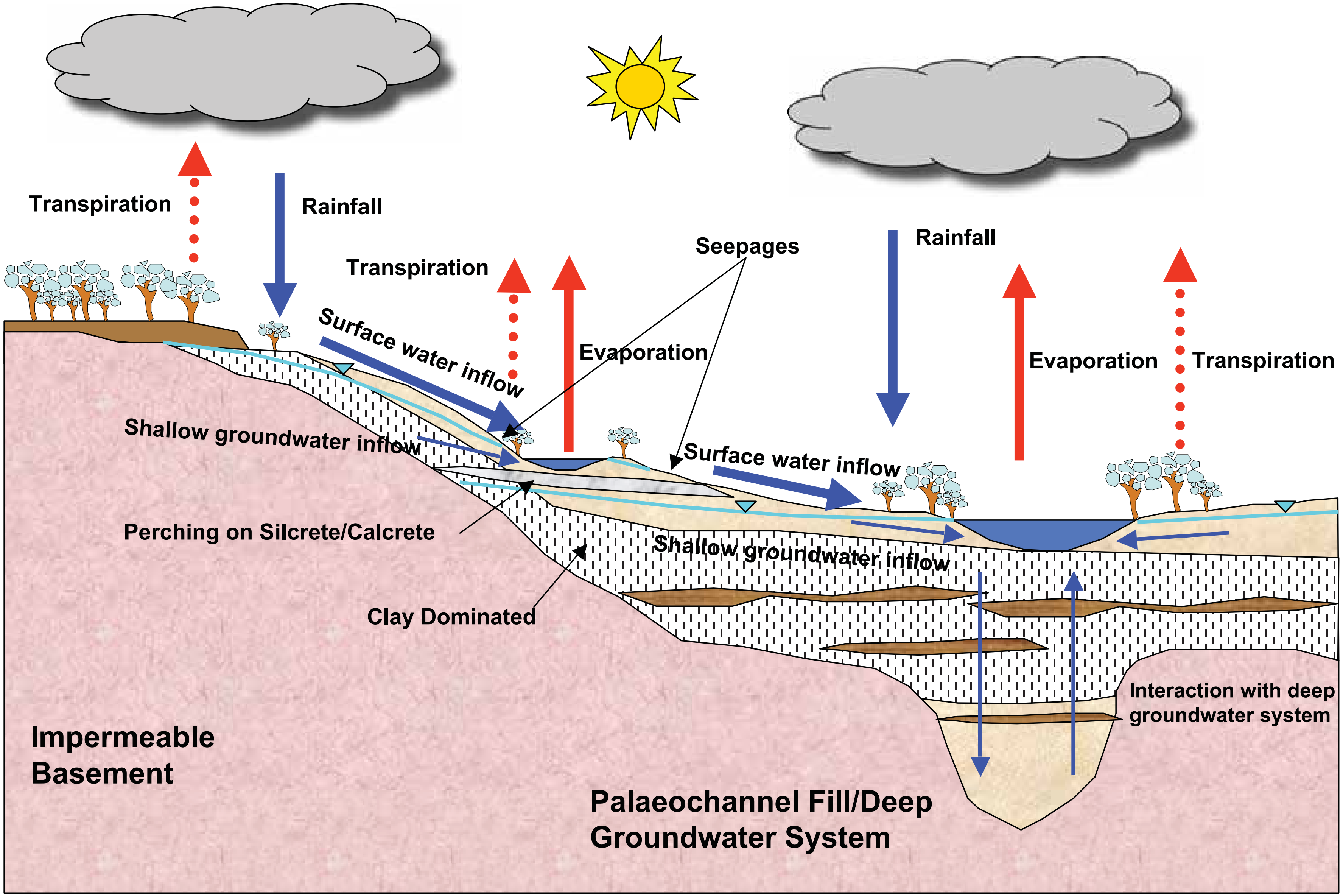
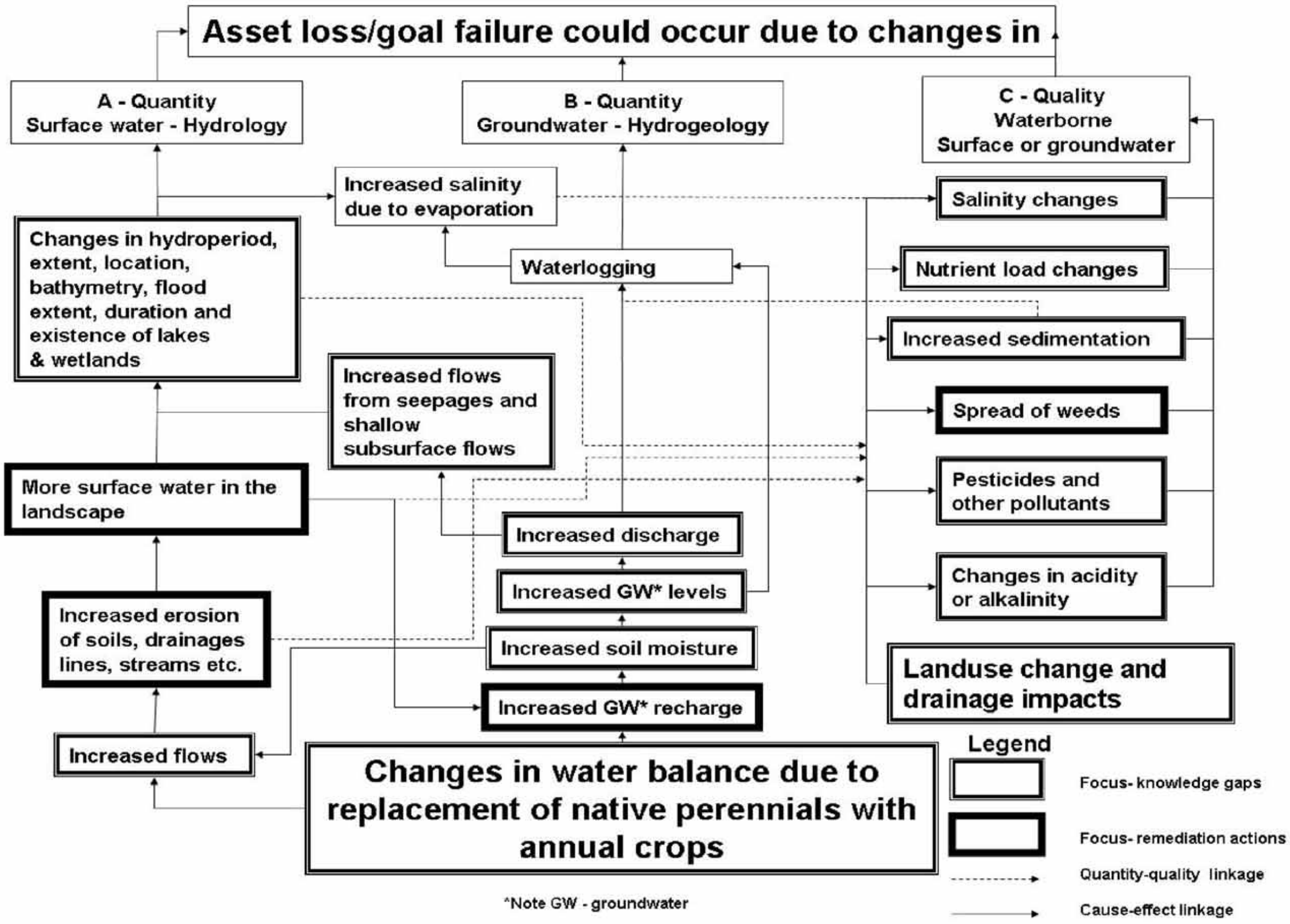


Figure 4. Quantity, quality, and cause-effect linkages arising from changes to water balance.

Note: Different styles of boxes identify areas where the current focus is remediation and others where the focus is on filling knowledge gaps.



Some of the on-ground actions that can be implemented now include:

- direct protection (fencing, management of environmental weeds, introduced and problem native animals) and linking of existing remnants to maintain and enhance their water use, particularly in the immediate catchments of the priority assets; and
- surface water management works to prevent waterlogging and recharge, and thus enhance the quality of water flowing to assets.

These actions enhance the current state of assets. While future investigations will lead to additional works and new approaches, these immediate actions will still be required as part of the overall management of altered hydrology. For example, surface water management and revegetation activities undertaken as part of an Integrated Catchment Management (ICM) project which covers the majority of the Inering Hills Land System in the BMNDRC will contribute to increased protection of biodiversity assets including priority wetlands and remnant vegetation identified in this plan. These activities will address some of the threats posed by altered hydrology and lack of ecological resources brought about by habitat loss. Future work will build on these current activities, but not replace them.

For many key assets, further investigation and monitoring is required to identify and quantify the critical pathways outlined in Figure 4. Although further investigations to fill knowledge gaps will dominate activities over the next three to five years, as noted above, new knowledge will be converted to on-ground actions as soon as practicable.

The range of activities proposed to address hydrological threats for the life of this plan is outlined in five tables (7-11) below. A synopsis of each follows.

Surface and groundwater threats – water balance and salinity

Changes in water volumes, salinity concentrations and salt loads are the most common threats arising from altered hydrology. Much of the degradation of biodiversity assets of the BMNDRC is due to these threatening processes. However, there are substantial knowledge gaps regarding the specific hydrological relationships affecting biodiversity assets of the BMNDRC. Monitoring and investigation are crucial to filling these gaps. Understanding the biophysical processes of the catchment is critical to manage the impacts of altered hydrology. Therefore, while the focus will initially be on monitoring and investigation, once sufficient data exist, models will be developed to allow quantification of the biophysical processes occurring in the BMNDRC.

Research into the tolerances and thresholds of biota in biodiversity assets will occur concurrently. This will allow the feasibility of meeting the operational goal to be determined on an asset specific basis. The effect and relative benefit of various mitigating measures, as well as tolerances and thresholds, will be explored with models to determine which single (or combination of) management interventions will be most successful. The work of Walshe et al. (2007) provides examples of how analyses and decisions will be made in NDRCs. Detailed cost/benefit analyses will be completed, where appropriate, with these models. Table 7 details these activities, outcomes and management action targets.

In the short term, the use of deep drains by land managers to lower the water table and therefore remediate soil waterlogging and salinity will also need to be monitored and assessed. Deep drains are currently used by some catchment landholders, and it is a salinity management tool that may be considered to protect key biodiversity assets. However, the saline and sometimes highly acidic water some deep drains produce may create negative downstream environmental impacts. Therefore, the use of deep drains would only be considered where downstream impacts can be effectively managed.

Waterborne threats – acidification, nutrients, erosion and sedimentation

Changes in water and salinity levels are not the only effects of altered hydrology. Changes in water and soil chemistry, and in waterborne material, can also degrade biodiversity assets. For example, land use change and associated hydrological changes have modified biophysical processes that affect the composition of water and soil, including concentrations of carbonate, magnesium, potassium, oxygen, sulphate and changes to pH (acidity/alkalinity). Contaminants including metals, organic compounds such as fuels, increased nutrient levels or increased erosion and sediment transport can also degrade biodiversity assets.

Management actions depend on the occurrence and the extent to which waterborne threats are found to exist, and the intensity of their impacts on biodiversity assets. The main processes which are known to pose a threat in the BMNDRC are:

- Acidification – changes in water level or movement, sediment disruption and/or land use practices (such as deep drainage) can generate increased acidity in both water and soil.
- Altered nutrient cycles – increases in nutrient levels can cause eutrophication in water bodies as evidenced, for example, by algal blooms. Some types of algal bloom are toxic to humans and other organisms. Excessive nutrients can kill many native flora. Banksias, for example, are particularly sensitive to the effects of specific nutrients such as phosphorus.

- Erosion and sedimentation – increased runoff and reduced soil cohesion can lead to accelerated rates of erosion, sedimentation and increased water turbidity.

Data to tackle these issues will be included in catchment modelling and asset management, as well as determining EWR where practicable. This is particularly important for biodiversity assets in lower landscape positions, such as valley floor vegetation and wetlands, which are typically at risk from the effects of altered hydrology. Tables 10 to 12 detail management actions to address these waterborne threats.

Hydrology and climate change

The potential impact of climate change on biodiversity is significant and is becoming increasingly well recognised. However, it is still not well researched or understood. Past climate variability and change has played a key role in shaping ecosystems and the distribution of species across the State (Environmental Protection Authority 2006). Climate change will affect biodiversity directly through changes in temperature, rainfall and extreme events (climate variability) but also indirectly through altering the scale and nature of existing threats to biodiversity of which salinity (or altered hydrology) is just one of a number. This will bring changes at a landscape level and to ecosystem services as species adapt, emigrate or immigrate and others become isolated. Note that where excess groundwater is causing problems, a drying climate may ameliorate some hydrological problems, although this may be counteracted by increasing heavy summer rainfall events.

The Indian Ocean Climate Initiative (IOCI) have provided one estimate of the likely changes from climate change (IOCI 2002, IOCI 2005). The whole of the south-west of Western Australia, on average, is predicted to undergo changes in climate patterns which are summarised in Table 6 (from IOCI 2005).

In particular, the terrestrial ecosystem impacts of climate change are expected to be most obvious in the south-west with modelled temperature increases of several degrees Centigrade and a significant reduction in rainfall in this century (IOCI 2005). Recent research shows that this decrease in average annual rainfall has almost entirely resulted from the loss of rainfall in late autumn and early winter months. Work by CSIRO (2006) broadly supports these estimates.

Potential implications of climate change for the BMNDRC will be assessed through the catchment and asset specific hydrological models. These models will need to be combined with detailed scenarios and climate change projections as well as climate change impact predictions[20], from other groups such as the Intergovernmental Panel on Climate Change (IPCC) and IOCI. For example, scenarios and projections of climate change will need to examine the potential impact of declining winter rainfall as well as increasing high intensity summer rainfall events on the biodiversity assets of the catchment.

In the broader context of climate variability, to address the potential impact of high and low temperature extremes, average temperature rises and increased evaporation potential, DEC has commenced research into:

- biodiversity response modelling to investigate the vulnerability of Western Australia's plants and animals to climate change; and
- developing a climate change – biodiversity strategy.

The results of these initiatives and relevant research will be incorporated into the recovery planning process as they become available.

Table 11 summarises management actions to address climate change impacts on altered hydrology and biodiversity assets.

Table 6. IOCI climate predictions averaged over the entire southwest

Climate variable	Condition at 2030	Condition at 2050
Mean summer temperature	+0.5° to +2.1°C	Continued increase
Mean winter temperature	+0.5° to +2.0 °C	Continued increase
Mean winter rainfall	-2% to -20%	Continued decrease
Winter potential evaporation	+0% to +10%	Continued increase
Frequency of extreme climate events	Increased but not quantified.	Further increased.

20 Climate change impact predictions are distinguished from climate change projections to emphasise that climate projections rely on the emission/concentration/radiative forcing scenario used. These are based on a number of assumptions and are therefore subject to considerable uncertainty.

Table 7. Management actions to address surface and groundwater threats – water balance and salinity impacts on biodiversity assets

Activities	Outputs	Management action targets
Map salinity risk across catchment.	1. Catchment salinity risk maps completed (2008).	Representative wetland biodiversity assets reviewed, and re-ranked according to current value for biodiversity conservation and level of salinity threat (2009). Representative terrestrial biodiversity assets mapped and ranked according to current value for biodiversity conservation and level of salinity threat (2009).
Describe wetland distribution and develop classification system. Rank wetland assets threatened by salinity.	2. Report on wetland classification describing ranked wetland assets threatened by salinity (2009). 3. Selection of a suitable Claypan representative wetland to add to priority biodiversity assets (2008). 4. Further refining of selection of a representative 'primary saline wetland and channels' as a priority asset (2008).	
Describe the distribution and identify priority terrestrial assemblages threatened by salinity.	5. Report describing assets and methods used to map, define and rank terrestrial assemblages threatened by salinity (see further work identified in Section 3: includes a vegetation survey of the main drainage line and Koobabbie Farm (2009).	
Install and maintain catchment monitoring network for surface and groundwater.	6. Monitoring network for surface and groundwater in the catchment in place (2008). Monitoring network designed to assess surface and groundwater trends at the catchment scale and at the sub-catchment scale of priority assets. 7. Surface water and groundwater quantity and quality trends in the catchment reported every two to five years, dependant on significance of data collected, and built into hydrological decision systems and models. A review report of data collected to date to be completed in 2008.	Effective analyses based on EWRs and risk assessments, combined with hydrological models that support decisions on the management of surface and groundwater to achieve the operational goal by 2012. (Note, logic trees and other decision tools will be used in the interim to guide and document management decisions.)
Investigate the tolerances and thresholds for condition decline/mortality for all biodiversity assets targeted for management. Initial focus on representative assets. Determine EWR, initially for the representative priority wetlands.	8. Report on EWR for priority assets as a basis for predictive modelling. Results to be extrapolated across the catchment (2012).	

Table 7. Management actions to address surface and groundwater threats – water balance and salinity impacts on biodiversity assets continued…

Activities	Outputs	Management action targets
Develop catchment and asset specific models (including water balance, interaction and ecological models) through targeted investigations including: hydrology; hydrogeology, ecology, vegetation type and sedimentology incorporating water quantity and quality. Waterborne hazards need to be included.	9. Water balances (coarse) for catchment and individual assets determined (2008). Water balances (refined) for catchment and individual assets determined by 2010, or as soon as seasonal conditions allow for hard-data collection to adequately calibrate models. 10. Catchment wide hydrological models (LASCAM, DYRIM, LISFLOOD) parameterised and calibrated (2012). 11. Priority asset surfacewater – groundwater interaction models developed (2015). 12. Waterborne 'contamination' issues such as elevated nutrient loads (including eutrophication), elevated acidity or alkalinity levels, erosion sedimentation and turbidity will be included in models where possible. 13. Other models developed as appropriate. 14. Assessment of deep drainage as a management tool at priority assets, including environmental impacts.	
Complete surface water management project (SWMP) (demonstration). Monitor and communicate results.	15. Twenty-two kilometres of grade banks, 12km of fencing (revegetation, waterways, and remnant vegetation), and 35ha of revegetation established. 16. One case study report and one field day (2008).	Catchment landholders informed of benefits of surface water management, that is, cost effective and profitable.
Encourage, including use of incentives, surface water management on lands delivering excess water to priority assets. Document cost-sharing arrangements and priority assets, and priority landforms (eg, upland deep sands).	17. Five thousand hectares treated per year (2007-2012) with contour banks and similar structures established in the catchments of priority assets.	Reduced impacts of altered hydrology on priority biodiversity assets, and for catchment as a whole (see ecosystem services targets).
Promote development of corporate standard for vegetation condition monitoring	18. Responsibility for this output is at a corporate level. Implementation of a pilot study using 'VegMachine' software.	Consistent and Statewide applicable flora condition assessment standards.
Maintain and improve robustness of native vegetation monitoring transects at priority biodiversity assets.	19. Vegetation health reported every three years, and data used, where applicable, in decision tools.	Effective analysis that supports decisions on management of surface and groundwater to achieve the operational goal by 2012.

Activities	Outputs	Management action targets
Protect remaining remnant vegetation	20. Two hundred hectares per year fenced (2007-2012). 21. Arrangements for improved management for conservation and water use in place (2010) e.g. voluntary management agreements through Land for Wildlife or similar.	Increased water use by native vegetation in the catchment, and thus improve recharge control. Improved condition and protection of remaining native habitat.
Undertake revegetation for priority assets where surface water, erosion control and/or groundwater recharge reduction are required.	22. Thirty hectares of revegetation per year on upland slopes 23. Twenty hectares of revegetation per year adjacent (or within 20 metres) of key assets.	Reduced or stabilised negative impacts at the assets, reduced erosion/sedimentation and reduced groundwater pressure over the long-term (20-50 year timeframe).
Implement interim on-ground actions to protect wetland assets (Gypsum wetlands – W001 & W002 and fresh/brackish wetlands W011+W012+109; W015+W016)	24. Draft plan of recovery actions for selected wetland assets completed (2008).	Improved targeting of short to medium term on-ground actions for selected biodiversity assets threatened by altered hydrology.
Outcome(s): There will be two key outcomes from the above work. Firstly, by 2012 an adequate hydrological model, combined with EWR investigations, will have been used to generate improved targeting of management actions to redress changes from altered hydrology. Secondly, the interim on-ground actions will have reduced the threat posed by altered hydrology.		

Table 8. Management actions to address waterborne threats to biodiversity assets – acidification

Activities	Outputs	Management action targets
Monitor surface and groundwater of the BMNDRC for elevated acidity levels.	1. Annual reporting of acidity and pH trends in the BMNDRC.	Understanding of the potential for altered acidity/alkalinity balances to negatively impact the biodiversity assets, and revise management action accordingly (2010).
Site specific investigations where elevated acidity is detected.	2. Contingent on whether acidification problem exists.	
Investigate buffering capacity of receiving water bodies.	3. Report identifying the relative buffering capacity of priority wetlands which are likely receiving water bodies (2008).	
Determine biota tolerances and thresholds to elevated acidity levels.	4. EWR developed for priority biodiversity assets based on current research into tolerances and thresholds for condition decline and mortality in biota (2009).	
Assess risk of negative impacts from altered acidity/alkalinity on priority and other assets.	5. Report assessing risk and cost/benefit analysis of protecting assets threatened by altered acidity (2010). 6. Report on combining the information obtained as part of the activities detailed above with catchment and asset specific models (2010).	
Outcome: This work will provide a basis to prioritise management action to address the threat posed by acidification to cause asset decline or goal failure for biodiversity assets. On ground actions will reduce the potential for further acidification impacts on biodiversity assets. This is of particular relevance to the impacts of deep drainage on biodiversity assets.		

Table 9. Management actions to address waterborne threats to biodiversity assets – altered nutrient cycles and eutrophication

Activities	Outputs	Management action targets
Monitoring of surface and groundwater of the BMNDRC for elevated nutrient and reduced dissolved oxygen (DO) concentrations which result from eutrophication.	1. Annual reporting of concentrations and trends in nutrient and DO concentrations.	Understanding of the potential for altered nutrient cycles and eutrophication to negatively impact biodiversity assets. This must focus on assets downstream of areas of excess nutrient generation (2010). Reduction of the impacts of altered nutrient cycles and eutrophication on biodiversity assets while maintaining farm business (2010).
Site specific investigations where elevated nutrient or low DO concentrations are detected.	2. Report detailing the source and concentration of the elevated nutrient concentrations and their relationship with reduced DO levels, particularity if detected in or near priority assets.	
Determine biota tolerances and thresholds to elevated nutrient and reduced DO (eutrophication) and natural light (where applicable) levels (will include documenting EWR for specific assets).	3. Report on acceptable levels of nutrient loading and eutrophication in priority assets (2008).	
Undertake risk assessment of the potential for altered nutrient cycles and eutrophication to negatively impact on representative and other assets.	4. Detailed risk assessments and cost/benefit analysis of protecting assets threatened by altered nutrient cycles and eutrophication. (Note, will include assessment at catchment scale) (2008).	
Outcome(s): Understanding of the distribution, trends and consequences of altered nutrient cycles and eutrophication on priority biodiversity assets of the BMNDRC. Influence the use of fertilisers on rural properties to maintain productivity while reducing negative impacts on biodiversity assets. With plant based and/or engineering options, on ground actions will reduce the threat to, and impact on, biodiversity assets.		

Table 10. Management actions to address waterborne threats – erosion and sedimentation

Activities	Outputs	Management action targets
Erosion monitoring and assessment of upper parts and areas of steep topography in the catchment.	1. Annual reporting of trends in turbidity. 2. Report on erosion in the upper part of the catchment using elevated turbidity levels as an indicator of accelerated erosion rates (2008).	Identification and understanding of current and potential areas of accelerated erosion in the BMNDRC based on turbidity trends as an indicator (2010). Reduction in the impacts of accelerated erosion, sedimentation and elevated turbidity on biodiversity assets while contributing to sustainable land use (2010).
Sedimentation assessment of lower parts of the catchment, particularly wetlands and water courses.	3. Report on levels of sedimentation in the lower parts of the catchment with a focus on representative wetland assets (2009). 4. Five thousand hectares targeted on-ground actions to improve degraded water courses where feasible (As part of surface water management activities) (2007–2012).	
Determine biota tolerances and thresholds to impacts of accelerated erosion and sedimentation with a focus on macroinvertebrates and vegetation in wetlands and water courses.	5. Report, based on existing research, detailing tolerance and threshold levels for priority assets (2008).	
Assess the risk of negative impacts from erosion and sedimentation to priority and other assets.	6. Report assessing risk and cost/benefit analysis protecting assets threatened by elevated turbidity and accelerated rates of erosion and sedimentation – includes catchment and asset specific models (2008).	
A catchment wide program to reduce erosion and associated soil loss - focusing on properties upgradient of priority assets.	7. An on farm program covering 25,000ha to assist landholders to reduce erosion and soil loss (2007–2012).	

Outcome(s): This work will provide a basis to prioritise management action to address the threat posed by the waterborne impacts of erosion and sedimentation on biodiversity assets. On ground actions will improve soil retention on rural properties. This will maintain productivity and reduce in situ and downstream impacts on biodiversity assets.

Table 11. Management actions to address climate change impacts on altered hydrology and biodiversity assets

Activities	Outputs	Management action targets
Determine palaeoclimatic record of the BMNDRC.	1. As part of DEC wheatbelt-wide investigation, a palaeoclimatic record of the last 10,000 years for the BMNDRC as a calibration point/s for General Circulation Models (GCMs) (2009 if possible).	Risk/benefit analysis of climate change impacts on hydrology of the BMNDRC, based on climate change scenarios. Planning activities use a risk management approach which incorporates new information as part of an adaptive management process.
	2. A report on detailed downscaled GCM predictions at a catchment scale using a local calibration point (2010).	
Run down-scaled GCMs and generate catchment scale predictions of climate change. Investigate climate change impacts on water balance and altered hydrology.	3. A set of predictions regarding impacts of climate change on altered hydrological regimes (2010). 4. Models developed above used for assessing the impacts of climate change on altered hydrology in the BMNDRC (2011).	
Translate research on climate change to assess potential impacts on BMNDRC biota.	5. Update on relevant climate change research reported as part of annual operational planning. Where applicable, this should include the implications or recommendations for management planning or actions to protect biota. 6. Installation of a weather station in the west of the BMNDRC to complement the Dalwallinu (Bureau of Meteorology) and McAlpine (CSIRO) stations (2008). Data collection to occur on the basis of needing to understand climate variability for the purpose of managing priority assets.	

Outcome(s): There will be two key outcomes from the above work. Firstly, by 2013 the potential impacts of climate change will be modelled and used to predict likely impacts on altered hydrology and biodiversity assets. Secondly, management activities will be geared to incorporate new information on climate change impacts to biodiversity assets, as it becomes available, and on-ground revegetation activities will increase capacity of biodiversity assets to adapt to impacts of climate change.

ENVIRONMENTAL WEEDS, DISEASES, INTRODUCED AND PROBLEM NATIVE ANIMALS

Environmental weeds, diseases, introduced and problem animals all have the potential to impact on biodiversity assets in the BMNDRC. For example, environmental weeds displace native endemic plants, particularly at disturbed sites, by competing with them for resources. This can reduce levels of floral diversity and can also alter animal habitats, support introduced and problem native species and diseases, increase fire hazard and impede drainage. Problem native animals can predate or compete with other native fauna thus reducing food, habitat and ultimately, population viability. The movement of stock and other introduced animals can accelerate erosion. Plant diseases can degrade native plant communities through condition decline or mortality which, in turn, can also impact on their dependent fauna.

The biophysical threat analysis in Section 4 identified that, in general, threat levels are considered to be low relative to other threats, particularly altered hydrology. However active management and ongoing monitoring is required to prevent new introductions or the impacts of the further spread of existing weeds, problem animals and disease. Table 12 identifies the main activities to address these threats. A summary is provided below for each of these threats.

Environmental weeds

A number of environmental weeds have become well established in the BMNDRC. There are also a number of species, currently localised, that have the potential to spread given favourable conditions. Environmental weeds have been found at all priority asset sites. However, typically, sandy seep wetlands (W009; W011+ W012+109; W015+W016; W020) have the highest weed populations. The spread of weed species is accelerated by stock grazing.

Thirty-four species of environmental weeds have been recorded in the BMNDRC. Three have been identified as high priority in the DEC Environmental Weed Strategy (CALM 1999b), seven are listed as agricultural weeds under the *Agriculture and Related Resources Protection Act* 1976 and 15 were identified as important as part of the Landholder survey (Table 1, *Appendix 13* has a complete list and status). Declared weeds are a priority for management. There is a statutory requirement for detection and eradication by both landholders and the relevant government agencies (DEC and DAFWA primarily).

Currently, only a small proportion (11 of 58 landholders surveyed) actively control weeds in remnant vegetation. Barriers to weed control identified by landholders include lack of finances, time constraints and difficulty in accessing areas (CALM & Colmar Brunton 2005).

The best way to reduce the threat of environmental weeds is to stop their spread because eradication of environmental weeds, once established in an area, can be both time-consuming and costly. An additional principle in weed removal programs is that consideration is given to filling the environmental niche left after weed removal. This is particularly important when a weed occupies a large part of a site and a precautionary approach will be used when designing weed control programs. Herbicides and manual removal are the typical management responses where weed communities are found. Herbicides may not be an appropriate management practice in some ecosystems where native species are susceptible. An effective weed control program will eliminate artificial disturbance and enrichment, prevent new introductions and fill vacant environmental niches.

Plant diseases

Due to the location of the BMNDRC, DEC considers that the degree of threat posed to native plant communities and their dependent fauna by *Phytopthora cinnamomi* or 'dieback' is generally low to moderate. This is due in part to the fact that the BMNDRC occurs in a rainfall zone of less than 400mm per annum which is not favourable to the spread of the fungus. However, this does not inhibit the fungus from occurring in permanently wet areas and assets low in the landscape if it is introduced through vehicle or animal movement. The other *Phytopthora* species (*P. citricola* and *P. megasperma*) which may be present are not currently considered by DEC to cause significant impacts relative to other threatening processes.

'Mundulla yellows' is a slow, progressive dieback and yellowing disease found in many eucalypts. It is thought to be caused by a virus, viroid or phytoplasma agent, although other causes (both biotic and abiotic) are possible. It is believed to occur in areas near roads and towns but also in proximity to drainages (Paton & Cutten, 1999). These areas will require targeted monitoring for potential infection. As a little known and only recently described disease it has the potential to seriously affect native species, revegetation with native species and eucalypt plantations. It has been recorded in the Northern Agricultural Region and has the potential to impact on the biodiversity assets of the BMNDRC. The key to managing Mundulla yellows will be identification of the cause. If it is biotic, management will need to be directed towards averting an epidemic. For a solely abiotic disease, a different management strategy will be needed (Hanold et al. 2006).

Introduced and problem native animals

Sixteen introduced and problem animals have been identified in the BMNDRC (Table 2, *Appendix 13* has a complete list and status). These include agricultural stock as well as introduced predators and herbivores and problem native species which are summarised here. Eight of these are declared under the Agriculture and Related Resources Protection Act 1976[21]. Introduced and problem native animals have a long history of access to remnant vegetation and wetland areas in the BMNDRC. This access has lead to physical disturbance and permanent loss of vegetation and a range of impacts contributing to degradation of biodiversity in these areas.

Uncontrolled access of agricultural stock represents a significant threat to biodiversity assets, although this is not considered by landholders as being problematic (CALM & Colmar Brunton 2005). For example, many of the primary saline wetland areas are seriously degraded as a result of stock access. Grazing of plants adapted to saline conditions is a production value of biodiversity utilised by many landholders. The impacts of grazing on key biodiversity assets need to be monitored and managed to prevent negative impacts on representative biodiversity assets. Other wetland types, particularly those with water quality suitable for stock consumption, are commonly accessible to stock. While some areas are already degraded or modified as a result of the impact of introduced and problem species, the approach taken here is to address on-going threats to biodiversity assets and to enable the recovery of degraded assets where practicable. The focus will initially be on priority assets. It should be noted that the threat of uncontrolled access posed to gypsum lakes has been addressed through fencing. All other wetland types are, to some degree, currently still accessible to stock.

Allowing assets to recover from the impacts of problem animals provides a number of benefits. These include the opportunity for existing habitat types to expand, and increased physical stability of an area. These could, in turn, recover some of the degraded ecosystem services of biodiversity such as moderation of surface water flows, reduction of sediment transport and artificial nutrient enrichment. Preventing stock access to vegetation remnants and other natural areas through fencing will be a key management action to protect biodiversity assets.

Introduced herbivores and predators are widespread in the BMNDRC. Foxes, cats and rabbits are sighted regularly throughout the catchment. Rabbits have similar impacts as agricultural stock. Biological control of rabbits is through myxomatosis and rabbit haemorrhagic disease. Foxes and cats differ in that they mainly impact on small native mammals and birds through predation. Some of the existing research on predator removal suggests that fox control, on its own, results in an increase in cat numbers (Risbey et al. 2000). Monitoring of predator distribution and abundance across the catchment will be conducted annually. From the biological survey work of Keighery et al. (2004) it appears that the house mouse (*Mus musculus*) may also be a significant problem, although there are currently no realistic control methods.

Problem native species are those with an increased abundance and/or altered distribution since European settlement, and which also threaten other native species. In BMNDRC, these are the western grey kangaroo, galah, little corella, and western long-billed corella. The main impact of these species is that their grazing can have a negative impact on existing vegetation as well as detrimental effects on the success of vegetation regeneration and revegetation. In addition, the nesting behaviour of many problem bird species is destructive, aggressive and tends to displace other, less common species such as the Major Mitchell and Carnaby's black cockatoos.

The mobility of introduced and problem animals in the landscape presents a challenge for management. For example, local eradication of cats and foxes frees up areas for re-invasion from adjacent areas. The frequency, timing and area of application of control measures are key considerations for management. The general principle is that synchronised, large-scale and sustained implementation of control measures is more effective than a piecemeal or individual landholder approach. For the BMNDRC efforts will be driven largely by DEC but may require a shire-facilitated approach across different land tenures to involve as many landowners and stakeholders as possible. While coordination of such control measures is a major task and resource intensive, evidence from successful control programs, for example foxes, suggests there are clear benefits of this approach.

Landholders consider problem animals, in terms of their economic and environmental impacts, to be foxes, cats and kangaroos. These were the species most likely to be controlled regularly (CALM & Colmar Brunton 2005). Control techniques used include baiting, shooting and trapping. The key barrier identified by landholders to addressing threats posed by introduced and problem animals was lack of time followed by cost, paperwork, inadequate leadership and coordination.

Specific management actions are detailed in Table 12.

21 Species declared under the Act places an obligation on landholders to control them.

Table 12. Management actions to address impacts of environmental weeds, disease and introduced and problem native animals

Activities	Outputs	Management action targets
Environmental weeds and disease		
Review existing weed information, map occurrence and distribution of weeds and prioritise weed management actions. Remove weeds threatening biodiversity assets.	1. Report reviewing weed occurrence and distribution in BMNDRC and, in consultation with stakeholders, prioritised management actions (2007). 2. Program of weed removal/suppression at priority assets with a particular emphasis on sandy seep wetlands (W009; W011+ W012+109; W015+W016; W020) (2008). 3. Monitoring of weed distribution and abundance at selected sites across the BMNDRC (every two years, and/or after episodic flood events. 4. Regular progress reports of monitoring activities and control programs through BMNDRC newsletter – additional communication activities as necessary (ongoing).	Control of disease and environmental weed species required by legislation. For priority biodiversity assets: • implement an effective weed control program with a target 50% decrease in area for priority weeds by 2015 and no new weed introductions. • No new introduction of new disease and reduce area affected by diseases. Within the BMNDRC, implement targeted control of any relatively new occurrences of priority weeds (especially those with a relatively low frequency of occurrence, low area of occupancy, and low area of distribution).
Review existing plant disease information and map occurrence and distribution. Enforce decontamination and disease suppression activities where required.	5. Review of new information regarding weeds (annually). 6. Report reviewing the plant disease occurrence and distribution in the vicinity of the BMNDRC (2009) 7. Monitoring areas of vegetation decline (where disease is suspected) for evidence and occurrence of plant diseases (annually – starting 2009). 8. Review of new information on plant diseases (every two years, and/or after new evidence suggests changes to management). 9. Plant disease suppression where outbreaks are detected (as appropriate)	
Introduced and problem animals		
Review existing introduced and problem animal distribution. Remove existing and future threats to biodiversity assets from introduced and problem animals.	1. Report reviewing the introduced and problem animal distribution in BMNDRC and, in consultation with landholders, prioritised management actions (2009). 2. Program for control of introduced/problem animals at priority assets W057+ W058 + W059 (bentonite wetlands); W011 + W012 + 109 and W015 + W016 (fresh-brackish wetlands); and W011 + W002 (Gypsum wetlands) by (2009). This choice is based on assets being adjacent to an extensive area of remnant vegetation (bentonite and gypsum wetlands); and being a drought refuge for native fauna (fresh-brackish wetlands). Control measures of target species to thoroughly consider effectiveness.	Exclusion of agricultural stock from priority assets by fencing. Reduce: • rabbits foxes and cats • western grey kangaroos to levels considered not detrimental to biodiversity conservation (based on best available scientific information).

Table 12. Management actions to address impacts of environmental weeds, disease and introduced and problem native animals…

Activities	Outputs	Management action targets
Introduced and problem animals		
	3. Targeted monitoring of introduced/problem animal distribution and abundance at selected priority biodiversity assets (every two years). 4. Regular progress reports of monitoring activities and control programs through BMNDRC newsletter – additional communication activities as necessary (ongoing). 5. Review of new information regarding introduced and problem native animals (every two years, and/or after new evidence suggests changes to management).	No new introduced and problem animals.
Outcome(s): A reduction in the existing and potential future threats to biodiversity assets from impacts of weeds, diseases and introduced problem animals.		

REGIMES OF PHYSICAL DISTURBANCE

Regimes of physical disturbance, such as fire, flood, and drought, are a natural and integral part of ecosystem processes which can be influenced by human factors. Some regimes of physical disturbance will degrade biodiversity assets. The impacts of climate change are also likely to contribute to changes in these regimes. A brief description of these threats and their management in BMNDRC is given below and in Table 13.

Fire

Biodiversity assets may be threatened by fire regimes in which the time between successive fires is either too long, too short or the intensity or timing is detrimental to some biodiversity assets. However, determining the pre-European fire regime, particularly frequency and intensity, is difficult. Some assumptions can be made based on the physical setting of natural vegetation, but the highly fragmented nature of the landscape has created a situation under which natural fire regimes may no longer be appropriate. The knowledge gaps concerning appropriate fire regimes for the biodiversity assets of the BMNDRC are being addressed at a State level.

In the short term, management responses will include installation and maintenance of appropriate fire breaks combined with 'best practice' management of wildfires consistent with existing departmental guidelines. Management actions will also have regard to relevant shire regulations and the *Bushfires Act 1954* and consider opportunities for weed control following wildfire to protect and maintain biodiversity.

Cyclones and floods

Flood events redistribute large quantities of water, salt and other waterborne materials, including weed seeds, throughout the system. This may result in severe impacts on biodiversity assets, particularly those low in the landscape where excessive inundation may cause extensive plant death. However, under some circumstances particular species can respond positively to flooding. For example, woodland species such as salmon gum, morrel and York gum, and melaleucas in valley floor areas may regenerate prolifically following flooding. Anecdotal evidence suggests flooding events have had widespread negative impacts on both remnant vegetation and agricultural production within the BMNDRC. The management response will be dictated by the outcome of modelling assessments, once these are complete, but may include the construction of bunds to protect areas where flooding presents a high risk of goal failure.

Drought

Since European settlement, serious droughts in Western Australia have affected the BMNDRC. Drought will put biodiversity assets under considerable stress as wetlands can dry out for extended periods and vegetation can die due to lack of water. The management response will be dictated by the outcome of modelling assessments once these are complete, but may include artificial watering (such as by redirection of surface flows) for areas where drought presents a high risk of goal failure. Management responses to both drought and flood require development of models and an understanding of Ecological Water Requirements (EWRs), dependent on development of predictive models. These models and EWRs will be developed as part of the response to the threat of altered hydrology.

Erosion

Wind erosion

Water erosion has been dealt with under altered hydrology; however, wind erosion is a substantial threat in the south-western part of the BMNDRC. The light, sandy soils prevalent in this area are highly erodible. Soil erosion may make it difficult for plants to recolonise badly effected sites. Fencing to exclude stock and revegetation of grazed sites will partially mitigate the threat of erosion. Deposition of soil during dust storms from paddocks onto adjoining remnant vegetation can produce localised 'smothering' and facilitate the introduction of weeds. Management responses may include revegetation or geotechnical solutions in areas where wind based erosion is threatening high value assets.

Impacts of pollution

Based on the biophysical threat analysis undertaken in 2003, it is unlikely that there are any contaminated sites within the BMNDRC. However it will be important to reassess and verify this in the near future when information is made available via the DEC Contaminated Sites Registry.

A list has been included (Table 3 and 4, *Appendix 13*) to provide a guide to the potential pollutants which could be present and will be analysed as part of routine monitoring. The potential for negative impacts of pollution and implications for management are given above in the waterborne threats section of altered hydrology and below in the section on competing land uses. The management response will be dictated by the outcome of routine monitoring and the nature of any potential pollutants.

Impacts of competing land uses

The following is a generic list of the threats to biodiversity assets of the BMNDRC from competing or incompatible land uses. However, based on existing biophysical threat analysis, these issues are considered a low risk to biodiversity assets (with the exception of herbicide drum dumps in wetlands) and are therefore only listed here. At present, only the first two threats have been identified as potentially impacting on priority biodiversity assets:

- fertiliser drift and other edge effects
- illegal waste management activities (dumping)
- soil structure decline
- recreation (particularly inappropriate site development)
- mines and quarries
- urban development
- transport networks (maintenance and construction).

Options to improve the security of natural lands include land purchase for conservation and voluntary conservation covenants, neither of which may be implemented without landholder agreement.

Table 13. Management actions to address threats to biodiversity assets – detrimental regimes of physical disturbance

Activities	Outputs	Management action targets
Fire		
Protect priority assets from wildfires. Undertake fire suppression consistent with regional fire plans.	1. Firebreaks constructed around priority assets that are of suitable size and consistent with standard DEC regional procedures (annual requirement). 2. Develop a plan to address weed response to wildfire which may impact on priority biodiversity assets (2008).	Appropriate fire regimes for the priority biodiversity assets of the BMNDRC.
Incorporate appropriate fire regime information for biodiversity assets of the BMNDRC as new information becomes available.	3. Report on asset specific, appropriate fire regime (2010). 4. If required, prescribed burning plan developed and implemented (2010).	
Cyclones and floods		
Minimise the risk of unacceptable impacts from flooding and cyclones on biodiversity assets.	5. By using the catchment and asset specific models and an understanding of past and potential future climate regimes, predict the extent and duration of flooding under the possible range of rainfall events.(2013)	Develop management responses appropriate to the threats as analysis is completed, i.e. artificial maintenance schemes or engineering/geotechnical solutions.
Drought		
Investigate the potential for unacceptable impacts from drought on biodiversity assets.	6. By using the catchment and asset specific models and potential future climate regimes, predict the duration of potential droughts (rainfall scarcity outside of natural variation) and the implications for biodiversity assets (2013)	

Activities	Outputs	Management action targets
Erosion (wind)		
Investigate areas of current wind based erosion in the BMNDRC.	7. Report on site investigation of areas surrounding priority assets to assess location, cause, extent, threat posed by wind erosion (2009). 8. Establish priorities for management of the cause and impacts of wind erosion on priority biodiversity assets (2009).	No priority biodiversity assets lost or degraded further due to wind erosion or competing land uses.
Impacts of competing land uses		
Examine the need and potential to purchase natural lands within the BMNDRC; and commence the land purchase process where appropriate (2009). Identify locations of herbicide dumps in wetlands, remove and ensure proper disposal.	9. Priority areas of remnant vegetation identified on the basis of their contribution to the national reserve system as candidates for purchase. Communication to catchment landholders DEC's desire to purchase significant areas of natural lands (2008). 10. Areas significant for conservation, and management of competing land uses, purchased (ongoing). Refer to actions under 'Insufficient ecological resources' to maintain viable populations (Table 15). 11. Map of herbicide dumps with schedule and procedures for handling and disposal prepared (2008).	
Outcome(s): A reduction in the threat posed to biodiversity assets from fire, cyclones, floods and drought. In the interim, installation of firebreaks will reduce the threat posed by wildfires. Work being undertaken to address the threat of altered hydrology will contribute to managing the threat posed by cyclones, floods and drought. Revegetation activities will also contribute to reducing wind erosion.		

BUILDING AN APPROPRIATE CULTURE

For many people, biodiversity conservation is an abstract idea disconnected from their lives and wellbeing. Therefore it is important to describe the human values of biodiversity so that people understand its importance to them personally. (See Table 3 in Section 4: Linking recovery achievements to priority cultural values and related assets). Without such linkages, there would be little support for expending human resources, financial or otherwise, on conservation (Wallace et al. 2003). Consequently, inadequate understanding of biodiversity conservation values among stakeholders, including government agencies, may hinder management success in the BMNDRC. Similarly, the culture in any of the stakeholder groups may be a barrier to successful implementation of this recovery plan. For example, if DEC officers do not bring an appropriate understanding of agricultural needs to their catchment work, this will be a barrier to successful recovery work.

Collectively, all these socio-cultural threats to achievement of the operational goal for the BMNDRC are brought together under the banner of inappropriate culture. It is emphasised that, as used here, culture is only considered inappropriate in the context of the operational goal for the BMNDRC – it is not a comment on culture as such. The response to this threat, as indicated in the section heading, is to build an appropriate culture for successful implementation of the recovery plan.

To date, while most landholders have some understanding of the biodiversity values of the BMNDRC, they have also acknowledged that there is much to learn. Lack of time and money were identified as the greatest barriers to gaining a better appreciation of biodiversity conservation (CALM & Colmar Brunton 2005). At the same time, many catchment landholders will themselves have important information on biodiversity in the catchment, including its value, and it is important to capture this information.

Anecdotal evidence suggests that, although landholder attitudes vary, wetlands with more obvious biodiversity are more highly valued. Freshwater wetlands with remnant fringing vegetation are widely considered to be assets, for both intrinsic, amenity and productive use values. Some saline playas are valued for the recreational opportunities they provide or for landscape amenity.

As 95 per cent of the BMNDRC is privately owned and 73 per cent of the remnant vegetation is on private property, landholder and community consultation and involvement is vital for the management of key biodiversity assets and threat mitigation. The cooperation of landholders is necessary in order to implement management practices that are sympathetic to biodiversity conservation.

It is also essential to communicate the importance of biodiversity in the BMNDRC to a State and national audience. This recovery plan is part of this process, however, where appropriate, other opportunities will also be taken to widely communicate the biodiversity values of the BMNDRC. A communication plan will be developed to ensure activities in this area are well targeted and cost-effective. (See Tables 1 and 2, Appendix 14 for a draft communications plan. The table also includes a number of other actions to ensure a cohesive, supportive culture to implementation of the recovery plan.) These actions include resource support for the recovery team, management of meetings, production of the catchment newsletter, and staff training.

Table 14. Building an appropriate culture

Activities	Outputs	Management action targets
Develop cost sharing/financial incentives for landholders within the BMNDRC who want to protect high priority biodiversity assets.	1. Program of implementation for cost sharing arrangements, where appropriate and possible. These arrangements will explicitly acknowledge the full range of land, water and biodiversity values. This is relevant to all activities previously identified as necessary to protect representative and priority biodiversity assets (2008).	Activities protecting priority assets implemented under a cost sharing arrangement where applicable with the cost-sharing arrangements themselves explaining all values addressed by the related management action.
Implement methods for consulting with, and disseminating information to, stakeholders in the BMNDRC as outlined in the communications plan.	2. Reporting of cost sharing arrangements and available funds for the future (annual). 3. Development and implementation of a communication plan to increase socio-political support (2009). 4. Capture of local knowledge on biodiversity and its values. Report by 2010. 5. Annual Report disseminating summaries of current status and trends in biodiversity assets (annual).	Communication of all aspects of the recovery plan to the catchment landholders and community in general.
Train staff training, where required, in economic and socio-cultural aspects of agricultural ecosystems.	6. All recovery workforce understand and empathise with economic and socio-cultural aspects of agricultural ecosystems within six to 12 months of appointment.	Culture of personnel involved in recovery work supports positive partnerships with all stakeholders to achieve operational goal.

Outcome(s): All stakeholders better understand the values of biodiversity in their lives, and a supportive culture develops that supports the implementation of the recovery plan.

ECOLOGICAL RESOURCES TO MAINTAIN VIABLE POPULATIONS

To be effective, on-going conservation of biodiversity assets in the BMNDRC requires that sufficient ecological resources, such as food, water and oxygen, shelter and access to mates, are available to support viable populations of plants and animals. Clearing in the wheatbelt has resulted in highly fragmented habitats and disrupted ecosystem processes. This has led to small population sizes and likely loss of viability. Measuring viability is complex and, at present, little is known about the minimum viable population sizes for native plants and animals in the WA agricultural zone. (See *Appendix* 12 – 'Two broad approaches' on how to manage for biodiversity conservation).

Research is being undertaken to quantify some of the genetic and ecological factors that correlate with population viability and how they are affected by population size, disturbance regimes, and landscape position. Preliminary results show some strong effects of population size, condition and landscape context on the reproductive capacity of some plant species (Yates et al. 2006, Byrne et al. 2007, Coates & Dixon 2007, Coates et al. 2007, Yates et al. 2007). What is known is that high levels of both endemism and co-dependence, typical of much Australian flora and fauna, means that these ecosystems are particularly sensitive to human-induced change. In addition, long-lived organisms such as many trees may persist for decades without being viable in the long term. As work on viability analyses is developed and becomes available it will be incorporated into the overall assessment of threats to biodiversity assets in the BMNDRC.

From a management perspective, dealing with this threat and its impacts on population viability means that, in addition to effectively addressing all the threats identified previously, effective habitat size is increased. This will be achieved by creating buffers and linkages using native species, reconstructing ecosystems and regenerating degraded areas.

It should be noted that a number of the activities used to address hydrological threats and control introduced and problem species will help to address the lack of ecological resources. For example, revegetation, surface and groundwater management and weed control programs can contribute to ecological resources by expanding habitat area and improving habitat condition for many species. Therefore, strategic planning of revegetation activities, in particular, can be used to address multiple threats. For example, plantings for hydrological control may be designed, using general planning principles[22] in the first instance, to increase ecological resources for a range of native species. In this context, it is useful to note that belts of oil mallees may increase the habitat for a wide range of native species (Smith 2006).

The main focus activities in response to this threat are shown in Table 15.

22 Such as the more habitat resources, the better; the more connected ecosystems, the better; the lower the perimeter-to-area ratio of remnant bushland, the better.

Table 15. Insufficient ecological resources to maintain viable populations

Activities	Outputs	Management action targets
Revegetation		
Develop vegetation management plans for each priority asset (includes revegetation).	1. Vegetation management plans initially for assets **W004; W070** (primary saline wetland and channels); **W001** (gypsum wetland); **W011 + W012 + 109; W015 + W016** (fresh/brackish wetlands); and **W057 + W058 + W059** (bentonite wetlands): (2008).	Optimise habitat quantity and condition for 50ha per year 2007–2012 of revegetation (refer to actions under surface and groundwater threats (Table 7).
Investigations		
Investigate usefulness of furthering the 'modified focal species' study to get a better understanding of issues of long-term viability of populations.	2. Assessment report on the utility of the 'modified focal species approach' for future work on population viability in the BMNDRC (2008). 3. Biennial review of literature to assess new information on population viability (2009).	Best available information on population viability incorporated into management actions.
Investigate opportunity for strategic land purchase or applying conservation covenants adjoining priority assets to improve protection of habitat.	4. Up to date list of potential sites for possible purchase or covenanting arrangements (annually reviewed) See actions under competing land uses (Table 13).	Key remnants linked and buffers around priority assets through acquisition and covenants.
Investigate and confirm whether Bentonite wetlands are Threatened Ecological Communities (TECs)	5. Assessment report on TEC status of W057 + W058 + W059 (bentonite wetlands) (2008)	Priority assets threatened by salinity identified.
Outcome: Significantly increased resources to maintain viable populations of target biota. [This implies that sufficient new habitat will be created to ensure that target biota cross viability thresholds. That is, this work will be aimed at changing the viability status biota, not merely incremental improvement.]		

PROGRESS TO DATE

Since the BMNDRC was established in 2001 the management team has been planning and implementing actions to address threats posed by salinity so that the current biodiversity of selected sites is maintained. The biophysical threat analysis in Section 4, which was undertaken in 2003, identified a number of key activities that could be undertaken immediately to address threats to the biodiversity in the BMNDRC while the information necessary for this plan was collected and analysed.

EXPENDITURE AND OUTPUTS

To date, effort and expenditure has been in response to five threats. Figure 5 shows expenditure in the BMNDRC to date according to these threat categories and Table 16 is a summary of the key management activities, outputs and expenditure[23]. Amounts shown are State Government recurrent funds expended in the catchment including salaries, vehicles, on-ground implementation, contracts and consultancies. However it should also be noted that the expenditure of other agencies and external funds, for example from the Natural Heritage Trust, are not shown in this breakdown of expenditure.

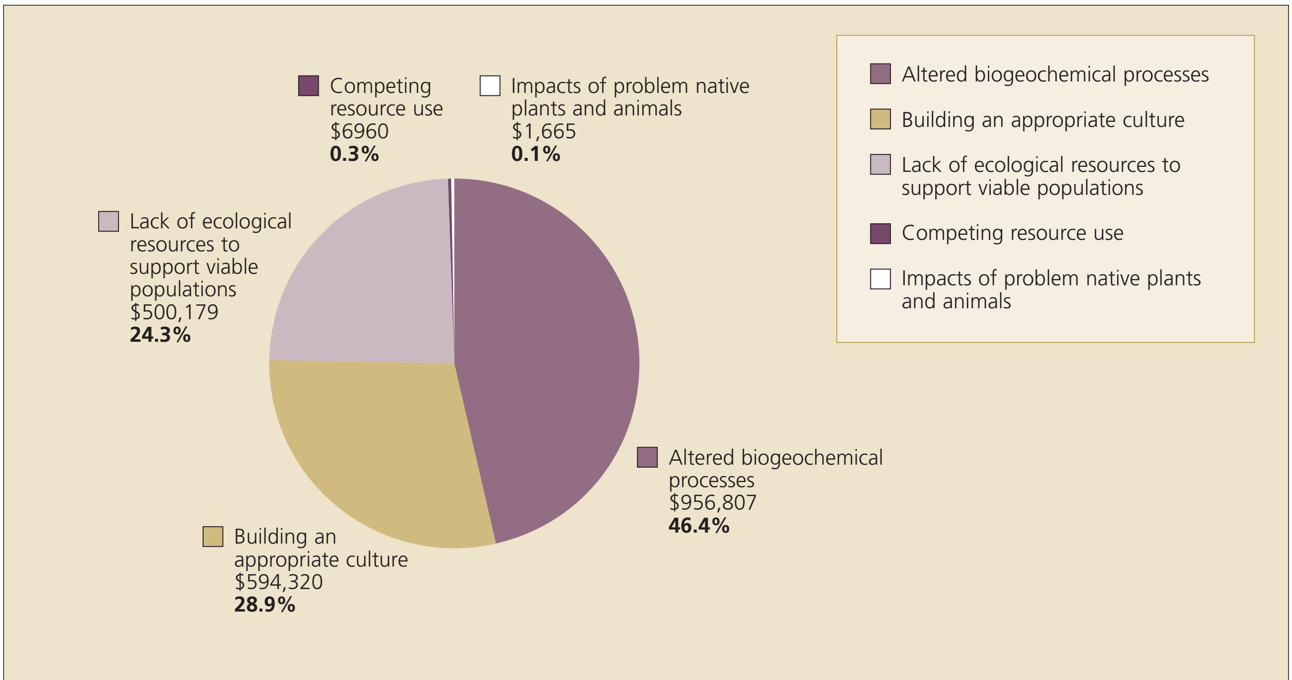
The main focus of work to date has been building baseline data and evidence to develop sound management actions. This has involved specialists in wetland ecology, hydrogeology, landscape ecology, agricultural water management, native flora and fauna surveying and social science. Collecting and interpreting data to assess the threat posed by altered hydrology makes up the majority of expenditure.

Altered hydrology

As noted above, work to date has focused on building the knowledge needed to support selection of management actions. In responding to altered hydrology, three main areas of activity and expenditure have been revegetation for hydrological control, engineering works and monitoring and research investigations.

The emphasis in revegetation for hydrological control has been on non-commercial species, which covered 42ha and included 18km of fencing, compared to nine ha of commercial species. Apart from revegetation, an important on-ground outcome has been engineering works including the surface water management demonstration site. Lessons are being incorporated into plans for surface water management throughout the catchment to protect priority biodiversity sites.
It is important to note that work on altered hydrology, such as the water management demonstration site, addresses the threat of insufficient ecological resources by creating new habitat through revegetation at the same time as improving recharge and discharge management.

Figure 5: Expenditure according to threat category (2001-2006) ($2,059,934.73)



23 Activities with a total expenditure of less than $10,000 between 2001 and 2006 are not described in table.

Table 16. Key management activities, outputs and expenditure (2001-2006)

Threat	Activities	Outputs	Expenditure
Altered biogeochemical processes	Revegetation for hydrological control (commercial and non commercial species)	8 sites (42ha) with 8 landholders 149,000 seedlings 22km of fencing	$162,679
	Engineering works on private property to protect public assets	7 reports 4 properties treated (1000ha) 22km of earthworks	$156,012
	Monitoring and research investigations	7 reports – Refer to Appendix 15 for a list of reports	$631,155
		Sub total:	$949,846
Building an appropriate culture	Establishing and maintaining: communication pathways with the broader catchment landholders and State community; All management planning work is costed against this item NDRC Steering Committee; DEC Recovery Catchment team.	15 groups and 14 interpretive items	$292,564
		5 media releases 20 meetings with 11 groups	$292,173
		Sub total:	$584,737
Lack of ecological resources to maintain viable populations	Biological surveys Creating buffers and corridors Other research Note: revegetation for this purpose also contributes to hydrological control.	50 surveys 3 landholders including 35ha with 48,000 seedlings 9km of fencing 6 reports – Refer to Appendix 15 for a list of reports	$291,461 $94,374 $102,102
		Sub total:	$487,937
Summary of all other activities with <$10,000 expenditure over 2001-2006		Sub total:	$37,412
		TOTAL	**$2,059,934**

Monitoring has involved a significant amount of funds, and is critical to building the models upon which management action will be based. Monitoring has included, for example, the installation of a network of catchment and asset-scale piezometers and an associated monitoring regime, and assessment of the impact of secondary salinity on vulnerable species such as aquatic invertebrates. Sampling of wetland water levels and quality in the BMNDRC commenced in 2003 as part of general and priority wetland monitoring programs. Although most sampling has been conducted opportunistically, basic water quality parameters of electrical conductivity, pH, and temperature have been recorded at 50 wetlands in the BMNDRC. However, as there are over 1,000 discrete wetlands in the BMNDRC, multiple assessments have only taken place at a few wetlands.

Groundwater monitoring includes 89 piezometers in broad transects across the catchment (depth is measured at five to six week intervals and salinity and pH at longer intervals), and a further 46 piezometers focussed at five representative wetlands (depth is measured at five to six week intervals and salinity and pH at longer intervals). Nine piezometers are measuring depth at an oil mallee trial site within the catchment (Stacy's site) and monitoring of a further 25 piezometers is being overseen (Marchagee Catchment Group and Waddy Forest LCDC).

Surface water monitoring includes surface water gauging at three representative wetlands, two water management demonstration sites, and 13 catchment-wide sampling sites. Records are collected from data loggers at five to six week intervals. In addition, surface water quality is measured at 15 catchment scale culverts, three representative wetlands and five deep drains. These are sampled opportunistically. Records from six catchment scale 'tipping bucket' rain gauges are collected at five to six week intervals.

Activities to date have provided useful hydrogeological data at a regional scale. However, this data is not suitable for describing detailed processes for individual biodiversity assets. These monitoring gaps and a lack of comprehensive understanding of the hydrological system of the BMNDRC are a significant constraint to conserving the biodiversity assets of the BMNDRC. Accordingly, a key focus of this plan is to obtain more information and improve knowledge of the hydrology, hydrodynamics and biota of priority wetlands. For example, following identification of representative biodiversity assets in 2004–2005, detailed hydrological investigations were undertaken in July 2006 at five sites to provide a more detailed understanding of hydrological processes (URS 2007).

In addition to sampling associated with the BMNDRC, a better understanding has been gained from other projects being undertaken in the area. Where possible, DEC has directly accessed data from custodians of these projects or through published results to build on knowledge of the BMNDRC. Other organisations include:

- Department of Agriculture and Food WA
- bore network in Buntine to investigate deep drain effects
- bore network to model groundwater equilibrium with oil mallee plantings
- Engineering Evaluation Initiative
- bore network at Nugadong Road East to monitor water quality in a deep drain
- Department of Water
- Water Corporation, water quality data on water catchment adjacent to Buntine nature reserve
- landholder surface water and groundwater quality monitoring
- analysis of farm water quality sourced from dams and windmills
- bore networks on the western side of BMNDRC and as part of Waddy Forest LCDC and Marchagee Catchment Group.

Building an appropriate culture

Building an appropriate culture is a two-way process that involves engaging, being informed by, and informing stakeholders and the public at local, regional, State and national scales. It is essential that the operational goal and related values of the BMNDRC meet important community needs. Building an appropriate culture is largely about ensuring that communication and related processes link the operational goal with community needs. The costs of recovery planning activities are included in this category, as the planning process and its products are a key mechanism for stakeholder engagement. Therefore, it is not surprising that this category has been the second most significant area of expenditure during the main planning phase.

Apart from recovery planning itself, activities have delivered useful information about landholder attitudes and behaviour which has been crucial to developing appropriate management responses. Establishing strong representation from catchment landholders, providing support for the catchment steering committee and putting in place an effective DEC management team have also been key areas of effort.

The team has expertise and experience in a wide range of disciplines including hydrology, wetland and catchment management, geographical information systems, data management and project management. Putting together and maintaining a well-managed team with the necessary skills and dedication has been a necessary but challenging task. The location of the BMNDRC some 200km from the DEC Midwest Regional Office has provided advantages in terms of being part of a larger regional DEC team and in being able to attract and retain staff in Geraldton as a significant regional location. Nonetheless, operational costs are higher for a large catchment like the BMNDRC which must contend with long distances.

As broad-acre farming accounts for close to 85 per cent of the area of the BMNDRC, the development of a strong communications network which promotes an understanding of catchment wide issues and appreciation of different perspectives has been an important foundation activity in the BMNDRC. For example the BMNDRC team has developed a newsletter, the *Buntine-Marchagee Catchment News* (currently up to its thirteenth issue), which has been well received. An important part of building an appropriate culture is including people in demonstration activities as described above Not only does this type of work deliver valuable on-ground outcomes for both agricultural production and biodiversity conservation, it is an adaptive management process from which all participants learn.

Finally, it should be noted that expenditure on building an appropriate culture is expected to decrease in relative terms as the initial planning phase is completed and management action increases.

Lack of ecological resources

Activities to increase ecological resources – such as food, shelter and corridors for movement – and thus improve the viability of biota have focused on flora and birds. Research by CSIRO (Huggett et al. 2004) has provided the management team with a map of landscape scale priorities that is used to target expenditure for optimum biodiversity benefits at a catchment scale. Other activities include planting revegetation buffers and corridors using both commercially prospective and non-commercial species which provide habitat or improve habitat condition for many species. A monitoring regime is in place for all revegetation undertaken as part of the BMNDRC project. Survival and performance measurements are recorded at two intervals after establishment. These activities will continue although the emphasis will vary based on periodic reassessments of threats and annual operational planning.

It should be noted that revegetation to counteract lack of ecological resources also contributes to hydrological control.

6 IMPLEMENTATION, MONITORING AND EVALUATION

This section establishes the implementation process and outlines the framework that will be used for monitoring and evaluating progress towards achieving the BMNDRC's operational goal. It builds on the activities undertaken to date and brings together activities that manage ecosystem processes, identified in Section 5, with the operational goal as well as the priority cultural values for biodiversity conservation identified in Section 2.

Overall, the next decade (2008–2017) of implementation will involve:

- Increased on-ground works adjacent to selected wetland assets.
- Continued application of the water management (surface and groundwater) approach in the BMNDRC as an important tool for managing altered hydrology.
- Building of time series data through maintaining the well established hydrogeological monitoring network – needed for calibrating and contributing to hydrogeological models (such as LASCAM/DYRIM and LISFLOOD[24]). In time, these models will form the basis for further refinement of the extent of risk posed by salinity and altered hydrology and lead to better targeted management responses.
- Refinement and formalising of the wetland classification approach and application to the whole catchment which will be a key piece of work in the next two years.
- Quantification of the threat posed by acidification, altered nutrient cycles, eutrophication, erosion and sedimentation, in part through research into the environmental requirements of a selection of biota.
- Building understanding of modelled predictions of climate change and its impacts on hydrology.
- Mapping the distribution and impact of physical disturbances, such as fire and wind erosion, as well as mapping the distribution of environmental weeds, disease, introduced and problem animals and documenting their impacts on biodiversity. This will provide priorities for management.
- Ongoing efforts to build a culture that supports achievement of the operational goal for BMNDRC. This will include demonstration projects, regular newsletters, stakeholder training (including DEC staff), a communications plan and further development and use of cost-sharing arrangements.
- Continued application of decision-making tools to identify priority threats to biodiversity assets and assess the merit of alternative management actions. A risk-based approach will be used to document and communicate how uncertainty is dealt with in deciding management actions.

MONITORING AND EVALUATION FRAMEWORK

Monitoring progress and evaluating performance will initially focus on the five priority wetlands selected as representative biological communities.

There are two key questions that must be addressed. Firstly, are the biodiversity assets which are necessary to achieve the operational goal (and related resource condition targets) being adequately conserved, protected or recovered? And secondly, are the priority cultural values listed in Section 2 being delivered? These questions are dealt with separately below.

OPERATIONAL GOAL AND RESOURCE CONDITION TARGETS

The operational goal can be framed as a 10-year Resource Condition Target (RCT) which aims to maintain the richness, distribution, abundance and condition of biological communities that form the priority biodiversity assets. There are two measures to the resource condition target:

- physiochemical[25]
- biological

These two measures are summarised in Table 17. A template table of criteria and measures for the list of priority wetlands of the five wetland types is provided in Appendix 17. It should be noted that criteria and measures used will be mostly biological until the systems are better understood. These will be addressed through monitoring and reporting by regional recovery catchment officers. Progress towards developing and achieving these resource condition targets will be reported annually with commentary on goal achievement.

24 These terms refer to models which will be used to predict flooding extent and duration under various management regimes and mitigation measures LASCAM/DYRIM is a combination of two models – a three dimensional catchment scale runoff model (LASCAM) and DYRIM, which is a hydraulic model. LISFLOOD is a digital elevation model which models rainfall runoff to calculate flood extent and durations.

25 Refers to physical characteristics and chemical composition.

Gaps in monitoring

A number of actions will address existing monitoring gaps:

- Continued refinement of sampling techniques and the refinement of selection of indicator species used for evaluating resource condition. For example, intra-seasonal aquatic invertebrate sampling is planned for 2007 (early, middle and late winter sampling times) to determine the most suitable one-off sampling time each year. This will aim to improve reliability of data collected and improve links between data collected and resource condition.
- Selection of appropriate indicator species for Ecological Water Requirements (EWRs) for particular species and wetland types in the BMNDRC.
- Collection of time series data of:
    - groundwater trends specific to priority wetlands, especially evidence over an 'above average rainfall' year to give indication of variability;
    - nutrient trends specific to priority wetlands, especially evidence over an 'above average rainfall' year to give indication of variability;
    - environmental weed distribution specific to priority wetlands, especially evidence over an 'above average rainfall' year to give indication of the influence of seasonal variability (for example, surface water or increased soil profile moisture, or an increased length of season may instigate a new distribution and abundance of environmental weeds).
- Selection of a fauna group (like waterfowl) or particular species dependent on the wetland as an indicator of resource condition.

As part of the planning and management process for natural diversity recovery catchments (refer to Figure 1) a major review of goal achievement will be conducted at five and 10 yearly intervals. This evaluation activity will also be used to improve decision-making, enhance organisational learning and ensure achievement of the operational goal for the BMNDRC by meeting resource condition targets for biodiversity assets.

Table 17. Example of resource condition targets by asset

Resource condition target (by asset type)		Recovery criteria (examples only)	Progress report (asset status)
Wetland types (1-5)	Physiochemical • water quality • water quantity • biological distribution • abundance • condition	• Salt load or concentration maintained for wetland • Depth to groundwater for wetland • No further deterioration in vegetation	• (Same, better, worse)

CULTURAL VALUES

As part of the monitoring and evaluation process it is vital to assess achievement of the cultural values outlined in Table 3, Section 4. For the most part, these will be achieved by activities described in relation to the resource condition targets. However, in the case of ecosystem services, it is necessary to develop additional criteria to assess whether values are being maintained or improved. These criteria will be developed and tested during the first two years of plan implementation, and after appropriate amendment, will be added to the recovery plan and reporting process.

IMPLEMENTATION PROCESS

Annual operational planning and works

Scheduling of priority actions and the delivery of outputs is given at Table 18. These outputs are grouped according to the categories of threats posed to biodiversity assets and will form the basis for annual operational planning by the Midwest Region with advice from the recovery catchment team. These are relative priorities and may be adjusted as new knowledge is gained. This is part of the planning and management process for natural diversity recovery catchments (refer to Figure 1) which includes a feedback process to regularly assess constraints and how they affect management feasibility.

The 'warning light' approach shown in Table 18 provides an indication of possible barriers to implementation. 'Green lights' are relatively well established tasks or those unlikely to pose significant issues in implementation. 'Amber' or 'red lights' apply to activities which are at risk of running behind schedule. For the most part, these risks relate to activities that are highly dependent on successful completion of other activities. Thus the warning system is designed to help operational personnel keep track of susceptible activities and, where necessary, adapt.

The recovery catchment managers will, as part of the standard departmental budget process, prepare an annual works program based on Table 18, which will be recorded in the standard budgeting and expenditure template used in the salinity program (*Appendix* 16). The proposed budget will be assessed by the Manager, Natural Resource Branch, who will recommend an allocation for endorsement by the Director, Nature Conservation.

Under the direction of the Regional Manager, Midwest, allocated recovery funds will be spent on approved works.

Annual reporting process

All expenditure and outputs will be reported in the standard template (Appendix 16), which will be submitted by 31 August of each year for the preceding financial year. In addition, progress against the resource condition targets will be outlined annually, with periodic major reviews.

Table 18. Threat categories and timeline for delivery of management outputs

Traffic light approach Green lights - well established tasks Amber or red lights are at risk of running behind schedule

	Timing										
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Surface and groundwater threats – water balance and salinity impacts on biodiversity assets											
1. Catchment salinity risk maps completed (2008).											
2. Report on wetland classification describing ranked wetland assets threatened by salinity (2009).											
3. Selection of a suitable Claypan representative wetland to add to priority biodiversity assets (2008).											
4. Further refining of selection of a representative 'primary saline wetland and channels' as a priority asset (2008).											
5. Report describing assets and methods used to map, define and rank terrestrial assemblages threatened by salinity (see further work identified in Section 3: includes a vegetation survey of the main drainage line and Koobabbie Farm (2009).											
6. Monitoring network for surface and groundwater in the catchment in place (2008). Monitoring network designed to assess surface and groundwater trends at the catchment scale and at the sub-catchment scale of priority assets.											
7. Surface and groundwater quantity and quality trends in the catchment reported every two to five years, dependant on significance of data collected, and built into hydrological decision systems and models. A review report of data collected to date to be completed in 2008.											
8. Report on EWRs for priority assets as a basis for predictive modelling. Results to be extrapolated across the catchment (2012).											
9. Water balances (coarse) for catchment and individual assets determined (2008). Water balances (refined) for catchment and individual assets determined by 2010, or as soon as seasonal conditions allow for hard-data collection to adequately calibrate models.											
10. Catchment wide hydrological models (LASCAM, DYRIM, LISFLOOD) parameterised and calibrated (2012).											
11. Priority asset surface water – groundwater interaction models developed (2015).											
12. Waterborne 'contamination' issues such as elevated nutrient loads (including eutrophication), elevated acidity or alkalinity levels, erosion sedimentation and turbidity will be included in models where possible.											
13. Other models developed as appropriate.											
14. Assessment of deep drainage as a management tool at priority assets , including environmental impacts.											
15. 22km of grade banks, 12km of fencing (revegetation, waterways, and remnant vegetation) and 35ha of revegetation established (2007), (demonstration catchment).											

Table 18. Threat categories and timeline for delivery of management outputs

Traffic light approach — Green lights - well established tasks; Amber or red lights are at risk of running behind schedule

	Timing										
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
16. One Integrated Surface Water Demonstration Catchment case study report and one field day (2008).	Amber	Amber									
17. 5000ha treated per year (2007–2012) with contour banks and similar structures established in the catchments of priority assets	Green	Green	Amber	Amber	Amber	Amber					
18. Promote development of corporate standard for vegetation condition monitoring Note – Responsibility for this output is at a Corporate level. Implementation of a pilot study using 'VegMachine' software (2008).	Green	Green									
19. Vegetation health reported every three years at priority assets, and data used, where applicable, in decision tools (2012).			Green	Green	Green	Green					
20. 200ha per year fenced (2007-2012) (remnant vegetation)	Amber	Amber	Amber	Amber	Amber	Amber					
21. Arrangements for improved management for conservation and water use in place (2010) e.g. voluntary management agreements through Land for Wildlife or similar.	Amber	Amber	Amber	Amber							
22. 30ha of revegetation per year on upland slopes.	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
23. 20ha of revegetation per year adjacent (or within 20 metres) of key assets.	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
24. Draft plan of recovery actions for selected wetland assets completed (2008).	Red	Red									
Waterborne threats to biodiversity assets – acidification											
1. Annual reporting of acidity and pH trends in the BMNDRC.	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
2. Investigate and determine buffering capacity of receiving water bodies. Note – Contingent on whether acidification problem exists.	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
3. Report identifying the relative buffering capacity of priority wetlands which are likely receiving water bodies (2008).	Amber	Amber									
4. EWR developed for priority biodiversity assets based on current research into tolerances and thresholds for condition decline and mortality in biota (2009).	Red	Red	Red								
5. Report assessing risk and cost/benefit analysis of protecting assets threatened by altered acidity (2010).	Amber	Amber	Amber	Amber							
6. Report on combining the information obtained as part of the activities detailed above with catchment and asset specific models (2010).	Amber	Amber	Amber	Amber							
Waterborne threats to biodiversity assets – altered nutrient cycles and eutrophication.											
1. Annual reporting of concentrations and trends in nutrient and Dissolved Oxygen concentrations.	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green

Table 18. Threat categories and timeline for delivery of management outputs

Traffic light approach Green lights - well established tasks | Amber or red lights are at risk of running behind schedule

	Timing										
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
2. Report detailing the source and concentration of the elevated nutrient concentrations and their relationship with reduced Dissolved Oxygen levels, particularity if detected in or near priority assets.											
3. Report on acceptable levels of nutrient loading and eutrophication in priority assets (2008).											
4. Detailed risk assessments and cost/benefit analysis of protecting assets threatened by altered nutrient cycles and eutrophication. (Note, will include assessment at catchment scale) (2008).											
Waterborne threats – erosion and sedimentation.											
1. Annual reporting of trends in turbidity.											
2. Report on erosion in the upper part of the catchment using elevated turbidity levels as an indicator of accelerated erosion rates (2008).											
3. Report on levels of sedimentation in the lower parts of the catchment with a focus on representative wetland assets (2009).											
4. 5000ha Targeted on ground actions to improve degraded water courses where feasible (as part of surface water management activities) (2007–2012).											
5. Report, based on existing research, detailing tolerance and threshold levels for priority assets (2008).											
6. Report assessing risk and cost/benefit analysis protecting assets threatened by elevated turbidity and accelerated rates of erosion and sedimentation – includes catchment and asset specific models (2008).											
7. An on farm program covering 25,000ha to assist landholders to reduce erosion and soil loss (2007–2012).											
Climate change impacts on altered hydrology and biodiversity assets											
1. As part of DEC wheatbelt-wide investigation, a palaeoclimatic record of the last 10,000 years for the BMNDRC as a calibration point/s for General Circulation Models (GCMs) (2009 if possible).											
2. A report on detailed downscaled GCM predictions at a catchment scale using a local calibration point (2010).											
3. A set of predictions regarding impacts of climate change on altered hydrological regimes (2010).											
4. Models developed above used for assessing the impacts of climate change on altered hydrology in the BMNDRC (2011).											
5. Update on relevant climate change research reported as part of annual operational planning. Where applicable, this should include the implications or recommendations for management planning or actions to protect biota.											

Table 18. Threat categories and timeline for delivery of management outputs

Traffic light approach Green lights - well established tasks; Amber or red lights are at risk of running behind schedule

	Timing										
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
6. Installation of a weather station in the west of the BMNDRC to complement the Dalwallinu (Bureau of Meteorology) and McAlpine (CSIRO) stations (2008). Data collection to occur on the basis of needing to understand climate variability for the purpose of managing priority assets.											
Environmental weeds and disease											
1. Report reviewing weed occurrence and distribution in BMNDRC and, in consultation with stakeholders, prioritised management actions (2008).											
2. Program of weed removal/suppression at priority assets with a particular emphasis on sandy seep wetlands (W009; W011+ W012+109; W015+W016; W020) (2008).											
3. Monitoring of weed distribution and abundance at selected sites across the BMNDRC (every two years, and/or after episodic flood events).											
4. Regular progress reports of monitoring activities and control programs through BMNDRC newsletter – additional communication activities as necessary (ongoing).											
5. Review of new information regarding weeds (annually).											
6. Report reviewing the plant disease occurrence and distribution in the vicinity of the BMNDRC (2009).											
7. Monitoring areas of vegetation decline (where disease is suspected) for evidence and occurrence of plant diseases (annually – starting 2009).											
8. Review of new information on plant diseases (every two years, and/or after new evidence suggests changes to management).											
9. Plant disease suppression where outbreaks are detected (as appropriate).											
Introduced and problem animals											
1. Report reviewing the introduced and problem animal distribution in BMNDRC and, in consultation with landholders, prioritised management actions (2009).											
2. Program for control of introduced/problem animals at priority assets W057+ W058 + W059 (bentonite wetlands); W011 + W012 + 109 and W015 + W016 (fresh-brackish wetlands); and W011 + W002 (Gypsum wetlands) by (2009). This choice is based on assets being adjacent to an extensive area of remnant vegetation (bentonite and gypsum wetlands); and being a drought refuge for native fauna (fresh-brackish wetlands). Control measures of target species to thoroughly consider effectiveness.											

Table 18. Threat categories and timeline for delivery of management outputs

Traffic light approach Green lights - well established tasks; Amber or red lights are at risk of running behind schedule

	Timing										
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
3. Targeted monitoring of introduced/problem animal distribution and abundance at selected priority biodiversity assets (every two years).											
4. Regular progress reports of monitoring activities and control programs through BMNDRC newsletter – additional communication activities as necessary (ongoing).											
5. Review of new information regarding introduced and problem native animals (every two years, and/or after new evidence suggests changes to management).											
Inappropriate regimes of physical disturbance											
1. Firebreaks constructed around priority assets that are of suitable size and consistent with standard DEC regional procedures (annual requirement).											
2. A plan to address weed response to wildfire which may impact on priority biodiversity assets (2008).											
3. Report on asset specific, appropriate fire regime (2010).											
4. If required, prescribed burning plan developed and implemented (2010).											
5. By using the catchment and asset specific models and an understanding of past and potential future climate regimes, predict the extent and duration of flooding under the possible range of rainfall events (2013).											
6. By using the catchment and asset specific models and potential future climate regimes, predict the duration of potential droughts (rainfall scarcity outside of natural variation) and the implications for biodiversity assets (2013).											
7. Report on site investigation of areas surrounding priority assets to assess location, cause, extent, threat posed by wind erosion (2009).											
8. Priorities for management of the cause and impacts of wind erosion on priority biodiversity assets (2009).											
9. Priority areas of remnant vegetation identified on the basis of their contribution to the National Reserve System as candidates for purchase. Communication to catchment landholders DEC's desire to purchase significant areas of natural lands (2008).											
10. Areas significant for conservation, and management of competing land uses, purchased (ongoing) Refer to actions under Insufficient ecological resources to maintain viable populations (Table 15)											
11. Map of herbicide dumps with schedule and procedures for handling and disposal prepared (2008).											

Table 18. Threat categories and timeline for delivery of management outputs

Traffic light approach Green lights - well established tasks · Amber or red lights are at risk of running behind schedule

	Timing										
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Building an appropriate culture											
1. Program of implementation for cost sharing arrangements, where appropriate and possible. These arrangements will explicitly acknowledge the full range of land, water and biodiversity values. This is relevant to all activities previously identified necessary to protect representative and priority biodiversity assets (2008).											
2. Reporting of cost sharing arrangements and available funds for the future (annual).											
3. Development and implementation of a communication plan to reduce lack of socio political will/support (2009).											
4. Capture of local knowledge on biodiversity and its values. Report by 2010.											
5. Report disseminating summaries of current status and trends in biodiversity assets (annual).											
Insufficient ecological resources to maintain viable populations											
1. Vegetation management plans initially for assets W004; W070 (primary saline wetland and channels); W001 (gypsum wetland); W011 + W012 + 109; W015 + W016 (fresh/brackish wetlands); and W057 + W058 + W059 (bentonite wetlands), (2008)											
2. Assessment report on the utility of the 'modified focal species approach' for future work on population viability in the BMNDRC (2008).											
3. Review of literature to assess new information on population viability (biennial), (2009).											
4. Assessment report on TEC status of W057 + W058 + W059 (bentonite wetlands) (2008).											

REFERENCES

Abeysinghe, P. B. (2002) 'Bentonite, attapulgite and common clays in Western Australia.' *Mineral Resources Bulletin 20*. Perth, Western Australia, Geological Survey of Western Australia.

Agriculture Western Australia, Department of Conservation and Land Management, Department of Environment & Water and Rivers Commission (1996) *Western Australian Salinity Action Plan*. Prepared for the Government of Western Australia.

Alderman, A. & Clarke, M. (2003) *Resource management technical report: Moore River catchment appraisal. Geraldton, Western Australia*, Department of Agriculture.

Allaby, A. & Allaby, M. (Eds) (2003) *Oxford dictionary of earth sciences*, Oxford, Oxford University Press.

ANZECC & ARMCANZ (1996) *National principles for the provision of water for ecosystems*, Occasional Paper SWR No. 3. Canberra, Australia, Sustainable Land and Water Resource Management Committee, Subcommittee on Water Resources.

Australian Bureau of Statistics (2005) *Year book Australia: 1988 special article – Drought in Australia*. Available on http://www.abs.gov.au/Ausstats/abs@.nsf/0/068F13BCCD03F27BCA2569DE001F1072?Open.

Australian Bureau of Statistics (2007) 2001 *Census of population and housing: Community profiles*. Accessed 23rd May, 2007. Available on-line at http://www.abs.gov.au/websitedbs/d3310114.nsf/Home/census.

Baxter, J. L. & Lipple, S. L. (1985) *1: 250 000 Geological series explanatory notes: Perenjori Western Australia. Sheet SH/50-6 International Index*. Perth, Western Australia, Geological Survey of Western Australia.

Beard, J. S. (1980) 'A new phytogeographic map of Western Australia'. Western Australia. Herbarium Research Notes, 3, 37-58.

Burbidge, A. A. (2004) *Threatened animals of Western Australia*, Department of Conservation and Land Management.

Bureau of Meteorology (2005) Daily rainfall data for stations 8275 Anro, 8017 Buntine, 8018 Buntine East, 8037 Coorow PO, 8039 Dalwallinu, 8230 Elena, 8028 Hakea, 8067 Koobabbie, 8084 Manavi, 8080 Maya, 8021 Sunnydale, 8130 Watheroo, 8139 Wubin PO, and 8146 Ytinichie. Unpublished data. Perth, Western Australia, Commonwealth Bureau of Meteorology.

Byrne, M., Elliott, C., Yates, C. J. & Coates, D. J. (2007) 'Extensive pollen dispersal in a bird-pollinated shrub, *Calothamnus quadrifidus*, in a fragmented landscape', *Molecular Ecology*, 16, 1303-1314.

CALM (1995) Dryandra Woodland Management Plan 1995-2005. Management Plan Number 30. Perth, Western Australia, Department of Conservation and Land Management.

CALM (1999a) *Nomination document for the Buntine-Marchagee Natural Diversity Recovery Catchment. Geraldton, Western Australia*, Department of Conservation and Land Management, Midwest Region.

CALM (1999b) *Environmental weed strategy for Western Australia.* Department of Conservation and Land Management.

CALM (2005) *Definitions, categories and criteria for threatened and priority ecological communities.* Department of Conservation and Land Management.

CALM (2006) Buntine-Marchagee Natural Diversity Recovery Catchment (BMNDRC). Unpublished minutes from the Steering Committee meeting 31st March 2006. Maley Park Recreation Centre, Coorow.

CALM & Colmar Brunton (2005) *Buntine-Marchagee Natural Diversity Recovery Catchment: Landholder Survey 2005 – 2010.* Geraldton, Western Australia, Report prepared by the Department of Conservation and Land Management and Colmar Brunton.

Carter, J. D. & Lipple, S. L. (1982) *1: 250 000 Geological series explanatory notes: Moora Western Australia. Sheet SH/50-10 International Index.* Perth, Western Australia, Geological Survey of Western Australia.

Coates, D. J. & Dixon, K. W. (2007) 'Current perspectives in plant conservation biology'. *Australian Journal of Botany*, 55, 187-193.

Coates, D. J., Sampson, J. F. & Yates, C. J. (2007) 'Plant mating systems and assessing population persistence in fragmented landscapes', *Australian Journal of Botany*, 55.

CSIRO (2006) *Climate change scenarios for initial assessment of risk in accordance with risk management guidance.* Aspendale, Victoria. CSIRO Marine and Atmospheric Research.

Davies, S. & Ladd, P. (2000a) *A survey of the flora of remnants within the Waddy Forest Land Conservation District.* The Waddy Forest Land Conservation District Committee.

Davies, S. & Ladd, P. (2000b) *A survey of the flora remnant vegetation within the Marchagee Catchment.* Report prepared for the Marchagee Catchment Group of the Coorow Land Conservation District.

Davies, S., Ladd, P. & Loomes, D. (2001) A survey of the flora of remnant vegetation within the Marchagee catchment: Second report. For the Marchagee Catchment Group of the Coorow Land Conservation District in conjunction with the National Heritage Trust.

Davies, S. J. J. F. (1990) Report on a survey of the wildlife of Koobabbie: March and September 1990. Coorow, Western Australia, Unpublished report prepared for Alison and John Doley of Koobabbie.

DEC (2006) A 100-year Biodiversity Conservation Strategy for Western Australia: Phase One: Blueprint to the Bicentenary in 2029 (Draft). Kensington, Western Australia, Government of Western Australia.

DEC (2007) *Analysis of the BMNDRC remnant area at risk of secondary salinity.* Analysis used LandMonitor and Huggett et al. (2004) native vegetation shape files, and used ArcGIS 9 software. LandMonitor salinity risk is derived from: Evans, F.H. and Caccetta, P.A. (nd). Salinity risk prediction using Landsat TM and DEM-derived data. CSIRO, Perth, WA. Geraldton, Western Australia, Department of Environment and Conservation, Midwest Region.

Dell, J., Harrold, G., Kitchener, D. J., Morris, K. D. & Muir, B. (1979) *Biological survey of the Western Australian wheatbelt.* Records of the Western Australian Museum No. 8. Part 7: Yornaning Nature Reserve. Perth, Western Australia, Department of Mammals and Survey, Western Australian Museum.

Department of Environment (2003) *Salinity Investment Framework.* Interim Report – Phase 1. Department of Environment Resources Science Division.

Department of the Environment and Heritage (2003) *National framework for Natural Resource Management standards and targets.* Report prepared for the Department of the Environment and Heritage by the Natural Resource Management Ministerial Council.

Durrant, J. D. & Guthrie, N. A. (2004) 'Faunas of unflooded saline wetland floors of the western Australian wheatbelt'. In Keighery, G. J., Halse, S. A., Harvey, M. S. & McKenzie, N. L. (Eds.) *A biodiversity survey of the Western Australian agricultural zone.* Records of the Western Australian Museum. Supplement No. 67. Perth, Western Australia, Department of Conservation and Land Management and the Western Australian Museum.

Environmental Protection Authority (2006) *State of the Environment report Western Australia draft 2006*, Perth, Government of Western Australia.

Farmer, D., Stanton, D. & Coles, N. A. (2001) *Surface water assessment and recommendations for Lake Bryde Recovery Catchment. Western Australia*, Report prepared by the Engineering Water Management Group, Dept. Agriculture for the Department of Conservation and Land Management.

Farmer, D. L., Stanton, D. & Coles, N. A. (2002) *Surface water impact assessment and recommendations for Upper Fitzgerald/ Lake Magenta Nature Reserve, Western Australia*, Report prepared by the Engineering Water Management Group, Dept. Agriculture for the Department of Conservation and Land Management.

Frost, F., Hamilton, B., Loyd, M. & Pannell, D. (2001) *Salinity: A new balance.* The report of the salinity taskforce established to review salinity management in Western Australia.

Geological Survey of Western Australia (1990) *Geology and mineral resources of Western Australia*, Western Australia Geological Survey, Memoir 3. Perth, Western Australia.

Government of Western Australia (2002) *Salinity: A new balance*, Government's response to the salinity taskforce report. Government of Western Australia.

Griffin, T. & Goulding, P. (2004) *Soil landscape mapping for the Buntine Marchagee Recovery Catchment*. Land Resource and Monitoring. Resource Management Technical Report No. 267. Report produced by the Department of Agriculture for the Department of Conservation and Land Management.

Hamilton-Brown, S. (2002) *Interim Recovery Plan, Herbaceous plant assemblages on bentonite lake beds (Vegetation types 1,2,3,&7) and margins (vegetation types 4,5&6) of the Watheroo-Marchagee region: Interim recovery plan 2002-2007.* Wanneroo, Western Australia, Department of Conservation and Land Management.

Hanold, D., Gowanlock, D., Stukely, M. J. C., Habili, N. & Randles, J. W. (2006) 'Mundulla Yellows disease of eucalypts: descriptors and preliminary studies on distribution and etiology'. *Australasian Plant Pathology*, 35, 199-215.

Harold, G. (2000) *Fauna of the Marchagee Catchment. Albany, Western Australia*, Report prepared by Moloch Fauna Consultants for the Marchagee Bushcare Catchment Group.

Harold, G. (2001) *Fauna of the Marchagee Catchment*. Albany, Western Australia, Report prepared by Moloch Fauna Consultants for the Marchagee Bushcare Catchment Group.

Harvery, M. S., Waldock, J. M., Guthrie, N. A., Durrant, B. J. & McKenzie, N. L. (2004) 'Patterns in the composition of ground-dwelling araneomorph spider communities in the Western Australian wheatbelt'. In Keighery, G. J., Halse, S. A., Harvey, M. S. & McKenzie, N. L. (Eds.) *A biodiversity survey of the Western Australian agricultural zone*. Records of the Western Australian Museum Supplement, Number 67. Welshpool, Western Australia.

Holling, C. S. (1978) *Adaptive Environmental Assessment and Management*, London, Wiley, Reprinted by Blackburn Press in 2005.

Huggett, A. J., Parsons, B., Atkins, L. & Ingram, J. A. (2004) Taking on the challenge: Landscape design for bird conservation in Buntine-Marchagee Catchment. Internal technical report on Component 1 of 'Testing approaches to landscape design in cropping lands' project. Perth, Western Australia and Canberra ACT, CSIRO Sustainable Ecosystems.

IOCI (2002) *Climate variability and change in south west Western Australia*. Perth, Western Australia, Indian Ocean Climate Initiative Panel.

IOCI (2005) *IOCI reports key findings of recent research into south-western climate*, Bulletin No. 6. Indian Ocean Climate Initiative.

Keighery, G., Halse, S. A. & McKenzie, N. (2001) 'Why wheatbelt valleys are valuable and vulnerable: the ecology of wheatbelt valleys and threats to their survival'. *Dealing with Salinity in Wheatbelt Valleys: Processes, Prospects and practical options*. Merredin, Western Australia.

Keighery, G. J., Halse, S. A., Harvey, M. S. & McKenzie, N. L. (2004) *A biodiversity survey of the Western Australian agricultural zone.*, Welshpool, Western Australia., Western Australian Museum, Supplement No. 67.

Kitchener, D. J., Chapman, A., Dell, J. & Muir, B. G. (1979) *Biological survey of the Western Australian Wheatbelt. Part 10: Buntine, Nugadong and East Nugadong Nature Reserve and Nugadong Forest Reserve.* Records of the Western Australian Museum Supplementary Series. 9:127. Perth, Western Australia, Western Australian Museum.

Kitchener, D. J., Chapman, A., Muir, B. G. & Palmer, M. (1980) 'Conservation value for mammals of reserves in the Western Australian wheatbelt.' *Biological Conservation*, 18, 179-207.

Lane, J. A. K., Pearson, G. B., Clarke, A. G., Winchcombe, Y. C. & Munro D. R. (dec), (2004) *Depths and salinities of wetlands in South-Western Australia: 1977-2000.* Department of Conservation and Land Management.

Lehtonen, T. R., Lemmetyinen, J., Pihakaski, S. & Portin, P. (1998) *Elsevier's Dictionary of Biology*, Turku, Finland, Elsevier.

Lynas, J., Storey, A. W. & Sheil, R. J. (2006) *Buntine-Marchagee Natural Diversity Recovery Catchment (BMRC). Wetland invertebrate fauna monitoring: August 2005. Crawley, Western Australia*, Report prepared by the Aquatic Research Laboratory, University of Western Australia for the Department of Conservation and Land Management, Midwest regional office.

Lyons, M. N., Gibson, N., Keighery, G. J. & Lyons, S. D. (2004) *Wetland flora and vegetation in the Western Australian wheatbelt. A biodiversity survey of the Western Australian agricultural zone.* Welshpool, Western Australia, Western Australian Museum, Supplement No. 67.

McConnell, C. & Pillai, M. (1995) *Hydrogeological overview: Marchagee area.* Geraldton and Moora, Western Australia, Department of Agriculture.

McFarlane, D. J., George, R. J. & Caccetta, P. A. (2004) The extent and potential area of salt-affected land in Western Australia estimated using remote sensing and digital terrain models. 1st National Salinity Engineering Conference. Perth, Western Australia.

Mittermeier, R. A., Gil, P. R., Hoffman, M., Pilgrim, J., Brooks, T., Mittermeier, C. R., Lamoruuex, J. & Da Fonseca, A. B. (2005) *Hotspots revisited: Earth's biologically richest and most threatened terrestrial regions.* Conservation International.

Northern Agricultural Catchments Council (NACC) (2004) Draft Regional Natural Resource Management Strategy. Northern Agricultural Region of Western Australia. Prepared by the Northern Agricultural Catchments Council (NACC)

Natural Resource Management Ministerial Council (2003) *National framework for Natural Resource Management standards and targets.* Report prepared for the Department of the Environment and Heritage by the Natural Resource Management Ministerial Council.

Paton, D. C. & Cutten, J. (1999) Distribution, spread and progression of *Mundulla Yellows in South Australia. Mundella Yellows: A new threat to our native vegetation – Meeting the challenge.* University of South Australia, Proceedings of the seminar presented by the Conservation Council of South Australia in association with the University of Adelaide.

Pinder, A. M., Halse, S. A., McRae, J. M. & Shiel, R. J. (2004) *Aquatic invertebrate assemblages of wetlands and rivers in the Wheatbelt region of Western Australia*, Records of the Western Australian Museum Supplement. Perth, Records of the Western Australian Museum.

Queensland Department of Natural Resources and Mines (2005) SILO Data Drill for location Lat, Long: -30.05 116.20 (DECIMAL DEGREES), 30 03'S 116 12'E.

Richardson, J., Keighery, G. & Manson, W. (2005) *A baseline of vegetation health for the Buntine-Marchagee Recovery Catchment. Geraldton, Western Australia*, Department of Conservation and Land Management.

Risbey, D. A., Calver, M.C., Short, J., Bradley, J.S., Wright, I.W. (2000) 'The impact of cats and foxes on the small vertebrate fauna of Heirisson Prong, Western Australia, II. A field experiment'. *Wildlife Research* 27, 223-235.

Sanders, A. (1991) *Oral histories documenting changes in wheatbelt wetlands* Occassional paper 2/91 Department of Conservation and Land Management.

Saunders, D. A. (1985) 'Human impact: The response of forest and woodland bird communities. Whither the future'. In Keast, J. A., Recher, H. F., Ford, H. A. & Saunders, D. A. (Eds) *Birds of Eucalypt Forests and Woodlands: Ecology, Conservation, Management.* Chipping Norton, NSW, Surrey Beatty.

Saunders, D. A. (1989) 'Changes in the avifauna of a region, district, and remnant: the wheatbelt of Western Australia. A case study.' *Biological Conservation* 50, 99-135.

Saunders, D. A. (1993) 'A community-based observer scheme to assess avian responses to habitat reduction and fragmentation in South-Western Australia'. *Biological Conservation*, 64, 203-218.

Shepherd, D., Beeston, G. R. & Hopkins, A. J. M. (2001) *Native vegetation in Western Australia: Extent, type and status.* Resource Management Technical Report No. 249. Department of Agriculture, Western Australia.

Short, J. & Parsons, B. (2004) A test of the Focal Species approach in Western Australia. *Final report for Land and Water Australia project CSE 9: Testing approaches to landscape design in cropping lands: Component three report (Western Australia).* Wembley, Western Australia, CSIRO Sustainable Ecosystems.

Short, R., Farmer, D., Whale, P. & Coles, N. A. (2006) *Surface water assessment for the Buntine-Marchagee Recovery Catchment:* Resource Management Technical Report No. 299. South Perth, Western Australia, Report prepared by the Engineering Water Management Group, Dept. Agriculture for the Department of Conservation and Land Management.

Sinclair Knight Merz (2001) *Impact assessment and management of drainage water discharge to lakes in the Moore River Catchment, WA,* Report for Water and Rivers Commission.

Sinclair Knight Merz (2003) *Buntine-Marchagee Natural Diversity Recovery Catchment surface water management plan* (Includes – Catchment Report, Demonstration Report and Individual Property Reports). Report prepared for the Department of Conservation and Land Management.

Smith, P. (2006) 'Oil mallees and biodiversity: A win-win for farmers and wildlife'. *Dinkum Oil (Oil Mallee Association of Western Australia Inc.).* Autumn 2006.

Sparks, T., George, R., Wallace, K., Pannel, D. J., Burnside, D. & Stelfox, L. (2006) *Salinity Investment Framework Phase II.* Perth, Western Australia, Department of Agriculture and Food, Department of Environment and Conservation, Department of Water.

Speed, R. & Strelein, M. (2004) *Groundwater investigation: Buntine-Marchagee Natural Diversity Recovery Catchment.* Resource Management Technical Report No. 282. Resource Management Technical Report. Geraldton, Western Australia, Department of Agriculture.

Speight, J.G. (1998) Landform. In *Australian Soil and Land Survey Field Handbook.* Second Edition (McDonald, R.C., Isbell, R.F., Speight, J.G., Walker, J. & Hopkins, M.S.) (Australian collaborative Land Evaluation Program, CSIRO Land and Water, Canberra.

State Salinity Council (2000) *The salinity strategy: Natural resource management in Western Australia.* Perth, Western Australia, State Government of Western Australia.

Storey, A. W., Sheil, R. J. & Lynas, J. (2004a) Buntine-Marchagee Natural Diversity Recovery Catchment wetland invertebrate fauna monitoring: August 2004. Crawley, Western Australia, University of Western Australia, report to Department of Conservation and Land Management, Midwest Regional Office.

Storey, A. W., Sheil, R. J. & Lynas, J. (2004b) Buntine-Marchagee Natural Diversity Recovery Catchment Wetland invertebrate fauna monitoring: November 2003 data analysis and interpretation. Crawley, Western Australia, University of Western Australia, Report to Department of Conservation and Land Management, Midwest regional office.

Tyler, M. J., Smith, L. A. & Johnstone, R. E. (2000) *Frogs of Western Australia.* W.A Museum Perth.

URS (2007) *Hydrological Investigation Buntine-Marchagee Natural Diversity Recovery Catchment. Geraldton,* Department of Environment and Conservation.

Wallace, K. (2001) *State Salinity Action Plan 1996 – Review of the Department of Conservation and Land Management's programs.* January 1997 – June 2001. Department of Conservation and Land Management.

Wallace, K. (2006) 'A decision framework for natural resource management: a case study using plant introductions'. *Australian Journal of Experimental Agriculture*, 46, 1397-1405.

Wallace, K. J. (2005) Principles underlying budget recommendations: Salinity program 2005-06. Internal Report. Kensington, Western Australia, Department of Conservation and Land Management.

Wallace, K. J., Beecham, B. C. & Bone, B. H. (2003) *Managing Natural Biodiversity in the Western Australian Wheatbelt: A Conceptual Framework*. Kensington, Western Australia, Department of Conservation and Land Management.

Walshe, T., Jones, S. & Massenbauer, T. (2007) Decision framework for Natural Diversity Recovery Program (Implementation). University of Melbourne, Unpublished report prepared for the Department of Environment and Conservation.

Walshe, T. V., Halse, S. A., McKenzie, N. L. & Gibson, N. (2004) *Towards identification of an efficient set of natural diversity recovery catchments in the Western Australian wheatbelt. A biodiversity survey of the Western Australian agricultural zone.* Records of the Western Australian Museum supplement No. 67. Department of Conservation and Land Management and the Western Australian Museum.

Walters, C. J. (1986) *Adaptive Management of Renewable Resources*, New York, McGraw Hill.

Western Australian Museum (2005) Western Australian Museum, Queensland Museum and Museum & Art Gallery of NT collections databases. Accessed 15th September. Available on http://www.museum.wa.gov.au/faunabase/prod/index.htm.

Yates, C. J., Coates, D. J., Elliott, C. & Byrne, M. (2006) 'Composition of the pollinator community, pollination and the mating system for a shrub in fragments of species rich kwongan in south-west Western Australia', *Biodiversity and Conservation*, 16, 1379.

Yates, C. J., Elliott, C., Byrne, M., Coates, D. J. & Fairman, R. (2007) 'Seed production, germinability and seedling growth for a bird-pollinated shrub in fragments of kwongan in south-west Australia', *Biological Conservation*, 136.

ATTACHMENT 1: GLOSSARY AND ACRONYMS

GLOSSARY

abundance
Has two dimensions absolute abundance – describing the total number of individuals of a taxon (usually a species) per unit area or volume or relative abundance which is the total number of individuals of a taxon in relation to all other studied taxa, usually expressed as a percentage. Abundance emphasises the proportions of constant and dominant species (Lehtonen et al. 1998).

activity
A specific task or grouping of tasks which use up resources to produce an output.

adaptive management
A systematic process for continually adjusting policies and practices by learning from the outcome of previously used policies and practices. Each management action is viewed as a scientific experiment designed to test hypotheses and probe the system as a way of learning about the system (Holling 1978, Walters,1986).

aeolian
The erosion, transport and deposition of material due to the action of wind at or near the Earth's surface (Allaby & Allaby 2003).

algal bloom
Sudden growth of algae in an aquatic ecosystem. This may be a naturally occurring cycle or may be induced by nutrient enrichment.

alluvial
Unconsolidated terrestrial sediment that has been deposited by flowing water (Speed & Strelein 2004).

ameliorate
To make or become better; improve (DEC 2006).

animal
(i) any living or dead member of the Kingdom Animalia (other than a human being);

(ii) any viable or non-viable progeny, larvae, embryo, egg or sperm of an animal or other part, product or genetic material of an animal from which another animal could be produced;

(iii) any part of an animal; and

(iv) the carcass of an animal (DEC 2006).

aquatic
Living or growing in, on, or near water (usually taken to mean fresh water, as opposed to marine) (DEC 2006).

aquifer
A geological formation or group of formations able to receive, store and transmit significant quantities of water.

Archaean
See geological time scale.

avifauna
Pertaining to birds.

bathymetry
The measure of the depth of the ocean floor (in this case wetland) from the water surface; equivalent of topography of water body (Allaby & Allaby 2003).

bedrock
The solid unweathered rock (typically ferrous igneous granite or mafic igneous dolerite in the wheatbelt), or parent material which underlies the loose material (regolith), such as soil, sand, clay, or gravel.

bentonite
Is the industrial term used for some of the minerals in the smectite group (also known as the montmorillonite group) of clay minerals (Abeysinghe 2002)

biodiversity
The variability among living organisms and the ecosystems and ecological complexes of which those organisms are a part. Includes:

(i) diversity within native species and between native species;

(ii) diversity of ecosystems; and

(iii) diversity of other biodiversity components (DEC, 2006).

biodiversity asset
Threatened taxa and ecological communities, significant ecosystems or taxa.

biogeographic regions (IBRA and IMCRA)
Interim Biogeographic Regionalisation for Australia (IBRA) is a framework for conservation planning and sustainable resource management within a bioregional context. IBRA regions represent a landscape-based approach to classifying the land surface from a range of continental data on environmental attributes, including climate and geomorphology. Likewise, Interim Marine and Coastal Regionalisation for Australia (IMCRA) is a single, ecosystem-level regionalisation of Australia's coastal and marine environments (DEC 2006).

Bioregion
The Interim Biogeographic Regionalisation for Australia (IBRA) divides the Australian continent into 85 bioregions.

biota
All life, including plants, animals and fungi (DEC 2006).

buffer
In the context of this recovery plan, a buffer is a form of physical barrier, which is used to protect environmentally sensitive biota from threats. For example, a band of remnant vegetation around a wetland may reduce weed incursion, surface water flows, and chemical drift from surrounding land uses.

CAR reserve
See comprehensive, adequate and representative reserve system.

catchment
Area of land drained by a river and its tributaries (DEC 2006).

colluvial
General term applied to loose and incoherent deposits where the mode of transportation is uncertain (Allaby & Allaby 2003).

comprehensive, adequate and representative reserve system
A reserve system that is characterised by the following: comprehensiveness – inclusion of the full range of ecosystems recognised at an appropriate scale within and across each bioregion, adequacy – the maintenance of the ecological viability and integrity of populations, species and communities, and representativeness – the principle that those areas that are selected for inclusion in reserves reasonably reflect the biotic diversity of the ecosystems from which they derive (DEC 2006).

condition
The presence of all appropriate elements and occurrence of all processes at appropriate rates in relation to a specified goal. For example, vegetation in good condition would be expected to have all expected species present and be reproducing at the rate expected under natural conditions.

conservation
The protection, maintenance, management, restoration and enhancement of the natural environment (DEC 2006).

crystalline basement
Solid impervious rock consisting of minerals in a crystalline state. Also see bedrock definition (Allaby and Allaby, 2003).

deleterious
Hurtful; noxious; destructive; pernicious.

detrital
Applied to material derived from the mechanical breakdown of rock by the process of weathering and erosion.

diatomite
Diatom-rich sediment, which has been laid down by in a lacustrine or deep sea environment.

dieback
A symptom of disease in trees and other vegetation in which the foliage progressively dies from the extremities; commonly referred to with respect to native forests or woodlands. (See Phytophthora dieback and Phytophthora cinnamomi.) (DEC, 2006).

distribution
Spatial range of a species or other systematic taxa in a certain area Refers to how organisms are distributed in space. For example, vegetation may be evenly distributed or clumped. Similarly, animal species may have continuous or disjunct distributions (Lehtonen et al. 1998).

dolerite
Fine grained mafic igneous rock rich in iron and magnesium that occurs as intruded vertical dykes throughout the Yilgarn Craton.

dyke
A planar body of intrusive rock that cuts through the surrounding rock (Speed & Strelein 2004).

ecological community
A natural assemblage of organisms that occurs in a particular type of habitat (DEC 2006).

ecosystem
Means a dynamic complex of ecological communities and their abiotic environment interacting as a functional unit (DEC, 2006).

ecosystem services
The transformation of a set of natural assets, such as soil, plants, animals, air and water into services that are valued by humans. Examples include the provision of clean water, maintenance of liveable climates and atmospheres (carbon sequestration), pollination of crops and native vegetation, fulfilment of people's cultural, spiritual, intellectual needs, and provision of options for the future, for example though the maintenance of biodiversity (DEC 2006).

endemic
Species naturally restricted to a specified region or locality (DEC 2006).

erosion

The part of the overall process of denudation that includes the physical breakdown, chemical solution, and transport of material (Allaby & Allaby 2003).

eutrophication

The enrichment of water by nutrients, such as compounds of nitrogen or phosphorus. It causes an accelerated growth of algae and higher forms of plant life. These consume more oxygen often leading to an oxygen deficit, which can have a major detrimental effect on the fish other aquatic organisms.

evaluation activities

Provide comprehensive analysis to determine how well, and in what ways policies, strategies and programs are working. They include an assessment of efficiency (determining whether existing delivery arrangements can be improved) and effectiveness (determining whether or not the program strategies are having the desired effect) and are used to support management decision making at appropriate points in the life of the policy, strategy or program. The information used in these activities may be both directly and indirectly related to the expected outcomes and outputs of the policy, strategy or program (Natural Resource Management Ministerial Council 2003).

Evaluations may need to consider:

- unforeseen consequences, particularly social and economic impacts;
- external factors impacting on program delivery and likely achievement of outcomes (including social and economic factors)
- attribution – the extent that program strategies contribute to, or are responsible for, achievement of desired outcomes.

exotic

An animal occurring in a place that it is not native to.

fauna

Animals found in a specific area (DEC 2006).

feral species

A domesticated species that has become wild, for example donkey, camel, horse, pig and goat (DEC 2006).

flora

Plants found in a specific area – see plant definition (DEC 2006).

Fluvial

related to rivers and streams.

fringing

Constituting the border, or edge.

geological time scale

Archaean Geological age used to describe rocks older than 2,500 million years.

Proterozoic was an eon in geological time that lasted from 2.5 billion years ago to 542 million years ago.

Permo-Carboniferous Strata deposited between the Carboniferous (360–290 million years ago (mya)) and Permian (290–248 mya) periods that are not differentiated due to the presence of transitional fossils

genera (plural of genus)

A group of organisms marked by common characteristics and evolutionary background; more precisely, it is the category of biological classification between Family and Species.

geomorphology

The scientific study of the landforms on the Earth's surface and of the processes that have fashioned them.

germplasm

The genetic material, especially its specific molecular and chemical constitution that compromises the inherited qualities of an organism.

gneiss

General petrological term of applied to coarse-grained, banded rocks that formed during high-grade regional metamorphism.

granite

A coarse grained intrusive igneous rock composed of quartz, feldspar and micas.

granitoid

A term used to encompass the granitic rock types – see granite

groundwater

Water within the saturated zone below the ground.

gypsum

Evaporate mineral $CaSO_4$. $2H_2O$; occurs in bedded deposits in association with halite and anhydrite. It is very insoluble and therefore the first mineral to precipitate from evaporating seawater.

habitat

Means the biophysical medium-

(i) occupied (continuously, periodically or occasionally) by an organism or group of organisms; or

(ii) once occupied (continuously, periodically or occasionally) by an organism or group of organisms, and into which organisms of that kind have the potential to be re-introduced.

hydraulic conductivity
A measure of the ability of a material to transmit fluid.

hydro-aeolian
Pertaining to water (hydrological/hydrogeological) and wind (aeolian) processes.

hydrodynamics
The study of fluids in motion. The study is based upon the physical conservation laws of mass, momentum, and energy.

hydrogeology
The scientific study of the occurrence and flow of groundwater.

hydrology
The study of the hydrologic (water) cycle. While it involves aspects of geology, oceanography, and meteorology, it emphasises the study of bodies of surface water on land and how they change over time.

hydroperiod
Cyclical changes to the amount or stage of water. Changes to a hydroperiod may result in increased/decreased time periods of inundation

indurated
Rendered hard through cementation.

inundation
The process by which the land surface becomes flooded or covered with water. Note that extended periods of inundation may lead to waterlogging – see definition.

in situ
In its original place.

interim recovery plans
Documents for the management and protection of threatened taxa or threatened ecological communities where no full recovery plan has been prepared. Interim recovery plans prescribe immediate actions that are necessary to halt the decline and commence recovery of a species or ecological community (DEC 2006). (See recovery plans.)

introduced species
A species occurring in an area outside its historically known natural range as a result of intentional or accidental dispersal by human activities (including exotic organisms and genetically modified organisms) (DEC, 2006).

invasive species
Species introduced deliberately or unintentionally outside their natural habitats where they have the ability to establish themselves, invade, outcompete natives and take over the new environment (DEC, 2006).

invertebrate
Any animal without a backbone (vertebral column) such as insects, squid, snails and worms (DEC 2006).

lacustrine
Pertaining to a lake (i.e. lacustrine sediments are deposits associated with current or historical location of wetlands/lakes).

landscape
A mosaic where the mix of local ecological communities and ecosystems or land uses is repeated in a similar form over a kilometre wide area. In agricultural areas, a landscape unit that is repeated with a similar pattern of land use, including natural habitats. From a biodiversity perspective, the distances over which significant species occur should govern the upper size limit of a landscape for biodiversity planning (DEC 2006).

littoral zone
The area in shallow fresh water and around lake shores where light penetration extends to the bottom sediments, giving a zone colonised by rooted plants.

macroinvertebrate
Invertebrates (lacking a backbone), which can be seen with the naked eye.

Management action targets
Short-term targets (one to five years), relating mainly to management actions or capacity-building. Targets contribute to progress towards longer-term resource condition targets. Examples of management action targets include: X hectares of recharge zones within region to be revegetated by year Y or X km of riparian zone to be fenced and managed for conservation and landscape function. Note: Management Action Targets (MATs) are quantified wherever possible. However, as setting targets is an iterative process and some of the work is in its early stages, some outputs will need to be delivered in order for their respective MATs to be framed as specific, measurable, achievable, realistic and time-bound. Draws on definition used in National Framework for Natural Resource Management Standards and Targets (Natural Resource Management Ministerial Council 2003)

marine
Inhabiting salt water in, or connected to, the sea (DEC 2006).

monitoring
The regular gathering and preliminary analysis of information needed for day-to-day management or evaluation. Monitoring activities provide indicative information to track and review the performance of policies, strategies and programs at regular intervals to inform management decision-making. This indicative information must directly relate to the expected outcomes and outputs of the policy, strategy or program. Monitoring provides information on what is occurring and what the program, policy or strategy is achieving (Natural Resource Management Ministerial Council 2003).

monitoring activities
Provide indicative information to track and review the performance of policies, strategies and programs at regular intervals to inform management decision-making. This indicative information must directly relate to the expected outcomes and outputs of the policy, strategy or program (Natural Resource Management Ministerial Council 2003).

Monitoring and Evaluation Framework
A Monitoring and Evaluation Framework structures monitoring and evaluation activities to provide accurate, cost-effective and timely performance information for management decision making. Monitoring and evaluation activities use many of the same data sources, and complement one another in covering the full range of issues affecting the performance of an activity. Because of the differences between the two activities, each requires different management structures and processes (Natural Resource Management Ministerial Council 2003).

native species
A species that is indigenous to Western Australia (DEC 2006).

natural diversity recovery catchment
An area established as part of the 'natural diversity recovery catchment program' under the State Salinity Strategy to help recover and protect significant natural areas, particularly wetlands, from salinity and waterlogging. Selection is based on a number of criteria, including representative of nature conservation values and the likelihood of recovering and protecting areas from salinity (DEC 2006).

natural resource management
Management of land, water, air and biodiversity resources of the State for the benefit of existing and future generations, and for the maintenance of life support capability of the biosphere. Includes use of natural resources by extractive and mining industries (DEC 2006).

non-passerine
See passerine.

observation bore
A shallow bore with slotted intake section across the saturated interface that provides a direct measurement of actual depth to the water table (Speed & Strelein 2004).

organism
Includes -

(i) part of an organism;

(ii) the reproductive material of an organism; and

(iii) an organism that has died (DEC 2006).

outputs
A specific deliverable or product which is the result of activity.

palaeo
Use to denote ancient or past.

Palaeochannel An ancient fluvial, incised drainage valley that has been in-filled with sediments

palaeoclimatic
The study of past climates from the traces left in the geologic record.

palaeodrainage
An area where previous drainage has incised (and often filled) a valley with sediment. An area where water has historically flowed along preferred pathways.

passerine
Of or relating to birds of the order Passeriformes, which includes perching birds and songbirds such as the jays, blackbirds, finches, warblers, and sparrows.

Perennial
Used here in relation to vegetation that typically lives for more than two growing seasons. All trees and shrubs are perennials.

pest
Any animal that has a negative effect on human or economic activities. They can include both introduced and native species.

Phytophthora cinnamomi
A soil-borne organism (often referred to as a fungus) belonging to the Class Oomycetes or 'water moulds', known to cause root-rot disease in Australian flora species. (See dieback.) (DEC 2006).

Phytophthora dieback
Death or modification of native vegetation caused by Phytophthora cinnamomi (DEC 2006).

phytoplasma
Formerly known as 'Mycoplasma-like organisms' or MLOs, are specialised wall-less bacteria that are obligate parasites of plant phloem tissue and some insects. They can't be cultured in vitro in cell-free media.

piezometer
A bore that has a discrete slotted intake section at its base and is sealed above the intake to measure groundwater pressure at the depth of the intake section. It must be emphasised that the point of measurement in a piezometer is at its base, not at the level of water in the casing (Speed & Strelein 2004).

Permo-Carboniferous
See geological time scale.

plant
Means -

(i) any living or dead member of the Kingdom Plantae;

(ii) a seed or spore, whether it is viable or non-viable;

(iii) a part, product or genetic material of a plant from which another plant could be produced; and

(iv) any other part of a plant (i.e. not referred to in (ii) or

(iii) above, e.g. a 'non-reproductive' part) (DEC 2006).

playa lakes
Large, shallow, level floored closed depression, intermittently water filled, but mainly dry due to evaporation, bounded as a rule by flats aggraded by sheet flow and channelled stream flow (Speight 1998)

primary salinity
Salinity that existed in the Australian landscape prior to European settlement.

Proterozoic
See geological time scale

recharge
The downward movement of water that is added to the groundwater system.

recovery plans
Documents that set out the research and management actions necessary to stop the decline, and support the recovery, of listed threatened species or threatened ecological communities. The aim of a recovery plan is to maximise the long-term survival in the wild of a threatened species or ecological community. Recovery plans are appropriate for species or ecological communities where sufficient information is available to prescribe recovery actions with confidence (see interim recovery plans) (DEC 2006).

regolith
The mantle of material on top of basement, including soil, alluvium, and material weathered in situ from basement.

relictual taxa
Applied to taxa (see definition in this glossary), which have survived while other related ones have become extinct.

Resource Condition Targets
Are specific, time-bound and measurable targets, relating largely to resource condition. The timeframe for achievement of these targets is 10–20 years. They are developed iteratively. Examples include: X hectares of specific native vegetation type within region at year Y maintained or regenerated or X stream sites within region in specific river condition category by year Y (Natural Resource Management Ministerial Council 2003).

richness
The number of species or other taxonomic unit per unit area.

saprolite
A clay-rich, thoroughly decomposed regolith formed in situ by chemical weathering of igneous or metamorphic rocks (Speed & Strelein 2004).

sedimentation
Process of deposition, at or near the earths surface, of material derived from pre-existing rock, biogenic sources or precipitated by chemical processes.

sequester
To cause withdrawal into seclusion; To remove or set apart; segregate.

silcrete
A zone rendered hard (indurated) by secondary cementation with amorphous silica (Speed & Strelein 2004).

species
A group of organisms that -

(i) interbreed to produce fertile offspring; or

(ii) possess common characteristics derived from a common gene pool; and includes

(iii) a sub-species (DEC 2006).

species abundance
See abundance

species condition
See condition

species distribution
See distribution

species richness
See richness

stakeholder
A person, group of people, organisation or government with a share or an interest in an issue (DEC 2006).

sub-crop
An occurrence of strata (geological) beneath an inclusive stratigraphic unit.

succulent steppe vegetation
Soft, fleshy-leaved saltbush and bluebush shrubs and the succulent samphires which characterise vegetation of alkaline and saline soils.

sub-strata wetland
A wetland which has unusual substrata, when compared to typical wetland sediments (i.e. sand, silt, organic material or mixed clay). In the BMNDRC this refers to gypsum, pure bentonite or granite substrates.

surfactant
Any substance that when dissolved in an aqueous solution reduces its surface tension between it and another liquid.

surficial
Pertaining to or lying on the surface of the earth. Surficial geology is the study of surficial deposits including soils.

sustainability
Meeting the needs of current and future generations through integration of environmental protection, social advancement and economic prosperity (DEC 2006).

target landscapes
A landscape-scale unit where populations of as many native taxa as possible have the greatest probability of remaining viable. Area of natural environment and its spatial configuration are the two key factors used to identify target landscapes.

taxon (taxa pl.)
A group or category, at any level, in a system for classifying organisms (DEC 2006).

threatened ecological community
An ecological community that is threatened by destruction and is formally listed as either vulnerable, endangered, critically endangered or presumed destroyed (DEC 2006).

threatening process
A biophysical process which can impact on biodiversity assets and prevent achievement of a specific conservation goal. Refer to Appendix 13 for a full description of threats (DEC 2007).

viroid
An infectious particle, similar to but smaller than a virus, that consists solely of a strand of RNA (ribonucleic acid) and is capable of causing disease.

water balance
Accounting for all water inputs and all water outputs within a system.

water repellence
Water repellence/repellent behaviour in soil is caused by dry coatings of hydrophobic (water hating) material on soil particles or aggregates, as well as hydrophobic organic matter, such as fungal strands and particles of decomposing plant material.

water table
A surface which represents the boundary between the zone of saturation (below) and the unsaturated zone (above).

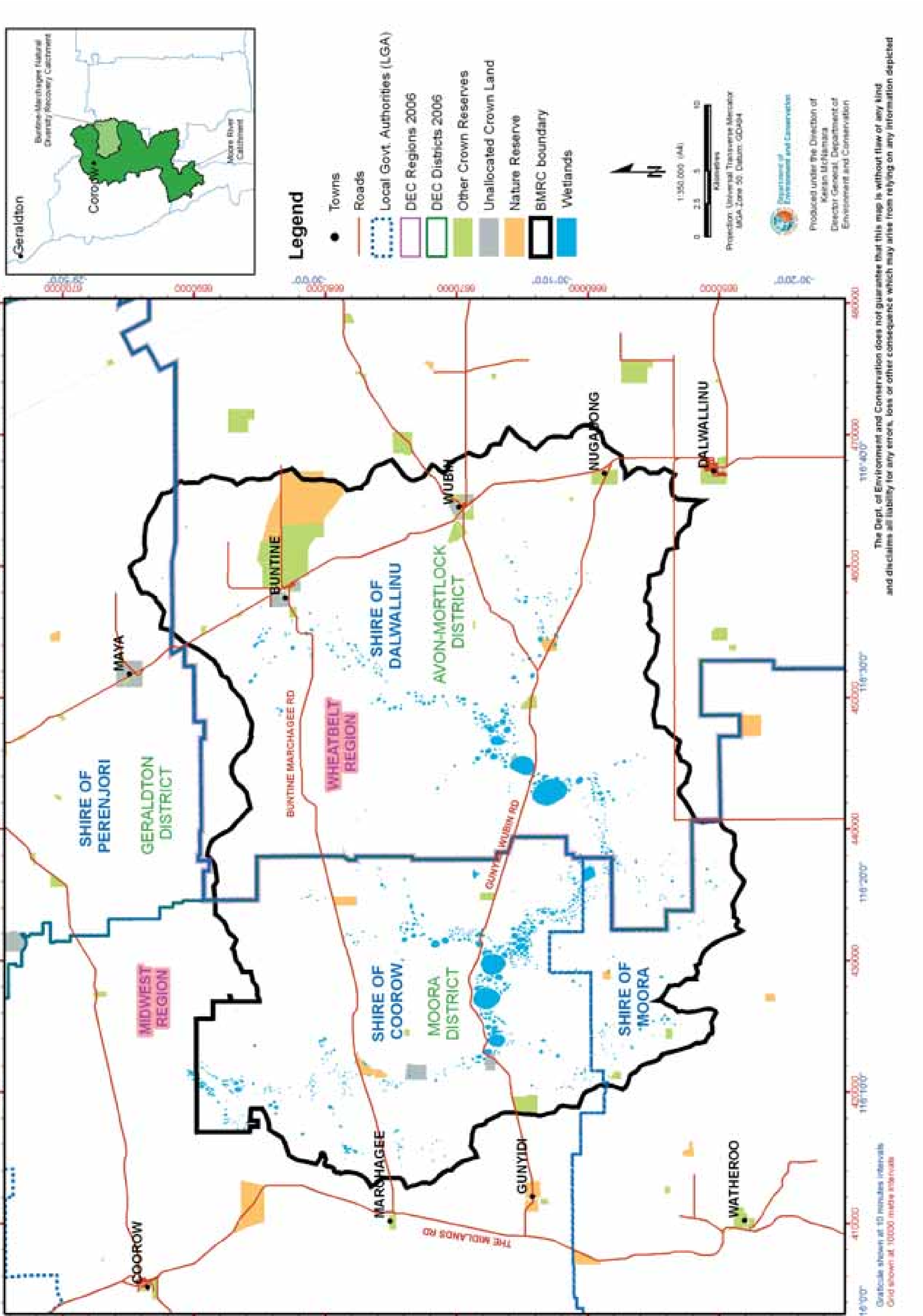
weathered
The breakdown of rocks and minerals at and below the earth's surface by the action of physical and chemical processes.

Yilgarn Craton
A large area of Archaean, stable, granitic, continental crust that underlies most of south-west Western Australia.

ACRONYMS

ASS	Acid Sulphate Soils
ANZECC	Australian and New Zealand Environment Conservation Council
ARMCANZ	Agricultural and Resource Management Council of Australia and New Zealand
BMNDRC	Buntine-Marchagee Natural Diversity Recovery Catchment
BOM	Bureau of Meteorology
CAMBA	China-Australia Migratory Bird Agreement
CAR	Comprehensive, Adequate and Representative (see Glossary for further information)
CSIRO	Commonwealth Scientific and Industrial Research Organization
DAFWA	Department of Agriculture and Food Western Australia
DEC	Department of Environment and Conservation
DIA	Department of Indigenous Affairs
DRF	Declared Rare Flora
DYRIM	Dynamic River Model
ECI	Ecological Condition Indicators
EPBC	Environmental Protection and Biodiversity Conservation Act 1999
EWR	Ecological Water Requirements
GCM	General Circulation Models
IBRA	Interim Biogeographic Regionalisation for Australia
ICM	Integrated Catchment Management
IOCI	Indian Ocean Climate Initiative
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union Conservation of Nature, now the World Conservation Union.
JAMBA	Japan-Australia Migratory Bird Agreement
LASCAM	Large-Scale Catchment Model
LCDC	Land Conservation District Committee
LISFLOOD	is a two-dimensional hydrodynamic model specifically designed to simulate floodplain inundation in a computationally efficient manner over complex topography.
NACC	Northern Agricultural Catchment
NAR	Northern Agricultural Region
RCT	Resource Condition Target
SAP	Salinity Action Plan
SIF	Salinity Investment Framework
SWMP	Surface Water Management Project
TAG	Technical Advisory Group
WATSSC	Western Australian Threatened Species Scientific Committee

ATTACHMENT 2: THE SPATIAL SCALE OF THE ASPIRATIONAL GOAL



ATTACHMENT 3: SOCIAL, ECONOMIC AND PHYSICAL CHARACTERISTICS OF THE BUNTINE-MARCHAGEE NATURAL DIVERSITY RECOVERY CATCHMENT

SOCIAL AND ECONOMIC CHARACTERISTICS

Community profile

The total population of the four Shires that overlap with the BMNDRC is just over 6,000 (Australian Bureau of Statistics 2005). Shire populations are reasonably stable with only small increases or decreases since the 1996 Census. The exception to this is the Shire of Perenjori, which has seen a 12.3 per cent decrease in population since the 1996 Census (1996–2001) and a decrease of 22.3 per cent since the 1991 Census (1991–2001) (Australian Bureau of Statistics 2007).

For more information on the community profile of the BMNDRC, see Section 3.2 (Social structure) of the Landholder Survey (CALM & Colmar Brunton 2005).

Economic profile

Broadacre farming is the dominant industry in the BMNDRC. The biggest contributors to the economies of the four shires represented are cereals, legumes and oilseed crops, followed by meat and livestock products (Table 3.1).

The productivity of some of the agricultural land in the BMNDRC is also being threatened by altered hydrology, particularly salinity. For more information on the economic profile of the BMNDRC, see Section 3.3 (Farming systems) of the Landholder Survey (CALM and Colmar Brunton 2005).

Infrastructure

A range of (locally) important community services and public utilities are based in the centres of Dalwallinu, Coorow, Moora, and Perenjori. Shire offices are located within each of the centres. Other services for the catchment community include:

- primary schools in Dalwallinu, Wubin, Buntine, Moora, Watheroo, Coorow, Perenjori and Latham;
- secondary schools in Carnamah (to Year 10), Dalwallinu and Moora;
- hospitals at Dalwallinu, Moora and Three Springs;
- medical centres at Dalwallinu, Coorow, Perenjori, Moora; and
- telecentres at Dalwallinu, Kalannie, Coorow, Perenjori and Moora.

Utility corridors bring electricity, gas, telephone (including internet) and water service networks to private properties. Domestic water is generally supplied through rainwater collection and bores on farms. The Water Corporation supplies the towns of Buntine, Coorow and Dalwallinu through the Regional Town Water Scheme.

The BMNDRC has a well developed transport network. Major arterial roads include the Midlands Road which lies west of the catchment boundary and the Mullewa-Wubin Road within the eastern boundary. Two rail corridors service properties in the BMNDRC: one is located to the west of the catchment boundary, the other is within the eastern boundary. These railway corridors are leased from the Western Australian Government by Westnet Rail and the rolling stock is owned and operated by Queensland Rail.

CULTURAL HERITAGE

Indigenous cultural heritage

All Aboriginal sites, including those not yet listed with the Department of Indigenous Affairs (DIA), are protected under the *Aboriginal Heritage Act* 1972. Under this legislation it is an offence for anyone to alter in any way an Aboriginal site or artefact without the relevant Minister's permission. The register of the National Estate (compiled and maintained under the *Australian Heritage*

Table 3.1. Economic value of agricultural activities within the Shires of Dalwallinu, Coorow, Moora and Perenjori in 2003 (P. Toser, pers. comm. 2005)

Shire	Number of farms	Average area of holding (hectares)	Crops Total value of crops ($)	Meat Total value of slaughterings ($)	Livestock products Total value of livestock products ($)
Dalwallinu	150	4881	89,181,441	5,466,521	9,795,203
Moora	148	3177	51,601,895	8,807,344	11,659,591
Coorow	90	2741	33,989,370	4,695,934	5,149,169
Perenjori	87	5435	42,857,162	2,163,472	3,783,140

Council [Consequential and Transitional Provisions] Act 2000) also contains a list of Aboriginal heritage that should be conserved. As part of best practice in cultural heritage management it is important that both of these registers are consulted prior to undertaking any potentially damaging operations.

Three Aboriginal cultural heritage sites of significance occur within the BMNDRC, at Buntine Rock, Nurgian and Chiarcono (Figure 1, *Appendix 5*). There is limited information, obtained from the Department of Indigenous Affairs in August 2006, indicating that Buntine Rock contains artefacts and is thought to have been a source of drinking water, whilst Nurgian and Chiarcono are believed to be stone structures. The Nugadong Rockhole, which is located within the Mia Moon Reserve, is not listed with the DIA.

The recovery catchment is part of the traditional land of two Aboriginal groups, the Yamaji (also spelt Yamatji) and the Nyoongar. These traditional lands cover areas within the catchment and the broader Northern Agricultural Region. Various Aboriginal language groups exist within the Yamaji and Nyoongar peoples including Yued, Taylor, Widi Binyardi, Badimia, Widi, Amangu and Arnold Franks people. Yamaji people are the traditional owners of land and coastal waters extending north from the coast at Greenhead, to Onslow and the Ashburton River. From Onslow the boundary extends east along the Ashburton to the Great Northern Highway then south through Sandstone, south-west to Lake Moore and west to Greenhead on the coast. Nyoongar people are the traditional owners of all land south of Coorow and Lake Moore (NACC 2004).

Non-Indigenous cultural heritage

A number of non-Indigenous cultural heritage sites lie within or in the vicinity of the BMNDRC. A list of these and a description of applicable legislation is given at Table 1, Appendix 5. This list includes Jun Jun Spring, Salt Lake Well and Koobabbie Homestead and buildings in the Coorow Shire, and Dalwallinu Townsite within the Dalwallinu Shire. The Buntine Nature Reserve and the Wubin Wheatbin (*Appendix 5*) are listed on the Commonwealth Register of National Estate. The latter is also listed with the National Trust of WA.

Recreational use

The 1,000 or so wetlands of the BMNDRC provide a range of nature-based visitor opportunities. There is a growing tourism industry in the eastern part of the catchment based on observing wildflowers, and both the Great Northern Highway and Mullewa-Wubin Road are favoured destinations for viewing spring displays of wildflowers and acacias. Some of the wetlands are used by locals for a range of recreation activities, including boating, waterskiing and other water sports, swimming and picnics (CALM & Colmar Brunton 2005).

Recreation sites within the BMNDRC are low key and have limited infrastructure. The Shire of Dalwallinu manages a picnic area at Buntine Rocks, adjacent to Buntine Nature Reserve. Other sites used for recreation include Gunyidi Pool and Mia Moon Reserve. There are no formal recreation facilities at these sites and there is anecdotal evidence of uncontrolled vehicle access.

PHYSICAL CHARACTERISTICS

Climate

The climate of the BMNDRC is characterised by warm-temperate to semi-arid conditions with hot, dry summers and winter-dominated rainfall. January is the hottest month and July the coldest. Monthly averages of daily minimum and maximum temperatures range from 16 to 39˚C in January and five to 20˚C in July.

Annual rainfall totals decrease from west to east across the catchment, averaging 380mm at Coorow and 327mm at Wubin (Bureau of Meteorology 2005). Pan evaporation in the catchment far exceeds rainfall and is typically 2300mm per annum (Queensland Department of Natural Resources and Mines 2005). The majority of rainfall is received in winter; however the highest daily rainfall totals are more often recorded in summer or early autumn due to thunderstorms or cyclonic low-pressure systems.

For more information regarding rainfall trends and their analysis for the BMNDRC, see *Appendix 6* of the Supporting Information Document.

Regional geology

The BMNDRC is underlain by Archaean granites and gneisses of the Yilgarn Craton, a geological basement structure which formed between 3,800 to 2,500 million years ago (mya) (Carter & Lipple 1982, Baxter & Lipple 1985). Numerous dolerite dykes, formed during the Proterozoic era (2,500–543 mya) intrude on this granitic basement. These dykes become more common towards the west of the catchment, however they rarely occur at the surface due to sedimentary covers (McConnell & Pillai 1995, Speed & Strelein 2004). Granite basement outcrops, occasionally containing dolerite dykes, are more common in the northern and eastern parts of the catchment. The crystalline basement of the catchment is largely covered by a thick layer of gritty clay (saprolite) which is the product of in situ weathering. A geological history and stratigraphic column for the BMNDRC is presented in *Appendix 6*.

Geomorphology

The relative long-term stability of the Yilgarn Craton has resulted in the surface being weathered to a gentle, undulating topography (Alderman & Clarke 2003). Extensive palaeodrainages occur across the Yilgarn Craton due to previous periods of extensive, high volume rainfall. This is an important feature as these ancient drainages can frequently, at least partially, constrain the location and orientation of modern drainages.

It is believed that widespread palaeochannel formation began in inland Western Australia at the end of the Permo-Carboniferous glaciation period (286 mya) (Geological Survey of Western Australia 1990). While there is potential for palaeochannels to exist in the BMNDRC, their exact nature and location is currently unknown. There are, however, sections of palaeodrainages which are still active fluvial systems, the sediments of which have been intermittently eroded and redeposited by water movement since their formation.

Aeolian, alluvial and colluvial reworking of surficial sediments has occurred across much of the catchment. These sediments are generally thin (rarely more than 10–20 metres thick) and cover an extensive area of the catchment as a mixed alluvial and colluvial soil cover with abundant regolith development particularly over granitoid sub-crops. A conceptual overview of the geomorphology of the BMNDRC is included in *Appendix 6* of the Supporting Information Document.

Soils

Thirty-four soil-landscape units have been mapped (subsystems and phases) in the catchment. These belong to five soil-landscape systems: Inering Hills, Upsan Downs, Ballidu, Balgerbine and the Wallambin. A soil-landscape map of the BMNDRC at the scale of 1:100,000 was prepared by Griffin & Goulding (2004) and is at Appendix 6. Each of the map units was described and the soils expected to be present from the point observations were proportionally allocated. About 10 per cent of the area's soils are comprised of hydro-aeolian valley floor soils, including modern lacustrine sediments. These are highly variable ranging from: saltpans, silts and sands, clays, bentonite, diatomite, and gypsum. The remainder of the catchment has soils considered to be younger or immature which are associated with exposed and partially weathered parent rocks.

Land capability

Capability assessments for particular land uses can be used to prepare specific land degradation hazard maps. Land capability has been assessed for each land unit in the BMNDRC (Griffin & Goulding 2004). However there are no land capability maps for the BMNDRC as the methodology is being reviewed. Assessments have been completed for five land degradation issues considered most relevant to the survey area: salinity risk, structural degradation, waterlogging, water repellence and wind erosion.

Surface and groundwater hydrology

Surface water hydrology, groundwater hydrogeology and wetlands (which can result from the interaction of surface and groundwater) are considered separately here for the purposes of discussion. However, it is important to recognise that these topics are not independent components of the environment and that the interaction between hydrology, hydrogeology and wetlands can be very complex. To manage biodiversity assets it is essential to understand how they collectively interact and affect the persistence and condition of biological populations and communities.

Hydrology (surface water)

It is widely recognised that the number and magnitude of surface water runoff events in the wheatbelt have significantly increased since clearing for agricultural production (Farmer et al. 2001, 2002, Sinclair Knight Merz 2001, Short et al. 2006). The BMNDRC operates predominantly as a series of internally draining sub-catchments with surface water flows occurring at local scales. The likelihood of streamflow depends on a number of factors including: soil type, soil properties (water repellence, infiltration rates and hydraulic conductivity), topography, vegetation type and density. These factors, along with intensity and duration of rainfall events, contribute to the catchment's ability to generate surface water flow.

While catchment-scale surface water flows are relatively infrequent (one to two times every 10 years[26]), when the braided drainage line of the valley floor does flow, surface water flows south-west from the Buntine sub-catchment, and north west from the Nugadong sub-catchment to the east of the BMNDRC. Surface water flows are shown in Appendix 6. Surface water then flows through a series of large playa lakes in the Lakeview and Mason's sub-catchments, and then heads north west to the playa lakes in the Meelya sub-catchment. Surface water from the Kooringa catchment also contributes to these playa lakes before heading north through the Koobabbie sub-catchment at the western boundary of Koobabbie farm.

26 The last occurrence followed Tropical Cyclones Elaine and Vance in 1999.

At this point the Koobabbie sub-catchment meets the drainage outlet of the Latham Lakes Chain. This is the surface water outlet of the BMNDRC. Local-scale surface water flow events in the BMNDRC occur over relatively short time scales, often less than 24 hours, conversely catchment-scale surface water flows and associated pools of water may persist for many days or weeks.

Water quality in natural drainage lines and artificial drains varies considerably, ranging from fresh to highly saline, and highly acidic to mildly alkaline.

Hydrogeology (groundwater)

Since the clearing of perennial deep-rooted vegetation, more rain infiltrates through the soil profile to the underlying aquifers. This has resulted in an increase in groundwater levels in affected aquifers. Areas which used to be seepages or wet on a seasonal basis are now permanently wet or seasonally inundated. Three groundwater systems have been identified in the BMNDRC. Groundwater occurs within weathered bedrock in the saprolite profile, the sediments of palaeochannels and within superficial sandplains (Speed & Strelein 2004).

The majority of groundwater in the catchment is stored in the saprolite profile. The yield and quality of groundwater in this zone is variable but is generally low, meaning it is difficult to abstract significant quantities and it has a high salt content. The location of palaeochannel sediments within the BMNDRC is unknown, although it is likely that a number of palaeochannels exist within the vicinity of the main drainage line (Sinclair Knight Merz 2003, Speed & Strelein 2004, URS 2007). Sand sheets dominate the west and south-western regions of the BMNDRC. These highly permeable sands are often underlain by a less permeable silcrete horizon resulting in sandplain seeps where the edge of sand systems and silcrete occur near the soil surface. Palaeochannels are also important as they represent a larger more extensive groundwater system that may be interacting with existing wetlands. Asset specific investigations are required to determine whether this interaction occurs.

Wetlands are the result of interactions between geology, hydrology, hydrogeology and geomorphology. It is therefore logical to assume that altered hydrology (particularly dryland salinity) can have a dramatic impact on wetlands and the biota within and near them. Artificial wetlands are human made excavations in the landscape, such as dams, drains, and infrastructure such as troughs that may provide habitat for aquatic species. These are not considered in the context of this recovery catchment plan. However, changes to hydrology have brought about variations in the distribution of wetlands whereby natural depressions previously dry or seasonally wet are now permanent wetlands. Where these areas, which are the result of altered hydrology, have been colonised by biodiversity now at risk elsewhere in the landscape, they are considered under this plan.

As the biological communities and other biota associated with wetlands are threatened by salinity they are discussed in detail under the section titled 'Biodiversity assets threatened by salinity'.

ATTACHMENT 4: BIODIVERSITY ASSETS OF THE BUNTINE-MARCHAGEE NATURAL DIVERSITY RECOVERY CATCHMENT

FLORA

At a broad scale, the BMNDRC lies within the Southwest Botanical Province. The vegetation of the South West Botanical Province has been mapped to show original natural vegetation before the arrival of Europeans (Beard 1980). Eleven 'Beard' vegetation types occur in the catchment (Shepherd et al. 2001). These comprise (and covered by area before settlement) six shrubland types (77 per cent), three woodland types (14 per cent) and two 'succulent steppe' types (nine per cent). Table 1, *Appendix 7*, summarises the pre-European and current extent of these vegetation types. Of about 180,000 hectares of native vegetation, 20,000 hectares or 11 per cent remains. This represents a reduction in area of each type ranging from 64 per cent to 95 per cent. The area of each vegetation type remaining ranges from 11 hectares to 6093 hectares, Table 1, *Appendix 7*.

At a finer 'bioregion' or IBRA[27] scale, approximately 75 per cent of the recovery catchment is within the 'Avon Wheatbelt 1' (AW1) Ancient Drainage sub-region of the Avon Wheatbelt Region and 25 per cent is in the 'Geraldton Sandplain 3' (GS3) Lesueur sub-region of the Geraldton Sandplain Region (Figure 1, Appendix 7). The vegetation of the AW1 component of the catchment is characterised by Melaleuca spp. shrublands in the main drainage line, woodlands of eucalypts on the lower slopes, with mallee eucalypts on the mid-slopes, and shrublands on the upper slopes. The vegetation of the GS3 component of the catchment is distinct from the AW1 area and is characterised by shrublands across the whole landscape. The dominant taxa of these two sub-regions and the landscape position they are associated with is described in Appendix 7 (following Figure 1). The woodlands in the lower slopes have been extensively cleared for their productive soils. There are now two woodland types along with several shrubland types that are limited in both extent remaining and representation in the reserve system. Table 2, Appendix 7, documents the 'limited extent' of these types characterised by area and representation in the reserve system in the context of the Northern Agricultural Region and Statewide[28].

In contrast to many other agricultural catchments in both the Avon Wheatbelt and Geraldton Sandplains IBRA bioregions, the BMNDRC has a relatively large area of remnant vegetation (close to 20,000ha or ~11 per cent). Of this remaining native vegetation, 503 vegetation remnants over one hectare in size were surveyed by Huggett et al. (2004). This study provides the most recent and detailed mapping of vegetation in the catchment. The survey identified 24 native vegetation 'associations' based on six broad formations (Table 3, Appendix 7 and Figure 2, Appendix 7).

These associations comprise:

- 12 woodlands
- seven shrubland (four in the Geraldton Sandplains IBRA and three in the Avon-Wheatbelt IBRA)
- two wetlands
- one sedgeland
- one grassland (on previously cleared land)
- one heathland

There is a pattern to the size and location of these remnant associations. Although size varies considerably, remnants above 100 hectares (37 in total) comprise 63 per cent of the total area, while remnants equal to or under 100 hectares (466 in total) comprise 37 per cent of the total area (Table 4, *Appendix 7*). Bigger remnants, which are fewer in number, comprise about two-thirds of the total area of remaining native vegetation. The smaller remnants are more numerous and comprise about one-third of the total area. Most remaining remnant vegetation is on private land (73 per cent) with 11 per cent in nature reserves (Table 5 and 6, *Appendix 7*).

A total of 743 plant taxa, 239 genera and 76 families have been identified in the BMNDRC based on the combined terrestrial flora surveys reported in CALM (1999a), Huggett et al.(2004),, Davies et al. (2001), and Kitchener et al. (1979).

THREATENED FLORA

Declared Rare and Priority Flora

The distribution and population numbers of many plants in Western Australia have been seriously affected as the result of a number of threatening processes including clearing vegetation for agriculture. Any plant taxa threatened with extinction can be declared by the Western Australian Environment Minister under the *Wildlife Conservation Act as Declared Rare Flora – Extant*

27 The Interim Biogeographic Regionalisation for Australia (IBRA) divides the Australian continent into 85 bioregions. 404 sub-regions have now also been defined Australia-wide based on major geomorphic features in each bioregion.

28 The terms 'limited extent' and 'poorly represented' refer to a classification scheme used by the International Union Conservation of Nature (IUCN) now the World Conservation Union.

Taxa[29]. A number of other plant taxa have also been designated a Priority category (P) ranging from P4 to P1, the highest priority, while their threatened status is under review, particularly as their distribution and threats are poorly known. Descriptions of the two categories of Declared Rare Flora (DRF) and four categories of Priority Flora can be found in *Appendix 9* (Conservation Codes).

Forty-five threatened plant taxa occur in the BMNDRC. This comprises twelve DRF, nine P1, six P2, sixteen P3 and two P4. Sixteen plant families (out of a total of 60) are represented. The five families with the greatest numbers of Declared Rare and Priority Flora are Myrtaceae (eight), Proteaceae (seven), Mimosaceae (six), Myoperaceae (four) and Papilionaceae (four) (Table 9 *Appendix 7*). Of the 45 Declared Rare and Priority Flora, six are covered by written management plans. Two have a full recovery plan (written in 1995), and four have interim recovery plans (three current and one out-of-date). A complete list of DRF and priority species and their management status is presented in Table 10, *Appendix 7*).

Threatened Ecological Communities

Threatened Ecological Communities (TECs) are naturally occurring assemblages of plants and animals endorsed by the Western Australian Environment Minister as being threatened with extinction by human activity, or in danger of being destroyed or significantly modified by development and other pressures from people. A description of the definitions, categories and criteria for threatened and priority ecological communities is provided in CALM (2005). A short description of TECs is provided in the Glossary.

There are no known occurrences of TECs in the BMNDRC. Further surveys will be undertaken to determine if new occurrences of listed TECs, or other plant communities that may meet the criteria for listing, occur in the area. For example, two communities that may meet the criteria for listing but for which there is insufficient information are:

- A herbaceous plant assemblage that appears to be restricted to the lake beds and margins of bentonite-based wetlands in the Watheroo-Marchagee area has been recorded close to the BMNDRC (Hamilton-Brown 2002). This assemblage has been formally endorsed by the Environment Minister as a TEC. The assemblage is dominated by the herbs *Triglochin mucronata*, *Trichanthodium exile*, *Asteridea athrixioides* and *Puccinellia stricta* on the lakebeds, and *Podolepis capillaris*, *Angianthus tomentosus* and *Pogonolepis stricta* on the lake margins (Hamilton-Brown 2002). The plant species are characterised by their dependence on the bentonite (saponite) substrate. In some instances, varying densities of *Casuarina obesa* trees and *Melaleuca lateriflora* subsp. *lateriflora* and *Acacia ligustrina* shrubs occur with the herbaceous assemblages. It is highly likely that the bentonite wetlands that have been identified in the BMNDRC are also TECs, however this needs to be confirmed by surveys when the lakes flood and the herbaceous assemblage can be identified.
- *Eucalyptus camaldulensis* woodland (river red gum) is an uncommon association in the catchment. River red gums sometimes occur across the lake floor of perched fresh water wetlands in other parts of the northern wheatbelt (Lyons et al. 2004). One particular river red gum community about 90 kilometres north of the BMNDRC was previously listed as Critically Endangered, but its status has since been reviewed and it is now considered totally destroyed due to massive hydrological change and subsequent death of much of the original wetland plant community. River red gums are known to occupy areas of perched fresh water wetlands in the BMNDRC. They are also known to be at, or near, their southern-most limit of distribution. They occur in 11 remnants in the catchment and are severely reduced in area by land clearing and salinisation. River red gum woodland is characterised by its uniqueness of habitat and provides regionally important drought refuges for a diverse range of fauna. Amphibians, reptiles, invertebrates and many other fauna are associated with this habitat type (Huggett et al. 2004). Additional work is required to establish the status of these assemblages in the BMNDRC.

FLORA OF SPECIAL INTEREST

Short-range endemics

CALM (1999a) documents three possible short-range endemics in the BMNDRC. Short-range endemics are species that occupy a small spatial area. The three species are:

- *Eremophila vernicosa ms* (Declared Rare Flora), presumed extinct until it was rediscovered on private land in the catchment in 1998/99;
- *Halosarcia koobabbiensis ms* (Priority 1), known only from the 'type locality' on Koobabbie Farm; and
- *Caladenia drakeoides ms* (Declared Rare Flora) which occurs on private land (Koobabbie Farm) and within the braided channel east of Gunyidi.

29 This declaration means that declared plants cannot be disturbed without Ministerial approval. A list of rare flora is maintained for the whole State and the status of listed plants is reviewed annually.

Iconic/charismatic taxa

These are taxa that have public significance and important cultural values in the BMNDRC as well as at a State and national level. This status exists regardless of their level of protection or rarity. These taxa currently include:

- The *Acacia* genus which has particular significance to the local community. For example, the BMNDRC has one of the highest concentrations of Acacia taxa found anywhere in the world. A species of Acacia is also the floral symbol of the Dalwallinu Shire.
- *Eucalyptus salmonophloia* (salmon gum) which has a large and stately appearance together with its pink-salmon coloured bark. This gives it a charismatic status locally and nationally as an icon of the WA wheatbelt.
- *Eucalyptus salubris* (gimlet) has a strongly fluted trunk, together with glossy copper coloured bark which provides a high level of identification and curiosity among people associated with the WA wheatbelt.

Other special flora (prospective commercial and revegetation taxa of interest)

Some taxa in the BMNDRC known for their salt and/or waterlogging tolerance, and thus suitability for 'niche' area revegetation, are under investigation for their commercial prospects. Details of these species and their characteristics are provided in *Appendix 7* (after Table 10).

These include:

- Broombush complex (*Melaleuca atroviridis* (upland form), *M. stereophloia*, *M. hamata* (some selections) and *M. zeteticorum*)
- Swamp sheoak (*Casuarina obesa*)
- 'Major oil mallee species' *Eucalyptus kochii* subsp. *plenissima* and *Eucalyptus kochii* subsp. *kochii*
- 'Minor oil mallee species' *Eucalyptus myriadena* subsp. *myriadena*
- Prospective 'woody crop options' *Acacia saligna*, *A. lasiocalyx*, *A. microbotrya*, and *A. stenophylla*

Undescribed taxa

Two undescribed taxa from the genus Halosarcia, *H*. sp Gunyidi (M.N. Lyons 2607) and *H*. sp aff. *undulata* (M.N. Lyons 2622) were recorded during the biodiversity survey of the agricultural zone (Lyons et al. 2004). *H*. sp. Gunyidi (M.N. Lyons 2607) is only known from three populations in the northern wheatbelt. Formal description and naming will require revision of the genus. A single collection of *Heliophila* sp. Gunyidi (R.G. Rees 42) was made during the biodiversity survey. The specimen, lodged at the Western Australian Herbarium, is the first collection for the State, however it is not certain if the species is native or exotic (M.N. Lyons pers. comm. 2006).

A full list of plant taxa surveyed by Huggett et al. (2004), Davies et al. (2001), Kitchener et al. (1979), and CALM (1999a) are held with, and updated by BMNDRC staff at the DEC Midwest Regional Office. This list also identifies the number of plant taxa per family, the number of plant genera per family, and the number of plant taxa in each genera. The list is stored electronically under BMNDRC\Flora\ and as at October 2007 is called 'BMNDRC_Flora_Master_list'.

FAUNA

A total of 613 fauna species has been recorded in the BMNDRC. This is based on the records of Harold (2001), Huggett et al. (2004), and Lynas et al. (2006) as well as survey data published by the WA Museum in 1979 and 2004. Surveys reported in Kitchener et al. (1979) and Dell et al. (1979) were based on Museum records. Surveys undertaken in the catchment's three nature reserves are documented in Short & Parsons (2004) and the work of Burbidge (2004) was associated with the development of the State Salinity Strategy. The variety of fauna is representative of the central wheatbelt and includes: 273 aquatic invertebrates, 71 species of terrestrial invertebrates, 156 species of bird, 76 species of reptile, 19 species of mammal, 16 species of amphibian, and two species of fish. A summary of each type of fauna is provided here. Species lists of fauna (including those recorded as locally extinct) are found in Table 1 and 2, *Appendix 8* in the Supporting Information Document. It should be noted that local extinctions may have occurred without being identified in these surveys. There are also local sightings which have not been recorded officially. This means there may be differences between species recorded in official records and anecdotal reports.

Aquatic invertebrates

Three surveys of aquatic invertebrates have been conducted in the catchment by researchers from The University of Western Australia's School of Animal Biology (Storey et al. 2004 a&b, Lynas et al. 2006). From these surveys, a total of 273 taxa of invertebrates have been recorded in the wetlands, from 86 families and 24 orders (Lynas et al. 2006). Families with the highest diversity of taxa included Ostracoda (31 taxa), Dytiscidae (18), Chironomidae (15), Hydrophilidae (13) and Cyclopoida (13).

Most aquatic invertebrates collected so far in the BMNDRC commonly occur across southern Australia. There are, however, some notable exceptions:

- *Hexarthra propinqua*, a new species of rotifer which is the first record from Australia of a species previously recorded principally from Europe;
- *Trichocerca obtusidens*, a rotifer which has not formally been recorded from Australia;

- possible new species of non-biting midge (Chironomidae) (*Cladopelma* sp. nov.);
- two native species of brine shrimp, *Parartemia serventyi* and *Parartemia contracta*, endemic to south-western Australia;
- *Daphniopsis australis* (a small cladoceran) recently collected in WA for the first time (previously this species was known only from a few localities in eastern Australia);
- *Daphniopsis* sp. nov, which is either an undescribed or recently named species not previously recorded from WA;
- *Sarscypridopsis* sp. (an ostracod) has previously been recorded only from Dunn Rock Nature Reserve and the sediments of Toolibin Lake; and
- Calamoecia salina (a copepod) which occurs across southern Australia in relatively undisturbed naturally saline wetlands; the species has been recorded in WA three times in recent years (Storey et al. 2004a).

Endemic taxa were consistently recorded from the freshwater wetlands which also supported the greatest overall species richness.

Analysis of the results of the BMNDRC invertebrate survey showed water chemistry to be a strong determinant of the invertebrate fauna composition of wetlands. This highlights the threat posed by altered hydrology to these assets. Within the wetlands of the BMNDRC, greater invertebrate species richness, species diversity, levels of endemism and conservation values were associated with fresh and brackish wetlands than saline or hypersaline wetlands (Storey et al. 2004a). It has also been demonstrated that wetlands impacted by altered hydrology, including secondary salinity, support assemblages of aquatic invertebrates that are regionally less diverse than those of primary saline wetlands (Pinder et al. 2004). In the case of primary saline wetlands that become salinised, while the richness of individual wetlands may not decrease, at a regional level there is a loss in diversity as all wetlands become reduced to largely the same set of species. Refer to the section on Wetland Assemblages for a discussion of the threat posed by salinity to wetlands.

Terrestrial invertebrates

The biodiversity survey of the Western Australian agricultural zone (Keighery *et al*., 2004) undertaken between 1997 and 2003, included several sampling sites within the BMNDRC. Terrestrial invertebrate fauna associated with wetlands of the Western Australian wheatbelt consisted of a mixture of widespread, regionally restricted, and short-range endemic species. Terrestrial invertebrates collected as part of the biodiversity survey focused mainly on spiders and scorpions. Sixty-five species of spider and six species of scorpion were recorded. These results are likely to be a significant underestimation of the spider and scorpion diversity in the BMNDRC (Harvery et al. 2004).

Many species collected in the aquatic invertebrate surveys were terrestrial invertebrates, often with their larval stages living in wetlands. Examples include 55 fly taxa (Order Diptera), four caddis-fly taxa (Order Trichoptera), two mayfly taxa (Order Ephemeroptera), 14 dragonfly and damselfly taxa (Order Odonata), three butterfly taxa (Order Lepidoptera), 29 beetle taxa (Order Coleoptera) and eight bug taxa (Order Hemiptera).

A study of the terrestrial invertebrate fauna of the Western Australian wheatbelt has shown that species found in the inundation zone of wetlands (the dry lake floor and samphire) are not simply a subset of that found in fringing samphire and melaleuca or surrounding woodland. As part of this study, five saline wetlands were surveyed including sites within 50km of the BMNDRC. Of 356 species, 198 were from the inundation zone and 229 from woodland. Of these only 72 species were common to both areas. It is thought that differences in microhabitat have an effect on which species are found on dry lake floors and associated vegetation or fringing woodlands. (Durrant & Guthrie 2004).

Many short-range endemic species were also recorded in this invertebrate survey. It is therefore probable that invertebrate fauna of individual saline wetlands are quite unique and valuable. Given the similarities between the conditions at the sites sampled as part of this study and those of the BMNDRC, wetlands of the BMNDRC may be rich in terrestrial invertebrates, many of which will be confined to particular microhabitats. Organisms utilising this habitat are quite often only able to do so by developing strategies for surviving periodic flooding of the wetland floor. This means that permanent changes in the inundation regime brought about by altered hydrology are likely to have severe impacts. Changes in the chemical composition of lake floors, such as those brought about by increasing salinity, may also have deleterious effects on burrowing species.

Birds

Despite extensive habitat loss and the introduction of a range of feral predators, the BMNDRC continues to support a diverse assemblage of birdlife. A 'Focal Species Study' using the avifauna of the BMNDRC was conducted by CSIRO between August 2001 and October 2003. Over 18,000 bird sightings, representing 110 species, were recorded during surveys conducted in 2001 and 2002 (Huggett et al. 2004).

The total number of bird species known from the BMNDRC is 156 (Western Australian Museum 2005). The most common species recorded in the CSIRO study was *Cacatua roseicapillia* (galah) followed by *Petroica goodenovii* (red capped robin). The next highest count for a species in a remnant was *Lichmera indistincta* (brown honeyeater) with 91 individuals observed within a patch of *Banksia* spp. *Barnardius zonarius* (Australian ringneck) was recorded in the most vegetation remnants (232 out of the 316 remnants surveyed), followed by *Rhipidura leucophrys* (willie wagtail) and *Lichenostomus virescens* (singing honeyeater). The habitats most supportive of a diversity of bird life were York gum with jam or mallee, and shrublands and mallee with understorey (Huggett et al. 2004).

Reptiles

Seventy-six reptile species were recorded in the area. This represents 29 per cent of known reptile species of the wheatbelt (Western Australian Museum 2005).

Lizards constitute the majority of the catchments' recorded reptiles. The skinks (family Scincidae) are the most diverse group with 25 species being recorded. Fourteen species of geckos (Gekkonidae), 10 species of legless lizard (Pygopodidae), nine species of dragon (Agamidae) and three species of monitor lizard (Varanidae) were recorded. There are also 13 species of snake known to occur in the BMNDRC. Twelve are venomous front-fanged elapids (Elapidae), and the other is the woma python (*Aspidites ramsayi*, Family Pythonidae).

Many of the skinks and geckos found in the BMNDRC are endemic, with 10 species of skink endemic to Western Australia and one endemic to the south-west. Three of the gecko species in the catchment are endemic to the State and one is endemic to the south-west.

Mammals

Current information on mammal species in the BMNDRC is based on Museum records (Western Australian Museum 2005) of surveys undertaken in the catchment's three nature reserves (Short and Parsons 2004), surveys associated with the wheatbelt biological survey, and opportunistic observations made during other projects (Davies 1990, Harold 2000, 2001). Nineteen species of native mammal have been recorded in the BMNDRC out of a total of 46 still remaining in the wheatbelt (CALM 1995). Of these 19 species, four are species of macropod (kangaroos and their relatives), four dasyurids, three rodents and four species of bat. Several introduced mammals are also prevalent in the BMNDRC. The house mouse (*Mus musculus*), black rat (*Rattus rattus*), rabbit (*Oryctolagus cuniculus*), feral cat (*Felis catus*) and European red fox (*Vulpes vulpes*) are all commonly observed in the area.

Amphibians

Sixteen species of frog have been recorded in the BMNDRC according to Western Australian Museum records (Western Australian Museum 2005). Seven species are defined as burrowing frogs (Tyler et al. 2000). The frogs found in the BMNDRC are typical south-west species, although the BMNDRC represents the northern range extent of many of these. While frogs are found throughout the landscape, the concentration of species diversity and richness in the vicinity of freshwater wetlands puts these animals at risk from the effects of altered hydrology, particularly salinity.

Fish

Western Australian Museum records have identified two species of fish in the BMNDRC (Western Australian Museum 2005). While there have been numerous historical sightings by landholders of gobies migrating up the Waddy valley system (B Fowler pers. comm. 2006), aquatic invertebrate surveys between 1999 and 2005 recorded only one specimen of Swan River goby (*Pseudogobius olorum*) within the BMNDRC (Lynas et al. 2006). There is anecdotal evidence to suggest that black bream (*Acanthopagrus butcheri*) have been introduced to the catchment.

RARE/THREATENED FAUNA

Many fauna species in Western Australia have had their distribution and population numbers seriously affected by several, sometimes interacting and often compounding, threatening processes since European settlement. The destruction and degradation of habitat and the introduction of feral species have been among the most significant. Mammals in particular have been significantly impacted. In the agricultural districts of Western Australia, 13 species of mammal have disappeared and less than half of those which originally occurred are regarded as common (Kitchener et al. 1980, Saunders 1985). While the region's birds have fared a little better in the last 80 years, two wheatbelt bird species are known to have become extinct in the wheatbelt[30] (Saunders 1989).

30 Burbidge (2004) considers that no Western Australian bird species are extinct, and, although two subspecies have disappeared from WA, other subspecies of both these birds persist elsewhere in Australia. Note: interpretation differs here in the context of geographical areas and the importance of subspecies. In Saunders 1989, the wheatbelt is defined as the agricultural area between the 300 and 600mm rainfall isohyets. See Huggett (2007) for a further analysis of extinction of birds in the WA wheatbelt and the BMNDRC.

There have also been significant declines in the range and/or abundance of bird species recorded in the wheatbelt since 1937: 31 per cent for non-passerine species and 75 per cent for passerine species (birds of the order *Passeriformes* which includes perching birds and songbirds) Just eight per cent of bird species showed an increase in range or abundance in this period and these were all passerine species (Saunders 1993). While none of the original 24 frog species or 142 reptiles have become globally or regionally extinct, it is likely that local extinctions of these groups of animals may have occurred (Burbidge 2004)[31]. Interestingly, in the case of amphibians, while abundance has decreased, species richness has generally been maintained (J.D Roberts pers. comm. 2007).

The WA Environment Minister may declare any fauna that is likely to become extinct, is rare, or is otherwise in need of protection to be 'specially protected'. Once a species is nominated as threatened it is assessed through a scientific review process followed by a Ministerial endorsement process. The Western Australian Threatened Species Scientific Committee (WATSSC) is an independent scientific advisory body established by the Minister, which assesses the conservation status of communities and makes recommendations to the Minister. The *Wildlife Conservation Act 1950* provides for the Minister to declare fauna species to be specially protected under four schedules. In addition there is a 'reserve list' of priority taxa. Although priority species are not provided legislative protection, they are monitored by the department as species that are uncommon or in decline and may require elevation to threatened status at a future date.

Eight rare/threatened fauna and six priority fauna occur in the BMNDRC. Table 1 in *Appendix 8* describes these schedules and identifies which of these types of rare/threatened or priority fauna occur in the BMNDRC. *Appendix 9* includes a description of the conservation codes used to describe the conservation status of flora and fauna in Western Australia. This includes the conservation taxa Declared Rare Flora, priority flora and rare/threatened and priority fauna.

FAUNA OF SPECIAL INTEREST

Species at their geographic limit

Based on brief investigation of vertebrate records from the Western Australian Museum, there are a number of fauna species found in the BMNRDC which are at the geographic limits of their distribution:

- northern/eastern – western brush wallaby *Macropus irma*, honey possum *Tarsipes rostratus*, white-tailed dunnart *Sminthopsis granulipes*, Gould's snake *Unechis gouldii*
- southern/eastern – ornate stone gecko *Diplodactylus ornatus*, robust striped gecko *Strophurus michaelseni*
- eastern – sandplain worm lizard *Aprasia repens*, western spiny-tailed skink *Egernia stokesii badia*, *Lerista christinae*, *Lerista lineopunctata*, *Lerista praepedita*
- southern – hooded scaly-foot *Pygopus nigriceps*
- western – unadorned desert skink *Egernia inornata*

It should be noted however that an extensive analysis of fauna at their geographic limit has not been completed for the BMNDRC. It is likely that, on closer investigation, more vertebrate species are likely to be at their geographic limit in the catchment. This is also likely to be the case with invertebrates (Western Australian Museum 2005).

Migratory species

The Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) provides a listing of migratory species (listed under the Convention on the Conservation of Migratory Species of Wild Animals [Bonn Convention] and the Japan-Australia Migratory Bird Agreement [JAMBA] and China-Australia Migratory Bird Agreement [CAMBA]). There are 23 migratory species (all birds) found in the BMNDRC.

Iconic/charismatic fauna species

All of the following species have significance and important cultural values to people in the catchment regardless of whether they are specially protected, rare or threatened species. All except one are birds. Species which have been noted and described by landholders include:

- Carnaby's black cockatoo (*Calyptorhynchus latirostris*), found only in Western Australia and one of only two species of white-tailed cockatoo found anywhere in the world. Breeding sites in the BMNDRC are the most significant in the northern wheatbelt.
- Red-tailed black cockatoo (*Calyptorhynchus banksii*), with its glossy black colouring apart from orange-red bands on the tail, is seasonally nomadic across the catchment. The red-tailed black cockatoo makes use of nesting hollows in mature eucalypts.
- Major Mitchell's cockatoo (*Cacatua leadbeateri*), a cockatoo with distinctive pink and white colouring and long crest, is resident in the catchment and reliant on nesting hollows in mature eucalypts.
- Mulga parrot (*Psephotus varius*) is less conspicuous

31 The study area extended from near Northampton (latitude 28º S) to near the south coast, and from near the west coast east to just beyond Esperance (longitude 123º E).

than the large cockatoos. It is admired for its colours and swift flight. It is usually observed on the ground feeding and occurs more frequently in the east of the catchment.

- Red-capped robin (*Petroica goodenovii*) is a small and colourful bird that is common in the woodlands and shrublands of the catchment and can often be spotted perching on a fence ready to pounce on prey. It features in the BMNDRC logo.
- Bush stone-curlew (*Burhinus grallarius*) has become scarce in the catchment, probably because of predation by the fox and cat. It is now seldom seen or heard but is remembered for its eerie call and tameness around farm homesteads.
- Malleefowl (*Leipoa ocellate*), once widespread in the catchment, is now seen infrequently but is a focus of conservation efforts by the North Central Mallee Fowl Preservation Group who conduct widespread annual fox baiting.
- Australian bustard (*Ardeotis australis*) was once common across the catchment. Old photos record hunting parties displaying their bustard ‘catch’ – the bustard provided sport and a tasty meal. Clearing for agriculture and predation by foxes have caused numbers to decline. Today, locals are thrilled if they happen to see a bustard.
- Hooded plover (*Charradrius rubicollis*) is an infrequent visitor to salt lakes of the catchment and is most often observed in wet years.
- Echidna (*Tachyglossus aculeatus*) although infrequently seen, still appears to be widespread across the catchment.

Other biota

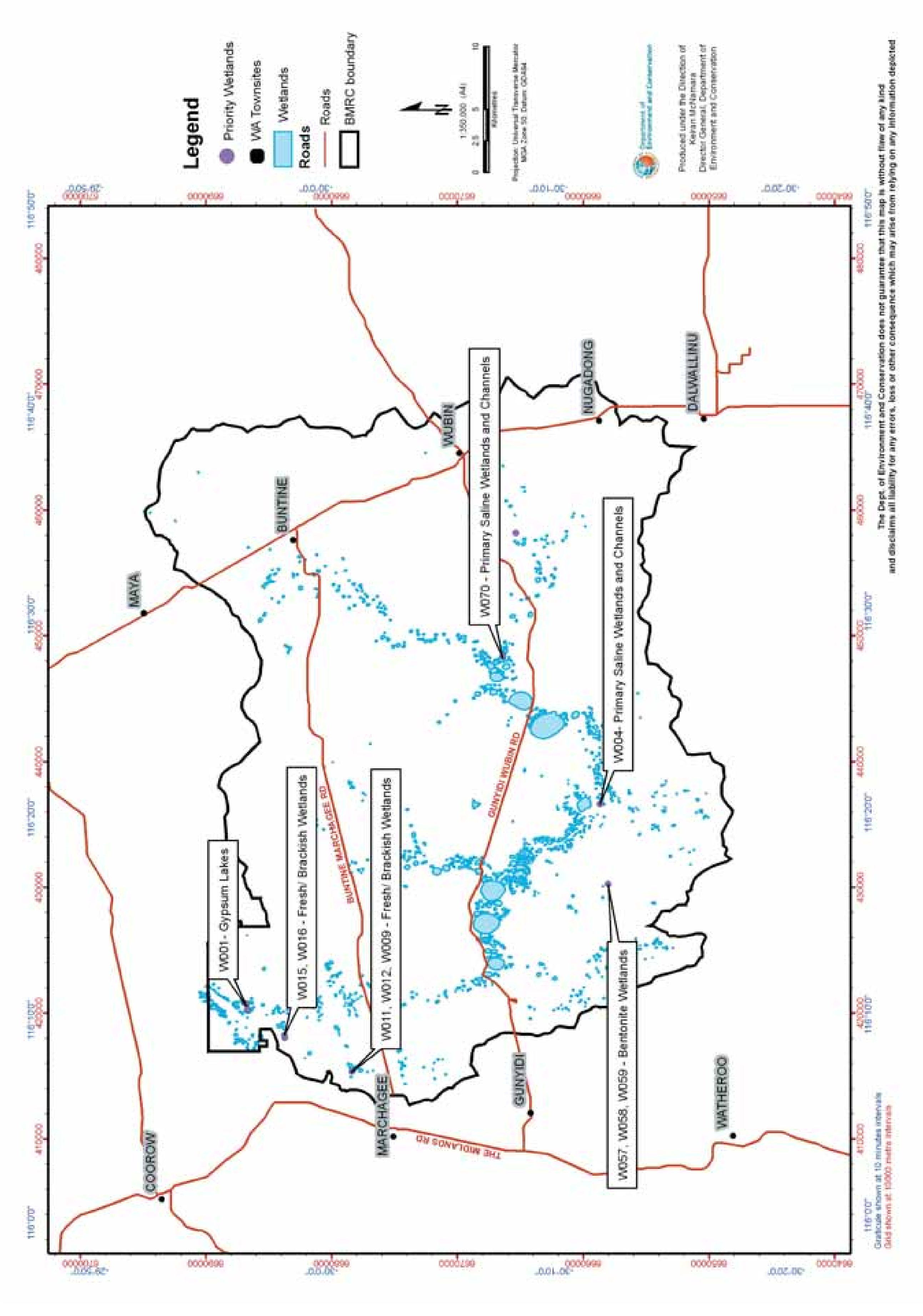
This includes fungi, bacteria and other organisms of conservation significance. There are some declared rare and priority fungi species in the State. While none are currently identified within the BMNDRC, these organisms are currently poorly named and described. It is therefore possible that in the future fungi, bacteria or other organisms of importance may be found within the BMNDRC.

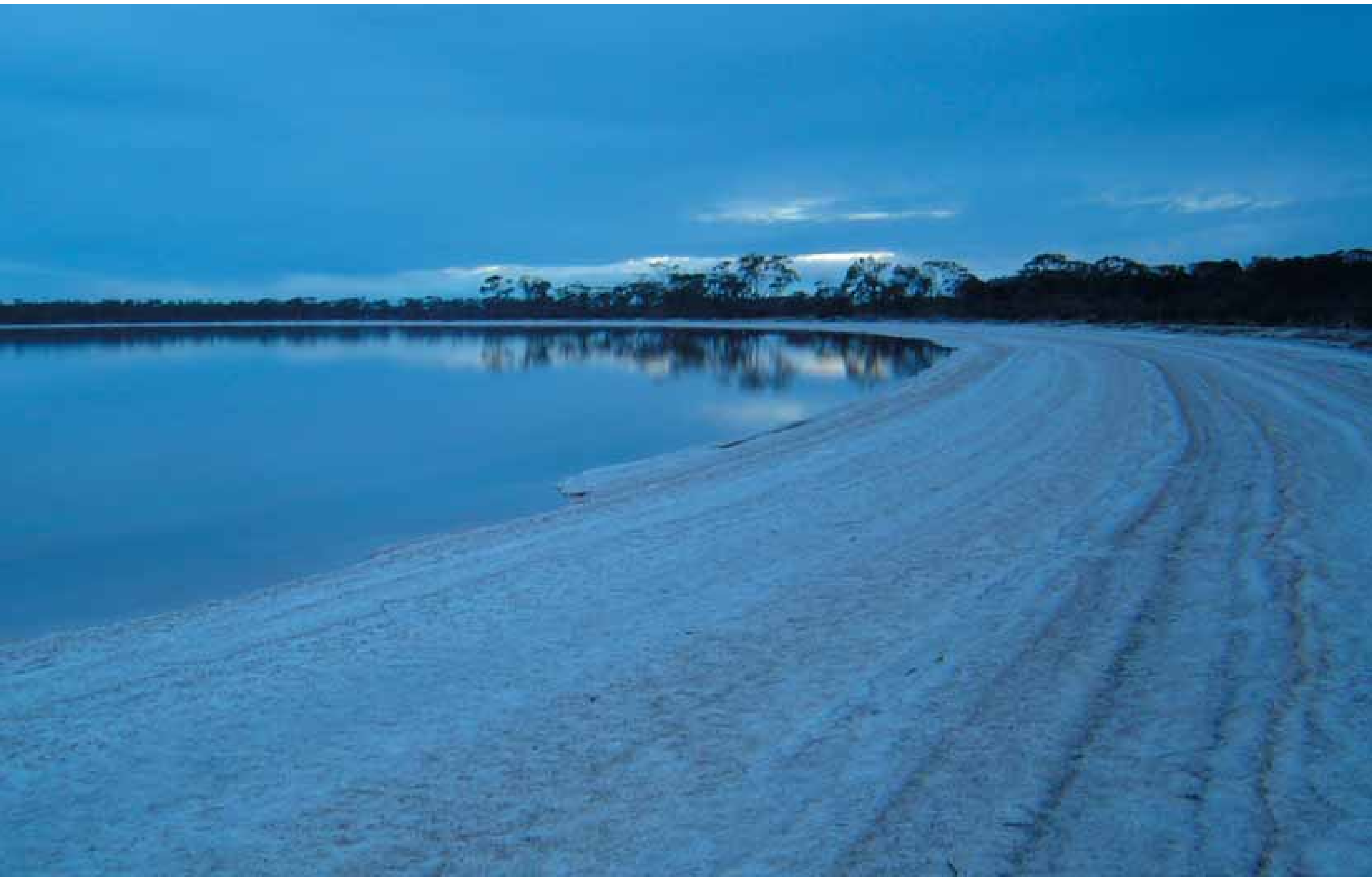
ATTACHMENT 5: SUMMARY OF BMNDRC BIODIVERSITY ASSETS THREATENED BY ALTERED HYDROLOGY

Category	Type	Sub-type	Asset
Species/sub-species/hybrids (taxa diversity)	Native flora and vegetation	Declared Rare Flora (DRF) and priority taxa	DRF *Caladenia drakeoides* Priority 1: *Acacia trinalis* *Eremophila koobabbiensis* *Gnephosis setifera* *Halosarcia koobabbiensis* ms *Hydrocotyle hexaptera* Priority 2: *Fitzwillia axilliflora* *Podotheca pritzelli* Priority 3: *Persoonia chapmaniana* *Sarcocornia globosa* *Triglochin stowardii*
		Relictual Species	Relictual/Gondwana species. Currently unknown, standard information on special taxa across the agricultural region is required (Wallace 2005).
		Species at their geographic limit of occurrence	*Eucalyptus salmonophloia* (salmon gum) *Eucalyptus myriadena* *Melaleuca lateriflora* subsp. *acutifolia* *Juncus pallidus* (pale rush) *Eucalyptus sargentii*
		Short-range endemics	*Halosarcia koobabbiensis* ms (Priority 1) *Caladenia drakeoides* ms (DRF – critically endangered)
		Iconic/charismatic species	*Eucalyptus salmonophloia* (salmon gum) *Eucalyptus salubris* (gimlet)
		Other special flora	The broombush (*Melaleuca* spp) complex (*Melaleuca atroviridis* (upland form) *M. stereophloia*, *M. hamata* (some selections) and *M. zeteticorum*) Swamp sheoak (*Casuarina obesa*) *Eucalyptus myriadena* subsp. *myriadena* River red gum woodland Granite derived soils supporting remnant vegetation on the lower slopes
		Aquatic plants	Currently unknown
		Common plants	Common plants are generally managed as part of biological communities. *Acacia arida* (G. Keighery *pers. comm.* 2006)
	Native fauna	Threatened fauna	The BMNDRC supports occurrences of rare and priority fauna. The threat posed to these by salinity is unknown.
		Relictual fauna	Currently unknown
		Fauna at their geographic limit of occurrence	Currently unknown Probably some birds, although no wetlands of significance

Category	Type	Sub-type	Asset
		Migratory species	Probably some birds, although no wetlands of significance have been identified.
		Iconic/charismatic species	Currently unknown
		Aquatic fauna	Currently unknown
		Common fauna	Currently unknown
		Threatened ecological communities	Bentonite wetland communities (requires survey to confirm as TEC)
	Other organisms	Terrestrial assemblages Aquatic/wetland assemblages Terrestrial and wetland	The following vegetation associations (these are a subset of terrestrial assemblages) threatened by salinity: *Allocasuarina huegeliana* woodland (rock sheoak woodland on deep yellow sand); *Eucalyptus sargentii* woodland (salt river gum); *Hakea recurva* or *Hakea preissii* woodland; *Eucalyptus salicola* (salt gum woodland, adjacent to salt lakes); *Melaleuca thyoides* (shrublands of perched drainage lines and samphire); Fresh/brackish wetland (rushes): *Juncus pallidus*, Melaleuca, occasional river red gum or swamp oak; River red gum woodland, adjacent to fresh or brackish wetlands; Salmon gum woodland (may have some York gum, gimlet *Eucalyptus myriadena* or mallee); Swamp oak woodland: adjacent to brackish or saline wetlands; Samphire wetlands (saline): occasional Melaleuca or swamp oak; Gimlet woodland: may also have some salmon gum (sometimes as a co-dominant), red morrel, York gum or mallee; and Melaleuca/Acacia shrubland with occasional emergent trees or mallees.
Biological communities (ecosystem diversity)	Common ecological communities		Of the six wetland assemblages recognised within the BMNDRC the following are known to be threatened by salinity: Primary saline wetlands and channels; Fresh/brackish wetlands; Freshwater claypans; Bentonite wetland assemblages (possibly threatened by salinity); and Gypsum lake assemblages (possibly threatened by salinity).
	Landscapes		The BMNDRC is a representative priority landscape unit, selected at the State level.

ATTACHMENT 6: LOCATION OF PRIORITY WETLANDS





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