# Buntine-Marchagee

## Natural Diversity Recovery Catchment







## RECOVERY PLAN: 2007 – 2027

## SUPPORTING INFORMATION



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Buntine Marchagee Catchment

# BUNTINE-MARCHAGEE
# NATURAL DIVERSITY RECOVERY CATCHMENT

Supporting information to the recovery plan 2007–2027

*This document explains important issues that would otherwise need significant diversions in the Buntine-Marchagee Natural Diversity Recovery Catchment Plan. Some of these appendices are drafts or working papers that have been developed as part of the plan's preparation or are snapshots of existing information. As such they should not be viewed as official documents or up-to-date publications. They are designed to provide accesss to background information and provide details of published references.*

*Please note the Department of Environment and Conservation was established on 1 July 2006 with the merger of the Department of Environment and the Department of Conservation and Land Management.*

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Buntine Marchagee Catchment


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## APPENDIX 1: SELECTION CRITERIA FOR RECOVERY CATCHMENTS

***Table 1**: Relevant stakeholders and their responsibilities for the Buntine-Marchagee Natural Diversity Recovery Catchment*

| Criterion | Comment |
|---|---|
| Biodiversity values at risk | This is the primary criterion for selecting recovery catchments for natural diversity. Recovery catchments will contain very high nature conservation values at risk. Assessment of catchments will involve the following attributes:<br>• how representative the catchment biota is of important natural communities;<br>• presence of threatened communities and species;<br>• species and community richness;<br>• whether the catchment provides an important biological corridor (e.g. that connecting Lake Magenta Nature Reserve and Fitzgerald River National Park), or other significant ecological service; and<br>• international or national significance of the area (e.g., Ramsar Convention, Directory of Important Wetlands in Australia). |
| Biogeographic representation | It is desirable to have recovery catchments that represent a range of situations. For example, as many IBRA regions as practicable will be represented, consistent with other criteria. |
| Opportunities for R&D or demonstration sites | R&D or demonstration sites, particularly those with State or national or international significance, might include special management techniques for:<br>• nature conservation;<br>• farm economics;<br>• cultural change or improved social interaction; and<br>• Landcare. |
| Tenure of land at risk | While conservation lands that are the focus of recovery catchments for natural diversity should be vested with the NPNCA, other land tenures may be considered for selection as recovery catchments if they are sufficiently important for nature conservation and threatened by salinity. |
| Representation of hazard | The greater the hazard to an important site, the greater the urgency for action. However, recovery catchments will be selected that represent a range of hazard situations including those that are threatened in the longer term by salinity, but are at present in good condition. |
| Potential for success | In the main, catchments will be selected that are likely to lead to success. This will involve, for example, taking into consideration:<br>• 'Physics' of pressure (e.g. is hydrological pressure overwhelming?);<br>• area of catchment (bigger catchments are generally more difficult to recover);<br>• degree of threat;<br>• level of landcare community support, knowledge and enthusiasm;<br>• potential to use prospective commercial species in revegetation; and<br>• Current area and distribution of remnant vegetation (the more the better). |
| Socio-political considerations | There will be demands from a plethora of socio-political stakeholder groups ranging from catchment groups to Federal agencies and politicians. The demands from these groups will need to be taken into consideration. |

# APPENDIX 2:
# NOMINATION DOCUMENT FOR THE BUNTINE-MARCHAGEE RECOVERY CATCHMENT[1]

This document – nominating the Buntine-Marchagee catchment to become the fifth Natural Diversity Recovery Catchment designated under the State Salinity Strategy (Government of Western Australia 2000) – is a reproduction of the original nomination document produced by the Department of Conservation and Land Management in 1999. Most of the information contained in this document has been updated in the Recovery Catchment Plan. The appendices in this section refer to those in the nomination document only and not to the supporting information document.

## Proposed Natural Diversity Recovery Catchment: Buntine-Marchagee catchment

This document outlines the case for the Buntine-Marchagee catchment to become the fifth Natural Diversity Recovery Catchment designated under the State Salinity Strategy (Government of Western Australia 2000).

## Catchment overview

The Buntine-Marchagee catchment straddles the boundary of the Geraldton Sandplains and Avon-Wheatbelt Interim Biogeographic Regionalisation of Australia (IBRA) regions (Figure 1). The catchment includes vegetation typical of the northern Avon-Wheatbelt and the sandplain communities of the Geraldton Sandplains. In the southern part of the catchment, the sandplain in dissected by wide and poorly defined saline drainage lines that are often referred to as 'braided channels'. These consist of large areas of samphire and associated shrubs, small meandering saline streams, many open saline pans of varying sizes, and pockets of slightly elevated land supporting eucalypts. The majority of saline streams, open saline pans and samphire areas in this catchment are naturally saline (primary salinity). That is, they have not developed due to water tables rising since clearing for agriculture.

North of the Buntine-Marchagee, there is a catchment running west from Latham with more subdued topography. The two catchments join just east of Marchagee Nature Reserve (Figure 2). Koobabbie Farm, which contains some of the larger fenced remnants in the Buntine-Marchagee catchments including a number of Priority Flora, lies on the junction of the catchments.

Because only two wetlands in the Buntine-Marchagee catchment were sampled as part of the Salinity Action Plan surveys, and because visual inspection showed the braided channels in the Latham catchment and Marchagee Nature Reserve were very similar to the Buntine-Marchagee channel, wetland sites from these areas were used to help document the likely faunal values of Buntine-Marchagee (see Table 2, Figure 2). We refer below to this group of wetlands being in the 'Marchagee area'.

Downstream from Marchagee Nature Reserve, west of the Midlands Road, water from Buntine-Marchagee and Latham discharges into Capamouro Swamp and Lake Eganu. These well-known wetlands are in large nature reserves but have become saline during the past 30 or more years as a result of increasing salinisation in the upstream catchment (of which Buntine-Marchagee and Latham make up a significant proportion). These lakes, and the Marchagee Nature Reserve, are not included in the proposed Recovery Catchment but may also benefit, to some extent, from recovery actions.

There are a number of national parks and nature reserves located in (and surrounding) the Buntine-Marchagee catchment. These are shown in Figure 3.

Clearing of native vegetation for agricultural purposes began in the Buntine-Marchagee catchment in the 1890s with the arrival of the Midlands Railway. Large-scale clearing continued into the 1970s with the last land clearing occurring in the early 1990s.

Rising water tables are becoming an issue in the catchment. Research has shown that water tables in valley floors are shallow in many places and are therefore very susceptible to changes in the water balance. Sandplain seeps have undergone very rapid and significant increases in volume in recent years. This increasing level of water tables has expressed itself in some areas as a degradation of low-lying vegetation.

1 Note: Information contained in this document may be out of date.

## Biodiversity values of Buntine-Marchagee catchment

***Table 1**. Salinity strategy biological survey sites shown in Figure 1 or mentioned in text*

| Sites within proposed recovery catchment | | |
|---|---|---|
| **Biodiversity sites: terrestrial fauna and flora** | **Terrestrial flora sites** | **Wetland sites: aquatic invertebrates, birds and floristics** |
| WU02 | WU5A | SPS157 |
| WU03 | WU5B | SPS158 |
| WU04 | WU16 | |
| WU05 | WU20 | |
| WU13 | | |
| **Relevant sites outside proposed recovery catchment** | | |
| WU06 | WU12 | SPS155 |
| DN01 | WU13 | SPS171 – just N of Figure1 |
| DN02 | WU15 | SPS172 – just N of Figure 1 |
| DN08 | WU17 | SPS201 |
| | WU21 | SPS203 |

### Flora values

#### *Upland flora*

Buntine Nature Reserve, a large remnant supporting good examples of upland plant communities, lies at the top of the Buntine-Marchagee catchment. Numerous smaller upland remnants occur on private land and species lists for many of them have been provided by Davies and Ladd (2000). Davies and Ladd will do additional surveys over the next two years. To date, they have recorded 278 taxa, including populations of seven taxa on CALM's Priority Flora list. Several areas of sandplain vegetation largely on private land also occur within the catchment.

Terrestrial biological survey sites have been established in the eastern part of the catchment, largely within Buntine Nature Reserve (Figure 2). They include five primary survey sites (fauna and floristics) and four additional floristic sites. Data for these sites are yet to be compiled.

#### *Wetland-associated flora*

Two wetlands within the catchment (SPS157 and 158) were sampled as part of the Salinity Strategy Biological Survey. A total of 145 species of wetland-associated flora were recorded from the margins of the two sites (Appendix 1). Seven species of Declared Rare and Priority Flora were recorded (Table 2).

*Table 2. Declared Rare and Priority Flora recorded from wetland sites SPS157 and SPS158 in the Buntine-Marchagee catchment*

| Declared Rare and Priority Flora | Status |
|---|---|
| *Ptilotus fasciculatus* | DRF (presumed extinct) |
| *Fitzwillia axilliflora* | P2 |
| *Frankenia bracteata* | P1 |
| *Gnephosis setifera* | P1 |
| *Goodenia pussiliflora* | P2 |
| *Hydrocotyle hexaptera* | P1 |
| *Podotheca pritzelii* | P2 |

Floristically, the plant communities recorded from SPS157 and 158 provide good examples of the flora and plant communities of naturally saline drainage lines within the northern wheatbelt and reflect, at least at a regional scale, the flora and plant communities within the remainder of the catchment. Further survey of the mosaic of communities within the drainage line, or braided channel, between Buntine and Marchagee is likely to record a large proportion of the regional flora of these systems.

The braided channels include large corridors of remnant vegetation and retain good examples of shrublands and woodlands of these systems. The remnants on Koobabbie Farm and Mailey's farm are in particularly good condition and include several taxa of note (see below).

#### *Priority flora*

The catchment includes populations of 39 taxa listed on CALM's 1999 Declared Rare and Priority Flora lists (Appendix 2). These taxa occur within the braided channels, sandplain and uplands of the catchment. Of particular note are:

- *Caladenia drakeoides* ms (Critically endangered) which occurs on private land east of Marchagee Nature Reserve (Koobabbie Farm) and within the braided channel east of Gunyidi;
- *Halosarcia koobabbiensis* ms (Priority 1) known only from the type locality on Koobabbie Farm in the lower part of the catchment;
- *Ptilotus fasciculatus* (currently listed as Presumed extinct) known from Koobabbie Farm and Mailey's farm near SPS158 in the Buntine-Marchagee catchment and from Kondinin Salt Marsh. These specimens were previously determined as *P. caespitulosus*. The status of the taxon will be amended to Declared Rare Flora (extant);
- *Hydrocotyle hexaptera* ms (Priority 1), from the margins of SPS157, which is undescribed (although a

manuscript name exists) and previously recorded only from Lake King; and

- *Eremophila vernicosa* ms (Presumed extinct) which was recently rediscovered on private land within the catchment.

Two other undescribed species were recorded from SPS157 and 158, namely *Halosarcia* sp. Gunyidi (M.N. Lyons 2607) and *Halosarcia* sp. aff. *undulata* (M.N. Lyons 2622). Based on current collections (all made during the Salinity Strategy survey of the northern wheatbelt), the populations at SPS157 and 158 represent the southern limit of the distributions of these species.

## Fauna values

### *Upland fauna*

A recent survey in the Buntine-Marchagee catchment by Harold (2000) recorded 51 species of bird, four non-volant mammals, six frogs and 24 reptiles but noted that considerably more species may be present. Harold will do additional surveys over the next two years. Sampling by CALM in Buntine Nature Reserve (which is not yet complete) found an additional two species of non-volant mammals and four reptiles. A large number of frogs were collected but await species-level determinations. Thirty-seven per cent of non-volant mammals known from the wheatbelt and 29 per cent of reptiles have been recorded in the Buntine-Marchagee catchment in recent surveys and it is likely that further surveys will increase these percentages.

### *Aquatic invertebrate fauna*

A total of 104 species of aquatic invertebrate fauna were collected in spring 1999 at the six wetlands sampled in the Marchagee area (Appendix 3). Although only two of the wetlands are in the Buntine-Marchagee catchment itself (SPS157 and 158), the others are in connected catchments and, taken together, the six wetlands give a more accurate impression of the fauna of the braided channels in the Buntine-Marchagee catchment than do SPS157 and 158 alone.

The braided channel wetlands of the Marchagee area contained a mix of salt-lake invertebrate communities, with salinity being the major factor determining community structure. There was an inverse relationship between salinity of a wetland at time of sampling and species richness: the number of species varied from 11 in SPS157, which was almost three times saltier than seawater, to 61 in the slightly brackish SPS203. The types of species also varied according to salinity, with salt lake specialists in the saltier wetlands and a large number of ubiquitous freshwater species in brackish wetlands.

Visual inspection suggests the braided channels of Buntine-Marchagee catchment contain all the wetland habitats represented by the six wetlands in Table 2. The braided channels support a significant proportion of the regional invertebrate fauna, especially salt-adapted species. The total number of aquatic invertebrate species in the wheatbelt is probably around 800 (Pinder et al. 2001) and, with 104 species recorded in spring 1999, the braided channel supported about 13 per cent of the whole wheatbelts' aquatic invertebrate fauna and a very much larger proportion of the fauna typical of saline systems in the northern wheatbelt. Further sampling under different climatic conditions will increase the species list from the catchment.

*Significant invertebrate species*

Four of the species records from the braided channel wetlands are worthy of mention:

- *Daphniopsis australis* (a small cladoceran) was collected in Western Australia for the first time in SPS201 (previously this species was known from a few localities in eastern Australia);
- *Daphniopsis* sp nov, recorded from SPS158, is either an undescribed or recently named species not previously recorded from Western Australia;
- *Sarscypridopsis* sp. 165 (an ostracod) has previously been recorded only from in Dunn Rock Nature Reserve and the sediments of Lake Toolibin; and
- *Calamoecia salina* occurs across southern Australia in naturally saline wetlands but the SPS158 record was only the second from more than 150 Salinity Strategy wetland samples. The species has been recorded in Western Australia three times in recent years (see Maly *et al*. 1997).

### *Waterbirds*

The braided channel wetlands of the Marchagee area do not contain major waterbird habitats supporting large numbers of birds. More important waterbird habitats occur further downstream in the Touche lakes, Capamouro Swamp and Lake Eganu. In spring 1999, after extensive flooding, the braided channels as a whole probably had a moderately diverse waterbird fauna but there were low numbers and few species in individual pans (Table 3). For example, the most species-rich braided channel wetland (SPS171) supported nine species and only 77 birds in spring 1999, while Capamouro Swamp supported 283 birds of 13 species. Counts at Lake Eganu have been much higher: 5,396 birds of nine species in spring 1998. Previous counts of ducks alone include 8,628 ducks of four species in autumn 1989 and 3,570 ducks of 10 species in autumn 1990 (Halse *et al*. 1990, 1992).

***Table 3**. Waterbirds counted in the braided channel wetlands in the Marchagee area in spring 1999.*

| Waterbird | SPS157 Gunyidi Lake East* | SPS158 Gunyidi Lake West* | SPS171 Latham Lake | SPS172 Just's Lake | SPS201 Marchagee NR Lake West | SPS203 Marchagee NR Lake East |
|---|---|---|---|---|---|---|
| Black swan | | | 3 | | | |
| Australian shelduck | 2 | 2 | | | | 3 |
| Australasian shoveler | | | 2 | | | |
| Grey teal | | 4 | 11 | | 3 | |
| Pink-eared duck | | | 12 | | | |
| Hardyhead | | | 3 | | | |
| Hoary-headed grebe | | 11 | 28 | | 2 | 22 |
| Eurasian coot | | | 15 | | | 6 |
| Black-fronted dotterel | | | 2 | | | |
| Red-kneed dotterel | | | 1 | | 2 | |
| Red-necked avocet | | 22 | | | 5 | |
| **TOTAL No. OF SPECIES** | **1** | **4** | **9** | **0** | **4** | **3** |
| **TOTAL No. OF BIRDS** | **2** | **39** | **77** | **0** | **11** | **31** |

## Biological values at risk in the Buntine-Marchagee catchment

Of the biological values outlined, rising watertables and salinity are less likely to affect the upland vegetation and probably the majority of the upland reptile and mammal species. However the loss of integrity in the area will have effects on fauna but these cannot be predicted at this stage. The wetland flora, and particularly the five species listed are at risk from the effects of rising watertables and salinity. The surveys so far have shown that the aquatic invertebrate fauna is potentially at high risk with significant differences in composition of the fauna of primarily and secondarily saline sites. This is particularly true of the four significant invertebrate species mentioned above.

## Biogeographic representation

The Buntine-Marchagee catchment straddles the boundary of the Geraldton Sandplains and Avon-Wheatbelt IBRA regions. The catchment includes vegetation typical of the northern Avon-Wheatbelt and the sandplain communities of the Geraldton Sandplains.

Thirty-seven per cent of non-volant mammals known from the wheatbelt and 29 per cent of reptiles have been recorded in the Buntine-Marchagee catchment in recent surveys and it is likely that further surveys will increase these percentages.

The braided channels of the Buntine-Marchagee catchment support a significant proportion of the regional invertebrate fauna, especially salt-adapted species. The total number of aquatic invertebrate species in the wheatbelt is probably around 800 and, with 104 species recorded in spring 1999, the braided channel supported about 13 per cent of the whole wheatbelts' aquatic invertebrate fauna and a very much larger proportion of the fauna typical of saline systems in the northern wheatbelt. Further sampling under different climatic conditions will increase the species list from the catchment.

## Opportunities for research and development/demonstration sites

This recovery catchment is the first braided naturally saline channel to be nominated as a Natural Diversity Recovery Catchment. As such it provides opportunities for investigating and demonstrating techniques of water control applicable to large areas of the Northern Agricultural Region and Wheatbelt. The Marchagee Catchment Group established plantings of maritime pines and sandalwood in 1999 and has plans for further plantings in 2000. Significant interest has been shown in oil mallee plantations in the area with plantations currently being established.

## Tenure of land at risk

Rising saline water tables and the resulting salinisation are affecting both Crown reserves and private land, however, not all land in the catchment is at risk from salinity. Affected or potentially affected areas are mainly located in the floor of the catchment.

The nature reserves (management order with the NPNCA) within the catchment are:

- Buntine Nature Reserve 26837 (1,919ha)
- Unnamed Nature Reserve 21175 (121ha)
- Unnamed Nature Reserve 28669 (157ha) *
- Unnamed Nature Reserve 38401 (107ha)*

*Threatened by rising water tables

The management order for Buntine Reserve, 16,379 (1,370ha), is with the Minister for Water Resources. The purpose of the reserve is Water and Conservation of Flora and Fauna. The reserve is considered to be of high conservation value. It is therefore proposed to commence negotiations to vest the majority of the reserve with the NPNCA.

Many of the naturally saline playa lakes in the catchment are Unallocated Crown Land. The potential for vesting these areas with the NPNCA will be explored.

## Representation of hazard

The salinity hazard situation in the Buntine-Marchagee catchment differs from existing natural diversity recovery catchments in that:

- the area is threatened by rising water tables but has not yet reached a critical stage;
- it is naturally saline and at risk mainly from secondary salinity;
- the system is based on a braided drainage channel rather than a lake system; and
- the system represents the agricultural lands to the east of the Darling Fault and in the Northern Agricultural Region.

Although braided channels are common in the wheatbelt as a whole, no attempts at restoring or recovering this form of wetland have been undertaken. As this has not been attempted previously no assurance of success can be given, however the information gathered from attempting recovery activities in this catchment will be applicable across a very large area of the wheatbelt.

## Potential for success

### Hydrological changes

The hydrology of the area is poorly understood due to a lack of long-term data. The results of the Agriculture WA Focus Catchment project in the Marchagee Catchment, although unpublished, suggest that some 14.5 per cent of the arable areas of the catchment have become saline and this may increase to 20 per cent in the next 10 years.

Within the Marchagee Catchment dramatic increases in the volumes of some sandplain perched lake systems have been observed in the past 10 years. Many of these areas are not highly saline at this stage.

A series of approximately 60 monitoring bores have been installed in the Marchagee Catchment in the past 18 months. Although no trend data are available at this early stage, results show shallow water tables exist in the valley floors. These areas are likely to be susceptible to small changes in the water table.

### Catchment characteristics

The catchment covers approximately 140,000ha. Land monitor data show that only four per cent of the Marchagee Catchment is vegetated. However the techniques used in determining the vegetated areas are aimed at determining woody vegetation greater than two metres high with more than 15 to 20 per cent vegetation cover. This under-represents the true vegetated area in the catchment as the naturally saline drainage channels, often dominated by samphire and low-density shrublands, are often not captured. It is estimated that the area of remnant vegetation incorporating the samphire flats and significant vegetated areas outside the Marchagee Catchment but within the Buntine–Marchagee catchment is likely to be closer to eight to 10 per cent of the total area.

### Local support

The recovery catchment encompasses a number of catchment groups based on a combination of physical and social groupings. The groups are the Coorow Land Conservation District Committee (Coorow LCDC), Marchagee Catchment Group, the Waddy Forest Land Conservation District and the East Maya Land Conservation District.

The Marchagee Catchment Group covers the majority of the catchment. The group has been very active with the appointment of a Bushcare Support Officer to the Coorow LCDC to assist with the implementation of an NHT Natural Heritage Trust (NHT)-funded project beginning in 1998. The NHT project 'Marchagee Catchment Bushcare Project' was funded in 1998–1999 and has continued in 1999–2000 with a planned continuation to 2000–2001. Bushcare support for the group has resulted in a high level of understanding of nature conservation and the role of CALM. The Marchagee Catchment was an Agriculture Western Australia 'Focus Catchment' in 1998; however the report on the area is still to be published. This delay in reporting results has resulted in a degree of disillusionment within the group. As a consequence the community consultation process to be conducted prior to commencing the recovery catchment will be of great importance.

The Waddy Forest Land Conservation District group has also been very active. The Waddy Forest group covers the north-western end of the Buntine-Marchagee catchment

and is responsible for a number of NHT funded projects. In 1998–1999 the group was funded to conduct a survey of remnant vegetation of the Waddy Forest area. The group has recently assumed control from the Coorow Shire of the NHT funded project 'Coorow Roadside Vegetation Rehabilitation'.

The West Maya Land Conservation District Committee and Buntine-West Wubin Land Conservation District Committees have not been very active recently. These two groups cover the eastern edge of the Buntine-Marchagee catchment. Both committees are currently re-establishing themselves with newly elected officer bearers. Many of the landholders in this area and members of these committees are members of the Liebe Group, a very active group promoting whole farm planning benefits with a strong production orientation.

A series of meetings with the various groups is planned for the near future. Discussions with a number of local landholders and the Coorow LCDC Bushcare Support Officer have indicated that there is likely to be support within the local community for the area to become a Natural Diversity Recovery Catchment.

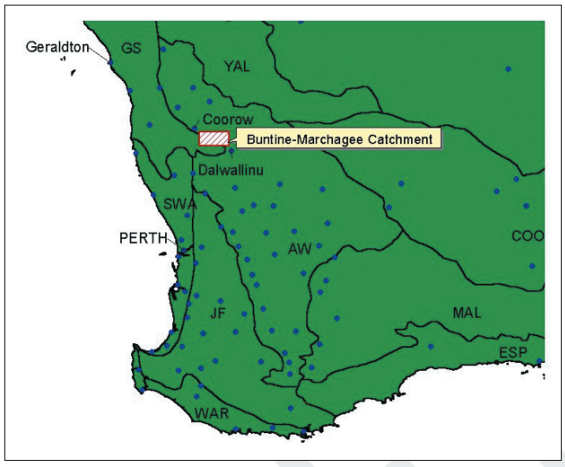



***Figure 1**. IBRA Regions of South Western Australia.*
*Note: AW = Avon-Wheatbelt, GS = Geraldton Sandplains.*

A number of local advocates have been identified. In addition the presence in the community of a *Land for Wildlife* Officer is beneficial and will assist with communications with the community. Strong local community support is also evident for the Coorow LCDC Bushcare Support Officer.

## Socio-political considerations

In the past the area has had little direct interaction with CALM apart from the involvement of Bushcare Officers. This project represents an opportunity to improve relations with the local Shires of Dalwallinu and Coorow and demonstrate CALM's role in biodiversity conservation and the salinity strategy.

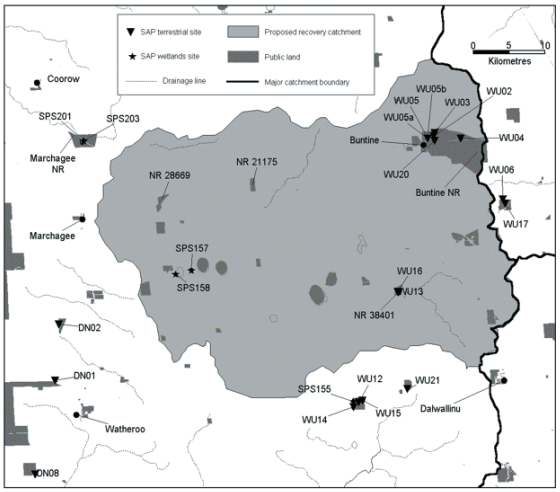



***Figure 2**. Buntine-Marchagee proposed natural diversity recovery catchment*

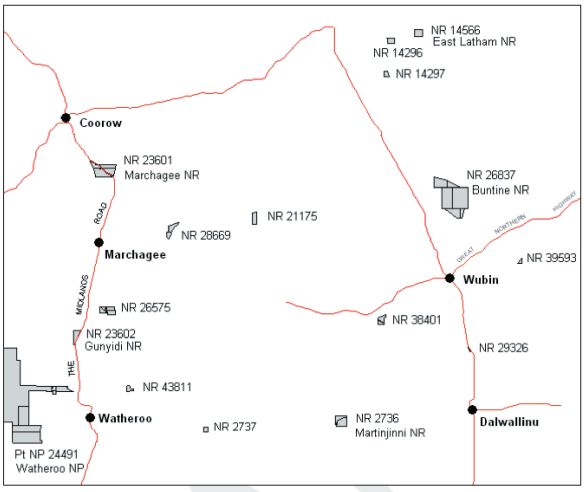



***Figure 3**. National parks and nature reserves located in (and surrounding) the Buntine-Marchagee proposed natural diversity recovery catchment.*

## APPENDIX 3: STAKEHOLDERS AND THEIR RESPONSIBILITIES

***Table 1**: Relevant stakeholders and their responsibilities for the Buntine-Marchagee Natural Diversity Recovery Catchment*

| Stakeholder Group | | Responsibilities |
|---|---|---|
| Landholders | | Implementation of recovery actions will rely heavily on the adoption of landholders, and landholders will have significant opportunities to attain some of their own goals through the recovery process. |
| State Government | Department of Conservation and Land Management (CALM) | CALM is responsible for the management of the Natural Diversity Recovery Catchment program, native flora and fauna. CALM manages 2,225ha of reserves in catchment. |
| | Conservation Commission of Western Australia (CCWA) | Controlling body for CALM and the body in whom the national parks, nature reserves, conservation parks, State forests and timber reserves are vested. |
| | Department of Agriculture and Food (DAFWA) | Provision of technical advice (e.g. hydrology, farming systems), and implementation of Soil and Land Conservation Act, Agricultural and Related Species Protection Act. |
| | Department of Environment (DoE) | Provision of technical advice (e.g. hydrological), note roles in relation to EPA and drainage. |
| | Department of Indigenous Affairs (DIA) | Provision of advice on aspects of Indigenous cultural heritage. |
| | WA Museum | Provision of education and information, research. |
| | Forest Products Commission (FPC) | Provision of technical advice (e.g. tree crops). |
| Federal Government | Department of Environment and Heritage (DEH) | Provision of funding and national direction, e.g., via the Natural Heritage Trust. |
| | Commonwealth Scientific, Investigation and Research Organisation (CSIRO) | Provision of technical advice and research. |
| | Grains and Research Development Corporation | Provision of technical advice and research. (Australian grain industry). |
| | Land and Water Australia | Provision of technical advice (sustainable primary industries; rivers; vegetation; future landscapes). |
| | Australian Bureau of Agricultural & Research Economics (ABARE) | Provides agricultural statistics and forecasts. |
| | Australian Broadcasting Corporation (ABC) | Communication and media. |
| Local government | Shires of Coorow, Dalwallinu, Moora Perenjori | Implementation of recovery actions will require support and contribution from the local Shires. |
| Catchment Management Body | Moore Catchment Council (MCC) | Assists in development and delivery of natural resource management initiatives. |
| Natural resource management councils | The Northern Agricultural Catchment Council (NACC) | Provides a leading role in identifying and funding priority directions for natural resource management across the Northern Agricultural Region. |
| | Yamatji Land & Sea Council | |

***Table 1**: Relevant stakeholders and their responsibilities for the Buntine-Marchagee Natural Diversity Recovery Catchment (continued)*

| Stakeholder Group | | Responsibilities |
|---|---|---|
| Service providers | Telstra, Optus, Westrail, Western Power, Water Corporation, Main Roads WA | Provides community services and manage infrastructure within the catchment. |
| Cooperative research centres | Cooperative Research Centre (CRC) for Plant-based Management of Dryland Salinity | Supports research in the development of profitable and sustainable farming systems to manage both recharge and discharge. |
| Private consultants and contractors | | Provide financial, agronomy, chemical and animal husbandry and earthwork services. |
| Non-government organisations | Greening Australia | Engages the community in vegetation management to protect and restore health, diversity and productivity of our unique Australian landscapes. Links practical on-ground works for environmental management with regional natural resource management networks, national research and development organisations, business, government and community leaders. |
| | Australian Conservation Foundation (ACF) | Campaigns for a national policy and investment response to salinity, including biodiversity conservation and commitment of necessary funding. |
| | WWF Australia | Works to help protect and sustain biologically diverse environments via on-ground field projects, and seeks to influence policy formulation. |
| | Birds Australia | Supports conservation, research projects and recovery actions for Australian birds and their environment. |
| Community groups | Land Conservation District Committees (LCDCs) | Provide landcare advice and networks that assist in the facilitation of information exchange, coordination of activities and sharing of resources |
| | North Central Mallee Fowl Preservation Group | Encourages community awareness of the mallee fowl and its declining population and implements works for its preservation. |
| | Dalwallinu Woodlands Development Group | Aims to preserve the Dalwallinu Townsite Woodlands through a program of management and rehabilitation. |
| | Liebe Group | An agricultural production-oriented group that works to sustain and enhance the rural environment through a whole systems approach to agriculture. |
| | Midwest Oil Mallee Association | Provision of technical advice and opportunities for funding assistance. |
| Educational institutions | Primary and secondary schools, universities and TAFE colleges | Provide a focus for education and interpretation. In the case of universities, provide technical advice. |
| General community | | |

## APPENDIX 4: CULTURAL VALUES

***Table 1**: Contributions of biodiversity to cultural values in the Buntine-Marchagee Natural Diversity Recovery Catchment (BMNDRC)*

| Cultural values | Definition (Wallace *et al*. 2003) | Value as expressed in BMNDRC |
|---|---|---|
| **Intrinsic, spiritual, philosophical values** | All humans operate within either an explicit or implicit set of philosophical beliefs that:<br>• Establish and explain the role of humans in the world/universe, including birth, death, etc; and<br>• Provide guidance for how we should live our lives and interact with other people, other organisms, and the inanimate world.<br>Biodiversity resources are an important part of our spiritual/philosophical and moral framework. Intrinsic values are incorporated here given that they are a statement of beliefs. | A high priority biodiversity value in the BMNDRC and an important driver for community support for biodiversity conservation in general. To meet this value in the BMNDRC it is important to conserve, as far as practicable, the biodiversity of the catchment at all levels, that is, at the genetic, taxonomic and living assemblage levels. |
| **Ecosystem service values** | Are those values that contribute to the maintenance of our environment and ensure that life can persist. This term has been variously used, and is often now defined to incorporate all the values in this classification. Examples of ecosystem services include flood mitigation and nutrient stripping by wetlands, local and global climate amelioration, and de-activation of pollutants. | Important ecosystem service values of biodiversity in the BMNDRC are its roles in flood mitigation, nutrient stripping, sediment control, and climate amelioration. To maintain and enhance these services it will be important to protect the current distribution of vegetation, and to increase its amount. |
| **Amenity values (including aesthetics)** | Amenity values include aesthetic values – such as the scenic values of natural landscapes – and shade and shelter values – such as the use of bushland remnants around houses and yards that provide shade and shelter from wind. | Catchment landholders have placed a high value on maintaining the biodiversity of the catchment to deliver aesthetic values. Thus it is important to, as far as practicable, at least maintain the current aesthetic values of the catchment's biodiversity. At least in the short-term, works to achieve the above two values should also deliver the necessary outcomes here. |
| **Opportunity values** | The conservation of natural resources provides for a range of future opportunities. Most obvious is the germaplasm resource in native plants. There are many equivalents for land and water resources, for example, protection of water resources we may wish to harvest in the future. Thus opportunity values are those values listed elsewhere in this table that are not currently realised. | At least in the short-term, works to achieve the above two values should also deliver the necessary outcomes here. |
| **Scientific and educational values** | Biodiversity resources are widely used for scientific and educational purposes. For example, maintaining a set of representative, undisturbed soils is essential if we wish to understand the changes brought about by various uses. Other examples include the widespread use of natural lands to research natural processes, and as an educational resource by schools. | At least in the short-term, works to achieve the above two values should also deliver the necessary outcomes here. |
| **Leisure/ recreation values** | The importance of natural environments for recreation and tourism is well known. Research links recreation in natural environments to both physical and mental health. There are strong links between recreation and amenity values. | At least in the short-term, works to achieve the above two values should also deliver the necessary outcomes here. |

***Table 1**: Contributions of biodiversity to cultural values in the Buntine-Marchagee Natural Diversity Recovery Catchment (BMNDRC) (continued)*

| Cultural values | Definition (Wallace *et al*. 2003) | Value as expressed in BMNDRC |
|---|---|---|
| **Consumptive use values** | These include the values of natural resources harvested for domestic use that do not pass through a market. | Not considered a priority value in the BMNDRC. Note, however, that some work with local landholders may deliver consumptive values to farmers. For example, revegetation undertaken for water control may also provide a firewood resource for landholders. |
| **Productive use values** | Are the values of natural resources that are harvested commercially. | Not a specific objective of the actions to recover biodiversity. However, to protect the biodiversity assets in the catchment requires that economically attractive management options are developed for farmers that help them to be more sustainable and manage in a way that is more compatible with biodiversity values in the catchment. For example, profitable woody crops may help control recharge and better protect biodiversity assets and native chenopod shrublands in the catchment have been used for stock grazing. |

# APPENDIX 5: CULTURAL HERITAGE

***Figure 1**: Significant Indigenous and non-Indigenous cultural heritage sites in the BMNDRC*

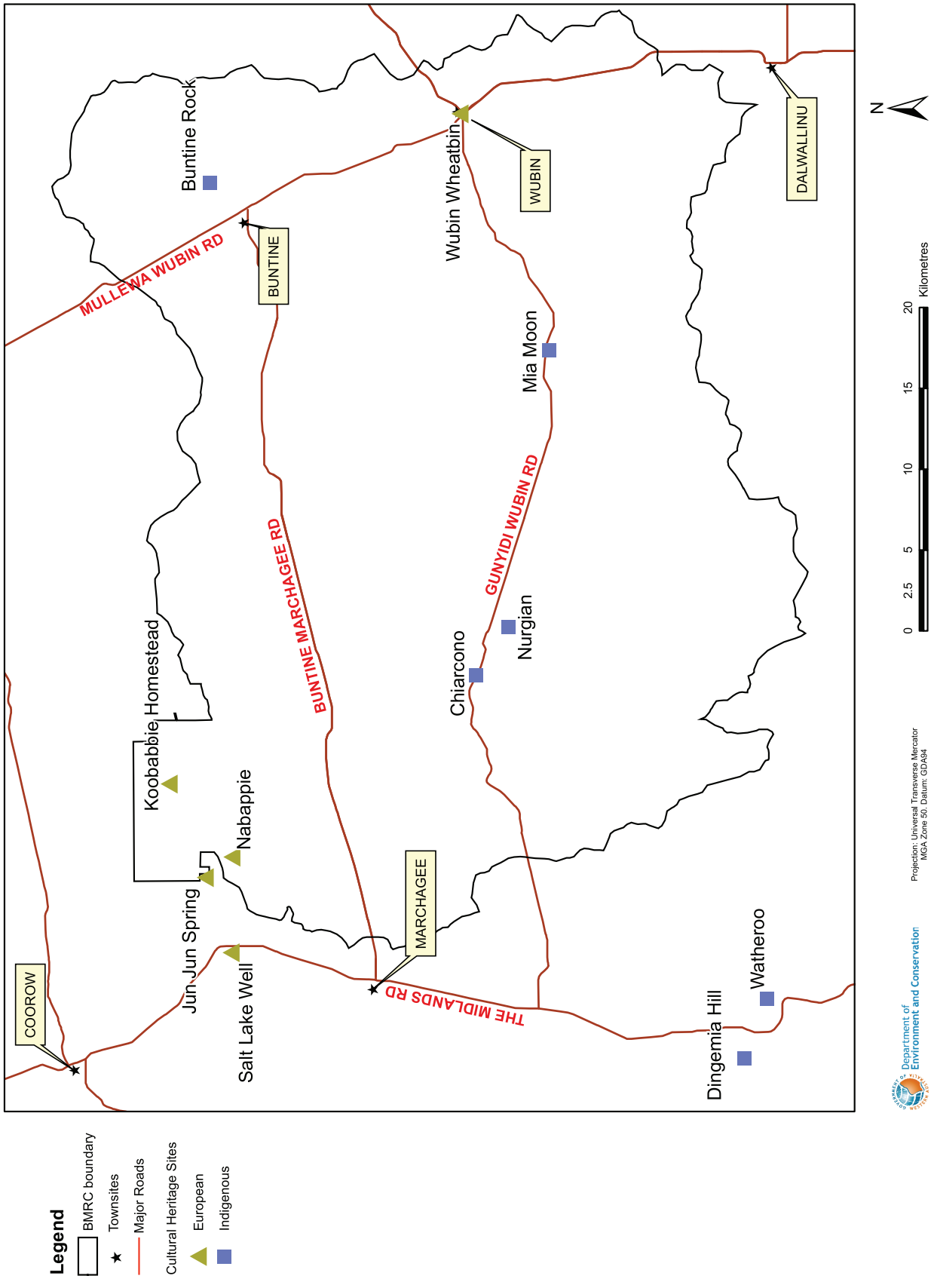


***Table 1**: Sites of non-Indigenous cultural heritage in the BMNDRC (As collated in 2006)*

| Shire | Site | Comment | Heritage listing |
|---|---|---|---|
| **Coorow** | Jun Jun Spring | Surveyed by John Forrest, settled by Alexander and Janet Jones who built a house on the east side of Jun Jun Spring in 1905 and left in 1906. Associated with early settlement of Coorow. | Municipal Inventory |
| | Nabappie | Connected with early settlement of the area. Purchased by William Long in 1869 from the Crown. Subsequently the land was sold in 1902 to F.H. Thomas. Location 682 was purchased by Alexander Jones and he refused Thomas access to the spring. A subsequent survey through Location 2922 ensured access. | Municipal Inventory |
| | Gunyidi Pool | Used as a recreation site (swimming hole) until it dried up. Locals have various theories on why the water hole dried up. | |
| | Ytiniche Well | Dug by monks from New Norcia for pastoralism in era of Bishop Salvado | |
| | Salt Lake Well | Sunk by early pioneers to provide water for sheep while under the care of shepherds on large pastoral areas associated with early pioneers, particularly the Long family. | Municipal Inventory<br>CALM's RATIS database |
| | Marchagee Roadhouse Site | The roadhouse was constructed in 1965 and very busy in the 1960s and closed in the mid 1980s. Business reduced as traffic began to use Brand Highway in preference to the Midlands Road. A second roadhouse was located next to it but was burnt down. | Municipal Inventory |
| | Marchagee Townsite | Historic site without built features | |
| | Koobabbie Homestead and buildings | Shearer's quarters, stables, workers houses, shearing shed, garage/engine room, outbuildings-portray development of the pastoral industry and associated industry in the district in the twentieth century. | Municipal Inventory |
| | Lonsdale Homestead | Associated with Long family-settlement of the Coorow district and establishment of the pastoral industry over 130 years. | Municipal Inventory |
| | Longs Well | | |
| | Marchagee Hall | Constructed 1933. | |
| **Dalwallinu** | Dalwallinu Town Site and associated sites (sites not within the BMNDRC but adjacent) | Dalwallinu District High School<br>Dalwallinu Fire Station<br>Former Dalwallinu Hotel<br>Former Dalwallinu Police Station<br>Dalwallinu Post Office<br>Former Dalwallinu Railway Station<br>Dalwallinu Recreation Centre<br>Dalwallinu Swimming Pool | |

***Table 1**: Sites of non-Indigenous cultural heritage in the BMNDRC (As collated in 2006) – continued*

| Shire | Site | Comment | Heritage listing |
|---|---|---|---|
| **Dalwallinu** *(cont.)* | Dalwallinu Town Site and associated sites (sites not within the BMNDRC but adjacent) *(continued)* | Dalwallinu Town Dam<br>Former Dalwallinu Town Hall and Road Boards Office<br>Dalwallinu Townsite Bushland<br>Dalwallinu War Memorial<br>Old School Site<br>The Five Graves<br>Old Courthouse and Tourist Centre<br>The Old Well sunk in 1909. Only purpose now is to serve as a memorial to the early settlers of the area. | Municipal Inventory |
| | Wubin Townsite and associated sites | Wubin Wheat bin<br>Wubin Hall<br>Wubin Hotel Motel<br>Wubin Post Office and House<br>Wubin Primary School<br>Wubin Railway Station Information Centre<br>Pioneer Graves | National Trust,<br>Interim WA Register of Heritage Places,<br>Municipal Inventory,<br>Register of National Estate (Wubin Wheat bin)<br>Municipal Inventory (remaining sites) |
| | Buntine Rock/ Buntine Nature Reserve | First 'European' picnic organised at Buntine Rock by the Buntine Station Master Vic Bond involving settlers from Wubin, Latham and Buntine. Vic Bond was a lover of trees and planted many in the vicinity of the Buntine Townsite | Register of National Estate |
| | Mia-Moon | | |
| | Nugadong (Noogadong) Rockhole | Used by both Aboriginal people and then settlers. | |
| | 'Mara' | In 1868 the New Norcia monastery purchased a property at Watheroo, 'Mara' (meaning bitter water) from the deceased estate of Joseph Purser who had taken up land in 1851. Here they built a two-storey homestead, stonewalled kitchen, stone sheds. A priest, brothers, Aboriginals and ticket-of-leave men who were the shepherds lived here, and during winter months pastured sheep along the route to Ninghan and back again. A line of wells beginning with Mara and extending east and north mark their way. The known ones (some in the BMNDRC) are Bobawina, Tarcuta, Mirawana, Nhaglianhy, Matinjinna, Billum Billum Swamp, Nugadong, Chinamen's Well, Jibberding and one close to White Wells on the Great Northern Highway. | |
| | Snake Tree Corner | Located on Dinnie Road | Municipal Inventory |

Sources of information:

- Municipal Inventory of Heritage Places (Coorow Shire); Municipal Inventory of Heritage Places (Perenjori Shire); History of Water Supplies of the Dalwallinu District (Dalwallinu Shire); Curtin University of Technology Environmental Bulletin No. 24; DEC database; Department of Indigenous Affairs (DIA) Register of Abroiginal Sites; and
- Personal communication with Doris Broun (unpublished document); Vera Long; Doris Long; Patrick Mullaley NACC Indigenous Officer; and the Benedictine Community, New Norcia.

### Non-indigenous cultural heritage

The Department manages non-Indigenous cultural heritage to meet the management requirements of a range of State and Commonwealth legislation. In addition to the CALM Act, the protection of cultural heritage is covered in State legislation such as the *Marine Archaeology Act 1973*, the *Heritage of Western Australia Act 1990* and the *Land Administration Act 1997*. Commonwealth legislation includes the *Historic Shipwrecks Act 1976*, the *Environmental and Heritage Legislation Amendment Act (No 1.) 2003*, the *Environment Protection and Biodiversity Conservation Act 1999*, the *Protection of Movable Cultural Heritage Act 1986*, the *Australian Heritage Council Act 2003* and the *Australian Heritage Council (Consequential and Transitional Provisions) Act 2003* (repeals the *Australian Heritage Commission Act 1975*).

The *Heritage of Western Australia Act 1990* provides for the registering and protection of sites of historic interest as 'heritage places'. These sites are registered on the Western Australian 'Register of Heritage Places' database and must not be damaged or altered unless permitted by the Heritage Council of Western Australia. The Act also requires local government authorities to maintain an inventory, referred to as the 'Municipal Inventory', of places of heritage significance in their area. This often contains sites which are not registered on the 'Register of Heritage Places', but which the Department should consider in management. There is also the Commonwealth 'Register of the National Estate', which includes places deemed by the Australian Heritage Council as having national estate values as described under the *Australian Heritage Council (Consequential and Transitional Provisions) Act 2003*. Many sites may also have some historic interest, but may not have been assessed or are not considered significant enough to be worthy of listing under the legislation. These sites are entered on the Department's 'Recreation and Tourism Information System' (RATIS) database, which helps to build up knowledge of cultural sites and historic events, including their location, condition and significance to the community.

# APPENDIX 6: PHYSICAL CHARACTERISTICS

## Rainfall trends

Long term average and highest daily rainfall values are shown at Table 1.

Rainfall data is recorded at 14 Bureau of Meteorology (BOM) weather stations throughout and nearby to the BMNDRC (Figure 1), and four automated tipping-bucket rain gauges (pluviometers) installed on private land by CALM between 2004 and 2005. Data from the latter will be used to increase the spatial resolution of rainfall trends captured by BOM. The long-term average, highest daily rainfall records and the date at which these occurred for each of the BOM stations are presented in Table 1. It is worth noting that BOM has only one automated weather station in the region, located in Dalwallinu (Figure 1). All other stations are manually recorded by non Bureau of Meteorology employees, including landholders.

Like many other regions in Western Australia, rainfall inter-annular variability in the BMNDRC is high. For example in 1914 Dalwallinu received only 120mm of rain (Figure 1), and in contrast the same station received over 670mm of rainfall in 1999. Rainfall trends are detailed further in the following sections.

***Table 1**: Long-term average and highest daily rainfall totals observed within or in close proximity to the BMNDRC (Bureau of Meteorology 2005)*

| Station | Station ID | Data currency | Mean annual rainfall (mm) | Highest daily rainfall (mm) | Date of highest rainfall |
|---|---|---|---|---|---|
| Watheroo | 8130 | 1899–2005 | 410 | 101 | 4 June1933 |
| Manavi [1] | 8084 | 1908–2004 | 402 | 93 | 14 April 1961 |
| Coorow PO | 8037 | 1912–2005 | 392 | 127 | 14 April 1961 |
| Anro | 8275 | 1982–2005 | 376 | 92 | 21 March1999 |
| Hakea | 8238 | 1908–2004 | 362 | 115 | 28 Mar 1971 |
| Dalwallinu | 8039 | 1912–2005 | 360 | 91 | 28 January 1990 |
| Maya [1] | 8080 | 1912–2004 | 345 | 120 | 14 April 1961 |
| Ytiniche | 8146 | 1913–2004 | 342 | 126 | 29 January 1990 |
| Buntine | 8017 | 1915–2000 | 341 | 114 | 14 April 1961 |
| Koobabbie | 8067 | 1911–2005 | 340 | 136 | 14 April 1961 |
| Sunnydale | 8021 | 1956–2004 | 329 | 137 | 28 March 1971 |
| Wubin PO | 8139 | 1922–2005 | 323 | 136 | 14 April1961 |
| Buntine East | 8018 | 1929–2005 | 313 | 130 | 27 May 1999 |
| Elena | 8230 | 1943–2005 | 290 | 105 | 28 March 1971 |

1. Significant data inconsistencies present

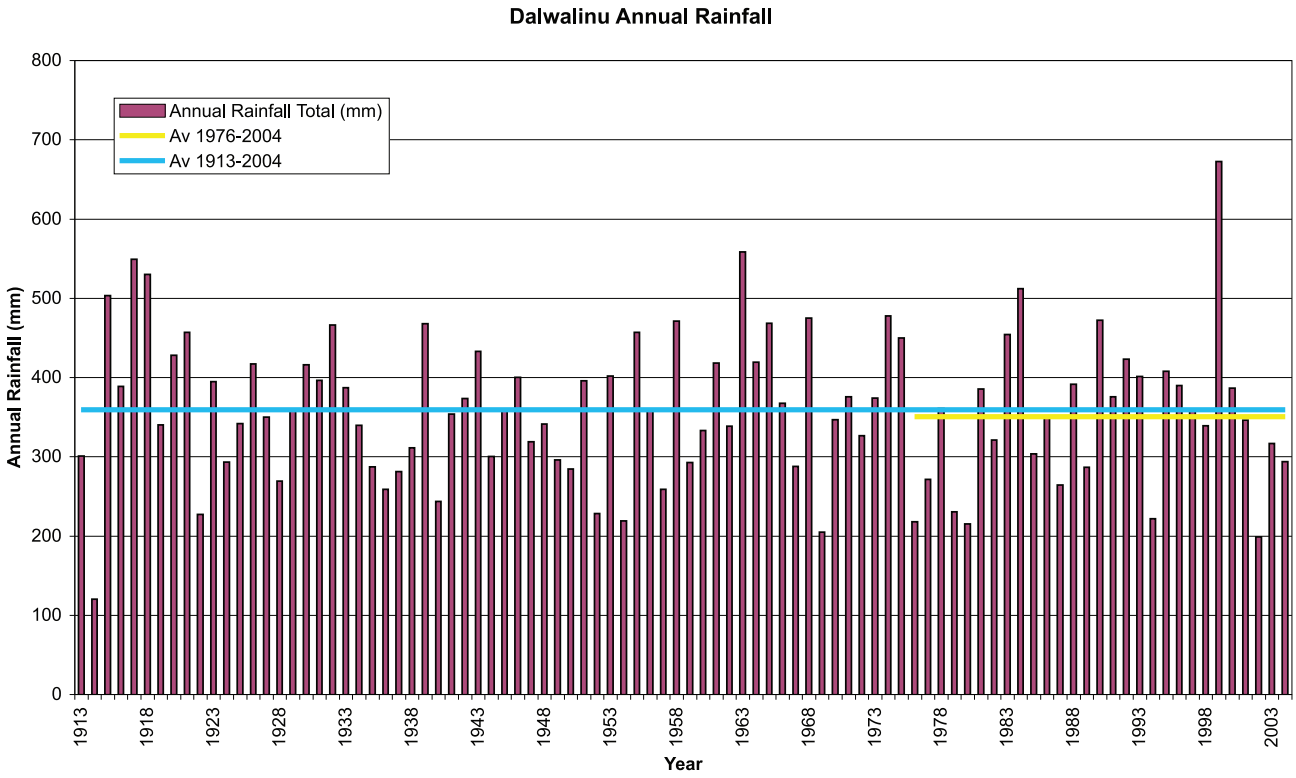



***Figure 1**: Annual rainfall recorded at Station 8039, Dalwallinu from 1913 to 2004 (Bureau of Meteorology 2005).*

## Rainfall analysis

Rainfall analysis was carried out by the Department of Agriculture and Food's Engineering Water Management Group using long-term composite rainfall records available from the Bureau of Meteorology (Short et al., 2006). A three-day or 72-hour event analysis was used to extract all rainfall events occurring within that time period for the years between 1910 and 2001 where the total rainfall exceeded 30mm.

Analysis revealed that large rainfall events have a tendency to occur at catchment scales. There is little evidence of significant events being restricted to particular sections of the recovery catchment, however up to 40mm more rainfall was recorded in the eastern BMNDRC area during these significant events. In summary, the data sets reflect the rainfall delivery mechanism common in the northern agricultural zone, with winter frontal systems more dominant in the western sectors and summer thunderstorm activity more prominent in the eastern sector.

Only two winter rainfall events greater than 100mm were recorded in the eastern sector, and five recorded in the western sector for the years 1910–2001. A number of these large rainfall event totals have occurred since 1960 however there is no definitive trend towards a greater frequency of these events. It is projected that two to three rainfall events exceeding 70mm may occur in the BMNDRC within the next 10 years (Short et al., 2006)

## Geological History

***Table 2**: Geological timetable*

| Eon | Era | Period |
|---|---|---|
| **Phanerozoic Eon** (543 mya to present)[2] | **Cenozoic Era** (65 mya to today) | **Quaternary** (1.8 mya to today)<br>– Holocene (10,000 years to today)<br>– Pleistocene (1.8 mya to 10,000 yrs)<br>**Tertiary** (65 to 1.8 mya)<br>– Pliocene (5.3 to 1.8 mya)<br>– Miocene (23.8 to 5.3 mya)<br>– Oligocene (33.7 to 23.8 mya)<br>– Eocene (54.8 to 33.7 mya)<br>– Paleocene (65 to 54.8 mya) |
| | **Mesozoic Era** (248 to 65 mya) | **Cretaceous** (144 to 65 mya)<br>**Jurassic** (206 to 144 mya)<br>**Triassic** (248 to 206 mya) |
| | **Paleozoic Era** (543 to 248 mya) | **Permian** (290 to 248 mya)<br>**Carboniferous** (354 to 290 mya)<br>**Pennsylvanian** (323 to 290 mya)<br>**Mississippian** (354 to 323 mya)<br>**Devonian** (417 to 354 mya)<br>**Silurian** (443 to 417 mya)<br>**Ordovician** (490 to 443 mya)<br>**Cambrian** (543 to 490 mya)<br>**Tommotian** (530 to 527 mya) |
| **Precambrian Time** (4,500 to 543 mya) | **Proterozoic Era** (2500 to 543 mya) | **Neoproterozoic** (900 to 543 mya)<br>**Vendian** (650 to 543 mya)<br>**Mesoproterozoic** (1600 to 900 mya)<br>**Paleoproterozoic** (2500 to 1600 mya) |
| | **Archaean** (3800 to 2500 mya) | |
| | **Hadean** (4500 to 3800 mya) | |

2 mya = million years ago

## Conceptual geomorphology

Playford (2003) describes how the Permo-Carboniferous (286 mya) glaciation of Gondwana may have impacted on Western Australia. He speculates that the Early Permian (290–248 mya) ice sheet may have exceeded 5,000m thickness over southern Western Australia. The subdued to flat Western Australian landscape is probably derived from glacial planing. Playford (2003) also draws attention to present day subglacial meltwater below the Antarctic ice sheet and evidence of subglacial channels in Western Australia. He speculates that much of the palaeoriver system of inland Western Australia probably first developed as Early Permian subglacial channels.

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). The alluvial/fluvial deposits contained in the palaeodrainage channels are largely believed to be Eocene (54–36 mya) in age. This fluvial activity has incised palaeochannels the Yilgarn Craton, on which the BMNDRC is located, and much of the eroded material was likely deposited in the Perth Basin to the west of the catchment (Geological Survey of Western Australia 1990). The exact nature and location of palaeochannels in the BMNDRC is currently unknown. However sections of palaeo-drainages, which are still active fluvial systems, have been intermittently, reworked since then.

The BMNDRC has generally subdued relief and the general direction of drainage is from east to west. Speed and Strelein (2004) note that the major drainage lines are populated with hundreds of lakes and that lake chains are not usually a dominant characteristic of valley floors in the northern agricultural region of Western Australia. They reported intersecting up to 38m of alluvial sediments at a drill site among lakes in the main drainage line.

Speed and Strelein (2004) note that the main drainage line in the BMNDRC approaches within 3.5km of the western catchment divide before turning north. This is within about 20km of the Darling Fault. At a drill site in a seemingly minor tributary in the south-west of the Recovery Catchment they report intersecting 17m of alluvial sediments. This site is some 20m higher in elevation than the main drainage line. It is possible that uplift along the Darling Fault diverted drainage in the proto-Buntine-Marchagee catchment northward. Further, alluvial sediments may have been isolated and elevated in the south western part of the Recovery Catchment, even reversing flow in sections of uplifted palaeochannel.

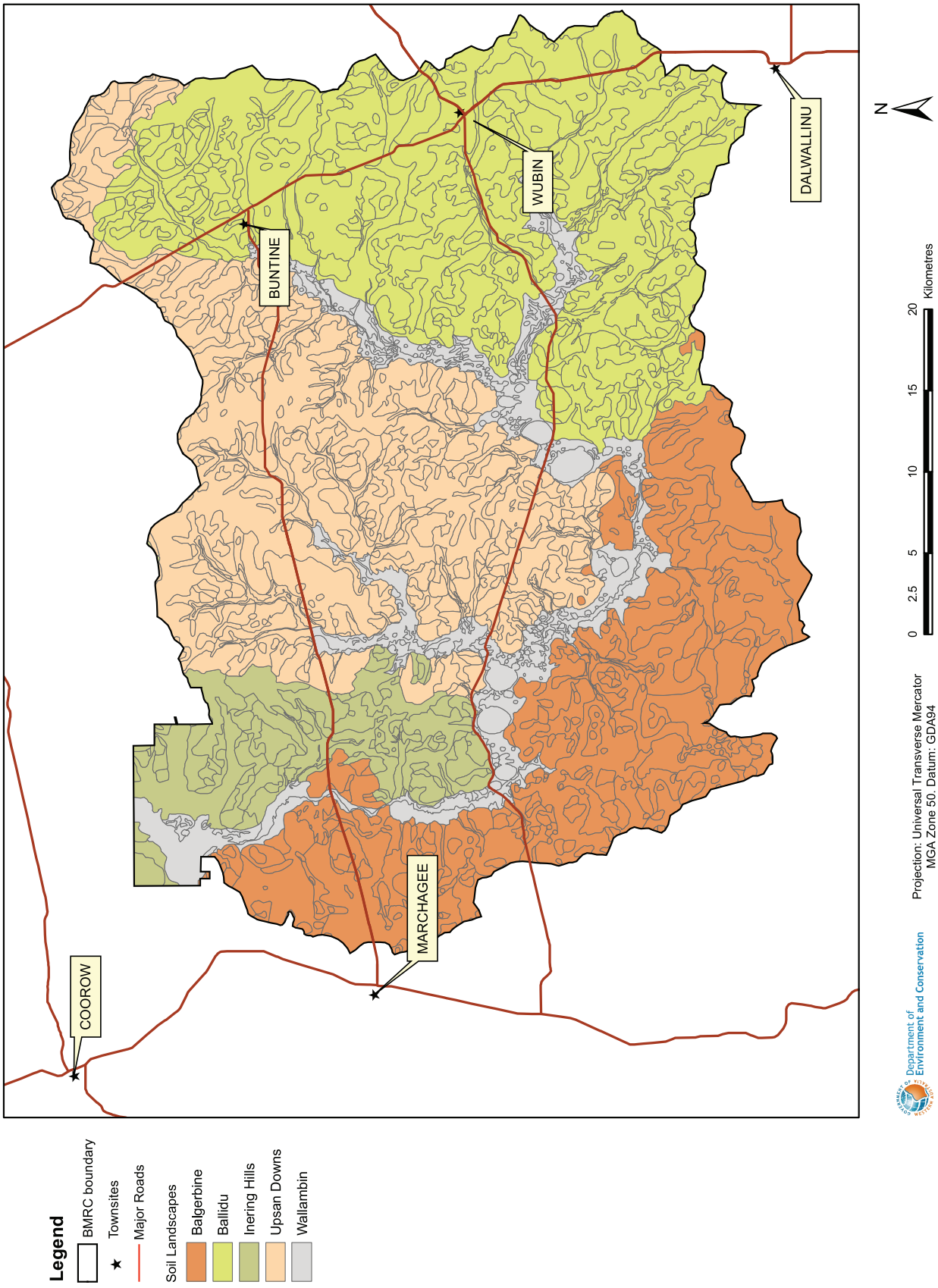
About 50km south-east of the BMNDRC, there is another drainage line that stands out remarkably in Landsat imagery because of its numerous lakes. The Damboring lake chain is also unusual in that it has the appearance of an isolated fragment of a once more extensive system. Also evident in Landsat imagery is a lineation trending east-southeast from the Darling Fault about 10km south of Watheroo. This lineation shows up as a feature in the Landmonitor digital elevation model. The lineation truncates the Damboring lake chain, and a further 70km east-southeast, truncates the Koorda lake chain and appears to displace the Cowcowing Lakes.

If the lineation is a fault along which transverse movement has captured palaeodrainage and displaced palaeochannels then it appears to pre-date the Darling Fault as it doesn't appear to have displaced that feature. A conclusion is that the palaeochannels are ancient features as speculated by Playford (2003).

In summary:

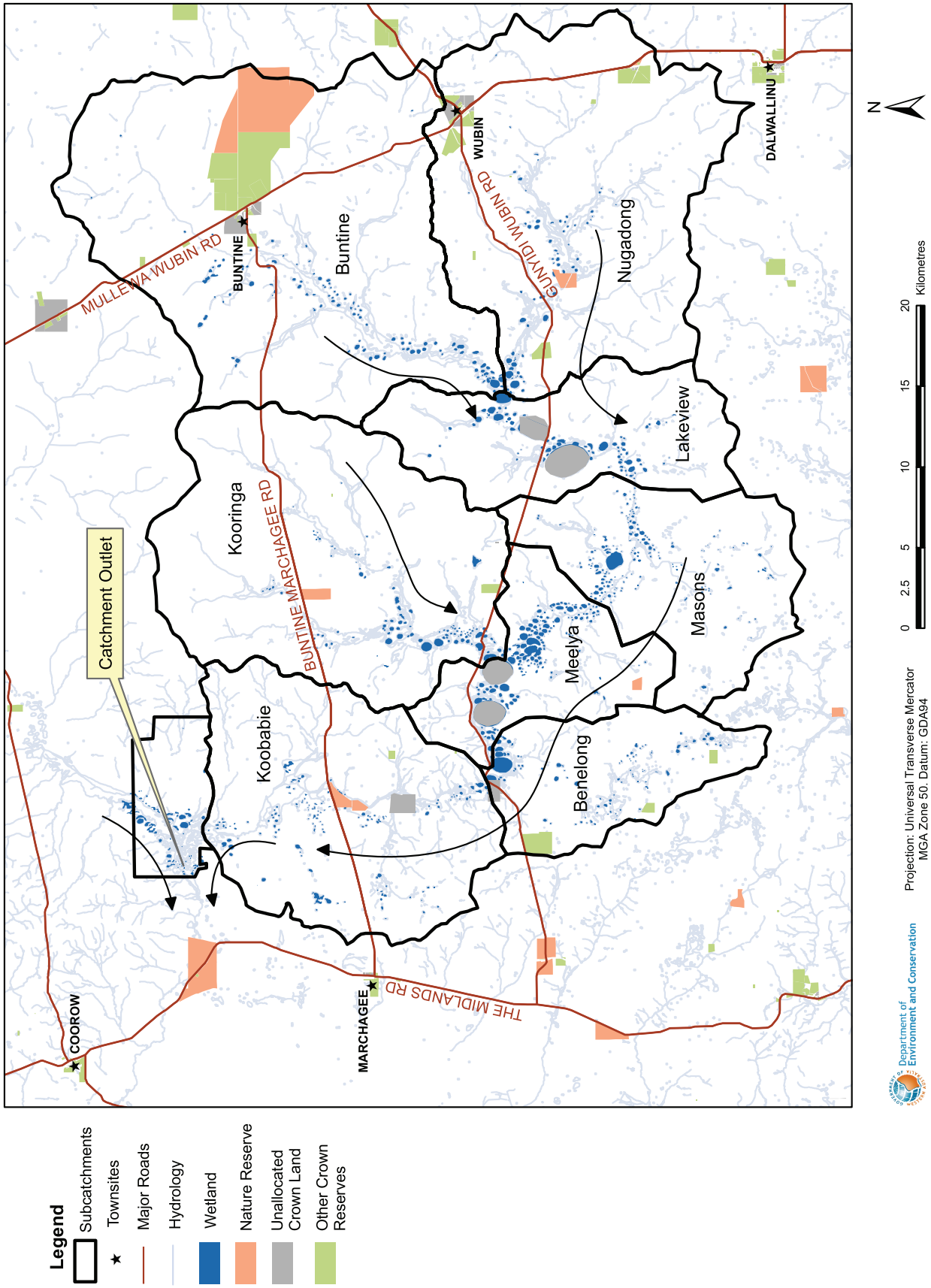
- Palaeochannel features in the Recovery Catchment could be relict from Permian (248–290 mya) glaciation.
- Uplift along the Darling Fault may have diverted drainage northward stranding or reversing flow in sections of palaeochannel.
- Alluvial fill within the palaeochannel is probably of Eocene (54–36 mya) age given the prevalence of remnant deposits and valley fill of this age on the Yilgarn Craton (Wilde and Backhouse 1977; Geological Survey of Western Australia 1990; Speed and Mahtab 2001).
- Sediments in stranded sections of palaeochannel maybe older than Tertiary (1.8–65 mya).

***Figure 2**: Landscape mapping for the five geomorphologic/soil landscape systems in the BMNDRC.*



## Hydrology, hydrogeology and wetlands

***Figure 3**: Surface water flow in the BMNDRC.*



# APPENDIX 7: FLORA

***Table 1**. 'Before' and 'after' land clearing comparisons of the area of 11 vegetation types broadly mapped by Beard. The original area is listed from the most to the least proportion of area covered.*

| Beard's vegetation types | Original area (ha) | Original % of catchment | Current area (ha) | Current % of catchment | % Reduction of original extent |
|---|---|---|---|---|---|
| **Shrublands**; *Acacia neurophylla*, *A. beauverdiana* and *A. resinomarginea* thicket. (a33, 34, 35) | 49,026 | 27 | 6,093 | 3.4 | 87 |
| **Shrublands**; *Allocasuarina campestris* thicket with patches of heath. (C3Sc xZi) | 47,132 | 26 | 2,691 | 1.5 | 94 |
| **Shrublands**; scrub-heath on yellow sandplain *Banksia-Xylomelum* alliance in the Geraldton Sandplain and Avon-Wheatbelt Regions. (x8SZc) | 42,074 | 23 | 5,753 | 3.2 | 86 |
| **Medium woodland**; York gum. (C6Mi) | 17,186 | 9 | 2,073 | 1.1 | 87 |
| **Succulent steppe with woodland** and thicket; York gum over Melaleuca thyoides and samphire. (e6Mi m5Sc) | 12,909 | 7 | 2,093 | 1.2 | 83 |
| **Medium woodland**; York gum and salmon gum. (E6,8Mi) | 6,196 | 3 | 316 | 0.2 | 95 |
| **Succulent steppe** with thicket; *Melaleuca thyoides* over samphire. (M5Sc k3Ci) | 1,951 | 1 | 256 | 0.1 | 86 |
| **Medium woodland**; salmon gum. (E8Mi) | 1,321 | 1 | 83 | 0.05 | 93 |
| **Shrublands**; scrub-heath *Acacia-Ecdeiocolia* association in the south-west Geraldton Sandplain Region. (x19SZc) | 694 | 0.4 | 244 | 0.1 | 64 |
| **Shrublands**; *Allocasuarina campestris* thicket. (c3Sc) | 502 | 0.3 | 31 | 0.02 | 94 |
| **Shrublands**; *Acacia* thicket with patches of heath. (anSc xZi) | 207 | 0.1 | 11 | 0.01 | 95 |
| **TOTALS** | **181,008** | **100** | **19,987** | **11** | |

## Dominant flora and associated landscape position of IBRA sub-regions within the BMNDRC

Dominant taxa of the 'Avon-Wheatbelt 1' component include, [3] *Melaleuca uncinata* complex in the main drainage line, *Eucalyptus salmonophloia*, *E. salubris*, *E. longicornis*, *E. loxophleba*, on the lower slopes, *E. loxophleba*, *E. subangusta*, *E. kochii* subsp. *plenissima*, *E. obtusiflora*, *E. flocktoniae* subsp. *flocktoniae*, *E. erythronema* subsp. *marginata*, *E. arachnaea*, *E. rigidula*, *E. stowardii* on the mid slopes and *Grevillea*, *Melaleuca*, *Allocasuarina*, *Hakea* and *Acacia* spp. on the upper slopes.

Dominant taxa of the 'Geraldton Sandplain 3' component include, *Melaleuca uncinata* complex in the main drainage line, *M. thyoides* on perched drainage lines, *Actinostrobus arenarius*, *Banksia* spp., *Xylomelum angustifolium*, *Melaleuca*, *Acacia*, *Eremaea* and *Eucalyptus* spp.

3 See section titled 'other special flora (prospective commercial and revegetation taxa of interest)' for an explanation of the *Melaleuca uncinata* complex and the additional taxa and name changes associated with this complex.

***Table 2**. Beard's vegetation types occurring in the BMNDRC with <2,000ha and <10 per cent of original extent in the Northern Agricultural Region (NAR) and the State (applied to 'all native vegetation' and native vegetation in the IUCN 1-1V reserve system). The status for the Moore Catchment (MC) is also given in parenthesis. Source for the NAR and the State (Richardson* et al.*, 2004); Source for the MC (Alderman and Clarke 2003).*

| | All native vegetation (Limited extent) | | | | Native vegetation in reserves (Poorly represented) | | | |
|---|---|---|---|---|---|---|---|---|
| [4] **Beard vegetation type (6 of the 11 within the BMNDRC)** | <2,000 ha NAR | <2,000 ha State | <10% NAR | <10% State | 0% NAR | <15% NAR | 0% State | <15% State |
| **E6,8Mi** Medium woodland; York gum and salmon gum | | | Yes (7% MC) | | Yes | | | Yes |
| **E8Mi** Medium woodland; salmon gum | Yes | | | | Yes | | | Yes |
| **A33,34,35** Shrublands; *Acacia neurophylla*, *A. beauverdiana* and *A. resinomarginea* thicket. | | | Yes | | | Yes (10% MC) | | Yes |
| **C3Sc xZi** Shrublands; *Allocasuarina campestris* thicket with patches of heath. | | | Yes (6% MC) | Yes | Yes | | Yes | |
| **M5Sc k3Ci** Succulent steppe with thicket; *Melaleuca thyoides* over samphire. | | | | | | Yes | | Yes |

4 The representation of these vegetation types in IUCN 1-1V reserves is given for the NAR and the State (0 per cent or < 15 per cent of original extent). Those shaded are extremely limited in extent (< 2,000ha and/or < 10 per cent of original extent remaining in NAR or the State) and poorly represented in the IUCN 1-1V reserve system (0 per cent and/or < 15 per cent of original extent remaining in NAR or the State), (Richardson *et al.*, 2004).

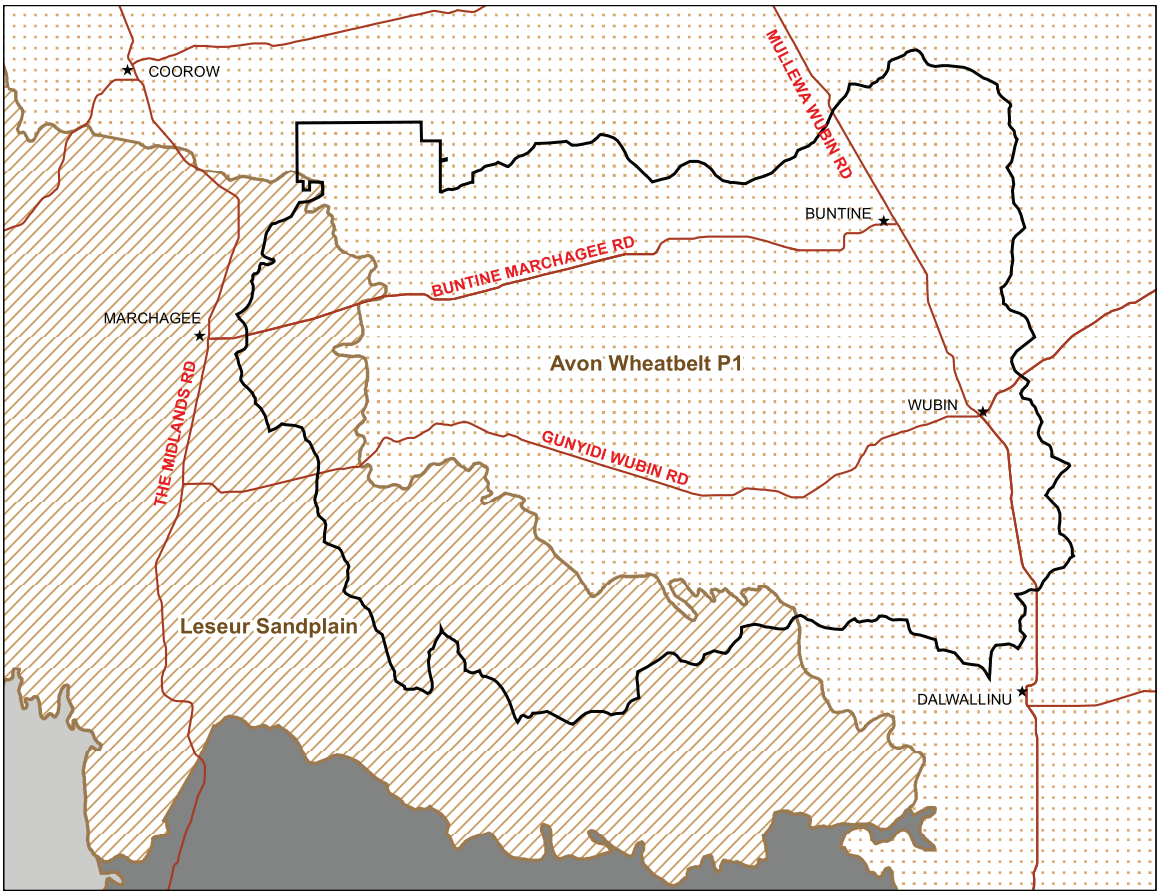



***Figure 1**: The Avon-Wheatbelt (Avon-Wheatbelt P1 sub-region) and Geraldton Sandplains (Lesueur sub-region) IBRA regions cover the BMNDRC.*

***Table 3**. Twenty-four terrestrial native vegetation associations and their relationships in the BMNDRC. Source: Huggett* et al. *2004.*

| Broad vegetation formations | Description of terrestrial vegetation associations [1 and 2] | Number of remnants |
|---|---|---|
| **Woodlands** | *Allocasuarina huegeliana* woodland: rock sheoak woodland on deep yellow sand. | 1 [3] |
| | Salt River gum woodland: *Eucalyptus sargentii*, adjacent to saline wetlands. | 1 |
| | *Hakea recurva* or *Hakea preissii* woodland | 1 |
| | Salt gum woodland: *Eucalyptus salicola*, adjacent to salt lakes. | 1 |
| | River red gum woodland: adjacent to fresh or brackish wetlands. | 11 |
| | Salmon gum woodland: may have some York gum, gimlet *Eucalyptus myriadena* or mallee. | 14 |
| | Mallee (no understorey). | 15 |
| | Swamp oak woodland: adjacent to brackish or saline wetlands. | 18 |
| | Gimlet woodland: may also have some salmon gum (sometimes as a co-dominant), red Morrell, York gum or mallee. | 33 |
| | Mixed woodland: no dominant species: includes mixes of York gum, salmon gum, gimlet, yorrell and mallees. | 45 |
| | York gum/jam woodland: may include other eucalypts, including mallees. | 150 |
| | Mallee (with understorey): understorey commonly *Acacia* or *Melaleuca* species; may have occasional emergent eucalypts. | 161 |
| **Shrublands (Geraldton Sandplain IBRA)** | Shrublands of perched drainage lines: *Melaleuca thyoides* and samphire [4]. | 1 |
| | Sandplain cypress shrubland: understorey often sedgy; occasional *Banksia* and woody pear. | 13 |
| | Mixed shrubland (sandplain): *Eremaea* or *Melaleuca* dominated shrubland on sandy soils. | 32 |
| | *Banksia*/woody pear shrubland: often with sandplain cypress | 42 |
| **Shrublands (Avon-Wheatbelt IBRA)** | *Grevillea*/Jam/Dodonaea/*Eremophila* shrubland: mainly regrowth on previously cleared land. | 17 |
| | *Melaleuca*/*Acacia* shrubland: with occasional emergent trees or mallees. | 142 |
| | Tamma/wodjil/*Melaleuca* shrubland: *Allocasuarina,* wodjil acacias and *Melaleuca*; occasional emergent mallee on sandy, lateritic or granite soils. | 229 |
| **Wetlands** | Fresh/brackish wetland (rushes): *Juncus pallidus*, *Melaleuca*, occasional river red gum or swamp oak. | 6 |
| | Samphire wetlands (saline): occasional *Melaleuca* or swamp oak. | 22 |
| **Sedgeland** | *Ecdeiocolea monostachya* or *Mesomelaena stygia*, emergent tamma, *Melaleuca*, Banksia, woody pear or sandplain cypress. | 12 |
| **Grassland** | Native perennial grasses (*Austrostipa*, *Austrodanthonia*, *Aristida* spp.) on previously cleared land. | 1 |
| **Heathland** | Low (<1m high, some emergent) species rich shrubland | 14 |

1 Those associations threatened by salinity are shaded.

2 To be counted in the mapping process, vegetation needed to be greater than three Landsat pixels (= 3 x 25 x 25m). Narrow or small vegetation associations like those fringing lakes were underestimated during the mapping process (L. Atkins *pers comm*). Likewise, most roadside vegetation was not recorded in the BMNDRC.

3 Those associations with a value of one are shaded.

4 The samphire association includes halophytic vegetation (salt loving plants) associated with remnant vegetation and doesn't include samphire vegetation in paddocks (Huggett *et al*. 2004).

***Figure 2***. *Mapping by Huggett* et al. *2004, identified 24 native vegetation 'associations' from six broad formations. Remnants above one ha were interpreted and ground-truthed. A total of 503 remnants of native vegetation were mapped in the BMNDRC. Note, vegetation doesn't appear in the Koobabbie Farm area, as this wasn't mapped by Huggett* et al. *2004.*

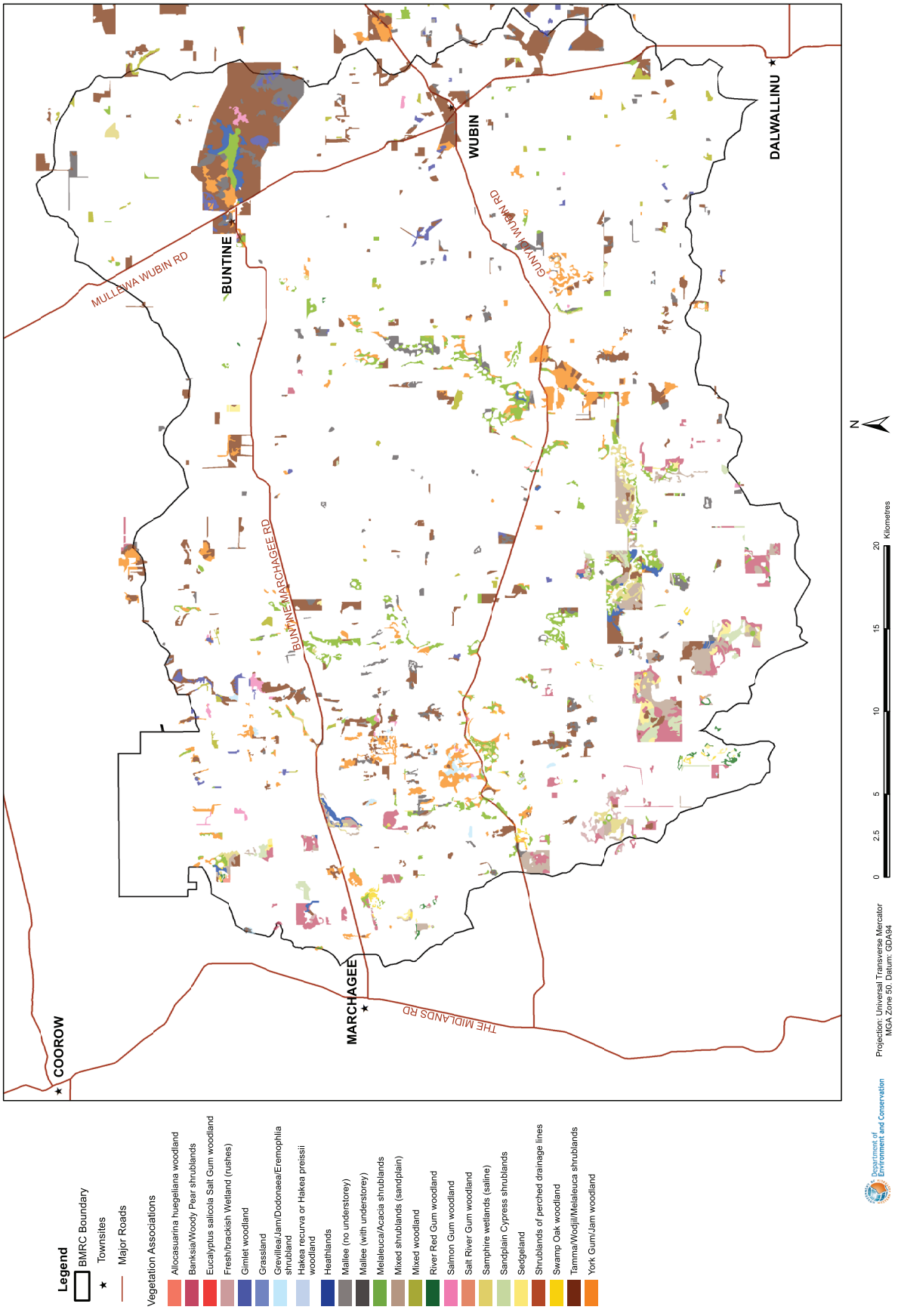


***Table 4**. The number and area of vegetation remnants in the BMNDRC, divided into seven size classes (Huggett* et al. *2004). Note, an extra 2,340ha was recorded outside (and in close proximity to) the BMNDRC boundary.*

| Size class (ha) | Number of remnants (and their percentage of the total number in parenthesis) | Total area of size class (ha) (and the percentage of the total area in parenthesis) |
|---|---|---|
| 0–25 | 365 (72) | 3,404 (15) |
| 26–50 | 64 (13) | 2,235 (10) |
| 51–75 | 20 (4) | 1,238 (5) |
| 76–100 | 17 (3) | 1,512 (7) |
| 101–200 | 19 (4) | 2,817 (13) |
| 201–500 | 13 (3) | 3,719 (17) |
| 501–4000 | 5 (1) | 7,409 (33) |
| **TOTAL** | **503** | **22,338** |

***Table 5**. Land tenure, ordered from most to least, of the native vegetation in the BMNDRC.*

| Land tenure of native vegetation | Area (hectares) | Percentage of tenure |
|---|---|---|
| Freehold land | 14,667 | 73 |
| Nature reserve | 2,354 | 11 |
| Other crown reserve* | 1,561 | 8 |
| Crown reserves vested in Local Government | 717 | 3 |
| Unallocated Crown land | 429 | 2 |
| No 'parcel id number' | 369 | 1 |
| Unvested Crown reserve | 89 | <1 |
| Miscellaneous lands – railway | 39 | <1 |
| Miscellaneous lands – Closed Road | 0.3 | <1 |
| **TOTAL** | **19,998** | **100** |

* Areas of Crown reserve are often lake beds.

***Table 6**. Area of each nature reserve in the BMNDRC and those at serious short term risk of rising saline ground water.*

| Nature reserve (name and identification number) | Area (hectares) |
|---|---|
| Buntine 26837 | 1,919 |
| Un-named 28669 | *157 |
| Un-named 21175 | 121 |
| Un-named 38401 | *107 |
| Jock's Well (unofficial name) 20025 | 40 |
| Nugadong (unofficial name) 29326 | 10 |
| **Total** | **2,354** |

* At serious short-term risk of rising saline ground water.

***Table 7**. The number of taxa and families recorded in various flora surveys in the BMNDRC.*

| Flora survey's | No. of taxa | No. of families | Comments |
|---|---|---|---|
| Gibson *et al.* (2004) | Not specific to the BMNDRC, although quadrats within the BMNDRC will have flora records: see CALM 2001. | | |
| Huggett *et al.* 2004 | 303 | 41 | All 503 remnants in the BMNDRC were assessed. Species list developed from 162 quadrats in 66 remnants. |
| Davies *et al.* 2001 | 396 | 58 | 1999: Species list developed from quadrats in 20 remnants on 11 farms.<br>2000: Species list developed from quadrats in 11 remnants on 10 farms (two remnants overlapping with the 1999 study). |
| CALM, 1999 | 144 | 41 | Species recorded from wetland sites SPS157 and 158 in 1999. |
| Beard, 1980 | Not specific to the BMNDRC | | |
| Kitchener *et al.* 1979 | 126 | 32 | Species list developed from quadrats in the Buntine and Nugadong Reserves. |

***Table 8**. Summary of the native plant taxa recorded in the BMNDRC*

| | Taxa | Genera | Family |
|---|---|---|---|
| a) Total numbers | 743 | 239 | 76 |
| b) The five most numerous recorded genera | 56 | *Acacia* | Mimosaceae |
| | 35 | *Melaleuca* | Myrtaceae |
| | 34 | *Eucalyptus* | Myrtaceae |
| | 20 | *Verticordia* | Myrtaceae |
| | 17 | *Grevillea* | Proteaceae |
| c) The five families with the most numerous genera | | 31 | Asteraceae |
| | | 20 | Myrtaceae |
| | | 17 | Poaceae |
| | | 13 | Papilionaceae |
| | | 12 | Proteaceae |
| d) The five most numerous recorded families | 148 | | Myrtaceae |
| | 63 | | Proteaceae |
| | 56 | | Mimosaceae |
| | 39 | | Chenopodiaceae |
| | 33 | | Papilionaceae |

***Table 9**. Summary of plant families with threatened taxa and the number of taxa in each conservation category. Families are listed in order of their collective representation (most to least).*

| | Number of times each family is represented in each conservation code | | | | | |
|---|---|---|---|---|---|---|
| **Family** | **R** | **P1** | **P2** | **P3** | **P4** | **Total** |
| Myrtaceae | 1 | 2 | 1 | 3 | 1 | **8** |
| Proteaceae | | 1 | 1 | 4 | 1 | **7** |
| Mimosaceae | 2 | 1 | | 3 | | **6** |
| Myoporaceae | 2 | 1 | 1 | | | **4** |
| Papilionaceae | 3 | | | 1 | | **4** |
| Asteraceae | | 1 | 2 | | | **3** |
| Lamiaceae | 1 | | | 1 | | **2** |
| Chenopodiaceae | | 1 | | 1 | | **2** |
| Goodenaceae | | | | 2 | | **2** |
| Amaranthaceae | 1 | | | | | **1** |
| Chloanthaceae | 1 | | | | | **1** |
| Orchidaceae | 1 | | | | | **1** |
| Apiaceae | | 1 | | | | **1** |
| Frankeniaceae | | 1 | | | | **1** |
| Rhamnaceae | | | 1 | | | **1** |
| Juncaginaceae | | | | 1 | | **1** |
| **Total** | **12** | **9** | **6** | **16** | **2** | **45** |
| **TOTAL number of Declared and Priority taxa:** | | | | | | |

***Table 10**. Declared and Priority Flora in the BMNDRC, including the salinity risk status, DEC District, management status and data source.*

| Conservation code [5] | Salinity risk (S) | Taxa | DEC District: Moora or Avon-Mortlock (Mo/A-M) | Management status: IRP: Interim Recovery Plan FRP: Full Recovery Plan | Data source [6] |
|---|---|---|---|---|---|
| R | | *Acacia recurvata* | Mo | | 1 |
| R | | *Acacia vassalii* | Mo | IRP [7] (2003-2008) | 1, 2, 3 |
| R | S | *Caladenia drakeoides* | Mo | IRP (2003-2008) | 1, 3 |
| R | | *Chorizema humile* | Mo | IRP (1999-2002) | 1,2 |
| R | | *Daviesia dielsii* | A-M & Mo | | 1,2, 3 |
| R | | *Eremophila pinnatifida ms* | A-M | IRP (2002-2007) | 1, 3 |
| R | | *Eremophila vernicosa* | Mo | | 1, 3 |
| R | | *Eucalyptus rhodantha* var. *rhodantha* | Mo | FRP (1995) | 1 |
| R | | *Gastrolobium appressum* | Mo | | 1, 3 |
| R | | *Hemiandra gardneri* | A-M & Mo | | 2, 3 |
| R | | *Pityrodia axillaris* | A-M | | 1, 3 |
| R | | *Ptilotus fasciculatus* | Mo | | 1, 3 |
| P1 | S | *Acacia trinalis* | Mo | | 1, 3 |
| P1 | S | *Eremophila koobabbiensis* | Mo | | 2 |
| P1 | | *Eucalyptus subangusta* subsp. *virescens* | Mo | | 1, 3 |
| P1 | | *Frankenia bracteata* | A-M | | 3 |
| P1 | S | *Gnephosis setifera* | A-M | | 2, 3 |
| P1 | S | *Halosarcia koobabbiensis* ms | Mo | | 3 |
| P1 | | *Grevillea pinifolia* | A-M & Mo | | 3 |
| P1 | S | *Hydrocotyle hexaptera* | | | 3 |
| P1 | | *Verticordia dasystylis* subsp. *oestopoia* | Mo | | 2 |
| P2 | | *Eremophila sargentii* | A-M & Mo | | 1 |
| P2 | S | *Fitzwillia axilliflora* | A-M | | 3 |
| P2 | | *Grevillea nana* subsp. *abbreviata* | A-M | | 2, 3 |
| P2 | S | *Podotheca pritzelli* | A-M | | 3 |
| P2 | ? | *Scholtzia* sp. *Gunyidi* (J.D.Briggs 17) | Mo | | 2 |
| P2 | | *Stenanthemum grandiflorum* | A-M | | 3 |
| P3 | | *Acacia filifolia* | Mo | | 2, 3 |
| P3 | | *Acacia isoneura* subsp. *nimia* | A-M | | 2, 3 |
| P3 | | *Acacia scalena* | A-M | | 2, 3 |
| P3 | | *Calytrix plumulosa* | A-M | | 2, 3 |
| P3 | | *Eucalyptus macrocarpa x pyriformis* | Mo | | 2, 3 |
| P3 | | *Grevillea asparagoides* | A-M | | 2, 3 |
| P3 | | *Grevillea granulosa* | A-M | | 2, 3 |
| P3 | | *Grevillea thyrsoides* subsp. *pustulata* | Mo | | 2 |
| P3 | | *Lechenaultia galactites* | A-M | | 2, 3 |
| P3 | | *Lechenaultia juncea* | Mo | | 2, 3 |
| P3 | | *Microcorys tenuifolia* | A-M & Mo | | 3 |
| P3 | S | *Persoonia chapmaniana* | A-M & Mo | | 3 |
| P3 | S | *Sarcocornia globosa* | Mo | | 2, 3 |
| P3 | S | *Triglochin stowardii* | Mo | | 2, 3 |
| P3 | | *Urodon capitatus* | A-M | | 2 |
| P3 | | *Verticordia venusta* | A-M | | 2, 3 |
| P4 | | *Banksia benthamiana* | A-M | | 2, 3 |
| P4 | | *Eucalyptus rhodantha* var. *petiolaris* | Mo | FRP (1995) | 1, 3 |

5 Conservation codes: R = Declared Rare Flora, P1 = Priority 1 Flora, P2 = Priority 2 Flora, P3 = Priority 3 Flora, P4=Priority 4 Flora.

6 1=Threatened Flora Database record, DEC Species and Communities Branch; 2 = Western Australian Herbarium record; 3 =CALM (1999). Nomination document for the Buntine-Marchagee Natural Diversity Recovery Catchment. Geraldton, Western Australia, Department of Conservation and Land Management, Midwest Region

7 Interim Recovery Plan

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

There are some taxa in the BMNDRC known for their salt and/or waterlogging tolerance, suitability for 'niche' area revegetation and that are under investigation for their commercial prospects. These are:

- The Broombush complex (*Melaleuca uncinata* sens. lat.). This complex was widely recorded in the catchment by Huggett *et al*. 2004. Forty-six quadrats out of 162 recorded this species. Broombush spp. commonly occurs as dense thickets, the stumps of many are observable in the main drainage lines of the BMNDRC – a reminder of where they once grew before the changed hydrology. Until 2004, the name '*Melaleuca uncinata*' incorporated several forms, which occurred over many parts of the Wheatbelt topography as well as into the goldfields, the Nullarbor and into the forest regions of the south-west. Craven *et al*. (2004) revised the broombush complex, and eleven species of the complex are now recognised seven being newly described. These are: *M. atroviridis*, *M. exuvia*, *M. interioris*, *M. osullivanii*, *M. scalena*, *M. vinnula*, and *M. zeteticorum*. The revision gave a clear understanding of the true *Melaleuca uncinata*, which is now found to be distributed along the south coast of WA and therefore is no longer a recognised species name in the Northern Agricultural Region. The species relevant to the BMNDRC are: *M. atroviridis*, *M. hamata*, *M. stereophloia*, and *M. vinnula*. The broombush complex contains taxa with salt and/or waterlogging tolerance – useful characteristics in developing commercial native tree crops for the lower landscape 'niche' of the wheatbelt. Note that the resprouting characteristics of this complex are variable; and strong resprouting is a fundamental requirement to be commercially useful. Brushwood fencing has utilized several of the species from within '*M. uncinata*'.
- Swamp sheoak (*Casuarina obesa*). There are 18 remnant 'association' occurrences of this taxa in the BMNDRC. This taxon is usually associated with drainage lines, edges of salt lakes and seasonally inundated fresh-water areas. It can tolerate highly saline conditions and will grow in permanently waterlogged sites (fresh water only). However, its survival and growth will be affected by frequent inundation by saline water. The Forest Products Commission (FPC) and others are investigating this species for its timber producing potential. The wood is fine textured and has a pale appearance with subtle medullary rays. This species fits a niche area for revegetation and also has potential (if managed with forestry techniques) to produce a timber crop.
- *Eucalyptus kochii* subsp. *plenissima* and *Eucalyptus kochii* subsp. *kochii*. Subspecies *plenissima* usually grows in a flat landscape position in the lower landscape. Soils are usually sandy loam with a preference for reddish sandy and sandy loam soils. This taxon is a 'major species' within the emerging oil mallee industry. 'Major species' are those that give selection for the major wheatbelt soils and landscape positions and have been planted in large numbers, and their performance assessed. Subspecies *kockii* usually grows in the upper landscape position. Soils are usually yellow sand. This taxon is also a 'major species' within the emerging oil mallee industry.
- *Eucalyptus myriadena* subsp. *myriadena*. This taxa usually occurs low in the landscape with a preference for heavier grey clay soils. It has some degree of salt tolerance, will tolerate seasonal waterlogging and will also tolerate very high soil pH. It is a 'minor species' within the emerging oil mallee industry. 'Minor species' are those with fewer farm plantings and less bush plants available for selection than other more generalist species, e.g. York gum (*Eucalyptus loxophleba* subsp. *lissophloia*). This species is also thought to be a 'mallet' form in some areas, and so, would be unsuitable (P.J. White, pers. comm). This species, in at least one location of the agricultural zone, is outperforming the other choices of oil mallee species (P.J. White, pers. comm).
- *Acacia* spp. Maslin and McDonald (2004) identified a number of *Acacia* species in their evaluation of *Acacia* as a woody crop option for Southern Australia. Four categories, each with a species list represented the top ranking species – with category one having the most suitable qualities. There are four of the 12 Western Australian species listed that fall within the BMNDRC. These are: *Acacia saligna* (Cat. 1), *A. lasiocalyx* and *A. microbotrya* (Cat. 2), and *A. stenophylla* (Cat. 3).

# APPENDIX 8: FAUNA

***Table 1***. *Rare/threatened and priority fauna in the BMNDRC*

| **Fauna Schedule under the *Wildlife Conservation Act 1950*** | **Occurrence of fauna species in the BMNDRC** |
|---|---|
| **Schedule One**<br>Fauna that is rare or likely to become extinct | Carnaby's black cockatoo (*Calyptorhynchus latirostris*)<br>Malleefowl (*Leipoa ocellate*)<br>Western spiny-tailed skink (*Egernia stokesii badia*)<br>Shield-backed trapdoor spider (*Idiosoma nigrum*) |
| **Schedule Two**<br>Fauna presumed to be extinct (but that may be rediscovered) | None recorded but such species may occur in the BMNDRC |
| **Schedule Three**<br>Birds protected under an International Agreement | None occur in the BMNDRC |
| **Schedule 4**<br>Other specially protected fauna<br>e.g. Uncommon or have commercial value | Major Mitchell's cockatoo (*Cacatua leadbeateri*)<br>Peregrine falcon (*Falco peregrinus*)<br>Woma python (*Aspidites ramsayi*) |
| **Priority fauna** | **Occurrence of fauna species in the BMNDRC** |
| **Priority 1**<br>Taxa with poorly known populations on threatened lands | None occur in BMNDRC |
| **Priority 2**<br>Taxa with few, poorly known populations on conservation lands | Barking owl (*Ninox connivens connivens*) |
| **Priority 3**<br>Taxa with several, poorly known populations, some on conservation lands | None occur in the BMNDRC |
| **Priority 4**<br>Taxa considered to be adequately surveyed, or which sufficient knowledge is available, and are not currently threatened, but need monitoring | Hooded plover (*Charadrius rubricollis*)<br>Bush stonecurlew (*Burhinus grallarius*)<br>White-browed babbler (*Pomatostomus superciliosus ashbyi*)<br>Crested bellbird (*Oreoica gutteralis gutteralis*)<br>Western brush wallaby (*Macropus irma*) |
| **Priority 5**<br>Taxa not threatened but in need of monitoring, that are subject to a specific conservation program, which if ceased would result in the species becoming threatened within five years. | None occur in the BMNDRC |

The Commonwealth's *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) provides a listing of nationally threatened fauna species. Most of the threatened species in the BMNDRC that are listed as 'endangered' and 'vulnerable' under the EPBC Act are also listed as threatened under the State's *Wildlife Conservation Act 1950*. In addition, this Act protects marine species (listed under section 248). Sixteen listed marine bird species are found in the BMNDRC.

The department, often in collaboration with other State and Federal agencies and other parties, prepares recovery plans for the most threatened species. Species within the BMNDRC that have recovery plans include Carnaby's black cockatoo (this species has an approved State recovery plan and a national recovery plan is in preparation) and the mallee fowl which has a national recovery plan.

# APPENDIX 9: CONSERVATION CODES

## Western Australia:

### Relating to Fauna

SP = Specially Protected under the *Wildlife Conservation Act 1950*, and in particular:

(SP1) = Rare or likely to become extinct;

(SP2) = Presumed extinct;

(SP3) = Protected under an international agreement between the governments of Australian and Japan; and

(SP4) = Other specially protected fauna (other than for reasons given above).

### Relating to Flora and Fauna

CR = Taxa ranked as Critically Endangered under the criteria for the 2006 IUCN categories.

EN = Taxa ranked as Endangered under the criteria for the 2006 IUCN categories. VU = Taxa ranked as Vulnerable under the criteria for the 2006 IUCN categories.

### Relating to Fauna

P1 = Priority 1 species: Taxa with few, poorly known populations on threatened lands.

P2 = Priority 2 species: Taxa with few, poorly known populations on conservation lands.

P3 = Priority 3 species: Taxa with several, poorly known populations, some on conservation lands.

P4 = Priority 4 species: Taxa considered to be adequately surveyed, or which sufficient knowledge is available, and are not currently threatened but need monitoring.

P5 = Priority 5 species: Taxa not threatened but in need of monitoring, that are subject to a specific conservation program, which if ceased would result in the species becoming threatened within five years.

E = Endemic.

**Commonwealth's *Environmental Protection and Biodiversity Conservation Act 1999***:

EN = Endangered; (Flora and Fauna)

VU = Vulnerable; (Flora and Fauna)

Mig = Migratory species that are also listed under the Bonn Convention and the JAMBA and CAMBA agreements; (Fauna)

Mar = Marine species listed under section 248 of the EPBC Act. (Fauna)

**International/Other: (Flora and Fauna)**

T = Threatened according to the IUCN categories:

(CR) = Critically Endangered -facing an extremely high risk of extinction in the wild in the immediate future;

(EN) = Endangered – facing a very high risk of extinction in the wild in the near future;

(VU) = Vulnerable – facing a high risk of extinction in the wild in the medium-term future.

(Flora and Fauna)

LR = Lower Risk when evaluated against the IUCN categories as does not satisfy the threatened criteria but does fit:

- (nt) Near Threatened – not Conservation Dependent but is close for qualifying for Vulnerable;
- (lc) Least Concern – not Conservation Dependent or Near Threatened.

## The Department of Environment and Conservation DECLARED RARE AND PRIORITY FLORA LIST for Western Australia

### CONSERVATION CODES

*R: Declared Rare Flora – Extant Taxa*
Taxa which have been adequately searched for and are deemed to be in the wild either rare, in danger of extinction, or otherwise in need of special protection, and have been gazetted as such.

*X: Declared Rare Flora – Presumed Extinct Taxa*
Taxa which have not been collected, or otherwise verified, over the past 50 years despite thorough searching, or of which all known wild populations have been destroyed more recently, and have been gazetted as such.

*1: Priority One – Poorly known Taxa*
Taxa which are known from one or a few (generally <5) populations which are under threat, either due to small population size, or being on lands under immediate threat, e.g. road verges, urban areas, farmland, active mineral leases, etc., or the plants are under threat, e.g. from disease, grazing by feral animals, etc. May include taxa with threatened populations on protected lands. Such taxa are under consideration for declaration as 'rare flora', but are in urgent need of further survey.

*2: Priority Two – Poorly Known Taxa*
Taxa which are known from one or a few (generally <5) populations, at least some of which are not believed to be under immediate threat (i.e. not currently endangered). Such taxa are under consideration for declaration as 'rare flora', but are in urgent need of further survey.

*3: Priority Three – Poorly Known Taxa*
Taxa which are known from several populations, and the taxa are not believed to be under immediate threat (i.e. not currently endangered), either due to the number of known populations (generally >5), or known populations being large, and either widespread or protected. Such taxa are under consideration for declaration as 'rare flora' but are in need of further survey.

*4: Priority Four – Rare Taxa*
Taxa which are considered to have been adequately surveyed and which, whilst being rare (in Australia), are not currently threatened by any identifiable factors. These taxa require monitoring every five to 10 years.

# APPENDIX 10: WETLAND CHARACTERISATION

## BACKGROUND

Wetland characterisation, the description of wetlands according to unique geomorphic, hydrologic or biologic features, has been attempted in many settings (Semeniuk and Semeniuk 1995; Ramsar Convention Bureau 1999; Meney 2003). The large spatial scales involved and the necessity to make generalisations about complex and dynamic systems often limits the effectiveness of the characterisation process.

Traditionally, wetland characterisation schemes have been developed in such a way as to maximise their effectiveness at either very large or fairly small scales. In the former instance, the goal is to develop broad groups of wetlands within a country, state or region. Parameters utilised are often based on geomorphology with a generalised consideration of hydrology. For instance, the classification scheme proposed by the Ramsar Convention (Ramsar Convention Bureau 1999) is used to develop consanguineous suites of wetlands on a global scale. At this scale, the ability to collect detailed data is compromised and generalised parameters (such as size, shape and geographic location) are utilised.

Where the scale of operation is smaller, it is feasible to obtain more specific data and a more detailed characterisation may be undertaken. In these instances, quantitative water quality and biodiversity data is often combined with details of the hydrological and geomorphologic setting to develop a precise description of wetland function. For example, a detailed wetland characterisation scheme was undertaken in the Lake Bryde Natural Diversity Recovery Catchment in 2003 (Meney and Coleman 2003). That study involved two visits to 22 wetlands, recording information about vegetation of the lake bed and littoral zone, geomorphic profile, water chemistry and evaporite type, soil type and hydroperiod. The quantity of information collected in the Lake Bryde characterisation allowed the development of precise wetland groups.

The BMNDRC project falls somewhere between these two scales of characterisation. A great deal of data is required to distinguish between the character of wetlands that are, at a broad level, fairly similar. However, obtaining these data for a system that spans some 180,000 hectares and includes over 1,000 wetlands is prohibitively expensive and time consuming.

## A CHARACTERISATION SCHEME FOR THE BMNDRC

The aim of the characterisation process in the BMNDRC is to divide the catchments' wetlands into groups of similar biological values. This is the first time such a process has been attempted in the Northern Agricultural Region, and so, there is no existing model to follow. An ideal characterisation scheme would assess the total biodiversity in each of the catchments' wetlands, determining suites of like wetlands and assigning relative conservation value. However, the large number of wetlands in the BMNDRC, and the paucity of biodiversity data for the area, makes such an empirical characterisation unfeasible. It is, therefore, necessary to seek surrogate measures to replace direct determination of biodiversity.

Previous research, both in the BMNDRC (Storey et al. 2004a; Storey et al. 2004b; and Lynas et al. 2005) and in other systems (Blinn et al., 2004; Pinder et al., 2004), has consistently shown that water chemistry has a strong influence on the richness and diversity of aquatic biota supported by a wetland. Salinity is a particularly good indicator with the greatest biodiversity, greatest degree of endemism and highest conservation value occurring in fresh water bodies. Salinity is far easier to measure than biodiversity but a comprehensive water-monitoring program for 1,000 wetlands is still not feasible in the current context.

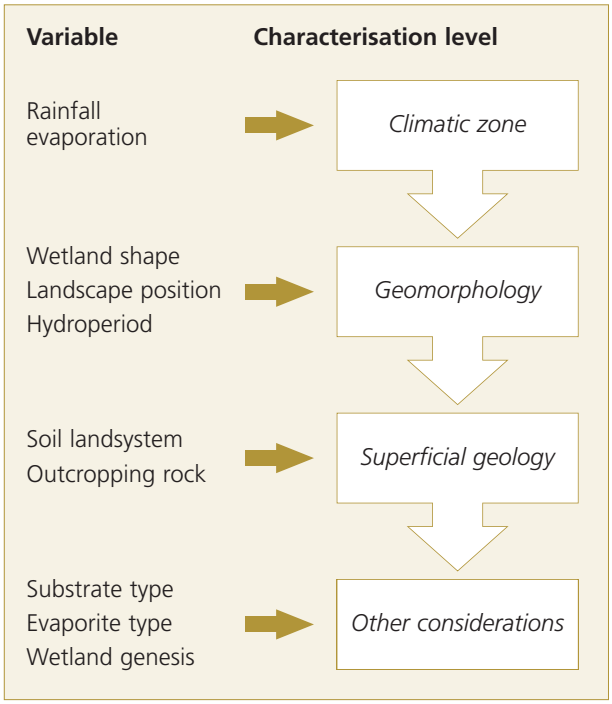
The scale of the BMNDRC wetland system makes it necessary to rely on remotely sensed data and spatial datasets to undertake characterisation. The concentration of salt in a water body cannot be measured remotely, but it may be inferred by observing combinations of other related parameters such as the position of a wetland in the landscape, the surrounding soil type and the nature and condition of fringing vegetation. Utilising geomorphic and topographic data to predict water quality is an attempt to generalise the biotic character of wetlands based on non-biotic parameters (*hereafter* referred to as wetland characterisation).

A characterisation scheme for the wetlands of the BMNDRC is proposed here (Figure 1). This is an initial attempt at developing character-based groups within the wetlands of the catchment, derived from available spatial datasets. It utilises geomorphic and topographic data to predict the water quality of individual wetlands, with water quality acting as a surrogate measure for biodiversity. It is, therefore, an attempt to generalise the biotic character of wetlands based on non-biotic parameters. This characterisation scheme will be continually refined with the addition of biological survey and water quality data collected in the BMNDRC.

### Climatic zone

At a global scale, the primary determinant of wetland occurrence and distribution is climate. Wetlands are more

***Figure 1*** *– The structure of the proposed characterisation scheme for the BMNDRC, showing required inputs and resultant groups of similar biological values.*




abundant where annual rainfall exceeds evaporation and decrease in frequency in less humid climates. The various climatic zones on earth also develop unique wetland morphologies and characters (Semeniuk and Semeniuk 1995).

At a localised scale, variations in soils, stratigraphy and hydrology will influence the function of wetlands. These factors may override climatic effects by determining the way that rainfall and runoff is retained. However, the biology and hydrology of a wetland system are still strongly influenced by the amount of rainfall received, its timing and the rate of evaporation.

The small variation in rainfall across the BMNDRC made it difficult to delineate by climatic regime. All the wetlands in the catchment, therefore, experience a warm temperate to semi-arid climate with low, winter dominated rainfall and occasional summer storm events.

## Geomorphology

The geomorphic classification developed by Semeniuk and Semeniuk (1995) describes wetlands in terms of their host landform and wetness. This scheme has been widely adopted as a means to provide a basic physiographic descriptor for wetlands in varying settings. A summary of the classification categories is shown in Table 1. The two axes of the matrix show the depth/period of inundation and the morphology of a wetland, based on the position of its occurrence in the landscape.

## Superficial geology

Geologic setting and processes influence the occurrence and character of wetlands in the BMNDRC. The occurrence of wetlands in the landscape is a function of a topography shaped by tectonism, weathering and erosion.

These same processes determine the distribution of soils in the catchment and, through this, the character of wetlands. As products of weathering soils characteristics reflect those of the parent rock and the processes to which it was exposed. Some characteristics, such as chemical composition, are transmitted to groundwater as it percolates through the soil. The character of an area's soil, therefore, influences the character of the wetlands formed when groundwater is expressed at the surface.

Interaction between the wetlands of the BMNDRC and the soils on which they occur can result in the salinisation of the wetlands. Groundwater rise has been experienced across the BMNDRC and secondary salinisation results where rising groundwater intersects salty soils. The quantity of salt stored in soil is largely dependant on the composition of that soil. Light, sandy soils are readily leached by rainfall and do not retain salts as readily as heavier, clays and loams.

## Other considerations

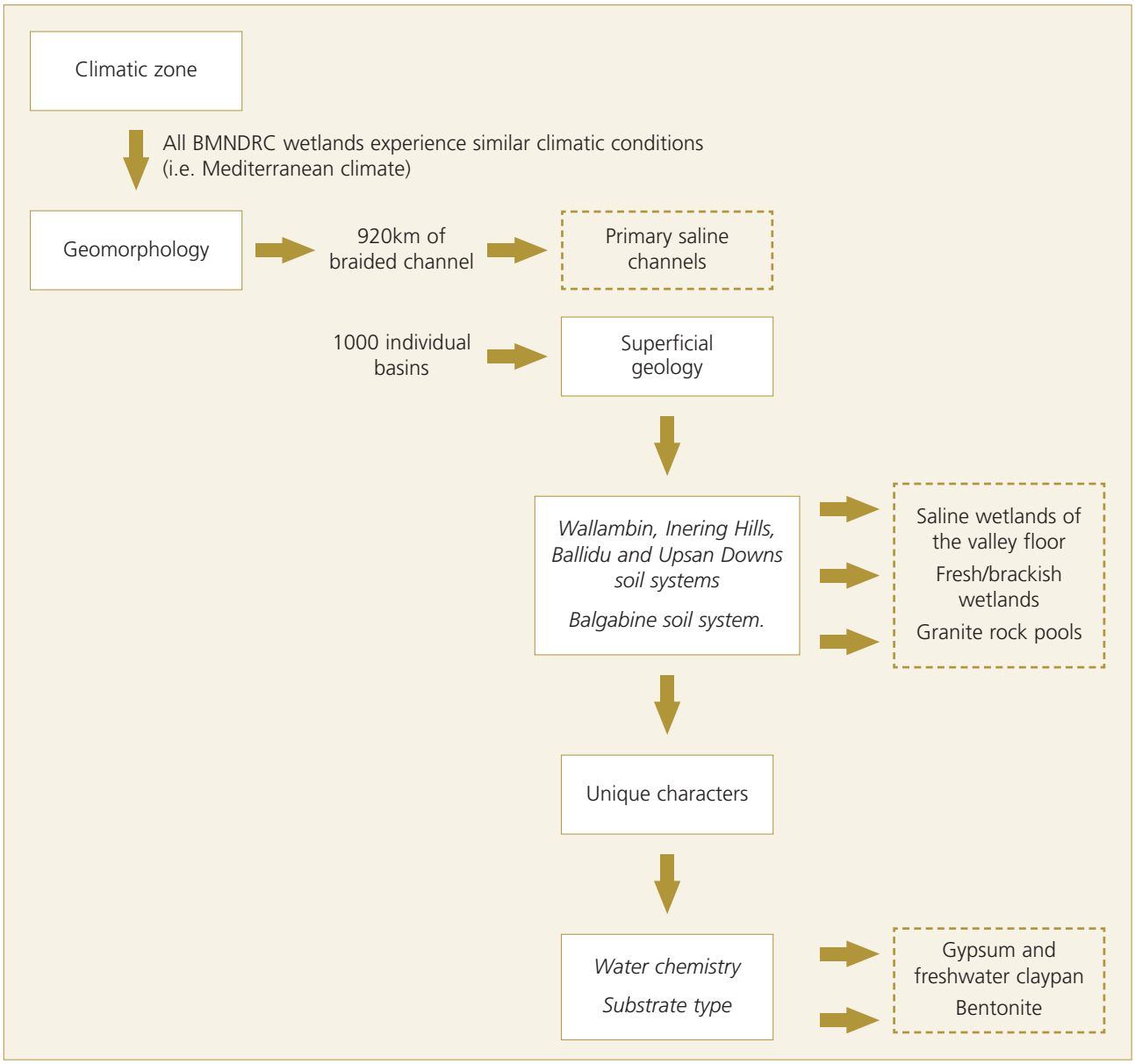
The preceding characterisation scheme does not yet recognise the full diversity of the catchments' wetlands. Some wetland types, unique due to the nature of their substrate or evaporites, cannot be identified from remote sensed data. These have been located in the catchment as

***Table 1*** *– A geomorphic characterisation scheme for wetlands (Semeniuk and Semeniuk 1995).*

| | LANDFORM | | | | |
|---|---|---|---|---|---|
| **Water longevity** | **Basin** | **Channel** | **Flat** | **Slope** | **Highland** |
| Permanent inundation | Lake | River | | | |
| Seasonal inundation | Sumpland | Creek | Floodplain | | |
| Intermittent inundation | Playa | Wadi | Balkarra | | |
| Seasonal waterlogging | Dampland | Trough | Palusplain | Paluslope | Palusmont |

a result of contact with landholders or, opportunistically, during field work. To date, two unique substrate wetland types have been recognised, bentonite and gypsum (Figure 2). These classes will be retained as unique types and members added to the groups as more are found. Developing a method to recognise these wetlands via remote sensing would greatly facilitate this process.

***Figure 2*** *– Applying the characterisation scheme to the BMNDRC, showing resultant groups of wetlands with similar biological values.*



# APPENDIX 11: SELECTION OF REPRESENTATIVE WETLANDS

Selecting representative wetlands that are considered to be of the highest value in terms of delivering the operational goal you would ideally assess the total biodiversity in each of the catchments' wetlands, determining suites of like wetlands and assigning relative conservation value. However, the large number of wetlands in the BMNDRC (>1,000) and the paucity of biodiversity data for the area, makes such an empirical characterisation unfeasible. It is, therefore, necessary to seek surrogate measures to replace direct determination of biodiversity.

The aim of wetland characterisation process was to determine suites of like wetlands. These wetland groups are termed 'consanguineous suites' and are defined by similarity in physical setting and causative factors of wetland development.

Six wetland types were recognised from the BMNDRC wetland characterisation process. These are;

a) primary saline wetlands including channels;
b) fresh/brackish wetlands;
c) bentonite wetlands;
d) freshwater claypans;
e) gypsum lakes; and
f) granite rock pools.

Once wetlands were grouped into similar types the next step was to select the most intact examples of each of the wetland types for further investigation. Four of the six wetlands types had sufficient water to sample aquatic invertebrates and physico-chemical parameters (a, b, e, and f). In total 21 wetlands were sampled (Figure 1).

Wetlands sampled for aquatic invertebrates and physico-chemical parameters were ranked according to the total number of aquatic invertebrate taxa recorded (temporary and permanent taxa), the number of conservation significant fauna (including south-west endemic, locally endemic, new species to science and IUCN redlisted fauna), the total number of vertebrate fauna (fish, frogs and birds), and per cent temporal pairwsie similarity. Wetlands were then listed according to their mean rank (Lynas et al., 2006).

Hypersaline wetlands that recorded the highest fauna species diversity and least, between-year variation were W002, W061, W001, W004 and W019 (Table 1). Landholder willingness to participate in further investigations saw W070 replaced W019 as a priority site. In addition, wetland SPS203 was included for future comparisons.

The priority hypersaline wetlands for future investigations and monitoring are W002, W061, W001, W004, W070 and SPS203 (shaded rows in Table 1).

Fresh/brackish wetlands that recorded the highest fauna species diversity and least, between-year variation were W011, W020, W010, W009, and W072 (Table 2). Of particular conservation importance is the new *Cladopelma* species from W011, new species of *Hexarthra* (rotifer) and *Orthocladiinae* (chironomid) from W072, the collection of

***Table 1**. Rank of hypersaline wetlands based on number of total invertebrate fauna, number of total vertebrate fauna, per cent temporal similarity, and the number of conservation significant fauna. Wetlands presented in ascending order based on their mean rank (Lynas* et al.*, 2006).*

| Wetland No. | Total invertebrate | Total vertebrate | % Pairwise similarity | Conservation significance | Mean rank |
|---|---|---|---|---|---|
| W002 | 1 | 1 | 6 | 1 | 2.25 |
| W061 | 2 | 2 | 4 | 4 | 3 |
| W001 | 5 | 2 | 1 | 4 | 3 |
| W004 | 2 | 5 | 2 | 4 | 3.25 |
| W019 | 5 | 2 | 3 | 4 | 3.5 |
| W070 | 4 | 5 | 5 | 4 | 4.5 |
| W008 | 5 | 5 | 8 | 2 | 5 |
| W056 | 5 | 5 | 7 | 4 | 5.25 |
| W018 | 5 | 5 | 9 | 4 | 5.75 |
| SPS203 | 10 | 5 | 12 | 2 | 7.25 |
| WOO6 | 11 | 5 | 10 | 4 | 7.5 |
| W007 | 13 | 5 | 11 | 4 | 8.25 |
| W071 | 12 | 5 | 13 | 4 | 8.5 |

***Figure 1**: Wetlands sampled for aquatic invertebrates and physico-chemical parameters in BMNDRC in 1999, 2003–2005. In total 21 wetlands were sampled.*

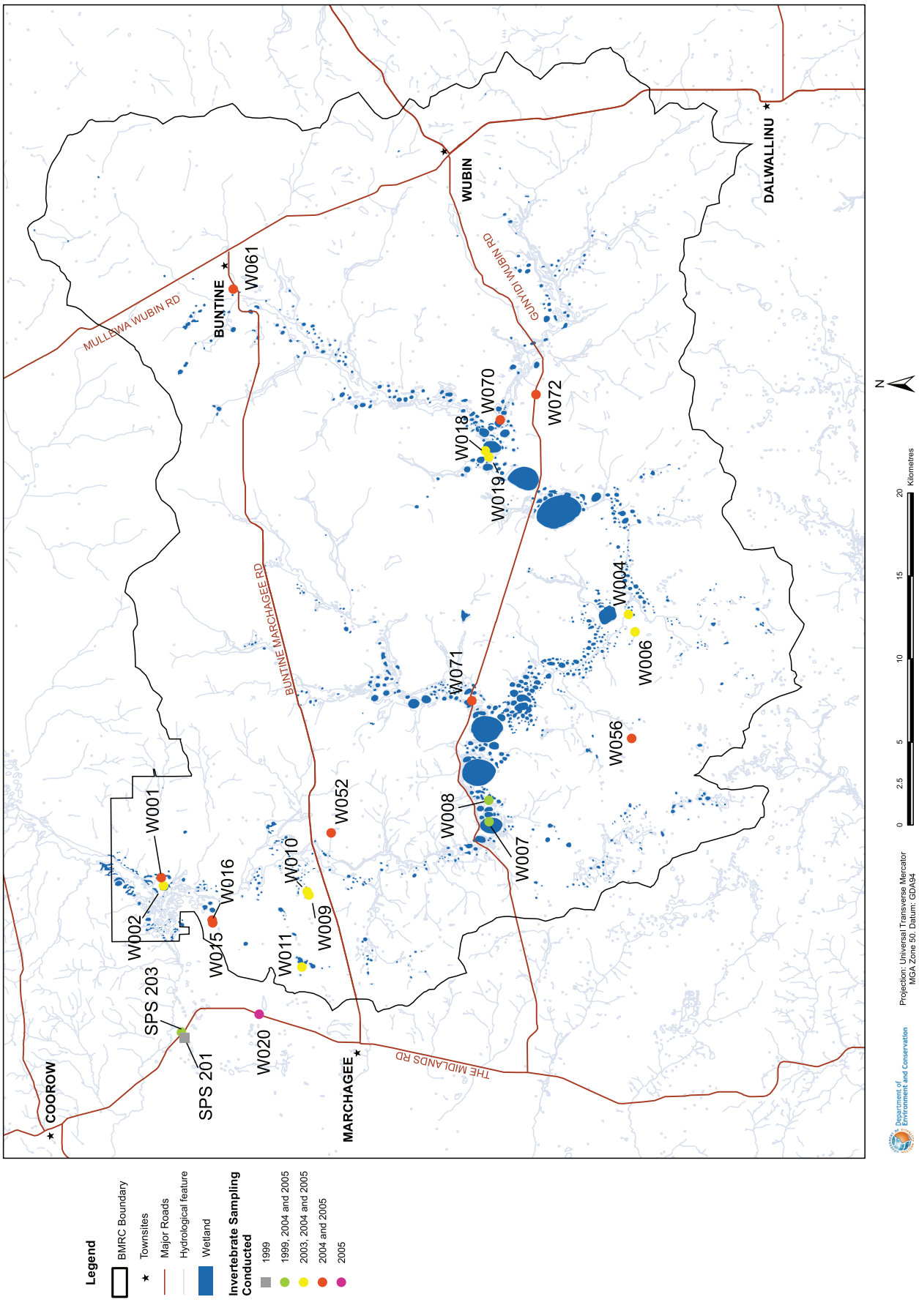


***Table 2**. Rank of fresher water wetlands based on the number of total invertebrate fauna, number of total vertebrate fauna, per cent temporal similarity, and the number of conservation significant fauna. Wetlands are presented in ascending order based on their mean rank.*

| Wetland No. | Total invertebrate | Total vertebrate | % Pairwise similarity | Conservation significance | Mean rank |
|---|---|---|---|---|---|
| W011 | 1 | 3 | 3 | 1 | 2 |
| W020 | 3 | 1 | NA | 3 | 1.75 |
| W010 | 4 | 5 | 1 | 2 | 3 |
| W009 | 5 | 2 | 4 | 3 | 3.5 |
| W072 | 2 | 5 | 7 | 5 | 4.75 |
| W015 | 6 | 5 | 2 | 6 | 4.75 |
| W016 | 8 | 4 | 5 | 6 | 5.75 |
| W052 | 7 | 5 | 6 | 6 | 6 |

*Proales daphicola* (rotifer) from W009 which constitutes a new record for Western Australia, and the presence of the Swan River goby from W009.

The priority fresh/brackish wetlands for future investigations and monitoring are W011 (includes W012), W020, W010, W009, W015 and W016 (shaded rows in Table 2). The granite rock pool (W072) was not considered at threat from secondary salinity therefore further investigations will be limited to monitoring water quality.

Two wetlands types did not have sufficient water to sample aquatic invertebrates and physico-chemical parameters; they were the Bentonite wetlands and Freshwater claypan.

The Bentonite wetlands chosen as representatives are W057, W058 and W059 due to their close proximity to one another, they are situated in a significant area of intact remnant vegetation and the landholder is willing to participate in further investigations.

To date there is only one known example of a freshwater claypan which is W074. This wetland will be included as a representative for further investigations.

## Selecting representative wetland assemblages

### Key points

- To select representative wetlands of the highest value you would ideally assess the total biodiversity in each wetland.
- Due to the large number of wetlands in the BMNDRC (>1,000) and the paucity of biodiversity data for the area surrogate measures to replace direct determination of biodiversity were required.
- Salinity is a particularly good indicator with the greatest biodiversity, greatest degree of endemism and highest conservation value occurring in fresh water bodies.
- Measuring the salinity of the more than 1,000 individual wetlands in the BMNDRC was still not feasible.
- The concentration of salt in a water body cannot be measured remotely, but it may be inferred by observing combinations of other related parameters.
- Utilising geomorphic and topographic data to predict water quality is an attempt to generalise the biotic character of wetlands based on non-biotic parameters.
- Characterisation of the BMNDRC wetlands determined suites of wetlands with similar physical settings and causative factors of development.
- Six wetland types were recognised: primary saline wetlands including channels; fresh/brackish wetlands; bentonite wetlands; freshwater claypans; gypsum lakes; and granite rock pools.
- The most intact examples of each of the wetland types were sample for aquatic invertebrates and physico-chemical parameters.
- Wetlands were ranked according to fauna species diversity and least, between-year variation to determine priority representative examples for each of the wetland types.
- Priority hypersaline wetlands for future investigations and monitoring are **W002**, **W061**, **W001**, **W004**, **W070** and **SPS203**.
- Priority fresh/brackish wetlands for future investigations and monitoring are **W011** (includes W012), **W020**, **W010**, **W009**, **W015** and **W016**.
- The Bentonite wetlands and the freshwater claypan didn't have sufficient water for sampling aquatic invertebrates and physico-chemical parameters.
- Priority bentonite wetlands chosen are W057, W058 and W059.
- The priority freshwater claypan chosen is W074.

### Asset goal

**The objective is to broaden knowledge and understanding of wetland values and ecology to develop appropriate management regimes for different wetland types in the BMNDRC.**

### Priority actions:

- High. Undertake surveys, monitoring and field trials to broaden knowledge and understanding of wetland values and ecology.
- High. Develop, implement and review risk assessments for wetland types, targeted to specific salinity threats and impacts.
- High. Develop and maintain wetland information systems.
- High. Develop, implement and review Wetland Recovery Plans, and their operations plans, for priority wetlands identified in the BMNDRC.
- Medium. Review and evaluate the wetland classification process in conjunction with the state framework.
- Medium. Document social, cultural and economic values of different wetland types.

### Performance measure

Water Recovery and Operational plans prepared and implemented for each of the priority representative wetlands listed above by 2010.

# APPENDIX 12: SELECTING REPRESENTATIVE FLORA

## BACKGROUND

To accommodate the operational goal, the development of flora management priorities would ideally be based on knowledge of all the elements of flora diversity in the BMNDRC. For example, complete mapping of local endemism, taxonomic diversity across the catchment, and genetic variation within and between taxa. These factors would then contribute to assigning relative conservation values. As attaining this level of knowledge is not practical, a substitute or surrogate measure of biodiversity was required in place of a direct measure. The most suitable surrogate of flora biodiversity was remnants of native vegetation. Priorities for remnant vegetation management were, in the first instance, determined independently of fauna and/or combinations of physical and biological diversity. Later in this section however, priority wetlands (a combination of physical and biological attributes) are introduced to help determine a representative sample of high priority remnants of native vegetation.

The priority setting method described below is based on a catchment scale; the BMNDRC. Within the BMNDRC, the spatial distribution of remnants varies considerably. There will be some landscapes with 40 per cent native vegetation, some with 20 per cent, and some with five per cent. The scale of the analysis (at 180,000ha) will inevitably result in some areas of the catchment with low priority. Priorities, however, in no way indicate that some remnants have little value. They simply represent a particular scale of planning and the application of broad brush well recognized ecological principles.

Priorities are based on a best-bet approach, using current knowledge and understanding, and will inevitably change at some point in the future. That is, they are to be used as a guide for management and never as an absolute measure of flora priorities.

### Two broad approaches

(Beecham 2003) notes that the many new approaches to biodiversity conservation around the world generally fall into two groups. These two groups are broadly identified as an 'indicator' or an 'efficiency of allocation' based approach.

The first of these approaches identifies management priorities on the basis of selecting an 'indicator', 'umbrella', 'keystone' or 'focal' species. This approach reasons that managing for the requirements of an 'indicator' species will overlap with the requirements of a substantial number of other species.

The main drawbacks of the 'indicator' species approach are in the assumptions made. One assumption is that populations are generally no longer affected by the influences of habitat loss, fragmentation or change in condition. As the wheatbelt is highly fragmented, it's very unlikely that the local and regional loss of species is complete – in particular, those fauna chosen as indicator species that are the most 'area' or 'fragmentation' or 'condition' sensitive (Short and Parsons 2004). Another assumption is that restoration actions to bring remnants (habitat) up to a minimum standard (of size, connectivity, shape or condition) will accumulate species at a similar rate and quality to that experienced in the decline phase. That is, the minimum requirements (of size, connectivity, shape or condition) recommended are more than likely to be an underestimation. This mismatch of decline and accumulation of species is called the 'hysteresis effect' (Hobbs 1999). Hobbs, 1999, also highlights that restoration technologies applicable to the wheatbelt are, not surprisingly, well below the quality of pre-European habitat. That is, the mismatch in habitat quality between pre-European and restored habitat is also likely to translate into an underestimation of minimum requirements. A further drawback is the concept itself of using one species as an indicator of the requirements of others. While this approach was identified as a starting point, and never as a 'one species fits all', it has attracted much criticism from researchers who have interpreted the 'indicator' concept as one that caters for the requirements of most other species and sometimes all other species (Short and Parsons 2004).

The main benefits of the 'indicator' approach are that the indicator species is often a well recognised tangible local entity; and it is easier to explain the rationale to stakeholders than many other approaches. Also, some of the most recently applied 'indicator' approaches have focused on engaging stakeholders and giving more consideration to practicalities of application than previously. For example, the 'modified' focal species approach as trialed in the BMNDRC incorporated a workshop with farmers to help select revegetation sites that accommodated the needs of conservation as well as paddock scale efficiency (Huggett et al., 2004). The reasoning for this was to improve the likelihood of farmer adoption of the recommendations. (Pannell 2003) makes the point that engagement with farmers is often overlooked, especially in an economic context, in nature conservation planning on private land.

The second group broadly identifies the most efficient way to represent the greatest number of biodiversity assets in the smallest possible area. The efficient allocation of scarce resources is the main focus of this approach and not 'effective' conservation. The highly fragmented nature

of the wheatbelt means that this approach may select many smaller size assets (areas of habitat/remnants) to achieve targets, and miss the importance of conserving long-term viable populations.

In both approaches, acknowledging the importance of conserving long-term viable populations is limited. This is probably a function of there being little specific evidence on this subject. However, Smallwood, 2001 and Margules et al. 2002, cited in Beecham 2003, highlight the point that a viable population is the fundamental unit for conserving biodiversity. Alternative thoughts to this are that current biodiversity should be assessed independent of viability, citing that viability is primarily an issue of 'management'. Further, even habitat configuration and connectivity could be considered viability parameters (Bayliss 2004).

Viability of populations was considered worth exploring further here, as the knowledge of biodiversity per se, is at best, limited for the BMNDRC (and most other places in the WA agricultural zone). Brooker and Margules, 1996, however, do suggest a useful guide to selecting for species richness at the remnant level. Their studies using 'plant diversity' as an indicator of biodiversity have shown the importance of retaining 'beta diversity' (diversity of habitats) in assessing the relative conservation value of remnants.

Assuming all habitat requirements are met, the question of what constitutes a minimum viable population for any particular species is one that was first seriously studied by two researchers in Australia. These researchers (Main and Yadav 1971) studied macropods on small land-bridge islands off the coast of WA and gave minimum viable population numbers for a range of macropods (Quammen 1996). These researchers defined the minimum viable population as the population size likely to persist indefinitely.

While the question of 'how much is enough' in relation to the requirements of any or all species is one of the most difficult and challenging problems in conservation biology (Quammen 1996), there is some useful evidence and ecological 'rules' that can be practically applied.

Factors influencing long-term viable (or persistent) populations:

Evidence for persistent populations comes from a collection of real life studies and computer modeling of fauna. The population requirements of flora in the agricultural region are little understood at this point (D. Coates, pers. comm).

The main factors reported to be influencing the persistence of fauna populations in altered landscapes are the type of organism, size of habitat patch, configuration of habitat, perimeter of habitat, matrix quality and the landscape size and location (see Beecham 2003 for a summary). To add to the complexity of influence, these factors are also interacting.

A number of researchers have reported habitat loss thresholds whereby probability of extinction changes substantially. In general, many of these studies indicate that when habitat loss is less than 70 to 80 per cent, localized species extinction is attributable almost wholly to habitat loss. In contrast, when habitat loss approaches 70 to 80 per cent and/or greater, the influence of habitat fragmentation becomes equally influencing and/or takes over as the greatest influence on the probability of extinction.

As ecological boundaries are complex, the size and location of the cultural planning unit used, in this case the BMNDRC, will undoubtedly cross over ecological boundaries. That is, ecological assets within the BMNDRC may (or may not) be strongly influenced by assets outside of the catchment. Likewise, there may be important ecological boundaries within the catchment. The two sharply distinct bioregions in the catchment are a logical division.

Given the aim of conserving biodiversity; ecological support for area, shape, connectivity and condition of habitat, indicates these are the most important factors in determining priorities for the remnant vegetation in the BMNDRC. The overwhelming support for 'area' is highlighted by (Bennett and Mac Nally 2004): they state that the relationship between habitat area and both the size of species populations and number of animal species (richness) are among the most strongly supported 'rules' in ecology. That is, the greater the population size of a species, the more resilient it is to extinction (a viability issue), and the optimisation of species richness is the core requirement of biodiversity conservation. On population size, Quammen, 1996, highlights the many perils of small population sizes (with localised extinction being the greatest peril). Jarrod Diamond (in Quammen, 1996), in discussing the merits of a 'single large' area over 'several small' areas, (the single large or several small debate – SLOSS) also states that the larger the area, the greater the likelihood of rare species occurrences. In addition, larger areas of vegetation are usually more resilient to threats, e.g. dealing with the threat of a rising watertable.

## METHODOLOGY

The IBRA region, representation of vegetation types, remnant size and shape, and remnant condition were the main elements collectively used to develop priorities. These are each described below.

### IBRA

The Lesueur Sandplain sub-region and the Avon-Wheatbelt (ancient drainage) sub-region components of the BMNDRC were independently analysed on the basis of their sharply contrasting landforms and vegetation types. Remnants intersecting the boundary between Lesueur and Avon-Wheatbelt were included in the analysis of both areas.

### Limited-in-extent vegetation types

A desktop analysis was undertaken using ArcView 3.2a. Beards 1:250,000 pre-European vegetation mapping was used to identify vegetation types that are extremely limited in extent (less than 2,000ha or less than 10 per cent) in the State or the Northern Agricultural Region (NAR). Four vegetation types were identified; two woodland types and two shrubland types. Coincidently, these same vegetation types are also poorly represented in the IUCN 1-1V National Reserve System in the NAR and the State (Richardson et al. 2004).

Fine scale vegetation association mapping by Hugget et al. 2004, was used to support the capture of limited-in-extent vegetation types at the State and regional level. As Beard's vegetation mapping is very course, there was a risk that some limited-in-extent non-mallee local woodland types may be missed. The status of eucalypt woodland types in the wheatbelt is widely known to be limited-in-extent – by virtue of being heavily cleared for agriculture. Given this status, all non-mallee woodland associations mapped at a finer scale by Hugget et al. 2004, were identified in the analysis.

### Size, shape and condition of remnant vegetation

Again, a desktop analysis was undertaken using ArcView 3.2a. Vegetation mapping by Hugget et al. 2004, was used as the basis for size, shape and condition analysis. Remnants in each of the two biogeographic regions above one hectare were assessed for size and grouped into percentile categories representing the largest to the smallest remnants. In no way was the exclusion of remnants of one hectare or smaller an indicator of their lack of biological importance.

The remnant based 'condition', recorded by Hugget et al. 2004 as 'good', 'moderate' or 'poor' was used in the analysis.

### Connectivity

Connectivity was not specifically used in the analysis. A connectivity analysis method to add value to the other elements in the analysis was not found. For example, because of the spatial patterning in the BMNDRC, any one method applied across the whole catchment would be biased in some way. Compare the following two examples:

a remnant is large in area, has many directly connected linear arms as part of its shape, extends up the 1.8km at its widest, is identified as one remnant by Arcview, and has few remnants within a two-km radius.

a remnant is moderate to small in size, is square in shape and has many surrounding small remnants within a two-km radius.

Item b) will rate highly for connectivity and item a) will rate very low, despite it having directly connected vegetation extending over a substantial distance. The distance or area used to estimate connectivity is also another bias. That is, the values used are arbitrary and essentially without ecological context.

At the catchment scale, the strength of discrimination derived from using remnant size and remnant area/perimeter ratio was very influential. That is, adding a biased form of connectivity into the analysis was considered by the authors to be counterproductive to the final product. An alternative method to judge catchment scale connectivity was considered reliable by the authors: this was to visually select the best size and area/perimeter class of remnants that fall in the most direct route between the priority selected remnants.

A variety of software developed to analyse habitat connectivity is freely available. Its potential to minimise bias over a catchment of 180,000ha, and to give ecologically meaningful results, over-and-above the use of those elements already in the analysis was considered limited by the authors.

### Other factors

Factors other than biogeographic regions, representation, size, shape and condition of remnant vegetation were considered. These factors were included on the basis of giving another level of evaluation. For example, wetland priorities, as determined by another selection process, can be compared against vegetation priorities. These were:

- wetland priorities; current and proposed;
- presence of Declared Rare and Priority flora; and
- vegetation associations in the BMNDRC mapped by Hugget et al. 2004 with a remnant based occurrence of one.

These items were developed as themes in the Arcview project, but were not in the selection analysis per se.

### Salinity threat

The area threatened by salinity was identified using generic mapping (Landmonitor). This mapping identifies the area covering the lowest two meters of elevation of the various landscapes within the BMNDRC.

Remnants with any part intersecting with salinity threat

were selected. In some instances, only a very small percentage of a remnant intersected with salinity threat. This methodology was applied on the basis that salinity is best managed at a landscape scale and remnants are best managed as a whole.

### CAR reserve system

The CAR reserve system is a nationally applied system of protected areas that address comprehensiveness, adequacy and representativeness (CAR) of all its component ecosystems. This approach was used as a guide to prioritise assets. For example, comprehensiveness was considered by treating each of the two bioregions in the catchment independently in the analysis. Adequacy was considered by using size, shape and condition as the key elements in the analysis. Representativeness was considered by giving selection influence to those vegetation associations limited-in-extent in the Northern Agricultural Region and/or the State.

Fifteen per cent reservation of original (pre-European) extent is the target for the CAR system. A brief explanation of the meaning of each element is:

- **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.

### External influences on biodiversity asset management

As mentioned previously, biodiversity assets within the BMNDRC may be strongly influenced by assets outside of the catchment, or even visa-versa. Given the large scale of assets to the west and east of the BMNDRC, these may be the most important influence on the long-term viability of those assets within the catchment. That is, animals pollinate most of our native vegetation, and the interaction with those sourced from these large areas may be playing an irreplaceable function.

A course analysis was undertaken of the gap area between the western border of the BMNDRC and the Watheroo National Park and Pinjarrega and Capamauro nature reserves. Likewise, the same was done for the gap area between the eastern border of the BMNDRC and the clearing line boundary. The gap distance, average distance between remnants, area of native vegetation, number of remnants and the average size of remnants was calculated.

## THE ANALYSIS

Inevitably, when multiple elements are used to assess the value of something, and where priorities are required, a relative value must be given to each element in the assessment. Scoring systems are commonly questioned for their over-simplifying of complex environments, however, in this instance, the assessment elements are somewhat basic, and the scoring number-range low. For example, if there was detailed biological information known about each remnant, then judgements between many more elements, and perhaps a greater scoring number-range would be necessary. This would introduce the need for a high level of interpretation, and possibly over-simplification.

Initially, remnant size and shape (area/perimeter ratio (A/P)) were independently ranked into percentile categories. The categories were: 0 to 10 per cent (the best 10 per cent), 11 to 20 per cent, 21 to 40 per cent, 41 to 60 per cent and 61 to 100 per cent (the lowest 40 per cent in area and A/P ratio).

Remnant size, A/P ratio, representation of vegetation types, and condition were then each given a score (or weighting) from zero to three. For example, remnants in the top 10 per cent size category were given a score of three; those in the 11 to 20 percentile category were given a score of two; and all others were given a score of one. The remnant A/P ratio was calculated the same way. Condition score was adopted from the CSIRO remnant survey (Hugget et. al. 2004) with a scale of one (poor) to three (good).

Vegetation associations of limited extent were identified according to Richardson et al. 2004. Any remnant containing a vegetation association of limited extent was given a 'limited extent' score of three, while all other remnants scored zero (table 1-8)

Scores for size, shape, condition and limited extent vegetation were added to create a summary score. This scoring system gives the possibility of scores between three and 12, where 12 is high and three low priority. However the actual output range was five to 12. Three levels of priority were derived from the analysis: high (12) , medium (10–11) and low (five–nine). These were shown graphically (Figure 1).

Visual assessment was used to determine the influence of:

- wetland priorities; current and proposed;
- presence of Declared Rare and Priority flora; and
- vegetation associations in the BMNDRC mapped by Hugget et al. 2004 with a remnant based occurrence of six or less.

Also, connectivity was visually assessed against the selected priority remnants to determine its influence.

***Table 1-8**. Remnant size and shape, representation of vegetation types and remnant condition were given scores based on their relative value. Each IBRA sub-region was analysed independently.*

| Size | Score |
|---|---|
| **Lesueur Sandplain IBRA sub-region** | |
| 0–10 percentile (⩾135.7ha) | 3 |
| 11–20 percentile (⩾56.0 and <135.7ha) | 2 |
| 21–100 percentile (<56.0ha) | 1 |

| Size | Score |
|---|---|
| **Avon-Wheatbelt IBRA sub-region** | |
| 0–10 percentile (⩾70.9ha) | 3 |
| 11–20 percentile (⩾29.3 and <70.9 ha) | 2 |
| 21–100 percentile (<29.3ha) | 1 |

| Area/perimeter ratio | Score |
|---|---|
| **Lesueur Sandplain IBRA sub-region** | |
| 0–10 percentile | 3 |
| 11–20 percentile | 2 |
| 21–100 percentile | 1 |

| Area/perimeter ratio | Score |
|---|---|
| **Avon-Wheatbelt IBRA sub-region** | |
| 0–10 percentile | 3 |
| 11–20 percentile | 2 |
| 21–100 percentile | 1 |

| Vegetation types of limited extent | Score |
|---|---|
| **Lesueur Sandplain IBRA sub-region** | |
| Yes or no | 3 or 0 |

| Vegetation types of limited extent | Score |
|---|---|
| **Avon-Wheatbelt IBRA sub-region** | |
| Yes or no | 3 or 0 |

| Condition | Score |
|---|---|
| **Lesueur Sandplain IBRA sub-region** | |
| Good | 3 |
| Moderate | 2 |
| Poor | 1 |

| Condition | Score |
|---|---|
| **Avon-Wheatbelt IBRA sub-region** | |
| Good | 3 |
| Moderate | 2 |
| Poor | 1 |

## RESULTS

### IBRA

The Lesueur Sandplain component has a higher percentage of remnant vegetation than the Avon-Wheatbelt component: 17.4 per cent (7,113ha within 40,763ha) compared to 11.3 per cent (16,355ha within 144,886ha). The overall BMNDRC percentage of remnant vegetation is 12 per cent (22,338ha within 185,649ha)

### Vegetation types of limited extent

By the spread of sizes and shapes selected in the high priority class (figure 1), the inclusion of this element substantially influenced the results. There were approximately 650 patches of vegetation identified as being limited in extent. These patches totalled 10,770ha.

### Priority Remnants

High priority remnants were those with a size and shape in the top 10 per cent. They also had at least one vegetation type of limited extent and had a 'good' condition score. Priority classes, the number of remnants in each, and the number at risk of salinity are given below.

- High Priority Remnants: 26 (23 at risk of salinity);
- Medium Priority Remnants: 116 (54 at risk of salinity); and
- Low Priority Remnants: 419 (233 at risk of salinity).

### Connectivity

Visual selection of catchment scale connectivity, using the top two priority classes as a guide was reasonably self evident. The interpretation has been left open for further discussion. This includes the identification of important cultural linkages such as, rail reserves and road reserves and important natural linkages, such as drainage lines.

### Other factors

'Wetland priorities'; current and proposed, was the only 'other factor' displayed in figure 1. Other factors that were considered as a theme in the Arcview project were:

- Presence of Declared Rare and Priority flora; and
- Vegetation associations in the BMNDRC mapped by Hugget et al. 2004 with a remnant based occurrence of six or less.

These factors were included as themes for the purpose of giving a 'second cut' visual based selection.

### Salinity threat

The area with potential for developing, or currently with, a shallow water table occupies about 55,698ha, or 30 per cent of the BMNDRC. About two thirds of all remnants are in-part or wholly at risk of developing a shallow water table (or already have a shallow watertable), (Figure 1).

### External influences on biodiversity asset management

To the west of the catchment, there is a substantial area of remnant vegetation; the Watheroo National Park and Pinjarrega and Capamauro Nature Reserves. These areas tally about 65,000ha. Collectively, they are broadly linear in shape, approximately parallel to the western boundary of the BMNDRC and extend further north and south than the BMNDRC western boundary. The distance between the BMNDRC and this large area of remnant vegetation ('the gap') ranges from 12–24km. The average distance between remnants in the gap area was 104m. The area of remnant vegetation in the gap area was 12,427ha. The number of remnants in the gap area was 1,327. And the average size of remnants was 9.36ha.

To the east of the catchment, the clearing line is at 14–24km from the eastern boundary of the BMNDRC. The un-cleared remnant vegetation here is extensive and extends northwards and eastwards. Even though the clearing line boundary is less parallel to the catchment boundary than the western side, the gap distance is similar to the western side. The average distance between remnants in the gap area was 220m. The area of remnant vegetation in the gap area was 9,895ha. The number of remnants in the gap area was 802. And the average size of remnants was 12.34ha.

The connectivity of the gap area was broadly assessed to be substantially higher on the western side of the BMNDRC than on the eastern side. Comparisons were:

- the western gap contained remnant-to-remnant average distances about half those in the eastern gap;
- there was a larger total area of remnant vegetation in the western gap; about 25 per cent more than in the eastern gap; and
- there was a greater number of individual remnants in the west gap; approx 1,327 compared to 802 in the eastern gap.

Conversely, average remnant size was larger in the eastern gap; at approximately 12.3ha compared to 9.4ha in the western gap. The width of the gap area was similar for both sides.

## DISCUSSION

The analysis used remnants of native vegetation as a surrogate for biodiversity. Priority was given to remnants with perceived higher viability, by virtue of their size, shape and condition. In addition, 'limited extent' vegetation types were given influence in the selection process.

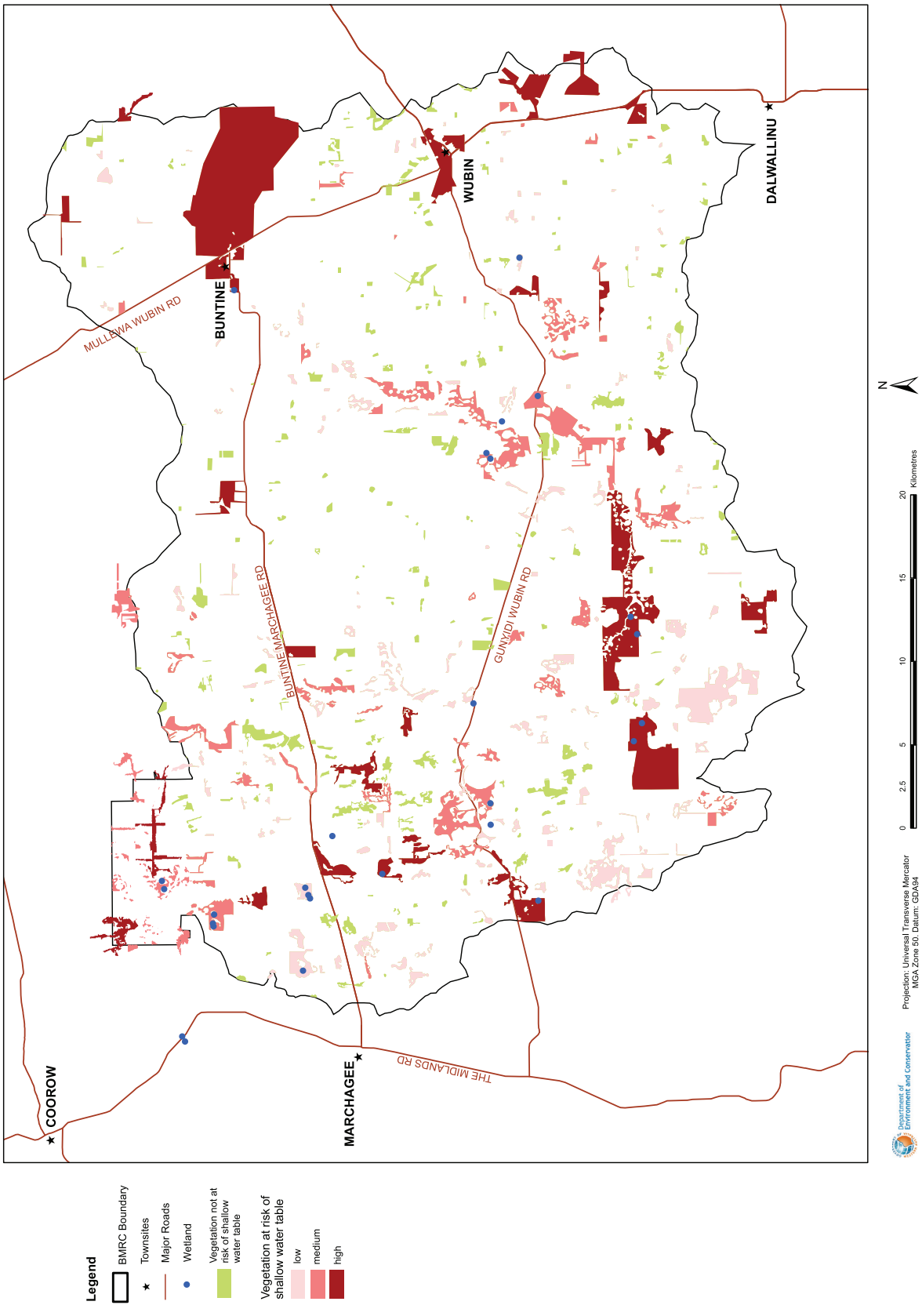
One alternative approach is to intensely survey many elements of the biodiversity itself, e.g. mammals, frogs, reptiles, spiders, scorpions and plants, and base the priorities on the current level of biodiversity. McKenzie *et al.* 2004 surveyed these elements in their terrestrial biodiversity survey of the WA agricultural zone and found they each had a distinct influence on the ensuing biodiversity model. Given the demands of time and resources, this approach is rarely undertaken at local scales, at an intensity valuable to planning. However, this approach has shown that if managing strictly for current biodiversity, the ensuing model is likely to be different to surrogate based approaches. The implication of this is that any priority setting approaches using surrogates for biodiversity should use the developed priorities as a guide only, and with some discretion.

The quality native vegetation mapping by Hugget *et al.* 2004 proved very useful in the analysis. One constraint of the mapping however, was the limited mapping[8] of the main drainage line. The main drainage line is a focal point of the catchment. It's also a naturally saline braided system and is likely to contain plant taxa of interest to managing the changed hydrology of agricultural landscapes. The recent revision of the Broombush complex (*Melaleuca uncinata* sens. lat.) by Craven *et al*. (2004), highlights our limited knowledge of plant taxonomy in naturally saline areas. Instigating flora survey work in the main drainage line appears an urgent action given we currently have evidence of human induced (mostly the changed hydrology) permanent loss and change of native vegetation in this area. A number of wetland priority areas also occur in or near the main drainage line.

Assessing each IBRA sub-region on the basis of their distinct differences proved useful. For example, the Lesueur Sandplain sub-region remnants were close to double the size of those in the same size class in the Avon-Wheatbelt sub-region. The analysis also highlighted that there was no 'limited in extent' Lesueur Sandplain shrublands, i.e. *Banksia*/woody pear shrubland; Mixed shrubland (sandplain); *Eremaea* or *Melaleuca* Sandplain cypress shrubland; and Shrublands of perched drainage

8 Vegetation mapping of Koobabbie Farm also needs revising.

***Figure 1***. *Remnant vegetation priorities in the BMNDRC. The darkest colour indicates high priority; the next lightest colour indicates moderate priority; and the lightest colour indicates low priority. The light green colour highlights those remnants not at risk of developing a shallow watertable. Note, because there was no vegetation type mapping for Koobabbie Farm, scoring for limited-in-extent vegetation types in the analysis was not possible. This is why all the vegetation on Koobabbie Farm is shown as low priority. However, in keeping with the analysis, all non-mallee woodland types on this property will be treated as high priority. The mapping will be adjusted as soon as the vegetation types are identified.*



lines. This is likely to be a result of the more well reserved (Nature Conservation reserves and National Parks) status of the Lesueur Sandplain sub-region and its different clearing and agricultural history as compared to the Avon-Wheatbelt sub-region.

The Avon-Wheatbelt component has a longer cropping history than the Lesueur Sandplain component. In contrast, the Lesueur Sandplain component, until more recent times, has had more of a focus on growing stock than the Avon-Wheatbelt component. This history is mostly a consequence of the initial land clearing and cropping of the more productive lower landscape areas, or those with the best nutrient reserves and water holding capacity. This distinction however, mostly changed during the 1960/70s, with the availability of modern fertilisers and leguminous pastures and crops.

Uniquely, as well as the Lesueur Sandplain and Avon-Wheatbelt sub-regions being distinctly different, their boundary in the BMNDRC is mostly along the naturally saline braided drainage line (system of wetlands).

Using 'limited in extent' vegetation types in the analysis was a necessity based on using the principles of the nationally applied CAR reserve system. Given that this element was given equal rating to the best size, A/P ratio and remnant condition, and was not given overriding priority, 'limited in extent' vegetation types are spread through the three priority categories, i.e. high, moderate and low. If however, at any point there is a need to increase or decrease the influence of this element in the analysis, then the rating values can easily be changed and the analysis re-run.

Size, shape and condition, combined with limited-in-extent vegetation types were the four key items in the analysis. These items are all fundamental to the national CAR approach. Importantly, the output of the analysis is a broad guide to catchment scale priorities and not to be taken as a definitive measure. That is, the inputs into the analysis, i.e. size, shape, condition, and 'limited in extent' vegetation types are a crude representation of biodiversity per se. In particular, there must be recognition that all remnants, regardless of their features are candidates for housing unique genetic material, species and/or living assemblages. The many prominent characters of biodiversity in the south-west of WA (includes the agricultural zone) demonstrate this point. That is, being a global hotspot for plant diversity; having invertebrate diversity matching that of plants (Keighery *et al.* 2004); and having high diversity of soil based fungi – sometimes equalling diversity and endemism of plants (CSIRO Forestry and Forest Products – FungiBank). Also, many co-dependant relations occur between plant and plant, plant and animal, plant and microbe and plant-microbe-animal interactions (Lamont, 1992). Furthermore, in the agricultural zone, inter-grade plant species are common; hybridization in plants is often recorded; turnover of species is relatively high – estimated flora conservation intervals to be less than 15km (Burgman, 1988); and as mentioned in the flora section, the agricultural zone is home to the world's greatest number of *Acacia* taxon.

The comparisons of the priorities developed using the methodology in this report contrast with those suggested by Hugget *et al.* 2004 in their landscape design for bird conservation in the BMNDRC. This was expected, given the different criterion used in each. Hugget *et al.* 2004, focused on the perceived requirements of those birds most sensitive to remnant area, habitat-type area, remnant isolation and remnant condition. Thus, those remnants perceived to be of a sufficient size for example, were given a low priority. In contrast, the methodology used in this report gave preference to increasing size.

The issue of species viability is one that is limiting to, and very important to managers. Work on the viability needs of plant species in the agricultural zone is restricted to three species in CALM's Wheatbelt Region and is focused on just some of the many viability elements (D. Coates pers comm.). One of the elements of viability is plant recruitment, especially in the context of fire. There is some evidence that the commonly employed practice of fire exclusion from remnants in the agricultural zone is artificially and substantially reducing their biodiversity. For example, *Allocasuarina* spp. have been observed to be dominating areas that were previously species-rich heathland. Interpretation suggests that the heathland is dependent, in part, on a particular fire frequency for maintenance of biodiversity (D. Coates pers comm.).

Implicit in the question about the role of fire is the influence of weeds. Weeds are often associated with smaller sized remnants on farmland and roadside native vegetation. An understanding of the future of these areas is not well established and is likely to be limiting to management of priority assets. Given that small sized and/or narrow strips of native vegetation are likely to play an important role in connectivity in the BMNDRC, the role of fire in the presence of weeds will be priority action.

In the context of viability, further assessment of connectivity as a contributing factor to species viability within the BMNDRC, may identify a suitable software package to add to, and improve on, the main elements of the analysis. One particular element of connectivity that is probably always overlooked (especially with software packages) is the role of 'paddock trees' or very small fragments of native vegetation, i.e. anything less than one hectare (Vesk and MacNally, 2005). Because of the extreme edge-effects operating at this scale, as mentioned

above in the context of weed invasion, these individual trees and small areas are unlikely to have the capacity to self-regenerate. That is, their contribution to connectivity will be lost as they senesce. In particular, in landscapes where the percentage of remnant vegetation is around 20 per cent or less, these trees/small areas play an increased role in conservation. As mentioned earlier in this section, at low percentages, the effects of fragmentation (poor connectivity) become at least, if not more limiting than the lack of habitat. Also, these areas, because of their low percentages, are of high value in the context of being a 'skeleton' to build on, and give important evidence of the variety of soil-vegetation inter-relationships (Vesk and MacNally, 2005). For example, linear roadside native vegetation is often the only continuous transect that demonstrates the diversity of complex soil-plant inter-relationships. There are many discrete areas of the BMNDRC that have a very low percentage of native vegetation cover. In the absence of direct determination of biodiversity, giving consideration to paddock trees and small areas of native vegetation as well as the various remnant priorities would seem to be a precautionary approach in the context of the operational goal.

The interaction between various living organisms is, like the other elements of viability, a particularly important one. Lamont 1992, highlights how current changes in ecosystem functioning, oblivious to most citizens, can take many decades or even greater than a century to become obvious enough to engender wider community concern. The flora and fauna most at risk are those associated with a 'keystone' or 'co-dependant' species. These co-dependant relations occur between plant and plant, plant and animal, plant and microbe and plant-microbe-animal interactions. A simple example is between the black cockatoo and a *Banksia* species. Black cockatoos are the main feeders on the larvae of *Arthrophora* sp. moth. The wood boring larvae of this moth destroys the flower heads and seed set of *Banksia tricuspis*. In the absence or decline of the omnivorous black cockatoo (the primary feeder of the moth larvae), *Banksia tricuspis* will immediately function differently. However, the readily observable evidence of this change may not be distinguished for decades or perhaps even beyond a century. For instance, long-lived plants that resprout after disturbance and only depend on regeneration from seed at relatively long intervals (perhaps once per century) are at risk. If these species have a problem with seed production, then the implications are likely to go unnoticed for a very long time.

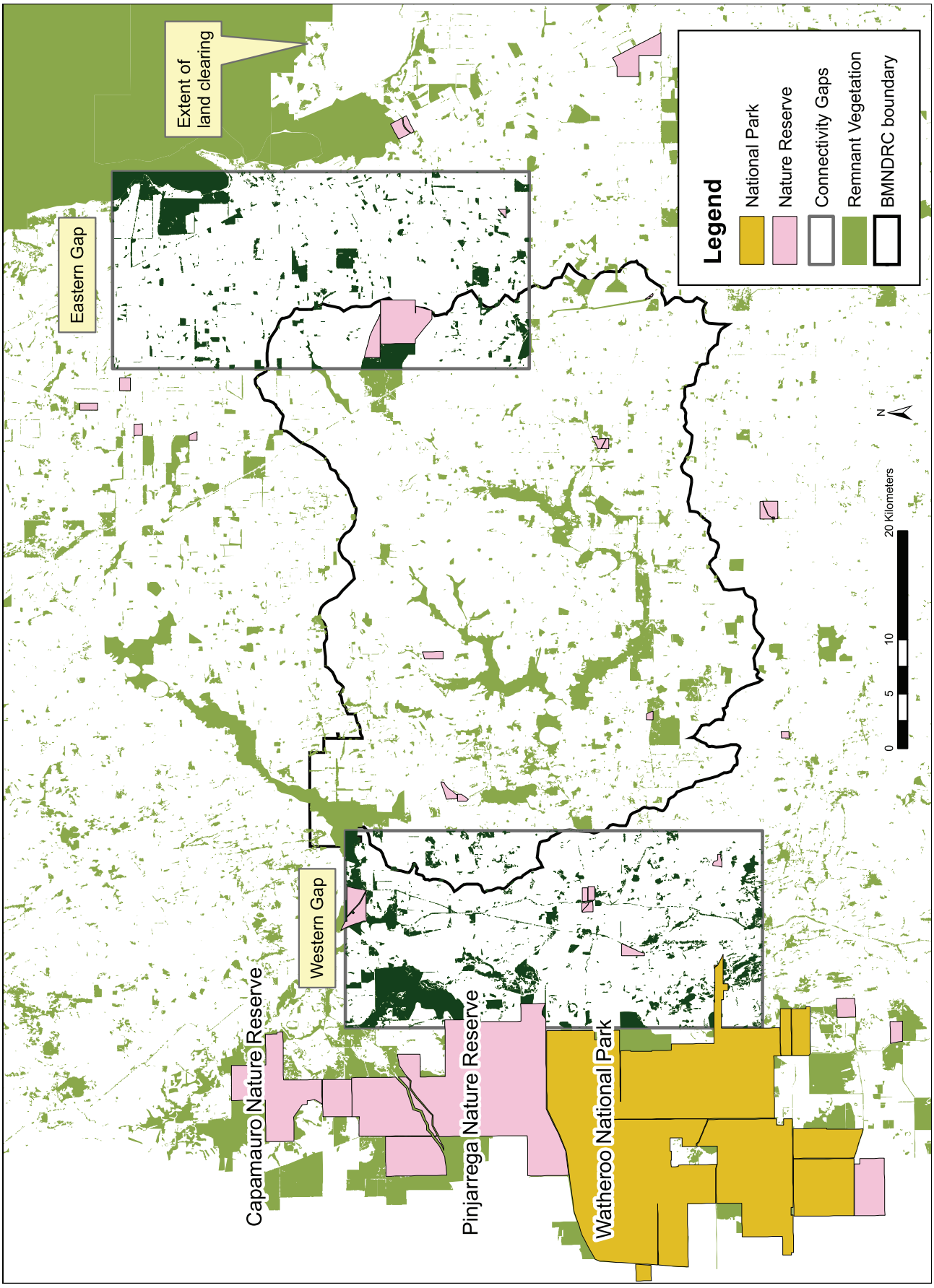
The interaction between various living organisms is at the core of exploring the influence of large extensive areas of remnant vegetation on the surrounding landscapes. The role of very large areas of remnant vegetation, such as those to the west and east of the BMNDRC is uncertain (figure 2). Local observations from landholders living on the western side of the catchment, indicate there is a substantial flow of birds, especially Carnaby's black cockatoo (A. Doley pers. comm), sourced from the large scale remnants west of the catchment. If this is the case, then understanding their contribution to the remnants in the BMNDRC would be a great addition to setting management priorities.

The contrast between, and the implications of different scales of planning, as mentioned in the introduction, is evident when interpreting the value of connectivity to viability. At small scales and low percentages of native vegetation, small fragments including paddock trees have an important conservation role, e.g. at farm or sub-catchment levels. At the BMNDRC scale however, the degree of 'edge' habitat is the enemy. (Quammen 1996) sums this up well: the implication of giving too much weight to connectivity is in favouring those species least in need of protection. These are the good travellers, the feisty competitors, those resistant to extinction; the generalist fauna species that benefit from increased edges in the landscape. These species are already immensely favoured via habitat fragmentation and the myriad of accompanying edges. In particular, giving favour to these species increases competition for resources with those having the greatest need – the specialists, the less competitive creatures, the reluctant travellers, the non-generalists.

The condition of remnant vegetation, like its size and shape, influences habitat value, and so its viability. The remnant based condition rating devised by Huggett *et al.* 2004, was a calculated value derived from initial data collected for each vegetation association within each remnant. The calculated 'remnant' rating was proportionate to the size of each vegetation association. Foliage cover of trees, shrubs, herbs and weeds, litter cover, presence of fallen timber and grazing history were the main elements used by Huggett *et al.* 2004 to assess vegetation condition. The weighting for each element was based on its relative importance to bird conservation.

Recording the change in condition of remnant vegetation over time will be fundamental to interpreting the influence of threatening factors and devising a suitable management response. Gibbons *et al.* 2006, notes two dominant notions of the interpretation of condition. The first is based on structure and/or composition of vegetation; and where a benchmark, intact site (or near to intact) is used as a reference point. The second is based on specific processes, for example, the leakiness of the site, or the vectors of introduced dieback. Gibbons *et al.* 2006 suggests the scale of mapping is one of the most

***Figure 2***. *Rectangular shapes were used on either side of the BMNDRC to broadly assess the connectivity between the catchment and the large areas of remnant vegetation on the western and eastern side*



influential factors in choosing a suitable condition surveillance method. Measuring condition change, particularly for the purpose of improving biodiversity management, is in its infancy and so, offers good opportunities to apply, test and adapt the chosen approach.  No particular approach has been chosen at this point. Selecting and applying a condition surveillance approach will be a high priority action for this project to meet the operational goal.

The areas at risk of developing a shallow watertable, were introduced after the factors of size, shape, condition and vegetation-of-limited-extent were analysed. The 'Landmonitor' risk mapping is a broad guide only and is restricted to valley areas of the various landscapes within the BMNDRC. That is, the risk of developing a shallow water table in other areas such as hillsides and break-of-slopes are not represented. Also, the risk mapping does not discriminate between areas of high and low risk. For example, it's likely that some of the area at risk will not be directly affected by a shallow water table for some decades or at all. In addition, the risk mapping is a prediction only, based on very course inferences and is based on there being no change to agricultural land management. There is also no expected change in climate in the risk predictions.

Despite the area at risk of developing a shallow water table is 30 per cent of the BMNDRC, a large number of remnants, occupying the majority of remnant area, are at risk in-part or wholly. The threat from salinity beyond the valley areas of landscapes – at this point not mapped, will undoubtedly broaden the extent of area of remnant vegetation at risk of developing a shallow watertable

# APPENDIX 13: BIOPHYSICAL THREATS

## ALTERED BIOGEOCHEMICAL PROCESSES

The term altered biogeochemical processes refers to changes to the biological, geological, physical and chemical environment subsequent to European settlement in the wheatbelt region, which was most evident after the mid 20th Century. Altered biophysical processes include, but are not limited to, changes to hydrology, nutrient cycles, and climate.

### Hydrological processes

Altered hydrology can be caused by numerous factors, such as artificial drainage, extraction of groundwater, and construction of dams and weirs. However the most significant factor altering hydrological processes in the wheatbelt has been the replacement of perennial deep-rooted native vegetation with shallow rooted annual crops and pasture.

#### *Secondary Salinity*

Annual crops and pastures use less water than native vegetation as a consequence of reduced rainfall interception, decreased evapotranspiration, and inability of winter crops to utilise summer rainfall. Changes to the water balance causes increased surface water runoff and increased infiltration of water through the soil profile to the underlying water table.

Increases in surface water runoff may enhance the transportation of water and sediments to lower parts in the landscape which in-turn contributes to erosion, sedimentation, and waterlogging (see following sections). Whilst an increased infiltration of rainfall to the underlying water table results in an upward movement of groundwater toward the surface. This process mobilises stored salts in the soil profile, transporting them to the root zone and soil surface. This results in deteriorations to vegetation health and changes to the soil structure, further enhancing waterlogging and secondary salinity (Cramer and Hobbs 2002). Furthermore, once groundwater is within one to two metres from the surface then the process of capillary action and evaporation further concentrates salts within soil or groundwater (Tille *et al.*, 2001).

Roads and other infrastructure are also susceptible to the impact of rising groundwater tables and secondary salinity (Clarke *et al.*, 2002), however they can also act as physical barriers to surface water flow and in turn enhance the accumulation of surface water and recharge of underlying aquifers exacerbating the affects of secondary salinity.

#### *Waterlogging*

Water logging is defined as a "soil condition whereby excess water in the root zone inhibits gas exchange with the atmosphere" (McFarlane et al., 1989). Waterlogging can occur due to a number of factors such as the presence of a shallow water table, compaction of a soil profile, and the expression of water near perched groundwater systems. At sites where water logging has gradually become the dominant condition, plants have adapted their root morphology and will often flourish. Other species however may tolerate only short periods of waterlogging or may be hyper-sensitive to waterlogging. Waterlogging often occurs in sympathy with secondary salinity, thus further increasing the stresses upon the ability of a plant to uptake water and nutrients.

#### *Water repellence*

Water repellence occurs where surface soils become hydrophobic resulting in an uneven wetting pattern (Moore and Blackwell 2004). Water Repellent Soils (WRS) occur naturally and are caused by fungal and plant residues, with sandy soils being the most affected. WRS can also be induced by land management due to the influence that activities such as agriculture have upon organic carbon content (positive relationship) and fine mineral materials (negative relationship).

Repellent surface soils can reduce rainfall infiltration, increase evaporation, and increase surface water runoff and erosion (Chan and Heenan 1993). Each of these properties has significant impacts such as reduced agricultural productivity, loss of topsoil, loss of soil fauna, poor recruitment of native species, and increased volumes of surface water recharging the valley floor.

### Acidification

#### *Soil acidification*

Historically, a large proportion of the yellow sandy earths occurring throughout the eastern and north-eastern wheatbelt were naturally acidic. All soils are naturally susceptible to acidification however sandy soils are more prone to acidity due to their low buffering capacity. Since the clearing of vegetation and the advent of agricultural practices the distribution of acidic soils has increased (Moore *et al.*, 2004). Agricultural practices in particular have enhanced acidification of soils by continually removing or exporting trace elements. In many cases soil acidification can be overcome through treatments such as the addition of lime and trace elements.

The change of a soil from relatively neutral to acidic over time can result in the mobilisation of heavy metals such as aluminium and manganese. A pH of <4.5 is considered a threshold for aluminium toxicity. When a soil becomes acidic, crop yields are commonly reduced (Schoknecht 2004). Currently the simplest method available for

assessing the acidity is to physically analyse soil samples. Although this is relatively straightforward (Moore *et al.*, 2004), obtaining and processing samples is time consuming.

### *Ferrolysis of Clays*

Clay-rich soils located on the valley floors, and in wetlands in the wheatbelt are often subject to alternate periods of wetting and drying. A number of complex microbial and chemical reactions can occur such as ferrolysis (Schoknecht 2004). Ferrolysis is the cyclic process where during the wetting phase, Ferric Iron ($Fe^{3+}$) is reduced to Ferrous Iron ($Fe^{2+}$) and cations are displaced from the clay humus complex (Schoknecht 2004). This process is followed by oxidisation during the drying phase when the soil dries again and may result in increased acidity, which in turn can accelerate the weathering process (Little and Gilkes 1982).

It is unclear whether acidic surface water often found in the valley floors in wheatbelt regions is a result of these processes or other factors such as rising groundwater tables, groundwater expressions, or the transport of acidified groundwater via deep drainage networks (Schoknecht 2004).

### *Groundwater Acidification*

As with acidic soils, acidic groundwater naturally occurs throughout much of the wheatbelt region in Western Australia (Mulcahy 1967). The development of acidic groundwater is thought to be caused through the process of ferrolysis (as above), and occurs where groundwater systems lay near weathered rock containing pyrite ($FeS_2$) (Ball 2005). The delineation between natural and human induced occurrences of acidic groundwater is difficult to determine because of the complexity of chemical reactions within the soil regolith.

For example, groundwater acidification was investigated in a study conducted in the Lake Muir-Unicup Recovery Catchment near Manjimup (Smith *et al.*, 2004). Groundwater in this area seasonally intercepts an iron-rich and organic-rich regolith. As a consequence of seasonal groundwater level fluctuations, oxidising processes occur during the dry phase (pH decreases), and reducing processes (pH rises) during the wet phase of the groundwater cycle. This process leads to acidification of groundwater. Groundwater sampled from the region was found to contain high levels of Cadmium (Cd), Chromium (Cr), Copper (Cu), Nickel (Ni), and Zinc (Zn). This study not only highlights the complexity of processes occurring within groundwater systems but also emphasises the potential implications of acidic groundwater being expressed in the landscape, in particular on wetland environments that intercept acidic groundwater tables.

In addition to the mobilisation of heavy metals, discharging groundwater may be iron-rich. Upon oxidisation iron oxides may precipitate from solution resulting in the 'plugging' of soil pores. When this occurs in hillside seeps, such as at the break of slope or adjacent to dolerite dyke intrusions, seeps often migrate upslope causing further land degradation (Schoknecht 2004). Acidic groundwater may also lead to damage to infrastructure such as roads and buildings (Hunt and Patterson 2004).

## Nutrient Cycles

### *Eutrophication*

In the nutrient-poor soils of the Western Australian wheatbelt, broad-acre crops require regular application of nutrients to ensure adequate growth. Following application, these nutrients may be transported by wind and water away from the site of application. Wetlands located in the lowest parts of the catchment often become receiving points for nutrients. Consequently these may become nutrient enriched and with favourable climatic conditions result in increased primary productivity (i.e. proliferation of large masses of phytoplankton and benthic algae) (Boulton and Brock 1999). Some species of these produce toxins which may directly impact upon the biodiversity within the wetland. In addition, once growth has subsided there is typically a period of decomposition which results in a depletion of oxygen, again impacting upon the aquatic flora and fauna. These processes are characteristic of a nutrient enriched, or eutrophic wetland.

### *Climate Change*

Given the significant potential adverse effects of climate change, the issue has been the subject of intense international and national focus. Responses to climate change involve a number of global, national, State and local level initiatives including, for example, the United Nations Framework Convention on Climate Change, the Kyoto Protocol, and the National Greenhouse Strategy[9]. On a national level, 'loss of climatic habitat caused by anthropogenic emissions of greenhouse gases' has also been identified as a key threatening process under the Environmental Protection Biodiversity Conservation (EPBC) Act. However, given actions underway or planned as part of national responses to climate change[10], a Threat Abatement Plan has not been prepared for this threatening process. At State level, the *Western Australian Greenhouse Strategy* (Western Australian Greenhouse Taskforce 2004) facilitates fulfilment of the State's

9 These initiatives are described in more detail in the Western Australian Greenhouse Strategy (Western Australian Greenhouse Taskforce 2004).

10 e.g. the National Greenhouse Strategy and the National Biodiversity and Climate Change Action Plan 2004-2007.

responsibilities regarding national and international agreements regarding climate change.

The issue of predicting and responding to climate change is complicated by substantial knowledge deficits and uncertainty. These are numerous but include, for example, uncertainty regarding the interplay of natural climate variability (including phenomena such as the El Niño Southern Oscillation and related weather systems) and human induced climate change. There is also uncertainty regarding future levels of global greenhouse emissions, the capacity of oceans and biological systems to absorb carbon dioxide or other greenhouse gases and the global and regional atmospheric and ocean system responses to these chemical changes. Still less certain are region-specific impacts of predicted changes to particular climate factors and natural environments. In view of these uncertainties, climate change management strategies need to:

- use adaptive management principles that generate a better understanding of the interaction between species/community resilience and climate factors;
- be flexible to allow use of better knowledge as it is generated;
- promote the resilience of species/communities to climate change by limiting or reducing those pressures over which we have some management control;
- manage for uncertainty (e.g. by increasing the conservation reserve system as appropriate and providing buffers, corridors and refugia); and
- monitor changes to species/community structure and representation over time.

In recognition of the need to better understand climate variability and change and facilitate informed adaptation strategies, actions aimed at reducing knowledge deficits are at the forefront of both National and State Greenhouse Strategies. *The Western Australian Greenhouse Strategy* provides for the continuation of the Indian Ocean Climate Initiative (IOCI)[11] as a key method of doing this. The Western Australian Greenhouse Strategy also includes specific provision for investigation into the biodiversity impacts of future climate change. More specifically, under the strategy CALM has commenced work on actions requiring it to:

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

At individual reserve level, the implementation of strategies in this plan aimed at reserve creation, pest animal and weed control, fire management, and re-introduction programs, will help improve the resilience of species and ecosystems and hence decrease their vulnerability to climate change. In addition, strategies in this plan aimed at rehabilitation of vegetation and reducing overgrazing by introduced and native herbivores will also assist in contributing to climate change management initiatives by increasing the amount of carbon that is sequestered in the land – promoting an increase in vegetation cover helps to reduce contributions to atmospheric concentrations of carbon dioxide. As discussed in the preamble to this chapter, the management of climate change requires an adaptive management approach, where management policies and practices are continually improved by learning from the outcomes of operational programs, research and monitoring. There is an acknowledged level of uncertainty about what implications climate change has for the planning area and which policies and practices are best to manage this.

## IMPACTS OF PROBLEM PLANTS (INTRODUCED AND NATIVE)

### Environmental Weeds

Environmental weeds are invasive plant species, not endemic to an area, that establish themselves in natural environments and proceed to adversely modify natural processes. Biological invasions are one of the most important drivers of biodiversity change (Vitousek *et. al.* 1997).

Environmental weeds have the potential to reduce the abundance of native species (plant and animal), contribute to species extinction and alter ecosystem level processes and genetic and evolutionary change (Vitousek *et. al.* 1997). They can also harbour pests and diseases and increase fire hazard.

The direct cost of environmental weeds to agricultural industries is estimated at $3.3 billion per annum nationwide. In Western Australia's agricultural systems, weed control costs have been estimated at 20 per cent of production costs and can be significantly higher in some instances. There is greater investment in agricultural weed control than environmental weed control, with farmers investing in weed control to allow, and increase, agricultural production.

Values of weed free natural environments remain unpriced in the market system and therefore fewer resources are allocated to the control of environmental weeds as compared to agricultural weeds (Mason *et al.*, 2005).

An integrated approach to environmental weed management was developed in the Environmental Weed Strategy for Western Australia (CALM, 1999). As part of

11 A long-term cooperative research program involving the Bureau of Meteorology, CSIRO and Western Australian Government departments, including CALM)

this strategy, environmental weeds are rated in terms of their environmental impact on biodiversity. The criteria used to determine the rating for each weed are:

- *Invasiveness* – ability to invade bushland in good to excellent condition or ability to invade waterways;
- *Distribution* – wide current or potential distribution including consideration of known history of distribution elsewhere in the world; and
- *Environmental Impacts* – ability to change the structure, composition and function of ecosystems and in particular an ability to form a monoculture in a vegetation community.

The CALM Policy Statement (Draft) Environmental Weed Management is used in conjunction with the Environmental Weed Strategy (EWS) to guide the approach and priority setting for the control of environmental weeds on lands and waters managed by the Department. Priorities for action are to first control any weed impacting upon threatened or priority flora, fauna or ecological communities, or weeds occurring in areas of high conservation value. The next priorities are to address high, moderate, mild and then low EWS-rated environmental weeds in decreasing priority as resources allow.

Landholders, including CALM, are legally responsible for eradicating plants declared under the *Agriculture and Related Resources Protection Act 1976*, although the Act does preserve CALM's right to decide priorities and the level of control according to resources.

There were 34 weed species recorded in the BMNDRC (Table 1). Three of these have a high rating in CALM's Environmental Weed Strategy (1999), and seven are listed under the *Agriculture and Related Resources Protection Act 1976*. Fifteen (of the 34) were identified by landholders as being the most important (CALM and Colmar Brunton 2005).

State legislation and policies on weeds, such as the *Agriculture and Related Resources Protection Act 1976* (ARRP) provide wide powers for the detection and eradication of pests. Landholders and agencies with land management responsibilities (e.g. CALM) are required by legislation to manage 'declared' plants on their individual properties.

Weeds can be transported by a number of vectors. In the BMNDRC, there is the potential for weeds to be introduced by:

- using exotic perennial species in agriculture;
- contaminated machinery;
- contaminated agricultural stock (e.g. wool contamination; seeds in faeces);
- use of inappropriate species in revegetation;
- the faeces of native animals, including seed eating birds;
- wind-borne spores;
- garden escapees;
- wind-blown light-weight seed;
- water (e.g. surface water run-off); and
- translocation by earthworks (e.g. shifting soil from one farm/paddock to another during earthworks construction or by contaminated soil moved via trucking from one location to another);

In addition, "the technology for genetically engineered organisms is now available, and the possibility that genetically modified plants, micro-organisms and even animals may be released into the wild is real. Their likely impact on biological diversity is not yet known, although it is reasonable to assume that at least some will behave like invasive alien species" (Saunders *et al.*, 2000).

Currently, only a few landholders in the BMNDRC actively control weeds in remnant vegetation (CALM and Colmar Brunton 2005). The majority of weed control involves spraying. Barriers mentioned by landholders to managing weeds in remnant vegetation included financial cost, time and difficulty in accessing areas.

## IMPACTS OF PROBLEM ANIMALS (INTRODUCED AND NATIVE)

Problem animals in the wheatbelt consist of both introduced animals (includes species that have become established as wild or naturalised populations), and native species that have increased in numbers subsequent to European settlement. Problem animals have the potential to seriously impact on natural systems and human-use values through direct effects such as predation, habitat destruction, competition for food and territory, introduction of disease, and soil erosion. Examples of introduced animals include foxes (*Vulpes vulpes*), rabbits (*Oryctolagus cuniculus*), and cats (*Felis catus*), and native species including the western grey kangaroo (*Macropus fuliginosus*), the little corella (*Cacatua sanguinea*), the western long-billed corella (*Cacatua pastinator*), and pink-and-grey galah (*Cacatua roseicapilla*).

An objective of the Department is to achieve sustained strategic management of problem animals on DEC-managed lands as per the Department's Policy Statement (Draft) 'Management of Pest Animals'. The Department also has a responsibility to control declared animals on the lands it manages under sections 39 to 41 of the *Agriculture and Related Resources protection Act 1976*.

There are 16 introduced and/or problem animals in the BMNDRC (Table 2).

***Table 1**. Weed Species found in the BMNDRC as recorded in the *CALM Landholder Survey and by CALM staff. Their rating under the Environmental Weed Strategy (CALM, 1999) is given (from high to low – high is indicated with shading), and their status under the* Agriculture and Related Resources Protection Act 1976. *Note, that landholders are required by legislation to manage 'declared' plants on their individual properties.*

| Species | Common name | EWS Rating | Declared under the ARRP Act |
|---|---|---|---|
| **Eragrotris curvula* | African lovegrass | High | No |
| *Typha orientalis* (confirmation required) (Aust. Native) | Bull rush; broad-leaved cumbungi | High | No |
| *Moraea flaccida* | One-leaved cape tulip | High | Yes |
| *Moraea miniata* | Two-leaved cape tulip | Moderate | Yes |
| *Juncus acutis* | Sharp rush | Moderate | No |
| **Arctotheca calendula* | Capeweed | Moderate | No |
| **Cynodon dactylon* | Couch | Moderate | No |
| **Hordeum leporinum* | Barley grass | Moderate | No |
| **Lolium rigidum* | Annual ryegrass | Moderate | No |
| **Mesembryanthemum crystallinum* | Iceplant | Moderate | No |
| **Avena barbata* | Bearded oat | Moderate | No |
| **Avena fatua* | Wild oat | Moderate | No |
| **Raphanus raphanistrum* | Wild radish | Mild | No |
| **Carthamus lanatus* | Saffron thistle | Low | Yes |
| **Emex australis* | Doublegee | Low | Yes |
| **Chondrilla juncea* | Skeleton weed | Low | No |
| Citrullus lanatus | Afghan melon | Low | No |
| *Brassicaceae family* | e.g. canola | Low | No |
| *Lupinus angustifolius* | NZ blue lupin | Low | No |
| *Lupinus cosentinii* | WA blue lupin | Low | No |
| *Polygonum aviculare* | Wireweed | Low | No |
| **Echium plantagineum* | Paterson's curse | TBA | Yes |
| **Opuntia stricta* | Prickly pear | No record | Yes |
| *Tamarix aphylla* | Athel pine | No record | Yes |
| **Bromus* spp. | Brome grass | No record | No |
| *Atriplex undulata* | Wavy leaf saltbush | No record | No |
| *Chamaecytisis palmensis* | tagasaste | No record | No |
| *Medicargo* spp. | e.g. medic pasture species | No record | No |
| *Trifolium* spp. | e.g. clover pasture species | No record | No |
| *Pennisetum setaceum* | Fountain grass | No record | No |
| *Thinopyrum elongatum* | Tall wheat grass | No record | No |
| *Acacia iteaphylla* (Aust. Native) | Flinders Range wattle | No record | No |
| *Eucalyptus camaldulensis* (Aust. Native) | River red gum | No record | No |
| *Solanum hoplopetalum* (Aust. Native) | Afghan thistle | No record | No |

## IMPACTS OF DISEASE

### Disease caused by *Phytophthora spp*

The most significant disease threat to plants within the south-west botanical provenance is 'dieback' caused by the microscopic pathogen; *Phytophthora cinnamomi*. Areas at risk receive greater than 600mm per annum rainfall or are water gaining sites in the 400–600mm per annum rainfall zone (CALM 2003). The current known distribution of *Phytophthora cinnamomi* is from the south in the Fitzgerald River National Park, Shannon and D'Entrecasteaux national parks and extending north to Mt Lesueur National Park, with only a limited distribution into the wheatbelt (Sage et al., 2004). The most eastern

***Table 2**: Introduced and other problem animal species found in the BMNDRC as recorded in the CALM Landholder Survey 2003 and Invertebrate Survey 2004.*

| Species | Common name | Declared under the ARRP Act |
|---|---|---|
| *Oryctolagus cuniculus* | Rabbit | Yes |
| *Sus scrofa* | Feral pig | Yes |
| *Cacatua pastinator* | Western long-billed corella | Yes |
| *Cacatua sanguinea* | Little corella | Yes |
| *Cacatua roseicapilla* | Galah | Yes |
| *Canis lupis familiaris* | Feral dog | Yes |
| *Macropus fuliginosus* | Western grey kangaroo | Yes |
| *Dromaius novaehollandiae* | Emu | Yes |
| *Apis mellifera* | Feral bee | No |
| *Artemia parthenogenetica* | Brine shrimp | No |
| *Cherax destructor* | Freshwater crayfish (yabbie) | No |
| *Daecelo novaeguineae* | Laughing kookaburra | No |
| *Felis cattus* | Feral cat | No |
| *Mus musculus* | House mouse | No |
| *Platycerus zonarius* | Twenty-eight parrot | No |
| *Rattus rattus* | Black rat | No |

known extent of *Phytophthora cinnamomi* in the Northern Agricultural Region is near Eneabba within areas of remnant vegetation, such as the Beekeepers Nature Reserve.

### Other diseases affecting plants

Rusts are the second most frequent pathogens encountered on native plant taxa in south-western Australia (Shearer 1994). The gall rust (*Uromycladium tepperianum*) commonly affects *Acacia* species. Armillaria root rot (*Armillaria luteobubalina*) is widespread and infects a wide range of plants from coastal dune vegetation to woodlands of the south-west of WA. Disturbance events usually create wounds on plants thereby creating an opening for *A. luteobubalina* to readily colonise and infect. Factors that stress trees, such as drought, flooding, compaction of soil etc, weaken their defence systems and increase the chances of the disease developing. There is no simple method for controlling Armillaria, therefore prevention is the best treatment. Hygiene is essential for ensuring the disease is not spread from infected sites to uninfected sites.

*Botryosphaeria ribis* and *Cryptodiaporthe melanocraspeda* appear to be two of the most common aerially dispersed canker-causing fungi, and infect plant hosts mainly from the Proteaceae and Myrtaceae families (Shearer 1994). These mostly endemic pathogens can have substantial localised impact and in some cases even kill plant hosts. Cryptodiaporthe canker has decimated *Banksia coccinea* stands throughout the southern south-coast (Shearer 1994).

Mundulla yellows is a little known and only recently described disease with potential to seriously affect a number of our native plant species, revegetation on farms and possibly some eucalypt plantations. Mundulla yellows is a progressive slow dieback and yellowing disease of many eucalypts, now suspected of being caused by a virus-like agent. Advances in Mundulla Yellows research during recent years has opened the way towards identifying the cause of the disease. Until more specific knowledge is available, general plant hygiene practices will help minimise the risk through human activity of spreading diseases from plant to plant and into new areas.

## DETRIMENTAL REGIMES OF PHYSICAL DISTURBANCE

### Fire

Although well adapted to surviving disturbance by fire, regeneration of heath and shrub communities is highly rainfall dependant, with potential fire return intervals reported as ranging from three to 25 years in these fuel types. Fire is an integral part of the reproductive cycle of many of the plant communities of the south west of Western Australia and remaining areas of scrub heath in the catchment are likely to senesce in the absence of occasional fires (Bradstock and Cohn 2002; Daniel 2003).

Other vegetation types are less likely to experience fire. Salmon gum and Gimlet woodlands are characterised by a sparse understorey and a relatively widely spaced overstorey (although this vegetation structure may be the result of land management practices, rather than the natural state of this community). The passage of fire in these fuels is possible only under extreme conditions (Newbey *et al.*, 1995). The presence of mature Salmon gum or Gimlet in a community suggests a long period of fire exclusion although, where *Eucalyptus* species adopt a mallee habit, the prevalence of fire and the survival rate of individuals are both increased.

The fire regime of mallee vegetated areas is characterised by an approximately decadal cycle of large fires (Bradstock and Cohn 2002) followed by resprouting of trees from

epicormic buds protected beneath the soil. Halophytic communities that fringe many of the salt lakes and drainage lines throughout the wheatbelt will not carry fire due to the paucity, and succulent nature of fuels (Newbey et al., 1995).

Where fire has been excluded from the landscape the consequence is usually an increase in the fire interval, accumulation of large fuel loads and the occurrence of infrequent, but highly intense, fires. Impacts can range from senescence in vegetation types dependent upon fire as part of their reproduction and renewal cycle to severe fires with sufficient intensity to damage the root stock of resprouter species or the seedbed of reseeder species thereby reducing the potential for natural repopulation of an isolated remnant. Similarly, severe fires may be damaging to fauna species resident in a burnt remnant. A hot fire may destroy food sources and the destruction of habitat will increase the rate of predation. The destruction of mature trees with hollows in the cleared and fragmented wheatbelt landscape has serious implications for hollow dependent fauna, given the time taken for trees to form suitable hollows.

### Drought

Drought is a common and natural occurrence in many parts of Australia. Drought occurs during prolonged dry periods, when there is not enough water for the normal needs of users (this includes 'natural' and human demands). There are different levels of drought depending on the cumulative rainfall over periods of three month or more months. Serious rainfall deficiency occurs when rainfall is between five to 10 per cent of lowest recorded rainfall for the corresponding period. Severe rainfall deficiency occurs when rainfall is among the lowest five per cent for the period (Australian Bureau of Statistics 2005).

The impacts of drought are probably the most severe in agricultural areas and can disrupt cropping programs and reduce breeding stock numbers. Drought impacts are also felt at all levels of the ecosystem. Drought is a natural influence on ecosystems and should not be seen as a problem. However, impacts of drought can be exacerbated in areas where native vegetation is highly fragmented and comparatively small in area and consequently more susceptible to 'edge effects' such as wind and solar radiation.

Drought can threaten plant and animal populations, particularly those that may be rare or at the limit of their distributions. The success of bird nesting and egg production and numbers of young produced by native mammals are lower during periods of drought, as is the amount of invertebrate biomass. Water quality can also be affected by drought. Wetlands and waterways (such as creeks, and rivers) often require fresh water inputs to flush accumulated salts, nutrients and sediments. Extended periods of drought can result in an increased impact of salinity and eutrophication of water bodies.

### Erosion

#### *Wind Erosion*

The loss of vegetation and structure makes soils susceptible to water erosion. Soil loss also reduces the organic material and seed store within topsoil. Thus reducing the long-term viability of native remnants and the potential for natural colonisation of fallowed land (Boshammer 2004). The deposition of eroded soils can also be problematic as channels may silt up and alter flow paths. This may lead to alteration of hydrology in lakes, possibly to the detriment of biodiversity.

Deposition of eroded soils from denuded paddocks can produce localised smothering of native vegetation and introduce weed seeds, particularly along edges of native vegetation, roadsides and fencelines.

#### *Water Erosion and Sedimentation*

The factors that determine the susceptibility of a soil to water erosion are soil type, landscape position, slope, vegetation cover, soil structure, water repellence, and rainfall (quantity and intensity). Water erosion occurs at the point where the surface soil horizon reaches saturation and continued rainfall results in surface water flow. Soils considered as a high risk to water erosion are soils that are water repellent, denuded of vegetative cover, low organic content, high fine sand content and those soils already waterlogged.

Water erosion across the landscape can result in a transfer of soil, salt and nutrients to lower elevations in the landscape, particularly from shedding landscapes, such as laterite breakaways. This is a natural process however this water erosion and sedimentation has been accelerated due to the clearing of native vegetation, and changes to land use.

The increased sediment loads deposited in the lower landscape positions can have a number of impacts. These include change of surface water flow patterns, deposition of salt, and clogging of culverts and road drainage structures. Each of these may significantly impact upon surface water movement, waterlogging and therefore the development of secondary salinity. In addition, the redistribution of nutrients and organic-rich soil may contribute to eutrophication of water bodies (see previous sections for more information).

### Cyclones and floods

Wind damage may occur in association with severe thunderstorms, localised 'tornados' or cyclonic activity.

These events are relatively uncommon and, generally, do not result in widespread damage to native remnants, although individual plants in remnants may succumb. Deleterious effects are more likely to occur as a result of episodic high rainfall events.

A less frequent but more dramatic physical disturbance is flooding. Flood events can cause widespread waterlogging, flush saline water through the system, redistribute salt loads and dramatically erode the landscape. Prolonged inundation of low-lying areas in saline drainage channels can initiate extensive plant deaths, from which recovery may be poor. At the same time, in other areas of the landscape, flooding can promote significant regeneration of vegetation including woodland species such as york gum, salmon gum and morrel.

## Impacts of Pollution

### *Agricultural chemicals*

The Department of Environment, as part of the *Contaminated Sites Management Series* has prepared a list of common contaminants associated with various land uses. Table 3 presents a list of the common contaminants associated with agriculture (Department of Environment 2004). Arguably the most common contaminants are hydrocarbons, associated with fuels (i.e. diesel, petrol and oil), herbicides, pesticides, nutrients and heavy metals. The use of pesticides, herbicides and hydrocarbons are discussed below.

### *Herbicides and Pesticides*

After World War II, as technology developed and became more affordable, the use of petrochemical fertilisers increased significantly. The development of other chemicals soon followed. These included organo-chlorine pesticides (OCPs) such as DDT, lindane chlordane, dieldrin, aldrin, and heptachlor. Throughout developed countries such as Australia OCPs became popular because they were both highly effective and persistent.

The structure of OCPs makes them insoluble in water and highly soluble in fats, therefore having the ability to bio-accumulate in an organism. The accumulation of OCPs in organisms, particularly those at the top of the food chain, has been found to have a profound effect on the fertility and mortality of all animals (Carson 1962; Falkenberg et al. 1994). With this in mind, there is considerable attention paid to the impacts of OCPs upon human heath. Consequently the sale and use of DDT in Australia was

***Table 3**. List of common contaminant types associated with activities, industries and landuses associated with agriculture (Department of Environment 2004).*

| Industry, activity, landuse | Common contaminant types |
|---|---|
| Fertiliser manufacture or storage | Calcium phosphate, calcium sulphate, copper chloride<br>Sulphur, sulphuric acid<br>Molybdenum, selenium, boron, cadmium<br>Nitrates, ammonia |
| Intensive agriculture (including the blending and mixing of herbicides, fungicides, pesticides and fertilisers) | Carbamates<br>Organochlorine pesticides<br>Organophosphate pesticides<br>Herbicides (e.g. triazine, atrazine)<br>Nitrates<br>Metals (e.g. aluminium, arsenic, cadmium, copper, iron, lead, magnesium, potassium)<br>Nutrients (e.g. nitrogen, phosphorus)<br>Sulphur |
| Livestock dip or spray race operations and/or sheep and cattle dips | Metals (e.g. arsenic)<br>Carbomates<br>Organochlorine pesticides<br>Organophosphate pesticides<br>Herbicides<br>Synthetic pyrethroids |
| Storage facilities (e.g. diesel fuel storage) | Total petroleum hydrocarbons (TPH's)<br>Monocyclic aromatic hydrocarbons (e.g. benzene, toluene, ethylbenzene and xylene)<br>Metals<br>Phenols<br>Chlorinated hydrocarbons (e.g. trichloroethylene)<br>Oil and grease |

ceased in 1987 and the remainder of OCPs ceased in 1992 (Radcliffe 2002).

OCPs have a long half-life (i.e. to breakdown to half of the original level). For example, dependant upon soil properties, the half-life of DDT and Dieldrin can vary from 10 to 50 years, and heptachlor and chlordane between seven to 10 years (Ambrose 2000).

The implementation of soil conservation methods, such as no-till, has a number of benefits such as increased retention of soil structure and reduced loss of topsoil. Adoption of these practices has also contributed to an increased use of chemicals (Radcliffe 2002). The chemicals used currently in broad-acre cropping are listed in (Table 4). The list was compiled by contacting landholders, agency staff, and local agronomists. It provides a guide only as it is subject to variation due to factors including cropping rotation, type of farming equipment, soil type and farming practices. Specific information pertaining to each of these chemicals such as the toxicological information is readily available from the suppliers, thus is not covered in detail within this section.

*Other pollutants*

This section deals specifically with contamination from hydrocarbons (fuel and oil), cleaning agents, and disposal of chemical drums.

Fuels, in particular diesel is stored in moderate quantities (<10,000L) on farms. The majority of diesel tanks on farms are on elevated platforms and use gravity to deliver fuel. There is potential for fuel spills to occur, either from day-to-day filling operations or from the development of a leak. The construction of bunded compounds reduces the impacts of fuel spills, should they occur. Australian Standards have been developed for such purposes *(AS1940-2004 The storage and handling of flammable and combustible liquids)*.

Due to the impracticalities of returning farm machinery to the servicing agent, the majority of servicing and repairs occurs on-farm. Common pollutants resulting from these activities include waste oil, degreasing agents and other chemicals such as those found in water coolants. It is likely that historically, many landholders disposed of waste oil on their farms. Today it is expected that landholders dispose of their waste oil at the nearest landfill site or at one of a number of waste oil recovery stations.

With the advent of dependence of modern farming practices, large quantities of empty chemical drums are a waste disposal issue. Historically, many landholders disposed of chemical drums in or near salt lakes or buried or burnt them. Today this practice is considered environmentally unacceptable. The Department of Agriculture has produced guidelines (Guidance Note No.8) for appropriate disposal of empty chemical drums (Department of Agriculture 2002), however it is recommended that empty drums are disposed of appropriately and that collection initiatives such as the DrumMUSTER are used.

## IMPACTS OF COMPETING LAND USES

### Agricultural Impacts

#### *Soil structure decline*

*Surface soils*

The structure of surface soils (upper soil horizon, typically <10cm deep) is influenced by a number of factors such as the geology, relief, soil fauna, and overlaying vegetation. As a consequence of agricultural practices the physical and biological structure of surface soils has changed. Changes include the compaction of surface soils, loss of soil fauna (such as worms, termites and ants), reduced aeration, and loss of preferred pathways via deep root channels. These changes further lead to reduced infiltration and increased surface water runoff (see water erosion section above).

Soil fauna play an important role in maintaining soil structure, nutrient cycling, and competitive inhibition of pathogens (Roper and Gupter 1995). In contrast to old cropping methods, adoption of no-till methods have improved the structure of surface soils and viability of soil fauna (Chan and Heenan 1993). Stubble retention can also improve the health and diversity of soil fauna (Roper and Gupter 1995). Subsequently there needs to be greater emphasis on adoption of no-till cropping methods and retention of stubble to reduce the impacts associated with soil structure decline.

*Subsurface compaction*

Compaction layers form beneath surface soils as a consequence of vehicle movement, tillage practices, and stock movement (Needham *et al.*, 2004). Dense, relatively impermeable layers form in subsurface layers that may impede root extension through the profile, and can lead to perching of groundwater and reduced productivity. In addition these layers reduce access to nutrients and soil moisture and can increase the harmful effects of pathogens in topsoil (Needham *et al.*, 2004). In recognition of the impacts of subsurface compaction, many farmers undertake deep ripping, where the soil is mechanically ripped to depths often as high/or greater than 50cm deep.

Course to medium-grained soils with low organic carbon (< two per cent) are the most susceptible to subsurface compaction.

***Table 4**: Example of some of the types and application rates of synthetic chemicals currently used for broad-acre cropping in Western Australia*

| Crop type | Trade name | Active constituent | Group | Target species | Typical rate of application |
|---|---|---|---|---|---|
| **WHEAT pre-emergent weed control** | Triflur 480 | 480g/L trifluralin | D herbicide | Annual grasses and certain broadleaf weeds | 1,200mL/ha |
| | Logran | 750g/kg triasulfuron | B herbicide | Annual ryegrass, paradoxa grass and certain broadleaf weeds | 35g/ha |
| | Sonic 200EC | 200g/L cypermethrin | 3A insecticide | Controls a wide range of certain insect pests | 100mL/ha |
| **WHEAT post-emergent weed control (the selection of which chemicals to be used dependant upon weed type)** | Achieve | 400g/kg of tralkoxydim | A herbicide | Control of annual ryegrass and wild oats | 280–380g/ha |
| | Hoegrass | 500 g/L diclofop-methyl | A herbicide | Control of annual ryegrass and wild oats in wheat, barley, triticale and cereal rye | 750–1,000mL/ha |
| | Jaguar | 250g/L bromoxynil, 25g/L diflufenican | CF herbicide | Residual control of wild radish up to four weeks after application | 500mL/ha |
| | Tigrex | 250g/L MCPA (present as the iso-octyl ester), 25g/L diflufenican | F1 herbicide | Control of certain broadleaf weeds in winter cereals and clover | 500mL/ha |
| | L.V.E. MCPA | 500g/L MCPA present as the iso-octyl ester | 1 herbicide | Control of certain broadleaf weeds in cereal crops, grass pastures and grass seed crops | 500–800mL/ha |
| | Flowable Diuron | 500g/L diuron | C herbicide | Controls certain grass and broadleaf weeds | 200mL/ha |
| **LUPINS Pre-emergent** | Gesatop 600SC | 600g/L Simazine | C herbicide | Controls certain broadleaf weeds and grasses | 1,500mL/ha |
| | Gesaprim 600SC | 600g/L Atrazine | C herbicide | Selectively controls a wide range of weeds | 500mL/ha |
| | Roundup | 360g/L Glyphosate | M herbicide | Control against any annual and perennial broadleaf weeds and grasses | 1,000mL/ha |
| **LUPINS Post-emergent** | Brodal | 500g/L diflufenican | F herbicide | Control of certain weeds in clover-based pasture | 100mL/ha |
| | Aramo | 200g/L Tepraloxydim | A herbicide | Control of grass weeds in broadleaf crops | 300mL/ha |
| **CANOLA Pre/post-emergent** | Gesaprim 600SC | 600g/L Atrazine | C herbicide | Selectively controls a wide range of weeds | 400mL/ha |
| **CANOLA Post-emergent** | Aramo | 200g/L Tepraloxydim | A herbicide | Control of grass weeds in broadleaf crops | 300ml/ha |

*Edge effects*

Land clearing for agriculture has imposed artificial edges on habitat. These edges are the interface between remnant vegetation and land used for agricultural production. Native vegetation at, or near this interface experience greater extremes in temperature, stronger wind, increased light and also the effects of adjacent agricultural activities. The most prominent agricultural effects are those from weeds and the drift of synthetic herbicide, insecticide and fertilisers.

### *Constructed drainage*

*Deep drains*

Constructed drains are water management structures designed to provide a preferred pathway for the direction of surface and/or groundwater. Examples include WISALT banks, grade banks, level banks and deep drains. For the purpose of this report, only drains which are designed to intercept groundwater will be discussed. These will be given the broad name of deep drains, however it should be noted that many of the deep drains installed throughout the wheatbelt could arguably be considered as shallow drains as they are either not deep enough to intercept the groundwater table or they are poorly maintained and no longer perform as designed.

Deep drains are designed to intercept shallow (usually but not exclusively) saline groundwater occurring typically within three metres of the surface. This water is then transferred away from the area to a disposal point by means of gravity or mechanical pump. Consequently drains are commonly located in the valley floor and along natural drainage lines (De Broekert and Coles 2004). Through the removal of saline groundwater, these drains are thought to lower the local groundwater table thus removing stored salts and reducing waterlogging.

There are numerous studies evaluating the effectiveness of deep drains in removing water from agricultural land in the Western Australian wheatbelt. Examples include (Speed and Simons 1992), an unpublished study (R. Speed, *pers comm.*), and more recently there are studies by the Yarra Yarra Catchment Group (Regeneration Technology Pty Ltd 2004; Jolliffe and Mudgeway 2005) and the Department of Environment, under the Engineering Evaluation Initiative (EEI) (J. Byrne *pers comm.*). In more recent times, the impacts upon receiving environments is also gaining greater attention (Coleman and Meney 2000a; Coleman and Meney 2000b; Ali, *et al*. 2004; Hornbuckle et al. 2004).

The receiving environments for saline water discharge from deep drains are typically large naturally saline wetland systems, which occur along the valley floor of many catchments in the WA wheatbelt. Historically these areas were considered as having low cultural and biodiversity value. More recently though these systems are regarded as having a high biodiversity value due to the temporal and spatial variability of soil, vegetation, fauna, and water quality characteristics (Coleman 2001).

Large salt lake systems operate as evaporation basins for surface water and groundwater discharge. These areas may also act as buffers to flood events. By increasing the volumes of water being received by these wetland systems the buffering capacity may be reduced. Consequently, following large rainfall events there may be an increased chance of overflow from these terminal wetlands and an increase risk of waterlogging and secondary salinity on the surrounding vegetation. In addition, the water quality being exported from deep drainage systems is often hypersaline and in some cases may be acidic and contain high levels of heavy metals such as aluminium, manganese and iron (Ali *et al.*, 2004). Therefore playa lakes which are being used as evaporation basins for water from deep drains, which are already threatened by rising water tables, are at a greater risk of losing their biodiversity values.

### Recreation

There can be a variety of recreational usage of remnant vegetation and wetlands. Favoured pastimes in wetlands, depending on seasonal conditions, can include boating, water skiing, kayaking and nature based activities such as bird watching. Bush areas also provide opportunities for tourism, picnicking, wildflowers, bird watching, art and photography and a place for children to play.

While recreational usage of wetlands is generally of low impact and can exist comfortably with the aims of biodiversity conservation, vehicle use can be detrimental in some areas. For example, by disrupting wildlife, damaging vegetation, disturbing soil and potentially spreading weeds.

The opportunity for the community to utilise wetlands for low impact recreation can be seen as a way of developing more of an affinity with those wetlands, providing that damaging activities can be minimised.

### Urban development

Although the expansion of urban areas within the wheatbelt is limited, future urban development will be likely to have an impact on natural environments such as remnant vegetation and wetlands. Types of future urban development may include housing, expansion of infrastructure and industrial development. Reduction in size of bush remnants around townsites will reduce their resilience and viability in the longer term by increasing susceptibility to 'edge effects' such as increased

evaporation and solar radiation. In addition, disturbances associated with human activity may increase, for example weed invasion, pollution and deliberately lit fires. There are also likely to be negative impacts on wildlife from domestic animals such as dogs and cats.

*Land tenure*

Seventy-three per cent of remnant vegetation occurs on freehold land in the BMNDRC. When management of freehold land is sympathetic towards, and directly considers natural areas (i.e. remnant vegetation; wetlands), there is little need for an alternative regime, i.e. there is a high level of security for natural areas under current management. However, where management is unsympathetic, i.e. where enrichment and/or artificial disturbance is allowed in natural areas, then alternative management regimes will give the required security.

On freehold land, even when current management is highly secure for natural areas, there is no security over future management regimes. For example, when freehold land changes ownership, the new owner(s) may view a well-managed natural area as an opportunity to exploit for its short-term grazing value.

The Landholder Survey in the BMNDRC recorded that a large percentage of remnant vegetation was fenced, but very few of these areas were actively managed for conservation, e.g. weed control, fire management for conservation, feral animal control, establishing revegetation buffers to minimise the impact of adjacent agricultural practices).

## IMPACTS OF COMMUNITY VALUES

For many people, biodiversity conservation is an abstract idea disconnected from their lives and well being. Therefore it is important to describe the human values of biodiversity so that people understand its importance to them personally. Without such linkages, there would be little support for expending human resources-financial or otherwise-on conservation (Wallace *et al.*, 2003).

In the wheatbelt natural biodiversity contributes to the following human values:

a. consumptive use values;
b. productive use values;
c. opportunity values;
d. ecosystem service values;
e. amenity values (including aesthetic values);
f. scientific and educational values;
g. recreational values; and
h. spiritual/philosophical values.

Despite the ubiquity of saline wetland systems in the agricultural zone of Western Australia, comparatively little is known about their ecology. Recent research by Keighery *et al*. 2004 has gone some way to addressing this knowledge gap, but significantly more work is required before an adequate level of understanding of these systems will be reached. If researchers currently understand little of the functioning of saline wetland systems, it is reasonable to generalise that the general public understand less.

The worth of biodiversity conservation in relation to the wetlands is often underestimated by members of the community who may be unaware of the deleterious effects of secondary salinisation or the effect of land degradation on the range of biota that utilise naturally saline lakes.

Recovery catchments provide excellent opportunities for the Department to provide education to members of the public on the value of saline wetland systems and how to manage land to protect them.

## INSUFFICIENT RESOURCES TO MAINTAIN VIABLE POPULATIONS

Ensuring there are sufficient resources (e.g. food/nutrients, water, oxygen, shelter and access to mates) is fundamental to persistence of species (plants and animals). Given the agricultural zone of WA has vastly changed since European settlement; one of the most threatening agents to species persistence is lack of habitat, or suitable habitat. Many species are thought to be still in a state of population decline, despite the physical area of habitat more-or-less staying the same for at least the last two decades. Substantially reduced species population sizes are widely acknowledged as being a major step towards species extinction. Perhaps in the short to medium term, a particular species may appear unaffected by a reduced population size. However, the natural variability in environmental conditions is likely to cause further incremental population reduction over time, and thus increased closeness to extinction.

The extent of native vegetation in the agricultural zone has decreased by up to 95 per cent in some cases, since European settlement. The BMNDRC has had about 87–88 per cent of its native vegetation removed for agriculture. It's reasonable to assume that this degree of change (removal of resources) is going to have major implications on population viability. In particular, those species at greatest threat will be the specialists, the less competitive creatures, the reluctant travellers, the non-generalists.

# APPENDIX 14: COMMUNICATIONS PLAN

## PURPOSE

The purpose of the communication plan is to establish a program of public participation that will assist in achieving the operational goal.

## VISION

The vision for the communications plan is to have, by 2010, 'improved community awareness, appreciation and understanding of the biodiversity assets at risk from hydrological change, and optimised participation in their protection.'

## STAKEHOLDERS

There is a wide range of stakeholders that are engaged in activities that influence management of the natural resource base in the Buntine-Marchagee catchment. See Appendix 3 –stakeholders and their responsibilities

## KEY MESSAGES

An information, education and interpretation program is essential to achieve the operational goal of the BMNDRC.

In this Communications Plan, there will be a range of strategies to raise awareness and improve the communities understanding of the biodiversity assets of the BMNDRC and the processes that are threatening those assets (Table 1). In addition, a suite of different public participation tools and techniques will be used to communicate these objectives (Table 2).

## IMPLEMENTATION

The community have had the opportunity to be involved in the BMNDRC Project and the development of the Recovery Plan from the outset when an invitation to nominate to join the Steering Committee was issued. The Steering Committee is made up of key stakeholder groups, with more than half local landholders. Other stakeholders include catchment groups, private industry, the Department of Agriculture, the Department of Environment, CSIRO, Local Government and researchers.

All landholders have had the opportunity to provide their perspective on a range of issues/aspects regarding the Recovery Catchment through participation in the Landholder Survey (CALM & COLMAR BRUNTON, 2005). The survey provided an indication of landholders interested in implementing landcare and natural resource management works on their properties.

*The Buntine-Marchagee News* is used to provide information on past, present and future planned activities of the Recovery Catchment Project and general information on biodiversity and natural resource management. It is distributed to all landholders in the catchment and to other community stakeholders. It has provided a means of reaching a large and diverse audience and offers potential to influence attitudes in the long term.

Other documents and electronic products produced by the project, that has often involved collaboration with other agencies and researchers, are specifically targeted resources for use/reference by CALM and landholders, products include the Drill Report, Soil Landscape Mapping, Landscape Design for Bird Conservation, Recovery Catchment Surface Water Plan, Wetland Invertebrate Fauna Monitoring Reports, and, for those landholders who participated in the BMNDRC Landholder Survey, an up-to-date 1:20,000 Orthophoto base map of their property-which can be used for mapping new farm management activities.

The effective implementation of the recovery plan will depend on the development of a shared vision between CALM, landholders and the wider community that encompasses awareness, appreciation and understanding of the biodiversity assets at risk from threatening processes and a commitment to participate in their protection.

***Table 1**: Communication strategies to raise awareness and improve community understanding of biodiversity values of the BMNDRC and associated threatening processes.*

| Biodiversity issue | Communication objectives | Communication strategies | Primary target audiences* | Partners | Performance indicator |
|---|---|---|---|---|---|
| **Altered biogeochemical processes** | Improve community understanding of hydrology, acidification, altered nutrient cycles, climate change in the BMNDRC. | 1. Newsletter<br>2. Field day<br>3. Workshops<br>4. Technical reports<br>5. Joint planning<br>6. Displays<br>7. Interpretative materials (signage, brochures) | Landholders (1,2,3,4,5,6,7 )<br>Community Groups (1,2,3,4,5,6,7)<br>LGAs (1,2,3,5,7) | DAFWA<br>Universities<br>CRC for Plant-based Management of Dryland Salinity<br>NACC<br>MCC<br>CSIRO<br>Land & Water Australia | 1. Increased knowledge of hydrology, acidification, altered nutrient cycles, climate change<br>2. Adoption of integrated property water management plans within the catchment targeted at high priority biological assets. |
| **Impacts of problem plants (Environmental Weeds)** | Improve community understanding of problem plants (environmental weeds) in the BMNDRC. | 1. Newsletter<br>2. Field day<br>3. Joint planning<br>4. Education packages<br>5. Technical reports<br>6. Interpretative materials (signage, brochure) | Landholders (1,2,3,4,5)<br>LGAs (1,2,3,4,5,6)<br>Community Groups (1,2,4)<br>General Community (2,6)<br>Schools (4,6) | DAFWA<br>Non-government organisations<br>NACC<br>MCC<br>NHT<br>Universities<br>TAFE | 1. Preparation of weed control programs for the BMNDRC on a priority basis that identifies weed species present, size of infestation, rehabilitation requirements and level of threat to biodiversity assets.<br>2. Promotion of integrated weed control across land tenures in catchment i.e. farms, road and rail reserves.<br>3. Increased community knowledge of invasive weed species. |
| **Impacts of introduced and problem animals** | Improve community understanding of introduced and problem animals in the BMNDRC. | 1. Newsletter<br>2. Field day<br>3. Education packages<br>4. Technical reports<br>5. Joint planning<br>6. Interpretative materials (signage, brochure) | Landholders (1,2,3,4,5,6)<br>LGAs (1,2,3,5,6)<br>Community Groups (1,2,3,4,5)<br>General community (2,6)<br>Schools (3,6) | DAFWA<br>NACC<br>MCC<br>NHT<br>Universities<br>Community Groups<br>Non-government organisations | 1. Facilitation of integrated animal control and monitoring programs across different land tenures in the catchment<br>2. Establishment of partnerships between community and agencies/researchers to find solutions for mitigation of detrimental impacts of problem fauna in biodiversity. |

* Numbers relate to the type of communication strategy used in the previous column.

| Biodiversity issue | Communication objectives | Communication strategies | Primary target audiences* | Partners | Performance indicator |
|---|---|---|---|---|---|
| **Impacts of Disease (Disease caused by *Phytophthora*, other diseases affecting plants)** | Improve community understanding of disease threats and their potential impacts on biodiversity assets in the BMNDRC. | 1. Newsletter<br>2. Education packages<br>3. Technical reports<br>4. Interpretative materials (signage, brochure) | Landholders (1,2,3,4)<br>LGAs (1,2,4)<br>Community Groups (1,2,3,4)<br>General community (4) | DAFWA<br>NACC<br>MCC<br>Universities | 1. Provision of education, information on disease threats, recognition and management. |
| **Detrimental regimes of physical disturbance** | Improve community understanding of the impacts that natural occurrences of physical disturbance; drought, flood, fire, cyclones, erosion may have on biodiversity assets in the BMNDRC. | 1. Joint planning<br>2. Field days<br>3. Newsletter | Landholders (1,2,3)<br>Community groups (1,2,3) | DAFWA<br>Universities<br>Research Organisations<br>MCC<br>NACC<br>NHT | 1. Adoption of monitoring and evaluation techniques to improve knowledge and capacity to manage detrimental impacts.<br>2. Increased adoption, where appropriate, of revegetation and management of remnant vegetation to mitigate impacts of physical disturbance. |
| **Impacts of pollution** | Improve community knowledge of pollutants and how they may impact on biodiversity assets in the BMNDRC. | 1. Joint planning<br>2. Technical reports<br>3. Workshops<br>4. Field days | Landholders (1,2)<br>Community groups (1,2,3,4)<br>Private consultants (2) | DOE | 1. Facilitation of dialogue between stakeholders to mitigate the impact of pollutants on biodiversity. |
| **Impacts of competing land uses** | Improve community understanding of potential impacts of competing land uses on biodiversity in the BMNDRC. | 1. Joint planning<br>2. Interpretative materials (signage, brochures)<br>3. Newsletter<br>4. Workshops | Landholders (1,2,3)<br>LGAs (1,2,3,4)<br>General community (2) | DAFWA<br>Non-government organisations | 1. Facilitation of dialogue between stakeholders to improve knowledge and mitigate impacts of competing land uses on biodiversity.<br>2. Increased awareness of potential impacts of competing land uses on biodiversity values.<br>3. Increased adoption of options to improve security of natural lands.<br>4. Increased adoption of advice on ways to manage remnant vegetation and establish revegetation. |

***Table 1**: Communication strategies to raise awareness and improve community understanding of biodiversity values of the BMNDRC and associated threatening processes. (cont.)*

***Table 1**: Communication strategies to raise awareness and improve community understanding of biodiversity values of the BMNDRC and associated threatening processes. (cont.)*

| Biodiversity issue | Communication objectives | Communication strategies | Primary target audiences* | Partners | Performance indicator |
|---|---|---|---|---|---|
| **Impacts of community values** | Improve understanding of the linkages between conservation of biodiversity and human needs/values/perceptions in the BMNDRC. | 1. Field days<br>2. Displays<br>3. Newsletter<br>4. Education packages<br>5. Technical reports<br>6. Interpretative materials (signage, brochures) | Landholders (1,2,3,5,6)<br>Community groups (1,2,3,5,6)<br>Schools (4) | Non-government organisations<br>Universities<br>WA Museum<br>ABC | 1. Increased awareness and appreciation of biodiversity.<br>2. Increased awareness of the value of biodiversity to agricultural sustainability.<br>3. Increased awareness of incentives available to support Landholders who want to protect biodiversity assets. |
| **Insufficient resources to maintain viable populations** | Improve community understanding of biodiversity values/ assets; threats and management options within the catchment. | 1. Newsletter<br>2. Field days<br>3. Education packages<br>4. Technical reports<br>5. Joint planning<br>6. Displays<br>7. Interpretative materials (signage, brochures) | Landholders (1,2,3,4,5,6,7)<br>LGAs (1,2,3,4,5)<br>Community Groups (1,2,3,4,5,6,7)<br>General Community (2, 6, 7)<br>Schools (3) | DAFWA, Non-government organisations NACC<br>WA Museum<br>CSIRO<br>Land & Water Australia<br>DEH<br>Universities<br>ABC | 1. Increased awareness of the legacy of broad-scale clearing and implications for plants and animals.<br>2. Increased adoption of remnant vegetation protection (fencing and covenanting) and targeted revegetation projects utilising the concepts of landscape design promoted by CSIRO Sustainable Ecosystems. |

* Numbers relate to the type of communication strategy used in the previous column.

***Table 2**: Techniques and Resources for communicating public participation objectives*

| Tools and techniques | Resources required | Objective | Time frame |
|---|---|---|---|
| Logo (already have logo) | | Recognisable symbol of the catchment | To be used at every opportunity where appropiate |
| Signage | Time (site selection, design, material, construction, erection) including demonstration sites | Increased awareness of on-ground works, for example; surface water management, revegetation | Ongoing |
| Displays | Time<br>Personnel<br>Venue | Promotion of the recovery process, for example; at local Agricultural Society Shows (Perenjori, Dalwallinu, North Midlands, Moora) and other events as opportunity arises. 'Fixed' display/resource may be the BMNDRC Herbarium collection. | Agricultural shows – annually<br>Other – opportunistically |
| Newsletter | Time (Collation, preparation, editing)<br>Personnel<br>Access to computer<br>Graphic design, printing<br>Distribution (mail out) | Information source for broad audience | Three issues per year |
| Technical reports, case studies and other publications | Collation,<br>Publication<br>Distribution (mail out, email, handout at event) | Provide resource material, for example; revegetation handbook | Ongoing as resources become available |
| Education packages | Collation<br>Publication<br>Distribution<br>(Mail out, email, handout at event) | Provide resource material, for example; school packages | Ongoing as resources become available |
| Radio talkback | Time (preparation, interview) | Information to broad audience on Recovery process | As required |
| Field days | Time<br>Personnel<br>Venue<br>Catering | Encourage community participation – opportunity to provide information, share experiences/ideas in relaxed atmosphere | Annual – depending on 'themes' could consider nature conservation oriented day alternate years with hydrology/native perennials etc |
| Print media (including newspaper articles) | Time<br>Personnel | Promotion of Recovery process to broad audience, as well as catchment community | As required |

***Table 2**: Techniques and Resources for communicating public participation objectives (continued)*

| Tools and techniques | Resources required | Objective | Time frame |
|---|---|---|---|
| Workshops (including planning workshops and presentations at stakeholder meetings) | Time<br>Personnel<br>Venue<br>Whiteboard<br>Overhead projector<br>Powerpoint display unit<br>Catering | Opportunity for joint planning/sharing of ideas with catchment members and development of collaborative projects (research, training, implementing works etc) | Attendance at all LCDC/Catchment Group meetings as opportunity arises. |
| Meetings with steering committee | Time<br>Personnel<br>Venue<br>Whiteboard<br>Overhead projector<br>Powerpoint display unit<br>Catering | Opportunity to review recovery process<br>As required | |

## RISK

There are inherent risks in establishing public participation which include:

- Stakeholder inaction/disinterest (Community);
- Change of government policy;
- Insufficient resources (CALM);
- Unrealistic timeframes (CALM);
- Unrealistic expectations (Community);
- Targeting wrong stakeholders (CALM);
- Maintaining momentum (CALM and Community); and
- Factors over which CALM and the Community have no control, e.g. global economy, terms of trade for agriculture.

## EVALUATION

It will be necessary to evaluate the effectiveness of various communication tools and techniques over the duration of the recovery process. Flexibility will be needed where new approaches can be used when difficulties are encountered.

Methods that can be used to evaluate communication outcomes are:

- follow-up landholder survey;
- questionnaire;
- personal follow-up;
- workshop to allow reflection; and
- measurable assessment of outcomes.

# APPENDIX 15: MONITORING AND RESEARCH INVESTIGATIONS

The following is a list of reports commissioned by the Buntine-Marchagee Natural Diversity Recovery Catchment team as of November 2007.


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.

CALM & DEC (2003 – 2007) *Buntine-Marchagee Catchment News*, Issue 1 – 11. Newsletter prepared by the Department of Environment and Conservation (Buntine-Marchagee Natural Diversity Recovery Catchment team). Midwest Regional Office.

DODD N. (2006) Water Management Plan for the Demonstration Catchment: Buntine-Marchagee Natural Diversity Recovery Catchment. Prepared for the Department of Environment and Conservation, Midwest Regional Office.

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.

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.

HUGGETT, A., PARSONS, B., ATKINS, L. & INGRAM, J. (2004) Landscape design for bird conservation in Buntine-Marchagee Catchment, Western Australia., CSIRO Sustainable Ecosystems.

HUGGETT, A. (2007). Spring 2006 Bird Survey Report: Buntine-Marchagee Natural Diversity Recovery Catchment. Part of developing an M&E strategy to test the Focal Species Approach. Report prepared by Insight Ecology for the Department of Environment and Conservation, Midwest Regional Office.

HUGGETT, A. (2007). Autumn 2007 Bird Survey Report: Buntine-Marchagee Natural Diversity Recovery Catchment. Part of developing an M&E strategy to test the Focal Species Approach. Report prepared by Insight Ecology for the Department of Environment and Conservation, Midwest Regional Office.

HUGGETT, A. (2007). The classification and application of extinction risk categories in Australian ornithology, and how they apply to the BMNDRC. Short report prepared by Insight Ecology for the Department of Environment and Conservation, Midwest Regional Office.

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.

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.

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.

STOREY, A. W., SHEIL, R. J. & LYNAS, J. (2004a) 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.

STOREY, A. W., SHEIL, R. J. & LYNAS, J. (2004b) 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.

URS (Feb 2007) Preliminary Draft: Hydrogeology Investtigation of the Buntine-Marchagee Natural Diversity Recovery Catchment. Prepared for the Department of Environment and Conservation, Midwest Regional Office.

# APPENDIX 16: BUDGETTING TEMPLATE USED IN THE SALINITY PROGRAM

***Table 1***. *Standard budgeting and expenditure template used in the salinity program. All expenditure and outputs will be reported in this standard template.*

| **Cost centre number:** | **Financial year:** | **2007-08** | | |
|---|---|---|---|---|
| **Recovery Catchments** | | | | |
| **Threats** | **Work activities** | **Performance Measures** | **Statistics** | **Expenditure** |
| **1. Lack of ecological resources to support viable populations** | 1.1 Expansion of conservation estate through land purchases. Current efforts in this area are generally focussed on purchasing lands that enhance long-term viability of existing reserves and remnant systems. | No. of land parcels inspected | | |
| | | No. of land parcels purchased | | |
| | | Total area of land purchased | | |
| | 1.2 Biological surveys to identify lands (but not those for private land purchase) that should be incorporated into the conservation estate, used for seed orchards, revegetated, or accorded better protection for salinity control. | No. of areas surveyed | | |
| | | No. of recommendations completed (at regional level) | | |
| | | Total area agreed to come into conservation estate | | |
| | 1.3 Biological surveys (eg vegetation and floristics, mammal surveys, rare flora surveys and monitoring) as a basis for monitoring and planning. | No. surveys | | |
| | 1.4 Creating buffers (including habitat expansion) for remnant vegetation, but not including use of commercially prospective species. Involves use of funds for works on private property to protect biodiversity values, and includes fencing of revegetation. | a. No. sites | | |
| | | b. No. seedlings | | |
| | | c. Area of buffers | | |
| | | d. Total km of fencing | | |
| | | e. Total no. of landholders involved | | |
| | 1.5 Creating corridors (not including commercially prospective species) connecting remnant vegetation. Involves use of funds for works on private property to protect biodiversity values, and includes fencing of revegetation. | a. No. sites | | |
| | | b. No. seedlings | | |
| | | c. Area of corridors | | |
| | | d. Total km of fencing | | |
| | | e. Total no. of landholders involved | | |
| | 1.6 Using commercially prospective species to buffer or create corridors. | a. No. sites | | |
| | | b. No. seedlings | | |
| | | c. Area planted | | |
| | | Total km of fencing | | |
| | | Total no. of landholders involved | | |

| Threats | Work activities | Performance Measures | Statistics | Expenditure |
|---|---|---|---|---|
| | 1.7 Rehabilitation of degraded areas on Crown lands including:<br>– Rehabilitation of historic quarries.<br>– Planting disturbed parts of recreation sites in conjunction with other works funded under recreation program<br>– Removal of rubbish and site rehabilitation<br>– Revegetation of cleared areas. | No. sites rehabilitated<br>Area rehabilitated<br>No. of reserves involved (note, individual reserves should only be recorded once) | | |
| | 1.8 Improved protection and management of native vegetation on private properties including:<br>– Fencing of remnant vegetation on private property<br>– Coverage of private remnants by conservation covenants. | Km of fencing<br>No. of remnants<br>Area of remnants<br>No. of landholders involved<br>No. of sites covered<br>Area of sites covered | | |
| | 1.9 Research other than listed above. | List (separately) of reports and investigations | | |
| | 1.10 Re-construction of viable genetic resources (eg translocations/reintroductions). | No. of species<br>No. of individual animals | | |
| **2. Detrimental regimes of physical disturbance events, such as fire, cyclone, drought, flooding. At this stage, fire is the only disturbance proposed for management. All activities relate to fire management.** | 2.1 Planning and liaison. | Separate written list of plans and other documents | | |
| | 2.2 Fire suppression. | No. wildfires in dist/region<br>Area burnt in dist/region<br>No. wildfires attended outside district/region | | |
| | 2.3 Construction and maintenance of fire-access tracks. | Length (km) constructed<br>Length (km) maintained<br>No. of reserves on which construction work undertaken<br>No. of reserves on which maintenance work undertaken | | |
| | 2.4 Fuel reduction. | Area treated<br>No. of reserves treated | | |
| | 2.5 Burning for habitat management. | Area treated<br>No. of reserves treated | | |
| **3. Impacts of introduced plants and animals.** | 3.1 Weed control – bridal creeper. | No. sites treated<br>Area treated<br>No. reserves treated (note, individual reserves should only be recorded once)<br>No. private property sites | | |

| Threats | Work activities | Performance Measures | Statistics | Expenditure |
|---|---|---|---|---|
| | 3.2 Weed control – other. | No. sites treated | | |
| | | Area treated | | |
| | | No. reserves treated (note, individual reserves should only be recorded once) | | |
| | | No. private property sites | | |
| | 3.3 Rabbit control. | No. sites treated | | |
| | | Area treated | | |
| | | No. reserves treated (note, individual reserves should only be recorded once) | | |
| | | No. private property sites | | |
| | 3.4 Pig control. | No. sites treated | | |
| | | Area treated | | |
| | | No. reserves treated (note, individual reserves should only be recorded once) | | |
| | | No. private property sites | | |
| | 3.5 Fox control. | No. sites treated | | |
| | | Area treated | | |
| | | No. reserves treated (note, individual reserves should only be recorded once) | | |
| | | No. private property sites | | |
| **4. Impacts (on conservation values) of native plants and animals.** | 4.1 Control of plague locusts or other native species. | Area treated | | |
| **5. Impacts of disease.** | 5.1 Phytophthora management. | No. reserves surveyed | | |
| | | No. sites sampled | | |
| | | No. sites treated | | |
| | 5.2 Armillaria and other diseases. | No. reserves surveyed | | |
| | | No. sites sampled | | |
| | | No. sites treated | | |
| **6. Inappropriate use of pesticides, oil spills, chemical spills.** | | | | |

| Threats | Work activities | Performance Measures | Statistics | Expenditure |
|---|---|---|---|---|
| **7. Altered biogeochemical processes. Note that salinity and waterlogging control is the only activity shown. Nutrient stripping and carbon sequestration have not been included, but may be later** | 7.1 Contribute to the development of improved drainage assessment, practice and policy. | No. NOIs processed | | |
| | 7.2 Revegetation (generally of cleared areas on private property) with main objective of hydrological control. Includes fencing. Not including commercially prospective species. | Land conservation plantings | | |
| | | a. No. sites | | |
| | | b. No. seedlings | | |
| | | c. Area planted | | |
| | | d. Km of fencing | | |
| | | e. No. of landholders involved | | |
| | 7.3 Revegetation with commercially prospective species (generally of cleared areas on private property) with main objective of hydrological control. Includes fencing. | a. No. sites | | |
| | | b. No. seedlings | | |
| | | c. Area planted | | |
| | | d. Km of fencing | | |
| | | e. No. of landholders involved | | |
| | 7.4 Engineering works on Crown lands to protect public asset values. | List (separately) of investigations, reports | | |
| | | No. of sites treated | | |
| | | Length of structure; or | | |
| | | Area treated | | |
| | 7.5 Engineering works on private property to protect public asset values. | List (separately) of investigations, reports | | |
| | | No. of sites treated | | |
| | | Length of structure; or | | |
| | | Area treated | | |
| | | If appropriate, number of de-watering bores | | |
| | 7.6 Monitoring and research/investigations (other than listed for particular project areas above). | List (separately) of investigations, reports | | |
| **8. Inappropriate Culture** | 8.1 Management of recovery and related committees, input to catchment planning, liaison with local authorities and all other groups. | No. meetings | | |
| | | No. of groups dealt with | | |
| | 8.2 Communication, education, general training of external audiences. | No. of groups dealt with | | |
| | | No. of interpretive items | | |
| | | No. of media releases | | |
| | 8.3 Volunteer management. | No. volunteers | | |

| Threats | Work activities | Performance Measures | Statistics | Expenditure |
|---|---|---|---|---|
| **9. Competing resource use** | 9.1 Mining. | No. applications dealt with | | |
| | | No. of active mines in current year | | |
| | 9.2 Illegal activities (prosecutions/investigations). | No. breach reports prepared | | |
| | | No. prosecutions | | |
| | | No. successful prosecutions | | |
| | | No. days spent on patrol | | |
| | 9.3 Damage permits for kangaroos and other problem animals where problem relates to impinging on a resource use other than conservation. | No. damage permits | | |
| | 9.4 Consumptive and productive use of native biota (includes wildflower picking, apiary sites, firewood, aviary licences, etc.). | No. inspections | | |
| | | No. permits issued | | |
| | 9.5 Notices of intent to clear. | No. dealt with | | |
| | 9.6 Recreation. | See Parks and Visitor Services | | |
| | 9.7 Other proposed uses of bushland not listed above (Telstra, water pipes, bridges, etc.). | No. dealt with | | |
| | 9.8 Fauna rescues. | No. dealt with | | |
| | | | **Total** | |

# APPENDIX 17: RECOVERY CRITERIA TO MEET THE OPERATIONAL GOAL AND RESOURCE CONDITION TARGETS

Recovery criteria were not developed at time of publication. An example of how to approach this is shown below: extract from 3.3 Summary Table – Recovery Criteria: page 16 of the Toolibin Draft Plan.

| **Asset:** | | |
|---|---|---|
| Assessment:<br>1. Achieved<br>2. Some progress towards meeting criteria<br>3. Not achieved, no or limited progress towards meeting criteria | | |
| **Criteria** | **Assessment (notes and score)** | **Outcomes/comments** |
| **Biological** | | |
| No further deterioration is observed in the health of the fringing or adjacent native vegetation | | |
| Successful tree and shrub regeneration in all native vegetation associations of the fringing and adjacent area. | | |
| Based on available data, the lake supports sufficient species richness and abundance of invertebrates to ensure 'dependent fauna' food resources. | | |
| **Physical** | | |
| The minimum depth to the water table beneath Lake ? and (adjacent flats?) in spring, when the lake is dry, should be ?m. | | |
| The maximum salinity of lake water when the lake is full should be ? mg/1 Total Dissolved Salts (TDS). | | |
| The maximum salinity of inflow to the lake measured at ? gauging station should be ? mg/l TDS during the winter months when the lake is full. | | |

# APPENDIX 18: GLOSSARY

**Alluvial (see fluvial)**
Unconsolidated terrestrial sediment that has been deposited by flowing water (Speed & Strelein 2004).

**Aeolian**
Materials that are transported and deposited by wind.

**Asset**
A discrete physical, biological or human made entity that has value, or a location with multiple values (Department of Environment 2003). For example, the BMNDRC is a location that is an asset to the state because of the value of the many natural assemblages it contains. These assemblages are, in turn, the assets of the catchment. The current document is concerned with the conservation of natural assets. Any reference to biodiversity or assets should be taken as referring only to natural elements.

**Assemblage**
A location where biotic and abiotic components interact or the collective term for those components. Biotic components are the *biodiversity* of the assemblage; that is the different plants, animals and microorganisms, the genes they contain, and the ecosystems they form. Biodiversity is usually considered at three levels: genetic diversity, species diversity and ecosystem diversity. Abiotic components are processes and non-living elements of assemblages such as water and soil. Assemblages that are *natural* have not been brought into the catchment through human activity, as is the case with domestic stock, weeds, agricultural crops and constructed landscapes.

**Autecological**
The biological relations between a single species and its environment; ecology of an individual species.

**Biodiversity assets**
Threatened taxa and ecological communities, significant ecosystems or taxa.

**Capacitance probe**
A device utilising the principles of a capacitor, which consist of two conducting plates separated by a layer of dielectric material. In this particular case, water is used as the outer conducting plate. Changes in water depth result in a change to the capacitance properties of the probe, thus resulting in a method for measurement of water depth.

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

**Confined aquifer**
Is an aquifer that is confined between two confining layers, or aquitards

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

**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).

**Endemic species**
Species naturally restricted to a specified region or locality (DEC 2006).

**Fluvial (see alluvial)**
Related to rivers and streams.

**General wetland monitoring program**
Measuring and interpreting attributes of wetlands, e.g. water quality, surrounding vegetation health, abundance and diversity of aquatic invertebrates.

**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.

**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.

**IBRA region**
Interim Biogeographic Regionalisation of Australia: Are geographically distinct plant and animal communities, defined by geology, soils, climate, and predominant vegetation.

**Lacustrine**
Pertaining to a lake (i.e. lacustrine sediments are deposits associated with current or historical location of

wetlands/lakes).

**Lacustrine vegetation**
Lacustrine, in ecology, is the environment of a lake; of or relating to lakes; living or growing in or along the edges of lakes.

**Land unit**
The combination of qualified soil group and landscape position.

**Littoral vegetation**
The boundary between littoral (wetland-fringing) vegetation and abutting terrestrial vegetation can be difficult to quantify. Littoral vegetation is defined here as the vegetation that depends on interaction with the water of the wetland system to survive and/or experiences periodic or permanent inundation. The relevant area varies from a few, to hundreds, of metres in width, depending on the characteristics of the wetland and the morphology of the surrounding landscape. An individual assessment of wetlands is required to determine what constitutes the littoral zone of each, particularly as groundwater rise increases the area of inundation.

**Living assemblages**
Denote where biotic and abiotic components interact. Note however, while the abiotic components need to be managed, they are not the actual biodiversity asset.

**Non-passerine birds**
Relating to or characteristic of birds that are not perching birds, for example emus, cassowarys, ducks, and penguins.

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

**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.

**Playa lake**
A shallow temporary lake (following a rainstorm) on a flat valley floor in a dry region.

**Priority Flora**
Flora that is listed under a Conservation Code (see Appendix 9 for full description).

**Priority wetland monitoring program**
The most intensive measuring and interpreting of attributes of wetlands; that is: water quality, surrounding vegetation health, abundance and diversity of aquatic invertebrates, and ground-water.

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

**Taxa**
A grouping of organisms given a formal taxonomic name such as species, genus, family, etc; plural of Taxon.

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

**Toposequence**
A sequence of soils in the landscape, from the crest to the valley bottom.

**Unconfined aquifer**
Commonly called a water table aquifer, is an aquifer which the water table forms the upper boundary (i.e. no confining upper layer).

**Waterlogging**
Soil condition whereby excess water in the root zone inhibits gas exchange with the atmosphere.

**Wetland**
Lands where an excess of water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface (Cowardin, Carter et al. 1979). There are a great variety of wetlands because of differences in soils, topography, climate, hydrology, water chemistry, vegetation, and other factors, including human disturbance (US Environmental Protection Agency 2005). Wetlands are among the most productive ecosystems on earth and provide crucial biological functions at local and global scales.

**WISALT Banks**
Whittington Interceptor Salt Affected Land Treatment Society (WISALTS) is a society formed in 1978 to promote the use of modified absorption banks for controlling salinity. The banks are designed to control surface runoff and intercept sub-surface flow. Sealed with clay, they are designed to prevent leakage of water through them (Henscke 1989).

**Yilgarn Craton**
A large area of Archaean, stable, granitic, continental crust that underlies most of southwest Western Australia.

## APPENDIX 19: ACRONYMS

| | |
|---|---|
| ABARE | Australian Bureau of Agricultural & Research Economics |
| ABC | Australian Broadcasting Corporation |
| ACF | Australian Conservation Foundation |
| BMNDRC | Buntine-Marchagee Natural Diversity Recovery Catchment |
| CALM | Department of Conservation and Land Management |
| CCWA | Conservation Commission of Western Australia |
| CRC | Cooperative Research Centre |
| CSIRO | Commonwealth Scientific and Industrial Research Organisation |
| DAFWA | Department of Agriculture and Food |
| DEC | Department of Environment and Conservation |
| DEH | Department of Environment and Heritage |
| DIA | Department of Indigenous Affairs |
| DoE | Department of Environment |
| DRF | Declared Rare Flora |
| EEI | Engineering Evaluation Initiative |
| EPA | Environmental Protection Authority |
| EWS | Environmental Weed Strategy |
| FPC | Forest Products Commission |
| IBRA | Interim Biogeographic Regionalisation for Australia |
| IRP | Interim recovery plan |
| IPCC | Intergovernmental Panel on Climate Change |
| IUCN | The International Union for the Conservation of Nature and Natural Resources. Use of the name 'World Conservation Union' began in 1990, but the full name and the acronym are often used together as many people still know the Union as IUCN. The World Conservation Union was founded in October 1948 as the International Union for the Protection of Nature (or IUPN) following an international conference in Fontainebleau, France. The organization changed its name to the International Union for Conservation of Nature and Natural Resources in 1956. |
| LCDC | Land Conservation District Committees |
| MCC | Moore Catchment Council |
| Mya | Million years ago |
| NACC | Northern Agricultural Catchments Council |
| NAR | Northern Agricultural Region |
| NACC | Northern Agricultural Catchment Council |
| NDRC | Natural Diversity Recovery Catchment |
| NPNCA | National Parks and Nature Conservation Authority |
| OCP | Organo-Chlorine Pesticides |
| TEC | Threatened Ecological Communities |
| WA | Western Australia |
| WWF | World Wildlife Fund |

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## APPENDIX 21: PERSONAL COMMUNICATIONS

Annan, G. Economist, Department of Agriculture and Food (DAFWA), May 2006.

Broun, D. (nee Long), Member of pioneering Long family of Coorow; Coorow Heritage Group April 2004.

Byrne, J. CSIRO, Perth, 2006.

Coates, D. Senior Principal Research Scientist, Science Division. Department of Conservation and Land Management, Kensington, Perth WA. 2005.

Daniel, G. GIS Officer, Department of Conservation and Land Management, Midwest Region, 2005.

Desmond, A. Regional Nature Conservation Leader, Department of Conservation and Land Management, Midwest Region, 2005.

Doley, A. Landholder in the north-west of the BMNDRC. 2005.

Gilmour, D. Development Officer, Shire of Moora 2005.

Hall, S. Economic Development Officer, Shire of Dalwallinu, 2005.

Kealley, I. Regional Manager, Department of Conservation and Land Management, Goldfields Region, 2003.

Lyons, M. Research Scientist, Department of Conservation and Land Management, Science Division, Woodvale. 2005.

Mulalley, P. Natural Resource Management (NRM) Indigenous Support Officer Midwest Development Authority May 2006.

Scott, C. 4.08.05.

Speed, R. Regional Hydrologist, Department of Agriculture and Food. Geraldton, 2005.

Toser, Dr. P. Economist, Department of Agriculture and Food (DAFWA), July 2005

Watts, J. Recovery Catchment Officer Department of Conservation and Land Management, Midwest Region, 2005

White, P.J. Rural Advisory Officer, Department of Conservation and Land Management, Wheatbelt Region, 2005



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