BUNTINE-MARCHAGEE NATURAL DIVERSITY RECOVERY CATCHMENT

Supporting Information to the Recovery Plan 2005 – 2010

Preliminary Draft

September 2005

The Buntine-Marchagee Catchment aspirational goal is to:

"maintain the native species in a range of representative wetlands within the Buntine-Marchagee catchment by 2020".

Buntine Marchagee Catchment

Department of Conservation and Land Management
Conservation Commission of Western Australia

TABLE OF CONTENTS

APPENDIX 1: SELECTION CRITERIA FOR RECOVERY CATCHMENTS

Table 1: Criteria for Selecting Recovery Catchments

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: ◊ how representative the catchment biota is of important natural communities; ◊ presence of threatened communities and species; ◊ species and community richness; ◊ whether the catchment provides an important biological corridor (eg, that connecting Lake Magenta Nature Reserve and Fitzgerald River National Park), or other significant ecological service; and ◊ international or national significance of the area (eg, 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: ◊ nature conservation; ◊ farm economics; ◊ cultural change or improved social interaction; and ◊ 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: ◊ "physics" of pressure (eg, is hydrological pressure overwhelming?); ◊ area of catchment (bigger catchments are generally more difficult to recover); ◊ degree of threat; ◊ level of landcare community support, knowledge and enthusiasm; ◊ potential to use prospective commercial species in revegetation; and ◊ 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

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 discharge into Capamouro Swamp and Lake Eganu. These well-known wetlands are in large nature reserves but have become saline over 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 1890's with the arrival of the Midlands Railway. Large-scale clearing continued into the 1970's with the last land clearing occurring in the early 1990's.

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.

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 WU03 WU04 WU05 WU13	WU5A WU5B WU16 WU20	SPS157 SPS158
Relevant sites outside proposed recovery catchment		
WU06 DN01 DN02 DN08	WU12 WU13 WU15 WU17 WU21	SPS155 SPS171 - just N of Figure1 SPS172 - just N of Figure 1 SPS201 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 & 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 (Table 1, 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)
Fitwillia axilliflora	P2
Frankenia bracteata	P1

Gnephosis setifera	P1
Goodenia pussiliflora	P2
Hydrocotyle hexaptera	P1
Podotheca pritzellii	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 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. 2000) and, with 104 species recorded in spring 1999, the braided channel supported about 13 per cent of the whole wheatbelt's 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 3570 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			
Hardhead			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 as of note, 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 wheatbelt's 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 (1919 ha)
- Unnamed Nature Reserve 21175 (121 ha)
- Unnamed Nature Reserve 28669 (157 ha) *
- Unnamed Nature Reserve 38401 (107 ha)*

  *Threatened by rising water tables

The management order for Buntine Reserve, 16379 (1370 ha), 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 last ten 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 last 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 4 per cent of the Marchagee Catchment is vegetated. However the techniques used in determining the vegetated areas are aimed at determining woody vegetation greater then 2 metres high with more than 15 – 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 8-10 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, 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 funded project beginning in 1998. The NHT project "Marchagee Catchment Bushcare Project" was funded in 1998/99 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 1998/99 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.

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.

References

Davies and Ladd (2000). *A survey of the remnant vegetation within the Marchagee catchment*, unpubl. report to Marchagee Catchment Group, Coorow LCD.

Dell, J., Chapman, A., Kitchener, D.J. and Muir, B.G. (1979). Biological Survey of the Western Australian Wheatbelt; Part 9 Marchagee Nature Reserve. *Records of the Western Australian Museum.* Supplement No. 8.

Government of Western Australia (2000). *Natural Resource Management in Western Australia: The Salinity Strategy.* Prepared by State Salinity Council in association with community groups and government agencies.

Halse, S.A., Jaensch, R.P., Munro, D.R. and Pearson, G.B. (1990). *Annual waterfowl counts in south-western Australia - 1988/89.* Technical Report 25. Department of Conservation and Land Management, Perth.

Halse, S.A., Vervest, R.M., Munro, D.R., Pearson, G.B. and Yung, F.H. (1992). *Annual waterfowl counts in south-west Western Australia - 1989/90.* Technical Report 29. Department of Conservation and Land Management, Perth.

Harold (2000). *Fauna of the Marchagee catchment*, unpubl. report to Marchagee Catchment Group, Coorow LCD.

McConnell, C and Pillai. M. (2000). *Hydrogeology of the Marchagee Catchment.* Catchment Hydrology Group, AGWEST (Unpublished Report).

Maly, E.J., Halse, S.A. and Maly, M.P. (1997). Distribution and incidence patterns of Boeckella, Calamoecia, and Hemiboeckella (Copepoda: Calanoida) in Western Australia. *Marine and Freshwater Research.* Vol. 48., pp 615-621.

Pinder, A.M., Halse, S.A., Shiel, R.J. and McRae, J.M. (2000). Aquatic invertebrates of granite outcrops in south-western Australia: foci of diversification and refugia for aquatic invertebrates. *Journal of the Royal Society of Western Australia* (in press).

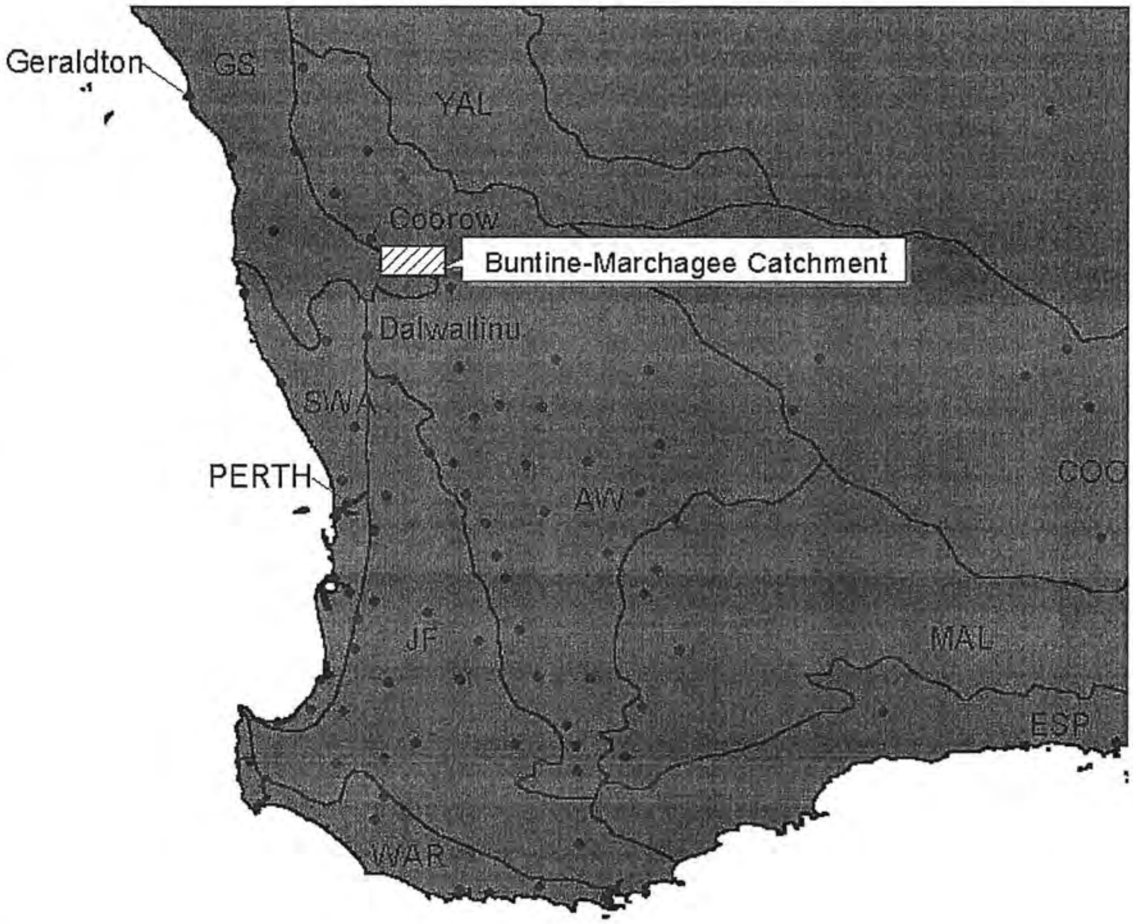


Figure 1. IBRA Regions of South western Australia
Note: AW = Avon-Wheatbelt, GS = Geraldton Sandplains.

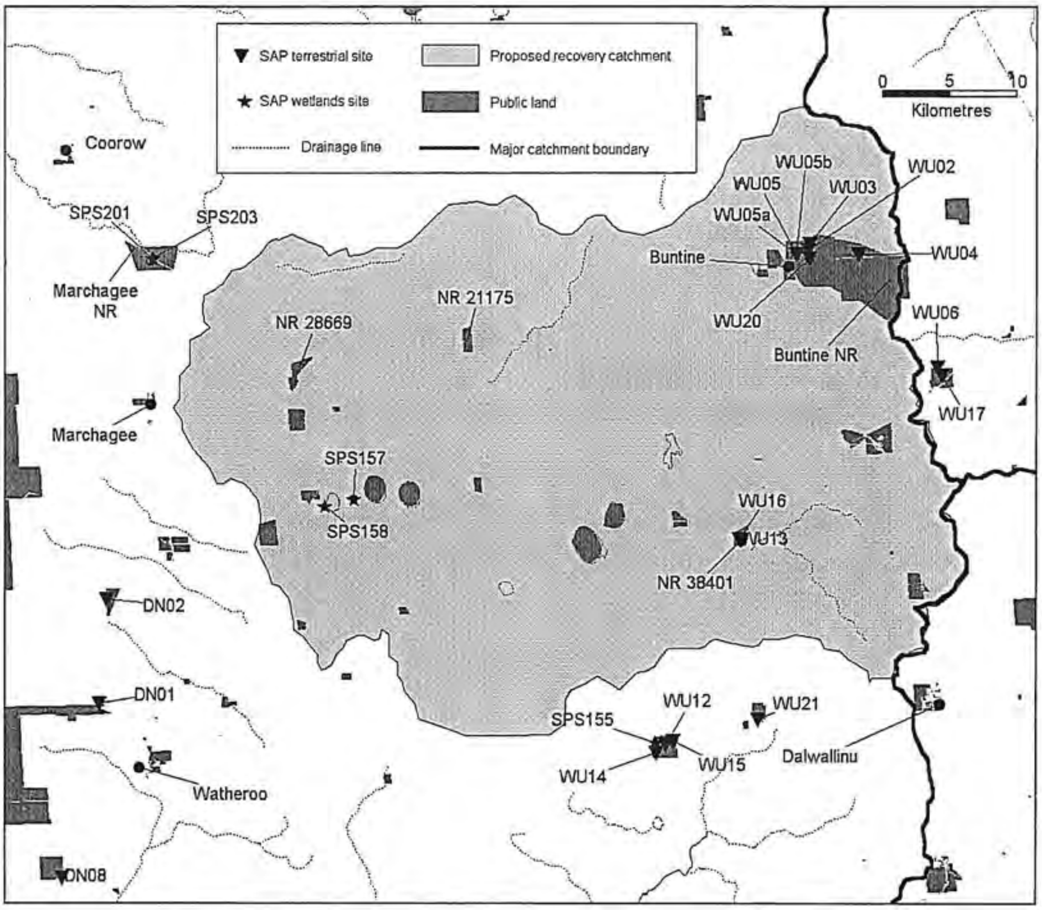


Figure 2. Buntine-Marchagee proposed natural diversity recovery catchment

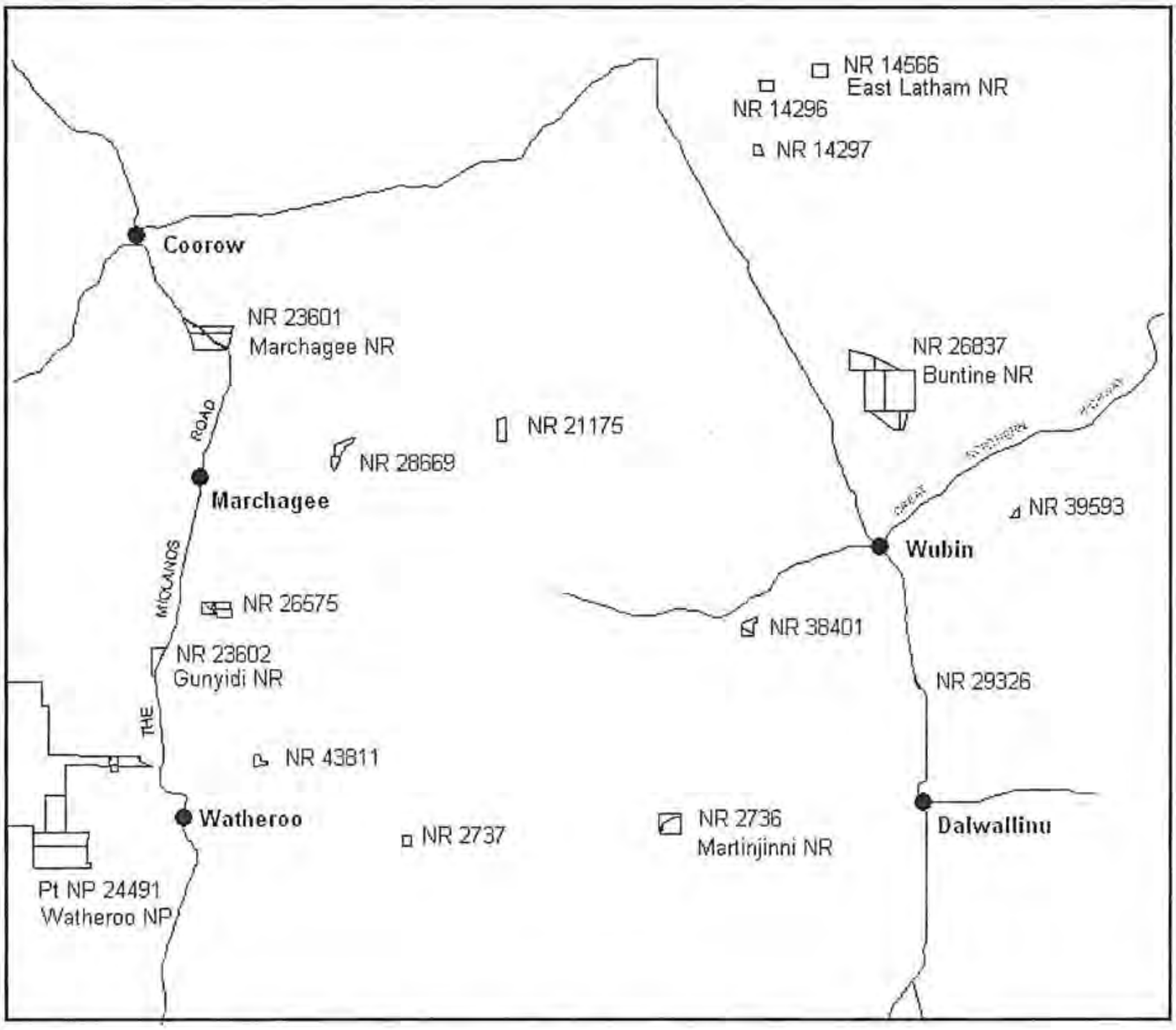


Figure 3. National parks and nature reserves located in (and surrounding) the Buntine-Marchagee proposed natural diversity recovery catchment

Appendix 1: Plant species recorded from wetland sites SPS157 and 158 in 1999

Species	Species
Aizoaceae	**Asteraceae (cont')**
Disphyma crassifolium	*Halosarcia pergranulata subsp. pergranulata*
Gunniopsis septifraga	*Halosarcia sp. aff undulata (M.N.Lyons sn)*
Gunniopsis quadrifida	*Halosarcia sp. Gunyidi (M.N. Lyons 2607)*
Carpobrotus modestus	*Gnephosis angianthoides*
* *Mesembryanthemum nodiflorum*	*Gnephosis drummondii*
Tetragonia diptera	*Cotula coronopifolia*
Amaranthaceae	*Rhodanthe polycephala*
Ptilotus divaricatus var. divaricatus	*Waitzia acuminata var. acuminata*
Ptilotus gaudichaudii	* *Hypochaeris glabra*
Ptilotus humilis subsp. humilis	* *Osteospermum clandestinum*
Ptilotus sp. Sunrise Hill (M.A.Burgman 4484)	*Senecio lautus subsp. maritimus*
Anthericaceae	*Senecio lautus*
Thysanotus manglesianus	*Senecio glossanthus*
Apiaceae	*Dithyrostegia amplexicaulis*
Hydrocotyle hexaptera P1	*Podolepis capillaris*
Trachymene ornata	*Schoenia filifolia subsp. filifolia*
Trachymene cyanopetala	* *Sonchus asper*
Hydrocotyle pilifera var. glabrata	*Rhodanthe manglesii*
Daucus glochidiatus	*Podotheca pritzelii P2*
Uldinia ceratocarpa	*Podolepis canescens*
Trachymene pilosa	*Podolepis lessonii*
Apocynaceae	*Blennospora drummondii*
Alyxia buxifolia	*Podotheca gnaphalioides*
Asphodelaceae	*Rhodanthe chlorocephala subsp. rosea*
Bulbine semibarbata	*Pogonolepis stricta*
Asteraceae	*Chthonocephalus pseudevax*
Gnephosis setifera P1	**Brassicaceae**
* *Arctotheca calendula*	* *Brassica tournefortii*
Erymophyllum tenellum	*Lepidium rotundum*
Brachyscome lineariloba	**Campanulaceae**
* *Ursinia anthemoides*	*Wahlenbergia preissii*
* *Urospermum picroides*	* *Wahlenbergia capensis*
* *Sonchus tenerrimus*	**Caryophyllaceae**
Gnephosis tridens	* *Petrorhagia velutina*
Brachyscome iberidifolia	**Centrolepidaceae**
Brachyscome perpusilla	*Centrolepis polygyna*
Lawrencella rosea	*Centrolepis humillima*
Brachyscome pusilla	*Centrolepis cephaloformis subsp. cephaloformis*
* *Sonchus oleraceus*	*Centrolepis aristata*
Podotheca angustifolia	**Chenopodiaceae**
Hyalochlamys globifera	*Didymanthus roei*
Fitzwillia axilliflora P2	*Enchylaena tomentosa*
Halosarcia fimbriata	*Atriplex holocarpa*
Atriplex hymenotheca	*Threlkeldia diffusa*
Maireana carnosa	*Sclerolaena eurotioides*
Halosarcia syncarpa	*Sclerolaena diacantha*
Halosarcia peltata	*Rhagodia drummondii*
Halosarcia halocnemoides subsp. nov inland variant	* *Gynandriris setifolia*
Halosarcia indica subsp. bidens	* *Plantago coronopus*
Crassulaceae	*Plantago aff. hispidula ng & ml 1732*

Crassula exserta	**Poaceae**
Crassula colorata var. colorata	* *Ehrharta longiflora*
Crassula colorata	* *Bromus rubens*
Crassula closiana	* *Bromus japonicus*
Cyperaceae	* *Parapholis incurva*
Schoenus nanus	* *Pentaschistis airoides*
Dasypogonaceae	* *Bromus diandrus*
Lomandra effusa	* *Briza maxima*
Droseraceae	* *Lamarckia aurea*
Drosera zigzagia	* *Vulpia myuros*
Drosera glanduligera	*Eragrostis dielsii*
Frankeniaceae	*Austrostipa elegantissima*
Frankenia bracteata P1	* *Schismus barbatus*
Frankenia setosa	**Portulacaceae**
Gentianaceae	*Calandrinia polyandra*
Sebaea ovata	*Calandrinia granulifera*
Geraniaceae	**Proteaceae**
Erodium cygnorum	*Hakea preissii*
Goodeniaceae	**Ranunculaceae**
Velleia rosea	*Clematis delicata*
Scaevola spinescens	**Santalaceae**
Goodenia berardiana	*Exocarpos aphyllus*
Goodenia pusilliflora P2	**Scrophulariaceae**
Haloragaceae	* *Parentucellia latifolia*
Gonocarpus nodulosus	**Solanaceae**
Iridaceae	*Nicotiana occidentalis*
Juncaginaceae	**Stylidiaceae**
Triglochin centrocarpum	*Levenhookia leptantha*
Triglochin mucronatum	*Levenhookia dubia*
Triglochin sp. C Flora of Australia	**Thymelaeaceae**
Loganiaceae	*Pimelea imbricata var. simulans*
Phyllangium sulcatum	**Urticaceae**
Malvaceae	*Parietaria cardiostegia*
Lawrencia squamata	**Zygophyllaceae**
Mimosaceae	*Zygophyllum eremaeum*
Acacia tetragonophylla	
Acacia acuminata	
Acacia eremaea	
Myrtaceae	
Melaleuca acuminata	
Eucalyptus loxophleba subsp. loxophleba	
Ophioglossaceae	
Ophioglossum lusitanicum	
Ophioglossum gramineum	
Papilionaceae	
Jacksonia arida	
* *Trifolium tomentosum*	
Pittosporaceae	
Pittosporum phylliraeoides var. microcarpa	
Plantaginaceae	

Threatened and priority flora known from the Buntine-Marchagee catchment

X – Declared rare flora (presumed extinct)	**Priority 2**
Amaranthaceae	**Asteraceae**
Ptilotus fasciculatus	*Fitwillia axilliflora*
Myoporaceae	*Podotheca pritzelii*
Eremophila vernicosa ms	**Goodeniaceae**
	Goodenia pusilliflora

R - Declared rare flora (extant)	Juncaginaceae
Lamiaceae	*Triglochin stowardii*
Hemiandra gardneri	**Lamiaceae**
Mimosaceae	*Microcorys tenuifolia*
Acacia vassalii	**Proteaceae**
Myoporaceae	*Grevillea nana subsp. abbreviata*
Eremophila pinnatifida ms	**Rhamnaceae**
Myrtaceae	*Stenanthemum grandiflorum ms*
Eucalyptus rhodantha var. rhodantha	
Orchidaceae	**Priority 3**
Caladenia drakeoides ms	**Chenopodiaceae**
Papilionaceae	*Sarcocornia globosa*
Daviesia dielsii	**Goodeniaceae**
Gastrolobium appressum	*Lechenaultia galactites ms*
Rutaceae	*Lechenaultia juncea*
Boronia adamsiana	**Mimosaceae**
	Acacia filifolia
Priority 1	*Acacia isoneura subsp. nimia*
Apiaceae	*Acacia scalena*
Hydrocotyle hexaptera	**Myrtaceae**
Asteraceae	*Calytrix plumulosa*
Gnephosis setifera	*Eucalyptus macrocarpa x pyriformis*
Chenopodiaceae	*Verticordia venusta*
Halosarcia koobabbiensis ms	**Proteaceae**
Chloanthaceae	*Grevillea asparagoides*
Pityrodia axillaris	*Grevillea granulosa*
Frankeniaceae	*Persoonia chapmaniana*
Frankenia bracteata	
Mimosaceae	**Priority 4**
Acacia pravifolia	**Proteaceae**
Acacia trinalis	*Banksia benthamiana*
Myrtaceae	
Eucalyptus subangusta subsp. virescens	
Proteaceae	
Grevillea pinifolia	

Appendix 3 - Aquatic invertebrates collected from braided channel wetlands in the Marchagee area in spring 1999

		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
PROTISTA							
Arcellidae	*Arcella* cf. *catinus*						1
ROTIFERA							
Hexarthridae	*Hexarthra fennica*			1		1	1
Brachionidae	*Brachionus plicatilis*		1	1	1		
	Brachionus rotundiformis			1			
	Keratella australis			1			
Colurellidae	*Lepadella ovalis*						1
Euchlanidae	*Euchlanis dilatata*						1
Lecanidae	*Lecane bulla*						1
	Lecane ludwigii			1			1
OLIGOCHAETA							
Tubificidae	Tubificidae						1
Enchytraeidae	Enchytraeidae					1	1
ARTHROPODA							
HYDRACARINA							
Eylaidae	*Eylais* sp.			1			1
Water mites'	Mesostigmata			1			
	Trombidioidea sp. 5					1	
ANOSTRACA							
Branchiopodidae	*Parartemia* sp.	1					
CLADOCERA							
Chydoridae	*Alona rigidicaudis* s.l.						1
	Alona cf. *rigidicaudis* s.l.			1			
	Alona cf. *rectangula novaezelandiae*			1			1
	Alona sp.			1			
	Pleuroxus sp.						1
Daphniidae	*Daphnia carinata*			1			1
	Daphniopsis australis					1	
	Daphniopsis pusilla				1		
	Daphniopsis sp.nov.		1				
Macrothricidae	*Macrothrix* sp. 1			1			1
	Macrothrix sp. 2			1			
OSTRACODA							
Cyprididae	*Australocypris insularis*	1	1		1	1	
	Bennelongia barangaroo			1			1
	Cyprinotus edwardi			1		1	1
	Diacypris dictyote				1		
	Diacypris compacta		1		1		
	Diacypris whitei	1					
	Diacypris sp. 562					1	
	Diacypris sp. 649 (aff.		1				

	whitei)						
	Mytilocypris mytiloides						1
	Mytilocypris tasmanica chapmani		1		1	1	
	Platycypris baueri		1		1		
	Reticypris clava		1				
Cypridopsidae	*Sarscypridopsis* sp. 165 (Bennetts)			1			
COPEPODA							
Centropagidae	*Boeckella triarticulata*			1	1		1
	Calamoecia clitellata		1				
	Calamoecia salina		1				
	Calamoecia sp. 342 (*ampulla* variant)			1			1
Cyclopoidae	*Metacyclops arnaudi* (sensu Kieffer)	1	1		1		
	Metacyclops sp. 442 (*salinarum* in Morton)			1			1
	Australocyclops australis						1
	Australocyclops similis			1			
	Mesocyclops brooksi						1
	Apocyclops dengizicus			1		1	
Harpacticoids'	*Schizopera clandestina*		1		1		
	Harpacticoida sp. 626						1
AMPHIPODA							
Ceinidae	*Austrochiltonia subtenuis*		1				1
ISOPODA							
Oniscidae	*Haloniscus searlii*					1	
COLEOPTERA							
Carabidae	Carabidae						1
Haliplidae	Haliplidae						1
Dytiscidae	*Allodessus bistrigatus*			1			1
	Antiporus gilberti			1			1
	Antiporus sp. (larvae)						1
	Sternopriscus multimaculatus			1			1
	Sternopriscus sp. (larvae)						1
	Necterosoma penicillatus	1	1	1	1	1	1
	Necterosoma sp. (larvae)						1
	Megaporus howitti			1			
	Megaporus sp. (larvae)						1
	Platynectes sp. (larvae)						1
	Rhantus suturalis			1			
	Rhantus sp. (larvae)						1
	Lancetes lanceolatus						1
	Onychohydrus scutellaris			1			
	Bidessini (larvae)						1
Gyrinidae	Gyrinidae (larvae)			1			
Hydrophilidae	*Berosus discolor*		1				
	Berosus sp. (larvae)			1	1	1	1
	Hydrophilidae (larvae)			1			1
Staphylinidae	Staphilinidae sp.	1					

DIPTERA							
Culicidae	*Aedes camptorhynchus*		1			1	
Ceratopogonidae	*Culicoides* sp.	1	1		1		1
	Monohelea sp. 1			1		1	1
	Nilobezzia sp. 2						1
Psychodidae	Psychodidae sp. 2					1	
Tabanidae	Tabanidae	1	1		1		
Stratiomyidae	Stratiomyidae			1		1	
Dolichopodidae	Dolichopodidae sp. A		1			1	1
Syrphidae	Syrphidae						1
Ephydridae	Ephydridae	1	1	1	1		1
Muscidae	Muscidae sp. A	1					
	Muscidae sp. F					1	
Chironomidae	*Procladius paludicola*		1	1	1	1	1
	Procladius villosimanus			1			
	Ablabesmyia notabilis			1			1
	Orthocladiinae sp. G					1	
	Tanytarsus barbitarsis	1	1		1	1	
	Tanytarsus sp. A (nr. K10)			1	1		1
	Chironomus tepperi			1			1
	Chironomus aff. *alternans*			1			1
	Dicrotendipes conjunctus			1			1
	Dicrotendipes lindae						1
	Polypedilum nubiferum			1			1
	Cryptochironomus griseidorsum			1			1
HEMIPTERA							
Corixidae	*Agraptocorixa parvipunctata*			1			
	Micronecta robusta			1			1
Notonectidae	*Anisops thienemanni*			1			1
LEPIDOPTERA							
Pyralidae	Lepidoptera sp. 4				1	1	
ZYGOPTERA							
Lestidae	*Austrolestes annulosus*			1		1	1
ANISOPTERA							
Aeshnidae	*Hemianax papuensis*			1		1	1
Hemicorduliidae	*Hemicordulia tau*			1			1
TRICHOPTERA							
Leptoceridae	*Oecetis* sp.			1			1
	Triplectides australis			1			1
TOTAL NO OF SPECIES		**11**	**22**	**51**	**19**	**24**	**62**
SALINITY (g/L TDS)		**92**	**37**	**5.3**	**53**	**21**	**4.2**

APPENDIX 3: BIODIVERSITY ASSETS OF NATURAL DIVERSITY CATCHMENTS

Table 1: Biodiversity assets of natural diversity recovery catchments

Biodiversity Assets			
BIODIVERSITY ASSET CATEGORY	**ASSET TYPE**	**ASSET SUB-TYPE**	**ASSET (Examples)**
Specific individuals (genetic diversity)	To be developed	To be developed	To be developed
Species/sub-species/hybrids (species diversity)	Native flora	DRF and priority taxa	Declared Rare Flora
			Priority 1
			Priority 2
			Priority 3
			Priority 4
		Special plants	Relictual/Gondwana species, including species representing phylogenetic diversity
			Plants at edge of geographical range, or outliers, short range endemics, etc.
			Icon/charismatic species, that is, species that have captured the publics imagination, such as red kangaroo paws, they represent important human values and are important biodiversity values
		Common plants	Common plants are generally managed as part of living assemblages
	Native fauna	Rare/Threatened fauna	Schedule 1: rare/likely to become extinct, Div 1 (mammals)
			Schedule 1; rare/likely to become extinct, Div 2 (birds)
			Schedule 1: rare/likely to become extinct, Div 3 (reptiles)
			Schedule 1: rare/likely to become extinct, Div 5 (fish)
			Schedule 1: rare/likely to become extinct, Div 7 (arachnids)
			Schedule 1: rare/likely to become extinct, Div 8 (crustaceans)
			Schedule 1: rare/likely to become extinct, Div 9 (millipedes)
			Schedule 4: other specially protected fauna, Div 1 (mammals)
			Schedule 4: other specially protected fauna, Div 2 (birds)
			Schedule 4: other specially protected fauna, Div 3 (reptiles)
			Other species at risk within the subregion, including Priority 1-4 Fauna
		Special animals	Animals at edge of geographical range or outliers, short range endemics, etc.
			Relictual/Gondwana species, including species representing phylogenetic diversity
			Migratory species
			Icon/charismatic species, species that have captured the publics imagination, such as kangaroos and dolphins, they represent important human values and are important biodiversity values

		Common animals	Common animals are generally managed as part of living assemblages
	Other organisms	For example, fungal, bacterial and other organisms of conservation significance	Note that there are some DRF and priority fungi
Living assemblages (ecosystem diversity)	Special communities	Rare/Threatened Ecological Communities	Listed TECs Priority 1-4 communities
		Restricted vegetation types	
		Living assemblages with high level of endemic species	
		Refugia, living assemblages valuable for their isolation from the mainland and its associated threatening processes	

Living assemblages (ecosystem diversity) cont.	Common ecological communities	Marine communities	Invertebrate community - coral
			Invertebrate communities - other
			Macroalgal and seagrass meadows
			Mangrove
			Microbial - stromatolites
			Sand and mudflat
			Coastal
		Terrestrial assemblages	Plant based communities (includes remnant vegetation)
			Assemblages on unusual geological features including rock outcrops
		Aquatic/wetland assemblages	Ramsar (note this is management, not asset type - section needs more appropriate divisions)
			Nationally important wetlands (note this is management, not asset type - section needs more appropriate divisions)
			Other wetlands
	Caves and underground water		Stygofauna and troglofauna
	Landscapes/seascapes	Marine	Proposed representative marine reserve system areas
			Representative seascapes
		Terrestrial and aquatic/wetland	Natural diversity recovery catchments (currently a sub-category of representative landscapes)
			Representative landscapes
			World Heritage Areas (actually a management type, rather than an asset)
			Living assemblages to deliver ecosystem processes

APPENDIX 4: CATCHMENT DESCRIPTION – PHYSICAL CHARACTERISTICS

Recovery Plan Area

The Midwest Region extends between Greenhead to north of Kalbarri and inland more than 800km. The region supported a population of 50,498 in June 2000 (2.8% of the State's population) with over 60% of the population living in the greater Geraldton area (Department of Local Government and Regional Development, 2001).

The Wheatbelt Region partially extends around the northern and eastern parts of the Perth Metropolitan area and extends northwards to the Midwest Region. It is also bordered by the Goldfields-Esperance Region to the east and the South West and Great Southern Regions to the south west and south. In 2002, the region supported a population of 72,282 and, unlike any other region within Western Australia, the population is spread evenly across numerous small population centres and there is no large, single, central urban area (Department of Local Government and Regional Development, 2003).

The BMRC is located within two Western Australian Planning Commission (WAPC) regions and four local government authorities viz:

WAPC "Midwest Planning Region;

- Shire of Coorow
- Shire of Perenjori

WAPC "Wheatbelt" Planning Region;

- Shire of Moora
- Shire of Dalwallinu

The majority of the BMRC (60%) falls within the Shire of Dalwallinu (Table 1). One third of the BMRC lays within the Shire of Coorow (31%), whilst the remainder lays within the Shires of Moora (7%) and Perenjori (1%).

Table 1 – Buntine Marchagee Recovery Catchment as a function of its constituent Local Government and locality areas.

Shire	Locality	Area (ha)	% of Catchment
Dalwallinu	Buntine	36 076	20
	Wubin	34 742	19
	Dalwallinu	18 579	10
	Miamoon	12 405	7
	Nugadong	7 175	4
	Total	*108 977*	*60*
Coorow	Marchagee	31 122	17
	Gunyidi	25 357	14
	Total	*56 479*	*31*

Moora	Watheroo	11 328	6
	Miling	2 216	1
	Total	*13 544*	*7*
Perenjori	Maya	2 008	1.1
	Total	*2 008*	*1*
Total		**181 008**	**100**

The majority of the BMRC is freehold land (95%) (Table 2), whilst CALM estate accounts for only 1.2% of the area.

Table 2 – Description of land tenure within the BMRC.

Land Tenure	Area (ha)	% of Catchment
Freehold Land	171 913	95.0
Nature Reserve	2 225	1.2
No Identifier	2 246	1.2
Unallocated Crown Land	1 726	1.0
Other Crown Reserve	1 610	0.9
Crown Reserves vested in Local Government	942	0.5
Miscellaneous lands - Railway	220	0.1
Unvested Crown Reserve	111	0.1
Miscellaneous lands - Closed Road	10	0.0
Miscellaneous lands - Road	4	0.0
Total	**181008**	**100**

Catchment Description

Climate

The Buntine-Marchagee Recovery Catchment experiences a warm temperate to semi-arid climate with hot, dry summers and predominately winter rainfall. January is the hottest month and July the coldest. Average maximum / minimum monthly temperatures range from 39/16°C to 20/5°C in these months.

Evaporation in the catchment far exceeds rainfall and is typically 2300 mm per annum (Queensland Department of Natural Resources and Mines, 2005).

Rainfall decreases from west to east across the catchment, averaging 380 mm p.a. at Coorow and 327 mm p.a. at Wubin (Bureau of Meteorology, 2005a). Although the majority of rainfall is received in winter, highest daily rainfall totals are commonly recorded in summer or early autumn. Significant summer rainfall events occur in association with thunderstorm activity and the passage of cyclonic low-pressure systems. Examples of this include April 1961, March 1971, and January 1990.

Rainfall data is recorded at fourteen Bureau of Meteorology (BOM) weather stations throughout and nearby to the BMRC (Figure 2), 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 4. 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 volunteers, including landholders.

Table 4. Long-term average and highest daily rainfall totals observed within or in close proximity to the BMRC (Bureau of Meteorology, 2005a)

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

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

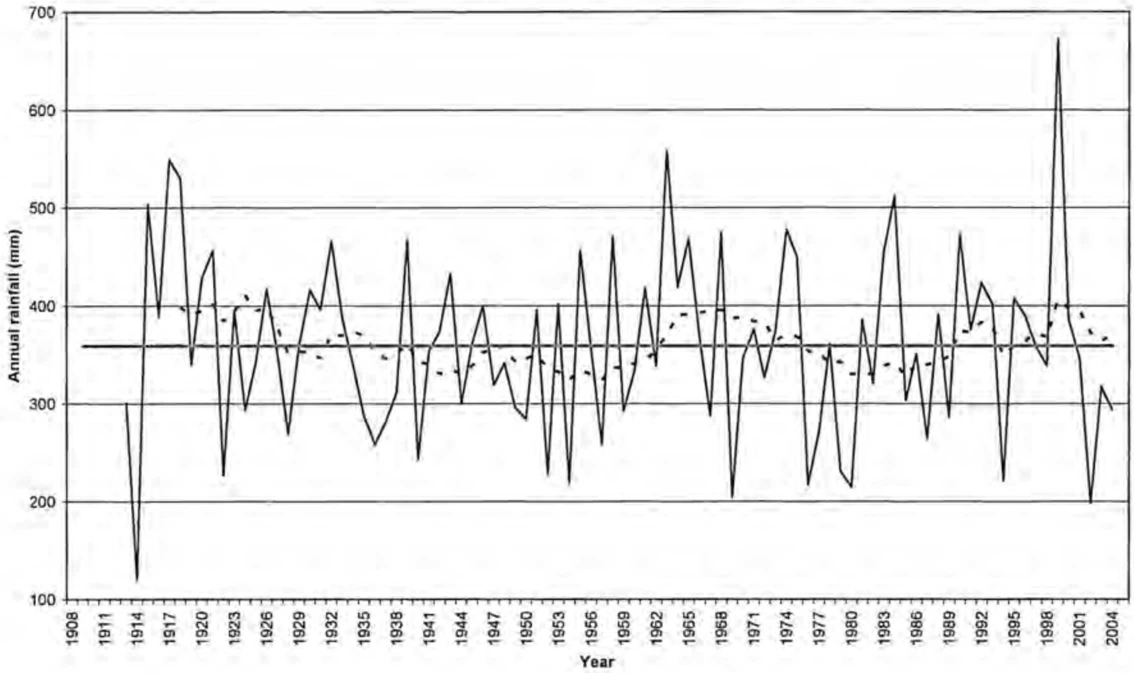


Figure 1. Annual rainfall recorded at Station 8039, Dalwallinu from 1913 to 2004 (black solid line), plotted with the 10 year mean (Black dotted line), and long-term average (solid grey line) (Bureau of Meteorology, 2005a).

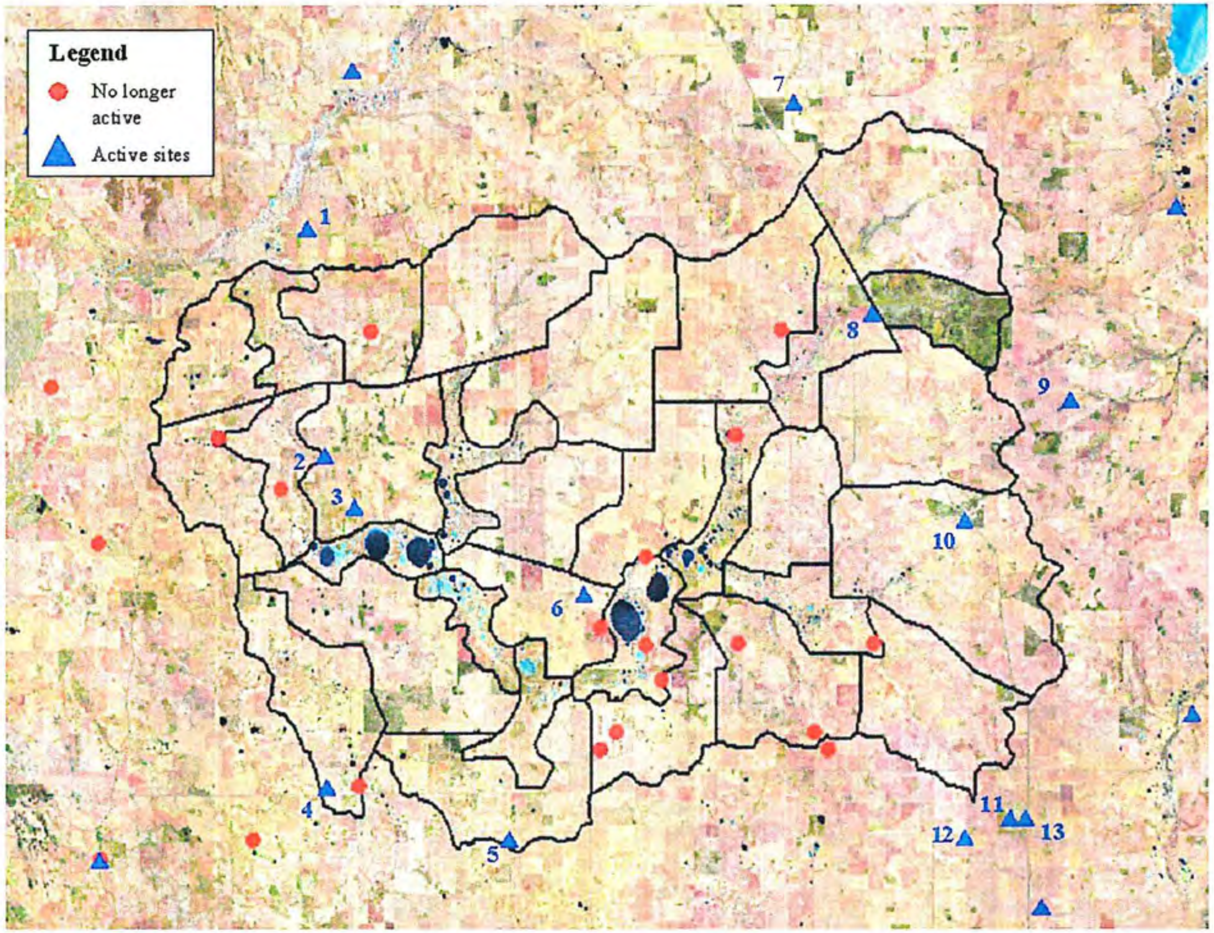


Figure 2. Location of the 14 Bureau of Meteorology weather stations and 4 automated tipping-bucket rain gauges located on private property (Short *et al* 2004).

Rainfall Analysis for the BMRC

Rainfall analysis was carried out by the Department of Agriculture's Engineering Water Management Group using long-term composite rainfall records available from the Bureau of Meteorology (Short et al., 2005). 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 30 mm.

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 40 mm more rainfall was recorded in the eastern BMRC 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 70 mm may occur in the BMRC within the next 10 years (Short et al., 2004).

Geology

The Buntine-Marchagee Recovery Catchment lies entirely on the western margin of the Yilgarn Craton. The Yilgarn Craton is a large area of stable granitic continental crust that underlies most of the southwest of Western Australia. It is more than 2500 million years old (Archaean age). Swarms of mafic doleritic dykes intrude the granitic bedrock. In the Recovery Catchment they are generally up to 10 metres thick with north to north-westerly orientation although crosscutting relationships occur (Carter and Lipple, 1982, Geological Survey of Western Australia, 1990).

The Darling Fault, which defines the western edge of the Yilgarn Craton, is about 17 kilometres west of the Recovery Catchment's western divide (Speed and Strelein, 2004).

The Yilgarn Craton has been planed down by aeons of erosion resulting in subdued relief. A thick profile of gritty clay saprolite (up to 50 m) derived from in-situ weathering typically mantles the crystalline bedrock resulting in poor exposure of bedrock throughout the Recovery Catchment. Crystalline bedrock or weathered bedrock regolith is further obscured by residual laterite profiles, colluvium and quartz sand. A surficial blanket of yellow sandplain covers the western and south western regions of the Recovery Catchment (Speed and Strelein 2004).

Conceptual geomorphology

The Recovery Catchment 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 38 m of alluvial sediments at a drill site among lakes in the main drainage line.

(Playford, 2003) describes how the Permo-Carboniferous glaciation of Gondwana may have impacted on Western Australia. He speculates that the Early Permian ice sheet may have exceeded 5000 m 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.

About 50 kilometres southeast of the BMRC, there is another drainage line that stands out remarkably in Landsat imagery because of its numerous population of 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 10 kilometres 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 70 kilometres 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).

Speed and Strelein (2004) note that the main drainage line in the Buntine-Marchagee Recovery Catchment approaches within 3.5 kilometres of the western catchment divide before turning north. This is within about 20 kilometres of the Darling Fault. At a drill site in a seemingly minor tributary in the southwest of the Recovery Catchment they report intersecting 17 m of alluvial sediments. This site is some 20 m 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.

In summary:

- Palaeochannel features in the Recovery Catchment could be relict from Permian 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 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.

Soil types and landscape mapping

Griffin and Goulding (2004) prepared a soil-landscape map of the Buntine-Marchagee Catchment at the scale of 1:100,000. This was based on draft soil-landscape mapping at the scale of 1:250,000 that was reviewed with the benefit of digital geology mapping, satellite imagery and digital elevation model derivatives such as shaded relief map. The mapping was briefly validated by field observations.

The map units were described and to each, the soils expected to be present from the point observations were proportionally allocated. From the model soil and land characteristics developed in the Map Unit database of the Department of Agriculture, interim land quality data was generated for each map unit. The main land quality issues for the catchment were briefly discussed.

Thirty-four soil-landscape units were mapped (subsystems and phases) in the catchment. These belong to 5 soil-landscape systems. Over fifty representative soils were recognised for the Buntine catchment. These were assigned to the mapped units and representative profiles were identified.

Land Capability

Land resource information can be used to predict the capability of an area of land to be developed and used for a particular land use without causing damage. Land capability assessment considers the specific requirements of the land use (e.g. unrestricted rooting depth or soil water availability) plus the risks of degradation associated with the land use (e.g. susceptibility to phosphorus export or wind erosion). It also utilises current understanding of soil properties, distribution and behaviour. This information is used to determine whether a soil or a mapping unit is susceptible to degradation or is suitable for a particular use (land use interpretation) and assists land managers in making decisions. The interpreted data is presented as land qualities.

Land qualities are attributes of the land that affect its capability for a specified use (Wells and King, 1989). Some characteristics such as water repellence or susceptibly to subsoil acidification can be attributed directly to soil. Others are linked directly to the land unit such as flood risk regardless of the soils present. Most land qualities are derived from a combination of soil and landscape characteristics.

Land qualities have been assessed for each land unit (the combination of qualified soil group and landscape position) in the BRMC (Griffin and Goulding, 2004). Land qualities are used when making capability assessments for particular land uses or to prepare specific land degradation hazard maps. Land capability has yet to be assessed and maps have not yet been developed. However, assessments have been completed for five land degradation issues considered most relevant to the survey area, including salinity risk, structural degradation, water logging, water repellence and wind erosion. Approximately 5% of the BMRC is currently saline and an additional 5% at moderate to high risk of becoming saline. These areas are mainly on the valley floors and to a lesser extent, the channels and alluvial plains.

All sandy soil types within the BMRC are commonly acidic. These include the deep sands, sandy earths and some sandy duplexes and include most of the soils in the catchment, with the exception of the Inering Hills and the Wallambin systems (Griffin and Goulding, 2004).

Subsurface compaction is mostly caused by plough pans and traffic pans. Plough pans occur in medium and fine textured soils and traffic pans occur in deeper soils. Soils susceptible to subsurface compaction typically have low organic carbon content and include loamy sands, sandy loams, sandy earths, yellow deep sands, loamy earths and red, yellow and brown loamy and sandy duplexes. More than half of the soils in the BMRC are highly susceptible to subsoil compaction. Surface soil structure decline occurs in soils with topsoils of sandy loams to clays and includes soils of the Inering Hills system and parts of the Ballidu and Upsan Downs system (Griffin and Goulding, 2004).

All soils of the BMRC are prone to water erosion, particularly where management practices (such as cultivation, overgrazing and burning crop stubble) expose the soil surface to rainfall.

Wind erosion is common on bare lighter soils with loose topsoils, such as pale deep sands, pale shallow sands and some yellow deep sands (Griffin and Goulding, 2004).

Finally, waterlogging occurs where infiltration of water is poor, for example, on clays in duplex soils. Most of the Wallambin system and the larger valleys of the Upsan Downs system are at high risk of water logging and the Ballidu and Inering Hills systems are at moderate to high risk of water logging (Griffin and Goulding, 2004).

From these assessments, five capability classes can be determined (although this has not yet occurred), which include;

1. Capability Class 1 – Very High
   Very few physical limitations present and are easily overcome. Risk of land degradation is negligible (Although experience has shown that very few land use developments have no negative effect on land degradation, hence capability class 1 will not occur for many land uses).
2. Capability Class 2 – High
   Some physical limitations affecting either productive land use or risk of land degradation. Limitations overcome by careful planning.
3. Capability Class 3 – Fair
   Moderate physical limitations significantly affecting productive land use or risk of land degradation. Careful planning and conservation measures required.
4. Capability Class 4 – Low
   High degree of physical limitations not easily overcome by standard development techniques and/or resulting in a high risk of land degradation. Extensive conservation requirements (Conservation or planning requirements likely to involve ongoing management).
5. Capability Class 5 – Very low
   Severity of physical limitations is such that its use is usually prohibitive in terms of either development costs or the associated risk of land degradation.

Hydrology

Conceptual surface water management strategy

A conceptual surface water management plan for the BMRC was completed by Sinclair Knight Merz (2003). They suggested that in the BMRC land degradation problems such as erosion, waterlogging and flooding were largely a consequence of clearing of native vegetation, and the ensuing increase in surface water runoff. Farmer *et al* (2001, 2002), and Cattlin *et al* (2002) have iterated similar conclusions for other areas of the dryland agricultural regions of the south west of Western Australia.

Following the completion of this report, the Engineering Water Management (EWM) Group of the Department of Agriculture was engaged to assess the hydrological and landscape functionality of the BMRC (Short et al., 2005). The outcomes of this report provide conceptual management strategies to assist CALM prioritise areas at risk and develop management plans.

For the purpose of the Short *et al* (2005) report, the BMRC was divided into eight topographically discrete sub-catchments determined using a Digital Elevation Model (DEM). Each of these discrete management units were then described for their physical characteristics, surface water hydrology, key landscapes and management issues, and management practices. Based upon estimations from another study in the Moore River catchment (Sinclair Knight Merz, 2001), 72-hour rainfall data was used to calculate the frequency of runoff events that might result in active surface water redistribution in the each of the sub catchments.

Short *et al* (2005) found that runoff accumulation and seepage discharge will tend to dominate the eastern catchment areas during years where regular smaller rainfall events keep profiles moist. In years where larger events associated with more intense summer events, such as following cyclonic activity and longer duration winter rainfall will result in runoff shedding from upper slopes into the valley floor. These events will have a tendency to promote sub-catchment discharge, causing hydraulic linkage of the main braided drainage channels.

This report also emphasised the association between impediment of surface water flows and the development of secondary salinity.

In conclusion, the division of the BMRC into these sub-catchment areas as described by Short *et al* (2005) provide appropriate management units in order for CALM to develop feasible management strategies to meet the BMRC goals outlined in the Recovery Catchment Plan. However, consideration must also be given to the potential for the topographical sub-catchments to hydrologically link following atypical rainfall events or successive years of above average rainfall.

Groundwater

Groundwater is a significant and important source of water for landholders in the Recovery Catchment however the yield and quality is variable. Fresh groundwater resources are scarce, discrete and largely unpredictable.

Assessment of groundwater resources in the Perenjori Map Sheet (capturing a small portion of the north-western boundary of the BMRC) was undertaken in 1991 (Commander and Mcgowan, 1991). This study revealed that extensive freshwater groundwater aquifers, being the Parmelia and Yarragadee Formations, are located west of the Urella Fault. The BMRC catchment boundary lies east of these formations, and given the nature of the underlying geology it is unlikely that extensive regional groundwater systems exist. However it is likely that local (1-3 km), and intermediate (5-10 km) groundwater systems dominate the catchment (Alderman and Clarke, 2003). This hypothesis is further supported by investigations in the Moore River Catchment by the Water and Rivers Commission (Stelfox, 2001).

Three groundwater systems have been identified in the BMRC. Groundwater occurs within weathered bedrock, sediments contained within palaeochannels and within surficial sandplain that mantles western and south western regions of the catchment area (Speed and Strelein, 2004). Each of these groundwater systems will be discussed briefly.

Weathered bedrock aquifer

Groundwater occurs within the weathered gritty clay saprolite profile. Groundwater is essentially absent in the underlying granitic crystalline bedrock. There is potential to obtain limited groundwater supplies from fractured rock in the upper transitional zone of the underlying crystalline bedrock, however predicting the location of supplies in fractured rock is imprecise. The amount of groundwater stored within fractured rock is insignificant compared with other stores of groundwater throughout the catchment.

The overwhelming majority of groundwater in the catchment is stored in the saprolite profile. The yield and quality of groundwater in this zone is variable but is generally low and of poor quality. Furthermore, groundwater in the valley floors is too saline to be of any use.

At the base of the saprolite a zone of grits and saprock (partially weathered rock) may be present from which useful supplies of stock water can be obtained. Above the zone of saprolite grits, the intensely weathered profile, typically characterised by pallid gritty clay, can form a semi-confining to confining layer above the grits. However, usually throughout the BMRC, the saturated saprolite is observed to be unconfined.

Palaeochannel sediments

Palaeochannels are ancient river systems which have been filled with sediment over time therefore characterised by variable sequences of sand, gravel, and clay. Each of these sequences has variable vertical and lateral hydraulic conductivities. Furthermore, hydraulic conductivity within each of these distinct horizons can also be highly variable.

The heterogenous nature of palaeochannel sediments means that there is a variety of processes influencing recharge and discharge throughout. For example, impeding clay layers near the surface may enhance the development of shallow perched surficial aquifers (Sinclair Knight Merz, 2003). Conversely, the deeper underlying saprolite grits are often highly permeable however lateral movement from aquifers may be relatively low due to a subdued relief. Consequently these deeper sequences may represent a recharge area for groundwater. Overlying clay horizons may acts as an aquitard, preventing upward movement of water to the upper horizons and the soil surface.

The location of palaeochannel sediments within the BMRC is not known, although it is likely that a number of palaeochannels exist within the vicinity of the main drainage line (Sinclair Knight Merz, 2003, Speed and Strelein, 2004). It is important to note that palaeochannel sediments and their associated aquifer(s) may operate at catchment scales. This may have implications for the management of groundwater in the BMRC.

Perched sandplain aquifer

Sand sheets dominate the west and south-western regions of the BMRC (Balgerbine land system). These sands are underlain by a less permeable silcrete horizon. This layer, dependent upon location in the landscape, typically lays about 3 metres below the surface (Sinclair Knight Merz, 2003).

Prior to clearing, it is likely that a relatively small proportion of precipitation would have infiltrated past the root zone, via means such as preferred pathways, to the underlying confining layer. In areas where the confining layer is close to the surface, it is likely that a shallow perched aquifer would have developed. Dependent upon landscape position and seasonal fluctuations, these shallow aquifers would discharge fresh water via seeps at the break of slope or in landscape depressions.

Since the clearing of deep-rooted vegetation there have been increased volumes of precipitation infiltrating through the soil profile to the underlying silcrete layer. As a consequence, groundwater levels in these perched aquifers have increased. Areas previously characterised by seasonal wetting or seepage are now permanently wet or seasonally inundated. There is both anecdotal and scientific evidence that this has occurred in the last few decades. Many of the perched sandplain wetlands in the western margins of the BMRC therefore did not exist prior to agricultural development. This is a recent phenomenon because these areas were the last to be cleared for agriculture due to the increased economic value of sandplain country in recent years.

A secondary consequence of rising groundwater levels in perched systems is the increased concentration of salts due to the influence of evaporation on groundwater within the capillary zone (0-3 m below the surface).

APPENDIX 5: CATCHMENT DESCRIPTION – CULTURAL CHARACTERISTICS

Agricultural Production Systems

The total area of the Buntine-Marchagee Recovery Catchment (BMRC) is 181,000 hectares with 84% (hectares) of the catchment classed as arable land.

More than 75% (133,174 ha), including a small proportion of land outside the BMRC was identified as arable land in the Landholder Survey. Broadacre farming is the predominant industry in the BMRC, with income derived from cereal and pulse grain crops, wool and meat. Wheat is the major and most valuable commodity produced (Table1 and Table 2). The average property size is 2,513 ha, ranging from 142 ha to 7,961 ha. However, due to a large standard deviation (1,601 ha) the median figure of 2,300 ha is probably a more useful figure.

Table 1: Arable land plantings by Landholders in the BMRC

Plants	Total area (Ha)	% of total	% of Landholders who have
Crops	**81,311**	73	**98**
Cereals	66,311	60	96
Legumes	13,828	12	74
Oilseed	912	1	9
Summer	27	<1	2
Pasture	**29,786**	**27**	**94**
Lucerne	973	1	8
Perennial grasses	1222	1	6
Tagasaste	560	1	19
Other Perennial Shrubs		<1	15
Commercial Trees		<1	12

Table 2: Livestock ownership by Landholders in the BMRC.

Livestock	Total Numbers	Average per property keeping this type of livestock
Sheep	87,241	1,856
Cattle	1,196	150
Other	107	15

The 'other' consisted mainly of angora goats, horses, ponies and alpacas.

Farming systems, in addition to the hazards of wind and water erosion, nutrient leaching, acidification, compaction, water repellence, waterlogging and salinisation, are threatened by issues such as herbicide resistance, climate change and declining terms of trade.

Community Profile

The BMRC falls within four local government areas, the Shires of Coorow, Dalwallinu, Moora and Perenjori.

The current population for the Shire of Coorow is estimated to be 1500 (2005). The main administrative centre is the town of Coorow, which has a population of about 200. Population is remaining relatively stable in the town of Coorow, tending to decline in the agricultural area and increasing in the coastal centres of Greenhead and Leeman. The rural sector is the mainstay of economic activity in the Shire (Goode, 2005).

The current population for the Shire of Perenjori is estimated to be 600. The main administrative centre is Perenjori where 350-400 people live. There has been a declining trend in the population since at least 1991 with around 3% average loss for the period 1991 to 1999. There is no other significant population centre, with the remainder living throughout the Shire, mainly in the agricultural and pastoral areas. Shortage of housing available for rental indicates a relatively stable town population. Agriculture and pastoralism are the mainstays of economic activity in the Shire (Goode, 2005)

The current population of the Dalwallinu Shire is estimated to be 1663. There has been a trend of increasing population. The town of Dalwallinu is located on major road and rail routes and is the administrative centre of the Shire. Agriculture is the main industry. Secondary industries and businesses associated with agriculture are a dominant feature. Mining contributes to the Shire economy with gypsum deposits mined in the eastern sector (S. Hall, *pers. comm.).*

The current population of the Moora Shire is 2780 (2005). The main administrative centre is the town of Moora. The economy of Moora is reliant on primary production but, in addition, has strong industrial, services and tourist industries emerging (D. Gilmour, *pers. comm.*).

Seventy percent of the total population (59 out of 84 Landholders) responded to the Landholder Survey. Results were considered *representative* of the BMRC community as a Census approach was used. There are approximately 84 landholders in the BMRC and 235 people living on these properties. The maximum number of people reported living on a property is 11, while 4 properties have no one in residence. The average number of people per property is 4. The largest demographic in the catchment are families with primary school age children. Seventeen percent of the catchment population are aged under 10, sixteen percent are aged between 31 and 40 and sixteen percent aged between 41 an 50 (Calm and Colmar Brunton, 2005b).

The average property size in the BMRC is 2,513 hectares and properties range from 142 hectares to 7,961 hectares.

Economic Profile

The Mid West Region's gross regional product was $2.8 million in 2001/02 (Table 3). Mining was the greatest contributor to the region's economy, this being $1.9 billion in 2001/02. Agriculture is also significant, contributing $613 million, of which $365 million came from wheat production in 2001/02. Manufacturing, tourism and fishing also contributed significantly to the regional economy ($222.4 million, $170 million and $157.5 million respectively) (Department of Local Government and Regional Development, 2001)

Similarly, in 2001/02, the Wheatbelt region's gross regional product was $2.8 billion (Table 3). Agriculture is the most significant industry, contributing $2.2 billion to the economy in

1999/00. Of this wheat and wool were the main activities, with others including cereal production, oilseeds, legumes, fruit and vegetables and livestock production. Mining is also important and this industry added 4515.5 million to the economy in 2001/02. Other significant industries include manufacturing, fishing and aquaculture and tourism, each contributing $154 million, $76.2 million and $74 million respectively (Department of Local Government and Regional Development, 2003).

Table 3: Major industries within the Midwest and Wheatbelt Regions, (Department of Local Government and Regional Development, 2001, Department of Local Government and Regional Development, 2003)

Mid West region		**Wheatbelt region**	
Sector	**$**[1]	**Sector**	**$**
Mining	1.9 billion	Agriculture	2.2 billion[2]
Agriculture	613 million	Mining	515.5 million[3]
Manufacturing	222.4 million	Manufacturing	154 million[6]
Tourism	170 million	Fishing and aquaculture	76.2 million[3]
Fishing	157.5 million	Tourism	74 million[3]
Gross Regional Product	**2.8 billion**	**Gross Regional Product**	**2.8 billion**[3]

The Northern Agricultural Region (NAR) of Western Australia has a diverse agricultural sector. It contributes 20 per cent of the State's gross value of agricultural production (GVAP) and is worth $871 million. The region contains 13 per cent of WA farms and accounts for 24 per cent of all farm land in the State's agricultural area.

The Northern Agricultural Region is heavily reliant on wheat production. In addition, the region produces almost half of the State's grain legumes. (Graham Annan, *pers comm*, Mandy Dearden, *pers comm*).

In each of the four Shires in the BMRC, crops had the greatest economic value compared with slaughterings and livestock products. The principal agricultural commodities produced in the BMRC are exported and as a consequence, a direct link exists between world economic growth and the local BMRC and NAR economies.

In terms of national broadacre farm performance, historically, farm cash incomes for Western Australian broadacre farms have exceeded the national average. In part, this a consequence of the large average enterprise size of Western Australian farms, compared with broadacre farms nationally. (ABARE 2005)

Compared with farms in the Northern Wheatbelt and the Central Midlands, farms in the Shires located within the BMRC are generally more profitable. For example, in 2000/01 farms in the Shire of Moora made an average profit of $60 per effective hectare and farms in the Shire of Dalwallinu, an average profit of $60 per effective hectare. This compares with a 5-yearly average for the Central Midlands of $60 per effective hectare and $40 per effective hectare for the Northern Wheatbelt (areas with <350mm rainfall) (Alderman and Clarke, 2003).

[1] In 2001/02
[2] In 1999/00
[3] In 2001

The 2003 Landholder survey indicated that annual expenditure on conservation works including fencing, revegetation and earthworks averaged $3000 or less for each. However, it is difficult to compare expenditures on conservation works as the market cost of each work is different. Other factors also affect the amount of money being spent such as commodity prices and climatic conditions causing income fluctuation. Generally, compared with expenditure on other farming activities, spending on conservation works is low.

Infrastructure

The BMRC has a well developed transport network, with 17km of Highway, 74 km of main roads, 130 km of other sealed roads, 502 kms of unsealed roads and 443 km of tracks. The Midlands road lies on the western boundary of the catchment and the Mullewa – Wubin Road on the eastern boundary. Main Roads W.A manages these two roads. The principal east-west routes in the Buntine-Marchagee Catchment are the Buntine-Marchagee Road and the Gunyidi-Wubin Road. These are managed either by local government authorities. Other sealed and unsealed roads and tracks within the BMRC are variously managed by local government authorities or individual Landholders.

Two railway lines service properties in the BMRC. These lines are owned by Westrail and the rolling stock is privately owned. The Midland Railway was constructed in 1894 and passes to the west of the BMRC, approximately following the Midlands Road. The Mullewa-Wongan Hills Railway passes through the eastern side of the BMRC. This line was completed in 1915. There are CBH Grain Receival points servicing properties in the BMRC located at McLevie, Wubin, Buntine, Marchagee, Coorow, Maya, Latham and Watheroo.

There are a range of public utilities and services within the BMRC which are significant to the communities. Utility corridors often link various electricity, gas, telephone and water service networks to private property. There is a myriad of distribution lines which deliver power to households and townsites, although no high voltage transmission lines pass through the catchment. These lines are managed by Western Power. Most properties within the BMRC have a telephone service and some landholders have access to fax and internet services.

Domestic water is generally supplied by rainwater collection and bores on farms. Water for the towns of Buntine, Coorow and Dalwallinu are supplied by the Water Corporation through the Regional Town Water Scheme.

Community Services

There is no additional information relating to community services within the BMRC.

APPENDIX 6: WETLAND CHARACTERISATION

Wetlands are 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 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). Two broad categories of wetland are recognised. Coastal wetlands are associated with tidal zones, often where fresh water meets seawater in estuaries. Inland wetlands form on floodplains, along rivers and streams, in depressions surrounded by dry land and in other locations where the groundwater table intercepts the surface or precipitation is sufficient to saturate the soil.Wetlands are found in every climatic zone and on every continent, except Antarctica (Gopal and Junk, 2001).

Background to Wetland Characterisation

The aim of the Buntine Marchagee Recovery Catchment project is to maintain the current biodiversity in a range of representative wetlands by 2020. The catchment includes over 1000 discrete wetlands arranged along the course of a saline braided channel. If management actions are to be targeted at threatened wetlands that are representative of the catchment, it is first necessary to characterise the 'types' of wetlands that occur there.

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 very 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 catchment in 2003 (Meney and Coleman, 2003). That study involved two visits to each of 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 but achieving this level of detail in a broad-scale study would be prohibitively expensive and time consuming.

The BMRC 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 1000 wetlands is prohibitively expensive and time consuming.

A Characterisation Scheme for the BMRC

The aim of the characterisation process in the BMRC is to divide the catchment's 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 catchment's wetlands, determining suites of like wetlands and assigning relative conservation value. However, the large number of wetlands in the BMRC, 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 BMRC (Storey et al., 2004a) 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 biota supported by a wetland. Salinity is a particularly good indicator with the greatest biodiversity, greatest degree of endemism and highest conservation value occurrent in fresh water bodies. Salinity is far easier to measure than biodiversity but a comprehensive water-monitoring program for 1000 wetlands is still not feasible in the current context.

The scale of the BMRC 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.

A characterisation scheme for the wetlands of the BMRC 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 tested against biological survey and water quality data collected in the BMRC. A number of wetlands in the catchment have been sampled for aquatic invertebrates, flora and water quality over the last 5 years. The information yielded by this sampling provides additional parameters by which to group the sampled wetlands. If the proposed characterisation scheme develops similar groupings for the sampled wetlands, it will be considered sufficiently accurate to extrapolate across the catchment. Refinement of the characterisation scheme will continue as further ground truthing is undertaken.

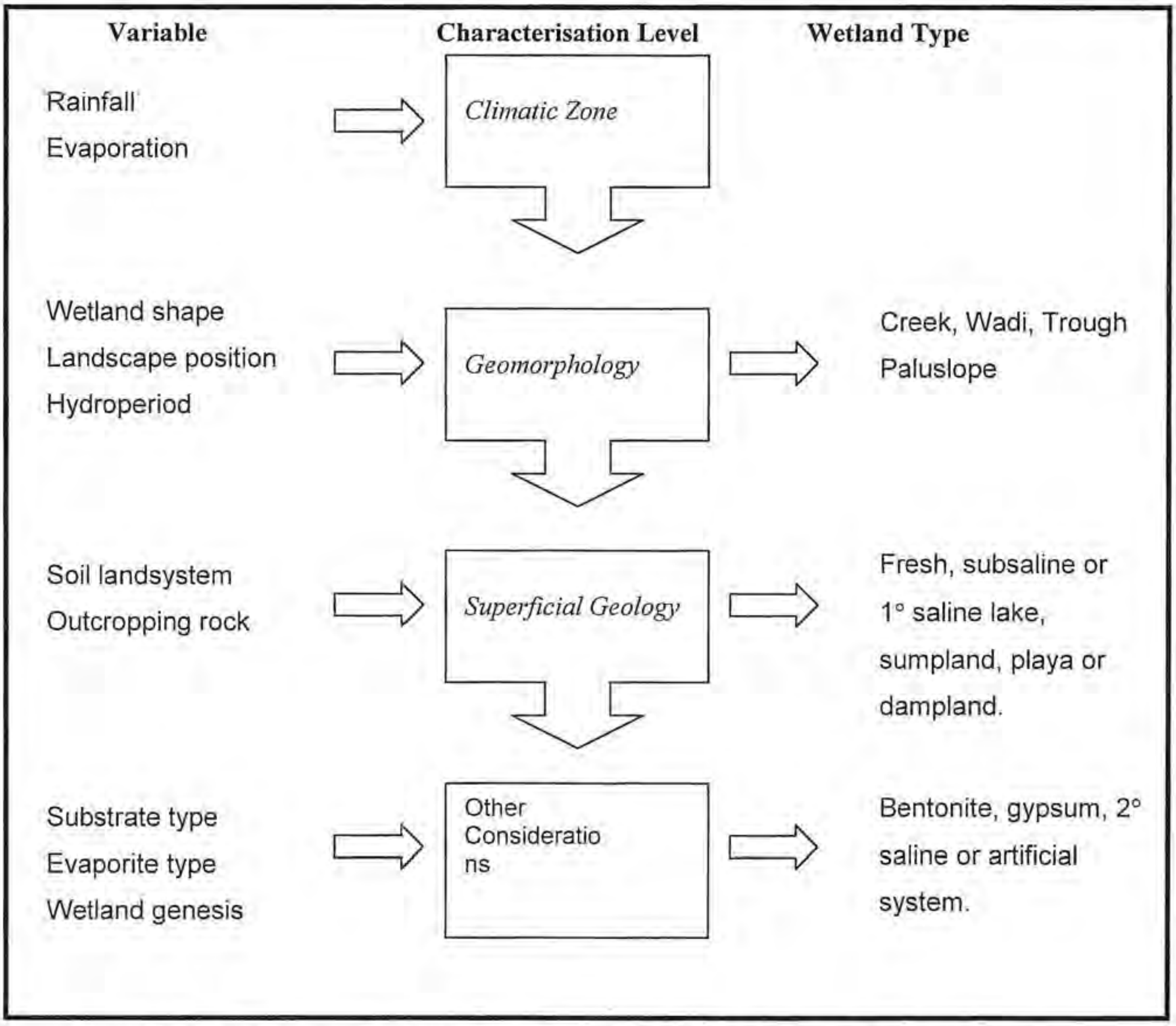


Figure 1 – The structure of the proposed characterisation scheme for the BMRC, showing required inputs and resultant groups of similar biological values.

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

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.

Table 1 – a geomorphic characterisation scheme for wetlands (Semeniuk and Semeniuk, 1995).

Water Longevity	Landform				
	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

Superficial Geology

Geologic setting and processes influence the occurrence and character of wetlands in the BMRC. 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 BMRC and the soils on which they occur can result in the salinisation of the wetlands. Groundwater rise has been experienced across the BMRC 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 catchment's 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 a result of contact with landholders or, opportunistically, during field work. To date, one unique substrate type, Bentonite, and one unique evaporite type, gypsum, have been found in the catchment. 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.

Results of the Wetland Characterisation

The wetland characterisation process in the BMRC aims to develop groupings of wetlands that share similar biodiversity. These wetland groups are termed 'consanguineous suites' and are defined by similarity in physical setting and causative factors of wetland development (Semeniuk, 1988).

The characterisation scheme described in Figure 1 was applied to the BMRC via a desktop GIS analysis of the catchment. Wetland suites were developed utilising the best information that is currently available. There are obvious shortcomings in this process and it will be refined as more information is collected in the ground truthing phase of the characterisation process.

Climate was discarded as a variable by which to distinguish between wetland types. The small variation in rainfall across the BMRC is not sufficient to delineate climatic regimes. 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.

The BMRC wetland chain has 1014 individual basins. Of these, the majority occur in the Wallambin soil system (69.5%), a substantial number in the Balgerbine soil system (21.4%) and small numbers in the Upson Downs (5.6%), Ballidu (2.8%) and Innering Hills (0.7%) soil systems.

Wetlands in the Wallambin soil system are primary saline remnants of the region's ancient drainage system. These wetlands lie at the lowest points of the catchment in the valley floor and are mostly broad, shallow basins that experience seasonal or periodic inundation. Although surface drainage now only occurs in very wet years, many of the area's soils developed in saturated conditions during the period when this drainage line was functional (Short et al., 2004). These soils store large quantities of salt, deposited by aeolian and alluvial processes.

The remnants of the ancient drainage system are expressed as a series of salt lakes connected by a braided drainage channel. GIS analysis of the geomorphology of the BMRC showed the catchment to contain some 918 km of braided channels. This figure will show interannular variation as flood surges scour the drainage channel and alter its morphology. There are no perennial channels in the catchment; the braided channel consists of a combination of creeks, wadis and troughs (seasonally inundated, intermittently inundated and seasonally waterlogged respectively). There are also a multitude of constructed drains in the catchment, which transmit water at various times.

This valley floor system separates aeolian Quaternary sands in the west of the catchment (Balgerbine system) from heavier Archaean weathering products in the east (Innering Hills, Upson Downs and Ballidu systems). Thus, the salinisation of wetlands is more prevalent in the east of the catchment with the western portion of the area typified by fresh to brackish seeps and basins.

At present, little is known about the few wetlands that have formed in the Upson Downs, Ballidu and Innering Hills soil systems. Desktop analysis shows these wetlands to occur at the lowest point of the landscape in each of these soil systems, generally within, or very near, the braided channel. Wetlands in these systems are, therefore, assumed to be similar in character to those of the Wallambin soil system.

The other major class of wetland are those on the Balgerbine soil system. These are seeps and expressions of perched aquifers that have formed on sandy soils in the catchment's west. They are generally naturally fresh to brackish, although secondary salinisation is common in this area.

Granitic bedrock outcrops at several points in the catchment. The rock pool wetlands that form on these outcrops have unique characteristics. Granite pools are fed by rainfall and surface water runoff with no groundwater interaction. This ensures they retain very fresh water, support a diverse suite of biota and have very high conservation value. The occurrence of granite rock pools can be determined by intersecting the locations of granite outcrops (mapped during detailed geological surveys of the catchment) with the locations of wetlands. To date, only two granite rock pools have been identified for inclusion in the wetland sampling program. However, with some 6000 ha of granite outcrop in the catchment, it is highly probable that other significant sites exist elsewhere.

There are two types of wetlands in the catchment defined by unique characteristics. At the northern end of the drainage line is a lake in which distinctive water chemistry causes the formation of calcium sulfate (gypsum) crystals, rather than the sodium chloride crystals seen across the majority of the area's lakes. A small number of basins have also been identified that share a unique substrate type. In these wetlands a bentonite floor supports a distinctive suite of vegetation and, although a lack of water has precluded sampling, possibly unique aquatic invertebrates.

It is difficult to quantify the artificial wetlands within the BMRC. GIS analysis suggests there are at least 466 dams in the catchment, along with 63 km of drains. A multitude of tanks, troughs, sumps and other features add to the list of artificial wetlands that may potentially provide habitat for aquatic fauna, but artificial 'wetlands' will be excluded from consideration in the current project.

Degraded wetlands, such as those that have become subject to secondary salinisation, form subgroups within each of the preceding categories.

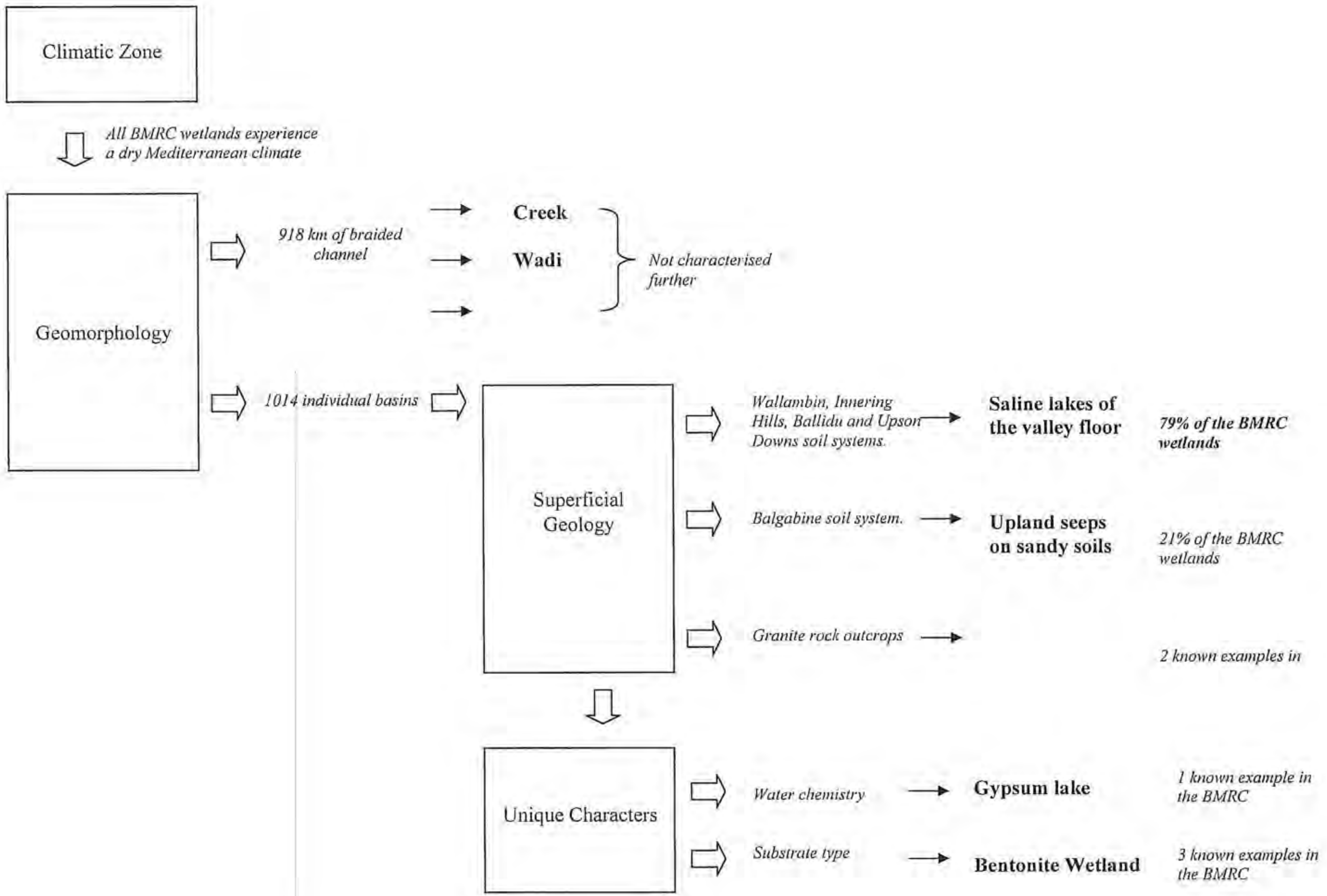
Wetland types in the BMRC expressed as a percentage of all BMRC wetlands.

Soil System	Basin Type (% of all wetlands)			
	Lake	Sumpland	Playa	
Balgerbine	12.1	6.7	0.0	→ Sandy Seeps
Ballidu	0.2	1.3	1.6	Primary saline wetlands
Innering Hills	0.4	0.2	0.1	
Upson Downs	2.6	3.0	0.0	
Wallambin	3.4	38.7	29.7	

Therefore :

saline sumplands = 43.2%
saline playas = 31.4%
sandy lakes = 12.1%
sandy sumplands = 6.7%
saline lakes = 6.6%

of all BMRC wetlands (approx).


Climatic Zone
All BMRC wetlands experience a dry Mediterranean climate
Geomorphology
918 km of braided channel
Creek
Wadi
Not characterised further
1014 individual basins
Superficial Geology
Wallambin, Innering Hills, Ballidu and Upson Downs soil systems.
Saline lakes of the valley floor
79% of the BMRC wetlands
Balgabine soil system.
Upland seeps on sandy soils
21% of the BMRC wetlands
Granite rock outcrops
2 known examples in
Unique Characters
Water chemistry
Gypsum lake
1 known example in the BMRC
Substrate type
Bentonite Wetland
3 known examples in the BMRC

Prioritisation of Wetlands

There are currently five unique wetland types recognised within the BMRC. The goal of the BMRC project is to maintain the current biodiversity in at least one wetland of each suite. The wetland selected for management action should contain biodiversity that is representative of the suite. It should be the wetland in each suite that is in 'best condition' having suffered the lowest level of impact due to the threatening processes that are occurrent in the catchment.

To date, limited assessment has been made of the biodiversity and condition of the BMRC. Twenty wetlands have been sampled for aquatic invertebrates and remnant vegetation has been mapped in the catchment. These are the only elements of the catchment's biota that are currently available for the determination of conservation priority amongst the catchment's wetlands.

Of the saline wetlands in the valley floor that were sampled in 2004, the greatest richness of aquatic invertebrate species was recorded in site W002, followed by W061 and W004. Site W004 has been selected as the highest priority wetland in this suite as it also lies within one of the larger patches of remnant vegetation in the catchment. The vegetation of this patch is quite diverse and includes shrubland, heath and mallee associations characterised by *Eucalyptus spp., Melaleuca spp., Acacia spp., Halosarcia spp.*, sandplain cypress, tamma and wodjil. The combination of a relatively rich aquatic invertebrate fauna and extensive, diverse, healthy vegetation makes W004 a stand-out site in the valley floor.

Site W002 has similar conservation value to site W004. It has not been selected as the priority wetland in this suite because it lies outside the true catchment boundary. It is also positioned in close proximity to the Gypsum Lake. Attempting to conserve this wetland would facilitate the concentration of management effort, however, the level of threat in this area is high. Site W061, although relatively rich in aquatic invertebrates, is highly degraded. Remnant vegetation surrounding this lake is in extremely poor condition and soils are extensively waterlogged. Cropping also occurs upslope in close proximity to this basin and impacts of eutrophication are evident. The level of threat at site W002 precludes it from consideration as a priority wetland.

Two groups of sandy seeps stand out as high priority examples of that suite. The first of these, colloquially referred to as 'Nearbappy', is a visually distinctive site consisting of a series of freshwater springs amongst *Melaleuca, Eucalyptus,Casuarina, Juncus and Typha* species. The two sites in this group that were sampled for aquatic invertebrates in 2004 were the 5th and 6th most species rich freshwater seeps. Although visually striking, well vegetated and supporting a diversity of aquatic invertebrates, this group is located very close to the saline drainage line. The level of threat posed by hydrological change is considered to be too great to include the sites of this group as priority wetlands.

Higher in the landscape in the Balgerbine soil system, is a group of fresh sandy seeps that better fulfil the requirements of a priority wetland. These wetlands (sites W009, 10 and 11) are typical sandy seeps, showing much greater depths and periods of inundation than would have occurred naturally. They are currently maintaining good water quality, although evapoconcentration of salts in the water body will occur without management intervention. This group includes the sandy seep with the greatest richness of aquatic invertebrate species, but the level of disturbance at this site precludes it from consideration here. A nearby site, W011, recorded the 3rd highest richness of aquatic invertebrates in the 2004 survey and is less threatened than its neighbours. Vegetation at W011 is reasonably healthy and diverse with areas of *\Melaleuca* and *Banksia.* Site W011 has, therefore, been selected as the priority sandy seep, based on observations of the richness of aquatic invertebrates, the diversity and vegetation and a seemingly managable level of threat.

The catchment's three bentonite wetlands (W057, 58, 59) are located in close proximity to one another. Little is known of the biodiversity of these assemblages, but they may support threatened ecological communities. The nature and condition of fringing vegetation is similar at each of the Bentonite wetlands. All three of these wetlands will be treated as priority sites, as they have potentially very high conservation value, are located in close proximity to one another and are small in size.

To date, only one example of a granite rock pool (W072) and one example of a gypsum dominated system (W001) are known in the catchment. Each of these is a priority site.

APPENDIX 7: BIODIVERSITY VALUES OF THE BMRC WETLANDS

The *assets* to be conserved in the BMRC are those *assemblages* and elements of the *biodiversity* that occur in *wetland* areas or contribute to the function of wetland areas as well as threatened species and communities that are at risk from hydrological change[4].

An *asset* is a discrete physical, biological or human made entity that has value, or a location with multiple values (Department of Environment, 2003). For example, the BMRC 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.

An *assemblage* is 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.

Wetland areas are 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 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.

The BMRC was nominated as a recovery catchment on the basis of the unique wetland system at its centre. This system includes at least 1000 wetlands, arranged along a saline braided drainage channel. They include perennial and non perennial lakes, seasonally damp swamps, salt pans, seeps and rock pools. The description of these assemblages will be a process that continues throughout the life of the BMRC project, however, nomination as a recovery catchment recognises that that this system is an asset that has:

- biota that are representative of important communities
- threatened communities and species
- high levels of community and species richness
- significant ecological function.

Values of the BMRC

Assets are valued becaue they help people to acchieve goals. In determining the relative value of assets, it is important to recognise that there are firm quantitative measures for economic values, but none for describing social and environmental values (Department of Environment, 2003). Indeed, the perceived benefit of these latter values may vary between individuals,

[4] The current document recognises that the BMRC has natural assets apart from those covered by this definition, but these are not the focus of the Recovery Catchment program. As such, these other assets are not covered by the following discussion. Information relevant to many of these is contained in the accompanying appendices.

depanant upon their spiritual and philisophical beliefs. The benefits obtained from natural assets by mankind can be described as intrinsic (spiritual / philosophical) values, opportunity values, ecosystem service values, research and education values, amenity values, recreation values, heritage values, productive use values and consumptive use values (Table 1).

Table 1: Wetland Values and their connection to human quality

Opportunity Values	The native flora and fauna of the south west of Western Australia are unique. The flora, in particular, is renowned internationally for its diversity. This diversity represents enormous potential for the development of new products, including industrial and medicinal products.
Ecosystem Service Values	Ecosystem services are the benefits that come to humans from natural processes. Examples of ecosystem services provided by wetlands include the provision of clean air and water, natural fertilisation and nutrient cycling in soils, mitigation of climate, pollination of plants including crops, control of pests and provision of genetic resources, (Cork and Shelton, 2000) Despite many of the BMRC wetlands being highly degraded they still provide an ecosystem service to the catchment, as well as contributing to processes operating at a global scale. The maintenance of natural ecosystems is more cost-effective than developing any engineering solution to simulate these processes (Cork, 2001). Of high importance in the BMRC is the mitigation of floodwaters by the catchment's wetlands. The BMRC wetlands store floodwaters and slowly release them downstream, slowing the flow of water and reducing peak water levels. This prevents broad scale flooding in times of high rainfall and reduces erosion by flowing water. By slowing water flows and providing areas of stagnant water, the BMRC wetlands also act as sediment and nutrient traps. Fine particles settling out in stagnant waters create a nutrient sink and reduce both sediment and nutrient loads downstream. While held in wetlands, water is filtered, purified and detoxified by a range of organisms including plants, invertebrates, and fungi. Areas of standing water contribute to groundwater recharge in the catchment. Where wetlands pool water over fractured bedrock, they contribute to recharge of groundwater aquifers. In other instances, however, they may encourage groundwater discharge by exposing large areas of water to evaporation and supporting plants that allow transpiration of groundwater. At a global scale, the sequestration of carbon by plants is an ecosystem service. Although much vegetation has been lost from the BMRC, the high productivity of wetlands means that remaining areas are even more important to the global capacity for sequestration of carbon.
Amenity Values	Amenity values include the aesthetic contribution of natural assemblages to the landscape and the contribution of particular assemblages to the development of a 'sense of place', for example, Salmon gum woodlands (*Eucalyptus salmonophloia*) provide a sense of the WA Wheatbelt. The wetlands of the BMRC provide vistas, without which the catchment would be a monotonous agricultural landscape. Viewsheds encountered in the catchment range from densely vegetated swamps to distinctive granite rock pools and expansive salt lakes. Although it is difficult to

	discuss landscape values in any quantifiable way, residents obviously hold this landscape in some esteem, as is evidenced by the naming of properties such as *Lakeview*
Research and Education	Natural settings provide opportunities to advance the understanding our land and how it works. Native vegetation also provides the only source of reference material if we wish to understand how agricultural practices have affected soil structure and other properties. Many educational institutes, therefore, use natural lands for educational purposes. Maintenance of these areas is essential if future generations are to be provided these same opportunities (Department of Environment, 2003). Despite the ubiquity of saline wetland systems in the agricultural zone of Western Australia, comparatively little is known about their ecology. Recent research (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. The BMRC presents researchers with several wetland types, showing a range of impacts, within a typical wheatbelt braided drainage channel. The variation in conditions encountered in the catchment, convenience of its central geographic location to population centres, growing body of research already undertaken, support of dedicated staff and cooperation of landholders all combine to make this catchment an ideal location for ongoing research into wheatbelt wetlands. If researchers currently understand little of the functioning of saline wetland systems, it is reasonable to generalise that the general public understand less. The list of values under discussion here clearly demonstrates the importance of these systems. Their worth is, however, often underestimated by members of the community who may be unaware of the deleterious effects of secondary salinisation or the effects of land degradation on the range of biota that utilise naturally saline lakes. The BMRC provides 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. The catchment has a high profile in the region, is located for access from Geraldton or Perth and contains sympathetic land managers. Provision of information to landholders, through schemes such as the Surface Water Demonstration Site, is already occurring and an extension of this program to include wetland sites would facilitate education.
Recreation	Recreation is a common human usage of natural environments. Recreational activities range from low impact, nature based pursuits such as bushwalking or bird watching to potentially disturbing activities such as trail bike riding. The BMRC has many examples of wetlands utilised for recreation. Evidence comes in the form of wetland names (Ski Lake, Cut-up Lake, Swimming Hole), anecdotes from landholders about watersports enjoyed locally and personal observations of infrastructure at various wetlands. Wetlands also provide opportunities for bird-watching, amateur botany and picnics. Many of the recreational activities enjoyed in the BMRC wetlands coexist comfortably with the aims of biodiversity conservation. Recreational usage of the wetlands is, therefore, not necessarily problematic. Indeed, if low impact usage encourages the community to develop an affinity with wetlands and, through this, with the conservation of wetlands, it may prove beneficial.
Intrinsic Values	Intrinsic value must be considered quite separately from the benefits derived from any usage or function of natural assemblages. The term

	refers to the value that assemblages have "in themselves," or "for their own sake". Intrinsic value cannot be quantified in any way, it is a philosophical principle that lies at the heart of conservation. As such, the intrinsic value to an individual of any natural assemblage will be dependant upon that individual's beliefs. Wetland systems are considered to be intrinsically valuable as representatives of an increasingly scarce ecosystem type. As wetland systems become scarcer, the intrinsic value of all remaining systems increases. The intrinsic value of these assemblages encompasses the value of the existence of unique and distinctive landforms and the contribution of their biota to the global genome. The wetlands of the BMRC are representative of a natural assemblage type that is both rare and threatened. Taxa may exist within these wetlands that will allow the development of valuable new industrial and medicinal products. The loss of these taxa to hydrological change or other associated land management issues would represent potential lost opportunities.
Heritage Values	Heritage values arise from the history of human interaction with a natural setting. The BMRC contains several Aboriginal and European historical sites. The first European settlers and drovers working in the catchment developed wells to access water, particularly along stock routes. Although the stock routes are now extinct, these wells have persisted and today function as artificial wetlands. Prior to European settlement, the BMRC wetlands would doubtless have held value for the Aboriginal people of the area. One of the catchment's wetlands incorporates a registered Aboriginal heritage site and there is also at least one known gnamma in the area.
Productive Use Values	Productive use refers to the benefits of products that are obtained from a natural setting and marketed prior to their usage. Some wetlands in the BMRC are utilised for agriculture.
Consumptive Use Values	Consumptive use refers to the benefits derived from products that are obtained from natural systems and utilised without passing through a market. For example, fresh and brackish water bodies are commonly used for watering stock or irrigation. Such usage is becoming more prevalent as rising groundwater increases the availability and permanence of water supplies however predictions indict a serious decline in water quality.

APPENDIX 8: WETLAND VEGETATION AND FLORA

Wetland 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 nature 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. It is, however, possible to make some generalisations about the wetland vegetation of the BMRC.

Aquatic and littoral vegetation is an important component of the BMRC wetland system. Vegetation facilitates the evapo-transpiration of groundwater, provides habitat and food for fauna, prevents erosion of fragile soils and uses nutrients that would otherwise accumulate in the soil and water column. Monitoring the diversity and health of aquatic and littoral vegetation in the catchment is essential to understanding the wetland system.

Coordinated monitoring of wetland vegetation in the BMRC commenced in 2004 (Richardson et al., 2005). The composition and structure of vegetation communities and the vigour of individual plants were recorded along transects that extend upslope from 27 of the catchment's wetlands. Although this program did not attempt to record total species richness, it nevertheless demonstrated that there is considerable diversity of vegetation types at the surveyed wetlands.

The composition and structure of littoral vegetation is largely determined by patterns of soil, level of water logging and historical land usage. The variety of soil units and patterns of land usage abutting wetlands in the BMRC has resulted in a diverse suite of wetland vegetation. These wetlands are most commonly fringed with samphire and a variety of herbaceous species, with an overstorey of *Melaleuca spp.* or *Casuarina obesa.* Only seven of the 27 surveyed wetlands supported aquatic vegetation and a total of eight species of water plants were collected from these[5].

The condition of fringing plant communities ranges from almost pristine to heavily impacted, according to the influence of groundwater rise and land management regimes in the vicinity. Vegetation of wetlands higher in the landscape tends to be in better condition, with granite rock outcrops maintaining the most natural suite of flora. The most significant effects of groundwater rise have occurred low in the landscape. At several lowland sites, water logging and permanent inundation of soils of the littoral zone have resulted in a total loss of fringing vegetation.

Livestock also cause significant impacts on the wetlands of the catchment. At sites where sheep are watered, grazing pressure and loss of soil structure has resulted in the degradation of vegetation and soil erosion.

[5] It should be noted that describing aquatic vegetation was not the principal aim of this survey and so, the methodology employed may not have provided comprehensive coverage of these wetlands (J. Watts, 2005. pers comm.).

Prior to the establishment of vegetation monitoring transects at the BMRC wetlands, the catchment's remnant vegetation was mapped by CSIRO as the first component of a focal species study (Csiro, 2004). Although this mapping provides a wealth of valuable information on the terrestrial vegetation of the catchment, it does not detail the vegetation of the wetlands. The focal species study considered only sedentary bird species present in the catchment and their usage of vegetation as habitat. It excluded lacustrine and littoral habitat as these more commonly support migratory species.

The other available source of information on the vegetation of the wetland system is Beard's vegetation association mapping (Beard and Sprenger, 1984). This was performed at a scale of 1:250 000 and the methodology and level of resolution do not differentiate between the vegetation of the littoral zone and surrounding terrestrial communities.

The vegetation of the BMRC wetlands is a key value to the catchment. Littoral and lacustrine vegetation has a range of functions, including maintaining water balance via evapotranspiration, providing habitat and food to fauna, preventing soil erosion and filtering impurities from water. Flora monitoring around the wetlands has shown the diversity of vegetation to be high and the condition to range from near natural to heavily impacted. Continuation of the wetland vegetation monitoring program will provide an indication of the interaction between vegetation and groundwater as well as quantifying the effects of groundwater rise on native vegetation.

Bentonite lake-bed vegetation

The vegetation of bentonic lake beds in the south-western area of the catchment are likely candidates for listing as TECs. (Hamilton-Brown, 2002) recorded a number of herbaceous plant assemblages on bentonite lake beds and margins only in the Watheroo and Marchagee region. These assemblages are currently listed as TECs (endangered). The plants are herbaceous and dominated by *Triglochin mucronata, Trichanthodium exile, Asteridea athrixioides* and *Puccinellia stricta* on the lakebeds, and *Podolepis capillaris, Angianthus tomentosus* and *Pogonolepis stricta* on the lake margins, (Hamilton-Brown, 2002). The plants are characterised by their dependence on the bentonite (saponite) substrate. This substrate is restricted to the lakebeds and margins of perched, ephemeral freshwater playa lakes and claypans of the Watheroo-Marchagee area (Hamilton-Brown, 2002). In some instances, varying densities of *Casuarina obesa* trees and *Melaleuca lateriflora* subsp. *lateriflora* and *Acacia ligustrina* shrubs occur with the herbaceous assemblages. The vegetation of the BMRC bentonite lakes should be assessed for TEC status.

APPENDIX 9 – TERRESTRIAL VEGETATION AND FLORA

Vegetation and Flora of the BMRC

Mostly because of the diversity of flora, the agricultural zone of Western Australia - a part of the Southwest Botanical Province (SWBP), is recognised internationally as one of the world's 25 'megadiversity hotspots' (Myers et al., 2000). It is the only such area in Australia and one of the few hotspots found in a developed country. This area is also recognised for its high concentration of endemic species (plants and animals occurring nowhere else).

Species rich plant groups such as *Acacia, Dryandra, Eucalyptus, Grevillea* and *Verticordia* characterise south-west WA. In particular, species diversity of the *Acacia* genus is at its highest concentration worldwide between Perth and Coorow. Indeed, a recent biological survey, of the agricultural zone of WA has shown this area to be more floristically diverse than previously supposed (Keighery et al., 2004). That survey also demonstrated that the agricultural zone is a central part of the mega-diverse Southwest Botanical Province.

The National Reserve System Program (NRS) was adopted to establish a comprehensive, adequate and representative (CAR) system of protected areas to conserve Australia's biodiversity. To ensure that the NRS encompassed the full range of biological and biophysical diversity across Australia, the Interim Biogeographic Regionalisation for Australia (IBRA) and Interim Marine and Coastal Regionalisation for Australia (IMCRA) were developed. The rationale behind this classification scheme is that physical processes drive ecological processes that, in turn, are responsible for driving the observed patterns of biological productivity and the associated patterns of biodiversity (Thackway and Cresswell, 1995). The current State-wide target levels for a CAR reserve system is set at 15%, consistent with national benchmarks (Calm, 2003).

The BMRC lies across the boundary of two bioregions; the Avon Wheatbelt and the Geraldton Sandplains (Figure 1). The IBRA divides Australia into 80 separate bioregions and 384 sub regions, based on climate, geology, soils, topography and vegetation. Characteristic flora and fauna were interpreted to describe these patterns (Cummings and Hardy, 2000).

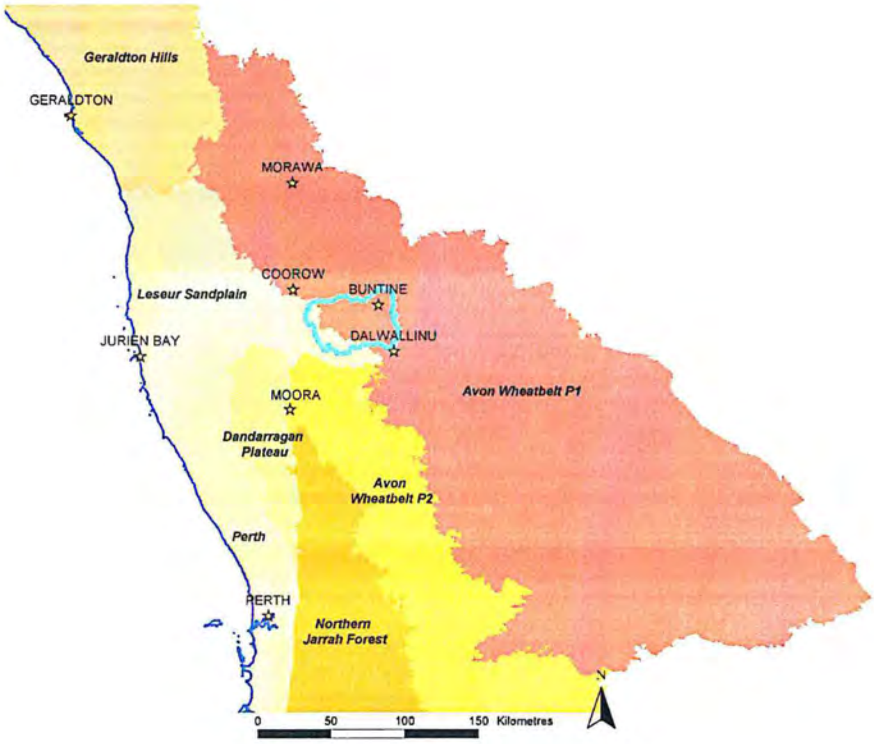


Figure 1: IBRA Regions in the BMRC

Table 1. Beard's vegetation types occurring in the BMRC with < 2000 ha and < 10 percent of original extent in the Northern Agricultural Region (NAR).

		LIMITED EXTENT				POORLY REPRESENTED			
Beard Code	**Beard description**	**<2000 ha NAR***	**<2000 ha State**	**<10% NAR**	**<10% State**	**0% NAR**	**< 15% NAR**	**0% State**	**< 15% State**
E6,8Mi	Medium woodland; York gum and Salmon gum			X		X			X
E8Mi	Medium woodland; Salmon gum	X				X			X
A33,34,35	Shrublands; *Acacia neurophylla*, A. *beauverdiana* and *A. resinomarginea* thicket.			X			X		X
C3Sc xZi	Shrublands; *Allocasuarina campestris* thicket with patches of heath.			X	X	X		X	
M5Sc k3Ci	Succulent steppe with thicket; *Melaleuca thyoides* over samphire						X		X

* The representation of these vegetation types in IUCN 1-1V reserves is given for the NAR and the State (0 percent or < 15 percent of original extent). Those shaded are extremely limited in extent (< 2000 ha and / or < 10% of original extent remaining in NAR or the State) and poorly represented in the IUCN 1-1V reserve system (0% and / or < 15% of original extent remaining in NAR or the State) (Richardson et al., 2005).

Table 2. Beard's vegetation types that are extremely limited in extent (< 10%) and poorly represented in the Moore Catchment (top end of the BMRC) and the BMRC.

Beard description*	Proportion of original cover remaining (%)	Poorly represented (<15%)
Shrublands; *Allocasuarina campestris* thicket with patches of heath.	6 %	6 %
Medium woodland; York gum and Salmon gum.	7 %	7 %
Shrublands; *Acacia neurophylla*, A. *beauverdiana* and *A. resinomarginea* thicket.		10 %
Medium woodland; York gum		11 %

* The shading denotes overlap with the NAR (Alderman and Clarke, 2003).

Table 3. 'Before' and 'after' land clearing comparisons of the area of 11 vegetation types broadly mapped by Beard.

Beard's vegetation description*	Original Area (ha)	Original percentage of Catchment	Current Area (ha)	Current percentage of Catchment	Percentage of original extent
Shrublands; *Acacia neurophylla, A. beauverdiana & A. resinomarginea* thicket	49026	27	6093	3.4	**12.4**+
Shrublands; *Allocasuarina campestris* thicket with patches of heath	47132	26	2691	1.5	5.7
Shrublands; scrub-heath on yellow sandplain *Banksia-Xylomelum* alliance in the Geraldton Sandplain & Avon-Wheatbelt Regions	42074	23	5753	3.2	**13.7**
Medium woodland; York gum	17186	9	2073	1.1	**12.1**
Succulent steppe with woodland and thicket; York gum over *Melaleuca thyoides* & samphire	12909	7	2093	1.2	16.2
Medium woodland; York gum & salmon gum	6196	3	316	0.2	5.1
Succulent steppe with thicket; *Melaleuca thyoides* over samphire	1951	1	256	0.1	**13.1**
Medium woodland; salmon gum	1321	1	83	0.05	6.3
Shrublands; scrub-heath *Acacia-Ecdeiocolia* association in the south-west Geraldton Sandplain Region	694	0.4	244	0.1	35.1
Shrublands; *Allocasuarina campestris* thicket	502	0.3	31	0.02	6.1
Shrublands; *Acacia* thicket with patches of heath	207	0.1	11	0.01	5.5
TOTALS	**181,008**	**100**	**19,987**	**11**	

* The shaded boxes in the 'percentage of original extent' column are those extremely limited in extent (<10%).

+ The bold figures in the same column are those poorly represented (<15%).

The finer scale vegetation mapping by (Huggett et al., 2004)was not used in this comparison, as it was incompatible with the Beard descriptions.

Table 4. Terrestrial native vegetation association classes and their relationships in the Buntine-Marchagee Catchment.

Broad Vegetation Formations	Description of terrestrial vegetation association	Number of remnants with this vegetation formation
Woodlands	*Allocasuarina huegeliana* woodland: rock sheoak woodland on deep yellow sand.	1*
	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.	2
	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 morell, 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)	Shrublands of perched drainage lines: *Melaleuca thyoides* and samphire[+].	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)	*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 emergents) species rich shrubland	14

* Those associations with values of one or two are shaded.

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

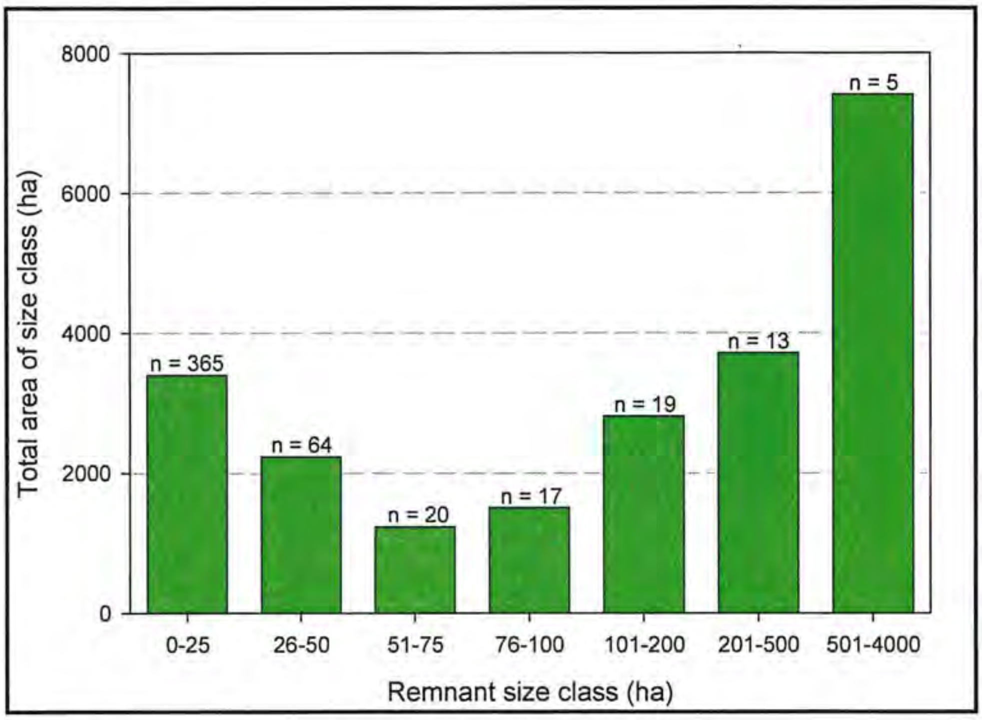


Figure 2. Distribution of remnant size classes in the Buntine-Marchagee Catchment. (Huggett et al. 2004).

Table 5. Land tenure, ordered from most to least, of the native vegetation described by Huggett et al. (2004).

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	less than 1
Miscellaneous lands - Railway	39	less than 1
Miscellaneous lands - Closed Road	0.3	less than 1
TOTAL	**19,998**	**100**

* Areas of Crown Reserve are often lake beds.

Table 6. Nature reserves in the BMRC at serious short term risk of rising saline ground water and their area.

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) 38401	10
Total	2,354 ha

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

Special tax or living assemblages

The Acacia genus

Worldwide there are 1,381 species of *Acacia*. Australia has 975 of these (71 percent) and Western Australia has 587 species (60 percent of Australia's *Acacia* species).

Figure 3. The highest worldwide concentration of Acacia species diversity is in southwest Western Australia. Source: www.worldwidewattle.com.

Declared and Priority flora

Declared rare flora
Native flora that is presumed to be extinct in the wild, or likely to become extinct or rare are afforded special protection by being declared to be 'rare flora' under the *Wildlife Conservation Act 1950*. These specially protected flora are sometimes referred to as 'threatened' or 'Declared Rare Flora' (DRF), and are declared by the Minister for the Environment by notice in the Government Gazette. A permit from the Minister is required before such flora can be disturbed in any way.

Priority Flora
In addition to rare flora, CALM also refers to 'priority' taxa. These are species that may be rare but there is insufficient survey data available to accurately determine their true status or which are rare but not currently as threatened as DRF and hence are being monitored. Although priority species do not have the same level of legislative protection as rare flora, the priority flora list is maintained as a mechanism to highlight flora of special conservation interest and encourage appropriate management activities in areas such as weed and feral animal control, fire management and site development.

Species are grouped from Priority 1 to Priority 4, each with their own definition according to the perceived urgency for further survey.

- Priority 1: taxa that are known from one or a few populations (generally <5) that are under threat;
- Priority 2: taxa that are known from one or a few populations (generally <5), at least some of which are under threat;
- Priority 3: taxa that are known from several populations, and the taxa are not believed to be under immediate threat; and
- Priority 4: taxa that are considered to have been adequately surveyed and which, whilst being rare (in Australia), are not currently threatened by any identifiable factors.

Other flora

Two undescribed taxa were recorded during the biodiversity survey of the agricultural zone (Keighery *et al.* 2004). These were *Halosarcia* sp. Gunyidi (M.N.Lyons 2607) and *Halosarcia* sp. aff.*undulata* (M.N.Lyons 2622). Based on survey collections in the northern wheatbelt, the populations of these taxa are at their southern limit of distribution. *Halosarcia* is a large and very complex genus. Formal description and naming will require revision of the genus, of which will be very difficult. As a general example, when the taxonomy is simple, undescribed taxa get published in about 5yrs.

M.N. Lyons also collected an unusual Brassicaceae sp. during the biodiversity survey. R.G. Rees collected improved plant material at a later date. It is currently in the herbarium under *Heliophila* sp. Gunyidi (R.G. Rees 42). It's still uncertain if it's a native or exotic (M.N. Lyons *pers comm.*).

Few non-vascular plants (e.g. mosses, liverworts) are included in Western Australian threatened and priority listings. These flora are poorly known in a taxonomic and conservation sense (it is estimated that only 1% of Western Australia's non-vascular flora is formally named), and their low representation on threatened and priority lists does not reflect their true conservation status (Brown et al., 1998).

The status of many taxa remains in doubt and it is likely that many P1 and P2 taxa may be listed as DRF when further assessment is undertaken. Likewise, surveys of poorly surveyed areas and / or surveys with greater intensity can reveal new populations and lower the threatened status of the taxa.

Table 7. Declared and Priority Flora within the BMRC.

Conservation Code[6]	Species	CALM District: Moora or Merredin (Mo / Me)	Management status	Data Source[7]
R	*Acacia recurvata*	Mo		1
R	*Acacia vassalii*	Mo	IRP[8] (2003-2008)	1, 2, 3
R	*Caladenia drakeoides*	Mo	IRP (2003-2008)	1, 3
R	*Chorizema humile*	Mo	IRP (1999-2002)	1,2
R	*Daviesia dielsii*	Me & Mo		1,2, 3
R	*Eremophila pinnatifida* ms	Me	IRP (2002-2007)	1, 3
R	*Eremophila vernicosa*	Mo		1, 3
R	*Eucalyptus rhodantha var. rhodantha*	Mo	Full Recovery Plan (1995)	1
R	*Gastrolobium appressum*	Mo		1, 3
R	*Hemiandra gardneri*			2, 3
R	*Pityrodia axillaris*	Me		1, 3
R	*Ptilotus fasciculatus*	Mo		1, 3
P1	*Acacia trinalis*	Mo		1, 3
P1	*Eremophila koobabbiensis*			2
P1	*Eucalyptus subangusta subsp. virescens*	Mo		1, 3
P1	*Frankenia bracteata*			3
P1	*Gnephosis setifera*			2, 3
P1	*Halosarcia koobabbiensis* ms			3
P1	*Grevillea pinifolia*			3
P1	*Hydrocotyle hexaptera*			3
P1	*Verticordia dasystylis subsp. oestopoia*			2
P2	*Eremophila sargentii*	Mer & Mo		1
P2	*Fitwillia axilliflora*			3
P2	*Grevillea nana subsp. abbreviata*			2, 3
P2	*Podotheca pritzelli*			3
P2	*Scholtzia sp.Gunyidi (J.D.Briggs 17)*			2
P2	*Stenanthemum grandiflorum*			3
P3	*Acacia filifolia*			2, 3
P3	*Acacia isoneura subsp. nimia*			2, 3
P3	*Acacia scalena*			2, 3
P3	*Calytrix plumulosa*			2, 3
P3	*Eucalyptus macrocarpa x pyriformis*			2, 3
P3	*Grevillea asparagoides*			2, 3
P3	*Grevillea granulosa*			2, 3
P3	*Grevillea thyrsoides subsp. pustulata*			2
P3	*Lechenaultia galactites*			2, 3
P3	*Lechenaultia juncea*			2, 3

[6] Conservation codes: R = Declared Rare Flora, P1 = Priority 1 Flora, P2 = Priority 2 Flora, P3 = Priority 3 Flora, P4=Priority 4 Flora.
[7] 1=Threatened Flora Database record, CALM Wildlife Branch, 2=Western Australian Herbarium record. 3=
CALM (2001) Proposed natural diversity recovery catchment - Buntine-marchagee Catchment. *calm midwest region.*
[8] IRP=Interim Recovery Plans

P3	*Microcorys tenuifolia*			3
P3	*Persoonia chapmaniana*			3
P3	*Sarcocornia globosa*			2, 3
P3	*Triglochin stowardii*			2, 3
P3	*Urodon capitatus*			2
P3	*Verticordia venusta*			2, 3
P4	*Banksia benthamiana*			2, 3
P4	*Eucalyptus rhodantha var. petiolaris*	Mo	Full Recovery Plan (1995)	1, 3

Table 8. Summary of plant families with threatened taxa and the number of taxa in each conservation category.

	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**	
TOTAL number of Declared and Priority taxa						45

* Families are listed in order of their collective representation (most to least).

Fig 4 **Fig 5**

Figure 4. ***Caladenia drakeoides*** **ms (DRF - critically endangered), which occurs on private land (Koobabbie Farm) and within the braided channel east of Gunyidi townsite.**

Figure 5. ***Halosarcia koobabbiensis*** **ms (P1), known only from the type locality on Koobabbie Farm.**

Fig 6 **Fig 7**

Figure 6. Ptilotus fasciculatus - (DRF), this species was presumed extinct in 1999. It is now known from Koobabbie Farm and Mailey's farm in the Buntine-Marchagee catchment and from the Kondinin Salt Marsh. These specimens were previously recognised as P. caespitulosus.

Figure 7. ***Eremophila vernicosa*** **ms (DRF), was presumed extinct until it was rediscovered on private land in the catchment (in 1998 / 1999).**

Threatened Ecological Communities

The Commonwealth's EPBC Act (Environmental Protection and Biodiversity Conservation) provides a listing of threatened ecological communities (TECs) and legislative protection is currently provided for TECs listed under this Act. However, under current State legislation, TECs are not afforded special protection (unlike individual flora and fauna), although this is proposed to change when the proposed Biodiversity Conservation Act is enacted. TECs are categorised under similar definitions in the EPBC Act and at the State level.

At the State level, nominated threatened ecological communities normally go through a review process, then through a Ministerial endorsement process. The Western Australian Threatened Ecological Communities Scientific Committee (WATECSC) is an independent scientific advisory body established by the Minister, which assesses the conservation status of communities and makes recommendations to the Minister regarding approval. The Department maintains a list of informal priority ecological communities as well as Ministerial-approved TECs. Some protection is provided under other State legislation, such as the Environmental Protection Act 1986.

APPENDIX 10: WETLAND FAUNA

In the last decade, the recognition of wetlands as high-value public assets has given increased impetus to their conservation (Government of Western Australia, 1996). Several natural diversity recovery catchments have been established where regionally important wetland systems are threatened by salinity and hydrological change. The BMRC was nominated as a recovery catchment on the basis of the unique wetland system at its centre. Nomination as a recovery catchment recognises that that this system has:

- biota that are representative of important communities
- threatened communities and species
- high levels of community and species richness
- significant ecological function.

The wetlands of the BMRC have persisted, many with their fringing vegetation, through the period of agricultural development because they are not suitable for cropping. Although stock access, hydrological change, eutrophication, sedimentation and feral animals have had deleterious effects on the wetland chain, this system remains a biological asset.

Maintenance of the biological values of the BMRC is the goal of the recovery plan. Effective measurement and monitoring of these values is, therefore, essential to the success of the project.

Many biological components contribute to the function of a wetland ecosystem. Those that have been described in the BMRC wetland system to date are discussed here. These biodiversity values represent the intrinsic and opportunity values of the genome and also provide ecosystem services.

Aquatic Invertebrates

The richness and diversity of aquatic invertebrates within the BMRC is probably not yet fully appreciated. To date, two surveys of aquatic invertebrates have been conducted in the catchment by researchers from the University of Western Australia's School of Animal Biology[9] (Storey et al., 2004b, Storey et al., 2004a). The first of these studies sampled just 8 of the catchment's one thousand discrete wetlands in November 2003; the second study sampled 20 wetlands in August 2004. Limited sampling was also undertaken during the collation of the Salinity Action Plan in 1999 (Salinity Action Plan, 1999).

The 2004 BMRC invertebrate survey reported a total of 153 taxa, at an average of 20 taxa per wetland (range of 0 to 52 taxa per wetland). The majority (80) of taxa recorded the BMRC were singletons, being found in only one of the sampled wetlands. Just 18 species were recorded at more than 5 of the 20 sampling sites. When combined with the eight wetlands sampled in November 2003, the total aquatic invertebrate species richness for the BMRC, to date, is 165 species (Storey et al., 2004a).

The species collected in the BMRC consisted of six Protista, twenty three species of Rotifera, eight Copepoda, nine Cladocera, sixteen species of Ostracoda, four species of Hydracarina, seven 'macro-crustacea', twenty Coleoptera (larvae & adults), six Hemiptera, thirty-three Diptera, four Trichoptera, two Ephemeroptera, ten Odonata, and two Lepidoptera.

[9] A third study by this team commenced in August 2005.

Table 1 – A comparison between the results of aquatic invertebrate surveys undertaken in the BMRC and elsewhere in the south west of Western Australia.

Location	Mean Taxa per wetland	Total Taxa Richness	# wetlands sampled	Reference
Two Peoples Bay Nature Reserve	56.7	170	3	(Storey et al., 1993)
Swan Coastal Plain	52.8	253	41	(Davis, 1993)
South Coast of Western Australia - Cape Naturalist to Albany	39.0 (summer) 32.4 (winter)	209	27	(Edward et al., 1994)
Perth Airport	30.0	125	9	(Kuchling et al., 1996)
Buntine Marchagee Recovery Catchment	20.0	153	20	(Storey et al., 2004a)

Comparisons between biological surveys should be made with caution due to differences in sampling methodology, intent and conditions. Further, it should be noted not all wetland types within the BMRC have been surveyed for aquatic invertebrates. These qualifiers aside, however, the wetlands of the BMRC do not seem to be species rich in comparison to other systems in the south west of Western Australia (Table 1). The invertebrate fauna recorded in the catchment's wetlands have, thus far, been ubiquitous and cosmopolitan, most species commonly occurring across southern Australia. Exceptions to this are species of non-biting midge (Chironomidae) (?*Cladopelma* sp. nov.); the rotifer *Hexarthra propinqua*, which is the first record from Australia of a species previous recorded principally from Europe; another rotifer, *Trichocerca obtusidens*, which has not formally been recorded from Australia; two native species of *Parartemia* (*Parartemia serventyi* and *Parartemia contracta*) and two species of concostracans, one being ubiquitous and one a south-west endemic. The few species that were considered endemic to southwestern Australia and those of greatest conservation value, tended to be in the fresh to brackish water sites (Storey et al., 2004a).

Analysis of the results of the BMRC invertebrate survey showed water chemistry/quality to be a strong determinant of the invertebrate fauna composition of wetlands. Within the wetlands of the BMRC, greater invertebrate species richness, species diversity, levels of endemism and conservation values were associated with fresh and brackish wetlands than saline or hypersaline wetlands (Storey et al., 2004a). This was also the finding of the more widespread biodiversity survey of the Western Australian agricultural zone (Pinder et al., 2004) . Importantly, the latter study also demonstrated that secondary saline wetlands support assemblages of aquatic invertebrates that area different and less diverse than those of primary saline wetlands. This finding supports the assumption that degraded wetlands, such as those subject to hydrological change, are a distinct group within the BMRC. It also highlights the importance of conserving both fresh/brackish and primary saline wetlands in the catchment to ensure the maintenance of a diversity of fauna.

Fish

No native fish are found within any of the wetlands of the BMRC. The area has few natural permanent water bodies. There is anecdotal evidence to suggest that black bream (*Acanthopagrus butcheri*) have been introduced to the catchment.

Birds

The only coordinated survey of birds in the BMRC was undertaken by CSIRO, between 2001 and 2002, as the first component of a focal species study (Huggett et al., 2004). That study was comprehensive, recording 18 068 bird sightings, representing 110 species in 316 patches of remnant vegetation. The aim of the study, however, was to identify sedentary bird species (species that are permanent residents of the catchment) and to determine their usage of terrestrial vegetation. Wetlands, which are utilised by migratory species to a greater extent than sedentary ones, were not surveyed and strict waterbirds and exotics were not recorded.

A limited waterbird survey was conducted in spring 1999, following extensive flooding in the catchment. Despite the greater than usual availability of water at that time, the catchment supported only a moderately diverse waterbird fauna, with low numbers and few species recorded in individual pans. One hundred and sixty waterbirds, representing 11 species, were recorded at the six surveyed wetlands (Calm, 2001).

Despite the lack of a dedicated bird survey in the BMRC wetlands, anecdotal evidence and opportunistic sampling suggests usage by a variety of bird species. The catchment does not contain any Ramsar wetlands, meaning that the area is not considered significant to migratory bird species at an international level. Despite this, the presence of a wetland chain containing a range of water qualities, habitat types and hydroperiods, in a predominately dry landscape, ensures its importance at a regional scale. Usage of the catchment by waterbirds may increase as rising groundwater increases the number of perennial water bodies in the catchment and the depth and period of inundation of the catchment's non-perennial wetlands. This effect will, however, be counter-balanced by an associated decline in water quality that will lead to a loss of wetland vegetation and aquatic invertebrate species diversity.

The waterbirds utilising the BMRC represent a significant biodiversity value. Birds are high order consumers and their presence in a wetland is an indicator of the health of that system. They are also the most visible of the fauna that access the catchment's wetlands and members of the community generally welcome their presence. Waterbirds, therefore, represent a useful educational tool and a mechanism for encouraging community involvement in wetland conservation. A dedicated survey of the waterbirds of the BMRC may serve the dual purposes of engendering community support for the project and providing useful information on the biodiversity and condition of the wetland ecosystem.

Terrestrial Invertebrates, Reptiles and Mammals in the Wetlands

Little is known about the extent to which terrestrial fauna utilise the BMRC wetlands. Knowledge of the catchment's terrestrial invertebrates, reptiles and mammals is limited and no attempt has been made to refine these data to the littoral zone. Mammals and reptiles visit wetlands to access water but it is unlikely that any species of these classes are confined to the BMRC wetlands. The interaction of terrestrial invertebrates with wetlands may be inferred from studies undertaken nearby.

A study of the invertebrate fauna of the Western Australian wheatbelt (Durrant, 2003) determined the effect of variations in micro habitat on wetland dwelling invertebrates. Five saline wetlands were surveyed (including sites approximately 50 km north and 50 km east of the BMRC) for terrestrial invertebrate fauna with the aim of determining whether there are species restricted to the dry lake floor, fringing samphire or fringing woodlands. A total of 356 species were recorded (123 spiders, 6 scorpions, 173 beetles, 45 ants, 4 earwigs and 4 isopods). Of these, 198 were from the inundation zone and 229 from woodland. Only 72 species were common to both areas, showing that the inundation zone fauna is not a subset of that found in woodland.

Many of the species recorded in that invertebrate survey were short-range endemics, suggesting the invertebrate fauna of individual saline wetlands are quite unique and valuable. Species in this habitat are likely to have developed strategies for surviving periodic flooding of the wetland floor but permanent changes in the inundation regime brought about by groundwater rise are likely to have severe impacts. Changes in the chemical composition of lake floors, such as are brought about by increasing salinisation, may also have deleterious effects on burrowing species.

The findings of Durrant (2003) are likely to prove valid in the BMRC. Conditions at sites sampled in the wheatbelt survey are similar to those in the BMRC and two of the five sampling sites are within 50 kilometres of the recovery catchment. Extrapolation of Durrant's results, therefore, suggests the BMRC wetlands may be rich in terrestrial invertebrates, many of which will be confined to particular microhabitats. A dedicated survey of the terrestrial invertebrate fauna of the BMRC wetlands will test these assumptions. This survey should follow the methodology of Durrant (2003) to enable comparison with the findings of that study.

APPENDIX 11: TERRESTRIAL FAUNA

The extreme pressures brought to bear on wheatbelt ecosystems by anthropogenic processes have been well documented (Beard and Sprenger, 1984, Wallace and Moore, 1987, Saunders et al., 1991). The Buntine Marchagee Recovery Catchment is no exception, lying principally within the Avon Wheatbelt IBRA region, from which 93% of native vegetation has been cleared (Beard and Sprenger, 1984). Even this high rate of clearing does not full describe the extent of biodiversity loss in the area; preferential clearing of vegetation assemblages thought to be indicative of agriculturally productive soils has resulted in the loss of 97% of York Gum, Wandoo and Salmon Gum woodlands in the wheatbelt. This has left native flora and fauna isolated in pockets of remnant vegetation amongst a highly fragmented landscape (Saunders et al., 1991). Furthermore, conservation management of these valuable remnants is difficult with 40% of remnants occurring on private property and a further significant portion constituted by roadside vegetation.

Not surprisingly, when faced with habitat loss of this magnitude, combined with predation and competition pressures from introduced species, land degradation, disease, increasing prevalence of weed species and altered fire regimes, the native fauna of the wheatbelt have suffered considerable declines. A 1987 report (Wallace and Moore, 1987) found that, since European settlement, 13 species of wheatbelt mammal become extinct and less than half the original species were (in 1987) regarded as common. Some of the extinct mammal species known to have inhabited the Western Australian wheatbelt include: *Perameles bougainville fasciata* (western barred bandicoot), *Potorous platyops* (broad faced potoroo), *Lagorchestes hirsutus hirsutus* (rufous hare-wallaby), *Onychogalea lunata* (crescent nailtail wallaby), *Leporillus apicalis* (lesser stick rat), *Notomys macrotis* (big eared hopping mouse) and *Notomys longicaudatus* (long-tailed hopping mouse) (Burbidge, 2004). The region's birds have fared a little better but; in the last 80 years, two wheatbelt avifaunal species are known to have become extinct[10] (Saunders, 1989). Further, since 1937, 31% of the 139 non passerine species and 75% of the passerine species recorded in the wheatbelt have declined in range and/or abundance (just 8% of bird species showed an increase in range or abundance in this period, these were all passerine species) (Saunders, 1993).

A number of sources are provide detail of the past and present fauna of the Buntine Marchagee recovery Catchment, and these were utilised in the compilation of the following sub sections.

- The Western Australian Museum maintains records of occurrence and location for all species for which a vouchered specimen has been collected. Records for the BMRC[11] were accessed via *Faunabase* on the 9th of March, 2005 (Museum of Western Australia, 2005).
- Kitchener *et al.*(1979) and Dell *et al.* (1979) conducted biological surveys of parts of the Western Australian wheatbelt, including several reserves within the BMRC, on behalf of the Western Australian Museum in the late 1970's.
- Moloch fauna consultants undertook a limited biological survey in several remnant vegetation patches in the Marchagee Catchment during 1999 and 2000 (Harold, 2001)
- CSIRO utilised the BMRC for a 'focal species' study between 1999 and 2004, undertaking an exhaustive survey of the area's bird populations (Huggett et al., 2004) and a trapping program for reptiles and mammals (Short and Parsons, 2004).
- The Biodiversity Survey of the Western Australian Agricultural Zone (Keighery et al., 2004), undertaken as part of the State Salinity Strategy includes 19 study sites in the

[10] Burbidge (2004) argues that no Western Australian bird species are extinct, and, although two subspecies have disappeared from WA, other subspecies of both these birds persist elsewhere in Australia.'

[11] The area searched was a rectangle bounded by the coordinates latitude 29.8628° south, longitude 116.0819° east and latitude 30.3124° south, longitude 116.7078° east.

BMRC. These provide the only available detail of the area's terrestrial invertebrates, but also report reptile, frog and mammal occurrences.

- The Department of Conservation and Land Management maintains a list of rare and endangered species in the state, along with a record of credible sightings.

Records of the Western Australian Museum indicate 11 species of amphibian, 36 species of bird, 12 species of mammal and 70 species of reptile have been collected within the boundaries of the BMRC. It is important to note that these records only represent species lodged with the museum, making this a very selective sample of the fauna of the area, reliant upon the degree of vouchering that has occurred. Vouchered specimens are, however, the only reliable data in terms of accurate identification and currency of taxonomy. Observational data are inherently more abundant and less accurate. If observational records (Harold, 2001, Huggett et al., 2004) are added to those of the Western Australian Museum, a total of 11 species of amphibian, 132 species of bird, 12 species of mammal, 69 species of reptile and 71 species of terrestrial invertebrate have been recorded within the BMRC. There are no records of native fish occurring within the catchment and a survey of the aquatic invertebrate fauna of the area has only recently commenced.

Species richness of the BMRC compares favourably with that of the region as a whole. (Short and Parsons, 2004) searched the literature for references to trapping and biological survey undertaken within Western Australian wheatbelt reserves. That report compiled a list of 13 species of amphibian, 23 species of mammal and 91 species of reptile to have been reliably recorded in the 54 isolated reserves to be surveyed in the last 40 years. Given the very low proportion of the BMRC held in reserve and the highly fragmented nature of the remainder of the landscape, these data suggest the typical wheatbelt fauna are well represented there.

An additional Faunabase search of land within 100 km of the BMRC indicates the extent to which that catchment shares a common fauna with its surrounds. The BMRC appears to host a fairly typical central wheatbelt fauna assemblage with 91% of species vouchered within that catchment also collected in the area within 100 km of its southern boundary. The incidence of common fauna is lowest to the east, where only 49% of species recorded within the BMRC are known to occur. Areas to the north and west fell between these extremes, with 78% and 68% of fauna species in common respectively.

Mammals

Since the time of European settlement, the mammals of Australia have suffered rapid and extreme declines in range and numbers (Burbidge, 2004). In Western Australia, the wheatbelt has experienced some of the most dramatic losses of mammalian biodiversity. This is attributable to the combined impacts of loss of habitat, changed fire regimes, increased competition for food, increased predation, trampling of burrows by stock and the introduction of new diseases.

The mammalian species surviving in the wheatbelt are probably those suited to existing within isolated patches of vegetation and, whilst patches as small as 30 ha may have value for the conservation of specific mammal (as well as plant and lower animal) populations, evidence suggests at least 40 000 hectares of native vegetation coverage is required to conserve a regional assemblage of mammals (Kitchener et al., 1980). The distance between remnants, the presence of connective corridors and the elapsed period of isolation are important factors in determining the response of both flora and fauna species to fragmentation of the landscape. Smaller remnants are more strongly affected by external influences, and so, are more dependant on external management (Saunders and Hobbs, 1991). The greatest richness of mammalian species in the Western Australian wheatbelt occurs at sites with low levels of habitat complexity, sandy and nutrient poor soils and low winter rainfall and temperatures (Burbidge *et al.* 2004). The reasons for these associations are unclear.

Our current knowledge of the mammalian species occurrent in the BMRC is based on historical records of the Western Australian Museum, surveys undertaken in the catchment's three Nature reserves during CSIRO's 'Focal Species Study' (Short and Parsons, 2004), surveys associated with the development of the State Salinity Strategy (State Salinity Council, 2000) and opportunistic observations made during other projects. Vouchered specimens have been returned for 11 species in this area and the CSIRO study recorded one additional species.

Several introduced mammals are prevalent in the BMRC. The house mouse (*Mus musculus*), black rat (*Rattus rattus*), rabbit (*Oryctolagus cuniculus*), feral cat (*Felis catus*) and European red fox (*Vulpes vulpes*) are all commonly observed in the area.

Birds

Despite extensive habitat loss, and the introduction of a range of feral predators, the BMRC continues to support a rich and diverse assemblage of bird life. Between August 2001 and October 2003, CSIRO undertook a 'Focal Species Study' using the avifauna of the BMRC (Huggett et al., 2004). That study provides the most comprehensive list of the BMRC's bird life. Over 25 weeks of field surveys, 316 (36%) of the catchment's patches of remnant vegetation were surveyed for birds. Transect based point surveys were also undertaken, across saline drainage lines, to determine whether bird species were using those areas as habitat.

The CSIRO focal species study recorded over 18 000 bird sightings, representing 110 species. The Western Australian Museum has recorded a further 22 bird species in the BMRC that were not observed during the CSIRO study, taking the total known species in the area to 132. Many of these species are migratory 'visitors' to the catchment, demonstrating the importance of the area's remnant habitat not just locally, but at a global scale.

The most common species recorded in the CSIRO study was the galah (*Cacatua roseicapillia*) followed by the red capped robin (*Petroica goodenovii*). On five occasions, a flock of over 100 galahs was observed within a remnant. The next highest count for a species in a single remnant was the brown honeyeater (*Lichmera indistincta*), with 91 individuals observed within a patch of *Banksia* spp. The Australian ringneck (*Barnardius zonarius*) was recorded in the most remnants (232 out of the 316 remnants surveyed), followed by the willie wagtail (*Rhipidura leucophrys*) and the singing honeyeater (*Lichenostomus virescens*). Interestingly, despite their seeming ubiquity in the catchment (G Daniel, *pers comm.*), corellas (*Cacatua tenuirostris*) were observed in less than 15% of the surveyed remnants. Overall, York gum with jam or mallee, shrublands and mallee with understorey were found to be the habitats most supportive of a diversity of bird life.

Reptiles

In the Western Australian wheatbelt, the most diverse reptilian fauna is associated with sites high in the landscape that have good drainage and experience high daytime temperatures (Burbridge *et al.* 2004). Accordingly, the BMRC supports a rich assemblage of reptile species with 69 species recorded in the area,,representing 29% of known reptile species of the Wheatbelt. This diversity may be attributable to the location of the catchment at the point of intersection of two biogeographical regions and the influence of the arid zone to the north. The reptile fauna of the BMRC includes elements of south west and aridzone assemblages.

Lizards constitute the majority of the catchment's reptiles with 21 species of skink (family Scincidae), 14 species of gecko (Gekkonidae), 10 species of legless lizard (Pygopodidae), 8 species of dragon (Agamidae) and 2 species of monitor lizard (Varanidae). There is a high level of endemism within these lizards, with eight species of skink endemic to Western Australia and one endemic to the south west and three of the catchment's gecko species endemic to the state. There are 13 species of snake found in the catchment, 12 of these being venomous, front fanged elapids and the other the woma python (*Aspidites ramsayi*).

Amphibians

The diversity of amphibia (principally frogs) in the Western Australian wheatbelt has been shown to be greatest in sandy soils and in the vicinity of freshwater wetlands. Many of Western Australia's frog species are burrowers and, it is thought, sandy soils better facilitate the development of burrows (Burbidge, 2004). Although frogs are found throughout the landscape, the concentration of species diversity and richness in the vicinity of freshwater wetlands puts these animals at high risk from the effects of hydrological change and salinisation.

Compared with the wetter areas of the far south-west, the diversity of amphibians in the BMRC is low. Eleven species of frog have been recorded, seven of which are burrowing frogs (Tyler et al., 2000). All the frog species found in the catchment are typical south west species, although the BMRC represents the northern range extent of many of these.

Terrestrial Invertebrates

The biodiversity survey of the Western Australian agricultural zone (Keighery et al., 2004) undertaken between 1997 and 2003, included several sampling sites within the BMRC. To date, this is the only systematic study to have included the terrestrial invertebrate fauna of the catchment. That report found the terrestrial invertebrate fauna associated with wetlands of the Western Australian wheatbelt to consist of a mixture of widespread, regionally restricted, short range endemic species. It was also shown that the inundation zone carries an invertebrate faunal assemblage that is distinct from that of surrounding vegetation (Bradley and Guthrie, 2004).

Sixty four species of spider and six species of scorpion were recorded within the BMRC by the biodiversity survey. An additional species of spider, the threatened shield-back trapdoor spider (*Idiosoma nigrum*), is thought to occur in the catchment, although it hasn't been recorded there since the mid 1950's.

Rare and other specially-protected fauna

At a State level, CALM has the statutory responsibility under the *Wildlife Conservation Act 1950* for fauna conservation, and all native fauna in Western Australia is protected under this Act. Nominated threatened fauna species normally go through a review process, then through a Ministerial endorsement process. The Western Australian Threatened Species Scientific Committee (WATSSC) is an independent scientific advisory body established by the Minister, which assesses the conservation status of communities and makes recommendations to the Minister regarding approval. The *Wildlife Conservation Act 1950* provides for the Minister to declare fauna species to be specially protected for the following reasons:

- they are threatened (i.e. they are rare or likely to become extinct) – the five species that occur in the BMRC are Baudin's black cockatoo (*Calyptorhynchus baudinii*), Carnaby's cockatoo (*Calyptorhynchus latirostris*), malleefowl (*Leipoa ocellate*), the Western spinytailed skink (*Egernia stokesii badia)* and the shield-backed trapdoor spider (*Idiosoma nigrum*).

- they are presumed to be extinct, but may be rediscovered – the species that may occur in the BMRC;
- they are covered by an international agreement – none of these occur in the BMRC; or
- they are uncommon or have commercial value – the three species that occur in the BMRC include Major Mitchell's cockatoo (*Cacatua leadbeateri*), the peregrine falcon (*Falco peregrinus*) and the woma python (*Aspidites ramsayi*).

In addition to specially protected fauna, the Department also maintains a 'reserve list' of priority taxa:

- Priority 1: Taxa with few, poorly known populations on threatened lands;
- Priority 2: Taxa with few, poorly known populations on conservation lands;
- Priority 3: Taxa with several, poorly known populations, some on conservation lands;
- Priority 4: Taxa considered to be adequately surveyed, or which sufficient knowledge is available, and are not currently threatened, but need monitoring; and
- Priority 5: 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.

Although priority species are not provided legislative protection, they are monitored by the Department as species that are uncommon or in decline and may require elevation to *threatened* status at a future date. Six priority species are found in the BMRC: the barking owl (*Ninox connivens connivens*), hooded plover (*Charadrius rubricollis*), bush stonecurlew (*Burhinus grallarius*), white-browed babbler (*Pomatostomus superciliosus ashbyi*), crested bellbird (*Oreoica gutteralis gutteralis*) and the Western brush wallaby (*Macropus irma*). All of these are Priority 4 taxa. Of these species, only two (malleefowl and Major Mitchell's cockatoo) were recorded during the CSIRO focal species study.

The following Department Policy Statements provide management direction for specially protected fauna:

- No. 33 - Conservation of Threatened and Specially Protected Fauna in the Wild; and
- No. 50 - Setting Priorities for Conservation of Western Australia's Threatened Flora and Fauna.

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 that are listed as 'endangered' and 'vulnerable' under the EPBC Act that occur in the BMRC are also listed as threatened under the State's *Wildlife Conservation Act 1950*. In addition, this Act also protects marine species (listed under section 248) and migratory species (listed under the Convention on the Conservation of Migratory Species of Wild Animals [Bonn Convention] and the Japan-Australia Migratory Bird Agreement [JAMBA] and China-Australia Migratory Bird Agreement [CAMBA]). There are 16 marine species and 23 migratory species (all birds) found in the BMRC.

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 BMRC that have recovery plans include Carnaby's Black cockatoo (This species has an approved State recovery plan and National recovery plan is in preparation). There is a National recovery plan for the malleefowl.

APPENDIX 12: OTHER VALUES OF THE BMRC CULTURAL HERITAGE AND RECREATION

Indigenous and Non-indigenous Cultural Heritage

Indigenous Cultural Heritage

There is no additional information relating to the indigenous cultural heritage values of the BMRC.

Non-indigenous Cultural Heritage

The Department manages non-indigenous cultural heritage to meet the management requirements of a range of State and Commonwealth legislation. 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 contain 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.

There are 33 historical sites within the BMRC (Table 1). Twenty-five of these are listed on the Western Australian 'Register of Heritage Places' as being registered on Municiple Inventories and include sites such as Jun Jun Spring, Salt Lake Well and Koobabbie Homestead in the Coorow Shire and Dalwallinu Town site within the Dalwallinu Shire. Salt Lake Well is also on the Department's RATIS list of cultural heritage. The Buntine Nature Reserve and the Wubin Wheatbin are listed on the Register of National Estate. Wubin Wheatbin is also listed with the National Trust of WA.

Table 1: Sites of Non-Indigenous Cultural Heritage in the BMRC

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 Spring	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 was surveyed through Location 2922 to ensure his 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 ere 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 CALM's RATIS database
	Marchagee Roadhouse Site	The roadhouse was constructed in 1965 and very busy in the 1960's and closed in the mid 1980's. 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	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	Dalwallinu District High School Dalwallinu Fire Station	Municipal Inventory

	associated sites (sites not within the BMRC but adjacent)	Former Dalwallinu Hotel Former Dalwallinu Police Station Dalwallinu Post Office Former Dalwallinu Railway Station Dalwallinu Recreation Centre Dalwallinu Swimming Pool Dalwallinu Town Dam Former Dalwallinu Town Hall and Road Boards Office Dalwallinu Townsite Bushland Dalwallinu War Memorial Old School Site The Five Graves Old Courthouse and Tourist Centre The Old Well sunk in 1909. Only purpose now is to serve as a memorial to the early settlers of the area.	
	Wubin Townsite and associated sites	Wubin Wheatbin Wubin Hall Wubin Hotel Motel Wubin Post Office and House Wubin Primary School Wubin Railway Station Information Centre Pioneer Graves	National Trust, Interim WA Register of Heritage Places, Municipal Inventory, Register of National Estate (Wubin Wheatbin) Municipal Inventory (remaining sites)
	Buntine Rock/Buntine Nature Reserve	First 'European' picnic organised at Buntine Rock by the Buntine Station Master Vic Bondinvolving 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 Reserve		
	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 BMRC) 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	Municiple Inventory

Recreation

There is no additional information relating to the recreation values of the BMRC.

APPENDIX 13: THREATENING PROCESSES

Introduction

In order to assess the feasibility of managing an asset threatened by salinity, it is necessary to identify all other existing and potential biophysical threats. This is because multiple threatening processes may affect management outcomes. For example, there is little benefit in protecting a biodiversity asset from salinity if an unmanageable invasive weed also threatens the asset. The threatening processes that have been identified in the BMRC are defined here.

Since European settlement of Western Australia, many wetland environments have been degraded by inappropriate land uses and management practices. The results of degradation are similar regardless of the cause: alteration of natural water regimes, loss of species diversity, salinisation, excessive inundation, water pollution and perturbation of natural processes (Calm, 2005).

The vegetation that occurs in, and around wetlands is an important component of the ecosystem. This vegetation assists in maintaining regular wetland water regimes, provides habitat and food for fauna, protects against salinity and erosion, provides natural beauty and helps maintain wetland function. The loss of vegetation; due to clearing, waterlogging, pollution, disease, grazing or salinisation; will result in the loss of these values.

Pollution of wetlands occurs as a result of various agricultural, industrial and domestic activities. Common contaminants in agricultural areas include pesticides, herbicides, acid drainage and fertilisers. Chemical pollutants are commonly harmful to flora and fauna while the use of fertilisers in a catchment can cause nutrient enrichment of wetlands. This has the potential to cause algal blooms in the water body which may be toxic to some fauna or lead to the development of anoxic conditions.

Natural processes also have deleterious effects on wetlands. Fire, floods, cyclones and drought are all naturally occurring processes that have the potential to damage wetland environments. Fire alters the habitat and food available to wildlife at wetlands. Floods, cyclones and drought can impact the natural water regime of the water body and the vegetation surrounding the wetlands. A healthy wetland system that is not subject to other anthropogenic pressures, however, should be sufficiently robust to withstand these natural occurrences.

Threats to the Wetlands of the BMRC

The BMRC is an extensively cleared agricultural catchment. With just 13% of the catchment's remnant vegetation remaining, a rise in the regional groundwater level is becoming increasingly evident. Broad scale agricultural production also creates the threats of spray drift, nutrient enrichment and the introduction of weeds, feral animals and stock. Not surprisingly in the face of these pressures, the wetlands of the BMRC are showing significant declines in biodiversity and functionality.

An assessment of biophysical threats to biodiversity and water assets in recovery catchments has been conducted (Table 1).

With the exception of disease, all of the threat categories identified are having a deleterious impact on the wetlands of the BMRC. Generally speaking, hydrological change represents the greatest threat to the biodiversity of the catchment's wetlands. At various sites, stock, weeds, agricultural activities, erosion and eutrophication also pose significant threats.

The threatening processes acting at a site, and the relative magnitude of those threats, are largely determined by the position of a wetland in the landscape. Because landscape position is also an important factor in the development of wetland groups, there is a tendency for similar threatening processes to act at wetlands of a consanguineous suite.

Table 1 – Summary of processing threatening the consanguineous suites of wetlands in the BMRC.

Threat Category	Management Issue	Probability that threat will cause goal failure with current and additional management									
		Saline V Floor		Sandy Seeps		Bentonite		Gypsum		Granite Pools	
Altered biogeochemical processes	Hydrological processes, particulalry salinity	1.0	0.9	1.0	0.7	0.2	0.1	0.7	0.6	-	-
	Nutrient cycles, including eutrophication	0.7	0.5	0.8	0.6	0.2	0.1	0.2	0.1	-	-
	Carbon cycle and climate change	-	-	-	-	-	-	-	-	0.3	0.3
Impacts of introduced plants and animals	Environmental weeds	0.8	0.7	0.8	0.7	0.3	0.1	0.1	-	1.0	-
	Feral predators	0.2	0.1	0.2	0.1	0.1	-	0.1	-	-	-
	Grazing by stock	0.8	0.1	0.8	0.1	-	-	-	-	-	-
Detrimental regimes of physical disturbance events	Flood	0.2	0.1	-	-	-	-	0.1	-	-	-
	Erosion	0.4	-	0.6	0.1	-	-	-	-	-	-
Impacts of pollution	Herbicide / pesticide use and direct impacts	0.2	0.1	0.3	0.1	-	-	-	-	-	-
	Secondary acidity (from drainage)	0.6	0.6	-	-	0.2	-	-	-	-	-
Impacts of competing land uses	Recreation management	-	-	-	-	-	-	-	-	-	-
	Illegal activites (e.g. rubbish dumping)	0.1	-	-	-	-	-	-	-	-	-
Impacts of community values	Attitudes to saving assets from threats	0.8	0.5	0.3	0.1	-	-	-	-	-	-

This table shows the probability that a given management issue will cause goal failure (loss of biodiversity) at each type of wetland under current management (left column) or with additional management (right column).

The probabilities of threats causing goal failure needs to be discussed with the projects Steering Committee after we present our current findings

Threat Analysis to the Wetlands of the BMRC

The following is a discussion of the main threatening processes impacting on wetlands in the BMRC. Each threatening process is discussed in the context of its capacity to cause the failure of the goal of the BMRC project under the current management regime and with additional management. Threats to artificial wetlands are not discussed as they are not considered natural biodiversity assets.

Altered Biochemical Processes

Hydrological processes

The alteration of a wetlands natural water regime can be caused by numerous factors, such as artificial drainage, extraction of groundwater, construction of dams and weirs, rising groundwater levels, or loss of native vegetation.

Secondary Salinity

The most significant factor affecting the hydrology of WA wetlands has been caused by the replacement of perennial deep-rooted native vegetation with shallow rooted annual crops and pasture. Annual crops and pastures use less water than native vegetation resulting in a rise in the water table. The upward movement of groundwater 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, resulting in waterlogging and secondary salinity (Cramer and Hobbs, 2002). The combined effects of water logging and salinity on wetlands include a reduction in water quality, a reduction in species richness of aquatic invertebrate communities, and the death of wetland vegetation.

Roads and other infrastructure in the BMRC are also susceptible to the impact 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 (Short et al., 2004). There are many examples throughout the BMRC where infrastructure impedes water movement, particularly subsequent to periods of high rainfall (Systems of Landcare, 2004).

Historically, the impediment of water movement in the BMRC has lead to road closures and costly repairs for both State and Local Governments. It is therefore pertinent, where feasible, that culverts, floodways and bridges are designed to industry specifications to manage surface water flows after high rainfall events (1:20 ARI for local roads, 1:50 ARI for main roads). This will ensure that repair and maintenance costs will be minimised and surface water is not allowed to recharge the underlying aquifer with saline water.

The department of Agriculture in Western Australia has used information collected for the Land Monitor project to produce a number of salinity risk maps. The areas identified as most prone to secondary salinity in the BMRC are those located in the valley floor and adjacent to these areas (0 to 2 m above the valley floor). Using this methodology it is estimated that about 5% of the BMRC is currently saline and an additional 5% is at a moderate to high risk of becoming saline (Griffin and Goulding, 2004). This figure may be an underestimate because a study undertaken in the Marchagee catchment area (over half of the BMRC area) estimated that 14.5% of this area is affected by salinity and may increase to 20% in the next 20 years (Mcconnell and Pillai, 1995).

In addition to the impacts of secondary salinity in the valley floor, salt scalds and water logging is commonplace in the mid-slope areas of the BMRC (Short et al., 2004). These areas occur where relatively porous upper soil horizons are underlain by less permeable horizons (often silcrete), or where shallow water tables are intercepted by dolerite dyke intrusions. As discussed above, evaporation of water from shallow water tables or ponded areas can lead to an increased concentration of salts on or near to the surface. This can lead to degradation of the soil structure and vegetation health both within the immediate vicinity and areas located down-slope.

As with many other catchments in the wheatbelt (George et al., 2004), the historical development of secondary salinity in the BMRC is believed not to occur in a linear manner, but instead developed in increments subsequent to unseasonal or high rainfall events. Conversations with a number of landholders in the BMRC indicate that dramatic increases in the affects of secondary salinity were evident after particularly wet years. For example a very wet year was experienced in 1963 with most Bureau of Meteorology weather stations in the catchment recording in excess of 600 mm annual rainfall (Bureau of Meteorology, 2005a). The majority of this fell in the winter months, where losses to evaporation were relatively low and large volumes of surface run-off would most likely have accumulated in the valley floor. Several landholders have indicated that significant impacts of secondary salinity were experienced in the valley floor in the following two years where agricultural productivity dramatically decreased. This was in spite of a return to average rainfall in 1964 and 1965.

With the aforementioned points in mind, further research is required to assess the extent of secondary salinity and the development of shallow water tables in the BMRC. In particular, greater focus must be placed upon the assessment of surface water and groundwater trends subsequent to unseasonal rainfall events or excessively wet years. This research may include a greater emphasis upon ground-truthing of remote sensing assessment techniques.

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.

In some instances, plants have adapted their root morphology and may flourish in waterlogged conditions. Other species however may tolerate either 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. With this in mind, vegetation communities located in the valley floor are particularly vulnerable to the impacts associated with waterlogging.

In the BMRC that the Wallambin soil system and other systems in the valley floor, such as the Upsan Downs, Ballidu, and Inering Hills have a moderate to high risk, and the valleys of the Balgerbine system at a lower risk of waterlogging (Griffin and Goulding, 2004).

Water repellence

Water repellence occurs where surface soils become hydrophobic resulting in an uneven wetting pattern (Moore and Blackwell, 2004). Repellent surface soils can reduce rainfall infiltration, increase evaporation, and increase generation of surface 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 velocities and volumes of surface water recharging the valley floor. Sandplain soils are the typically the most susceptible to water repellence however land use can also influence water repellence. Generally it is accepted that the cropping of legumes can increase water repellence and continuous cropping of cereal crops and adoption of no-till cropping can decrease water repellence (Moore and Blackwell, 2004). In the BMRC the Balgerbine system and parts of the Upsan Downs are most likely to have water repellent soils (Griffin and Goulding, 2004).

Acidification

Soil acidification

Historically, a large proportion of the yellow sandy earths occurring throughout the eastern and north-eastern wheatbelt were naturally acidic, however 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.

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). To date there have been no simple remote sensing techniques for identifying the susceptibility of soils to acidification, consequently the only method available for assessing the acidity is to physically analyse soil samples. This is relatively straightforward (Moore et al., 2004) however obtaining and processing samples can be time consuming.

Research undertaken by Griffin and Goulding (2004) identified that acidic soils and subsurface soils are common throughout the BMRC in all but the Inering Hills and Wallambin soil systems. The addition of lime is one solution to raise the pH of soils, and is the most common practice used by Landholders in the Buntine-Marchagee Recovery Catchment to ameliorate soil acidification (Calm and Colmar Brunton, 2005a).

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 may 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). Again, in the BMRC there is little information available about whether acidic surface water exists in the valley floors or whether there is the potential for clay-rich soils to generate acidic conditions.

Groundwater acidification

As with acidic soils, acidic groundwater naturally occurs throughout much of the wheatbelt regions 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.

Groundwater acidification was investigated in 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 levels of Cadmium (Cd), Chromium (Cr), Copper (Cu), Nickel (Ni), and Zinc (Zn), exceeding the relevant guidelines. 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 of the 'plugging' of soil pores. When this occurs in hillside seeps, such as at the break of slope or adjacent to dolerite dyke intrusions, then seeps often migrate upslope causing further land degradation (Schoknecht, 2004).

Lastly, acidic groundwater may also lead to damage to infrastructure such as roads and buildings (Hunt and Patterson, 2004).

To date, the CALM has collected limited data on the extent of acidic groundwater in the BMRC. This data is by no means comprehensive; therefore conclusions cannot yet be drawn. Within the Northern Agricultural Region there is also little known (Hunt and Patterson, 2004). Future monitoring programs will be implemented in the BMRC to increase our understanding of the extent of acidic groundwater within the catchment. In addition, new research initiatives by the CRC LEME group are to commence in the near future, with a particular focus on the environmental risks associated with acid-rich water and deep drainage systems. Information gathered by this group will be particularly relevant to the BMRC and future projects undertaken in the catchment.

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, become receiving points for nutrients. Wetlands receiving inputs of fertilisers may become nutrient enriched and, with favourable climatic conditions, become eutrophied.

Eutrophication, the rapid growth of aquatic algae or plants in response to excessive nutrients, has a range of deleterious effects on wetlands. These include the simplification of aquatic ecosystems due to the dominance of fewer species, reduction of light penetration, proliferation of toxic algae and the depletion of oxygen in the water column during the decomposition of a 'bloom'.

To date, there has been limited assessment of nutrients in the BMRC by the Department. Total soluble phosphorus and total nitrogen levels were measured in water sampled from eight wetlands in 2003 (Storey et al., 2004b), and twenty wetlands in 2004 (Storey et al., 2004a). In both investigations nutrient data were compared against the relevant guidelines (Anzecc, 2000). In 2003, total nitrogen was found to exceed these guidelines in all eight wetlands however the guideline for total phosphorus was not exceeded. In 2004, fourteen of the twenty sampled wetlands exceeded the trigger levels for total nitrogen, and total phosphorus trigger levels were exceeded at only one wetland.

Given the results from limited investigations and land uses in the BMRC, it is likely that a number of wetlands in the BMRC are at risk from eutrophication. The export of nutrients from agricultural activities to wetlands has both a negative impact on the biodiversity of wetlands, and an economic cost due to productivity potential. With this in mind, a reduction in nutrient export from farms will have a benefit for both the conservation of biodiversity and profitability of farming systems.

Climate Change

Current projections indicate the Western Australian agricultural zone may experience a drying trend as a consequence of climate change. There is insufficient data available to determine the extent of this trend, or the effect it may have on the BMRC. Climate change will remain a threatening process to be monitored across the wheatbelt.

Recent work on climate variability and climate change in the south-west of Western Australia (Indian Ocean Climate Initiative, 2002) has shown that over the last 30 years, there has been a 10 to 20% reduction in winter rainfall. Rainfall has decreased in the early winter months (May-July) with a slight increase in late winter and spring (August-October). Temperature increases have been observed in winter more so than summer, and are greater in daily minima than daily maxima. These trends are thought to represent a gradual change to a drier and warmer climate in Western Australia. It is anticipated that these changes will result in a reduction in streamflows generally, and a change to the drying and wetting phases (or hydroperiod) for wetlands. This may have implications for biodiversity values because natural ecosystems, particularly those already stressed, can be more vulnerable to change (Department of the Environment and Heritage, 2005).

In spite of these predictions, there are no consistent trends across south-west Australia. For example climate trends in the Greenough region, which lies west of the BMRC, reveal inconsistent rainfall trends over time (i.e. rainfall increasing in some areas) (Stuart-Street, 2005). The spatial and temporal variability of climate change is worth considering, given the wetter conditions experienced throughout the wheatbelt in the winter of 2005.

These points highlight the uncertainty of climate change and the potential impacts upon biodiversity values in the BMRC. With this in mind it is important that further investigations are implemented to assess the spatial and temporal variability of climate. This can be enhanced by increasing the number of climate recording stations in the catchment, and building close partnerships with key stakeholders and other government agencies. It is also pertinent that investigations are undertaken to evaluate the physiological responses of ecosystems to climate variables such as temperature, rainfall and evaporation.

Impacts of Altered Biochemical Processes on Wetlands

Primary Saline Wetlands of the Valley Floor

The palaeohydrology (i.e. historical formation) of salt lakes, or playas, in Western Australia is poorly understood. George and Coleman (2001) suggest that these systems formed due to a number of factors such as the presence of a shallow water table, impoundment of surface water flow, and the subsequent aeolian and fluvial deposition and erosion processes over time. The period of aridity in the Quaternary (< 1.8 mya) is believed to be particularly important for the formation of playas (Commander et al., 2001).

Large numbers of these wetlands occurring on the valley floor in the BMRC are naturally saline, or have been saline for hundreds if not thousands of years prior to European settlement. This is because in these wetland systems are typically connected with groundwater systems, thus operating as evaporation basins. Given the long periods of relative stability, the vegetation associated with these systems are largely adapted to either seasonally or permanent saline conditions.

Rising groundwater tables in recent times, has resulted in large areas, including those classed as primary saline, to become permanently or semi-permanently waterlogged. The consequence of these changes has been devastating, with extensive plant death, loss of habitat for associated terrestrial and aquatic fauna, and soil degradation. Although this process is already well advanced in the BMRC, some wetlands in the valley floor have persisted with few impacts. Continued groundwater change will inevitably lead to further decline of degraded sites, including plant deaths at greater distance from the wetland, and the degradation of those sites that remain in reasonable condition.

Hydrological processes, particularly waterlogging and salinisation, remain the greatest threat to the primary saline wetlands of the BMRC. Under the current management regime, these processes will inevitably cause the loss of most biodiversity from the valley floor of the catchment. Indeed, it appears that significant changes to land management practices at a catchment scale will be required if wetlands representative of the valley floor are to be maintained.

A lesser biogeochemical threat to these wetlands is perturbation of nutrient cycles, particularly excessive nutrient inputs causing the eutrophication of water bodies. This process is a lesser threat at primary saline wetland sites than at wetlands located higher in the landscape. This is largely due to differences in the properties of soils at these locations. The soils of the valley floor have a greater clay component than those of the sandplain in the west of the catchment. The high cation exchange capacity of clays allows nutrients to be adsorbed to soil particles. This translates to lower levels of nutrient leaching from paddocks and less nutrients entering these water bodies.

The impacts of disturbed nutrient cycling are varied between wetlands and this is largely the result of the proximity of cropped paddocks and the persistence of buffering vegetation. Excessive nutrient inputs result from the runoff and leaching of fertilisers following application to agricultural land. Wetland-fringing vegetation plays an important role in filtering excessive nutrients from runoff and groundwater, before they reach the water body. Where fringing vegetation has been lost to salinisation, water logging or clearing greater quantities of nutrients will enter wetlands. Cropping close to wetlands obviously reduces the opportunity for runoff to be filtered by vegetation.

Other processes threatening the primary saline wetlands of the BMRC have much lesser impacts than those of an altered hydrological regime. It may not be worth expending effort on these wetlands unless they can firstly be protected from groundwater rise, waterlogging and salinisation.

Seeps on Sandy Soils

Wetlands in the BMRC that have formed on sandy soils higher in the landscape are usually an expression of a perched aquifer or the result of a seep. Many of these wetlands were probably seasonal fresh to brackish damplands prior to clearing of the catchment. The loss of native vegetation, however, has increased the recharge of these wetlands, creating permanent water bodies. Evapo-concentration of salts in the water then leads to degradation of water quality.

The biodiversity of many sandy seeps is already substantially altered from that prior to clearing. Increased permanence of water at these sites has favoured a different suite of flora and fauna than that which would have occurred naturally. Particularly evident is the loss of trees from wetland floors and margins due to the effects of waterlogging. Vegetation loss is likely to occur at greater distances from these wetlands as the water logged area increases in extent. This process will be exacerbated by the decline in water quality inevitably related to the evapo-concentration of salts in standing water bodies.

The low salinity of sandy seeps has encouraged relatively high diversity in the aquatic invertebrate fauna. However, as evaporation of water continues, salt loads rise, and a loss of this diversity can be expected. Under the current management regime, therefore, goal failure is highly likely due to the loss of diversity in both wetland vegetation and aquatic invertebrate species. Additional management may make significant improvement to this prognosis at many sites, although it should be noted that large changes to land management practices would be required to reduce these threats to an acceptable level.

Nutrient enrichment of wetlands on sandy soils is common. Sands have low cation exchange capacity and fertilisers applied to these soils are readily leached by subsequent rainfall. It is common, therefore, for wetlands on sandy soils to receive significant quantities of nutrients in runoff. As with salts, nutrients will be evapo-concentrated over time and may be expected to have deleterious effects under the current management regime. Significant changes to fertiliser application practices will be required on many properties to ameliorate the threat posed by nutrient enrichment and eutrophication.

Other Wetland Types

Other wetland types, those characterised by unique substrates or evaporite types, are represented by few known examples in the BMRC. Three wetlands with a Bentonite substrate have been documented in the catchment. These are positioned relatively high in the landscape and the threat posed to two of these by hydrological change appears to be moderate. Vegetation is the only indicator of the biodiversity of these wetlands as a lack of water has precluded aquatic invertebrate sampling. Vegetation death, therefore, is indicative of goal failure. Degradation at W057 is not well advanced and will likely be reversible with the exclusion of drainage water input. This will, however, require landholder cooperation.

The sole gypsum dominated wetland in the catchment (Site W001) is located near the braided drainage line in the valley floor. It is likely that this site has suffered considerable hydrological change during the period of agricultural development. Vegetation surrounding the lake has been buffered from the effects of waterlogging by a substantial lunette, although some deleterious effects are beginning to appear amongst this vegetation.

The aquatic invertebrate fauna of the gypsum lake consists of only a handful of salt-tolerant species. It seems relatively unlikely that hydrological change poses a significant threat to these. Current management practices in the immediate vicinity of this lake are complementary to conservation, but its location at the terminal end of an extensively cleared catchment makes it vulnerable to the effects of upstream management. The input of nutrients and sediments from surrounding paddocks is of particular concern.

Water holes formed on granite rock outcrops are fed by rainfall and surface water runoff. There is no connection between these wetlands and the groundwater table. They are, therefore, not vulnerable to changes in the hydrological balance of the system. The drying trend locally associated with global climate change, however, may reduce the frequency and period of inundation of these wetlands. Although the biodiversity of the areas granite rock pools is currently poorly understood, it is reasonable to assume that a reduction in the water received by these pools may have deleterious affects.

Impacts of problem plant and animal species

In Western Australia the focus of biosecurity is on threats that impact agricultural market access, production efficiency, sustainability, environmental protection, product safety and public health. It is anticipated that a Regional (NAR) Biosecurity Plan will be developed that will identify key threats to industry and the environment as well as strategies to mange these threats (Hunt and Patterson, 2004).

Potential exists for the introduction of new damaging species to the BMRC. Agricultural activity and animals are potential vectors for the spread of new invasive weed species. The introduction of new feral animal species is less likely.

Many introduced ferals are able to out-compete native species for available resources. The monopolisation of food and shelter, by species such as rabbits, occurs to the detriment of native species.

Problem animals are native species that are impacting on natural values. There is evidence in the BMRC of deleterious impacts on vegetation attributable to corellas and kangaroos.

Environmental Weeds

Introduced plant pests compete with native species and/or agricultural crops and pastures, with the cost to agricultural industries being estimated at about $3.3 billion per annum nationwide. In WA's agricultural systems, weed control costs have been estimated at 20 per cent of production costs and can be significantly higher in some instances. Weed invasion is regarded as a severe threat to natural ecosystems, but cost is difficult to measure in monetary terms. (Hunt and Patterson, 2004).

Environmental weeds are plants that establish themselves in natural ecosystems and proceed to modify natural processes, usually adversely, resulting in decline of the communities they invade (Calm, 1999). Environmental weeds displace native plants, particularly on disturbed sites, by competing with them for light, nutrients, water and space. They can also have a significant adverse impact on other conservation values by altering animal habitats, harbouring pests and diseases, and increasing fire hazard.

An integrated approach to environmental weed management was developed in the *Environmental Weed Strategy for Western Australia* (CALM, 1999). As part of 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 that impacts on threatened or priority flora, fauna or ecological communities, or that occurs in areas of high conservation value, and then address high, moderate, mild and 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.

Like many other areas in the Northern Agricultural Region, the BMRC has been affected by introduced plant pests as a result of deliberate or accidental introductions since European settlement (Table 2). Many of these species have a very localised distribution, only occurring at the site where they were introduced but all with a latent potential to spread given favourable conditions. Others have already become widespread. Weeds can be transported by a number of vectors including water, the faeces of animals and seed eating birds, human transport, as wind-borne spores or as light weight seed.

In the BMRC, there is the potential for weeds to be introduced as a result of using exotic perennial species in agriculture, garden escapees, contaminated machinery and the use of inappropriate species in revegetation. 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 a reasonable to assume that at least some will behave like invasive alien species." (Saunders et al., 2000).

Table 2: Weed Species found in the BMRC as recorded in CALM Landholder Survey and their rating under the Environmental Weed Strategy (CALM, 1999)

Species	Common Name	Declared under the ARRP Act	EWS Rating
Carthamus lanatus	Saffron Thistle	Yes	Low
Emex australis	Doublegee	Yes	Low
Echium plantagineum	Paterson's Curse	Yes	
Eragrotris curvula	African Lovegrass	No	High
Arctotheca calendula	Capeweed	No	Moderate
Cynodon dactylon	Couch	No	Moderate
Hordeum leporinum	Barley Grass	No	Moderate
Lolium rigidum	Annual Ryegrass	No	Moderate
Mesembryanthemum crystallinum	Iceplant	No	Moderate
Raphanus raphanistrum	Wild Radish	No	Mild
Chondrilla juncea	Skeleton Weed	No	Low
Bromus sp	Brome Grass		
Opuntia stricta	Prickly Pear		
Avena barbata	Bearded Oat		
Avena fatua	Wild Oat		

State legislation and policies on weeds, such as the Agriculture and Related Resources Act 1976 provide wide powers for the detection and eradication of pests. Landholders are required by legislation to manage 'declared' plants on their individual properties and have a range of physical, chemical and biological options available.

Currently, only a few landholders in the BMRC actively control weeds in remnant vegetation. 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.

Environmental Weeds in Wetlands

The primary saline wetlands of the BMRC show impacts associated with invasive weeds. The various weeds common to agricultural areas are ubiquitous at the wetlands of this suite, persisting even in areas where salinisation and waterlogging have killed most other flora. In many instances, there is evidence that weed species have out competed and replaced natives. This represents a loss of floral diversity as well as a loss of food and habitat for native fauna. Weeds, therefore, currently represent a significant threat to the biodiversity of the catchment's primary saline wetlands.

Broad scale amelioration of this threat, even with additional management, is unlikely to be achievable. Invasive species are well established and are likely to persist amidst the agricultural landscape regardless of any attempts to eradicate them. The removal and exclusion of weeds from specific representative wetland sites may, however, be an achievable goal.

Weeds are prevalent at many of the seeps on sandy soils. Cropping is undertaken very near to the margins of many wetlands and this encourages the spread of agricultural weeds into remnant vegetation. Stock accessing wetlands also introduce weeds. The impact of weeds on native vegetation can be significant and the loss of floral diversity at affected sites, combined with losses in habitat and food for fauna, is sufficient to cause goal failure. Weed management will be very difficult due to the level of infestation across the catchment and extra management may have limited success in excluding weeds from many sites.

Weeds have had a significant impact on the native vegetation of the bentonite wetlands, resulting a loss of floral diversity. Management of these is required, and is probably achievable. There is no weed problem at the gypsum lake or granite rock pools.

Introduced and problem animals

Problem animals have the potential for serious impact on natural systems and values through direct effects such as predation, habitat destruction, competition for food and territory, introduction of disease, and through environmental degradation by selective grazing and accelerating erosion.

Problem animals can be either native species that are impacting on natural or agricultural values or both or feral animals (introduced species that have become established as wild or naturalised populations).

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

Introduced and problem animals found in the BMRC are listed in Table 3.

Table 3: Introduced and other problem animal species found in the BMRC as recorded in the CALM Landholder Survey 2003 and Invertebrate Survey 2004

Species	Common Name	Declared under the ARRP Act
Apis mellifera	Feral Bee	No
Artemia parthenogenetica	Brine Shrimp	No
Cacatua pastinator	Western Long-billed Corella	Yes
Cacatua sanguinea	Little Corella	Yes
Cacatua roseicapilla	Galah	Yes
Canis lupis familiaris	Feral Dog	Yes
Cherax destructor	Freshwater Crayfish (Yabbie)	No
Daecelo novaeguineae	Laughing Kookaburra	No
Dromaius novaehollandiae	Emu	Yes
Felis cattus	Feral Cat	No
Macropus fuliginosus	Western Grey Kangaroo	Yes
Mus musculus	House Mouse	No
Oryctolagus cuniculus	Rabbit	Yes
Platycerus zonarius	Twenty-eight Parrot	No
Rattus rattus	Black Rat	No
Sus scrofa	Feral Pig	Yes

The BMRC Landholder Survey (Calm and Colmar Brunton, 2005b) showed that animals considered most problematic for both economic and environmental impacts (foxes, rabbits and kangaroos) in the BMRC were most likely to be controlled regularly. Techniques used for control include baiting, shooting and trapping. Biological control occurs through myxomatosis and rabbit haemorrhagic disease (RHD). The key barrier to implementing measures to reduce threats from problem animals was time. Other barriers included cost, paperwork and leadership/coordination.

Introduced and problem animals in wetlands

Many of the primary saline wetland sites of the BMRC are too degraded to be threatened by stock access. Poor water quality and extensive vegetation loss limit the usefulness of these sites for watering and grazing sheep. Unfortunately, stock access remains a threat at those sites that maintain the best condition. In these instances, vegetation may be lost to grazing and soil structure destroyed by trampling. This, in turn, dramatically increases the risk of erosion, turbidity and sedimentation. Stock access will cause goal failure under the current management regime; however, with the cooperation of land managers, fencing wetlands will redress this issue.

Feral animals are prevalent in the valley floor, with evidence of rabbits, foxes and cats observed at many wetland sites. While these animals represent a threat to the biodiversity of the catchment, their effect on the suite of primary saline wetlands is minimal. Feral animals alone are unlikely to cause goal failure in this area, although additional management to prevent population increase is desirable.

Many of the wetlands of the Balgabine soil system are potable for stock and are used for watering sheep. Stock access represents a significant threat to these sites as heavy grazing leads to a loss of floral diversity and trampling destroys soil structure. Unmitigated, stock access will lead to goal failure at affected sites. Mitigation of the problem, by fencing wetlands, is an effective solution. Access to water can be maintained by pumping from the wetland to a paddock trough.

Feral animal activity is evident at sites with sandy seeps, but the impact of these species on wetland biodiversity is likely to be low.

There is no stock access to the gypsum lake, bentonite wetlands or granite rock pools. Feral animals access these wetlands, but no significant impacts are evident.

Impacts of Disease within the BMRC

Disease caused by Phytophthora

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 600 mm per annum rainfall or are water gaining sites in the 400-600 mm per annum rainfall zone.

The BMRC falls beneath the 400 mm per annum rainfall zone therefore the threat of *P. cinnamomi* causing significant changes to native plant communities and their dependent fauna is unlikely. Other *Phytophthora* species may be present however they are not likely to cause significant impacts compared to the other more threatening processes, such as secondary salinity.

Other diseases affecting plants

Rusts are the second most frequent pathogens encountered on native plant taxa in south-western Australia (Shearer, 1994) and the gall rust (*Uromycladium tepperianum*) commonly affects *Acacia* species producing galls.

Armillaria root rot (*Armillaria luteobubalina*) infects a wide range of plants from coastal dune vegetation to woodlands of the south-west of WA. The fungus is widespread and it is possible it is present within the BMRC however identifying the fungus as a specific cause of death may be difficult.

The highest impact of the disease is found in highly disturbed areas. 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 defense systems and increase the chances of the disease developing.

There is no simple method for controlling Armillaria. 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 significant localised impact and in some cases even kill plant hosts. However, in healthy and robust ecosystems they do not appear to be a serious threat to the long-term maintenance of biodiversity.

Detrimental Regimes of Physical Disturbance Events

Intact systems seldom suffer enduring damage from natural physical disturbance. The stresses induced by anthropogenic interference, however, significantly reduce the capacity of an ecosystem to withstand events such as fire, flood, drought and erosion. The primary saline wetlands of the BMRC are systems subject to considerable stresses and many of these have lost the capacity to endure detrimental physical disturbance events.

Physical disturbance events have some capacity to cause goal failure in the BMRC. Neither is problematic without the additional stressors associated with vegetation clearing, agricultural development and hydrological change. Soil erosion is a relatively easy threat to address with fencing and revegetation of wetlands having a high probability of success. Flood mitigation requires the control of surface water flows throughout the catchment and takes the cooperation of many landholders to be successfully implemented.

Although well adapted to a range of environmental stressors, the vegetation of the south west of Western Australia will suffer deleterious effects if exposed to detrimental regimes of physical disturbance events.

Fire

The Buntine Marchagee Recovery Catchment has been extensively cleared of native vegetation and intensively farmed for several decades. Remnant vegetation covers only 13% of the catchment and fragmentation of the landscape has left these patches highly isolated. Areas of contiguous native vegetation are restricted to 6 small nature reserves, which together, constitute less than 2% of the catchment's area.

Although the pre-clearing fire regime of the catchment cannot be quantified, extrapolation of data from areas of similar vegetation may provide some guiding principles. The majority of the catchment was formerly vegetated with various scrub heath assemblages, such as those that commonly occur on sandy soils across the south west of the state. In such an environment, fire would be expected to be a regular occurrence (Daniel, 2003), particularly given the propensity for thunderstorms in this part of the Wheatbelt. Heathland fuels burn rapidly and with considerable intensity. The lack of a substantial canopy allows wind speeds to remain high, fuels are fine and dry and the fuel load spatially continuous.

The long period of human influence in this catchment makes determination of the 'natural' fire regime impossible. Reliable historical records of fire occurrence are not available for this area, meaning that fire history is retained only where it is imprinted on remnant vegetation. Documentation of biological surveys undertaken by the Museum of Western Australia in the 1970's describe evidence of fire history at that time. These records indicate that most of Buntine Nature Reserve was burnt around 1960, whilst Nugadong Nature Reserve had two small fires around 1970 and more extensive fires in the early 1960's (Kitchener et al., 1979).

Paddock fires are a regular occurrence in the catchment, as they are across the grain producing regions of the state. These fires are usually either deliberately lit stubble burns or accidental ignitions resulting from the use of machinery, particularly harvesters, in dry paddocks. Anecdotal evidence suggests stands of remnant vegetation suffer periodic impacts of fire as a result of the spread of paddock fires into neighbouring bush or roadside vegetation. In addition to these paddock fire escapes, there is evidence within the catchment of landholders burning patches of remnant vegetation, either in an attempt to stimulate regeneration of senescent bush or to reduce the perceived risk of fire on a property.

Fragmentation of the landscape and degradation of remaining vegetation (particularly the loss of understorey due to grazing and salinisation of soil) has prevented the occurrence of extensive fires within the BMRC since the time of European settlement. These same factors increase the magnitude of the negative impacts attributable to the occurrence of relatively small fires in stands of vegetation already subject to numerous environmental stressors.

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 3 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 in the catchment 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). *Eucalyptus* woodland species are generally poorly adapted to survive the passage of fire at an individual level and will be killed by low scorch (I. Kealley, *pers. comm.*), with heat and smoke acting to stimulate regeneration by triggering recruitment from the seed bed (A. Desmond, *pers. comm.*). 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. The halophytic communities that fringe many of the catchment's salt lakes and drainage lines will not carry fire due to the paucity, and succulent nature of fuels (Newbey et al., 1995).

CALM has not traditionally undertaken any fire planning or pre-suppression in the reserves of the BMRC. The small size of these reserves, along with their isolation in the landscape, renders such processes unnecessary. Agriculturalists in the area maintain mineral earth breaks around paddock boundaries and, with the exception of deliberate stubble burns, plan for fire exclusion. Any alteration to this fire management regime is probably unnecessary.

Landholders in the catchment have expressed an interest in introducing fire to stands of senescing vegetation on private property. Many of the catchment's wetlands are surrounded by vegetation and an inappropriate fire regime in these remnants may have deleterious effects on the biodiversity of the wetland system. Providing advice or assistance to landholders wishing to undertake regeneration or fuel reduction burns in these areas may be a viable method of ensuring these are undertaken in a sensitive manner.

As is the case across most of Australia, the introduction of agricultural production systems has led to the exclusion of fire from the landscape. The usual consequence of attempts at fire exclusion is an increase in the fire interval, accumulation of large fuel loads and the occurrence of infrequent, but highly intense, fires. In the BMRC, remnant vegetation patches are mostly of such a small size that the potential for fuel accumulation, ignition and fire spread are all limited. This is evident from the lack of recent fire history in the area's reserves. The most likely effect of the observed alteration of the fire regime in the catchment is, therefore, senescence in those vegetation suites dependent upon fire as a part of the cycle of reproduction and renewal. This said, the potential remains for the occurrence of fires in remnant patches and, in some locations, these fires could be of sufficient intensity to cause damage to the root stock of resprouter species or the seedbed of reseeder species. Following such an event, the isolation of remnants will render natural repopulation of the site unlikely. Severe fires may be equally 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. Given the small range of many of the catchment's fauna species, reintroduction from 'neighbouring' remnants is unlikely in the aftermath of a localised 'extinction' event.

Flood

A less frequent, but more dramatic, disturbance is flooding. Flood events cause widespread waterlogging, flush saline water through the system and dramatically erode the landscape. The catchment's most recent flood event, in 1999, coincided with extensive plant deaths throughout the valley floor and many areas have shown poor recovery since. As discussed under wetland values, mitigation of flood waters is an ecosystem service provided by wetlands. Degradation of the BMRC wetlands has doubtless compromised their provision of this service.

Cyclones

Wind damage in the catchment may occur in association with severe thunderstorms, localised 'tornadoes' or cyclonic activity. These events are relatively uncommon and, generally, do not result in widespread damage to native remnants, although individual plants within remnants may succumb. Deleterious effects are more likely to occur as a result of episodic high rainfall events. In 1999, the central wheatbelt suffered widespread flooding as a result of unseasonably high rainfall in the Moore River catchment. Flooding may cause stress or death in local provenance species unable to survive waterlogging and the resultant redistribution of salt loads in the catchment. The previous incidence of a similarly wet year was in 1963 when Coorow received 661 mm of rainfall (compared to 649 mm in 1999). Anecdotal evidence suggests each of these events had widespread impacts on both remnant vegetation and agricultural production within the catchment.

Drought

Drought is a common occurrence in many parts of Australia. Drought occurs during prolonged dry periods, when there is not enough water for the normal needs of users. There are different levels of drought depending on the rainfall in three month or more periods and whether they lie below the lowest 10% of records. Serious rainfall deficiency occurs when rainfall is above the lowest 5% of recorded rainfall, but below the lowest 10% of rainfall. Severe rainfall deficiency occurs when rainfall is among the lowest 5% for the period (Australian Bureau of Statistics, 2005)

Drought is linked to the climatic conditions of an area and will depend on the resistance of plants to water shortages. Being more adapted to a dry climate, native species are well adapted to periods of low rainfall, particularly those in more arid environments. Cereal crops are more sensitive to water shortages (Bureau of Meteorology, 2005b).

The impacts of drought are probably the most severe in agricultural areas and can disrupt cropping programs and reduce breeding stock. Drought impacts are also felt at all levels of the ecosystem. There are impacts to native vegetation, including vegetation loss and soil erosion. Significant year to year climatic variation may influence vegetation at a given point in time and the rainfall of previous years can have long term effects on plant growth, flowering and seed set. For example, in eucalypts, an interruption anywhere in the bud/flower/fruit cycle will result in no seed development for that particular season. These impacts can be result in further follow-on effects such as influencing the abundance and movements of migratory birds that depend on flower derived resources like nectar and pollen. 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 be affected and there may be outbreaks of toxic algal blooms. Drought can increase the incidences of bushfires and dust storms. All of these impacts can be exacerbated in areas such as the BMRC where vegetation is highly fragmented (Bureau of Meteorology, 2005b).

Since European settlement, there have been a number of serious droughts in Western Australia, which have affected the BMRC. Significant periods of drought occurred between 1864 and 1866, in 1868, in 1888, between 1910 and 1914, in 1940, between 1944 and 1945 and between 1958 and 1968. More recently, the BMRC has seen periods of serious and severe rainfall deficiencies between April 2000 and August 2001 and between December 2001 and April 2003 (Australian Bureau of Statistics, 2005, Bureau of Meteorology, 2005b).

Erosion

Soil erosion is a significant threat to the wetlands of the Balgerbine soil system. These light sands are prone to blow outs and, this is frequently observed where stock access has removed native vegetation. The loss of soil to erosion makes goal failure highly likely, as plants will not recolonise the site once the erosive process becomes established. Fencing to exclude stock and revegetation of grazed sites will mitigate the threat of erosion.

Wind erosion

Wind damage may occur in association with severe thunderstorms, localised 'tornadoes' or cyclonic activity. These events are relatively uncommon and, generally, do not result in widespread damage to native remnants, although individual plants within remnants may succumb.

The loss of vegetation and structure makes soils susceptible to wind and water erosion. Soil loss reduces the likelihood of recolonisation by native species. 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.

Water erosion

Water erosion can occur on all soil types. The factors that determine the susceptibility of a soil to water erosion include soil type, landscape position, slope, vegetation cover, soil structure, water repellence, and intensity of rainfall. Water erosion occurs at the point where the surface soil horizon reaches saturation and continued rainfall results in surface water flow.

Water movement across the landscape can result in a transfer of soil and nutrients to lower elevations in the landscape. This has implications for the receiving environments such as roads, culverts, drainage lines and wetland systems. Eutrophication of water bodies can result from water erosion particularly where organic-rich soil is deposited confluent with nutrients.

Soils considered as a high risk to water erosion include soils that are water repellent, denuded of vegetative cover, low organic content, high fine sand content and those soils already waterlogged. In the BMRC all soil types are susceptible to water erosion however soils located on steep slopes, in particular the Inering Hills system, are at the highest risk (Griffin and Goulding, 2004).

Water erosion can be ameliorated through a number of means such as maintaining vegetative cover and construction of grade banks or level banks.

Sedimentation

The process of soil erosion transports soil particles from areas of high velocity to those of low velocity. Therefore material eroded from shedding landscapes, such as laterite breakaways, is transported to lower landscape positions. Fluvial, and colluvium processes therefore result in the transport of fine soil particles of sand, clay and silt to the valley floor. This is a natural process however this has been accelerated due to the clearing of native vegetation, and changes to land use. In addition, the construction of deep drains potentially increases the velocity and amount of water moving through the landscape, therefore increasing sediment deposition.

Sediment transport can have a range of impacts upon the physical and biological functioning of a catchment. In the BMRC there is clear evidence of sedimentation blocking culverts and other road structures. This leads to poor surface water flows, having economic implications for the various shires and potentially increasing recharge of groundwater behind physical barriers. Sedimentation of wetland systems can result in increased water turbidity, which affects the productivity of wetland systems; changing of the substrate composition, which can alter hydrological characteristics; and lastly (as discussed above) can increase the transport of organic-rich, and nutrient enriched soils from paddocks.

Impacts of Competing Land Uses

Agricultural Impacts

Soil structure decline

Surface soils

The structure of surface soils 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.

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 in the BMRC to reduce the impacts associated with soil structure decline.

In the BMRC, 'heavier' textured soils such as Brown loamy earths, and Red/brown non-cracking clays are most susceptible to compaction of surface soils and structural decline. These soil types are most-often found in the valley floor and lower slopes. These are typically found in the Inering Hills and in parts of the Ballidu and Upsan Downs systems (Griffin and Goulding, 2004).

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. 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).

Course to medium gained soils with low organic carbon (<2%) are most susceptible to subsurface compaction. More than half of the soils of the BMRC fall into this category (Griffin and Goulding, 2004).

The only method to alleviate subsurface compaction is through deep ripping. This technique has been used recently on some properties in the BMRC.

Expansion of agriculture in the catchment is unlikely as the vast majority of arable land is already in production therefore clearing of wetland vegetation is a now considered a low threat.

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 (Department of Environment, 2004). This list (Table 5) has been included to provide a guide as to the potential pollutants in the BMRC associated with agriculture.

The Contaminated Sites Act is currently under review in Western Australia. Once this bill has been passed, the Department of Environment will make available on-line a register of contaminated sites or sites which have been investigated. It is unlikely that there are any sites within the BMRC which have been investigated, however it will be relatively easy to verify in the near future if deemed necessary.

Table 5. 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 Sulphur, sulphuric acid Molybdenum, selenium, boron, cadmium Nitrates, ammonia
Intensive agriculture (including the blending and mixing of herbicides, fungicides, pesticides and fertilisers)	Carbamates Organochlorine pesticides Organophosphate pesticides Herbicides (e.g. triazine, atrazine) Nitrates Salinity Metals (e.g. aluminium, arsenic, cadmium, copper, iron, lead, magnesium, potassium) Nutrients (e.g. nitrogen, phosphorus) Sulphur
Livestock dip or spray race operations and/or sheep and cattle dips	Metals (e.g. arsenic) Carbomates Organochlorine pesticides Organophosphate pesticides Herbicides Synthetic pyrethroids
Storage facilities (e.g. diesel fuel storage)	Total petroleum hydrocarbons (TPH's) Monocyclic aromatic hydrocarbons (e.g. benzene, toluene, ethylbenzene and xylene) Metals Phenols Chlorinated hydrocarbons (e.g. trichloroethylene) Oil and grease

The trends of chemical use in the BMRC are anticipated to closely follow those of other agricultural regions in Australia. After World War II, as technology developed and became more affordable, the use petrochemical fertilisers increased significantly. The development of other chemicals soon followed. These included organo-chlorine pesticides (OCP's) such as DDT, lindane chlordane, dieldrin, aldrin, and heptachlor. Throughout developed countries such as Australia OCP's became popular because they were both highly effective and persistent. In the BMRC the use of these types of chemicals increased substantially in the late 1960's (Doley, 2003).

The structure of OCP's makes them insoluble in water and highly soluble in fats, therefore having the ability to bio-accumulate in an organism. The accumulation of OCP's 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 OCP's upon human heath. Consequently the sale and use of DDT in Australia was ceased in 1987 and the remainder of OCP's ceased in 1992 (Radcliffe, 2002).

OCP's 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 7-10 years (Ambrose, 2000). Given the persistence of these chemicals, it is likely that they are still present in the soil, water and within fauna associated with areas where OCP's have been historically applied in the BMRC.

A number of landholders, Government agency staff, and local agronomists were contacted by CALM to compile a list of the chemicals used currently (Table 6). This list is provided only as a guide and is subject to variation due to a large range of factors including cropping rotation, type of farming equipment, soil type and farm practices. Specific information pertaining to each of these chemicals such as the toxicological information is readily available from the suppliers, thus not covered in detail within this report.

The implementation of soil conservation methods, such as no-till, has a number of benefits such as an increased the retention of soil structure and reduced loss of topsoil. Adoption of these practices has also contributed to an increased use of chemicals (Radcliffe, 2002). Chemical use is now an integral part of broad-acre cropping and livestock production in the BMRC.

Table 6: Example of some of the types and application rates of chemicals currently used for broad-acre cropping in the Buntine-Marchagee Recovery Catchment

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	1,200 mL/ha^{-1}
	Logran	750 g/kg triasulfuron	B herbicide	Annual ryegrass, paradoxa grass and certain broadleaf weeds	35 g/ha^{-1}
	Chlorpyrifos 500 EC	500g/L chlorpyrifos	1B Insecticide	Broad-spectrum organophosphate insecticide	200 mL/ha^{-1}
	Sonic 200EC	200g/L cypermethrin	3A insecticide	Controls a wide range of certain insect pests	100 mL/ha^{-1}
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	280-380 g/ha^{-1}
	Hoegrass	500 g/L diclofop-methyl	A herbicide	Control of annual ryegrass and wild oats in wheat, barley, triticale and cereal rye	750-1,000 mL/ha^{-1}
	Jaguar	250 g/L bromoxynil, 25 g/L diflufenican	CF herbicide	Residual control of wild radish up to 4 weeks after application	500 mL/ha^{-1}
	Tigrex	250 g/L MCPA (present as the iso-octyl ester), 25 g/L diflufenican	F1 herbicide	Control of certain broadleaf weeds in winter cereals and clover	500 mL/ha^{-1}
	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	500-800 mL/ha^{-1}
	Flowable Diuron	500g/L diuron	C herbicide	Controls certain grass and broadleaf weeds	200 mL/ha^{-1}
Lupins Pre-emergent	Gesatop 600SC	600g/L Simazine	C herbicide	Controls certain broadleaf weeds and grasses	1,500 mL/ha^{-1}
	Gesaprim 600SC	600g/L Atrazine	C herbicide	Selectively controls a wide range of weeds	500 mL/ha^{-1}
	Roundup	360g/L Glyphosate	M herbicide	Control against any annual and perennial broadleaf weeds and grasses	1,000 mL/ha^{-1}
Lupins Post-emergent	Brodal	500 g/L diflufenican	F herbicide	Control of certain weeds in clover-based pasture	100 mL/ha
	Aramo	200 g/L Tepraloxydim	A herbicide	Control of grass weeds in broadleaf crops	300 mL/ha
Canola Pre/post-emergent	Gesaprim 600SC	600g/L Atrazine	C herbicide	Selectively controls a wide range of weeds	400 mL/ha

Canola Post-emergent	Aramo	200 g/L Tepraloxydim	A herbicide	Control of grass weeds in broadleaf crops	300 ml/ha

Other pollutants

A number of pollutants other than agricultural chemicals can be generated as a consequence of farming practices in the BMRC. 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 (<10,000 L) on farms. From observations made by CALM, 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. To reduce the chances of negative impacts on the environment it is preferable that all fuel storage tanks should be located within a bunded compound to Australian Standards *AS1940-2004 The storage and handling of flammable and combustible liquids*. CALM is not aware of any properties with appropriate containment bunds; however the potential for contamination of wetlands by fuel spill is considered to be relatively low.

Due to the impracticalities of returning farm machinery to the servicing agent, the majority of servicing and repairs occur on-site. 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 farmers disposed of waste oil on their farms however it probable that this practice has ceased. It is expected that farmers dispose of waste oil at the nearest landfill site or at one of the number of waste oil recovery stations. More information on the waste oil recovery program is available from WasteNet (available on http://www.wastenet.net.au/programs/oil).
With regards to the use of other chemicals, such as degreasers and water coolants, there is paucity of information available to determine the potential impacts on wetland ecosystems.

CALM has found no evidence of impacts associated with the disposal of waste oil, or other chemicals associated with vehicle servicing in the vicinity of wetlands in the BMRC.

With the advent of dependence of modern farming practices, large quantities of empty chemical drums are a waste disposal issue. There is evidence that these have been dumped in or near to salt lakes in the past. Subsequently these containers may have either been buried or burnt, a practice which is considered environmentally unacceptable (Department of Agriculture, 2002). As a consequence of this evolving issue the Department of Agriculture has produced guidelines (Guidance Note No.8) for appropriate disposal of empty chemical drums (Department of Agriculture, 2002). The Department of Agriculture recommends that empty drums are disposed of appropriately and that collection initiatives such as the DrumMUSTER are used.

DrumMUSTER is an initiative which alleviates pressure upon both local landfill sites and reduces the risk of environmental harm and harm to human health. With the new program in place it is unlikely that disposal of chemical drums will pose a threat to wetlands, although it is recommended that CALM staff remain vigilant. For more information on the DrumMUSTER organisation, access the following website (http://drummuster.com.au).

Impacts of agricultural chemicals and other pollutants on wetlands

As previously described, there is extensive usage of herbicides, pesticides and fungicides in the BMRC. Significant detrimental impacts will result if wetlands are exposed to these chemicals; either via surface water runoff, leaching or spray drift. The threat posed to wetlands is determined by a number of factors such as the proximity of paddocks to wetlands, the method of chemical application and the soil type of the area.

Paddocks do not immediately bound the majority of the wetlands of the valley floor. These, combined with the clay soils of the area, reduce the potential for chemicals to impact on wetlands of this suite. The use of agricultural chemicals in the catchment is, therefore, unlikely to cause goal failure in the primary saline wetlands of the valley floor.

The use of agricultural chemicals represents a significant threat to the wetlands of the Balgerbine soil system. Cropping is undertaken very close to wetlands, increasing the likelihood of spray drift, and sandy soils increase the rate of leaching of applied chemicals. Although some impacts of chemical usage have been observed in the catchment, it appears unlikely that these will cause goal failure under the current management regime. Coordinated monitoring of the entry of chemicals to these wetlands would, however, be advisable.

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 BMRC 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 groundwater occurring typically within 3 metres of the surface and transfer this water away from an area to a disposal point. Therefore drains are commonly located in the valley floor and along natural drainage lines (De Broekert. P. P. and Coles. A., 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 is anecdotal support for deep drains by many farmers, with reports of either improved crop yields or return of unproductive land to productivity.

In the BMRC, about 50% of farmers have implemented some form of drainage structures to alleviate rising groundwater tables or waterlogging (Calm and Colmar Brunton, 2005b). Due to the 'heavier' nature of the soils in the eastern parts of the BMRC the adoption of drainage, in particular deep drains, is more extensive in these areas. The sandplain soils in the west are not conducive to the construction of either surface water or deep drain structures.

CALM understands that there is one published scientific investigation into the effectiveness of deep drains in the BMRC (Speed and Simons, 1992), and one unpublished study (R. Speed, *pers. comm.)*. In addition there is a concurrent study occurring about 9 km east of the BMRC on the Nugadong Road West. Data is being colleted at this site by CSIRO Land and Water as part of the Engineering Evaluation Initiative (EEI) undertaken by the Department of Environment (J. Byrne *pers. comm*).

There are numerous studies which have evaluated the effectiveness of deep drains in removing water from agricultural land in the wheatbelt however there are few that have evaluated the quality of water being exported from these sites. In more recent times, the impacts upon receiving environments is gaining greater attention (Coleman and Meney, 2000a, Coleman and Meney, 2000b, Ali et al., 2004, Hornbuckle et al., 2004).

The receiving environment

The receiving environments for saline water discharge from deep drains are typically large saline wetland systems, which frequent the valley floor in many catchments in the wheatbelt. Historically these areas were considered as having a low cultural and biodiversity value. Increasingly, these systems are being considered 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 atypical rainfall events there may be an increased chance of overflow from these terminal wetlands and an increase risk to 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.

Illegal Activities

There are no landfill sites within the BMRC boundary however there are sites located in close proximity to the BMRC boundary near the towns of Coorow, Watheroo, Dalwallinu, and Perenjori. None of these landfill sites are registered with the Department of Environment (C. Scott, *pers comm.*); however these sites are regulated under the *Environmental Protection (Rural Landfill) Regulations 2002*. Each of these sites are classed as either Category 64, or Classes II and III under the Department of Environments (DoE) waste definitions (Department of Environment, 2005). These guidelines can be referred to with regards to the types of materials accepted. CALM is of the understanding that some of these landfill sites will be licensed with the DoE in the future.

In the BMRC it is not uncommon for waste generated on farms to be stockpiled on farms. Common materials include car bodies, old machinery, car batteries, fencing wire, and storage drums. Over time many of these materials degrade, however some of these materials may either be persistent or have the potential for negative impacts on the surrounding environments. The disposal of these materials in wetland environments in particular may have negative impacts on biodiversity values within the immediate area.

Rubbish dumping has traditionally been a threat to wetlands, particularly to salt lakes, or playas. It appears, however, that rubbish dumping in wetlands is now less common in the catchment. The reasons for this are dealt with below.

Recreation Management

There is recreational usage of the BMRC wetlands but this is generally low impact. Favoured past times are boating, water skiing, kayaking and nature based activities such as bird watching. Some wetlands do show signs of vehicle access and this may be detrimental to the biodiversity of those sites.

Mines and Quarries

Bentonite wetlands are mined for their clay. The BMRC has been surveyed and bentonite wetlands tested for mining viability. It is believed that all economic resources have been exploited and mining is not a threat to the remaining wetlands.

Urban development

The BMRC contains the townsites of Buntine and Wubin is close to Dalwallinu and Marchagee. Although the expansion of urban areas within the Wheatbelt is limited, future urban development may have an impact on areas of remnant bushland within the BMRC. For example, urban bushland around the town of Dalwallinu is likely to be cleared in the future for for townsite expansion.

Impacts of Community Values

As 94% of the Catchment is privately owned and 73% of the 13% remaining remnant vegetation is on private property, Landholder and community consultation and involvement is vital for the management of key biodiversity assets and threat mitigation. The cooperation of landholders is necessary in order to implement management practices that are sympathetic to conservation. In the 2003 BMRC Landholder Survey (Calm and Colmar Brunton, 2005b) the response rate to the questionnaire was good. Seventy-percent of the total Catchment population (59 out of 84 Landholders) answered the questionnaire, which in terms of area covered in the Recovery Catchment equated to approximately 75% (135,086 ha). Of those Landholders who participated, most had some level of understanding of the values of the BMRC. Salinity is seen by Landholders as the greatest on-farm threat (although acidic soils covered a greater area than that affected by salinity). Landholders indicated they are aware of the major environmental threats in the Catchment and in many cases are attempting to mitigate these. Landholders are attempting to combat salinity through earthworks, fencing and revegetating sandy seeps. Most Landholders felt these methods helped in the alleviation of the impacts of salinity.

However, despite this, Landholders acknowledged that there was much to learn about biodiversity conservation and the impacts of salinity. Anecdotal evidence suggests that, although landholder attitudes vary, wetlands with more obvious biodiversity are more highly valued. Fresh wetlands with remnant fringing vegetation are widely considered to be assets, for both intrinsic, amenity and productive use values. Some saline playas are valued for the recreational opportunities they provide or for landscape amenity. In general, however, landholders feel limited affinity for the wetlands of the BMRC and this represents a threat to their survival. Furthermore, although the majority of those who declined to participate in the survey did not have the time to take part, a small number declined as they believed that it was not worth their while and that such projects are not beneficial.

Consequently, in order to foster positive community attitudes and support for the management of the BMRC, engagement of the community is imperative. Of the Landholders who participated in the survey, most supported greater interaction and consultation between stakeholder groups and an ongoing commitment to the project by the BMRC Recovery Team, Landholders, and Landcare and community groups. The lack of time and money were seen as the greatest barrier to Landholders in the implementation of biodiversity conservation. Investment in works, including fencing, earthworks and revegetation by Landholders was generally $3000 or less per year. Hence, financial incentives were also seen as a way of encouraging the implementation of conservation works in the Catchment. Methods for consulting with the community are outlined in the BMRC Communications Plan (Appendix 14).

Insufficient Resources to Maintain Viable Populations

A priority for long-term conservation is the maintenance of viable populations, however little is currently known about what biological factors actually affect population persistence.

Current research aims to quantify the genetic and ecological factors that influence the viability of plant populations in the WA agricultural landscape and explore how these are affected by remnant characteristics such as size, disturbance and landscape position. Preliminary results from this study show some strong effects of population size, condition and landscape context on fecundity (D. Coates, *pers. comm.*).

APPENDIX 14: BUNTINE-MARCHAGEE RECOVERY CATCHMENT (BMRC) COMMUNICATION PLAN 2005-2010

Communication Plan Definition

Purpose

The purpose of the Communications Plan is to establish a program of public participation that will assist in the delivery and implementation of actions from the Recovery Plan. These actions will be aimed at reducing the impact of processes that are threatening biodiversity values in the Buntine-Marchagee Recovery Catchment.

Vision

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

Background

The Department of Conservation and Land Management (hereafter, CALM) is committed to protecting and conserving our State's rich biodiversity in partnership with the community. This is achieved through the management of over 24 million ha of State land and water reserves in sympathy with the surrounding environment. *X area of this land is in the wheatbelt of Western Australia, X area in the Northern Agricultural Region.* As part of its corporate vision the Department aims to 'develop community awareness and appreciation of the State's rich diversity of native plants, animals and natural ecosystems, and its unique landscapes, and promote community involvement in and support for their protection, conservation and restoration.'

The Western Australian State Salinity Action Plan (Agriculture Western Australia et al., 1996)and later the Salinity Strategy (State Salinity Council, 2000) identified Natural Diversity Recovery Catchments as a key measure for biodiversity conservation based on the 'identification of major, high priority public assets that are at risk from salinity and warrant significant, ongoing investment in their recovery and protection.' The Department has a responsibility to Government to develop and implement in partnership with landholders, land managers and the wider community a coordinated wetlands and Natural Diversity Recovery Program "to ensure that critical and regionally significant natural areas, particularly wetlands, are protected in perpetuity."

The BMRC is the fifth Natural Diversity Recovery Catchment established by the Department of Conservation and Land Management. It targets a naturally saline braided wetland system that is at risk from waterlogging and secondary salinity.

The aspirational goal of the Recovery Catchment is "to maintain the native species in a range of representative wetlands within the Buntine-Marchagee Catchment by 2020."

The BMRC is located approximately 200kms north-east of Perth. It covers areas within the Shires of Coorow, Dalwallinu, Moora and Perenjori. The majority (60%) of the catchment lies within the Shire of Dalwallinu, with a further 31% in the Shire of Coorow, 8% in the

Shire of Moora and the remaining 1% in the Shire of Perenjori. The Recovery Catchment Project for the most part follows the topographical divide of the Buntine-Marchagee wetland system. The area of the catchment covers approximately 181,000 ha.

Approximately 13% (24,000ha) of the BMRC is native vegetation and of this less than 2% (2,225ha) is managed by the Department of Conservation and Land Management (CALM) in six fragmented nature reserves.

Private property makes up 93.7% (169,527ha) of the catchment.

Stakeholders

There are a wide range of stakeholders that are engaged in activities which influence the management of the natural resource base in the Buntine-Marchagee Catchment.

Landholders

As at April 2005, the catchment had a population of 235 people. The largest group of landholders are families with primary school children. Results of the Landholder Survey conducted by CALM in 2003 indicate that the majority of landholders in the catchment identify salinity as the greatest threat to the sustainability and viability of their farming operations. Landholder participation will be fundamental to the implementation of recovery actions to protect biodiversity and achieve the aspirational goal of the Recovery Catchment.

Government Agencies

Various Federal and State Government Agencies are involved in on-ground works, research, extension of information, allocation of resources and regulation in relation to biodiversity/natural resource management in the catchment.

Commonwealth Government

Department of Environment and Heritage

The Natural Heritage Trust funds the position of Strategic Natural Resource Management (NRM) Facilitator for the Northern Agricultural Catchment Council (NACC). The role of the Strategic Facilitator is to assist the region to develop and put its NRM strategy in place. Strategic outcomes required from the position include: Government NRM policy and information communicated, stakeholder issues and achievements relayed to government, improved stakeholder engagement; an effective and well-functioning NRM facilitator network.

The Natural Heritage Trust provides funding to allow stakeholders in the BMRC and NAR to implement natural resource management projects, for example, Envirofund.

CSIRO (Commonwealth Scientific, Investigation and Research Organisation)

The main divisions of the CSIRO include; CSIRO Forestry & Forest Products, CSIRO Land & Water, CSIRO Plant Industry and CSIRO Sustainable Ecosystems. These groups are participants in research currently conducted by the CRC for Plant-Based Management of Dryland Salinity. An example of work already undertaken by CSIRO in the BMRC is the

Sustainable Ecosystems Division project 'Testing Approaches to Landscape Design in Cropping Lands'.

Grains Research & Development Corporation (GRDC)
The GRDC is responsible for planning, investing and overseeing research and development, and delivering improvements in production, sustainability and profitability across the Australian grain industry. Local landholders have the opportunity for input and representation to the GRDC.

Land & Water Australia (LWA)
The LWA invests in more than 20 research programs in the areas of: sustainable primary industries; rivers; vegetation; future landscapes. For example, the CSIRO project 'Testing Approaches to Landscape Design in Cropping Lands' was jointly funded by Land & Water Australia and the Department of Conservation and Land Management.

Australian Bureau of Agricultural & Research Economics (ABARE)
ABARE provides quarterly forecasts for the full range of export commodities. Recent research on economics of salinity control and related policy issues provides insights into the problem of salinity control that will be considered in regional plans being developed under the National Plan for Salinity and Water Quality. Surveys of Australian farms are conducted by ABARE on a regular basis.

Australian Broadcasting Corporation (ABC)
The ABC, particularly ABC radio, provides a vital communication link for the catchment community. It is important in providing general local, regional, state, national and international news. In addition, it provides more specialised information for rural listeners such as the Country Hour, Market Reports and Weather information.

State Government

Department of Conservation and Land Management
CALM deals with conservation of ecosystems, oil mallee reesearch, wetlands, biodiversity and other issues. Biodiversity programs operating within the region include Natural Diversity Recovery (the BMRC Project), CALM Covenant, Roadside Conservation Committee (RCC), Western Australian Threatened Species and Communities Unit (WATSCU), Land For Wildlife (LFW), Bushland Benefits. CALM collaborates with other agencies on natural resource management.

Department of Agriculture Western Australia (DoA)
DoA is responsible for policy, research and information provision on dryland salinity affecting agricultural areas and rural towns. Main project areas include engineering water management, chemical and sediment export, land use assessment and farming systems including sustainable grazing on saline lands.

Department of Environment (DoE)
The DoE brings together the former Department of Environmental Protection (DEP) and the Water and Rivers Commission (WRC). Western Australia's key regulatory body, it manages water quality, particularly for irrigation water and stream flows, and administers the Salinity Investment Framework.

Forest Products Commission (FPC)

The FPC oversees plantation management and commercial production from renewable timber resources.

Local Government

Local Government stakeholders in the BMRC include the Shires of Coorow, Dalwallinu, Perenjori and Moora. Their core responsibilities include road maintenance and construction and administrative role. In addition, they have a role as managers of biodiversity; on Crown Reserves that are vested with Local Government and on road reserves that often contain a significant proportion of the overall biodiversity in an area due to their linear extension across different habitats in the landscape.

Catchment Management Body

Moore Catchment Council (MCC)

The BMRC falls within the natural catchment boundary of the Moore Catchment. The Moore Catchment Council is a sub-regional group within the Northern Agricultural Region of Western Australia that assists in development and delivery of natural resource management initiatives.

Natural Resource Management Council

The Northern Agricultural Catchment Council (NACC)

NACC provides a leading role in identifying priority directions for natural resource management across the whole of the Northern Agricultural Region and is allied with four sub-regional groups including the Moore Catchment Council.

Service Providers

There are a range of public utilities within the BMRC which are significant to the communities. They include; Telstra, Optus, Westrail, Western Power and the Water Corporation.

Cooperative Research Centres

Cooperative Research Centre (CRC) for Plant-based Management of Dryland Salinity

This CRC focuses on developing profitable and sustainable farming systems to manage both recharge and discharge. The research effort brings together research effort from six State Government Agencies, three universities and CSIRO to address these issues through seven research programs-education, function of natural ecosystems, new and improved plant species, new farming systems, economic and social assessment, animal systems and biodiversity.

Private Consultants

Western Australian farmers use the services of private consultants more frequently and for a wider range of services than in any other state. While they access financial, agronomy, chemical and animal husbandry services from the private sector, little use is made of resource management advice. (Natural Resource Management in Western Australia The Salinity Strategy March 2000).

Contractors

Provide various services associated with natural resource management such as conservation earthworks.

Non-Government Organisations

Greening Australia

Greening Australia engages the community in vegetation management to protect and restore health, diversity and productivity of our unique Australian landscapes. Link 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)

The ACF has campaigned 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

Support conservation, research projects and recovery actions for Australian birds and their environment.

Community Groups

Land Conservation Committees (LCDCs)

LCDCs work under a formalised landcare structure created under the Soil and Land Conservation Act. The Act is administered for the Minister of Agriculture by the Commissioner of Soil and Land Conservation. Most landholders in the BMRC belong to an LCDC /Catchment Group. Some LCDC's are in recess. The LCDC's represent networks that could be targeted to assist in the facilitation of information exchange, coordinate activities and share resources in delivery of the Recovery Plan. Coorow LCDC acts as an umbrella body for the Marchagee Catchment Group.

Land Conservation District Committees in/adjacent to BMRC
Buntine West Wubin LCDC
West Nugadong LCDC
Pithara-Dalwallinu LCDC
Coorow LCDC
Waddy Forest LCDC
West Maya LCDC
Miling LCDC
Latham LCDC
Goodlands LCDC

Catchment Group
Marchagee Catchment Group

North Central Mallee Fowl Preservation Group

The 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

The Dalwallinu Woodlands Development Group aims to preserve the Dalwallinu Townsite Woodlands through a program of management and rehabilitation.

Liebe Group

The Liebe Group is an agricultural production-oriented group that works to sustain and enhance the rural environment through a whole systems approach to agriculture.

Educational Institutions

Schools

There are primary schools at Latham, Wubin, Perenjori, Moora, Watheroo, Coorow. Secondary schools are located at Moora, Dalwallinu, Carnamah

Tertiary Institutions

There is a Technical & Further Education (TAFE) College in Moora. Universities include Murdoch, University of Western Australia (UWA), Curtin and Edith Cowan.

Community

The BMRC encompasses a large geographical area with landholders in the west of the catchment tending to utilise the towns of Coorow, Watheroo and Moora as their social centres while in the east-Dalwallinu, Wubin, Buntine, Latham and Perenjori. Surrounding the BMRC are the communities of Dalwallinu, Coorow, Moora and Perenjori. In addition, there are visitors to the BMRC from Perth, other parts of Western Australia, interstate and international.

BMRC Steering Committee

The BMRC Steering Committee was established by CALM for the purpose of facilitating working with the community in the Buntine-Marchagee Recovery Catchment. The Steering Committee has representatives from key stakeholder groups including; landholders, CALM, Department of Agriculture, Educational Institutions-Murdoch and Curtin Universities, Shire Councillors, CSIRO, Department of Environment, Moore Catchment Council (MCC), Private Consultant-Landcare Technician, Northern Agricultural Catchment Council(NACC). The original Steering Committee was formed in 2002 and was made up of eighteen members. The group has since expanded and there are approximately 25 members. The Steering Committee meets as required.

Key Messages

An information, education and interpretation program is essential to achieve the aspirational goal of the BMRC which is "to maintain the native species in a range of wetlands within the BMRC by 2020".

The program will draw special attention to the priority biodiversity assets of the BMRC to be conserved to achieve the aspirational goal, the threats to these biodiversity assets and the options for management of threats.

These assets include;

Wetlands
- Valley floor.
- Gypsum.
- Bentonite.
- Sandplain.
- Flow lines.

Terrestrial vegetation
- Vegetation associations.
- Threatened Ecological Communities (TEC).
- Declared Rare Flora (DRF) and Priority Flora.

Fauna assets
- Threatened species.
- Special interest/icon species.

In addition, the program will promote understanding of the systems that underpin the BMRC environment including;

Ecology
- Ecosystems and processes.
- Evolution of plant communities and the sorts of animals associated with them.
- Time element-how long things take to establish, grow and recover once damaged or removed.

Geology
- Age
- History

Salinity Zones and Associated Biodiversity
- Pre-European extent
- Primary salinity
- Secondary salinity

Biogeographic Zones
- Flora (plants) and Fauna (animals), including Priority Species and Groups, Known Local Extinctions and Changes in Status, Recovery Plans

Appropriate Ecosystem Recovery Actions.

Value of biodiversity in catchment

The BMRC targets a naturally saline braided wetland system that is at risk from secondary salinity and waterlogging.

It contains significant diversity of terrestrial plants and animals:

- 39 taxa on the Department's Rare and Priority Flora List
- 37% of all known mammals and 29% of all known reptiles found in the wheatbelt
- A rich and diverse assemblage of bird life
- A mix of salt-lake invertebrates, including one species never before discovered in Australia, one species found only in two places in Western Australia, and another species found only in southern Australia.
- Supports about 13% of the whole wheatbelt's aquatic fauna and a larger proportion of the fauna typical of saline systems in the northern wheatbelt
- Contains good examples of the remnant vegetation found in the Northern Agricultural Region (NAR).
- It straddles two biogeographical systems, the Geraldton Sandplains and the Avon Wheatbelt.

Threatening Processes

The biological values outlined are potentially at risk from a variety of threatening processes, including;
- Increased fragmentation, loss of remnants and lack of recruitment/regeneration
- Altered biogeochemical processes (salinity, soil acidity, water repellence)
- Impacts of introduced plants and animals
- Impacts of problem native species
- Impacts of disease
- Detrimental regimes of disturbance
- Impacts of pollution
- Impacts of competing land uses
- Impacts of community values

Farming systems in the BMRC are also subject to most of these threatening processes.

Farmers identify salinity as the main threat to sustainability and viability of farming systems in the BMRC (CALM Landholder Survey 2003). Some of the works being implemented by farmers to address threats to farming systems will also be helping preserve biodiversity. Conversely, some works may have deleterious effects on the biodiversity values of the catchment.

Works being implemented to address threats include:
- Surface water management
- Subsurface water management
- Liming
- Stubble retention
- Minimum till
- Revegetation
- Protection of remnant vegetation
- Weed control
- Introduced and problem animal control.

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

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

Biodiversity Issue	Communication Objectives	Communication Strategies	Primary Target Audiences[12]	Performance Indicator
Increased fragmentation, loss of remnants and lack of recruitment/regeneration	Improve community understanding of plants, animals; values, threats and management options within the catchment.	1. Newsletter 2. Field Days 3. Education Packages/Technical Reports 4. Joint planning 5. Displays 6. Interpretative materials (signage, brochures)	Land Managers (1,2,3,4,5,6) Community Groups-LCDC's, Catchment Groups, Production Groups (1,2,3,4,5) Non-Government Organisations -WWF, Greening Australia, Birds Australia, North Central Mallee Fowl Preservation Group (1,2,3,4,5,6) Agencies-CALM (1,2,3,4,5,6) Schools (3,5,6) General Community (1,2,5,6)	1. Increased awareness of the legacy of broadscale clearing and implications for plants and animals. 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
Altered biogeochemical processes (mainly hydrology)	Improve community understanding of groundwater and surface water hydrology.	1. Field days 2. Workshops 3. Joint Planning 4. Interpretative materials (signage) 5. Displays	Land Managers (1,2,3,4,5) Community Groups-LCDC's, Catchment Groups, Production Groups (1,2,3,4,5), Agencies-CALM (1,2,3,4,5), DAWA(1,2,3,5) General community (4,5)	1. Increased knowledge of groundwater and surface water hydrology. 2. Adoption of integrated property water management plans within the catchment targeted at high priority biological assets.
Impacts of environmental weeds and introduced and problem animals	Improve community understanding of environmental weeds and their impact on biodiversity.	1. Joint planning 2. Education packages/Technical Reports 3. Newsletter 4. Displays	Land Managers (1,2,3) Agencies-CALM (1,2,3,4) DAWA (1,2,4) General community (2,3,4) Research Organisations (1,2,3)	1. Preparation of a weed control program for the BMRC on a priority basis that identifies weed species present, size of infestation, rehabilitation requirements and level of threat to biodiversity values. 2. Promotion of integrated weed control across different land tenures in catchment i.e. farms, road and rail reserves. 3. Increased community knowledge of invasive and potentially invasive weed species.

[12] Numbers relate to the type of communication strategy listed in the previous column.

				4. Facilitation of integrated feral animal animal control programs across different land tenures in the catchment.
Impacts of environmental weeds and introduced and problem animals	Improve community understanding of effective control methods for introduced and problem animals.	1. Joint planning 2. Education packages/technical reports	Land Managers (1,2) LGA's (1) Agencies-CALM (1,2) DAWA (2) General community (2) Tertiary Institutions (1,2) Research Organisations (1,2) North Central Mallee Fowl Preservation Group	1. Establishment of partnerships between community and agencies/researchers to find solutions for mitigation of detrimental impacts of problem fauna on biodiversity.
Impacts of disease (plants and animals)	Improve community understanding of disease threats and their potential impacts on biodiversity.	1. Education packages 2. Newsletter 3. Displays	Land Managers (1,2) General community (2) Agencies-CALM (1,2,3) DAWA (1,3)	1. Provision of education, information on disease threats, recognition and management
Detrimental regimes of disturbance	Improve community understanding of the impacts that natural occurrences of physical disturbance; drought, flood, fire, and high wind may have on biodiversity.	1. Joint planning 2. Field Days	Land Managers (1,2) Agencies-CALM (1) Tertiary Institutions (1) Research Organisations (1,2)	1. Adoption of monitoring and evaluation techniques to improve knowledge and capacity to manage detrimental impacts.
Impacts of pollution	Improve community knowledge of pollutants and how they may impact biodiversity values in the catchment.	1. Joint planning 2. Education Packages	Land Managers (1,2) Agencies-CALM (1,2) DAWA (1,2)	1. Facilitation of dialogue between stakeholders to mitigate the impacts of pollutants on biodiversity.
Impacts of competing land uses	Improve community understanding of potential impacts of competing land uses on catchment biodiversity values.	1. Joint Planning 2. Interpretative materials	Land Managers (1) Agencies-CALM (1) General community (1,2)	1. Facilitation of dialogue between stakeholders to improve knowledge and mitigate impacts of competing land uses on biodiversity. 2. Increased awareness of potential impacts of competing land uses on biodiversity values.
Impacts of	Improve understanding of	1. Field days	Land Managers (1,2,3,4,5,6)	Increased awareness and appreciation of

Community Values	the linkage between conservation of biodiversity and human needs/values/perception	2. Displays 3. Newsletter 4. Education packages/Technical Reports 5. Media 6 Interpretative materials	General Community (1,2,3,4,5,6) Schools (4) Researchers (4,2)	biodiversity. Increased awareness of the value of biodiversity to agricultural sustainability. Increased awareness by land managers of community perceptions of agriculture based on management of the natural resource base.

Table 2: Techniques and Resources for communicating public participation objectives

Tools and Techniques	Resources Required	Objective	Timeframe
Logo (already have logo)		Recognisable symbol of catchment	To be used at every opportunity where appropriate
Signage	• Time (Site selection, design, material, construction, erection) including demonstration sites	Increased awareness of on-ground works i.e Surface Water Management, Revegetation, Farm Forestry etc	Ongoing
Displays	• Time • Personnel • Venue	Promotion of the Recovery process, for example at local Agricultural Society Shows (Perenjori, North Midlands, Moora, Dalwallinu) and other events as opportunity arises. 'Fixed' display/resource may be the BMRC Catchment Herbarium collection to be, potentially based at Dalwallinu where the Shire is leading an initiative to establish an Environmental Interpretative Centre in the town.	Agricultural Shows-annual Other-opportunistically
Newsletter	• Time (Collation, preparation, editing) • Personnel • Access to computer • Graphic design, printing • Distribution (Mail out)	Information source for broad audience (all stakeholders)	Three issues per year
Reports and other publications (including education packages)	• Collation • Publication • Distribution (Mail out, email, handout at event)	Provide educational material e.g. revegetation handbook, school packages and technical reports to stakeholders	Ongoing as resources become available
Radio talkback	• Time (preparation, interview) • Personnel	Information to broad audience on Recovery process.	As required
Field days	• Time • Personnel • Venue • 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/earthworks/native perennial

			commercial species options oriented days-or 'two in one'.
Print media (including newspaper articles)	• Time • Personnel	Promotion of Recovery process to broad audience, as well as catchment community	As required
Workshops (including planning workshops and presentations at stakeholder meetings)	• Time • Personnel • Venue • Whiteboard • Overhead projector • Powerpoint Display Unit	Opportunity for joint planning/sharing of ideas with catchment members and development of collaborative projects (research, training, implementing works etc)	Attendance at all catchment LCDC/Catchment Group meetings and as opportunity arises.
Meetings with steering committee	• Time • Personnel • Venue • Whiteboard • Overhead projector • Powerpoint Display Unit • Catering	Opportunity to review Recovery process	As required

Implementation

The community have had the opportunity to be involved in the BMRC 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. 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 BMRC 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 values at risk from threatening processes and a commitment to participate in their protection.

Risk

There are inherent risks in establishing public participation which include;

- Stakeholder inaction/disinterest (Community)
- Change of Government policy (CALM)
- Insufficient resources (CALM)
- Unrealistic time frames (CALM)
- Unrealistic expectations (Community)
- On-ground politics (Community)
- Targeting wrong stakeholders (CALM)
- Maintaining momentum (CALM and Community)
- Factors over which CALM & Community have no control-climate change, global economy, terms of trade for agriculture
- Episodic events

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 may be used to evaluate communication outcomes may include;

- Follow-up landholder survey
- Questionnaire
- Personal follow-up
- Workshop to allow reflection
- Measurable assessment of outcomes.

Note Performance Indicators will be inserted from Recovery Plan when complete.

References

Conservation Science Western Australia, Volume Four Number Three December 2002 The Conservation and Utilisation Potential of Australian Dryland Acacias

Department of Conservation and Land Management Turquoise Coast Island nature Reserves Management Plan 2004

Northern Agricultural Integrated Management Strategy Group Draft Regional Strategy Natural Resource Management April 2000

Land & Water Australia 2004 National Dryland Salinity Program Dryland Salinity : On-farm Decisions and Catchment Outcomes A Guide for Leading producers and Advisors

Department of Conservation and Land Management July 2000 Public Participation Manual

Department of Environmental Protection Water and Rivers Commission Department of Conservation and Land Management Facilitation Toolkit A practical guide for working more effectively with people and groups

Chapman, Kelly Shark Bay World Heritage Area Communications Strategy 2003-2006

Government of Western Australia Natural Resource Management in Western Australia The Salinity Strategy March 2000

Northern Agricultural Catchment Council (NACC) 2004 Draft natural Resource Management Strategy Northern Agricultural Region of Western Australia

Water and Rivers Commission Communications Branch 1999 Planning Communications A guide for community groups

Land & Water Australia CSIRO Final Report for Land and Water Australia Project CSE 9 Testing Approaches to Landscape Design in Cropping Lands

Short, Jeff and Parsons, Blair A Test of the Focal Species Approach in Western Australia

Department of Conservation and Land Management A Conservation Case Study of Western Australia's Rejuvenated Drainage Subregion (Avon Wheatbelt 2) in 2003

Department of Conservation and Land Management Lake Bryde Catchment Communications Strategy

Department of Conservation and Land Management Walpole Wilderness Advisory Committee Walpole Wilderness Area February 2003 Draft Public Participation Strategy

Department of Conservation and Land Management 2003 Buntine-Marchagee Natural Diversity Recovery Catchment Landholder Survey

Wallace, K.J., Beecham B.C., Bone B.H. Managing Natural Diversity in the Western Australian Wheatbelt A Conceptual Framework

Hunt, L. & Patterson, G. (2004) Resource Management Technical Report: Technical assessment of Natural Resource Management Options in the Northern Agricultural Region of Western Australia

Department of Conservation and Land Management Public Participation Policy Principles.

1. Public participation processes will have a clearly stated purpose and clearly identified boundaries.

2. Public participation will be based on a shared understanding (with stakeholders) of principles, objectives, responsibilities, behaviour, assessment criteria and expected outcomes.

3. Participation will provide opportunities for input, representation and joint learning from all relevant stakeholders.

4. The participatory process will be objective, open, fair and carried out in a responsible and accountable manner.

5. Public participation processes will emphasise the sharing of information, joint learning and understanding.

6. Data and information used in the decision making process will be available to stakeholders.

7. Consensus will be emphasised with provision for dissenting views to be documented.

8. Appropriate staff, information and time will be allocated to ensure that the participatory process can be undertaken in a comprehensive manner.

9. The outcomes of public participation will form part of the decision making process.

10. Participants will be informed as to how their involvement affected the Department's or Government's decisions.

GLOSSARY

WISALT Banks
Whittington Interceptor Salt Affected Land Treatment Society (WISALTS) is a society formed in 1978 to promote the use of modifed absoption banks for controlling salinity. They 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).

REFERENCES

AGRICULTURE WESTERN AUSTRALIA, DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT, DEPARTMENT OF ENVIRONMENT & WATER AND RIVERS COMMISSION (1996) Western Australian Salinity Action Plan. Prepared for the Government of Western Australia.

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

ALI, R., HATTON, T., LAMBERT, T., BYRNE, J., HODGSON, G. & GEORGE, R. (2004) An assessment of the quality and quantity of discharge from deep open drains in Narembeen; wheatbelt of Western Australia. *1st National Salinity Engineering Conference.* Perth, Western Australia.

AMBROSE, K. (2000) The effect of soil type on organochloride animal uptake. Farmnote No.35/2000. Department of Agriculture, Western Australia.

ANZECC (2000) Australian water quality guidelines for fresh and marine water quality. Trigger values for south-west Australia for slightly disturbed ecosystems. Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ).

AUSTRALIAN BUREAU OF STATISTICS (2005) Year book Australia: 1988 special article - Drought in Australia. Available on http://www.abs.gov.au/Ausstats/abs@.nsf/0/068F13BCCD03F27BCA2569DE001F1072?Open.

BALL, J. (2005) Understanding and correcting soil acidity. Noble Foundation.

BEARD, J. S. & SPRENGER, B. S. (1984) Geographical data from the vegetation survey of Western Australia Vegetation Survey of Western Australia. *Vegmap Publications,* Occasional Paper, No 2.

BLINN, D. W., HALSE, S. A., PINDER, A. M., SHEIL, R. J. & MCRAE, J. M. (2004) Diatom and micro-invertebrate communities and environmental determinates in the western Australian wheatbelt: a response to salinisation. *Hydrobiologia,* 528, 229-248.

BRADSTOCK, R. A. & COHN, J. S. (2002) Fire regimes and biodiversity in semi arid mallee ecosystems. IN BRADSTOCK, R. A., WILLIAMS, J. E. & GILL, A. M. (Eds.) *Flammable Australia: The fire regimes and biodiversity of a continent.* Cambridge, England, Cambridge University Press.

BROWN, A., DANS, C. T. & MARCHANT, N. (1998) Wetern Australia's threatened flora. *Department of Conservation and Land Management.*

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

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

BUREAU OF METEOROLOGY (2005b) Living with drought. Available on http://www.bom.gov.au/climate/drought/livedrought.shtml.

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

CALM (2001) Proposed natural diversity recovery catchment - Buntine-marchagee Catchment. *calm midwest region.*
CALM (2003) Establishment of Comprehensive, Adequate and Representative Terrestrial Conservation Reserve System in Western Australia. *Department of Conservation and Land Management.*
CALM (2005) Threats to wetlands. Accessed 15th Septmber. Available http://www.calm.wa.gov.au/national_parks/wetlands/threats.html. Department of Conservation and Land Management.
CALM & COLMAR BRUNTON (2005a) Landholder Survey 2003: Draft report version 3. Geraldton, Western Australia, Report prepared by the Department of Conservation and Land Management and Colmar Brunton.
CALM & COLMAR BRUNTON (2005b) Landholder Survey 2005 - 2010
Preliminary Draft. Geraldton, Western Australia, Report prepared by the Department of Conservation and Land Management and Colmar Brunton.
CARSON, R. (1962) *Silent Spring,* New York, Penguin Books.
CARTER, J. D. & LIPPLE, S. L. (1982) 1: 250 000 Geological series explanitory notes: Moora Western Australia. Sheet SH/50-10 International Index. Perth, Western Australia, Geological Survey of Western Australia.
CATTLIN, T., STANTON, D., FARMER, D. & COLES, N. A. (2002) Surface water management strategy. Western Australia, Report prepared by the Engineering Water Management Group, Dept. Agriculture for the Shire of Yilgarn.
CHAN, K. Y. & HEENAN, D. P. (1993) Surface hydraulic properties of red earth under continuous cropping with different management practices. *Australian Journal of Soil Research,* 31, 13-24.
CLARKE, C. J., GEORGE, R. J., BELL, R. W. & HATTON, T. J. (2002) Dryland salinity in south-western Australia: Its origins, remedies, and future research directions. *Australian Journal of Soil Research,* 40, 93-113.
COLEMAN, M. (2001) Modelling the environmental processes in large saline wetlandsin the goldfields. *Salt Lake Workshop.* Bentley Technology Park. Perth, Western Australia, Centre for Land Rehabilitation, University of Western Australia.
COLEMAN, M. & MENEY, K. (2000a) Impacts of rural drainage on nature conservation values - cost effectiveness of the environmental impact Assessment process for evaluating drainage proposals. Department of Conservation and Land Management.
COLEMAN, M. & MENEY, K. (2000b) Impacts of rural drainage on nature conservation values - Nyabing Case study 1: Self Assessment.
COMMANDER, D. P. & MCGOWAN, R. J. (1991) Perenjori: 1:250 000 Geological Series, explanatory notes. Sheet SH50-06 International Index. Perth, Western Australia, Geological Survey of Western Australia.
COMMANDER, P., SCHOKNECHT, N., VERBOOM, B. & CACCETTA, P. (2001) The geology, physiography and soils of wheatbelt valleys. *Dealing with salinity in wheatbelt valleys, processes, prospects and practical options.* Merredin, Western Australia.
CORK, S. J. (2001) Ecosystem services: From doom to bloom. Accessed 15th September. Available from www.ccsa.asn.au/esa/ecosystem.htm. Conservation Council of South Australia.
CORK, S. J. & SHELTON, D. A. (2000) Biodiversity and ecosystem services: The question of value. Accessed 15th September. Available on http://nccnsw.org.au/member/cbn/projects/LifeLines6.2/Sci_EcoSer.html. Community Biodiversity Network.
COWARDIN, L. M., CARTER, V., GOLET, F. C. & LA ROE, E. T. (1979) *Classification of wetland and deepwater habitats of the United States,* Washington, D. C., US Fish and

Wildlife Service, Biological Services Program: FBS/OBS, US Government Printing Office.
CRAMER, V. & HOBBS, R. J. (2002) Ecological consequences of altered hydrological regimes in fragmented ecosystems in southern Australia: Impacts and possible management responses. *Austral Ecology,* 27, 546-564.
CSIRO (2004) Landscape design for bird conservation in Buntine-Marchagee Catchment, Western Australia. Prepared for CSIRO Land and Water and the Department of Conservation and Land Management
CSIRO Sustainable Ecosystems, Wembley.
CUMMINGS, B. & HARDY, A. (2000) Revision of the Interim Biogeographic Regionalisation of Australia (IBRA) and development of Version 5.1 – Summary Report. National Reserves System Section. Canberra, ACT, Environment Australia.
DANIEL, G. (2003) Wildfire threat analysis and fire prevention plan for Crown Lands between Coolgardie and Southern Cross. Kalgoorlie, Western Australia, Department of Conservation and Land Management.
DAVIS, J. A., ROSICH, R.S., BRADLEY, J. S., GROWNS, J. E., SCHMIDT, L. G., CHEAL, F., (1993) Wetland classification on the basis of water quality and invertebrate community data. *Wetlands of the Swan Coastal Plain.* Perth, Report of the Water Authority of Western Australia and Environmental Protection Authority.
DE BROEKERT. P. P. & COLES. A. (2004) Wetland basins for saline drainage water disposal, Bodallin and Elachbutting Catchments, eastern Wheatbelt, Western Australia. *Resource management technical report.* Perth, Western Australia, Department of Agriculture.
DEPARTMENT OF AGRICULTURE (2002) Environmental management best practice guidelines for the nursery industry. Miscellaneous publication 2/2002. Department of Agriculture, Western Australia.
DEPARTMENT OF ENVIRONMENT (2003) Salinity Investment Framework Interim Report-Phase I, 2003. Department of Environment, Salinity and land use impacts series. Department of Environment.
DEPARTMENT OF ENVIRONMENT (2004) Contaminated Sites Management Series: Potentially contaminating activities, industries and landuses. Perth, Western Australia, Department of Environment.
DEPARTMENT OF ENVIRONMENT (2005) Landfill waste classification and waste definitions 1996 (as ammended). Perth, Western Australia, Department of Environment.
DEPARTMENT OF LOCAL GOVERNMENT AND REGIONAL DEVELOPMENT (2001) An update on the economy of Western Australia's mid west region. *midwest development commission.*
DEPARTMENT OF LOCAL GOVERNMENT AND REGIONAL DEVELOPMENT (2003) An update on the economy of Western Australia's Wheatbelt region. *Wheatbelt Development commission.*
DEPARTMENT OF THE ENVIRONMENT AND HERITAGE (2005) Climate change in rural and regional Australia. Canberra, Department of the Environment and Heritage Australian Greenhouse Office.
DOLEY, A. (2003) "Koobabbie": ecological and economic sustainability. *Pacific Conservation Biology,* 9, 42-48.
DURRANT, J. D., GUTHRIE, N. A., (2003) Faunas of unflooded saline wetland floors of the western Australian wheatbelt. Confidential draft.
EDWARD, D. H., GAZEY, P. & DAVIES, P. M. (1994) Invertebrate community structure related to physico-chemical parameters of permanent lakes of the south coast of Western Australia. *Journal of the Royal Society of Western Australia,* 77, 51-63.

FALKENBERG, I. D., DENNIS, T. E. & WILLIAMS, B. D. (1994) Organochlorine pesticide contamination in three species of raptor and their prey in South Australia. *Wildlife Research*, 21, 163-173.

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

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

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA (1990) Geology and mineral resources of Western Australia: Western Australia Geological Survey, Memoir 3. Perth, Western Australia.

GEORGE, R. J., BENNETT, D. & SPEED, R. (2004) Salinity management: The case for focussing on wheatbelt valleys. *Salinity Solutions Conference*. Bendigo, Victoria.

GEORGE, R. J. & COLEMAN, M. (2001) Hidden menace or opportunity - groundwater hydrology, playas amd commercial options for salinity in wheatbelt valleys. *Dealing with Salinity in Wheatbelt Valleys: Processes, Prospects and practical options*. Merredin, Western Australia.

GOODE, S. (2005) An investigation of the option for the formation of a regional local government: Undertaken for the Shires of Carnamah, Coorow, Mingenew, Moorawa, Perenjori, and Three Springs. Stephen Good Consulting.

GOPAL, B. & JUNK, W. J. (2001) Biodiversity in Wetlands: an introduction. IN GOPAL, B., JUNK, W., (Ed.) *Biodiversity in wetlands: assessment, function and conservation*. Leiden, Netherlands, Backhuys Publishing.

GOVERNMENT OF WESTERN AUSTRALIA (1996) Western Australian Salinity Action Plan. Government of Western Australia.

GRIFFIN, T. & GOULDING, P. (2004) Soil landscape Mapping for the Buntine Marchagee Recovery Catchment. Land Resource and Monitoring. Resource Management Technical Report. Report produced by the Department of Agriculture for the Department of Conservation and Land Management.

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

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

HENSCKE, C. J. (1989) Review of WISALTS bank installations. Resource Management Technical Series No. 62. Department of Agriculture, Western Australia.

HORNBUCKLE, J. W., CHRISTEN, E. W. & FAULKNER, R. D. (2004) Improving subsurface drainage design - minimising the environmental impacts. *1st National Salinity Engineering Conference*. Perth, Western Australia.

HUGGETT, A. J., PARSONS, B., ATKINS, L. & INGRAM, J. A. (2004) Taking on the challenge: Landscape design for bird conservation in Buntine-Marchagee Catchment. Internal technical report on Compnent 1 of *Testing approaches to landscape design in cropping lands* project. Perth, Western Australia and Canberra ACT, CSIRO Sustainable Ecosystems.

HUNT, L. & PATTERSON, G. (2004) Technical assessment of natural resource management threats and options in the Northern Agricultural Region of Western Australia. Resource

Management Technical Report No. 289. Perth, Western Australia, Department of Agriculture.
INDIAN OCEAN CLIMATE INITIATIVE (2002) Climate variability and change in south west Western Australia. Perth, Western Australia, Indian Ocean Climate Initiative Panel.
KEIGHERY, G. J., HALSE, S. A., HARVEY, M. S. & MCKENZIE, N. L. (2004) *A biodiversity survey of the Western Australian agricultural zone.,* Welshpool, Western Australia., Western Australian Museum, Supplement No. 67.
KITCHENER, D. J., CHAPMAN, A., DELL, J. & MUIR, B. G. (1979) Biological survey of the Western Australian Wheatbelt. Part 10: Buntine, Nugadong and East Nugadong Nature Reserve and Nugadong Forest Reserve. *Records of the Western Australian Museum Supplementary Series. 9:127.* Perth, Western Australia, Western Australian Museum.
KITCHENER, D. J., CHAPMAN, A., MUIR, B. G. & PALMER, M. (1980) Conservation value for mammals of reserves in the Western Australian wheatbelt. *Biological Conservation,* 18, 179-207.
KUCHLING, G., BURBIDGE, A. A., HALSE, S. A. & STOREY, A. W. (1996) Survey of the Western Swamp Torotoise and its habitat at the Perth Airport: Report to the Federal Airports Corporation and the Australian Nature Conservation Agency. *Aquatic invertebrate surveys and water quality of Perth Airport Swamps.*
LITTLE, I. P. & GILKES, R. J. (1982) Aluminium substitution in goethites in soils from alluvium, Gippsland, Victoria. *Australian Journal of Soil Research,* 20, 351-355.
MCCONNELL, C. & PILLAI, M. (1995) Hydrogeological overview: Marchagee area. Geraldton and Moora, Western Australia, Department of Agriculture.
MCFARLANE, D. J., BARRETT-LENNARD, E. G. & SETTER, T. L. (1989) Waterlogging: A hidden constraint to crop and pasture production in southern regions of Australia. *5th Australian Agronomy Conference.* Perth, Western Australia, Australian Agronomy Society, Melbourne.
MENEY, K. & COLEMAN, M. (2003) Lake Characterisation, a technique for describing and comparing lakes in the wheatbelt. Perth, Western Australia, Report prepared by Syrinx Environmental Services and *actis* Environmental Services for the Department of Conservation and Land Management.
MENEY, K., COLEMAN, M., (2003) Lake Characterisation: A techniques for describing and comparing lakes in the wheat belt.
MOORE, G. & BLACKWELL, P. (2004) Chapter 3.1: Water repellence. IN MOORE, G. (Ed.) *Soil guide: A handbook for understanding and managing agricultural soils. Bulletin 4343.* Perth, Western Australia, A joint National Landcare and The Department of Agriculture, Western Australia Project.
MOORE, G., DOLLING, P., PORTER, B. & LEONARD, L. (2004) Chapter 5: Chemical factors affecting plant growth - Soil acidicty. IN MOORE, G. (Ed.) *Soil guide: A handbook for understanding and managing agricultural soils. Bulletin 4343.* Perth, Western Australia, A joint National Landcare and The Department of Agriculture, Western Australia Project.
MULCAHY, M. J. (1967) Landscapes, laterites and soils in southwestern Australia. *Landform studies from Australia and New Guinea.*
MUSEUM OF WESTERN AUSTRALIA (2005) Western Australian Museum, Queensland Museum and Museum & Art Gallery of NT collections databases. Accessed 15th September. Available on http://www.museum.wa.gov.au/faunabase/prod/index.htm.
MYERS, N., MITTERMEIER, R. A., MITTERMEIER, C. G., DA FONSECA, G. A. B. & KENT, J. (2000) Biodiversity hotspots for conservation priorities. *Nature,* 403, 853-858.
NEEDHAM, P., MOORE, G. & SCHOLZ, G. (2004) Chapter 4.2: Subsurface compaction. IN MOORE, G. (Ed.) *Soil guide: A handbook for understanding and managing agricultural soils. Bulletin 4343.* Perth, Western Australia, A joint National Landcare and The Department of Agriculture, Western Australia Project.

NEWBEY, K. R., KEIGHERY, G. J. & HALL, N. J. (1995) Vegetation and flora. IN KEIGHERY, G. J., MCKENZIE, N. L. & HALL, N. J. (Eds.) *The biological survey of the eastern Goldfields of Western Australia. Part 11. Boorabbin – Southern Cross Study Area. Records of the Western Australian Museum Suppliment No. 49.* Perth, Western Australia, Western Australian Museum.

PINDER, A. M., HALSE, S. A., MCRAE, J. M. & SHIEL, R. J. (2004) Aquatic invertebrate assemblages of wetlands and rivers in the Wheatbelt region of Western Australia: Records of the Western Australian Museum Supplement. Perth, Records of the Western Australian Museum.

PLAYFORD, P. (2003) The Permo-Carboniferous glaciation of Gondwana: its impact on Western Australia. Western Wildlife, 7, No. 1. Department of Conservation and Land Management.

QUEENSLAND DEPARTMENT OF NATURAL RESOURCES AND MINES (2005) SILO Data Drill for location Lat, Long: -30.05 116.20 (DECIMAL DEGREES), 30 03'S 116 12'E.

RADCLIFFE, J. C. (2002) Pesticide use in Australia. Parkville, Victoria, Australian Academy of Technilogical Sciences and Engineering.

RAMSAR CONVENTION BUREAU (1999) Classification system for wetland type. Ramsar Convention Bureau.

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.

ROPER, M. M. & GUPTER, V. V. S. R. (1995) Management practices and soil fauna. *Australian Journal of Soil Research,* 33, 321-339.

SALINITY ACTION PLAN (1999) Aquatic invertebrates collected from braided channel wetlands in the Marchagee area in spring 1999. Appendix 3.

SAUNDERS, D., MARGULES, C. & HILL, B. (2000) Environmental indicators for national state of teh environment reporting. IN YENCKEN, D. & WILKINSON, D. (Eds.) *Resetting the compass: Australia's journey towards sustainability.* Collingwood, Australia, CSIRO Publishing.

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

SAUNDERS, D. A. & HOBBS, R. J. (1991) Responses of bird species to habitat fragmentation in the wheatbelt of Western Australia: interiors, edges and corridors. IN SAUNDERS, D. A. & HOBBS, R. J. (Eds.) *Nature Conservation 2 - The role of corridors.* NSW, Surrey Beaty & Sons.

SAUNDERS, D. A., HOBBS, R. J. & MARGULES, C. R. (1991) Biological consequences of ecosystem fragmentation. *Conservation Biology,* 5, 18-32.

SCHOKNECHT, N. (2004) Acidity in the environment of south western Australia. Perth, Western Australia, Department of Agriculture.

SEMENIUK, C. A. (1988) Consanguineous wetlands and their distribution in the Darling System, Southwestern Australia. *Journal of the Royal Society of Western Australia.,* 70, 69-87.

SEMENIUK, C. A. & SEMENIUK, V. (1995) A geomorphic approach to global classification for inland wetlands. *Vegetatio,* 118, 103-124.

SHEARER, B. L. (1994) The major plant pathogens occurring in native ecosystems of southwestern Australia. *Royal Society of Western Australia,* 77, 113-121.

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

SHORT, R., FARMER, D., WHALE, P. & COLES, N. A. (2004) Surface water assessment for the Buntine-Marchagee Recovery Catchment. Western Australia, Report prepared by the Engineering Water Management Group, Dept. Agriculture for the Department of Conservation and Land Management.

SHORT, R., FARMER, D., WHALE, P. & COLES, N. A. (2005) Surface water assessment for the Buntine-Marchagee Recovery Catchment. Western Australia, Report prepared by the Engineering Water Management Group, Dept. Agriculture for the Department of Conservation and Land Management.

SINCLAIR KNIGHT MERZ (2001) Impact assessment and management of drainage water discharge to lakes in the Moore River Catchment, W.A., Report for Waters and Rivers Commission.

SINCLAIR KNIGHT MERZ (2003) Buntine-Marchagee Natural Diversity Recovery Catchment surface water management plan (Includes - Catchment Report, Demonstration Report and Individual Property Reports). Report prepared for the Department of Conservation and Land Management.

SMITH, M. G., HEARN, R. W. & WHEELER, I. B. (2004) Groundwater acidification in the Lake Muir - Unicup Recovery Catchment. *1st National Salinity Engineering Conference.* Perth, Western Australia.

SPEED, R. & MAHTAB, A. (2001) Groundwater study of the Piawaning townsite. Resource Management Technical Report No. 218. Department of Agriculture, Western Australia.

SPEED, R. & SIMONS, J. (1992) Deep Drains: A case study and discussion (South Buntine), Division of Resource Management, Technical Report No. 133. Moora, Western Australia, Department of Agriculture.

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

STATE SALINITY COUNCIL (2000) Natural Resource Management in Western Australia: The Salinity Strategy. Perth, Western Australia, State Government of Western Australia.

STELFOX, L. (2001) Assessment of Potential Groundwater Contamination from the Moore River: Hydrology Report. Waters and Rivers Commission.

STOREY, A. W., HALSE, S. A. & SHIEL, R. J. (1993) Aquatic invertebrate fauna of the Two Peoples Bay area, southwestern Australia. *Royal Society of Western Australia,* 76.

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

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

STUART-STREET, A. (2005) Greenough Region catchment appraisal 2005. Resource Management Technical Report No. XX. Geraldton, Western Australia, Department of Agriculture.

SYSTEMS OF LANDCARE (2004) Report on the Surface Water Management - Survey and Design of Demonstration Site Outlet. Moora, Western Australia, Systems of Landcare.

THACKWAY, R. & CRESSWELL, I. D. (1995) An Interim Biogeographic Regionalisation of Australia: A Framework for Establishing the National System of Reserves, Version 4.0. Canberra, ACT, Australian Nature Conservation Agency.

TYLER, M. J., SMITH, L. A. & JOHNSTONE, R. E. (2000) Frogs of Western Australia. *W.A Museum Perth.*

US ENVIRONMENTAL PROTECTION AGENCY (2005) Wetland definitions. Accessed 15th September. Available from http://www.epa.gov/owow/wetlands/what/definitions.html. US Environmental Protection Agency.

WALLACE, K. L. & MOORE, S. A. (1987) Management of remnant bushland for nature conservation in agricultural areas of South-Western Australia: Operational and planning perspectives. IN SAUNDERS D. A., ARNOLD, G. W., BURBIDGE, A. A. & HOPKINS, A. J. M. (Eds.) *Nature Conservation: The role of remnants of native vegetation.* Norton, NSW, Surrey Beatty and Sons.

WILDE, S. A. & BACKHOUSE, J. (1977) Fossiliferous Tertiary deposits on the Darling Plateau, Western Australia. Geological Survey of Western Australia, Annual Report 1976.

PERSONAL COMMUNICATIONS

Sue Hall, Economic Development Officer, Shire of Dalwallinu

Mike Lyons, Research Scientist, Department of Conservation and Land Management, Science Division, Woodvale

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

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

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

Russell Speed, Department of Agriculture.

J. Byrne

Craig Scott, 4.08.05

David Coates, 2004

D. Gilmour, Development Officer, Shire of Moora

Mandy Dearden, Development Officer 2000

Graham Annan, Economist, Northern Agricultural Region