PRELIMINARY OVERVIEW OF THE BRIGALOW BELT SOUTH BIOREGION (STAGE 1)

NSW WESTERN REGIONAL ASSESSMENTS

[SEPTEMBER 2000]

Brigalow Belt South

Resource and Conservation Assessment Council

PRELIMINARY OVERVIEW OF THE BRIGALOW BELT SOUTH BIOREGION (STAGE 1)

NSW NATIONAL PARKS AND WILDLIFE SERVICE WESTERN DIRECTORATE

A project undertaken for
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FINAL REPORT

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EXECUTIVE SUMMARY

The NSW National Parks and Wildlife Service is currently responsible to the Resource and Conservation Assessment Council for conducting various projects as part of a preliminary regional assessment of the Brigalow Belt South bioregion. This report provides a bioregional context to the more detailed regional assessment projects being undertaken within the Brigalow Belt South bioregion.

The Brigalow Belt South bioregion covers an area of 279 496 sq km, the 6th largest of the 80 recognised bioregions in Australia. In New South Wales the bioregion covers an area of 52 409 sq km which is 18.7% of the total bioregion and 6.5% of NSW.

The bioregion covers a large climatic range longitudinally, and lies within an ecological gradient or ecotone between the dry inland or Eyrean zone and the wetter coastal or Bassian zone. Consequently the area is environmentally heterogeneous, and is rich in biodiversity.

In order to formulate principles and criteria for conservation values, the first priority is to determine the attributes that distinguish the Brigalow Belt South bioregion from other regions, including the inherent characteristics of the biophysical environment, and the region's land use history, noting that the former in part determines the latter. The area has a significant cultural history which needs to be reflected in any conservation assessment.

This project was designed to provide a preliminary overview of the abiotic and biotic attributes of the New South Wales (NSW) portion of the Brigalow Belt South bioregion.

The project specifically aimed to:

- prepare a brief bioregional overview, including summary information from the Queensland portion of the bioregion. This would include but not be limited to:
  - a brief abiotic environmental description – climate, topography, soils and hydrology;
  - a description of the biodiversity – vegetation (pre 1750 and extant), fauna and flora species, conservation status of wildlife species and communities, threatened and regionally vulnerable species, populations or ecological communities, and possible threats to biodiversity; and
  - a brief land use description – current land uses, land condition, reserve status, conservation management and landscape management.
- provide a brief description of each province (Morgan and Terrey, 1992);
- review the bioregional information against the existing nationally agreed criteria for the establishment of a comprehensive, adequate and representative reserve system (JANIS, 1997), and other national and international criteria, and make general recommendations on how to apply these within the bioregion;
- identify known conservation priorities and determine how the bioregion currently meets these conservation priorities;
- assess the quality and completeness of the available data, and identify gaps and directions for future analyses; and

- make broad recommendations on how these conservation priorities might be achieved across the bioregion.

Superimposed on the high level of diversity within the region is a history of extensive change in the last 150 years with most of the land cleared of trees, native grasslands grazed and cultivated and the hydrology of the area significantly altered with disruption to water flow into the rivers, through the rivers and into underground aquifers.

In the light of this scenario and the fact that clearing and other damaging land management practices are continuing on freehold land, conservation requirements need to be determined using the most detailed environmental information available and assessed in the light of the nationally recognised conservation criteria.

At present, 2.6% of the NSW portion of the Brigalow Belt South bioregion is conserved. The International Union for the Conservation of Nature (IUCN) standard recommends that 10% of each major ecosystem type be conserved (Glowka *et al*. 1994). JANIS (1997) requires at least 15% of each forest ecosystem to be conserved.

The priority for reservation of a forest ecosystem is related to how much remains relative to its initial distribution, how much is currently conserved, and its vulnerability to threatening processes. The principle of comprehensiveness requires that the reserve system should sample each forest ecosystem within a region, and, that reservation to conserve biodiversity needs to focus on the continued viability of species and ecosystems rather than on the attainment of area based targets.

The current reserve system is strongly biased towards lands which have a relatively low value for alternate uses such as agriculture and timber production. An analysis of land capability shows a reservation bias towards the lowest land capabilities.

Within the bioregion, the majority of the conservation reserves are located in the south-west, and do not contain a representative sample of a large proportion of the ecosystems or plant communities. There is a clear bias towards less productive lands on public land.

Within the bioregion, the Pilliga and Goonoo State Forests represent the two largest blocks of remnant vegetation in a landscape which has less than a quarter of its native vegetation still remaining.

This preliminary overview of the environment of the bioregion and the flora and fauna studies undertaken as a part of this assessment indicates that:

- there is still a serious lack of information available for making decisions about the conservation priorities of the bioregion;
- the currently accepted national conservation criteria have not been met within the bioregion; and
- there is evidence of a greater biodiversity than previously understood.

There is a clear need to review the nationally accepted conservation criteria (JANIS 1997). Whilst the general conservation principles that apply to terrestrial ecosystems have been accepted, it is essential that bioregional specific principles and criteria which reflect the characteristics of inland systems are developed and applied.

The Brigalow Belt South bioregion features low levels of productivity, long timeframes for regenerative processes and significant fragmentation of vegetation across its landscape. The nationally accepted conservation criteria are inadequate for this bioregion, and need to be

modified to allow the unique characteristics of the bioregion to be reflected in conservation planning.

There is also a need to develop processes that deal with conservation on private lands. Private lands contain significant areas of conservation value, and ecosystems which are not represented in the current reserve system.

This project has highlighted the need for resources to be allocated to a thorough assessment of the conservation status of the bioregion and its components. All land management decisions for this bioregion should incorporate a precautionary approach.

Over the next 3 - 4 years, further evaluation of the biotic and abiotic values of the bioregion need to address the lack of detailed information available for comprehensive assessments and conservation decisions.

This report outlines some directions that future assessment should take, and lists a series of projects, continuing and new, that will enable Government to make land management decisions with confidence:

- further systematic fauna surveys;
- further targeted fauna and flora surveys;
- ecosystem and vegetation mapping;
- further plot-based flora sampling;
- an assessment of conservation criteria for the bioregion;
- C-Plan development and integration for the west;
- the derivation of species habitat and distribution models;
- ecosystem modeling and pre-European vegetation modeling;
- the evaluation of ecosystems and other surrogates for biodiversity;
- soil, landscape and geology mapping;
- a hydrological study that might address the effects of further vegetation clearing;
- an assessment of aquatic habitats;
- crown lands mapping;
- an assessment of the genetic diversity within and between bioregions;
- an assessment of Ecological Sustainable Forest Management;
- further assessment and consultation for Cultural Heritage values;
- a commitment to community involvement, communication and awareness; and
- a monitoring project, to provide a measure of adequacy of fauna and flora assessments.

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1. INTRODUCTION

This report has been prepared for the Resource and Conservation Council (RACAC) as part of the preliminary (Stage 1) Western Regional Assessment of the Brigalow Belt South (BBS) bioregion.

The Western Regional Assessments are to be carried out across the Western and Central Divisions of NSW with the Brigalow Belt South bioregion being the first. The assessments will provide scientific information on which to base Forest Agreements, as well as providing information for the use of other regional planning processes such as Regional Vegetation Management Committees and Catchment Management Boards.

Due to the short time available to undertake these preliminary (Stage 1) projects, this report must only be considered a brief summary of the results of initial surveys and analyses. This report can provide precautionary recommendations subject to further detailed assessments. A comprehensive (Stage 2) assessment will then be undertaken to verify this preliminary assessment.

The project was designed to provide a preliminary overview of the abiotic and biotic attributes of the New South Wales (NSW) portion of the Brigalow Belt South bioregion. This information provides a framework to be used, in conjunction with the more detailed reports from specific projects, to identify conservation goals within the region.

The project specifically aimed to:

- prepare a brief bioregional overview, including summary information from the Queensland portion of the bioregion. This would include but not be limited to:
  - a brief abiotic environmental description – climate, topography, soils and hydrology;
  - a description of the biodiversity – vegetation (pre 1750 and extant), fauna and flora species, conservation status of wildlife species and communities, threatened and regionally vulnerable species, populations or ecological communities, and possible threats to biodiversity; and
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- identify known conservation priorities and determine how the bioregion currently meets these conservation priorities;
- assess the quality and completeness of the available data, and identify gaps and directions for future analyses; and
- make broad recommendations on how these conservation priorities might be achieved across the bioregion.

The BBS is one of the largest of the 80 defined bioregions in Australia. Only the five bioregions which cover the vast inland desert and grassland regions: the Tanami, Great Sandy and Great Victoria deserts, the Mitchell Grasslands and the Channel Country; are larger. In total, the BBS covers an area of 279 496 sq km with 52 409 sq km in NSW and the remainder in Queensland (Thackway & Creswell, 1995). It extends south from the mid-Queensland coast (at about 23 50'S, from Alpha to Gladstone) and continues to south of Dubbo (32 21'S) in the central-west of NSW (Map 1).

Not only is the BBS large, it is also a complex area with considerable climatic, topographic and ecological variation. A comparison of the 13 bioregions occurring in Queensland indicates that its level of internal variation is only surpassed by the rich wet ecosystems of the Wet Tropics, Cape York Peninsula and Central Queensland Coast bioregions (Sattler & Williams, 1999). The BBS has been divided into twenty two provinces based on climatic, geological and geomorphological variation - fifteen of these are in Queensland and seven in NSW. The bioregions in NSW have not been analysed to the same level of detail as those in Queensland but some comparison is possible from Morgan's and Terrey's (1990) analysis of western NSW. They described 12 regions, six of which are larger than the Brigalow Belt but only two of these have a greater number of provinces. One is the Darling Riverine Plains with 3 sub-regions and 11 provinces, and the North-West Sands with 10 provinces.

The bioregion is named after the Brigalow tree (*Acacia harpophylla*) which grows as a forest or woodland on clay soils. Brigalow communities are thought to have covered between 4.7 and 6 million hectares at the time of European settlement of Australia (Isbell, 1962 and Johnson, 1980).

The clay soils preferred by Brigalow are relatively fertile and are considered to be valuable, productive agricultural lands when cleared. Consequently, clearing has been carried out for over a hundred years, having been greatly accelerated during the last forty or fifty years, especially in Queensland and NSW (State of the Environment, 1996).

The vegetation of the bioregion is much more varied than the name would suggest with Brigalow the dominant species in only 9 of the 15 provinces described for Queensland. In New South Wales the dominance of Brigalow as the primary vegetation alliance is further reduced with more southern influences in plant communities evident. It is present in only 3 of the 7 provinces and then not as a dominant species.

1.1 LOCATION AND AREA

The primary focus of this study of the BBS is the southern portion in NSW and in particular the portion south from Narrabri (Map 2).

In New South Wales the bioregion covers an area of 52 409 sq km which is 18.7% of the total bioregion and 6.5% of NSW. The majority of this is south of Narrabri with only a restricted narrow belt connecting the area to the Queensland portion of the bioregion. It includes the western slopes of the Great Dividing Range and borders the eastern edge of the Darling Riverine Plains.

For the remainder of the report, reference to the BBS will refer to the NSW portion of the bioregion. Explicit reference to the whole bioregion will be made where necessary.

2. ABIOTIC CHARACTERISTICS

2.1 CLIMATE

Located within the eastern sub-humid region of Australia the BBS includes much of the country with an annual rainfall of 500 - 750 mm from Townsville in Queensland to Dubbo in NSW.

In this analysis of the BBS, the climatic data for six meteorological stations are included. The east west axis of the bioregion is represented by Gilgandra in the west (31°72'S, 148°66'E; elevation 285m; 107 years of records) to Murrurundi in the east (31°77'S, 150084'E; elevation 466m; 126 years of records). Along the north south axis the stations are Dubbo to the south (32°21'S, 148°57'E; elevation 275m; 126 years of records), Narrabri in the centre (30°34'S, 149°75'E; elevation 212m; 105 years of records) and Texas (28°85'S, 151017'E; elevation 284m; 99 years of records) and Goondiwindi (28°55'S, 150°31'E; elevation 217m; 112 years of records) in the north. The climatic data for these stations are summarised in Figures 1 and 2.

In addition to considering the variation in weather patterns across the year using long term station data it is also essential to examine the microclimatic variation across the landscape by including topographic features in the analysis. The bioclimatic surfaces (Maps 3 & 4) indicate the range of microclimates and the consequent potential variation in the distribution and occurrence of plant and animal species across the bioregion.

Rainfall

In the bioregion the mean annual rainfall varies from about 550 mm in the west at Gilgandra to 823 mm on the eastern edge of the bioregion at Murrurundi. On the north - south gradient, mean annual rainfall is 587 mm in Dubbo, 651 mm at Narrabri and 659 mm at Texas on the Queensland border. Substantial rainfalls can occur at any time of the year but there is a peak in summer and a smaller peak in winter. The dominance of the summer rainfall decreases as latitude increases, with the exception of Murrurundi on the higher altitudes of the south east. At Dubbo the distribution of rainfall throughout the year is relatively even with a low in April. The bioclimatic surface for rainfall (Map 3) illustrates the variation in relation to topography, most notably the areas of higher rainfall around the Liverpool Ranges in the southeast and the higher outcrops of the Warrumbungles.

In summer, high intensity rain or thunderstorms can be common and can cause significant erosion. If the rain follows a tropical rain depression there is a high probability of flooding, particularly in the north of the bioregion. Severe flooding is also possible during winter, especially if the soils are saturated (NCMC, 1996). The wettest quarter for all these stations is December - February, the driest quarter is July - September (Nix, 1986), but the lowest number of rain days occurs in the March to May period for all stations. Evaporation rates are high in

summer and often exceed precipitation rates, so the net penetration of rainfall is greater in winter than in summer (NCMC, 1996).

Changes in annual rainfall patterns through time have been determined for the Gunnedah area by Crapper *et al*, (1995). Three important trends have been demonstrated from the 116 years of records:

- there has been a slow increase in the annual rainfall but this has not been a steady increase with above average rainfall occurring at the end of last century, followed by a long period of rainfall below the long-term average up to 1950 and then a third period of above average falls to the present time;
- the seasonal distribution of rainfall has significantly shifted through this period with the October to December and January to March quarter rainfalls significantly reducing and then increasing. In the January to March quarter, rainfall significantly decreased between 1915-1955, and increased between 1955-1975. The October to December quarter significantly decreased between 1900-1950, and increased between 1950-1970; and
- in the early 1990s the April to June rainfalls significantly increased and in association with the low evaporation and transpiration at that time of year, has led to significant increases in surface water run-off.

Extended periods of below average rainfall are recorded every 10 to 20 years and these are correlated with a high frequency of wildfire.

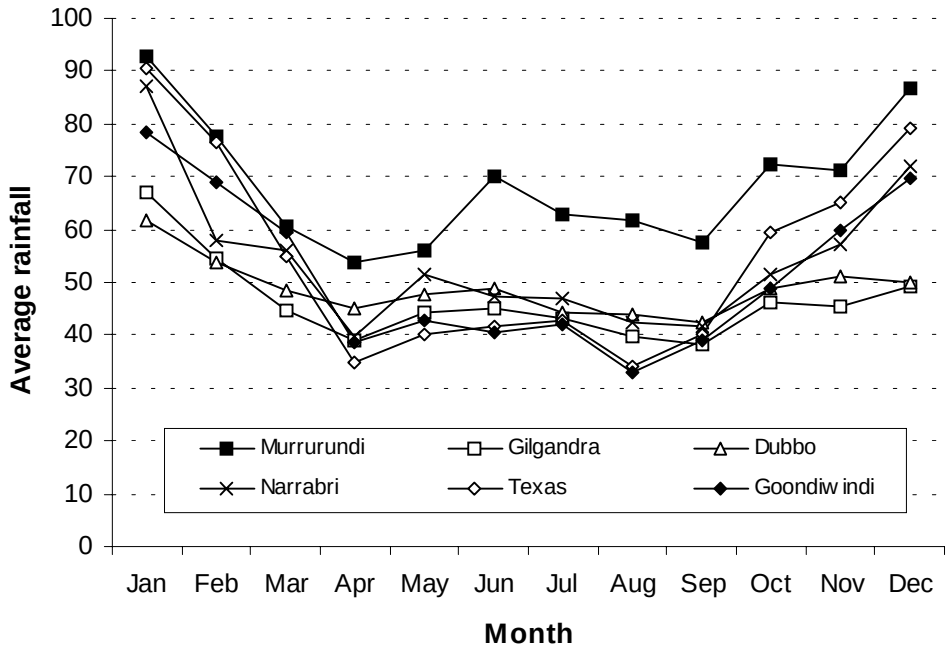

Figure 1. Average rainfall (mm) for each month based on records from the six weather stations used in this analysis; Gilgandra, Murrurundi, Dubbo, Narrabri, Texas, and Goondiwindi.

Temperature

Temperatures vary with altitude throughout the bioregion and have a large daily variation. The variation with altitude is clearly demonstrated by the bioclimatic surface for temperature (Map 4). Like the rainfall, the Liverpool and Warrumbungle Ranges have lower mean annual

temperatures than the rest of the bioregion, as do some of the isolated volcanic peaks between the two Ranges.

Mean monthly temperatures range from a maximum of 33°C in January to a minimum of 3°C in July (Figure 2) but daily maxima can reach 45°C and stay above 40°C for several days. Minimum temperatures can be as low as -9°C. Frosts are common with up to 100 days of frost each winter possible in the southern areas. Occasional snowfalls occur on the tablelands. Mean daily maxima and minima indicate a close similarity from April to October between the three southern locations which are 3°C to 4°C lower than the three northern stations. In summer, Murrurundi, which has a substantially higher altitude remains about 3°C lower but the other five stations have a much closer mean temperature. The differences in mean daily minimum temperature between the stations are indicative of the influence of latitude and altitude with Murrurundi being consistently lower than the others which all decrease with an increase in latitude.

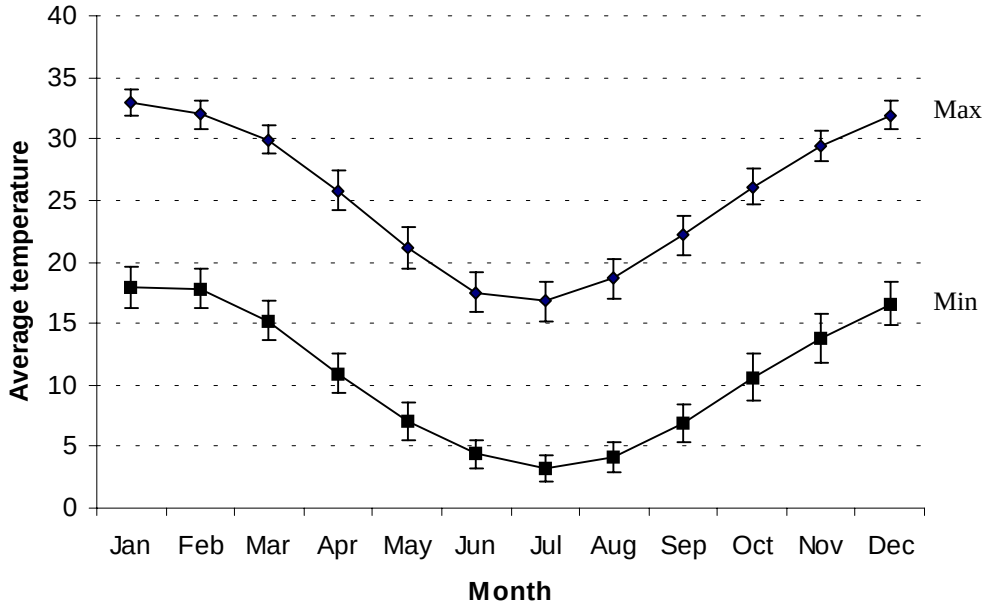

Figure 2. Average minimum and maximum temperature (0[c]) for each month based on records from the six weather stations used in this analysis; Gilgandra, Murrurundi, Dubbo, Narrabri, Texas, and Goondiwindi.

2.2 GEOLOGY, TOPOGRAPHY AND SOILS

The mesozoic sediments that predominate within the Brigalow Belt are the south-eastern extremity of the Great Artesian Basin (GAB). These sandstone beds form a generally undulating to low hilly landscape with some higher areas covered by Tertiary lava flows (Morgan & Terrey 1990).

Geological History

The BBS is underlain by ancient fractured crystalline rocks covered by sedimentary layers deposited during the Triassic and Jurassic periods (225 - 136 million years ago). In the Miocene epoch (23 - 5 million years ago) the area was subjected to igneous activity and subsequent

movements of the earth's crust (NWCMC, 1996). The broad lithology of the bioregion is illustrated on Map 5.

Much of the bioregion is comprised of cainozoic alluvium. In the south western portion the sedimentary deposits are the sandstones and mudstones of the Pulawaugh Beds of the lower and middle Jurassic period and the quartz Pilliga Sandstones of the upper Jurassic period. The Pilliga Sandstone is the major intake bed for water flowing to the west, dipping under younger sedimentary deposits and flowing into the GAB. During this period of sedimentary deposition, the GAB to the west and north-west was dropping and forming vast lakes. The landscape was then gradually eroded and uplifted and became one of worn sandstone ridges and mesas, surrounded by vertical cliffs and isolated by deep broad river valleys which were slowly being eroded away.

The volcanic activity in the Tertiary period then covered the whole area with vast lava flows and associated volcanic formations. The subsequent 13 million years of weathering reduced these vast flows to a few resistant volcanic formations – Liverpool Range, Warrumbungle Range and Nandewar Range (in the Nandewar bioregion) and many small conical hills. This weathering of the basalt ranges has produced the rich alluvium which has become the fertile floodplains now used extensively for cropping (Fairley, 1991).

Geological Features

There are a number of important geological features within the BBS. These include fossil sites as listed below and karst formations. No karst formations are recorded within the present boundaries of the bioregion, but several are within a 50 km buffer zone:

- Chalk Mountain - 113 ha;
- Black Jack Sill Gunnedah - 220 ha;
- Bingara palaeontological site - 1 ha - important site with significantly high diversity of Pleistocene fauna;
- Mendooran palaeontological site - 1 ha - Pleistocene fossils; and
- Lime Springs palaeontological site - 600 ha - contains evidence of megafauna possibly 10 000 years older than the known dating of megafauna.

Topography

Elevation varies from 1 200 m above sea level in the east to 100 m above sea level in the west. The highest country is the Liverpool Range, a western extension of the Great Dividing Range which crosses the area from east to west south of Tamworth and Coonabarabran and joins the Warrumbungle Range in otherwise gently undulating and flat country. A digital elevation model (DEM) for the bioregion (Map 6) demonstrates in more detail the variation in topography over the bioregion.

Soils

The long history of erosion of the landscape of the bioregion has resulted in the development of a variety of soils types. The major soil types of the BBS are shown on Map 7. North of Narrabri most of the bioregion has coarsely cracking grey and brown clays with some deep black cracking clays and red-brown earths in the north east. South of Narrabri there are four predominant soil types:

- deep black cracking clays over most of the low elevation eastern half with shallow black self mulching clays on the Liverpool Ranges;
- massive red and yellow earths in most of the western half;
- areas of red brown earths, loams along the Castlereagh and Talbragar Rivers; and
- shallow loams in the Warrumbungle Ranges.

The soils which developed directly on the basic igneous rocks such as basalt and tuff are generally heavy in texture with uniform to gradational profiles. These range from kraznozems and chocolate soils in the wetter parts to euchrozems and red, grey and black cracking clays on the drier western slopes. Over the Pilliga Sandstones there are mostly poor sandy or gravelly soils, sandy loams, duplex clays and sand or yellow earths, which are often skeletal. Along the major rivers the soils are deep and heavy, black, grey or red clays and rich alluvium (Banks 1995, 1998).

Deep, highly fertile black earths have developed on the basic alluvia and colluvia on the wide valleys below the basaltic ranges, including the Liverpool Plains. These are interspersed with red earths, red brown earths, solodics and sometimes euchrozems on the sandstone outcrops. On the Riverine plains of the west of the bioregion the soils have been derived from the Quaternary alluvia and have formed moderately fertile deep grey and brown cracking clays.

Soils have been mapped in detail for three areas within the bioregion: the 1:250,000 Dubbo map sheet (Murphy and Lawrie, 1998), the 1:100,000 Blackville map sheet (Banks, 1998) and the 1:100,000 Curlewis map sheet (Banks, 1995).

The distributions of soil types across the landscape are indicated in the province descriptions.

2.3 HYDROLOGY

The broad hydrological features of the Brigalow Belt South bioregion are illustrated on Map 8 which contains the rivers and tributaries, their catchment areas, areas of inundation and wetlands. The location of the Great Artesian Basin and the proposed zones (DLWC) in NSW are shown on Map 9.

Rising groundwater levels and associated stream salinisation are having a detrimental impact on wetland, terrestrial and base flow ecosystems across southern Australia. Wetlands are particularly vulnerable to changes in groundwater levels because a small change in the groundwater level can cause a significant change in the water availability for the vegetation (Hatton & Evans, 1998).

2.3.1 Rivers

Several major rivers and their tributaries, which are part of the large Murray - Darling River System, flow through the area. These include the MacIntyre, Gwydir, Namoi, Castlereagh, Goulburn, Talbragar and Macquarie Rivers and parts of their catchments. The Liverpool Ranges form the headwaters of both the Namoi and Hunter Rivers.

Rising salinity levels in the rivers are increasingly becoming a problem, especially in the upstream parts of the catchments. The salt loads study carried out as a part of the salinity audit (MDBC, 1999) has estimated the river salinities for 2020, 2050 and 2100 for each of the river

valleys supplying water to the Murray and Darling Rivers. It estimates that the Murrumbidgee River currently carries very high salt loads, second only to the Murray River. This is predicted to double over the next 100 years. The Murrumbidgee's levels are modest compared with those predicted for the Bogan, Macquarie, Castlereagh and Namoi Rivers which face sharp rates of increase in salt loads and salinity levels, with the salinity levels exceeding the World Health Organisation's (WHO) desirable limit for drinking. Specifically, the average salinities for the Macquarie, Namoi and Bogan are estimated to exceed the 800EC threshold within 20 years, and the Castlereagh within 50 years. These predicted levels have serious implications for both agriculture and the supply of drinking water for the population centres. Predicted average river salinities for the bioregion are listed in Table 1.

ANZECC (1999) guild lines for fresh and marine water quality suggest 110EC is considered an ecological warning sign. The WHO limit for drinking water is 800EC, and 1500EC is considered to have direct adverse biological effects and is deemed unsuitable for irrigation.

Table 1. Estimated salt loads for the Murray-Darling Basin (MDBC, 1999).

	Year			
	1998	2020	2050	2100
Murrumbidgee River	250	320	350	400
Bogan River	730	1,500	1,950	2,320
Macquarie River	620	1,290	1,730	2,110
Castlereagh River	640	760	1,100	1,230
Namoi River	680	1,050	1,280	1,550
Gwydir River	560	600	700	740

2.3.2 Wetlands

Wetlands are lands which are regularly or periodically inundated with sufficient frequency to influence the ecology of the area. Within the bioregion there are a few areas of inundation along the Namoi River, but the wetland habitats are more common along the rivers to the west.

The most significant wetland of the bioregion is Lake Goran which is in the Liverpool Plains and is listed in the Directory of important wetlands of Australia (1996). It is a seasonal swamp originally covered by Plains Grass *Austrostipa aristiglumis*. The majority of it has been cultivated, but parts that become regularly waterlogged have been retained as grassland. It is the largest natural water body in the Namoi Valley. It is privately owned and used for cropping and some grazing when dry. Only small areas (<10%) are inundated regularly. When full it provides significant habitat for waterbirds and may be important as a drought refuge, especially for migratory waders such as Red-necked Stint. Salinity is an increasing threat to the wetland as surface and ground water regimes are altered. The swamp deposits are within an internal drainage basin and are likely to be very old, especially in comparison with the deposits of the Riverine plains.

2.3.3 Subsurface waters

The Pilliga Sandstones form the intake area and aquifer beds in NSW for the GAB. The Oxley Basin in the south-eastern part of the bioregion is a separate groundwater basin. These aquifers supply water for both domestic and stock purposes. The alluvial soils of the Namoi River and its larger tributaries are an important source of groundwater.

The Department of Land and Water Conservation (DLWC) has proposed that the GAB in NSW be divided into four major zones (Map 9). Zone 1 is the recharge zone where groundwater enters the Pilliga Sandstone aquifer directly through exposed outcrops or via overlying strata where there is potential for downward groundwater movement. Zones 2, 3 and 4 are mostly outside the BBS to the west.

Research into the hydrology of the GAB has indicated that 1% of rainfall in the recharge areas enters this system but actual recharge could vary by an order of magnitude in either direction. Recharge from river systems could be significant and some quantification of this factor is essential before determining sustainable allocations. Proposed management of GAB requires strategies to prevent a decline in groundwater quality and quantity. The southern recharge zone of the GAB, especially where the sandstone beds are outcropping, is an area relatively susceptible to contamination. This may be offset by the fact that the watertables are very deep under the intake beds. The first principle of the NSW Groundwater Quality Protection Policy states that:

> '*All groundwater systems should be maintained so that their most sensitive identified beneficial use (or environmental value) is maintained*'.

The Pilliga and Goonoo Forests both occur on the Pilliga Sandstone recharge zone of the GAB. Removal or depletion of these forests could have a significant impact on the groundwater, with more water flowing through to the groundwater system. Initially this may have a beneficial impact by increasing groundwater pressures but there could also be a significant rise in groundwater levels resulting in waterlogging and salination of land in areas where dryland salinity is not currently a problem. Salination of the soil and shallow groundwater may also cause an increase in the salinity of water entering the GAB. Shallower watertables will also be more vulnerable to contamination. A detailed hydrological study is necessary to properly assess the potential of these likely impacts.

The Murray-Darling Basin is geologically and climatically susceptible to the concentration of salt in the landscape. This is because of the generally flat terrain, low rainfall and high evaporation rates which cause a concentration of salt in the groundwater (MDBC, 1999). Dryland salinity, which is caused by the rising watertables, is also a potential major land degradation issue, especially on the Liverpool Plains, an area with a Tertiary/Quaternary alluvial groundwater system (Zhang *et al*, 1997).

2.4 PROVINCES

Morgan and Terrey (1992) described seven provinces within the BBS in New South Wales (Map 10). The definition of these provinces was based on more detailed information on the variation in geology, landform, soils, climate and vegetation than that used to define the bioregion itself. The major differences are between those provinces formed on alluvial and colluvial deposits, those dominated by basalts and those occurring on the Mesozoic bedrock, as indicated in Table 2.

Table 2. Brigalow Belt Province Key (Morgan and Terrey, 1992).

Alluvials and colluvials dominant	Gently sloping fans, grey clays	1. Northern Outwash
	Plains, black earths	2. Liverpool Plains
	Plains, deep sandy texture -	3. Pilliga Outwash

	contrast soils	
Basalt dominant	High ranges	4. Liverpool Range
	Undulating, sandstone in valleys	5. Northern Basalt
Mesozoic sediments dominant	Coarse sediments, sandy soils	6. Pilliga
	Fine to medium sediments, red loams	7. Talbragar Valley

2.4.1 Northern Outwash: 8a

This province contains low red rises and a series of alluvial fans between Narrabri and the Queensland border on the western side of the bioregion. The fans have been formed by tributaries draining the sandstone and basalt areas to the east. The native vegetation is dominated by grasslands and open woodlands. These are continuing to be cleared extensively and developed for cropping. The coarser red soils may be intake areas for the aquifer. Some scalding is present.

2.4.2 Liverpool Plains: 8b

This province lies between Narrabri and Quirindi in the central eastern portion of the bioregion and is made up of extensive black soil plains punctuated by low sedimentary and volcanic hills. The grasslands and open woodlands on the foot slopes of the hills have been mainly cleared and are used for cropping. The southern parts of this province, in addition to the Liverpool Range Province and the eastern parts of the Pilliga Province make up the Oxley Basin.

Significant areas include a rugged area of Permian volcanics near Boggabri. This is a restricted geological formation with a vegetation cover similar to the sedimentary areas. The province contains Lake Goran, which is a seasonal swamp originally covered by Plains Grass.

2.4.3 Pilliga Outwash: 8c

This is a gently undulating plain of deep sandy soils formed by outwash from the sandstones to the east. Some of the areas with more productive soils around the margins of this province have been cleared for agriculture but most of the higher areas remain covered by western state forests. The remnant forests are predominantly found on coarser soils.

2.4.4 Liverpool Range: 8d

This province is in the south-east of the bioregion and encompasses the basalt plateau and slopes of the Liverpool Ranges. The higher rainfall of the plateau supports tall eucalypt forests which have been partly cleared and logged. The slopes on the southern side, within the Hunter River catchment have been cleared extensively and developed for pasture, but on the northern slopes the forests are on the whole still present. It is the primary catchment for the Oxley Basin and forms the headwaters of the Namoi and Hunter Rivers.

2.4.5 Northern Basalts: 8e

Lying between Narrabri and Yetman on the eastern side of the bioregion, this province has a gently undulating landscape resulting from erosion of the basalt layer to expose the underlying sandstone. The soils are rich and have been heavily cultivated. Almost no native vegetation remains except along waterways, and some small remnants on stony basalt hills and sandstone.

2.4.6 Pilliga: 8f

This is the largest of the seven provinces within this bioregion, stretching from Dubbo to Narrabri. It contains extensive sandstone hills with areas of high basalt peaks and predominantly sandy soils. Much of the forest has been cleared but there are large areas of state forest, especially on lands with rockier and shallow soils which are readily eroded or compacted. This province is the major area of aquifer for the Great Artesian Basin in New South Wales.

2.4.7 Talbragar Valley: 8g

This is the smallest of the seven provinces and includes the Talbragar River valley and land to the southern border of the bioregion. The finer sediments of this province provide rich soils which have largely been cleared for cultivation and grazing. Native vegetation only remains on the rocky sandstone hills formed by the inliers of the coarse Pilliga sandstone.

3. BIODIVERSITY

3.1 REGIONAL DIVERSITY

As is the case for the Queensland portion of this bioregion, few systematic regional surveys of biodiversity have been carried out for the Brigalow Belt South in New South Wales. Indeed, there has been very little survey of the flora and fauna at all in this area, no attempt to systematically classify the plant communities in detail, and no attempt to define ecosystems present. As a consequence understanding of the biodiversity and ecological of the bioregion is based on a combination of some small surveys, general broad plant community descriptions and incidental observations.

In addition to the 36 provinces described for the Brigalow Belt South bioregion in Queensland, Sattler & Williams (1999) defined 163 regional ecosystems on the basis of their soil type, vegetation structure and plant species dominance. These regional ecosystems are not restricted to particular provinces but can occur across the province divisions, indicating the relatively high level of complexity and ecological diversity within the bioregion when compared with other bioregions.

The complexity and ecological diversity of the Brigalow Belt South bioregion in NSW, indicated by the number of provinces and regional ecosystems, is a response in part to its location. The bioregion lies along the western edge of the Great Dividing Range extending onto the lowlands (Maps 6,10) to the west, and forms a transitional zone between the dry inland or Eyrean zone and the wetter coastal or Bassian zone. The nature of this transitional zone is reflected in the distribution of the plant and animal species found in the bioregion with some species, such as the Hopping Mouse, Mallee Fowl and Western Blue-tongue Lizard having Eyrean affinities, while others such as the Koala, Sugar Glider and Glossy Black-cockatoo have a Bassian affinity. Populations of species found at the extreme edges of their range can have important genetic values. This is illustrated by the population of Spotted Gum in the south-east of the bioregion. This represents the most western population of this species and is the source of supply for seed exported to more arid climates. Likewise, the Mallee Fowl population in the Goonoo State Forest is at the extreme eastern edge of its range.

3.1.1 The vegetation in 1750

The vegetation of the BBS prior to European settlement has been broadly described as predominantly open woodland with some large areas of open forest and tussock grassland. By 1988, tussock grassland and sown pasture are shown as having become the dominant vegetation types replacing almost all the open woodland which remains mostly in isolated patches). (Carnahan, 1976). The area of open forest has also been reduced (State of the Environment Report, 1996). Carnahan (1976) described the character of the vegetation prior to modification by Europeans in a little more detail, suggesting that the vegetation of most of the bioregion had an upper stratum of eucalypts, 10-30 m in height and with a crown density of 10-30% cover above an understorey of low trees. From Dubbo to Baradine, the overstorey structure is thought to have been more dense, with a cover of 30-70% with *Callitris* the dominant species. North-

east of Moree *Acacia* was dominant. Sparse woodlands and grasslands were thought to occur around Gunnedah and in the area of the Liverpool Plains.

More detailed descriptions of the pre-European vegetation, based on interpretation of historical records are provided by Benson & Redpath (1997), and van Kempen (1997). In general, Benson & Redpath demonstrate that the vegetation was a mixture of open forest over an open grassland, and areas of more dense 'scrubs'. They quote from Ludvig Leichhardt who wrote the following description in 1843:

> *The Liverpool Plains are one of those areas that still hold out the hope of something new to the botanist. When I crossed this strange region there were numerous Compositae in flower .... The Liverpool Plains have probably been the bed of a chain of lakes that contained numerous islands formed of sandstone and covered with forest composed of many different species of Eucalyptus. The Cypress pine (Callitris) grows here in many places, and the bush huts are built of its timber ....*
>
> *Between the Severn and the Condamine the country is flat, covered with forest which is very dense in some places, known to the colonists as 'brigalow scrub'. The brigalow is a species of Acacia with long, stiff, greyish phyllodes. It is associated with Casuarinas (forest oak), [narrow-leaved] ironbark and a species of banksia - the only one found far from the coast. The soil is very sandy except on small flats near the streams, where it contains more clay and vegetable mould. The 'apple tree' of the colonists, Angophora lanceolata, grows well on these flats. Just as the brigalow gives character to this part of the country, another species of Acacia, the myall (Acacia pendula) characterises the Liverpool Plains and the plains of the Gwydir ....*

The Pilliga Scrub, near Coonabarabran, has been referred to by various writers including Rolls (1981), as having been originally covered by open grassland, or an open forest with grassy understorey. These claims have been analysed and compared in detail by Mitchell (1991), Norris et al. (1991) and Benson & Redpath (1997), and all three analyses dispute this claim. In their analysis of Oxley's observations in that area Benson & Redpath (1997) point out that the forest was so dense in some areas that they 'could hardly turn their horses' and complained about the lack of grasses to feed their horses. Oxley's observations concur with the view that the Liverpool Plains were grasslands 200 years ago.

In her study of the Pilliga Cypress Pine Forests van Kempen (1997) considers that the only small patches were in their present form. She suggests that the ridges were vegetated with a shrubby undergrowth, the flats were grassland with scattered ironbark and White Cypress Pine *Callitris columellaris*, occasionally broken by belts of *Acacia*, Bull Oak *Allocasuarina luehmannii* and other shrubs. She believes that the historical evidence shows that the plant species composition has not changed but the species distribution was markedly different. Some of the conclusions drawn by this study differ from those by Benson and Redpath (1997). A detailed ecological analysis is still needed. The analysis by van Kempen (1997) relies heavily on the statements made by people working in the area and old records, without considering the processes of ecological succession effectively.

Vegetation changes in western NSW have also been examined by Denny (1994) who compared observations by explorers of inland NSW and observations of the same areas today. He notes that there have been relatively large changes in the amount of vegetation cover in the bioregion, with 58% of sites showing a decrease in cover. Where native vegetation persists, the species present appear to have remained the same. All the explorers mention the presence of possums. Some records describe them in their 'millions'. These are presumably the Common Brushtail Possum *Trichosurus vulpecula* which now is relatively uncommon throughout the region. A similar story exists for the Brolga *Grus rubicundus* and Bustard *Ardeotis australis*. The

township of Nyngan is described by Mitchell as being on a long pond of water with many ducks and native companions (Brolgas). The pond still exists but the Brolgas are rarely observed.

Modified ecosystems now predominate in the BBS with very little remaining in the presumed pre-European natural state. As part of the Murray Darling Basin Project the remaining woody vegetation in western NSW was mapped (M305). This analysis indicated that 76% of the bioregion has now been cleared of native vegetation, or substantially modified. Some types of vegetation have been preferentially cleared, with this being dictated by the vegetation type and land tenure. Clearing is still continuing with estimates for NSW of an average of 150 000 hectares of native vegetation being cleared annually between 1980 and 1995 (Benson & Redpath, 1997).

3.1.2 Threatening Processes

Listed threatening processes , under the Threatened Species Conservation Act 1995 (TSC), for this bioregion are predation by the red fox *Vulpes vulpes* and mosquito fish *Gambusia*, on native species.

There are many other threats to the native vegetation and wildlife that have been generally acknowledged in various reports and analyses. These include:

- rising saline water-tables due to loss of deep-rooted vegetation;
- acidification of the soil as a result of the application of fertiliser;
- changes to the natural drainage patterns
- intensive and frequent logging on both public and private lands;
- unsustainable firewood cutting;
- nutrification and other pollution of waterways from agricultural chemicals;
- introduction of exotic plant species; and
- altered fire regimes.

The majority of open forests, woodlands and native grasslands in the BBS have been cleared for agriculture and forestry activities. An estimate of the percentage of land cleared in the bioregion has been obtained from the M305 woody layer, mapped for the Murray Darling Basin Commission. In this analysis, the non-woody area is estimated as 76% of the bioregion, the majority of which represents cleared land. This has resulted in a serious fragmentation of the wooded environments. Species surviving in a fragmented landscape face a significant struggle for survival against the cumulative effects of fire, weed invasion and continued clearing. The major threats to biodiversity are continued tree clearing, high total grazing pressure and the proliferation of exotic species.

Clearing

Rates of clearing in this area are illustrated by the following figures:

- St George 1:250000 map sheet in the northern wheatbelt - 61% naturally vegetated in 1974 compared with 28% in 1994;
- between 1955 and 1990 there was a 185% increase in the clearing and cropping of previously grazed land on rich soils in the Goran Basin near Gunnedah (Gray, 1995). The increased clearing of deep rooted native vegetation in favour of annual crops is leading to a rising saline watertable in the Basin; and
- in the 1980s, 100 000 ha per year was cleared in NSW. This rate was reduced in the 1990s but continued at a high rate in areas growing cotton, wheat and rice. Estimates for the 1990s are 50 000 ha per year, then in 1991-1995 after the introduction of SEPP 46 the rate dropped to 30 000 ha per year (Benson, 1999).

In addition to clearing for agricultural and forestry activities, overgrazing, salination and chemical toxicity have been detrimental on the natural environment. For example, an increase in the total grazing pressure has led to sheet and gully erosion. Continuous grazing prevents the regeneration of plants from suckers or the recruitment of new individuals from seedlings. This is a factor of importance when comparing remnant wooded habitat on freehold land with that on crown land which is ungrazed or infrequently grazed.

Weed infestations

15% of the plant species in NSW have been introduced since European settlement, some of which have become weeds. There has been no analysis of the proportion of introduced species within the total list of plant species recorded for this bioregion. Some of these introduced species have been declared noxious weeds but these declarations vary across the bioregion. They include species such as Blackberry *Rubus fruiticosus*, Boxthorn *Lycium ferocissium*, Willows *Salicaceae babylonica* and White Broom *Chamaecytisus spp*. Some native species, such as the Cootamundra Wattle *Acacia baileyana*, are also considered a weed if growing in large numbers outside their natural range.

Feral animals

Predation by two introduced species, the red fox and mosquito fish, is listed as a threatening process. There are additional species recognised as having significant harmful and detrimental environmental impacts. The feral cat *Felis catus* has a direct predatory impact on fauna while others cause degradation through destruction of habitat for both plant and animal species, and competition for resources. These include rabbits *Oryctolagus cuniculus*, goats *Capra hircus*, horses *Equus caballus*, and feral pigs *Sus scrofa*, especially within wetland habitat. A number of bird species have been recognised as pests within the bioregion.

3.1.3 Centers of Endemism

The variable climatic and landform features of this bioregion seem to have resulted in a high degree of biogeographic uniqueness and a significant level of endemism. This has not been assessed in detail but there are indicators that this distinctiveness is a significant feature of the area. In addition to areas where species with a restricted distribution are known to occur, endemism is most likely to be associated with the isolated nature of some of the small volcanic peaks and the original isolation of the Liverpool Plains grasslands from other extensive grasslands.

In the Warrumbungle National Park there are a number of plant species which are either rare or very localised. These include the Black-eyed Susan *Tetratheca decora*, Geebung *Persoonia sp. aff. rigida, Phebalium viridiflorum* which is common on exposed trachyte lava flows, Star Bush *Asterolasia hexapetala*, *Zieria aspalathoiodes* and Mint Bush *Prostanthera granitica*. The small volcanic plugs between Coonabarabran and Tambar Springs have not been systematically surveyed and are likely to contain endemic forms or species. The Pilliga *Box Eucalyptus pilligaensis*, with its distribution centred in the Pilliga area is another very localised species. Studies of genetic diversity of White Box *Eucalyptus albens* and River She-oak *Casuarina cunninghamiana* (Moran *et al*, 1989) have been carried out with some samples from this region being included. These studies however have been limited in scope, and do not allow any interpretations to be made.

Two rodent species, the Pilliga Mouse *Pseudomys pilligaensis* and the Darling Downs Hopping Mouse *Notomys mordax*, were once restricted to the western slopes, on the eastern edge of the bioregion. The Darling Downs Hopping Mouse is presumed extinct. The Northern Hairy-nosed

Wombat *Lasiorhinus krefftii* is also assumed to have occurred through this region on the basis of fossil and historic records. The type locality of the Pilliga Mouse is in the Pilliga Forest, and the species is still known only from that forest (Briscoe *et al*, 1981). A similar species, the New Holland Mouse *Pseudomys novaehollandiae* has been found in the Goobang National Park just to the south of this bioregion. The bioclimate of the region also determines the distribution of some species of elapid snake such as De Vis' banded Snake *Denisonia divisi* and the Spotted-black Snake *Pseudechis guttatus* (Nix, 1986). Some genetic studies of animal species have included samples from this region, for example the *Gehyra australis* complex (King, 1983). Again, these genetic studies are too limited to make any interpretations.

3.1.4 Refugia

Refugia have been assessed for the arid and semi-arid regions of Australia by Morton *et al*, (1995). In their paper they define refugia as

> *'a region in which certain types or suites of organisms are able to persist during a period in which most of the original geographic range becomes uninhabitable because of climatic change'.*

This may include either long term or short term climatic change and may affect one or many generations of the species. The types of refugia defined by Morton *et al*, are islands, mound springs, caves, wetlands, gorges, mountain ranges, ecological refugia, refuges from exotic animals and refuges from land clearing.

The existence and significance of these refugia in the BBS has not been determined or assessed. There are, however, a number of areas that fall into this definition and require assessment. There is evidence of some endemic organisms in the Warrumbungle Ranges and in the area to the south of Narrabri. The Liverpool Ranges, the small isolated volcanic outcrops, the Liverpool Plains, the Pilliga Forest and the Goonoo Forest all represent areas which fulfil the criteria in the definition of refugia. There may also be remnant populations of species whose core distribution lies outside the bioregion.

3.1.5 Wilderness values

The determination of wilderness in this area is covered by both the Australian Heritage Commission Act 1975 and, in New South Wales, the Wilderness Act 1987. The Australian Heritage Commission Act 1975 provides for the establishment and maintenance of the Register of the National Estate which contains places with aesthetic, historic, scientific or social significance within the natural or cultural environment.

The criteria for listing include:

- Criterion A. Its importance in the course, or pattern of Australia's natural or cultural history (in A.1 the evolution of the flora, fauna, landscapes or climate, A.2 the maintenance of existing processes or natural systems at the regional or national scale, A.3 exhibiting unusual richness or diversity of flora, fauna, landscapes or cultural features);
- Criterion B. The possession of uncommon, rare or endangered natural or cultural features;
- Criterion C. The potential for providing information for a greater understanding of Australia's natural or cultural history; and
- Criterion D. Its importance in demonstrating the principal characteristics of a class of Australia's natural or cultural places or natural or cultural environments.

JANIS (1997) defines wilderness thresholds for the forest component of the National Reserve System. These JANIS criteria require that to be classified as wilderness an area must have a minimum National Wilderness Index of 12 and will generally be an area of at least 8 000 ha.

Using these criteria, two areas in the Pilliga Forest have been identified as provisional wilderness by Environment Australia (1999) (Map 11). These are mostly located within the Pilliga Nature Reserve but also include some State Forest and freehold land, one on each side of the Newell Highway. A closer examination of the area using an updated database may result in the inclusion of at least one other area in the Pilliga.

In New South Wales an area may be identified as wilderness by the NPWS Director General if:
- the area is, together with its plant an animal communities, in a state that has not been substantially modified by humans and their works or is capable of being restored to such a state;
- the area is sufficiently large to make its maintenance in a natural state feasible; and
- the area is capable of providing opportunities for solitude and appropriate self-reliant recreation.

An assessment of Wilderness in the Pilliga Forest has also been carried out by NSW NPWS (1999). In this report the natural heritage values of the Pilliga Scrub are summarised as:
- the largest area of native vegetation remaining in the central part of New South Wales and the largest tract of inland plains forest remaining in Australia;
- having diverse vegetation communities, from open forests and woodlands to dense heath and shrubland;
- several species of rare and threatened plants;
- numerous plant species of biogeographic importance, including some which are more typical of coastal regions and are found in the Pilliga at their western limit and arid land species found at the eastern limit of their distribution;
- habitat of threatened species of native fauna, including the Glossy Black-cockatoo, Regent Honeyeater, Pilliga Mouse and Koala; and
- scenic beauty consisting of sandstone cliffs, hidden gorges and spectacular wildflower displays.
- containing a significant number of pre-European contact archaeological sites.

Environment Australia's wilderness assessment of the Pilliga area identified the majority of the Pilliga Nature Reserve, a large proportion of Pilliga East State Forest, parts of Bibblewindi and Denobollie State Forests, all of Ruttley and Yaminba State Forests, some freehold land and a large area of vacant crown land. From this, three areas of land, totalling approximately 127 000 ha, have been identified as wilderness. They include the majority of Pilliga Nature Reserve, two timber reserves, parts of five freehold blocks, a large area of vacant crown land and parts of Pilliga East, Denobollie, Yaminba, Timmallallie and Wittenbra State Forests. Two major roads which run through the area (Newell Highway and Number One Break Road) have been excluded and one Crown road (part of Yearinan Road) is included.

3.2 FLORA

Very few systematic plant surveys have been carried out in the Brigalow Belt South in New South Wales. There have been some survey of the Pilliga Nature Reserve and the Brigalow Scrub, and a study of the biology and management of Ooline *Cadellia pentastylis* (Benson, 1993). Some sites from the northern wheatbelt study by Sivertsen (in prep) are also located within the BBS and most of the State Forests have been classified according to 'Lindsay Forest Types'. Dyson & Marston (1976) broadly mapped the 1:250 000 Curlewis map sheet in the Liverpool Plains area, Binns (1997) has analysed the floristic and vegetation patterns of 50 sites

on Coolah Tops, and some grassland sites from Prober (1996) also fall within the region. Fisher (1985) conducted a systematic survey of rainforest communities in the Liverpool Ranges, most of which fall within the south-east of the bioregion. Bryophytes and lichens have been sampled from several sites in the region by Eldridge (1996), and Eldridge and Tozer (1995).

A survey of the flora of the Goonoo forest was carried out by the National Parks Association of NSW in 1999. These data have yet to be analysed. There have been no systematic surveys of the Warrumbungle National Park but many species lists have been collected and these are currently being collated. Many observations are listed in the Wildlife Database for this Park. A list for the Pilliga Forest has also been collected by the Society for Growing Australian Plants. Records of the Dubbo Field Naturalists and Conservation Society contain many records of the area, especially the Goonoo Forest and Gilgandra Flora Reserve.

3.2.1 Plant Communities

The vegetation of the BBS is described by Thackway & Cresswell (1995) as eucalypt woodlands and open forests of ironbark *Eucalyptus melanophloia* and *E. crebia*, Poplar Box *E. populnea*, Spotted Gum *E. maculata*, White Cypress Pine *Callitris glaucophylla*, bloodwoods *E. trachyphloia* and *E. hendersonii*, brigalow-belah *E. harpophylla* and *Casuarina cristata*, and semi-evergreen vine thickets. Benson (1999) further describes the vegetation of the BBS as being mainly grassy woodland dominated by White Box *E.albens*, Bimble Box *E. populnea* and Pilliga Box *E. pilligaensis* with several species of ironbarks. Woodlands or more dense thickets are comprised of Belah *Casuarina cristata*, Bulloak *Allocasuarina leuhmannii* and Brigalow *Acacia harpophylla*. It has been estimated that only 5 000 of the original 250 000 hectares of Brigalow remain (Pulsford, 1984). White Cypress Pine and White Box mix with microphyll vine thickets on basalt rises.

Detailed descriptions do not exist for all the major plant communities and plant alliances within the BBS. The province descriptions by Morgan and Terrey (1992) provide the most complete coverage of the range of plant communities for the entire bioregion, but these are limited to one or two sentences listing the main species associated with each soil and landform type. Given that these are the only descriptions which systematically cover the whole area they are outlined below. While these communities are not mapped at all they can be readily located in the landscape by identifying the portions of the land profile in which they occur.

Detailed mapping of some plant communities in the southern part of the bioregion, and a vegetation survey with at least one quadrat in every State Forest south of Narrabri have been carried out as a part of this project. This mapping, and the results of the vegetation surveys are discussed in the report by Beckers. Beckers has also provided a detailed floristic description of the vegetation based on the association and alliance classifications of Beadle.

Plant Communities listed by Morgan and Terrey (1992) are outlined below (provinces indicated in brackets).

1. Poplar Box woodland with:
    (i) White Cypress, Wilga & Budda on brighter red loam soils (1);
    (ii) Belah and Brigalow on lower darker red loam soils (1, 5);
    (iii) White Cypress and Silver-leaf Ironbark on inner Gwydir fan (1);
    (iv) occasional Belah and Wilga in the north and Yellow Box in the south on finer alluvial soils (2);
    (v) White Cypress and Bulloak (3);
    (vi) White Cypress, Blakely's Red Gum, Pilliga Box and Mugga Ironbark (3).
2. Plains Grass grassland with:
    (i) Myall woodland and occasional Whitewood and Belah on high alluvial plains(1);

(ii) Bluegrass and Panics and occasional White Box and Wilga, and Hill Red Gum on steeper areas (2);
(iii) windmill grass and panic with scattered Poplar Box (2).

3. Belah woodland and open forest (2, 4) with Budda and occasional Whitewood and Wilga on low alluvial plains (1).
4. River Cooba on lower areas (1).
5. River Red Gum on lower areas and channels (5, 7) with:
   (i) Coolabah (1, 3);
   (ii) River Oak (2, 6, 7);
   (iii) Belah, Myall or Poplar Box on alluvial flats (5).
6. Lignum on low alluvials (1).
7. Open forests or woodlands of White box with:
   (i) White Cypress Pine and occasional Rough Barked Apple, Blakeley's Red Gum, Whitewood, Wilga and/or Kurrajong (2, 4, 6, 7);
   (ii) Yellow Box on coarse alluvials (2);
   (iii) Silver-leafed Ironbark and Fuzzy Box (3);
   (iv) occasional Rough-barked Apple on northern slopes and foot slopes of Liverpool Range (4);
   (v) Yellow Box and Blakeley's Red Gum on southern slopes and foot slopes of Liverpool Range (4);
   (vi) Silver-leaf Ironbark, Whitewood and Bulloak (5).
8. Hill Red Gum open forest (2).
9. Yellow box open forest with:
   (i) occasional Grey Box and Kurrajong (2);
   (ii) Blakely's Red Gum (4).
10. Open forest or fringing communities containing mixtures of Brigalow, Yarran, Budda, Wilga, Whitewood, Myall, Beefwood, Rosewood, Quinnine bush or Belah (3, 4, 5, 6).
11. Tall open forest of Silver-topped Stringybark, Manna Gum, Mountain Gum and some Snow Gum on the plateau of the Liverpool Range (4).
12. Tallow Wood, Blackbutt, Bluegum on the eastern slopes of the Liverpool Range(4).
13. Vineforest with Socketwood and Lillypilly (4).
14. Open forest of Silver-leaf Ironbark with White Cypress on rocky areas (5).
15. Scrubby open forest of Rusty Gum, White Cypress and Blakely's Red Gum on mid-slopes (5).
16. Moreton Bay Ash, Poplar Box, Wilga, Rough Barked Apple, Bulloak and occasional Whitewood on lower slopes (5).
17. Pilliga box woodlands with:
   (i) Poplar Box and Grey Box and Bulloak and Rosewood in the understorey (6);
   (ii) Yellow Box, and Blakeley's Red Gum (6);
   (iii) Rough-barked Apple on sandy alluvials, easterly aspect (6);
   (iv) Bulloak, Rosewood, Wilga (6).
18. Woodlands and open forests of Narrow-leafed Ironbark and White Cypress with:
   (i) Blue-leaf Ironbark, Hill Red Gum and occasional Black Cypress, White Bloodwood and White Gum; Mugga Ironbark and Red Stringybark may also occur (6);
   (ii) Hill Red Gum, Black Cypress and occasional White Gum on rugged acid volcanics (6);
   (iii) occasional Bulloak on lower areas (7).
19. Blue-leaf Ironbark, Hill Red Gum, Brown Bloodwood, White Gum and Black Cypress with a shrubby understorey on rocky areas (7).
20. Mallee (Congoo and Green) (6).
21. Grey Box woodlands with Fuzzy Box, Yellow Box and Rough-barked Apple on smaller tributaries (7).

While these descriptions provide a useful indication of some of the diversity of plant communities across the bioregion, they are clearly inadequate. They do not include any information about the composition of the understorey or groundcover, nor do they systematically analyse the variation in community structure. Both these factors are of critical

importance when assessing the conservation values of the communities and their value as habitat for wildlife. Their accuracy is also in need of assessment.

In addition to the above information there is an outline of Brigalow communities in NSW by Pulsford (1984), and detailed descriptions of the soil landscapes of the region, published by the Department of Land and Water Conservation, which also include a vegetation description. This information is incomplete and inconsistent in the approach used. These descriptions do not include understorey or groundstorey species.

Dubbo/Gilgandra Area

The following descriptions are based on the descriptions of the southern part of the bioregion in the soil report for the Dubbo 1:250 000 map sheet (Murphy and Lawrie, 1988), Biddiscombe (1963) and Grant (1984). The major plant alliances are:

Ironbark Woodlands

Mugga Ironbark *Eucalyptus sideroxylon* and Tumbledown/Hill Red Gum *E. dealbata*: Dry sclerophyll woodland association is mostly found on the slopes and sometimes the ridges of dry hills with shallow, stony soils. It is present on Mugga Hill on the Dunedoo Road to the north-east of Dubbo and in the Sappa Bulga Ranges.
Other Tree Species: White Cypress Pine, Black Cypress Pine, Blakely's Red Gum, Blue-leaved Ironbark, White Box.
Understorey Species: Currawang wattle, Deanes Wattle and Native Cherry.
Grass and Groundcover Species: Goodenia, Nodding Blue-lily, Porcupine Grass.

Narrow-leaved *Ironbark E*. crebra and White Cypress Pine *C. glaucophylla*: Dry sclerophyll woodland found extensively on deep sandy well drained soils such as are found in the Goonoo and Beni forests. Also remnants now often only found on shallow soils of the hillslopes, ridges and crests.
Other Tree Species: Bulloak
Understorey Species: Native Cherry, Deane's Wattle and Boobialla.
Grass and Groundcover Species: Red-anther Wallaby Grass

Blue-leafed (Red) Ironbark *E. nubila* woodlands*:* These occur on the shallow sandy soils from Pilliga sandstone east and north of Dubbo (especially well developed in the hilly country of the Goonoo forest), and sandstone and conglomerate ridges in the Ballimore area.
Other Tree Species: Tumbledown Red Gum and Black Cypress interspersed with the Narrow-leaved Ironbark communities.
Understorey Species: Low shrub understorey containing a mixture of species such as Currawang, Sword-leaved Wattle, Brachycome daisies, Micromyrtus, Fringe Myrtle and Scrubby Sheoak
Grass and Groundcover Species: No 9 wiregrass is always present. Goodenia, Bitter-pea and Tall Bluebell.

Box Woodlands

White Box *E. albens:* These woodlands occurs in undulating country on well drained, moderately fertile soils and forms mosaics with the Yellow Box – Blakely's Red Gum community. White Box is generally higher on the slope than the other two species.
Other Tree Species: Kurrajong, Mugga Ironbark, Tumbledown Red Gum, Weeping Boree, White Cypress Pine and Yellow Box.

Understorey Species: Coughbush, Deanes Wattle, Rosewood, Yarran and Bulloak.
Grass and Groundcover Species: Wallaby Grass, Speargrass, Plains Grass, Kangaroo Grass, Queensland Bluegrass, Wheat Grass, No 9 Wiregrass and Red-anther Wallaby Grass.

Grey Box *E. microcarpa* and Fuzzy Box *E. conica:* Common on the lower central western slopes, gently sloping or flat areas with red-brown earthy soils and red-podsols. There are extensive areas on alluvial soils where Grey Box is associated with Black Cypress Pine. The two box species are most commonly associated in the valleys especially the Macquarie River levees near Dubbo and the alluvial fans of larger creeks in the Talbragar valley. This community intergrades with the White Box and Yellow Box/Blakely's Red Gum associations. On some of the narrow river flats fringing the Talbragar River Fuzzy Box is replaced by the rough barked apple. Grey box may be replaced by Pilliga Box in the northern parts of the Dubbo area.
Other Tree Species: White Cypress Pine, Bulloak, White Box, Yellow Box, Pilliga Box, Rough-barked Apple and Kurrajong.
Understorey Species: Deanes Wattle, Wilga, Silver Cassia and Sticky Hopbush.
Grass and Groundcover Species: Speargrass, Plains Grass, Wallaby Grass ,Weeping Meadow Grass and Windmill Grass.

Yellow Box *E. melliodora* and Blakely's Red Gum *E. blakelyi*: These woodlands occur on undulating well drained country with deep fertile soils. Grades into White Box woodlands on the upper western slopes and Grey Box in the west. Mostly occurs on lower slopes and along small drainage lines.
Other Tree Species: Rough-barked Apple, White Box and River Red Gum.
Understorey Species: River Cooba and Kurrajong.
Grass and Groundcover Species: Wallaby Grass, Kangaroo Grass, Windmill Grass and Knob Sedge.

Poplar or Bimble Box *E. populnea*: The shiny green leaves of the poplar or bimble box are usually readily identified. It usually grows with White Cypress Pine on the better drained compact red-brown earth soils.
Other Tree Species: Tumbledown Red Gum, Yarran, Warrior Bush, Native Orange, Kurrajong and Bulloak
Understorey Species: Deanes Wattle, Wilga, Rosewood and various species of Emu Bush.
Grass and Groundcover Species: Speargrasses, Wallaby Grass and Purple Lovegrass.

Communities along Watercourses

River Red Gum *E. camaldulensis*: Found on Riverine floodplains with deep alluvial soils and grades into the Yellow Box, Blakelys Red Gum and White Box communities.
Other Tree Species: Blakelys Red Gum, Grey Box, Kurrajong, River Cooba, White Cypress Pine, Yellow Box and Rough-barked Apple.
Understorey Species: Deanes Wattle, River Bottlebrush and Kurrajong.
Grass and Groundcover Species: Rock Fern, Wallaby grasses, Weeping Meadow Grass and Native Carrot.

River Sheoak *Casuarina cunninghamiana*: This community grows on Riverine floodplains with deep alluvial soils where it may form pure forests or narrow woodlands fringing watercourses.
Other Tree Species: Blakelys Red Gum, Mugga Ironbark, Red Stringybark, Tumbledown Red Gum, White Cypress Pine and Yellow Box.
Understorey Species: Box leaved Wattle, Hopbush and Grass Tree.
Grass and Groundcover Species: Nodding Blue-Lily, Wallaby Grasses, Kangaroo Grass and Speargrass.

Shrublands

Weeping Myall *Acacia pendula* and Saltbush *Atriplex nummularia*: This community is interspersed with Bimble Box over the plains with grey clay soils. Look for it between Dubbo and Gilgandra on gently rising ground or in depressions.
Other Tree Species: Belah and River Cooba.
Understorey Species: Nitre Goosefoot and Spiny-fruit Saltbush
Grass and Groundcover Species: Spike rush and Weeping Lovegrass

Yarran *Acacia homalophylla*: This species is most commonly found on level plains and gently undulating rises with red-brown soils.
Other Tree Species: Bimble Box, Grey Box, Weeping Myall, Rosewood and White Cypress pine.
Understorey Species: Broad-leafed Hopbush, Deanes Wattle, Emubush and Silver Cassia.
Grass and Groundcover Species: Curly Windmill Grass, Wallaby Grass, Rough Speargrass, Flax Lily, Burr-daisy and Knob Sedge.

Pilliga and Goonoo Forests

In their study of the north-west Cypress/Ironbark forests of NSW, Date and Paull (pers com) have described eight broad vegetation communities in relation to the substrate of the area. These are:

- River Red Gum, White Box, Yellow Box, Mugga Ironbark, and Western Grey Box on the heavier loam soils with greater retention of soil water;
- Narrow-leaf Ironbark and White Cypress on the deep sandy well drained soils;
- Red Gums *E. blakeleyi* and *E. chloroclada* on the moister sandy and gravelly soils usually associated with intermittent drainage lines;
- Pilliga Box and Poplar Box on loams and sandy clays usually bordering heavy productive soils and sometimes on gravelly slopes and ridges;
- Blue-leaf Ironbark, Brown Bloodwood and Black Cypress Pine on skeletal and gravelly soils of outcropping sandstone ridges;
- Dwyers Red Gum or Tumbledown Gum and Black Cypress Pine on ridge areas;
- Broom *Melaleuca uncinata* on poor shallow clays which sometimes become waterlogged; and
- Green Mallee associated with Broom in the Pilliga. Near the Castlereagh River and in the Goonoo it forms more pure stands.

Date and Paull (1998) also carried out a detailed floristic and structural classification of their trapping sites.

The Liverpool Plains and Ranges

The vegetation of the Goran Basin and Liverpool Plains, Liverpool Ranges, Coolah Tops and Merriwa Plateau is described by Banks (1994, 1998). Recent vegetation surveys in the Curlewis area have found that there is a much greater diversity of species and vegetation structural types than has been indicated from previous vegetation analyses. The mapping of this area by Dyson and Marston (1976) provides a good general base map.

Until the 1950s the Goran Basin and Liverpool Plains were closed grasslands dominated by Plains Grass with Panics *Panicium spp*, Blue Grass *Bothrichloa spp*, Windmill Grasses *Chloris spp*, Wire Grasses *Aristida spp*, Spear Grasses *Stipa spp* and Wallaby Grasses *Danthonia spp* as sub-dominant species. There were also scattered clumps of Myall and River Red Gum occurring in the swamps and along the drainage lines. These areas are now dominated by dryland cropping systems with only a few small areas of Plains Grass and no salt bush.

The Liverpool Ranges have been partially cleared for cultivation and grazing. The area features woodlands with Yellow Box and White Box as the dominant tree species. Co-dominant species are River Red Gum, Blakeley's Red Gum, Rough-barked Apple, Belah, River Oak, Kurrajong, Wilga, Rosewood and Myall. More elevated areas of the Liverpool Ranges have wet and dry sclerophyll forests dominated by Silvertop Stringybark *E. laevopinea* with Manna *Gum E. viminalis*, Mountain Gum *E. dalrympleana* and Snow Gum *E. pauciflora* also present. Coolah Tops contains these species in addition to Black sally *E. stellulata* and Tea Tree *Leptospermum spp*. on the more swampy areas. The tall woodlands of the Merriwa Plateau contain Grey *Box E. moluccana*, Blakeley's Red Gum, Yellow Box, Forest Red Gum *E. tereticornis*, Rough-barked Apple and Kurrajong (Banks, 1998).

Brigalow Communities

For the Brigalow Plant Communities, which now have a very restricted distribution when compared with their historical extents, Pulsford has listed the following plant associations. Regenerated Whipstick Brigalow with:

- Belah and Wilga or Yellow wood;
- Wilga;
- vine thickets of Ooline or mixed species of softwoods;
- Bimble box and Pilliga box;
- Coolibah; and
- Gidgee and other *Acacias*.

3.2.2 Conservation Status of Plant Communities

Three communities have been listed under the NSW Threatened Species Conservation Act (1995):

- Ooline or Scrub Myrtle *Cadellia pentastylis*;
- Semi-evergreen vine thickets; and
- Carbeen.

Benson (1999) also lists Brigalow, box woodlands and Plains Grasses as being the most threatened plant communities in this bioregion.

At a national level, the Grassy White Box woodland community has been listed as an endangered community under the Commonwealth Endangered Species Protection Act (1992).

The Ooline community is a forest community in which the canopy is dominated or co-dominated by Ooline *Cadellia pentastylis*. Other canopy species include *Eucalyptus albens, E. beyeriana, E. chloroclada, E. melanophloia, E. pilligaensis, E. viridis* and *Callitris glaucophylla*. Understorey species include *Alstonia constricta, Beyeria viscosa, Carissa ovata, Einadia hastata, Geijera parviflora, Notelaea microcarpa,* and *Aristida* and *Austrostipa species*. Details of the species composition of individual stands is provided in Benson (1993). The species composition of stands varies, with stands on claystone having a more herbaceous understorey than those on sandstone or conglomerate. All stands are characterised by Ooline being the dominant overstorey species.

Stands of Ooline occur in northern NSW on undulating terrain on a variety of soil types, usually between 300 and 450 m above sea level. In NSW the community occurs in the Nandewar bioregion as well as in the Brigalow Belt South. It has been extensively cleared in Queensland. The total area of the Ooline community in NSW is about 1200 ha at 8 major locations (Benson, 1993), plus an additional location at Mosquito Creek. At all locations there has been a substantial reduction in the area of the community during the last 200 years (Benson, 1993).

Ooline is the only species in the genus and has affinities with rainforest species. The community may provide links to the more extensive rainforest cover of Australia which was present until the climate became more arid in the late tertiary period. It can resprout and coppice so the number of genetic individuals in some stands may be much fewer than the number of stems present.

Stands of the community occur under a variety of tenures. Some areas are conserved in the Scrub Myrtle Flora Reserve, Gamilaraay Nature Reserve and under a voluntary conservation agreement. Threats to the community include grazing and the accompanying soil compaction, resulting in poor seedling recruitment. The response of the species to fire is unknown, so the impact of altered fire regimes on the community is uncertain. Historically the major threat to the community has been from clearing, which has caused the dramatic reduction in its distribution. Further clearing would be a major threat to the survival of the community. Fragmentation of once extensive stands and the possibility of low genetic diversity within stands (because of the prevalence of vegetative reproduction) may pose long term threats to the survival of the community.

The Semi-evergreen Vine Thickets are a form of dry rainforest which is only found in the Brigalow Belt South and Nandewar bioregions in NSW. It is made up of vines, deciduous and/or facultatively deciduous tree species that have affinities with species from sub-tropical rainforest. Characteristic canopy dominants are *Cassine australis var. angustifolia*, Wilga *Geijera parvifolia*, and *Notelaea microcarpa var. microcarpa* but with emergents typical of the surrounding woodlands (White Box, Yellow Box and White Cypress). A detailed description of the community is provided by Benson *et al*, (1996).

The Semi-evergreen Vine Thickets grows on sites with deep loamy, high nutrient volcanic soils in areas with a reduced fire risk and a rainfall of 750 mm. The distribution was probably already restricted before European settlement. Since then it has been cleared for grazing and cropping, continuing until recently. Grazing may also adversely affect the regeneration of the community.

The Carbeen community occurs in the Darling Riverine Plains bioregion as well as in the Brigalow Belt South. The characteristic tree species are Carbeen *Eucalyptus tessellaris*, White Cypress Pine *Callitris glaucophylla*, and associated trees include *Corymbia dolichocarpa, E. populnea, E. camaldulensis, Casuarina cristata* and *Allocasuarina leuhmannii*. There is an extensive plant species list for this community but many species are present in only one or two sites, as a consequence of the size of the site and its recent disturbance history. It was originally an open forest but now often occurs only as a woodland or remnant trees.

Carbeen open forest occurs on well drained siliceous sands, earthy sands and clayey sands, and is a distinctive plant community on the Riverine plains of the Meehi, Gwydir, MacIntyre and Barwon Rivers. It has been recorded from the Local Government Areas of Moree Plains and Walgett. The community has mostly been cleared for grazing and cropping and is threatened by further clearing, land levelling and inappropriate fire management. Less than 500 ha of this community is within nature reserves.

The analysis carried out as a part of the Regional Vegetation assessment (NPWS, 2000) has defined the following plant communities of possible conservation concern within the Pilliga and Goonoo forests in addition to those listed by Benson (1999):

- Myall shrublands;
- Brigalow open forests;
- White Box woodlands;
- Yellow Box woodlands;
- Blue-leafed Ironbark open forests especially in association with Brown Bloodwood and Black Cypress Pine;
- Broad-leafed Ironbark open forests;
- Narrow-leaved Ironbark open forests;
- Mugga Ironbark open forests;
- River Red Gum open forests;
- Blakeley's Red Gum open forests;
- Baradine Red Gum open forests;
- Mallee (especially Green Mallee);
- Broombush; and
- *Themeda* grasslands.

The distribution and remaining area of these forest types have not been mapped in detail. This will be necessary before their status can be accurately assessed. In particular there has been very little effort in defining Cypress old growth forest and no work done to define old growth remnants of Ironbark or other eucalypt communities.

3.2.3 Plant Species Diversity

There are many plant species lists for parts of the bioregion, but no single list has been compiled for the whole region. The majority of records in the Wildlife Atlas (NPWS Database) are of threatened or ROTAP (Rare or Threatened Australian Plants) species (Briggs and Leigh, 1996). Other lists that exist include one provided by the Australian Society for Growing Native Plants (Armidale) for the Pilliga with 389 species, the various lists for the Warrumbungle National Park, and some of the vegetation surveys undertaken in Western Regional Assessment. There are also many plant lists being collated for the environmental impact assessment of many projects in the region.

Of the species known for the bioregion, there are 4 endangered and 12 vulnerable plant species listed by the Threatened Species Conservation Act 1995. The distribution of records of these threatened and ROTAP species across the bioregion is shown on Map 12. To the south of Narrabri the distribution of these species is mostly clustered, with records generally focussing places like the Goonoo Forest, the south-west corner of the bioregion around Dubbo, the Warrumbungles, Pilliga Nature Reserve, around Gunnedah, Goulburn River National Park and the Narrabri / Mount Kaputar area. Records are generally scattered across the area to the north of Narrabri. There is no evidence of any 'hot spots' with an exceptional aggregation of threatened species, but the density of sampling is low.

The endangered plant species (TSC) are:

Digitaria porrecta,
Euphorbia sarcostemmoides,
Indigophera efoliata,
Lepidium hyssopifolium.

The vulnerable plant species (TSC) are:

Bothriochloa biloba,

Cadellia pentastylis,
Dichanthium setosum,
Eriostemon ericifolius,
Goodenia macbaronii,
Homoranthus darwiniodes,
Lepidium aschersonii,
Rulingia procumbens,
Swainsona murrayana,
Swainsona recta,
Thesium australe,
Ziera ingramii.

Genetic diversity of plant species within the bioregion has not been investigated for many species however observations suggest that this would be justified for some. For example there is likely to be genetic variation in Plains Grass *Austrostipa aristiglumis* and Brigalow *Acacia harpophylla* because of their vast spatial distribution within the Brigalow Belt South (Beckers, pers com).

The proportion of introduced species, and their distribution and abundance within the bioregion has not been determined. In particular the distribution and abundance of declared noxious weeds across the bioregion, rather than within council boundaries, is necessary to properly assess the threat of weed invasion into natural environments within the bioregion.

3.3 FAUNA

The biodiversity of animal species within the BBS has been poorly assessed with very few systematic surveys having been carried out. Of those that have, most have been restricted to the Pilliga and Goonoo area, between Dubbo and Narrabri. The most comprehensive survey was that carried out for State Forests by Date & Paull (1995). They conducted a detailed survey of the Cypress forests between 1993 and 1995. Their survey covered mammals, birds, frogs and reptiles. As a part of this study, a survey of the bats of these forests was conducted by Coles (1995). Prior to these major surveys, trapping had been carried out near Baradine. During these surveys the Pilliga Mouse *Pseudomys pilligaensis* was first collected (Fox and Briscoe, 1980), which were followed up to find more specimens (Lim, 1992). Allomes *et al*, (1982) also carried out a limited survey of the Pilliga State Forests and adjacent areas but with limited results. More recently, bats were again surveyed at 30 sites in the Pilliga Nature Reserve by Parnaby and Hoye (1997).

As outlined in the preliminary fauna survey report for this project, there have been a variety of other records ranging from Museum surveys, bird atlas surveys (NSW and RAOU Atlases), the National Parks Association survey of the Goonoo forest, records of the Dubbo Field Naturalists and Conservation Society, and a variety of historical bird records. Although it is not within the BBS, the only fauna survey to target Brigalow was carried out by Ellis and Wilson (1992) in the Brigalow belt north-east of Bourke.

A total of 6 endangered and 52 vulnerable vertebrate species recorded from this bioregion are identified under the Threatened Species Conservation Act (1995). In the discussion of species diversity for each taxon, it must be noted that the total number of species and the number of threatened species is recorded from the NPWS Wildlife Atlas database. This is not a complete data set, but is the most comprehensive to date.

3.3.1 Invertebrates

Very little is recorded about the invertebrate diversity within the bioregion. Invertebrates are integral in the functioning of ecosystems. They form a large component of the biodiversity within a system, and can have a major impact on economics, both beneficial and harmful. Insects are a key resource in the food chains of any ecosystem, being utilised by all vertebrate taxa, and they play an important role in enhancing the decay of plant and animal material.

Some invertebrate research has been carried out within the bioregion. 88 sampling sites fall in the region as part of a survey of the common army worm *Mythimna converta* (*Lepidoptera*) undertaken by McDonald *et al,* (1995). Dr Robyn Gunning (Department of Agriculture, Tamworth) also undertakes regular invertebrate surveys throughout the region. Results of these surveys need to be considered in this assessment of the bioregion.

3.3.2 Fish and Other Aquatic Fauna

At this stage no list of the fish species found within the BBS has been compiled and this information should be sought from the Department of Fisheries. The NSW Fisheries and Rivers survey (Harris and Gehrke, 1997) which included sites within this bioregion, and numerous independent studies, confirm anecdotal information that native fish are in serious decline and that populations of introduced species such as the European Carp *Cyprinus carpio* and the Mosquito Fish *Gambusia spp* have increased significantly. Both have been recorded in streams in the Pilliga Forest. Mosquito Fish are listed as a threatening process in the BBS under the Threatened Species Conservation Act (1995).

The likelihood that continued clearing of vegetation will alter flow regimes and aquatic habitats in the streams and rivers of the bioregion needs to be assessed. Alteration to flood timing and the way in which water crosses a floodplain has the potential to affect both feeding and spawning of fish, along with many other plant and animal species. Containment of floods, isolation of wetlands, and the reduction of carbon inputs from floodplains to the lowland rivers all have a detrimental impact on river ecology.

Healthy riparian vegetation is an essential element for the proper functioning of aquatic ecosystems. Removal of the bank vegetation reduces bank stability, reduces the sediment trapping capacity of the bank, decreases the nutrient input into streams, and reduces an important food and habitat source for aquatic fauna. The invasion and infestation of introduced weeds, such as willows and *Lippia*, have a significant impact on aquatic environments.

3.3.3 Amphibians

Eighteen species of amphibian have been recorded in the Wildlife Atlas from the bioregion, with a total number of only 168 records for all species. This very low sampling effort must be considered when assessing the importance of habitat for the amphibian fauna in the region.

Map 13 shows the distribution of all records of amphibians, with the records of threatened species highlighted. The only records of threatened species are within a 50 km buffer zone. The sparsity of records in general suggests that this is more likely to be a result of inadequate sampling than of an absence of such species from the bioregion. Most records are from the Dubbo area in the south-west, the Warrumbungles, Coolah Tops and Gunnedah. There are substantially more records of frogs along the higher country to the east of the BBS than the lower areas to the west.

Only two scheduled frog species are predicted to occur in the BBS, the Green and Golden Bell Frog and the Yellow-spotted Tree Frog.

3.3.4 Reptiles

Sixty eight species of reptiles, including 1 endangered and 1 threatened species, have been recorded in the BBS, with a total number of only 984 records for all species.

The distribution of all reptile records for the bioregion is shown on Map 14, with the records of threatened species highlighted. The greatest intensity of reptile sampling has been in the Warrumbungles, Coolah Tops and Mount Kaputar, with a number of records from the Goonoo area and throughout the Pilliga. There are very few records from the area north of Narrabri. There are also large areas with no records, especially within the Pilliga and Liverpool Plains provinces. Because of the relatively small number of records, no generalisations about their distribution are possible.

Only 3 scheduled species are recorded within the bioregion, with others in the surrounding area, particularly to the east. These, and the scheduled species predicted to occur in BBS are:

Five-clawed Worm Skink,
Pale-headed Snake,
Underwoodisaurus sphyrurus,
Western Blue-tongue Lizard.

3.3.5 Birds

Within the BBS, 281 species of birds have been recorded in the Wildlife Atlas, with a total number of 18 261 records for all species.

The distribution of bird sightings recorded in the Wildlife Atlas is shown on Map 15. While there are many more records for birds than for the other vertebrate taxa, the distribution of these records reflects of the presence of population centres, National Parks, and the Pilliga and Goonoo Forests. There are relatively few records for the Northern Outwash and Northern Basalts provinces. In the Liverpool Range the records are almost exclusively from the National Park. The southern half of the Liverpool Plains has very few records as does the Liverpool Plains south of Gunnedah and the Pilliga south of Tambar Springs.

The records of the scheduled bird species in the bioregion are closely correlated with the distribution of all sightings (Map 16), suggesting that the more intensive sampling of some areas has led to the detection of rarer species. The Goonoo Forest stands out as a particularly important area for threatened species as does the Warrumbungle National Park. In the larger area of the Pilliga Forest there is a scattering of records throughout.

The scheduled bird species which have been recorded in the bioregion, and those which are predicted to occur in the BBS are listed below. Sightings of these species in the Goonoo and Pilliga Forests are marked as E for East Pilliga State Forest, W for West Pilliga State Forest and G for the Goonoo Forest.

Australasian bittern
Black bittern
Black-necked stork
Magpie goose
Freckled duck
Blue-billed duck

Cotton pygmy-goose
Osprey
Square-tailed kite (G)
Black-breasted buzzard
Grey falcon
Red goshawk
Malleefowl (E,G,W)
Brolga
Australian bustard
Plains wanderer
Bush thick-knee (curlew) (E, W)
Mongolian plover
Sanderling
Painted snipe
Black-tailed godwit
Squatter pigeon
Red-tailed black-cockatoo
Glossy black-cockatoo
Pink Cockatoo
Superb parrot (E,G,W)
Swift parrot (E,G,W)
Turquoise parrot (E,G,W)
Barking owl (E)
Powerful owl
Masked owl (E,G,W)
Eastern grass owl
Pink Robin
Regent honeyeater (E,G)
Painted honeyeater (E,G,W)
Pied honeyeater
Gilberts Whistler (G)

The Malleefowl population in the Goonoo Forest is of particularly important as it is the most significant eastern population of this semi-arid species still remaining. Historical records show populations in the Pilliga, and recent sightings confirm Malleefowl still exist in the Pilliga. Records of Malleefowl suggest they existed further east in the past, but the Pilliga and Goonoo areas always represented the eastern edge of their distribution. The Goonoo population is now completely separated from all others because the Goonoo is an isolated patch of forest with no connections to other areas within the range of this species. These large birds require large areas to maintain a viable population, particularly an isolated population such as in the Goonoo which has little potential for immigration. Estimates of home ranges range from 1.7 to 4.6 sq km, with some individuals having been recorded to travel long distances at certain times of the year. The greatest threats to this species have been, and remain, land clearing, grazing, fire and introduced predators, especially foxes (Marchant and Higgins, 1993).

The status of bird species in the sheep and wheat belt extending from the western portion of the central tablelands to the boundary of the western division, an area with 70% to 90% of the native vegetation cleared, has been investigated by Reid (1999) for the NSW NPWS. This study focused on woodlands and open forests, with some areas of grassland, mallee and other shrublands included. While there was little data from the BBS used in Reid's study, the results apply as it is a part of the Temperate Agricultural Zone. Sixty bird species were defined as most at risk (classified as threatened, declining or of special concern). These represent the old Australasian and Gondwanan lineages rather than the more recent arrivals like cuckoos, corvids, finches swallows, and true warblers. The groups of most concern include owls, dryland waders,

pigeons, parrots and cockatoos, treecreepers, wrens, thornbills, robins, babblers, quail-thrushes, whistlers and finches.

Remnant areas of native vegetation such as the Goonoo and Pilliga Forests represent extremely significant habitat patches for all these groups of bird species in this significantly cleared landscape. Selective removal of timber can also have a significant and detrimental impact on the survival of some species. It is critical to ensure the retention of all food sources at all times of the year. For example, the two main ironbark species in these forests do not flower at the same time of the year. The summer flowering is essential for many species, in particular the summer migrants using the area. While the winter flowering species are necessary at a time when food resources are generally limited. Proper assessment of these issues requires much more detailed analyses.

Some genetic studies of birds have been conducted in NSW, including a study of the diversity of the Crimson Rosella. This species has been divided into 3 races on the basis of genetic diversity, of which *Platycercus elegans elegans* exists within the bioregion. A study of the genetics of different vertebrate taxa is recommended within the bioregion. Common species which have, over time, become isolated through fragmentation of the landscape may be diverse at the genetic level. Under JANIS (1997), such diversity is required to be conserved.

3.3.6 Mammals

Eighty two species of mammal have been recorded in the Wildlife Atlas within the bioregion, with a total number of 1 631 records for all species. Records of mammals in the bioregion are illustrated on Map 17. The greatest density of records is from the south-west area around Dubbo and in the Goonoo Forest, the Warrumbungle National Park, the Pilliga, Coolah Tops and Mount Kaputar, which are the areas of most surveys and general observations. There are very few in the remainder of the Liverpool Range province, Pilliga south of Tambar Springs, Liverpool Plains north of Gunnedah. There is a scattering of records north of Narrabri. Almost a quarter of all these records are of the Greater Glider.

The distribution of threatened mammal species throughout the bioregion is illustrated on Map 18. There is a large number of records of threatened species, but the majority are of Koalas *Phascolarctos cinereus* with 245 observations. The majority of these are within the Warrumbungles, the Pilliga Forest and the area around Gunnedah. In addition to the Koala records, there have been several bat species recorded especially in the Pilliga. As with the other vertebrate taxa, there do not appear to be any other localities of particular importance for threatened mammal species, apart from Goonoo and Pilliga Forests.

The scheduled mammal species which have been recorded and those predicted to occur in the Brigalow Belt South in New South Wales are listed below. Sightings of these species in the Goonoo and Pilliga Forests are marked as E for East Pilliga State Forest, W for West Pilliga State Forest and G for the Goonoo Forest. # denotes species presumed extinct.

Bilby (#)
Western barred bandicoot
Spotted-tailed quoll (W)
Eastern quoll
Brush-tailed phascogale
Stripe-faced dunnart
Koala (E,G,W)
Eastern pygmy possum (E,G)
Squirrel glider (W)
Yellow-bellied glider

Rufous bettong (E)
Brush-tailed bettong (#)
Eastern hare-wallaby (#)
Black-striped wallaby
Bridled nailtail wallaby (#)
Brush-tailed rock-wallaby
Pilliga mouse (E,W)
Gould's mouse (#)
Long-haired rat
Yellow-bellied sheathtail bat (E,G,W)
Greater long-eared bat (E,W)
Common bent-wing Bat
Great pipistrelle
Greater broad-nosed Bat
Large pied bat (E,W)
Little pied bat (E,G,W)
Large-footed mouse-eared bat

Koalas are the best known of the scheduled mammal species in the bioregion and are highlighted by some local councils such as Gunnedah. The greatest concentration of Koalas is within the Pilliga Forest and Gunnedah areas. The tree species preferred by Koalas in this area are Blakely's Red Gum, River Red Gum and White Box, with Pilliga Box, Poplar Box, Narrow-leafed Ironbark and Rough-barked Apple used occasionally. Koalas also require special interaction trees in addition to their food trees.

In the past these tree species have been considered non-commercial, but current changes to the timber industry such as insultimber and charcoal mining may increase the detrimental impact on these species significantly. In the wildfires of late 1997, it was notable that there were many Koalas burnt and injured due to the fire burning more ironbark and box communities in the Pilliga than the Cypress Pine forests, which have been the main focus of forestry activity in recent times. This suggests that a shift in product demand by the forestry industry will incur a greater risk to Koala populations, along with other threatened species utilising the hardwood communities.

Opportunities and the time required to successfully regenerate suitable habitat are very difficult to estimate in the BBS. Germination, tree recruitment and growth rates of the forests in this drier, less productive and less predictable climate are much less than the forests of the east coast.

The Eastern Pygmy-possum *Cercartetus nanus* has only recently been listed as a vulnerable species because it appears to have a very patchy distribution and a low abundance within its broad distribution. From all existing studies in NSW, there were only five localities where more than 10 observations have been made. The Pilliga forest is one of these 5 locations.

The Pilliga Mouse is still known only from the Pilliga Forest and although there has been more success at trapping these mice recently, the preferred habitat is still essentially undefined. It is thought to prefer a mixed eucalypt forest, and a shrubby understorey with logs and litter on the ground. The common tree species are Blakely's Red Gum, Narrow-leafed Ironbark and Pilliga Box. It is highly likely that this species will be highly susceptible to detrimental impacts on groundstorey vegetation. The logging of ironbark and cypress forests in the Pilliga scrub areas will disturb groundstorey vegetation.

The potential for other mammal species to remain undetected in these remnant forests has been highlighted by the presence of a species of Hopping Mouse *Notomys*, which is known from

hairs found in a fox scat and footprints (Date, pers com). Hopping Mouse footprints have also been observed in the Goonoo Forest (Peet, pers com). As yet this elusive species has not been trapped.

Like the wheat-belt bird species, there are many mammal species which have declined in number as a result of the extensive clearing and fragmentation of habitat in this agriculturally intensive part of Australia. Many of these species are not considered threatened, but may reflect a more serious general decline. When historical records are analysed, the Common Brushtail Possum *Trichosurus vulpecula* for example, a species generally thought to be common, has suffered a serious decline in this bioregion. An analysis of records for species such as the Yellow-footed Antechinus *Antechinus flavipes* would be valuable for an understanding of the health of habitats in this area. Regional extinction's also need to be analysed.

Analysis of genetic diversity within the bioregion has been carried out for the Little Mastiff Bat *Mormopterus planiceps* which has been found to have 3 forms, the south-eastern form which is found in BBS, and the central and south-western form. The Greater Long-eared *Bat Nictophilus timorensis* is a vulnerable species which also has 3 forms with a similar distribution as for the Little Mastiff Bat. The Common Wallaroo *Macropus robustus* has several sub-species, with two in NSW, both of which are found in the BBS (*M. robustus robustus*, and *M. robustus erubescens*).

3.3.7 Feral Vertebrate Species

Feral vertebrate species in the BBS include cats, foxes, dogs, rabbits, goats, pigs, horses, various birds and fish. They are widely distributed throughout the bioregion as illustrated on Map 19. They are generally listed and acknowledged as a threat to native flora and fauna species, and plant communities. In the Pilliga and Goonoo cats and foxes are particularly destructive.

4. LANDUSE AND LAND MANAGEMENT

4.1 HUMAN OCCUPATION

4.1.1 Aboriginal Occupation and Land use

An adequate assessment for determining areas of Aboriginal cultural sensitivity for those areas that will be subject to logging within the Brigalow Belt South bioregion is required in order to maximise conservation outcomes for Aboriginal heritage. The method of investigation currently employed for assessing Aboriginal heritage in the Goonoo and Pilliga State Forests, should be the adopted as the framework for further assessments of the broader bioregion.

Information, which would assist with the assessment of Aboriginal cultural values for the remaining areas of the BBS, is available for some of the northern areas. Compared with the southern areas of the bioregion where data is scant, due to the rapidity of European colonisation, the northern regions have greater potential for information to be made available.

A comparison of the results of the Goonoo and Pilliga State Forest assessments thus far, highlights the variation of factors that exist for understanding where areas of cultural significance occur. The investigation of the Goonoo State Forest has relied greatly upon the recent location and recording of Aboriginal sites and what limited knowledge of the forest has been made available through Aboriginal consultation and historical archival research.

In addition, results of the investigation indicate that both forests are subject to separate landscape processes, which greatly effect efforts in locating areas of sensitivity. The Pilliga also contains a proportionately greater wealth of information of Aboriginal socio-economic and cultural history but, as a result, is more complex to compile information adequately in the short time made available. Other state forests and crown lands within the bioregion will also have varied environmental and historical differences.

Aboriginal stakeholder groups associated with the subject areas of the bioregion will also vary. To date, there have been eight Aboriginal organisations involved in the consultation and assessment process for the Pilliga State Forest alone. However, additional time and resources will need to be considered in order to allow Aboriginal community Elders to participate more effectively in the assessment process.

The information made available from the Aboriginal communities is critical for addressing the concerns of those communities associated with the forest areas. Of particular importance for the community Elders is the recording of Aboriginal sites that exist within the subject areas, including those vegetation communities which have high cultural association, and to preserve and conserve the landforms where these remaining elements of Aboriginal culture exist. The

importance of obtaining cultural information from community Elders is accentuated by the fact that they are the last known primary source of traditional knowledge for the region.

4.1.2 European settlement of the bioregion

The explorer John Oxley travelled through this region in about 1818 and returned to Sydney praising the virtues of the land for agriculture. It was not until about 1824 that squatters moved into the region. Squatting licenses were issued in 1836 for grazing activities. In the Dubbo region small farms and wheat farming began to emerge in the 1860s. It was in the 1880s that cropping began to expand dramatically, and with it the clearing of the forests and other native vegetation. Drought conditions existed at this time.

European settlement of the Liverpool Plains began in the 1830s. The land was mostly used for sheep and cattle grazing until the 1880s. At that time cropping became an important land use on the lighter textured red soils of the foot slopes, and clearing began. Major changes of rural land use have taken place in the BBS since the early 1950s when the technology became available to cultivate the heavy textured self mulching soils which had previously been used for grazing. Cropping on the foot slopes was progressively abandoned, and replaced by grasslands used for grazing.

Forest reserves were first dedicated in 1877 and 1878, when ‘management’ of the forests first began. This management was determined by the proposed use of the timber rather than by any understanding of the process of ecological succession or the impact of silvicultural activities, grazing and dry conditions on ecological processes. Changes in condition of the land were already being observed by the early land holders and by travellers like Sturt and Mitchell. After 1870 there are many descriptions of changes, and most were very aware of the damage being done to the rangelands well before the invasion by rabbits or the effects of drought (Mitchell, 1991).

4.2 LAND TENURE AND OTHER USES

4.2.1 Land Use

Land tenure mapping for the bioregion needs to be reviewed, in particular Crown Lands need to be accurately mapped and assessed. Mapping of state forests and reserves is shown in Map 20.

Freehold land (85% of the bioregion, 44 375 sq km)

Cropping and grazing/pastoral activities dominate agricultural activities, and freehold lands, in the bioregion. Cropping includes both dryland and irrigation farming producing a variety of crops including cereals, oil seeds and cotton. Pastoral production has an average of 1.01 head of cattle per hectare. Sheep production occurs widely through the bioregion.

Forestry (11% of the bioregion, 5 772 sq km)

There are many small forest reserves and flora reserves in addition to the two larger areas of forest managed by NSW State Forests in this bioregion. The small reserves are not discussed here.

Goonoo Forest: This forest of 62 836 ha was first dedicated in 1917 and the first management plan prepared in 1920. It is classified as a western hardwood forest with the dominant tree species being Narrow and Broad leaf Ironbark, Western Grey Box, Black Cypress Pine, Red Gum, Green Mallee, Bull Oak and White Cypress Pine. This description takes no account of the considerable variation in plant communities, plant species and topography across the forest. There are 8 nearby forest reserves but the MDBC M305 woody layer analysis demonstrates that there are no large areas of native forest and woodland adjoining these forests on freehold or leasehold land.

A summary of the management history in this forest by State Forests indicates that there has been a long history (> 100 yrs) of ironbark harvesting which has resulted in the regrowth forest now present. Ironbark has been harvested in this forest for sleepers, sawn timber, fencing, and firewood products. In addition to these, ironbarks are proposed to be mined for charcoal.

Records indicate that the hardwood yield since 1918 has been 6 231 m^3 per annum. This average extraction rate provides no indication of the variation in intensity during the period of harvesting (apart from the peak rate of 6 231 m^3 per annum between 1942 and 1957). There is no indication of the size or species of tree harvested, the rotations within the forest or the regeneration potential in relation to climatic conditions post harvesting. A minimal rate of harvesting has taken place in recent times.

State Forests of the Pilliga: There are 26 state forests incorporated into this area, covering an area of 389 589 ha. Most of these were dedicated in 1917. They are classified as White Cypress/Ironbark/Western Hardwood forests with the dominant tree species being White Cypress Pine, Narrow and Broad leaf Ironbark, Pilliga Box, Bimble Box, Black Cypress Pine, Red Gum and Bull Oak. There are 12 neighbouring state forests ranging in size from 79 ha to 9 803 ha. Some National Park estate is nearby, but this is almost entirely of different vegetation types.

As in the Goonoo, there has been logging in this forest for a long time, varying in intensity and impact. At present it services 6 sawmills, harvesting 52 000 m^3 per annum of cypress sawlogs and about 6 000 to7 000 m^3 per annum of ironbark. The White Cypress timber resource appears to have increased as a result of silvicultural treatment, however the impact on other tree species has not been assessed.

Crown lands (1.4% of the bioregion, 733 sq km)

Use of other crown lands is varied. An important part of this estate is the stock routes and stock reserves, many of which contain valuable remnants of native vegetation. They are extremely important as corridors for the movement of fauna between larger remnants. Some crown lands are used for grazing.

Conservation reserves (2.6% of the bioregion, 1 330 sq km)

Conservation reserves, as defined by the IUCN categories I – IV occupy 2.6% of the bioregion. The NPWS estate is listed below. The areas given are of the entire reserve although some cross the bioregional boundary.

Brigalow Park Nature Reserve - 202 ha
Pilliga Nature Reserve - 80 239 ha

Warrumbungle National Park - 21 533 ha
Binnaway Nature Reserve - 3 699 ha
Weetalibah Nature Reserve - 612 ha
Careunga Nature Reserve - 469 ha
Coolah Tops National Park - 10 578 ha
Coolbaggie Nature Reserve - 1 793 ha
Dapper Nature Reserve - 998 ha (includes area within SW Slopes bioregion)
Gomilaroi Nature Reserve - 113 ha
Goulburn River National Park - 70 102 ha (includes area within Sydney Basin bioregion)
Mt Kaputar National Park - 36 816 ha (includes area within Nandewar bioregion)
Wongarbon Nature Reserve - 99 ha
Cedar Brush Nature Reserve - 190 ha
Wingen Maid Nature Reserve - 1 077 ha (includes area within Sydney Basin bioregion)
Gilgai Flora Reserve No. 41 - 2 400 ha
Ginee Belah Flora Reserve No. 133 - 50 ha
Sand Money Flora Reserve No. 133 - 75 ha
Lanes Mill Flora Reserve No. 40 - 690 ha
Yearinan Flora Reserve No. 130 - 40 ha
Yarindury Flora Reserve No. 61 - 49 ha

Mining

The Department of Mineral Resources (DMR) will provide a list of areas of interest. There are 28 known mineral deposits within the bioregion

Tourism

This is largely based in towns and the major National Parks such as Warrumbungle and Coolah Tops National Parks. There is an increasing interest in the use of the wilderness area of the Pilliga.

Apiary industry

The Brigalow Belt South contains major beekeeping forest systems for NSW apiarists, with areas of the Pilliga State Forests and the Goonoo Forests being some of the most significant honey producing areas in NSW. Due to the location of the forests with regards to surrounding vegetation communities, apiary activities in the region are overwhelmingly of a commercial nature. Narrow-leafed ironbark, Western Grey Box, Yellow Box, River Red Gum and Blakeley's Red Gum are listed as important species for the apiarists (Sommerville, 1998 and 1999).

In the BBS, there are approximately 750 apiary permit sites on state forests, of 1.61 sq km each, and approximately 50 apiary permit sites on national parks land, of approximately 2 sq km each. Thus, in the bioregion there were approximately 800 apiary sites utilised in 1999, not include sites on crown and private lands.

The average number of hives on any one permit site in the Pilliga and Goonoo State Forests, or on National Parks lands, is 136. Therefore, in 1999 there were an estimated 108 800 hives operating in the forests and reserves of the bioregion. It is estimated that the average gross value of honey production produced by these hives is approximately $7.8m per annum. In addition to this, there is a considerable amount of money made through the exportation of bee stock to other countries.

Any negative impact on the tree species being utilised, and thus on the production of honey would have significant economical impacts on a large regional industry.

4.3 LAND CONDITION

4.3.1 Land Degradation

Several land degradation factors have been highlighted for the Brigalow Belt South bioregion. These include water salination, dryland salinity, scalding, sheet and rill erosion, gully erosion, mass movement, wind erosion, induced soil acidity and soil structure decline. All these factors have been mapped as part of the Soil Conservation Service Land Degradation Survey (SCS 1989). It is essential to note that the data used in this analysis is now ten years old, and the proportion of the land affected by these factors is likely to have increased.

River and Groundwater Salinity

Salinity levels in the rivers of the bioregion and the likely salination of groundwater has been outlined in Section 2.3 of the MDBC's Salinity audit (1999). Some details from the Salinity audit are outlined here.

Trends in the changing levels of salt concentrations in rivers within the Murray-Darling Basin have indicated that the salt concentrations for the rivers overlapping with the bioregion are increasing by 2-4 tonnes per km per annum in the Castlereagh / Macquarie systems, and < 1 tonne per km per annum in the Namoi River.

The amount of salt mobilised to the land surface in the Murray-Darling Basin is predicted to double from 5 million tonnes annually in 1998 to 10 million tonnes annually in 2100. The predictions are significantly greater for the river catchments within this bioregion. The predictions for the tonnes of salt mobilised to the land surface per year for these river catchments are shown in the Table 3.

The economic impact of rising watertables and salinity has been estimated for parts of Victoria and New South Wales including the Little and Talbragar Rivers in the Upper Macquarie catchment. The total cost for the Talbragar River catchment was estimated to be $1.6 million, with the major costs for repairs, maintenance and preventative works being borne by farmers.

Table 3. Estimated salt loads for the Murray-Darling Basin (MDBC, 1999).

	Year			
	1998	2020	2050	2100
Macquarie River	240 000	490 000	660 000	790 000
Castlereagh River	161 000	180 000	320 000	330 000
Namoi River	60 000	100 000	120 000	150 000
Gwydir River	7 000	20 000	50 000	60 000
Macintyre River	80 000	80 000	80 000	80 000

Dryland Salinity

Dryland salinity occurs on lands which are outflow zones for saline water tables. It is caused primarily by the clearing of native forests. It occurs most severely south of bioregion, but there are some areas mapped within this bioregion (SCS, 1989). The total annual national cost of dryland salinity has been estimated to be $270 million (Martin and Metcalf, 1998).

Dryland salinity has been studied in detail in one catchment within the BBS, on the Liverpool Plains. In this area changes in regional hydrology have caused rising water tables and salination. Over 195 000 ha of highly productive agricultural land (16% of the region) is estimated to be at risk over then next 10 years unless preventative action is taken. The main cause for the shift in the hydrological balance of the catchment that has led to the dryland salinity problems is believed to be the extensive clearing of the heavily timbered hills and ranges (Greiner, 1997).

The study of the Liverpool Plains catchment and its dryland salinity has incorporated the best available information required for integrated catchment management, the objective being to improve the management of dryland salinity through integrated catchment scale modeling. The models suggest that to reduce the recharge problem, the alluvial fans should be converted to perennial pasture rather than continuing to be used for cropping. Land use change may be necessary on the sedimentary hills to manage the local break of slope salinity. Other land use options being investigated include agro-forestry and cotton (Evans and Johnson, 1998, Greiner, 1997).

Scalding

Scalds form when the surface soil is removed by wind or water erosion, exposing a more clayey sub-soils which are relatively impermeable to water. It is formed mostly on texture contrast soils, or the floodplains of rivers or prior streams. There are some areas of moderate and severe scalding within the bioregion.

Sheet and Rill erosion

This is a problem which is most severe in cultivated land. The report includes the Mendooran and Gunnedah areas as being among the worst affected in the state. Sheet and rill erosion occurs mostly on cropping land, but can also occur on grasslands (SCS, 1989).

Gully Erosion

In NSW gully erosion is extensive on the western slopes, particularly the northern cropping belt between Moree, Tamworth and the Queensland border.

Mass Movement

Most mass movements occur on the coast but there are isolated occurrences west of the Great Dividing Range. The Liverpool Range is one of these areas where mass movement can occur.

Wind Erosion

The most severe wind erosion problems are found on the cultivated areas of light sandy and loamy soils, on the central and south-western slopes. This includes a band extending south from Dubbo as well as other areas further north in the bioregion.

Induced Soil Acidity

Soils in NSW have become acidified from a variety of causes including the use of acidifying nitrogen and elemental sulphur fertilisers, and the use of legumes to fix nitrogen. Some areas in the bioregion have the potential to become acid (SCS, 1989).

Soil Structure Decline

In 1987 the MDBC estimated the cost of this form of land degradation in the basin to be $144 million per year, much more than for any other form of degradation studied at that. It is a moderate problem in the northern tablelands and north-west slopes with the potential to become more serious (SCS, 1989).

4.3.2 Weeds and Feral animals

The invasive impact of weeds and the destructive effect of feral vertebrates has not been assessed on a landscape level for the BBS, although their impact at a more local level may be known. They are both factors with a potentially significant impact on the survival of plant communities, and fauna and flora species. A bioregional assessment of actual and potential impact is required.

4.4 LANDSCAPE MANAGEMENT

Until recently the land has been managed at a very local level with the farm unit being the basic unit of management. The introduction of Catchment Management Committees, SEPP 46, and the Native Vegetation Conservation Act (1997) which requires the formation of Regional Vegetation Management Committees (RVMC), has resulted in a broader focus for many land management issues, in particular the clearing of native vegetation. These committees include representatives from the managers of freehold land, government agencies and the community, and are an important step towards effective land management at the landscape level.

Applications for clearing freehold land are now necessary to fulfil the requirements of Native Vegetation Conservation Act (1997) and a Regional Vegetation Management Plan developed specifically for the region. There has been a reduction in the rate of clearing since the introduction of SEPP 46 (Benson, 1999). Through the Regional Vegetation Management Plans any approvals to clear should be considered at a landscape level rather than in terms of the farm unit.

4.5 CURRENT CONSERVATION MANAGEMENT

4.5.1 Formal Reserves (IUCN Categories I-IV)

The NSW conservation estate within the BBS includes national parks, nature reserves and flora reserves. National parks and nature reserves are administered by the NSW NPWS and flora reserves are administered by NSW State Forests.

National Parks and Nature Reserves

Land set aside as national parks and nature reserves have the conservation of biodiversity as their primary objective, but differ in the types of recreational activities that are allowed within them. Nature reserves have restricted entry and are managed primarily for their conservation values. National parks can be managed to include visitation for educational and recreational purposes.

Management of each of these reserves is set out in a Plan of Management prepared through a process of public consultation and review. The plan sets out the conservation values that are contained within the reserve, the threatening processes that are operating, and the management actions that are needed to protect the conservation values. These plans specifically address the issues of feral animal control and weed control. The plans also state the ecologically appropriate fire regimes needed within the reserve. They detail the mechanisms to manage the appropriate uses of the reserves by the community for scientific, cultural, educational and recreational purposes.

Flora Reserves

These lands are declared within State forests to protect their unique flora values. They are managed under the Regional Forest Management Plans. These plan set out the types of activities that can be conducted within the flora reserve, and specify the long term management objectives for the reserve.

4.5.2 Off-park Conservation

A number of formal mechanisms are available as incentives for landholders to set aside land for conservation purposes. These include Voluntary Conservation Agreements (VCA) and Wildlife Refuges under the National Parks and Wildlife Act (1974), and Property Management Agreements under the Native Vegetation Conservation Act (1997). Where these arrangements include covenants that are binding on the title of the land, they are recognised as a IUCN Class V reserve. Financial benefits associated with these mechanisms include land rate rebates and financial assistance with fencing and other management.

A further range of measures are currently being implemented for conservation needs outside the reserve system. These have arisen in response to the enactment of the Threatened Species conservation Act (1995) and the Native Vegetation Conservation Act (1997). The TSC allows for Joint Management Agreements to be entered into by Government agencies to protect threatened species and their habitats. Local Government authorities are required to report on the implementation of actions that are being undertaken as a result of Recovery Plans for species within their boundaries. The NVC sets a legislative basis for regional planning for the protection of native vegetation. Regional planning must consider the requirements for ecologically sustainable development and the protection of biodiversity. Management activities recommended by Benson (1999) to be incorporated into the Regional Vegetation Management Plans include fencing of remnants, identification of key grassland sites, maintenance of corridors and connectivity, enhancement of significant remnants, use of fire for management (eg. for the control of dense *Callitris* regrowth), the enhancement of riparian vegetation, and the restoration of riparian vegetation.

The practical implementation of the requirements of these Acts is being determined through the strategic planning work of the Catchment Management Committees, Regional Vegetation Management Committees and the Department of Land and Water Conservation.

The development and implementation of Ecologically Sustainable Forest Management (ESFM) is an integral component of the Comprehensive Regional Assessment (CRA) or a Regional Forest Agreement (RFA) processes in NSW. These determine forest land use and management on the basis of cultural heritage, natural heritage, and social and economic information, in a process of negotiations with all major stakeholders. The National Parks and Wildlife Services Threatened Species Unit are has the responsibility to negotiate licenses and conservation protocols for the management of threatened species within State Forest managed lands.

5. CONCLUSIONS

The Brigalow Belt South bioregion covers a large area and is very complex and diverse with a high degree of climatic, topographic, geological and ecological variation. Superimposed on this is a history of extensive change during the last 150 years with most of the land cleared of trees, native grasslands grazed and cultivated, and the hydrology of the area significantly altered with disruption of water flow to river systems and into underground aquifers.

In the light of this scenario and of the fact that clearing is continuing on freehold, conservation requirements need to be determined using the most detailed environmental information available and assessed in the light of the nationally recognised conservation criteria. The gaps in information available for this assessment are outlined below, as is an assessment of the bioregion using the conservation criteria.

5.1 FURTHER WORK REQUIRED

5.1.1 Abiotic environment

Climatic modeling

A better understanding of the climatic parameters on at local scales is necessary. The influence of climate on ecological variation needs to be defined. There is a significant amount of variation from north to south, east to west, and with altitude. On a broader scale the bioregion is an overlap zone between the Bassian and Eyrean influences. The relevance of this needs quantification. Effects of changes through time have been highlighted for the Gunnedah area (Crapper, Fleming and Kalma, 1997). The effect of change at a geological time scale needs to be assessed in relation to changes brought about through land clearing and agriculture

Hydrology

The hydrology of the bioregion, including the subsurface water has only been studied in detail for one catchment, the Liverpool Plains. Other work on the changes to river flows as a result of damming and extractive use needs to be examined. The impact of water use on the biodiversity of aquatic biota needs to be assessed. While there have been studies of environmental flows for rivers such as the Namoi and Gwydir, they are limited in extent and need to incorporate more detail from the broader catchment.

The impact of additional clearing on the subsurface water flows into the Great Artesian Basin and on local smaller sub-surface basins needs to be properly assessed.

Geology

There is a need to expand the coverage of geology and soil mapping (and attributes) where little or no data is available, and develop mapped coverages of soil and geology at a scale useable for habitat modeling.

Mapped soil attributes (including depth, fertility water holding capacity and stability) are fundamental, essential and urgently required as inputs to any modeling process, such as modeling of individual plant and animal species distributions, modeling of extant and pre-European vegetation, and modeling of site quality and associated wood resource attributes.

IBRA and Province boundaries

Verification of the Morgan and Terrey (1992) province definitions needs verification. The boundary of the bioregion itself also needs verification. These boundaries are based on topography, soil, geology and vegetation communities, and they need to be refined using data at a finer scale. This would enable bioregional conservation to be accurately assessed.

5.1.2 Biodiversity

Pre-European vegetation

A detailed environmental assessment to predict the extent of pre-European vegetation is essential. At present the sustainable harvesting approach practiced by State Forests in the Goonoo and Pilliga assumes the scenario of a grassy woodland outlined by Eric Rolls as the basic definition of the local environment (van Kempen, 1997). Three detailed papers noted in this overview cast serious doubt on Rolls' conclusions. An ecological study is necessary which incorporates the historical observations by early travelers through this country, observations recorded by Rolls and van Kempen for particular points in time, detailed data from the forests at present, an analysis of ecological succession, data on climatic cycles through the last century and an analysis of the effect of destructive events such as rabbit grazing, selective logging, silvicultural activities, clearing and cultivation of native vegetation, stock grazing and fire.

Centers of endemism

It is evident that there are endemic species of flora and fauna in the bioregion. This is due, in part, to the transitional climatic zone between wet coastal and arid inland areas. The extent and causes of endemism in the BBS compared to other bioregions needs to be assessed and analysed.

Refugia

In an environment such as the BBS, where so much vegetation has been altered or cleared, the values of isolated patches of vegetation, in terms of being refuges, are high. There are areas in the BBS, such as the Goonoo and Pilliga Forests which represent the last remaining large patches of contiguous forest. These are likely to be important refuges to many fauna and flora species within the bioregion. These areas need to be assessed and evaluated for their importance as refuges.

Vegetation assessment

Further vegetation assessment in the bioregion is required. As outlined in this report, some assessment has been made in the bioregion of vegetation communities, but it is clearly insufficient for a detailed analysis of the status of vegetation in the region.

In addition to the pre-European vegetation modeling required, a number of assessments need to be initiated and/or continued:

- continued effort in the collection of quadrat data for modeling is required. It would also be possible to produce a better definition of broad plant communities with a comparative analysis of the various descriptions that currently exist, if plot-based sampling of those communities were undertaken;
- further API mapping should be undertaken in order to map all forested lands both within and outside public lands. It is essential that vegetation is mapped across the entire bioregion, in order to model species habitats and pre-European vegetation;
- a detailed assessment of ironbark communities across their range is required, as well as in the BBS if these communities are to be targeted for charcoal production;
- an assessment of the conservation status of plant communities is required. To date only three communities have been listed under the TSC Act, however most communities have not even been considered because their vulnerability has not been assessed;
- a full list of plant species is needs to be compiled for the bioregion;
- the definition of plant communities in terms of the overstorey requires assessment. The understorey and tree seedling recruitment must be included. This will ensure that the floristic and structural differences between particular forest types on grazed land and in state forests and reserves are highlighted;
- the proportion of introduced plant species when compared with total number of plant species has not been determined and the distribution and impact of declared weeds has not been assessed. This assessment should be undertaken; and
- modeling of forest ecosystems and non-forest ecosystems across areas where mapping, either plot-based or API, do not adequately cover the area.

Fauna assessment

The continuation of fauna surveys and assessment is critical for the evaluation of conservation priorities. Assessments of the fauna in the bioregion to date are indicating a number of issues which would benefit from further investigation. For example, the decline in numbers of common species of possums. A comprehensive assessment of the bioregion, with regards to fauna requires that:

- invertebrates be assessed, either from existing information, or from existing and new information. At the very least, a list of genus/species should be compile for the bioregion;
- fish and aquatic habitats have not been assessed for this report. An aquatic assessment should be undertaken in the bioregion;
- continued targeted fauna species should be conducted in order to evaluate the conservation status of threatened species in the BBS;
- systematic fauna surveys need to be undertaken. Few systematic surveys have been conducted in the bioregion. A systematic survey design allows for the modeling of species habitat and species distributions; and
- a detailed analysis of vertebrate species which are known to have gone extinct, and other which may have been lost from the bioregion needs to be carried out.

5.1.2 Land use and land management

Accurate information reflecting land condition is needed as the current mapping information is crude and more than ten tears old. More recent detailed information does exist for some land condition characteristics. This information needs to be assessed in the context of the bioregion. This information should be available from the Department of Land and Water Conservation.

A land use assessment and mapping at a fine resolution for primary production in the bioregion is needed. For example, the changes in land use recommended by the hydrological studies of the Liverpool Plains suggest that land capability, in terms of ecological sustainability, needs to be carefully considered. This will be particularly important for decisions regarding the introduction of agro-forestry within that landscape. The broad scale land capability mapping by DLWC is inadequate for this assessment.

Information from the Department of Agriculture about measures being undertaken to prevent, reduce and restore land degradation needs to be obtained and assessed. Despite the fragmented and degraded nature of the native vegetation in the bioregion, clearing is continuing. The amount of existing and proposed land clearing should be assessed for the bioregion.

There is a clear need in the bioregion to accurately map land tenures. Crown land mapping is inadequate and likely to be erroneous as it exists.

Cultural Heritage

Cultural heritage values need to be continued to be assessed. There is a need to link cultural values with flora and fauna values within the bioregion. Aboriginal peoples need to be further involved in the assessment of lands for conservation value, with links being developed between cultural and natural heritage.

5.2 CONSERVATION CRITERIA AND TARGETS

The IUCN recommends that 10% of each major ecosystem type be conserved. At present there is only 2.6% of the NSW portion of the Brigalow Belt South bioregion conserved.

5.2.1 The JANIS criteria

These criteria require:

- protection of 15% of pre-1750 plant communities;
- protection of all rare or endangered ecosystems;
- protection of at least 60% of remaining vulnerable ecosystems;
- maximisation of the area of high quality habitat for rare, vulnerable or endangered species, high species diversity, refugia and centres of endemism to enable viable populations to be maintained;
- protection of 90% of wilderness areas;
- all old-growth needs to be conserved where it is rare or depleted, otherwise 60% should be conserved. The definition of oldgrowth needs to be addressed west of the Great Dividing Range to incorporate mature aged forest; and
- CAR and reserve design principles need to be considered;

- JANIS recognises that a CAR reserve system, in many regions, will need to include private land. The two key priorities for protection in private forests are; to ensure comprehensiveness, and to meet the special needs for rare, vulnerable and endangered species or ecosystems.

5.2.2 The National Forest Policy Statement

Amongst the goals and specific objectives outlined in National Forest Policy Statement (NFPS) is the declaration that there should be a sound scientific basis for sustainable forest management and resource use. This is not yet possible in the Brigalow Belt South bioregion. In particular, the use of Eric Rolls' interpretation of the original forest types present in the Pilliga is not based on a sound scientific analysis. There are also clear gaps in the availability and quality of existing biotic and abiotic data.

Under conservation in the NFPS, it states:

> *The protection of the full range of forest ecosystems and other environmental values is fundamental to ecologically sustainable forest management. It entails the maintenance of the ecological processes that sustain forest ecosystems, the biological diversity associated with forests (particularly endangered and vulnerable species and communities) and the protection of water quality and associated aquatic habitats.*

These environmental values and the impact of the proposed harvesting protocols have not yet been fully scientifically assessed for the forests in the bioregion.

The forest descriptions by State Forests of the Pilliga and Goonoo state that these are regrowth forests. Without a detailed assessment of the location, timing and extent of logging in these forests, and the misinterpretation of the original vegetation of the area, it is not possible to assert that the whole forest is 'regrowth'. The term 'old growth' forest has been defined for the east coast forests but not for these inland forests. The determination of an ecologically supportable definition is required before protection criteria are developed.

Ecologically sustainable forest management and codes of practice need to be addressed. Growth rates of the *Eucalypt* species in the Pilliga and Goonoo have not been assessed sufficiently to allow sustainable harvesting protocols to be developed. The growth rates are likely to be irregular and closely related to the variation in rainfall events. They are also likely to be lessened by the low nutrient status of the sandstone derived soils when compared with areas of nutrient rich soils. This assessment can not be based on reasonable estimates until detailed climate modeling of the bioregion is completed.

5.2.3 Conservation of biodiversity

A Comprehensive, Adequate and Representative (CAR) reserve system for forests requires that reserves should be designed to incorporate, as far as practical, all elements of biodiversity. In the National Strategy for the Conservation of Australia's Biological Diversity (1996), biological diversity is considered at three levels:

- genetic diversity;
- species diversity; and
- ecosystem diversity.

The NSW Biodiversity Strategy (1999) also addresses these issues.

The priority for reservation of a forest ecosystem is dependent on how much remains relative to its initial distribution and its vulnerability to threatening processes. The principle of comprehensiveness requires that the reserve system should sample each forest ecosystem within a region. Reservation to conserve biodiversity needs to focus on the continued viability of species and ecosystems rather than the attainment of area based targets.

High priority landscapes are landscapes that are least reserved, and most at risk of clearing. Land that has the lowest capability for agricultural purposes are most often found in reserves. This is reflected in the bioregion. It is important to include productive lands, and non-rugged lands into conservation areas in order to represent all plant and animal communities.

The presence of corridors linking patches of important habitat is essential to allow for adequate movement of species, and to prevent the loss of genetic diversity. These linkages are being generally recognised as essential in Vegetation Management Plans being developed in association with landholders in the region. Corridors also need to be an integral component in the assessment of conservation requirements. Linkages from the Warrumbungles to the Pilliga and between rivers such as the Talbragar and Castlereagh, are important.

5.3 CONSERVATION STATUS

The conservation status of the Brigalow Belt South bioregion is significantly lower than that recommended by the nationally established criteria (JANIS, 1997). At present 2.6% of the BBS is conserved (IUCN categories I - IV) within the formal reservation system. The majority of the conservation reserves are in the south-western areas of the bioregion and do not contain a representative sample of a large proportion of the ecosystems or plant communities

In the Queensland portion of Brigalow Belt South bioregion, 110 of the 167 (67%) regional ecosystems defined for the bioregion are currently represented in the reserve system (Sattler and Williams, 1999). Only 2.2% of the Queensland portion of the bioregion is conserved. The greatest deficiency in the reserve network is the low representation of the relatively productive landscapes, especially the alluvial, the tertiary clay plains and the pastoral lands in the moister eastern parts of the bioregion (Sattler and Williams, 1999). In their analysis, each of the 163 regional ecosystems defined for the Queensland portion of the bioregion have been described, with their conservation status defined as follows:

- endangered - less than 10% of pre-European extent remaining intact across the bioregion in Queensland or its distribution has contracted to less than 10% of its former range;
- of concern - 10 - 30% pre-European extent remains in an intact condition in the bioregion in Queensland, or in some cases they were in this class because of some land degradation present;
- of no concern at present - over 30% of pre-European extent remains in an intact condition, includes ecosystems with floristic diversity largely intact and little or no degradation.

This type of analysis cannot be undertaken for the NSW portion of the Brigalow Belt South until detailed definitions of ecosystems or plant communities have been completed. It is also important to note that the flora reserves within the NSW State Forest estate are not representative of the predominant forest communities in the Pilliga or the Goonoo, but are small patches of plant communities with no merchantable timber.

In their analysis of the conservation priorities in NSW, Pressey *et al*. (in prep) found the Brigalow Belt South bioregion to be of the third highest priority for reservation, with a large percentage of high priority landscapes due to the large proportion of the bioregion cleared. The

South-west Slopes had the highest priority followed by the Nandewar bioregion. Pressey *et al* also found that native woody vegetation occupies larger percentages of land with more rugged terrain and/or lower inherent land use potential (Figure 3). This analysis was replicated for the Brigalow Belt South bioregion. Within the BBS, woody vegetation is biased towards lands with higher ruggedness and/or lower inherent land use potential. Similar analyses show reservations are biased towards areas of higher ruggedness and/or lower inherent land use potential.

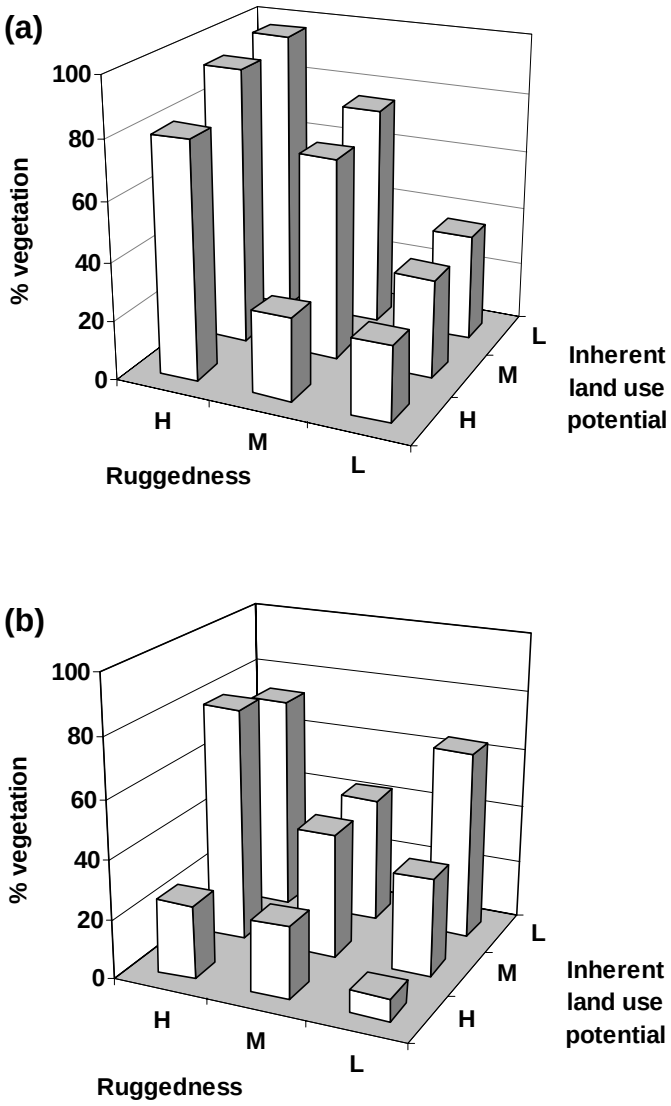

Figure 3. Vegetation in relation to ruggedness and inherent land use potential. H, M, and L indicate high, moderate and low classes; columns represent each combination of ruggedness and inherent land use potential; (a) percentages of land area with woody vegetation in the Central and Eastern Divisions; (b) percentages of land area with woody vegetation in the Brigalow Belt South bioregion.

5.3.1 Conservation Values of the Pilliga and Goonoo Forests

Within the bioregion the Pilliga and Goonoo Forests represent the two largest blocks of remnant vegetation in a landscape which has less than a quarter of its native vegetation still remaining. Other values of these forests are detailed in the specific project reports but include:

- identified wilderness in the Pilliga;
- important recharge areas for the Great Artesian Basin;
- further clearing would exacerbate dryland salinity in the area;
- represent important areas for carbon recycling;
- areas with probable 'old growth' not surviving in any other location;
- represent significant refugia within the bioregion;
- contain genetic diversity;
- contain a high diversity of threatened species;
- unknown levels of biodiversity, due to limited sampling effort; and
- habitat for species populations which have become isolated due to the fragmentation of forest in the bioregion.

Due to the importance of these remaining woodlands in the Central West and the preliminary nature of this assessment, the NPWS believes that any decisions made on resource use need to be precautionary and not jeopardise the biodiversity or ecological integrity of the forests. There is ample evidence to suggest that reserves are necessary in the bioregion and the State Forests provide the only viable option for large reserves to be developed. Thus reserve decisions must be made alongside any resource decisions.

6. RECOMMENDATIONS

A number of recommendations can be drawn from this report. These are likely to be reflected in each of the projects undertaken in Stage 1. These recommendations are outlined here. No processes are yet outlined on how these recommendations might be implemented in Stage 2.

Systematic fauna surveys

The systematic survey of fauna in all ecosystems is required if we are to adequately assess the status of fauna species populations within the bioregion. A systematic approach allows for greater scientific rigor, which can then be utilised in fauna species distribution and habitat modeling.

To date very little has been surveyed using a systematic approach. The majority of surveys have been targeted at areas or species of known value. Many of the species records within the region have been opportunistically collected, without detailed information on site/location attributes. Without such data these records are of limited value for conservation assessment through modeling.

Targeted fauna and flora surveys

Further targeted surveys need to conducted. Targeted surveys aim to assess species which are rare and/or cryptic, and are often missed using a systematic approach. Threatened species tend to be an indicator of high biodiversity, or the lack of it, and should be continued to be surveyed for on a broader and more comprehensive survey of the bioregion.

Ecosystem / Vegetation mapping

Whilst the Western Regional Assessment has to date produced vegetation mapping for a number of state forest and reserve areas, it is deficient in that all vegetated areas need to be mapped, across private lands as well as public, if we hope to accurately assess the conservation significance of areas within the bioregion. It is further critical to have this baseline data in order to model pre-European vegetation, which is critical for the setting of conservation targets as outlined by JANIS (1997).

Through the Regional Vegetation Management Plans any approvals to clear should be considered at a landscape level rather than in terms of the farm unit.

Plot-based flora sampling

There is a obvious need to continue the assessment of flora using plot-based sampling methods. The effort to date is patchy and clearly insufficient for the comprehensive assessments needed. There are gaps in areas, ecosystems and tenures. There are also serious temporal concerns about the sampling design, with a need to sample in the spring.

Assessment of conservation criteria

While there are general conservation principles that apply to all terrestrial ecosystems, it is essential that bioregion specific principles and criteria be developed and applied. This has been recognised in Australia by all State governments, and the Federal government, through their support of an Interim Biogeographic Regionalisation of Australia (Thackway and Creswell, 1995).

This bioregionalisation has provided the framework for Regional Forest Agreements, based on the notion that significant differences occur on a regional basis in environmental, ecological, biological, social and economic conditions.

There is a need to assess the adequacy of existing conservation criteria which apply to the bioregion. Criteria need to address the characteristics of the bioregion, reflecting the unique values and processes which influence the environment within individual regions.

C-Plan development and integration for the west

Whilst the time frames for Stage 1 of the assessments did not allow information which was adequate to be collated and integrated into C-Plan, C-Plan remains to be the accepted standard for all CRA/RFA processes to date and should be used to assess the conservation values of the bioregion. C-Plan allows data to be used for reserve selection in an interactive and systematic approach, incorporating representation and comprehensiveness, as outlined by JANIS.

A project needs to be put together to support and develop C-Plan for use in the bioregion

Species habitat and distribution modeling

Predictive modeling is a resource-efficient tool for conservation planning and reserve design. It is fundamental to meeting many of the WRA objectives.

The overall objective would be to identify areas of habitat significance for vertebrate fauna and vascular flora in the Brigalow Belt South. The areas of habitat significance to be identified fall into two categories:

i) modelled distributions of priority species categorised into habitat quality classes (including high quality habitat); and
ii) other areas of habitat significance (such as areas of high biodiversity and natural refugia).

Ecosystem modeling and Pre-European Vegetation modeling

JANIS Criterion 1, 2 & 3 - As a general criterion, 15% of the pre-1750 distribution of each forest ecosystem should be protected in the CAR reserve system; where forest ecosystems are recognised as vulnerable, then at least 60% of their remaining extent should be reserved; all remaining occurrences of rare and endangered forest ecosystems should be reserved or protected by other means as far as is practicable.

A project needs to be endorsed that incorporates existing data (if appropriate), and new data, into the development of a model of the pre-1750 distribution of all forest and non-forest ecosystems within the Brigalow Belt South bioregion.

Modeling should also be developed to extrapolate ecosystems and vegetation communities to all forests which have been unmapped for vegetation characteristics, which includes predominantly private tenures. The API project can map broad vegetation groups for such previously

unmapped forests, and this information can be used in conjunction with modeling procedures to produce a complete forest type map for extant forests in the Brigalow Belt South bioregion.

The complete vegetation map for all extant forests in the bioregion will be an important input to various other assessments, including fauna modeling, forest ecosystem mapping and old growth assessment.

Evaluation of ecosystems and other surrogates for biodiversity

The effectiveness of mapped forest ecosystems, or in their absence derived forest ecosystems, or landscape mapping, as surrogates for biodiversity should be assessed for the bioregion. Furthermore, some assessment should perhaps be focused at determining the coarseness or resolution of data needed to adequately assess conservation values within the bioregion.

Soil, landscape and geology mapping

The expansion of geology and soil mapping (and attributes) coverages should be undertaken where little or no data is available.

Mapped soil attributes (including depth, fertility, water holding capacity and stability) are fundamental, essential and urgently required as inputs to any modeling process (eg. modeling of individual plant and animal species distributions, modeling of extant and pre-European distribution of vegetation communities, and modeling of site quality and associated wood resource attributes).

Hydrological study

There is a need to assess the hydrological systems and pathways within the bioregion if we are to assess the impacts of clearing , or further alteration of native vegetation. There are reasonable concerns already noting the effects of clearing on the hydrological systems. These need to be further assessed.

Assessment of aquatic habitats

Aquatic vertebrates are continuously overlooked when assessing the conservation values of areas or regions. These taxa have tended to be dropped from assessments. There is a need to survey and assess aquatic systems for fish and turtles, as well as the frogs, as there are known threatened species of aquatic vertebrates within the region. Assessment of the aquatic ecosystems could further be extended to include an assessment of macro-invertebrates.

Crown lands mapping

Crown lands need to be mapped in order to assess the conservation values which may be contained within them. These areas are important resources in such a fragmented landscape, and are readily converted to conservation areas. The mapping and assessment or crown lands, in conjunction with state forests and reserves, will allow the assessment and need for off-reserve conservation management.

Genetic diversity assessment

There is a need to identify ecological groupings of taxa that exist as evolutionarily discrete populations, or cryptic species, by comparing the extent of geographic structuring of genetic diversity among flora and fauna from a variety of ecosystems.

This might allow some determination of whether major topographic and environmental barriers have affected long-term gene flow within the bioregion.

A genetic assessment of a range of species could provide insights into the historical population processes that have operated across the landscape, and how these vary among differing ecosystems. It could provide insight into the spatial scales appropriate for considering habitat protection of different taxa in order to adequately represent genetic diversity.

Ecological Sustainable Forest Management

A project should be developed to consider management options for:
- priority species;
- old growth forest;
- forest ecosystems;
- areas of high biodiversity;
- centres of endemism;
- natural refugia; and
- species poorly correlated with forest ecosystems.

The ESP Act and TSC Act provide the primary criteria for consideration of threatened species, populations and ecological communities. In reviewing and formulating management strategies and protection requirements, it will be necessary to include an assessment of the adequacy of existing measures in protecting State and Commonwealth listed species. It will also be important to coordinate the assessment approach for the biological and ecological data collection and review of management strategies within and across the bioregion to reflect conservation requirements across the entire range of priority species.

Cultural Heritage

Cultural heritage values need to be continued to be assessed. There is a need to link cultural values with flora and fauna values within the bioregion. Aboriginal peoples need to be further involved in the assessment of lands for conservation value, with links being developed between cultural and natural heritage.

Community communication and awareness

There is a clear need to involve and inform the community in and of the project and process. As well as including and utilising the community in the process, one possible outcome could be the publication of an ancillary report, designed specifically and aimed at local communities to give them the information collected in the assessment.

There is also a clear need to develop a project that communicates with landholders. This would be critical if we are to sample flora and fauna across tenures. The process and outcomes need to be explained to landholders to alleviate their concerns surrounding NPWS and threatened species legislation.

Monitoring project

A possible and worthwhile project would be to use a subset of the flora and fauna plots and sites, across a range of environments, and set them up as monitoring sites. These could then be monitored every 3 months over the 2-3 years the assessment runs.

This would give us an indication of the effectiveness of sampling effort. If, and I would expect, the monitoring plots have a far greater species richness and abundance, this information allows us to quantify the accuracy and effectiveness of our sampling effort over the whole region. We are then able to make valued judgements about how the areas need to be evaluated in the future.

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8. APPENDIX

LIST OF EXISTING DATA LAYERS

Coverage	Dataset Name	Description
Data Supplied to RACD		
Climate	rain25	average annual rainfall grid
	temp5	average annual temperature grid
Indices	rough_3	roughness grid of BBS supplied by HO (standard deviation of a 3x3 window around the cell)
	rough_5	roughness grid of BBS supplied by HO (standard deviation of a 5x5 window around the cell) NB this grid is more useful than the one above as the terrain is fairly flat and the roughness needs a larger are over which to calculate differences
Boundaries	bbs only.shp	Brigalow Belt South Bioregion shape taken from the IBRA shapfile
	buffer of whole bbs 50km.shp	50km buffer of the NSW portion of BBS
Wilderness	declared 11 1999.shp	Wilderness Act Declared wilderness - NPWS
	enviro aust wilderness proj 1999.shp	Provisionally Identified Wilderness (PIW) - EA
	identify.shp	PIW - NPWS (includes PIW over Pilliga Nature Reserve and surrounds)
Geology & Lithology	mdbc_lithology.shp	MDBC Lithology layer
	soil.shp	Soils shape supplied by HO
Vegetation	woody25buff	MDBC Woody / Non-woody grid cut to the 50km buffer of BBS
	comwollnp_55	Wollemi National Park veg mapping
	Binnaway NR.SHP	Binnaway Nature Reserve veg mapping
	Goobang NP.SHP	Goobang Natinal Park veg mapping
	Kirramingly NR.SHP	Kirramingly Nature Reserve veg mapping
	PILLIGA.SHP	Pilliga Nature Reserve veg mapping - partially superseed by recent API mapping
	Weetalibah NR.SHP	Weetalibah Nature Reserve veg mapping
	coolahforest_z55.shp	SFNSW forest typing over all of Coolah Tops NP and Warung State Forest
	coona shire veg.shp	Whiteheads mapping / modelling of vegetation within Coonabarabran shire
	east walgett shire veg dlwc ver2.shp	DLWC veg mapping covering the portion of East Walgett shire that intersect with the BBS
	hunter dlwc bj z55.shp	DLWC veg and land use mapping covering the hunter shire
	hunter dlwc z z55.shp	DLWC multi-attribute veg mapping covering the hunter shire
	m305 in buffer.shp	MDBC M305 structural and floristic layer cut to the 50km buffer of BBS
	sivertsen in bbs.shp	Sivertsen's wheatbelt veg mapping
	towarri_z55.shp	Towarri Nature Reserve veg mapping
	typ55.shp	Combined RN17 and Lindsay typing over selected forests in brigalow belt south. Used mainly as a guide as to the types in Pilliga State Forests. Biased towards production forest types

	vegcomgrnpmung_z55.shp	Veg mapping of Goulburn River NP and Munhorn Gap NR
	vegcommannr_z55.shp	veg mapping of Manobalai Nature Reserve
	vegetation communities.shp	veg mapping of Mt. Kaputar National Park
New / Substantially Modified Vegetation	ib_tenure_all	Communities containing ironbark across the Brigalow Belt south Bioregion divided by the tenure in which they occur
	ibwoodyeric	Communities containing ironbark across the brigalow Belt south Bioregion
	lindsay_grouped_types.shp	Lindsay typing of the pilliga state forests. These have been grouped by NPWS to form more meaningfull categories with less duplication than the original
	goonoo_api_grouped_v1.shp	WRA API mapping over Goonoo State Forest and Coolbaggie Nature Reserve. NOTE this is still being updated and may soon be superseeded
Flora	atlas_flora.shp	Flora records taken from NPWS Wildlife Atlas
	existingplots_bbs_ver2.shp	NPWS flora sites from surveys done before latest WRA surveys
	licenced_flora.shp	Flora records from various surveys around BBS, sources include SFNSW and UNE. This data is licenced to NPWS
	newsites_55.shp	
Fauna	atlas_fauna.shp	Fauna records taken from NPWS Wildlife Atlas
	licenced_fauna.shp	Fauna records from various surveys around BBS, sources include SFNSW and UNE. This data is licenced to NPWS
	nationalparksinbbs.shp	NPWS estate cut to BBS
	stateforestinbbs.shp	SFNSW estate cut to BBS
Cultural Heritage	cultural_all.shp	All located cultural heritage sites in the BBS, including recent Goonoo and Pilliga survey results
	goonoo geomorphological.shp	geomorphological units over Goonoo SF, Binnaway Nature Reserve and surrounds
Extra Data		
Vegetation	Eastern Bushlands Database	
Indices	bbs_fill	25m grid cell DEM coving the 50 km buffer of BBS
	bbs_dir	25m cell size flow direction grid coving the 50 km buffer of BBS
Geology & Lithology		MDBC Relief
Tenure	Crown Lease.shp	needs to be checked
	Crown Reserves.shp	needs to be checked
	Crown Other.shp	needs to be checked
	Crown Lands (under Moratorium).shp	needs to be checked
Administration	DL&WC Admin Regions.SHP	DLWC admin boundaries
	Rural Lands Protection Boards.SHP	RLPB boundaries
	catchment managment committies.shp	CMC boundaries
		RVC boundaries
	Aboriginal Land Council Areas.SHP	Local Aboriginal Lands Councils boundaries
	local government areas.shp	LGA boundaries
	Morgan & Terry Bioregions.SHP, provinces.shp	Bioregions and Provinces (IBRA, Morgan & Terry)
Geographical Features	major roads in nsw.shp, Minor Roads in NSW.shp	Roads (major & minor)
	Major Roads in the West.SHP, Minor Roads in the West.SHP	Roads (major & minor for the west only)
	Rivers Major.SHP, Rivers Minor.SHP	Rivers (major & minor)
		Rivers (major & minor for the west only)
	Major Towns.shp, locations in nsw.shp	Towns (major & minor)
	Builtup.shp	Built-Up Areas
	Railways.shp	Railways
	Lakes.shp	Lakes
	Swamps.shp	Swamps
	Bores.shp	Bores
	Areas of Inundation.SHP	Areas of Inundation
	Catchments.SHP	Catchments
	various	100k Map Sheets
	various	250k Map Sheets
	various	Landsats

Biota	latest version available through Atlas	Fa: Australian Museum records
(site data available from Infomaker)	latest version available through Atlas	Fa: CSIRO records
	latest version available through Atlas	Fa: RAOU bird records
	latest version available through Atlas	Fl: Canberra Herbarium TS records
	latest version available through Atlas	Fl: Melbourne Herbarium TS records
	latest version available through Atlas	Fl: Queensland Herbarium TS records
	latest version available through Atlas	Fl: RBG TS records
	latest version available through Atlas	Fl: UNE Herbarium TS records
	latest version available through Atlas	NPWS Atlas of NSW Wildlife records
	latest version available through Atlas	ROTAPs
	various	Bioclims for Scheduled Species, KTPs & ECCs
Cultural Heritage		Archaeographic Regions of NSW
		Archaeographic Regions & Systems of Central NSW
Others	NPA key.shp	NPA Key Conservation Areas