NSW WESTERN REGIONAL ASSESSMENTS

Nandewar

Biodiversity Surrogates

Vegetation

Final Report
September 2004

Project NAND06

RESOURCE AND CONSERVATION ASSESSMENT COUNCIL

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Nandewar

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Department of Environment & Conservation

Conservation Assessment and Data Unit

Dr Julian Wall

Project Number Nand06

RESOURCE AND CONSERVATION ASSESSMENT COUNCIL

INFORMATION

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Contents

List of Figures

List of Tables

Preface

The New South Wales Government recently initiated a Western Regional Assessment (WRA) of rural NSW to guide future planning and encourage partnerships to protect the environment. The initiative involves a number of government agencies - including State Forests of NSW (SFNSW), Department of Environment and Conservation (DEC), Department of Infrastructure, Planning and Natural Resources (DIPNR) and Department of Mineral Resources (DMR) - as well as local and regional stakeholders.

The WRA process considers environmental, economic and social values of forest and non-forest land systems focusing on conservation, land management and regional planning. The aim of the WRA is to deliver the following outcomes:

- adequate and complete core data layers to inform regional land use planning and conservation and resource management;
- enhanced partnerships between core agencies and interest groups concerned with natural resources and ecological sustainability, to increase sharing of information and to reduce duplication; and
- identification of a comprehensive, adequate and representative network of protected and managed areas for the Central and Western Divisions.

The Nandewar WRA follows that previously undertaken for the Brigalow Belt South Bioregion. The Nandewar WRA area encompasses parts of the Nandewar and New England Tablelands bioregions (within NSW only) which had not been previously assessed in either the Comprehensive Regional Assessments or the Brigalow Belt South WRA. Nandewar WRA projects include Aboriginal heritage and community consultation, biodiversity surrogates, conservation criteria, geology, mineral prospectivity, landscape conservation, socio-economics and wood resources.

This project constitutes the Vegetation Mapping and Survey component of the Nandewar WRA Biodiversity Surrogates Project (which also includes the Nandewar Fauna project) and is funded by Resource and Conservation Assessment Council (RACAC) and DEC. The project was undertaken by the Conservation Assessment and Data Unit (CADU) of DEC in Coffs Harbour, with input from the GIS Research and Development Unit of DEC in Armidale. The project has been overseen by a Technical Working Group comprising representatives from DEC, DIPNR and SFNSW.

Acknowledgment is due to members of the project's Technical Working Group, with particular thanks to Doug Binns (SFNSW) and Dr Graham Watson (DIPNR).

To all individuals and organisations who allowed use of their botanical data and particularly: The Royal Botanic Gardens, Tim Curran and Dr John T. Hunter.

For contribution to the implementation of this project, special acknowledgment is due to the following people:

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Simon Ferrier and Glenn Manion of Armidale GIS Unit for provision of generalised dissimilarity models, model integration and software development.

Finally, to all Nandewar landholders who granted DEC staff and contractors permission to enter their properties to map and survey native vegetation.

Project Summary

This report describes a native vegetation mapping and survey project undertaken in the Nandewar Western Regional Assessment (WRA) Study Area, which occupies about 2.7 million hectares in the north-west slopes area of NSW.

Key outputs of this project include a database of native flora, a map showing the current and predicted distribution of native vegetation communities, a profile of each community, and an overview of conservation and reservation status of each community at the landscape level. Final maps should be used with some caution at the local scale.

Completion of the final vegetation map required five separate tasks:

1. aerial photographic interpretation (API), in which vegetation patterns were delineated and defined across the landscape;

2. flora survey, in which botanical information was collected at numerous plots across the landscape (about 700 plots were sampled for the WRA, and 2 200 were available from previous work);

3. derivation of vegetation communities, achieved through statistical analysis of botanical plot data;

4. derivation of a probability surface for each community, undertaken by modelling its plot data against various environmental surfaces, then constrained by API; and

5. integration of constrained models into a final composite vegetation map (extant and predicted).

Over 1 600 native and 370 exotic taxa were recorded from 2 908 flora plots in Nandewar. White box (*Eucalyptus albens*) and white cypress pine (*Callitris glaucophylla*) were commonly recorded, and are regarded as the signature canopy species for the region.

A total of 113 vegetation communities were derived from plot data, then described and mapped across Nandewar. They include several widespread ironbark types, stringybark types, and box-gum types, and various restricted types including rainforest, shrubland and spinifex woodland. Native vegetation occupies just over one million hectares, or 38% of the total Study Area (including areas assessed in previous CRAs and WRAs). The remaining area has been cleared largely for grazing, with some cropping on the major river flats.

Of the 113 communities described, 23 are closely related to one of eight endangered ecological communities (EECs) listed under the *Threatened Species Conservation Act 1995* (*TSC Act*) at the time of writing. These are referred to as ‘potential EECs’, and include some of the box-gum and dry rainforest units. An additional 19 communities are considered regionally uncommon, based on their restricted range, uniqueness or perceived habitat value.

Compared to other areas of NSW, a relatively small proportion of the Nandewar WRA Study Area is included in the formal reserve system, with 15 reserves occupying 2.6% of the area. However, this includes parks and reserves that have already been assessed in previous CRAs and BBS WRA. When these previously reserve areas are excluded, the area of formal reserves in Nandewar covers just 0.9%.

One third of native vegetation communities in the whole of the Nandewar Study Area do not occur in the reserve system, including 11 potential EECs and 11 regionally uncommon types. These communities are represented to a limited extent on other types of public land (eg. Crown reserve and state forest), where formal or informal reservation is possible in the near term. However, major conservation initiatives will need to focus on freehold land, and to a lesser extent Crown leasehold land, which contain well over 80% of the native vegetation in Nandewar.

Acronyms and abbreviations

AMG	Australian Map Grid
API	Aerial Photograph Interpretation
BBS	Brigalow Belt South
CAR	Comprehensive, Adequate, Representative
CRAFTI	acronym for the Aerial Photograph Interpretation project undertaken for Comprehensive Regional Assessments
DEC	Department of Environment and Conservation (the National Parks and Wildlife Service is now part of DEC)
DEM	Digital Elevation Model
DIPNR	Department of Infrastructure, Planning and Natural Resources
DLWC	Department of Land and Water Conservation (now part of DIPNR)
EEC	Endangered Ecological Community
ESU	Environmental Stratification Unit
GCP	Ground Control Point
GIS	Geographic Information System
GPS	Global Positioning System
IBRA	Interim Biogeographic Regionalisation of Australia
JVMP	Joint Vegetation Mapping Program (for BBS)
NP	National Park
NR	Nature Reserve
NVMP	Native Vegetation Mapping Program
RACD	Resource Assessment and Conservation Division (of DIPNR)
RBG	Royal Botanic Gardens
ROTAP	Rare or Threatened Australian Plants

WRA	Western Region Assessment
asl	above seal level
mm	millimetres
ha	hectares
100K	1:100 000 mapscale

Glossary

Extant distribution	the modelled distribution of a vegetation community across parts of the landscape which retain native vegetation cover.
Fiducial point	a corner point of an aerial photograph, shown as a small ω symbol.
Map unit	vegetation community as represented spatially. A total of 108 map units were derived for Nandewar.
Potential EEC	a map unit derived for this project which, based on its floristic and structural composition, is likely to comprise areas of existiing EEC as listed under the *TSC Act.*
Predicted distribution	the modelled distribution of a vegetation community across the landscape, including extant and cleared areas. Shows which vegetation community has the greatest probability / potential to occur in a given environment.

i Introduction

Regional vegetation maps provide an invaluable tool for conservation planning because they enable assessment of the extent and reservation status of different vegetation units and provide key data for other initiatives such as forest connectivity, timber availability and land-use mapping. Over the past decade, the NSW Government has supported and used vegetation mapping as a major part of regional assessments. Vegetation maps were influential in developing Regional Forest Agreements in coastal NSW in the late 1990s, which aimed to establish a comprehensive, adequate and representative formal reserve systems whilst achieving long-term timber supply.

More recently, the NSW Government has supported vegetation mapping within the framework of two Western Regional Assessments (WRAs), in the Brigalow Belt South (BBS) bioregion, and the Nandewar Study Area. This project concerns vegetation mapping and survey for Nandewar Western Regional Assessment Study Area. It is part of the larger Biodiversity Surrogates Project, which also includes a fauna assessment. The major objectives are:

- to produce a mapped coverage of the current extent of native vegetation in Nandewar using aerial photograph interpretation (API), full-floristic survey data and agreed modelling techniques;
- to produce a mapped coverage of predicted vegetation in Nandewar using full-floristic survey data and agreed modelling techniques;
- to fill gaps in the distributional knowledge of plants of conservation significance in Nandewar through compilation of existing data; and
- to provide vegetation coverages, maps and point locality data for incorporation into the Landscape Conservation project and options development phases of the Nandewar WRA.

Detailed vegetation analysis for this project covered the whole includes the Nandewar Bioregion (within NSW), adjacent areas to the east and south not considered during coastal Comprehensive Regional Assessments (CRAs), and other adjoining areas which contributed relevant supporting information (eg. API and full-floristic site data). Inclusion of the latter areas was advantageous to this project as the additional floristic data were able to contribute to derivation, classification and mapping of Nandewar vegetation communities.

The reporting and map production extent was confined to the RACD-defined Nandewar Study Area, which included areas of Nandewar not previously assessed in either the coastal or western assessments, and for bioregional context only, all other previously assessed areas of the Nandewar bioregion occurring in NSW.

This report is separated into six chapters;

- Chapter 1 provides a map of the study region (separating the analysis extent and the Study Area reporting extent), and presents a descriptive overview of its biophysical features;
- Chapter 2 describes the API component of the project. API pathways and data capture methodologies used by DEC and DIPNR are discussed, integration with other mapped datasets described, and summary results of the final layer presented;
- Chapter 3 discusses all aspects of flora survey and data management. Existing datasets are listed, stratification and site selection discussed, and field survey method described. Compilation of a significant plants database for Nandewar is also discussed.
- Chapter 4 describes the approach used to derive vegetation communities for Nandewar from analysis of flora data. A final list of communities is presented and a detailed description of each community provided in a separate Appendix;
- Chapter 5 describes the various steps associated with derivation of the final extant and predicted vegetation maps. Preparation of environmental surfaces, modelling options, model constraints using API, final model selection, model integration and checking techniques are each discussed.
- Chapter 6 compares the vegetation types derived for Nandewar to those derived in other studies which encompass Nandewar (eg. statewide vegetation classifications) or are adjacent to Nandewar (ie. BBS groups and coastal forest ecosystems). For each vegetation type, information on predicted and extant area is provided, as well as area within the current formal reserve system.

At completion of this project, a number of key datasets were available in ArcView format, including a point locality layer of flora records in Nandewar, and a final vegetation coverage showing the current and predicted spatial extent of the 108 vegetation communities in Nandewar.

1 Study Area

1.1 BACKGROUND

The Nandewar Western Regional Assessment (WRA) Study Area (**Figure 1-A**) encompasses the New South Wales Nandewar IBRA[1] Bioregion and the western edge of the New England Tablelands IBRA Bioregion. The Study Area encompasses approximately 2.7 million hectares, extending 350 kilometres north to south from the Queensland border to the Liverpool Range, and 160 km east to west from the North East Comprehensive Regional Assessment (CRA) areas to the Brigalow Belt South (BBS) WRA area.

This Study Area includes 240 000 hectares of land previously assessed in coastal CRAs and BBS WRA that lie within the Nandewar Bioregion (see hatched area **Figure 1-A**). These previously assessed areas are included on maps to provide a bioregional context.

The Nandewar WRA study area includes: all of the major Nandewar provinces of Peel, Inverell Basalts, Northern Complex and Kaputar; part of five New England Tableland provinces of Severn River Volcanics, Glen Innes-Guyra Basalts, Tingha Plateau, Walcha Plateau and Eastern Nandewars; and a previously unassessed part of the Upper Hunter.

The extent of vegetation analysis and mapping was expanded for this study to include an additional 770 800 ha (**Figure 1-A**). This enabled inclusion of a large number of existing flora plots on the western boundary, rationalised the eastern boundary to include whole rather than part provinces, and incorporated the entire Nandewar Bioregion within NSW. Vegetation mapping datasets from previous projects were available for the larger area.

1.2 BIOPHYSICAL FEATURES

1.2.1 Climate

Average annual rainfall varies markedly across the Nandewar Bioregion, from 470 mm along the western boundary to 1100 mm on Mount Kaputar and along the northern slopes of the Liverpool Range (which forms the south-eastern boundary of the Bioregion). The majority of the Bioregion (91.5%) receives between 510 to 700 mm annually with rainfall generally decreasing from east to west, although this trend is significantly modified by topography with more elevated areas receiving between 100 to 200 mm more than the lowlands. A map of average annual rainfall across the Bioregion is presented in the *Atlas of Natural Resources* (AUSLIG 1990).

[1] IBRA: Interim Biogeographic Regionalisation of Australia

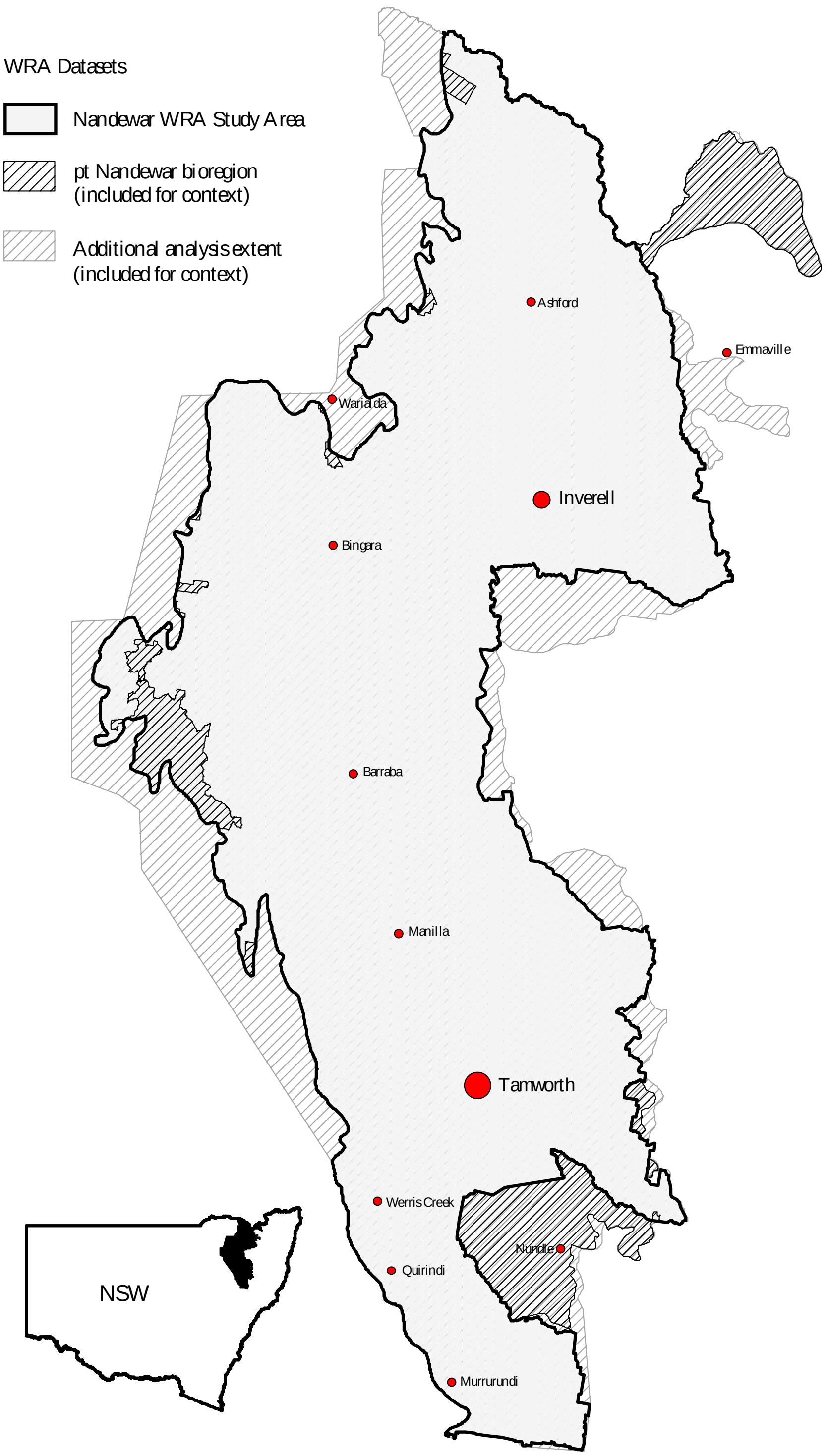

FIGURE 1-A

Nandewar WRA Study Area and Vegetation Analysis Extent

Average annual temperature also varies markedly across the Bioregion, with values strongly correlated with elevation. Temperatures range from an annual average minimum of 10.3°C on Mount Kaputar and on Crawney Mountain (south-east of Quirindi, on the Liverpool Range) to an annual average maximum of 18.8 °C in the far north-west near Glenarbon (on the Queensland side of the Dumaresq River). The cooler areas include the central portion of the Bioregion, along the Nandewar Range to Mount Kaputar, and the south-eastern periphery of the Bioregion, including the western edge of the Northern Tablelands and the northern slopes of the Liverpool Range. The warmer areas correspond to the lowlands of the three major river catchments, the MacIntyre, Gwydir and Namoi. A map of average temperature across the bioregion is presented in the *Atlas of Natural Resources* (AUSLIG 1990).

1.2.2 Geology and soils

The Nandewar region is geologically complex. It comprises an underlying basement of ancient metasediments, intruded in the higher elevation eastern margins by granitic uplift, and over-laid in many areas by tertiary basaltic flows. Superheating at the sediment-granite interface produced several grades of volcanised or metamorphosed sediments, in addition to restricted areas of serpentinite and limestone. This variability has resulted in a concomitant ecosystem diversity that is strongly patterned in relation to geological and climatic variation in the region. The Nandewar region is located at the distributional overlap of many temperate and semi-arid species.

Broad soils mapping at 1:2 million scale (AUSLIG 1990) shows that Nandewar is dominated by shallow and stony sandy loams, associated with the granites and sediments, and red brown earths and black cracking clays associated with volcanic substrate. Less widespread soils include deep alluvial loams. The deeper, better fertility soils occur at lower elevations along the valley floors, where the associated box type vegetation has been extensively cleared in the past, and where reservation is poor. The low ironbark, tumbledown red gum, stringybark and cypress vegetation communities on the shallow and less fertile skeletal loams of the steeper slopes and ridges are often intact and are relatively well reserved.

1.2.3 Vegetation overview

In a regional context, the vegetation of Nandewar contains elements of three vegetation types. The high elevation eastern margins support vegetation communities typical of the New England Tableland Bioregion, while the low elevation western parts support communities more typical of the Brigalow Belt South Bioregion. Vegetation considered typical of the Nandewar Bioregion (north-western slopes) occurs in a broad longitudinal band between these types.

The Vegetation of Australia (Beadle 1981) describes vegetation of the Nandewar region and surrounds in terms of floristic alliances and suballiances. Moderately fertile soils on the western part of the New England Tablelands support areas of grassy woodland of the

Eucalyptus melliodora – *E. blakelyi* alliance (yellow box – Blakely's red gum), while in less fertile areas various communities occur in the *E. laevopinea* – *E. caliginosa* – *E. youmanii* alliance (silvertop stringybark – broad-leaved stringybark – Youman's stringybark) and the *E. andrewsii* alliance (New England blackbutt). There are also confined areas of the *E. viminalis* – *E. rubida* suballiance (ribbon gum – candlebark), *E. mannifera* alliance (brittle or white gum), and *Eucalyptus nova-anglica* alliance (New England peppermint). Some of these also occur on the higher parts of the Mount Kaputar range in the west.

The hilly areas of the western slopes, where soils are generally shallow and of low productivity, support a number shrubby open forest and woodland communities. Beadle alliances and suballiances represented in these areas include the *E. crebra* suballiance (narrow-leaved ironbark), the *E. melanophloia* suballiance (silver-leaved ironbark) and the *Angophora leiocarpa* – *Eucalyptus* suballiance (northern smooth-barked apple – eucalypt). On lower altitude areas of more undulating terrain with fertile soils, open forest and woodland of the *E. albens* alliance (white box) becomes dominant, while on flatter areas the *E. melliodora* - *E. blakelyi* alliance (yellow box – Blakely's red gum) occurs.

A number of woodland communities in the following alliances or suballiances occur on the western side of Nandewar including *E. populnea* suballiance (bimble box), *E. populnea* – *Casuarina cristata* suballiance (bimble box – belah), *E. populnea* – *Callitris glaucophylla* suballiance (bimble box – white pine), *E. microcarpa* alliance (grey box) and *E. pilligaensis* alliance (Pilliga box). These are all represented in the Brigalow Belt. Small areas of grasslands of the *Dichanthium* spp alliance (bluegrass) and the *Austrostipa aristiglumis* alliance (plains grass) also occur.

Other vegetation types that have limited occurrences in Nandewar include the *E. viridis* alliance (green mallee), *Acacia pendula* alliance (myall), *Casuarina cristata* alliance (belah), and *E. camaldulensis* alliance (river red gum), which occurs along the major watercourses.

There are eight endangered ecological communities (EECs) listed under the *Threatened Species Conservation Act 1995* (*TSC Act*) which occur in the larger Nandewar region (analysis extent – **Figure 1-A**). The most extensive is the box-gum grassy woodland, which supports various associations of *E. albens* (white box), *E. melliodora* (yellow box) and *E. blakelyi* (Blakely's red gum), often co-existing with other eucalypts. The Howell shrubland EEC and Mckie's stringybark-New England blackbutt EEC are mainly confined to the Tingha Plateau province east of Copeton Dam. The semi-evergreen vine thicket EEC occurs on the edge of the black soil plains, often in association with belah, or on steep volcanic ridges and slopes (Curran PhD *in prep*). Derra Derra ridge contains the largest stand of vine thicket in NSW (Benson *et al*. 1996). *Cadellia pentastylis* (ooline) also forms a western rainforest EEC, confined in NSW to the Nandewar region (Benson 1989).

Other restricted EECs in the region include *Acacia harpophylla* (brigalow) woodland, *Corymbia tessellaris* (carbeen) woodland, and *E. nova-anglica* (New England peppermint) woodland on basalts and sediments of the New England Tablelands.

2 Aerial Photograph Interpretation

2.1 BACKGROUND

Aerial photograph interpretation (API) was used to capture spatial variation in vegetation floristics and structure within areas of Nandewar WRA not previously mapped by other projects. Two separate API programs were conducted simultaneously in 2003 to complete linework across the Study Area. DEC was responsible for mapping southern areas using API specifications designed for the Nandewar WRA, while the DIPNR mapped northern areas using recent specifications designed for the Native Vegetation Mapping Program (NVMP). Both methods relied on API to capture vegetative patterns, although attribution of captured patterns varied between programs.

2.2 EXISTING DATA

Several mapped vegetation datasets were available at commencement of this project. The most extensive was mapping undertaken by DEC in 2000-2002 for the NVMP. Over 30% of the study region was mapped during this project, including all areas within the Boggabri, Curlewis, Horton, Manilla and Tamworth 1:100 000 (100K) mapsheets. The project ultimately set mapping standards and developed API pathways and data capture protocol for vegetation projects undertaken for the Brigalow Belt South (BBS) and Nandewar WRAs.

Other datasets available for the project included mapping of Gravesend 100K mapsheet conducted by DLWC for the NVMP (Cannon *et al*. 2002), and CRAFTI mapping for the lower north east CRA (NPWS 1998). Royal Botanic Gardens (RBG) mapping of Ashford 100K mapsheet, at a broader scale, was also available. Fine-scale mapping of national park estate, commissioned by DEC over the past decade, was available for several Nandewar reserves including Arakoola NR (Hunter 2000a), Ironbark NR (Hunter 2002), Kings Plains NP (Hunter 2000b), Kwiambal NP (Hunter 1998) and Severn River NP (Hunter 2000c). SFNSW forest typing for the Nandewar WRA (Webster 2004) was integrated into the API coverage where previous linework was lower resolution. This included several northern parcels of state forest. Any gaps identified outside the extent of floristic mapping were ultimately in-filled using mapping of vegetation cover from other sources, including M305 mapping (Ritman 1995) on the Narrabri 100K sheet, DLWC land-use mapping in the Upper Hunter, and Eastern Bushlands Data (NPWS 1994) or DLWC cover class mapping in Clive, Croppa Creek and Stanthorpe100K mapsheets (Wall 1999).

Figure 2-A shows the spatial extent of existing mapping and WRA mapping, and **Table 2-A** summarises the mapping specifications adopted for each.

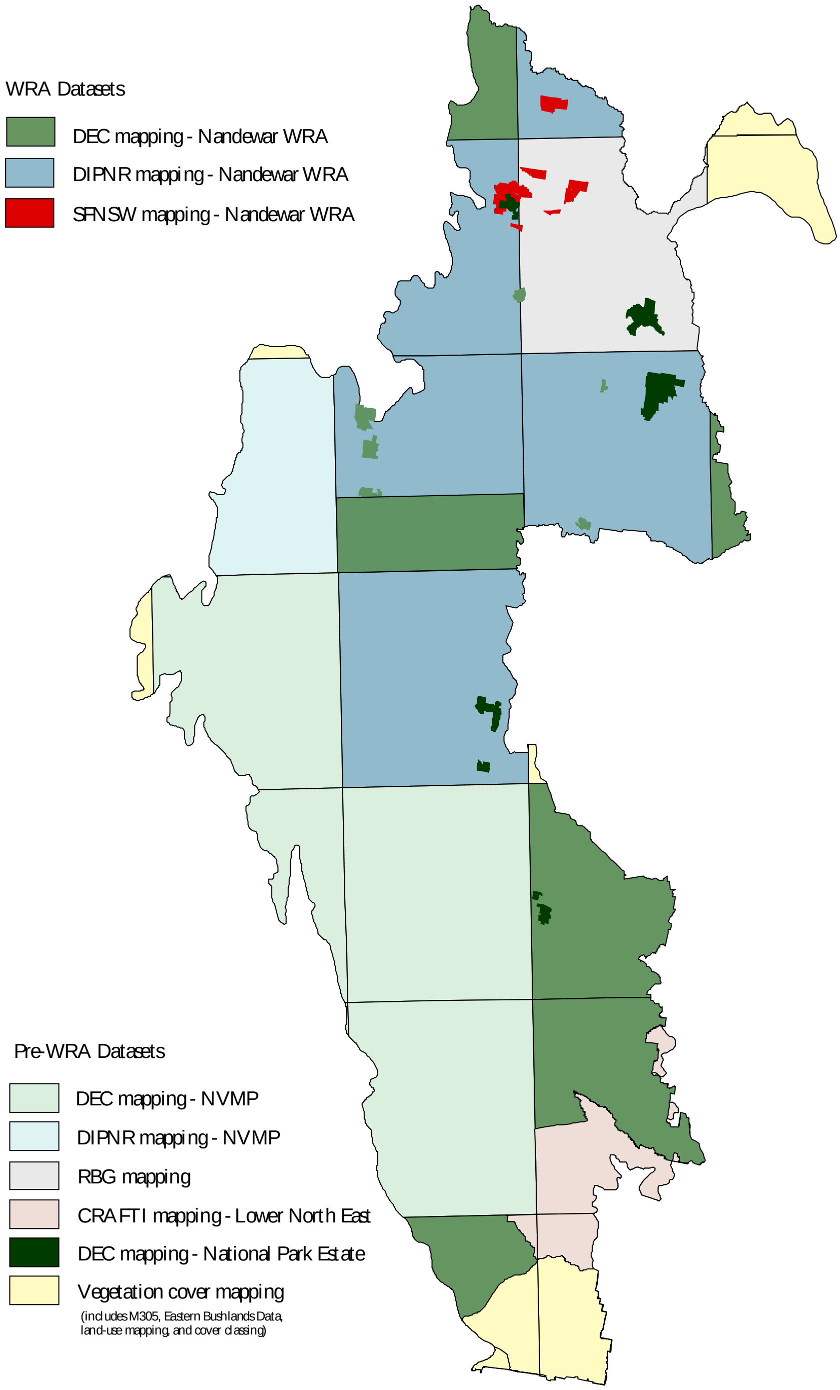

FIGURE 2-A

Existing & Nandewar WRA Vegetation Mapping

TABLE 2-A

Mapping specifications for API datasets used in Nandewar WRA

Dataset	100K mapsheet(s)	Air [A] Photos	Floristic Tag	% Cover	Growth Stage	Disturbance Tag	Spatial Accuracy	Reference
DEC mapping for Nandewar WRA	Bendemeer & Nundle	Yr 2002	yes	yes	yes	yes	< 50m	this document
	Bingara, Glen Innes & Murrurundi	Yr 2001	yes	yes	yes	yes	< 50m	this document
	Yetman	Yr 2000 *1:50K*	yes	yes	yes	yes	50-100m	this document
DIPNR mapping for Nandewar WRA	Bingara	Yr 2001	indicative only	yes	no	no	< 50m	*Unpubl. data*
	Cobbadah	post 1999	indicative only	yes	no	no	< 50m	*Unpubl. data*
	Inverell	post 1999	indicative only	yes	no	no	< 50m	*Unpubl. data*
	Texas	Yr 1999 *1:50K*	indicative only	yes	no	no	50-100m	*Unpubl. data*
	Yallaroi	Yr 2000 *1:50K*	indicative only	yes	no	no	50-100m	*Unpubl. data*
NPWS mapping of State Forests for BBS WRA – Stage 1	Bingara Boggabri	*various*	yes	yes	yes	yes	< 50 m	RACD 2003
NPWS mapping for BBS WRA - JVMP	Yallaroi	*various*	yes	yes	yes	yes	50-100m	RACD 2003
NPWS mapping for NVMP	Curlewis	Yr 1998	yes	yes	yes	yes	< 50m	*Unpubl. data*
	Boggabri, Horton & Manilla	Yr 1991	yes	yes	yes	yes	< 50m	*Unpubl. data*
	Tamworth	Yr 1993	yes	yes	yes	yes	< 50m	*Unpubl. data*
DLWC mapping for NVMP	Gravesend	~ 2000 *1:50K*	yes	yes	no	no	50-200m	*Unpubl. data*
RBG mapping	Ashford	~ 1990 *1:50K*	broad	no	no	no	50-200m	*Unpubl. data*

TABLE 2-A (*cont'd*)

Dataset	100K mapsheet(s)	Air [A] Photos	Floristic Tag	% Cover	Growth Stage	Disturbance Tag	Spatial Accuracy	Reference
CRAFTI mapping	Bendemeer	early 1990s	yes	no	yes	yes	10 – 100m	NPWS 1998
NPWS	Bundarra	early 1990s	yes	no	yes	yes	10 – 100m	NPWS 1998
	Clive	early 1990s	yes	no	yes	yes	20 – 200m	NPWS 1998
	Cobbadah	early 1990s	yes	no	yes	yes	10 – 100m	NPWS 1998
	Ellerston	Yr 1993	yes	no	yes	yes	10 – 100m	NPWS 1998
	Inverell	early 1990s	yes	no	yes	yes	10 – 100m	NPWS 1998
	Murrurundi	Yr 1994	yes	no	yes	yes	10 – 100m	NPWS 1998
	Nundle	Yr 1997	yes	no	yes	yes	10 – 100m	NPWS 1998
NPWS on-park mapping	*na*	various	yes	no	no	no	50m	various (section 1.2)
SFNSW mapping for Nandewar WRA	Northern State Forests in Ashford, Texas	recent *1:50K*	Yes (RN17 types)	no	no	no	50m	Webster 2004
DLWC canopy cover mapping	Bundarra	Yr 1994 *50K*	no	yes	no	no	50-200m	Wall 1999
	Clive	Yr 1992 *50K*	no	yes	no	no	50-200m	Wall 1999
DLWC Land Use Mapping - Hunter	Ellerston Murrurundi	*25K*	no	yes	no	no	??	*Unpubl. data*
Eastern Bushlands Data	Bundarra Clive Glen Innes Stanthorpe	*Satellite imagery*	no	no	no	no	??	NPWS 1994
M305 Mapping	Narrabri	*Satellite imagery*	no	no	no	no	??	Ritman 1995

A. all photos 1:25K scale unless otherwise indicated

2.3 API METHODOLOGY FOR NANDEWAR WRA

2.3.1 DEC approach

Delineation and attribution of native vegetation patterns from aerial photographs provided the base linework to assist construction of a final vegetation map for the Nandewar WRA. DEC produced linework for the Bendemeer, Glen Innes, Murrurundi, Nundle and Yetman 100K sheets, and part of Bingara and Inverell sheets.

The primary purpose of API was to define the spatial boundaries of vegetation associations from visual assessment of photo-patterns. This involved identifying and delineating unique photo-signatures (based on a combinations of texture, tone and colour) which represented species or species associations. A multi-attribute approach to typing each polygon was adopted in which the following were recorded:

- vegetation type;
- vegetation association (up to three dominant species);
- crown cover percentage;
- proportion of regrowth eucalypt;
- understorey structure; and
- disturbance.

Consistent with mapping undertaken for BBS (RACD 2003), a minimum threshold of 10% canopy cover and a minimum polygon size of ten hectares was adopted for this project, however, polygons as small as two hectares representing isolated remnants, or areas of special interest, were also delineated. The following resources were used to support API:

- Landsat TM 7 satellite imagery;
- topographic maps;
- geology maps;
- existing botanical plot data; and
- field surveys (ground truthing).

Experienced API contractors and staff with extensive knowledge of vegetation types occurring in Nandewar ensured a largely consistent and robust API coverage. A method for labelling and attributing polygons was standardised across interpreters and adhered to throughout the project. Mapping pathways were adapted from earlier work undertaken by DEC for the NVMP. **Appendix 2-1** shows flow diagrams of the mapping pathways and attribute tables of API classes adopted by DEC, and **Appendix 2.2** incorporates the list of API canopy types used by DEC, as derived from the API codestrings.

2.3.2 DIPNR approach

DIPNR was contracted by RACD to provide linework for Cobbadah, Inverell, Texas and Yallaroi 100K sheets and part of the Bingara 100K sheet. API was undertaken using recently modified NVMP pathways, in which polygons were assigned a label according to the observed vegetative pattern type, rather than one or more definitive species labels based on interpretation of canopy floristics. DIPNR provided a list of characteristic canopy species likely to be associated with different patterns. **Appendix 2.2** incorporates the API classes mapped by DIPNR in northern Nandewar.

2.4 DIGITAL CAPTURE OF LINEWORK

2.4.1 Preparation

Transparent overlays were affixed to all aerial photos requiring interpretation. A fine-nib technical pen filled with black ink was used for marking linework and coding onto each overlay. The following information was marked onto each overlay prior to data capture:

- aerial photo details (100K sheet, run number and print number);
- corner fiducial points;
- API linework (uniquely numbered polygons); and
- uniquely numbered ground control points (GCPs).

Between 6 and 10 GCPs were captured on each photo to enable digital ortho-rectification of the linework. AMG co-ordinates and elevation were recorded for each GCP.

2.4.2 Ortho-rectification

Ortho-rectification is the process in which raw linework captured during API is projected or moulded to the AMG grid. It essentially removes the spatial distortion evident in aerial photographs, which occurs as a result of elevation and slope differences influenced by parallax error, and is most acute at the photo periphery.

To ortho-rectify DEC linework in this project, each transparent overlay was detached from air photos and scanned at identical resolution using a flatbed A3 scanner, producing a jpeg image *(.jpg*). This file was imported into ERMapper software to produce an ERS file (*.ers*). Used in association with a digital elevation model (DEM) and GCPs, this file was ortho-rectified in ERMapper then imported into ArcView GIS as a build file (*.bil*). A number of GIS procedures were employed to convert the *.bil* file into a final ArcView shapefile (*.shp*). By overlaying the final shapefile with the original ortho-rectified .bil file, the appropriate polygon label was able to be assigned manually to each polygon. These labels were joined to an Access database containing the API attribute codes, thus establishing a final attribute table for each shapefile, which included floristic and structural data for each polygon.

2.4.3 Merging and editing other datasets

All the datasets listed in **Table 2-A** were merged together in ArcView, with precedence given to floristic spatial data where it coincided with non-floristic spatial data. Polygons comprising agricultural land, mines or urban areas were not included. A final visual check against Landsat imagery was undertaken, where any non-mapped areas of forest or woodland were digitised on-screen and incorporated into the final API layer. A small number of edits were also made to floristic labels in cases where known discrepancies existed between polygon tags and on-ground vegetation types.

2.5 SUMMARY OF FINAL LAYER

2.5.1 Background

The final API layer, for the larger analysis extent (**Figure 1-A**), comprised 51 237 polygons. The total area of the final layer was 1 641 500 hectares, representing 51.1% of the 3 211 900 hectare analysis extent. All polygons were classified into one of 878 ‘canopy’ classes based on the API code-string and/or comments regarding land cover (polygon types and canopy descriptions for the entire analysis extent are tabulated in **Appendix 2.2**). The 878 canopy classes were combined into 19 broad vegetation groups. The API layer was then clipped to the Nandewar Bioregion portion of the Study Area and an analysis undertaken of the area occupied by each broad vegetation type (**Table 2-B**).

2.5.2 Polygon types

Grassy white box is the most dominant vegetation type in the Nandewar Bioregion according to the API layer. It covers 12.9% of the Bioregion (over 20% of existing vegetation) while other box types (mainly bimble box, grey box and yellow box) cover 3.9%. Ironbark and stringybark types are also extensive, covering 10.5% and 6.6% respectively, with silver-leaved and narrow-leaved ironbarks, and red and silvertop stringybarks the most common and widespread.

The Box-Gum Woodland endangered ecological community (EEC) is likely to be contained within the spatial extent of polygons representing grassy white box types, Blakely’s red gum types, and box forest and woodland. The Semi-evergreen Vine Thicket and Howell Shrub-lands EECs are also represented in some of the dry rainforest and rock outcrop groups. The Mckie’s Stringybark–New England Blackbutt EEC occurs in a small number of polygons in the stringybark group.

TABLE 2-B

Summary statistics for main floristic groups in Nandewar Bioregion

Group	No polygons	Total area (ha)	% of Bioregion	Comments
Blakely's red gum types	1 308	44 293	1.8	Some polygons potentially contain Box-Gum EEC.
Box dominated forest & woodland	3 546	97 963	3.9	Some polygons potentially contain Box-Gum EEC.
Dry rainforest types	161	1 822	0.1	Locally uncommon, Some polygons contain SEVT or Ooline EECs.
Grassy white box types	9 604	321 843	12.9	All polygons potentially contain Box-Gum EEC.
Hill red gum types	1 140	31 877	1.3	
Ironbark dominant forest & woodland	6 844	260 420	10.5	
New England blackbutt forest types	2 388	74 114	3.0	
Riverine vegetation	779	19 285	0.8	
Rock outcrop vegetation	1 423	11 066	0.4	Some polygons contain Howell Shrubland EEC.
Rough-barked apple dominant	1 474	52 123	2.1	
Shrubby white box types	2 550	89 737	3.6	Some polygons potentially contain Box-Gum EEC.
Shrubland	804	14 003	0.6	
Smooth-barked apple dominant	359	11 191	0.4	
Spinifex woodland	43	2 910	0.1	Locally uncommon.
Stringybark dominant forest & woodland	4 363	163 981	6.6	A limited number of polygons contain Mckie's Stringybark-New England Blackbutt EEC.
Swamp/Wetland	51	503	0	Locally uncommon.
Tableland gums/peppermints	795	21 515	0.9	
Undetermined	*2 343*	*51 590*	*2.1*	*No floristic tag available*
Not mapped	*-*	*1 220 343*	*49.0*	*Cleared agricultural land, urban areas, large dams, pine plantations, mines, etc.*
	40 800	2 490 578		

2.5.3 Canopy cover

The majority of API polygons in Nandewar were attributed with a category of canopy cover percentage (CCP), which provided an estimate of the surface area of overstory tree crowns as a percentage of the total polygon area. This attribute was used as the basis for deriving an **extant vegetation** layer for Nandewar. All polygons tagged with a canopy density ≥ 20% were assumed to represent intact vegetation. Polygons tagged with a canopy density < 20% were checked against LandSat imagery, and those considered to represent intact vegetation were also retained. Polygons co-existing with treeless or semi-cleared landscapes were not included. **Figure 2-B** shows the distribution of extant vegetation in the Nandewar Study Area (including previously assessed areas). The total area is 1 018 900 hectares (38.2% of the Study Area). The remainder comprises either cropland, cleared pasture, scattered eucalypts, water storages, urban areas, pine plantations or mines.

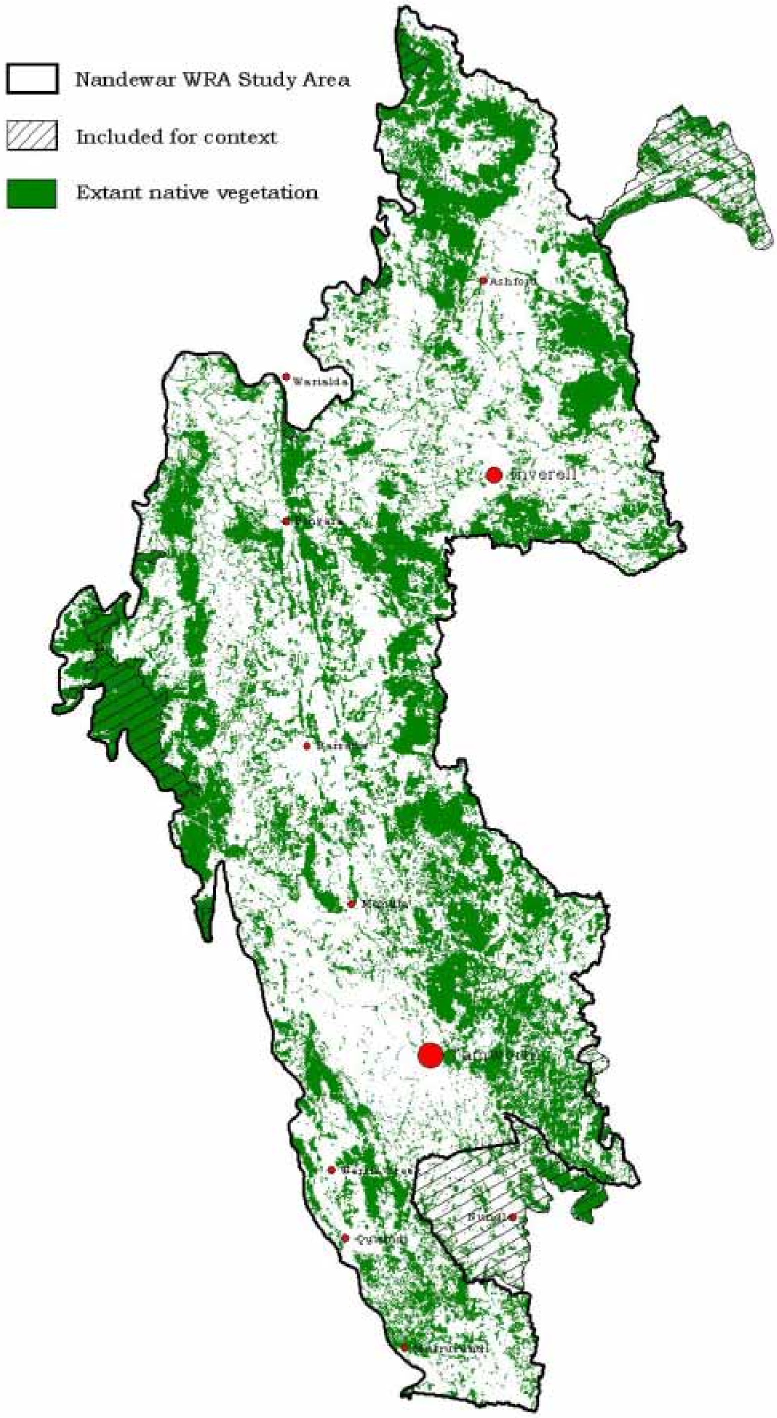

FIGURE 2-B

Distribution of extant vegetation in Nandewar

3 Flora Survey

3.1 BACKGROUND

The intent of flora survey for Nandewar WRA was to sample the floristic and structural characteristics of all vegetation types across the region. Several flora surveys had been undertaken prior to the WRA, providing a robust initial dataset from which to plan and conduct further survey. The region was stratified on the basis of geology, topography and climate, and under-sampled strata were targeted for further survey from November 2002 to November 2003.

The complete flora dataset provided a basis for derivation of a set of vegetation units (or communities) using standard analytical techniques. These units were mapped across the region by reconciling the API layer (Chapter 2) with expert and analytical modelling (Chapter 4).

3.2 EXISTING DATA

A relatively large set of plot data was available for the region prior to the Nandewar WRA. After discarding canopy-only sites, those with unusable abundance information, and those with an unusually low number of native species records (fewer than six as per RACD 2003), a total of 2 261 plots within 35 separate survey datasets remained for analysis (**Table 3-A**). Each plot comprised a list of all vascular plant species, and for each species a measure of cover and abundance was provided.

Figure 3-A shows the location of existing plots. The majority of plot surveys were conducted after 1995.

TABLE 3-A

Existing flora survey datasets available for Nandewar WRA

Data Set Source	Number of Plots	Type of Data	Plot Size (m)	Reference
Arakoola Nature Reserve flora survey	50	Full floristics with abundances	20x50	Hunter 2000a
Kings Plains National Park flora survey	42	Full floristics with abundances	20x50	Hunter 2000b
Kwiambal National Park flora survey	73	Full floristics with abundances	20x20	Hunter 1998
Severn River National Park flora survey	48	Full floristics with abundances	20x50	Hunter 2000c
Single National park flora survey	40	Full floristics with abundances	unspecified	Clarke et al. 2000
Mount Kaputar National Park flora survey (north)	90	Full floristics with abundances	unspecified	*Unpubl. data*
Mount Kaputar National Park flora survey (south)	50	Full floristics with abundances	20x20	Porteners 1998
Mount Kaputar sub-alpine survey	30	Full floristics with abundances	20x20	Porteners 1997
Gibraltar Nature Reserve flora survey	14	Full floristics with abundances	20x20	Hunter 2002
NPWS surveys of reserves in Armidale Area	124	Full floristics with abundances; plot and structural data	20x20	*Unpubl. data*
Threatened Species flora surveys	3	Full floristics with abundances	20x20	*Unpubl. data*
RBG Vegetation Data for the Ashford Mapsheet	86	Full floristics with abundances; plot and structural data	20x20	*Unpubl. data*
RBG Vegetation Data for the Clive Mapsheet	10	Full floristics with abundances; plot and structural data	20x20	*Unpubl. data*
RBG Vegetation Data for the Glen Innes Mapsheet	1	Full floristics with abundances; plot and structural data	20x20	*Unpubl. data*
RBG Microphyll Vine Thicket Survey	7	Full floristics with abundances; plot and structural data	20x20	Benson et al. 1996
RBG Ooline Vegetation Survey	31	Full floristics with abundances	20x20	Benson 1989
Tim Curran SEVT surveys	51	Full floristics with abundances	20x20	*Unpubl. Data Curran* (in prep.)
Alex Floyd Rainforest Surveys	1	Full floristics with abundances	unspecified	Floyd 1990
Moree Grassland survey	6	Full floristics with abundances	20x20	Hunter & Earl 2002
Flora survey of Namoi valley	7	Full floristics with abundances	unspecified	*Unpubl. data*

TABLE 3-A (*cont'd*)

Data Set Source	Number of Plots	Type of Data	Plot Size (m)	Reference
Northern Wheatbelt survey	18	Full floristics with abundances	20x20	Sivertsen & Metcalfe undated
Narrom_99 sites	13	Full floristics with abundances	50x20	*Unpubl. data*
John Hunter Granite Surveys	214	Full floristic nested quadrats with frequency data converted to cover abundance	10 quadrats nested to 22.5mx22.5m	Hunter & Clarke 1998
Eastlink Flora Survey	36	Full floristics nested quadrats with frequency data converted to cover abundance	10 quadrats nested to 32mx32m	Clarke *et al* 1995
North East Forests Biodiversity Study Flora Sites	3	Full floristics with abundances and plot, physical and structural data	20x20 within 20x50	NPWS 1994
Torrington State Recreation Area Vegetation Survey	1	Full floristics nested quadrats with frequency data converted to cover abundance	10 quadrats nested to 32mx32m	Clarke *et al* 1998
NPWS CRA flora surveys for UNE and LNE	44	Full floristics with abundances; plot and structural data	50x20	NPWS 1999
Flora Survey of Ben Halls Gap State Forest	10	Full floristics with abundances	20x20	Benson & Andrew 1990
SFNSW flora sites – Walcha Management Area	6	Full floristics with abundances; plot and structural data	20x20 within 20x50	Chapman & Binns 1995
DLWC flora survey for NVMP	206	Full floristics with abundances; plot and structural data	20x20	*Unpubl. data*
NPWS flora survey for NVMP	731	Full floristics with abundances; plot and structural data	20x20	*Unpubl. data*
DLWC survey for BBS WRA	75	Full floristics with abundances	20x20	*Unpubl. data*
NPWS survey for BBS WRA	73	Full floristics with abundances; plot and structural data	20x20	*Unpubl. data*
SFNSW survey of BBS WRA	62	Full floristics with abundances; plot and structural data	20x20	*Unpubl. data*
Darling Riverine Plains flora survey	5	Full floristics with abundances	20x20	*Unpubl. data*
Total	2 261			

3.3 ENVIRONMENTAL STRATIFICATION

This project adopted a strata layer developed by DEC as part of its contribution to the NVMP, in which the Nandewar and New England Tablelands Bioregions were stratified using a combination of five spatial information layers. These were geology, elevation, topographic position, aspect and major catchment. **Table 3-B** lists individual classes within each layer, and includes area and sampling intensity statistics prior to the Nandewar WRA. The environmental and geographical spread of the existing sites was generally good because much of the existing survey work had been designed to stratify site locations in relation to major environmental and geographical gradients.

TABLE 3-B

Environmental variables used for stratification

		within Nandewar WRA Region				
Environmental Variable	Classes	Gross area (ha)	Extant area (ha)	% extant	Existing plots	Survey intensity (plots/1000ha)
Major catchment	Gwydir	798 820	316 750	39.7	535	1.7
	MacIntyre	820 220	337 540	41.2	529	1.6
	Namoi	1 198 230	412 140	34.4	856	2.1
Geology	Acid volcanics	154 500	103 560	67.0	289	2.8
	Basalts	449 130	105 600	23.5	225	2.1
	Granites	492 660	290 700	59.0	463	1.6
	Leucogranites	1 240	990	79.8	2	2.0
	Limestone	2 660	990	37.2	8	8.1
	Quaternary sediments	142 420	32 030	22.5	65	2.0
	Sediments (high quartz)	383 440	150 270	39.2	254	1.7
	Sediments (low quartz)	1 175 460	374 710	31.9	590	1.6
	Serpentinite	15 760	7 580	48.1	24	3.2
Elevation (asl)	< 400m	747 770	229 130	30.6	478	2.1
	400-799 m	1 560 640	556 050	35.6	947	1.7
	800-1199 m	417 980	235 660	56.4	389	1.7
	≥1200 m	90 870	25 590	28.2	106	4.1
Topo. position	valley	556 140	207 030	37.2	361	1.7
	lower slope	875 010	295 360	33.8	485	1.6
	midslope	708 140	268 130	37.9	463	1.7
	upper slope	389 850	181 170	46.5	362	2.0
	crest	288 130	114 750	39.8	249	2.2
Aspect	north	290 030	156 340	53.9	275	1.8
	east	354 500	162 560	45.9	269	1.7
	south	242 870	154 500	63.6	288	1.9
	west	350 440	214 700	61.3	367	1.7
	Flat (< 3°)	1 579 430	378 330	24.0	721	1.9

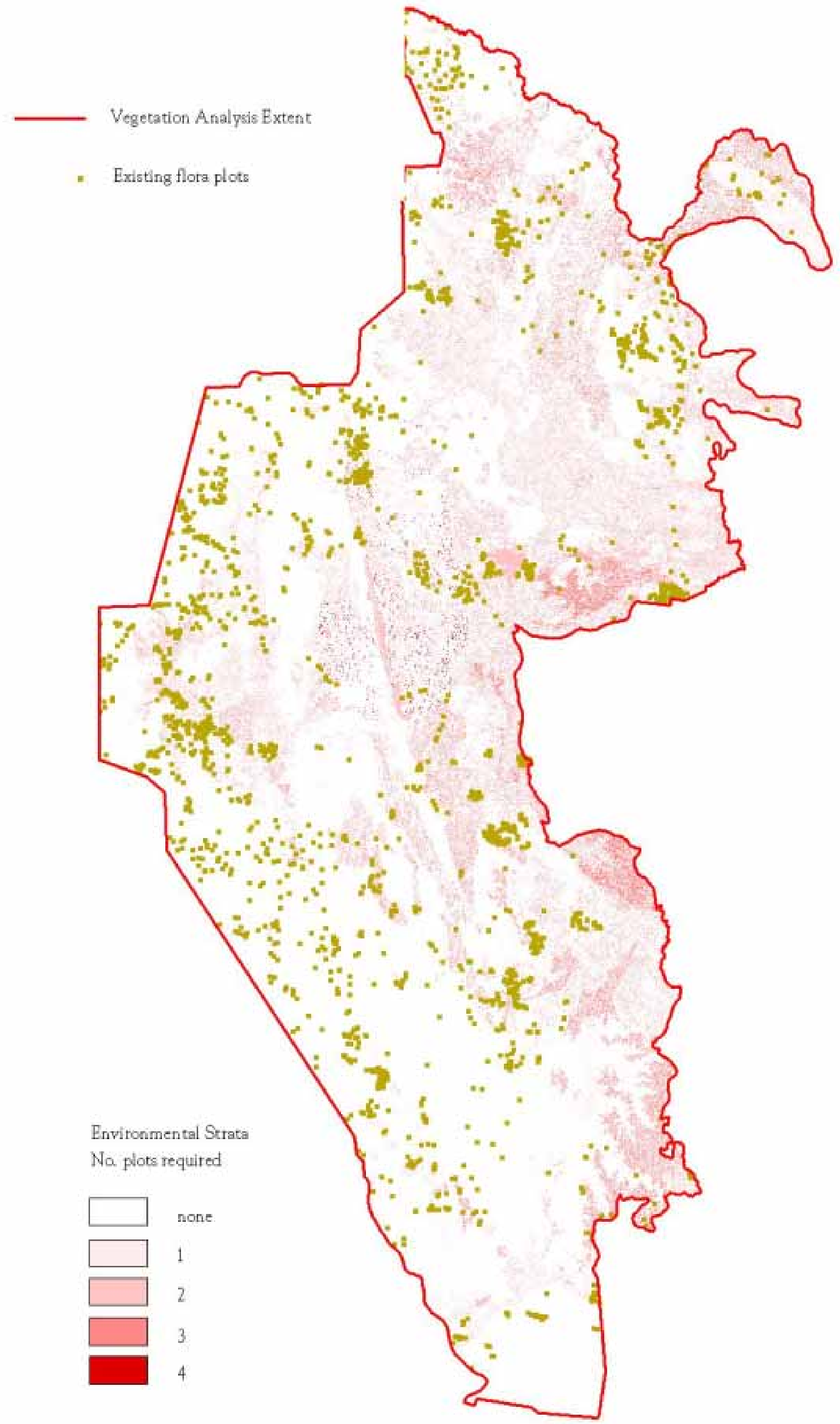

FIGURE 3-A

Pre-WRA flora sites and stratification

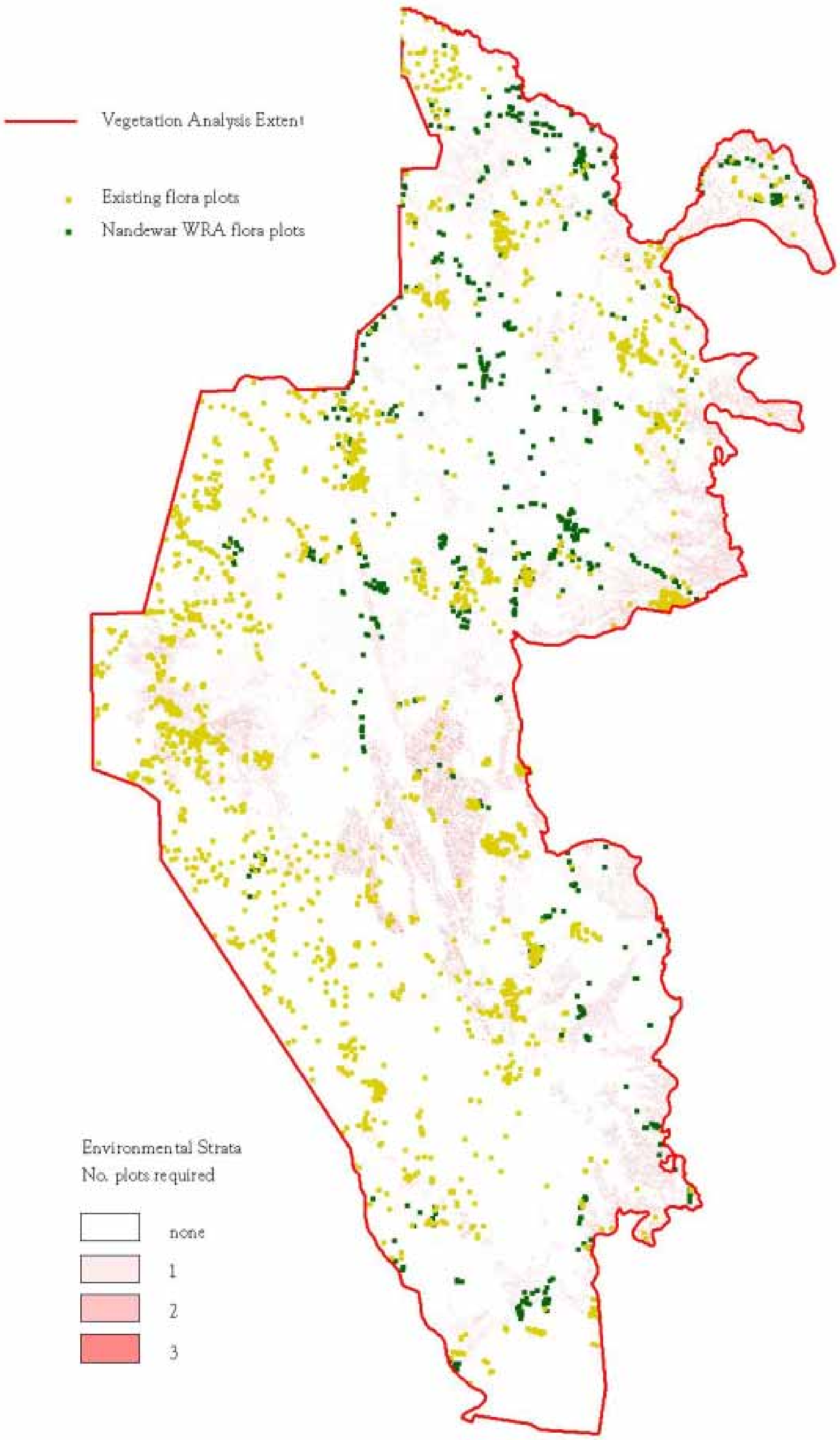

FIGURE 3-B

Nandewar WRA flora sites and stratification

The five environmental layers were subsequently merged into a combined coverage, masked by an extant woody cover layer and clipped to the Nandewar WRA analysis extent (see **Section 1.1**). A total of 636 unique combinations, or environmental stratification units (ESUs), comprising at least 100 hectares of extant forest and woodland, were recognised. Consistent with NVMP guidelines (eg. Cannon *et al.* 2002), the number of plots per ESU was determined using a proportional sampling approach as follows:

- 100 - 500 ha 1 plot
- 501 - 1500 ha 2 plots
- 1501 - 3000 ha 3 plots
- 3001 - 5000 ha 4 plots
- 5001 - 7500 ha 5 plots
- 7501 - 10500 ha 6 plots
- > 10500 ha 7 plots

The distribution of existing plots was reported against the strata layer to determine the pre-WRA sampling intensity of each ESU. A total of 280 ESUs required at least one additional plot to satisfy the above sampling intensity. A maximum of 4 additional plots was required for any ESU.

3.4 FIELD SURVEY

3.4.1 Plot location

Plot locations within target ESUs were initially identified in the office with the assistance of aerial photographs and ArcView GIS software. Ease of access, site condition and land tenure was considered in the location of future plots. Plots were situated on freehold land where possible to address past imbalances towards public land. Each plot was assigned AMG coordinates to assist location in the field. Plots were assigned to non-target ESUs in cases where unusual aerial photo patterns were observed, or where opportunistic plots were undertaken in the field.

Several flora surveys were conducted during the Nandewar WRA. Each survey was 3-5 days duration, and aimed to sample a minimum of 4 plots per day. A total of 417 plots were completed by DEC for the WRA, mainly in southern Nandewar. An additional 230 plots were completed by DIPNR, mainly in northern Nandewar. **Figure 3-A** and **Figure 3-B** provide a comparison of plot distribution and stratification before and after the WRA.

3.4.2 Field survey methods

Field survey was designed to meet the technical standards adopted by DEC in previous surveys for the north-east coastal CRAs (NPWS 1999) and North East Forests Biodiversity Study (NPWS 1994), and commensurate with standards employed by DIPNR as outlined in *Guidelines for Mapping Native Vegetation* (DLWC 2000).

Each plot was located in the field using a GPS. Upon location a 20 x 20m quadrat was delineated and marked with flagging tape, and all vascular plant species occurring within the plot were listed. A visual estimation of the cover abundance of each taxon was recorded using a 6-point modified Braun-Blanquet system of cover abundance classes (Mueller-Dombois & Ellenberg 1974).

Structural and physical data were also collected. Structural data included the predominant growth form, height range and percentage crown cover of the three dominant taxa within tall, midstorey and ground strata. Physical site data included altitude, slope, aspect, horizon elevation, soil depth and type, field geology and landform element. Other information included disturbance history and overall site condition. A site photograph was taken at the majority of sites.

Physical, structure and floristics proformas are provided in **Appendix 3-1**.

3.5 DATA MANAGEMENT

3.5.1 Data entry

All floristic data collected by DEC during the Nandewar WRA surveys were entered into an Access flora database (named YAVSD; NPWS 2002) between June 2003 and January 2004. All DIPNR survey data for WRA were imported into YAVSD in December 2003. Existing survey data were entered into YAVSD prior to the WRA. At completion of data entry, the database comprised a total of 2 908 sites, including 2 261 pre-WRA and 647 WRA sites.

The YAVSD database comprises four main input sections – site locality, physical information, disturbance history, and vegetation structure and floristics. Entered data are organised and stored in a number of backend tables. The relational capacity of YAVSD enables maintenance of links between these tables, and allows application of queries and functions to interrogate and interpret data.

3.5.2 Cover-abundance scoring

All 37 survey datasets retained for the Nandewar assessment comprised a list of taxa recorded in each plot, and a measure of the quantity of each taxon, based on either a combined cover-abundance score or as separate estimates of cover and/or abundance.

Although most observers aimed to assess the combined perpendicular projection of all aerial parts of individual taxa within each plot (RACD 2003), surveys generally differed in the number and size of cover and/or abundance classes, and may have varied considerably between observers. To provide some consistency between surveys in the Nandewar WRA dataset, the various scoring systems were expertly converted to a common 6 point Braun-Blanquet cover-abundance score comprising the following classes:

- 1 – uncommon (few individuals) with cover up to 5%
- 2 – common (numerous individuals) with cover up to 5%
- 3 – 6-25% cover
- 4 – 26-50% cover
- 5 – 51-75% cover
- 6 – 76-100% cover

Some spurious individual scores were also adjusted. **Table 3-C** lists the data conversion rules applied to cover and abundance scoring systems used in external datasets.

TABLE 3-C

Conversion of Cover Abundance Scores

Assessment methods used in original survey	Conversion rules
JVMP and NVMP standard in which cover and abundance recorded separately. Cover usually estimated to nearest 5%, or as <1% if applicable. Abundance estimated in one of six classes (1-6) based on number of individuals.	If Cover >5%, allocate to the following cover-abundance classes : 3 if cover 6-25%; 4 if cover 26-50%; 5 if cover 51-75%; 6 if cover >75%. If cover ≤5%, allocate to the following cover-abundance classes : 1 if abundance = 1 or 2 2 if abundance > 2
Northern Wheatbelt sites measured cover-abundance on a 7-point scale, as : 1 = one individual; 2 = few individuals and <5% cover 3 = numerous individuals and <5% cover 4 = 5-25% 5 = 26-50% 6 = 51-75% 7 = >75%	Allocate to 6-point score as follows: 1,2 = 1 3 = 2 4 = 3 5 = 4 6 = 5 7 = 6
Cadellia pentastylis and certain other overstorey records within Ooline sites not assigned a cover-abundance score, instead a stem count.	Cover-abundance scores assigned expertly, taking into account stem count and other features of the associated species list (eg. grass and understorey cover scores).
In a number of surveys, unusually high cover-abundance scores (5 and 6) were occasionally assigned to overstorey species.	Cover-abundance scores revised downwards according to the following rules : Eucalypt 5 or 6 = Eucalypt 4 Angophora 5 or 6 = Angophora 4 Callitris 6 = Callitris 5

3.5.3 Edits to floristic data

The nomenclatural and taxonomic accuracy of floristic data in the YAVSD database varied to some degree. A number of taxonomic and nomenclatural changes were thus made to species considered to have been either renamed or misidentified (**Appendix 3.2**). All taxa that were not identified to species level were removed from the database, unless it was considered that a genus was represented by only one species in the Nandewar region, in which case the record was updated.

3.6 SUMMARY OF NANDEWAR FLORA

3.6.1 All flora

On completion of data validation, the Nandewar WRA floristic database contained 104 904 individual records, including 95 281 native and 9 623 exotic (average 36 taxon in each plot). A total of 1 982 different taxa were recorded in the analysis extent, including 1 611 natives and 371 exotics.

The most frequently recorded native species in Nandewar were *Cheilanthes sieberi* ssp *sieberi*, *Cymbopogon refractus*, *Notalaea microcarpa* ssp *microcarpa*, and *Aristida ramosa*, each recorded in more than 40% of sites. A total of 30 native taxa were recorded in at least 20% of sites, including the canopy species rough-barked apple (*Angophora floribunda)*, white pine (*Callitris glaucophylla)*, black pine (*C. endlicheri)*, white box (*E. albens)* and tumbledown red gum (*E. dealbata)*. Over half of all native taxa, including 26 *Eucalyptus* species, were not particularly abundant in Nandewar, being recorded in fewer than 10 sites (ie. each of about 1 000 taxon was confined to a unique subset of 10 or fewer sites across the region).

The most frequently occurring weed species were prickly pear *(Opuntia stricta* var *stricta*) and flatweed *(Hypercharis radicata*), each present in at least 700 plots. Coolatai grass *(Hyparrhenia hirta*) was recorded in 316 sites (10.8% of all sites). Similar to natives, over half of all exotic taxa were recorded in fewer than 10 sites each.

A final data processing stage required that all exotic taxa be removed from the database prior to floristic analysis, as exotic species were not considered to assist in characterising native species groups (RACD 2003).

3.6.2 Significant flora

For the purpose of this section, significant flora species in Nandewar are those listed under either the *TSC Act* or the *Environment Protection & Biodiversity Conservation Act 1999* (*EPBC Act*), or in Rare or Threatened Australian Plants (ROTAP) (Briggs & Leigh 1996). A total of 70 significant taxon have been recorded in Nandewar, represented by 929 individual records. Significant taxon comprise about 5% of all native taxon in Nandewar. **Table 3-D** lists the significant plants and their status.

TABLE 3-D

Significant flora in Nandewar

Taxon	No. Records	Growth Form	TSC	EPBC	ROTAP
Acacia acrionastes	3	SH	E		yes
Acacia atrox	10	SH	E		
Acacia jucunda	2	SH	E		
Acacia macnuttiana	5	SH	E	V	yes
Acacia pubifolia	4	SH	E	V	yes
Angophora exul	7	TR	E		
Asterolasia sp. 'Dungowan Creek'	1	SH	E		
Asperula charophyton	3	FO			yes
Astrotricha roddii	77	SH	E	E	yes
Boronia granitica	17	SH	V	E	yes
Boronia ruppii	14	SH	E		
Cadellia pentastylis	39	TR	V	V	yes
Callistemon pungens	21	SH			yes
Capparis canescens	2	SH	E		
Derwentia arenaria	11	SH			yes
Dichanthium setosum	28	GR	V	V	
Digitaria porrecta	10	GR	E	E	yes
Discaria pubescens	26	SH			yes
Diuris pedunculata	2	FO	E	E	yes
Dodonaea hirsuta	3	SH			yes
Dodonaea rhombifolia	2	SH			yes
Eucalyptus caleyi ssp *ovendenii*	5	TR	V	V	yes
Eucalyptus elliptica	56	TR			yes
Eucalyptus malacoxylon	66	TR			yes
Eucalyptus mckieana	45	TR	V	V	yes
Eucalyptus nandewarica	22	TR			yes
Eucalyptus nicholii	11	TR	V	V	yes
Eucalyptus oresbia	4	TR	V		
Eucalyptus rubida ssp *barbigerorum*	9	TR	V	V	yes
Eucalyptus youmanii	47	TR			yes
Euphorbia sarcostemmoides	1	SH	E		yes
Euphrasia arguta	1	FO	E4		
Euphrasia orthocheila	1	FO			yes
Euphrasia ruptura	1	FO	E4		
Goodenia macbarronii	8	FO	V	V	yes
Grevillea beadleana	1	SH	E	E	yes

TABLE 3-D (*cont'd*)

Taxon	No. Records	Growth Form	TSC	EPBC	ROTAP
Grevillea beadleana	1	SH	E	E	yes
Hakea pulvinifera	10	SH	E	E	yes
Haloragis exalata	1	FO	V	V	yes
Hibbertia kaputarensis	26	SH			yes
Homopholis belsonii	5	GR		V	yes
Homoranthus biflorus	20	SH			yes
Homoranthus bornhardtiensis	2	SH	E		
Homoranthus prolixus	20	SH	V	V	yes
Indigofera baileyi	2	SH	E		yes
Isotropis foliosa	12	SH			yes
Leionema rotundifolium	19	SH			yes
Leionema viridiflorum	19	SH			yes
Macrozamia humilis	6	CY	E		
Micromyrtus grandis	6	SH	E	E	
Olearia gravis	19	SH			yes
Ozothamnus adnatus	2	SH			yes
Persoonia terminalis ssp *recurva*	11	SH			yes
Persoonia terminalis ssp *terminalis*	18	SH			yes
Phebalium glandulosum ssp *eglandulosum*	1	SH	E	V	yes
Picris eichleri	5	FO			yes
Picris evae	2	FO	V	V	yes
Polygala linariifolia	11	FO	E		
Pomaderris queenslandica	3	SH	E		
Prostanthera cruciflora	16	SH			yes
Prostanthera cryptandroides ssp *euphrasioides*	5	SH	V	V	yes
Prostanthera staurophylla	1	SH	V		
Pterostylis woollsii	9	FO			yes
Pulenaea setulosa	33	SH			yes
Rulingia procumbens	4	SH	V	V	yes
Rutidosis heterogama	6	FO	V	V	yes
Swainsona murrayana	1	SH	V	V	yes
Swainsona sericea	6	FO	V		
Thesium australe	47	FO	V	V	yes
Zieria odorifera	15	SH			yes
Corunastylis sp nov (Undescribed orchid – Howell)	1	FO			

Notes : Growth form codes; CY = cycad, FO = forb, GR = grass, SH = shrub, TR = tree
EPBC/TSC codes; E = endangered, V = vulnerable

A number of other taxa of conservation significance are known to occur in Nandewar, particularly associated with areas of serpentinite geology (see for example Hoskin & James 1998). Many of these species are undescribed at this stage, and may be listed under *TSC Act, EPBC Act* or ROTAP in the future. Further detailed survey and taxonomic studies will no doubt result in the discovery of more species of significance in Nandewar.

4 Floristic Analysis

4.1 BACKGROUND

Production of a vegetation map requires prior classification of floristic site data into a set of vegetation communities or groups, which form the basis of the final map units. Similar to previous assessments, this project employed a clustering algorithm in conjunction with full-floristic site data to generate a set of vegetation groups.

4.2 ANALYSIS APPROACH

Floristic data were analysed using a numerical hierarchical agglomerative process to partition sites into distinctive groups based on their floristic similarity. A value of dissimilarity was first calculated for every pair of survey sites by applying the Bray-Curtis measure of association (Bray and Curtis 1957) to cover-abundance data, using the ASO module of PATN (Belbin 1995). Sites were then grouped by applying a clustering algorithm with unweighted pair-group arithmetic averaging. As with floristic analysis undertaken for the BBS WRA (RACD 2003), the UPGMA routine in the FUSE module of PATN was used with a beta value of –0.1 (Belbin and McDonald 1993) to provide the cluster hierarchy, represented visually by a dendrogram. The Bray-Curtis groups were used as the basis of map unit derivation.

Following the initial clustering, a nearest neighbour analysis was conducted to identify potentially misclassified sites, defined as sites in which at least three of its five nearest neighbours belonged to a different group. Each of the reallocation rules listed in **Table 4-A** was applied in turn to each set of sites meeting its specific criterion for misclassification. Relationships amongst sites were re-examined between each step, and the criteria and rules applied iteratively until no further site reallocation was necessary. On completion of this task, a final expert reallocation was performed on any site comprising no nearest neighbours in its group, if that reallocation was found not to compromise any previous reallocation.

A total of 204 reallocations were made, representing about 7% of all sites. The effect of these reallocations increased the average percentage of the nearest five neighbours per site from 68.8% to 71.3%.

TABLE 4-A

Summary of reclassification criteria and rules

Misclassification criterion	Reallocation rule	No of Sites reallocated
All NNs in group other than site group	Reallocate to group containing the five NNs.	11
At least four NNs in group other than site group, and most similar NN in other group	Reallocate to group containing the four NNs.	28
At least three NNs in group other than site group, and two most similar NNs in other group	Reallocate to group containing the three NNs.	38
At least three NNs in group other than site group, and most similar NN in other group	Reallocate to group containing the three NNs.	42
No NNs in group	Reallocate to group containing one or more NNs if no previous allocations are compromised	85
NN – nearest neighbour		204

A non-hierarchical analysis (ALOC) was also undertaken to provide an alternative grouping with which Bray-Curtis groups could be compared after the nearest neighbour reallocations. In most cases there was strong correlation between a Bray-Curtis and ALOC groups, and these were considered robust groups. However, some groups were split or merged if obvious group patterns between Bray-Curtis and ALOC were observed.

Following the reallocation process, each group was expertly examined with respect to its geographical distribution, observer differences and within-group dissimilarity. Several sites were removed from further analysis at this stage, including geographic and ecological outliers. Some groups were also merged if they shared similar floristic, distribution and environmental values.

As the subsequent step to group definition, sites representing vegetation types that were readily mappable by API, but occupied limited geographic distribution, were merged to form separate groups. These were Bendemeer white gum, bimble box, brigalow, green mallee, grey box, Mckie's stringybark, ooline, melaleuca shrubland, mugga ironbark, Pilliga box, river oak, river red gum, semi-evergreen vine thicket, serpentinite spinifex and weeping myall. All of these groups contained robust sub-groups within the original dendrogram. As a final step, four groups not defined by site data analysis, but defined by API units, were added. These were map units 113, 115, 116 and 117.

4.3 DESCRIPTION OF VEGETATION GROUPS

All 113 groups are listed in **Table 4-B**. Profiles of the floristic composition, vegetative structure and physical environment of each group were prepared using summaries of available survey data (**Appendix 4.1**) Exotic species were included in the profiles despite being excluded from the original analysis.

TABLE 4-B

Nomenclature of final vegetation groups

MAP UNIT	NAME	No Sites
1	Black Pine Granite Outcrop Shrubby Woodland; tableland edge	50
2	Black Pine Granite Outcrop Shrubland/Open Woodland; tableland edge	23
3	White Pine/Orange Gum/Acacia Granite Outcrop Shrubland; Moonbi	10
4	Myrtle Shrubland (+- White Pine/Tumbledown Red Gum); Dripping Rock	3
5	Shrublands; Kaputar Trachyte	21
6	Orange Gum/Black Pine Shrubby Open Forest; north-east	51
7	Shrublands; Howell	44
8	Black Pine/Orange Gum/Tumbledown Red Gum Shrubby Open Forest; south-east	55
9	Black Pine/Tumbledown Red Gum/Narrow-leaved Ironbark Shrubby Open Forest; north-east	23
10	Black Pine/Tumbledown Red Gum/Narrow-leaved Ironbark/Red Stringybark Shrub/Grass Open Forest; Severn River	29
11	Caley's Ironbark/Orange Gum/Black Pine Shrubby Open Forest; Severn River	22
12	Orange Gum/Caley's Ironbark/New England Blackbutt Heathy Open Forest; Severn River	13
13	Black Pine/Rough-barked Apple/Stringybark Shrubby Open Forest; tableland edge	27
14	Orange Gum/Caley's Ironbark/Red Stringybark Shrub/Grass Open Forest; southern tableland edge	34
15	Rough-barked Apple/Blakely's Red Gum Grassy Open Forest; central tableland edge	27
16	New England Blackbutt/Youman's Stringybark Grassy Open Forest; tableland edge	40
17	Tumbledown Gum/Black Pine/*Acacia cheelii* Shrubby Open Forest; scattered	12
18	Tumbledown Red Gum/Dwyer's Red Gum Shrubby Woodland; western	12
19	Tumbledown Red Gum/Caley's Ironbark Shrubby Open Forest; Rock of Gibraltar	9
20	Narrow-leaved Ironbark/Pine/Brown Bloodwood Shrub/Grass Open Forest; north-west	37
21	Black Pine/Narrow-leaved Ironbark/Dirty Gum Grassy Open Forest; north-west	22
22	White Pine/Narrow-leaved Ironbark Shrub/Grass Open Forest; north-west	13
23	Black Pine/Northern Smooth-barked Apple Shrubby Open Forest; north-west	65
24	White Pine/Northern Smooth-barked Apple Shrubby Open Forest; north-west	15
25	Tumbledown Red Gum/White Pine/Silver-leaved Ironbark Shrubby Open Forest; northern	27
26	Tumbledown Red Gum/BlackPine Shrubby Open Forest; north-east	30
27	Tumbledown Red Gum/Orange Gum/White Pine Shrubby Open Forest; Kwiambal	18
28	Black Pine/Tumbledown Red Gum/Caley's Ironbark Shrub/Grass Open Forest; widespread	22
29	White Pine/Tumbledown Red Gum/Caley's Ironbark Shrubby Open Forest; widespread	72
30	Tumbledown Red Gum/Caley's Ironbark Shrubby Open Forest; scattered	9
31	White Pine/Silver-leaved Ironbark/Tumbledown Red Gum Grassy Open Forest; far north	25
32	White Pine/Tumbledown Gum Shrubby Open Forest ; northern	30
33	Dirty Gum/White Pine/Northern Smooth-barked Apple Shrub/Grass Open Forest; north-west	13
34	White Pine/Silver-leaved Ironbark/Tumbledown Red Gum Shrubby Open Forest; Kwiambal	62
35	White Pine/Silver-leaved Ironbark/Tumbledown Red Gum Shrubby Open Forest; northern	123
36	White Pine/White Box Shrub/Grass Open Forest; central	51
37	White Pine/White Box/Silver-leaved Ironbark Shrubby Open Forest; western	44
38	White Pine/White Box Grass/Forb Open Forest; widespread	75
39	White Box/White Pine Shrub/Grass Open Forest; central	37
40	Silver-leaved Ironbark/Black Pine/White Box Shrubby Open Forest; northern	29
41	Silver-leaved Ironbark/White Pine/Tumbledown Red Gum Shrub/Grass Open Forest; Ashford	12
42	White Box Shrubby Open Forest; widespread	32
43	White Box/White Pine Shrubby Open Forest; southern	46
44	White Box Grassy Open Forest; widespread (mainly southern)	20
45	White Pine/Narrow-leaved Ironbark Shrub/Grass Open Forest; south-west	65
46	White Pine/Silver-leaved Ironbark Grassy Open Forest; north-west	24
47	White Pine/Narrow-leaved Ironbark shrub/grass Open Forest; north-west	31
48	White Pine/Silver-leaved Ironbark/White Box Shrub/Grass Open Forest; Warialda-Bingara	16
49	Tea-tree Drainage Line Shrubland; scattered	13
50	Mountain Gum/Messmate/Snow Gum Montane Open Forest; far south-east	14
51	Black Olive Berry Cool Temperate Rainforest; far south-east	2
54	Tumbledown Red Gum/ Blakely's Red Gum Shrubby Open Forest; northern	10
55	Blakely's Red Gum/Rough-barked Apple/Red Stringybark Grassy Open Forest; tableland edge	11
56	Blakely's Red Gum/White Pine/Rough-barked Apple Grassy Open Forest; northern drainage lines	12
57	Yellow Box/Blakely's Red Gum Grassy Woodland; widespread	29

TABLE 4-B (*cont'd*)

MAP UNIT	NAME	No Sites
58	Rough-barked Apple Riparian Forb/Grass Open Forest; widespread	38
60	Blakely's Red Gum/Yellow Box Grassy Open Forest/Woodland; tablelands	32
61	White Box Grassy Open Forest; northern	27
62	Tumbledown Red Gum/Pine Shrubby Open Forest; northern	14
63	Rough-barked Apple/Red Stringybark Shrubby Open Forest; widespread	19
64	Black Pine/White Box Shrubby Open Forest; Kaputar	23
65	White Box/Silvertop Stringybark/White Pine Shrubby Open Forest; southern hilly	49
66	Silvertop Stringybark/Orange Gum Shrubby Open Forest; Horton	13
67	Rough-barked Apple/Silvertop Stringybark/Red Stringybark Grassy Open Forest; tableland edge	18
68	Silvertop Stringybark/Rough-barked Apple/*E. quinniorum* Shrubby Open Forest; southern tableland edge	20
69	White Box/Rough-barked Apple Shrubby Open Forest; Kaputar	25
70	Narrow-leaved Ironbark/Black Pine Shrubby Open Forest; Kaputar	20
71	White Box Shrubby Open Forest; Melville Range	33
72	Mallee Woodland; Duri Peak	8
73	Narrow-leaved Ironbark/Tumbledown Red Gum Shrubby Open Forest; Melville Range	31
74	Nandewar Box/New England Blackbutt/Red Stringybark Shrub/Grass Open Forest; Kaputar	27
75	Silvertop Stringybark/Nandewar Box Shrubby Open Forest; Kaputar mid elevation	20
76	Mountain Gum/Snow Gum Grassy Open Forest; Kaputar high elevation	21
77	Ribbon Gum/ Silvertop Stringybark Ferny Open Forest; Kaputar	7
78	Snow Gum/New England Peppermint Grassy Open Forest; tableland edge	9
79	Silvertop Stringybark/Rough-barked Apple Grassy Open Forest; southern hills	55
80	Rough-barked Apple/Silvertop Stringybark/Ribbon Gum Shrub/Grass Open Forest; far south	21
81	Redleg Grass Grassland/Open Woodland; western	22
82	Spear Grass/ Bluegrass Grassland/Open Woodland; central/southern	28
83	White Pine/Silver-leaved Ironbark Grassy Open Forest; northern	26
84	White Pine/Silver-leaved Ironbark Shrub/Grass Open Forest; central	25
85	Plains Grass/Bluegrass Grassland; western	22
86	Bluegrass Grassland; north-west	13
87	White Box Shrub/Grass Open Forest; north-west	11
88	Bluegrass/Spear Grass Grassland; northern	27
89	White Box/White Pine/Silver-leaved Ironbark Shrubby Open Forest; western	34
90	White Pine/Silver-leaved Ironbark Shrubby Woodland; western	16
91	Rough-barked Apple/White Box/Rusty Fig Shrubby Open Forest; Kaputar	9
92	Rusty Fig Dry Rainforest; scattered	29
93	Alectryon/Rusty Fig/Mock Olive Dry Rainforest; scattered	17
94	Belah/White Pine Shrubby Woodland (with patches of Semi-evergreen Vine Thicket); north-west	21
95	Bimble Box/White Pine Grassy Woodland; western	32
96	Brigalow Acacia Woodland; scattered	7
97	Silvertop Stringybark/Bendemeer White Gum Grassy Open Forest; Kaputar and southern tableland edge	23
98	Grey Box/Rough-barked Apple Shrub/Grass Open Forest; northern	22
99	Grey Box/Blakely's Red Gum/Yellow Box Grassy Open Forest; widespread	29
100	Mckie's Stringybark/New England Blackbutt/Rough-barked Apple Grassy Open Forest; tableland edge	33
101	Western Grey Box/Pilliga Box Grassy Open Forest; north-west	17
103	Mugga Ironbark/Black Pine Shrubby Open Forest; north-west	11
104	Mugga Ironbark/Stringybark Shrubby Open Forest; southern	1
105	Mugga Ironbark/Blakely's Red Gum Shrub/Grass Open Forest; Bingara	13
106	Weeping Myall Woodland/Shrubland; scattered	6
107	Ooline Open or Closed Forest; scattered	43
108	Paperbark Riparian Forb/Grass Low Closed Forest; widespread	10
109	River Oak Riparian Open Forest; widespread	57
110	River Red Gum Riparian Open Forest/Woodland; widespread	32
111	Stringybark/Spinifex Serpentine Woodlands; scattered	15
112	Green Mallee Mallee Woodland; scattered	9
113	Murrurundi stringybark	1
114	Semi-evergreen Vine Thicket; scattered	17
115	Swamp/wetland	6
116	Carbeen; far north-west	0
117	Conglomerate heathy open forest; far south-west	1
	Note. Groups 52, 53 , 59 & 102 do not exist.	2854

Diagnostic species within each group were identified using a fidelity analysis, which compares species frequency within a group to its frequency within all other groups. Species with a significantly greater frequency within the group were identified as positive diagnostic. Conversely, species with a significantly greater frequency outside the group were identified as negative diagnostic (see also Keith and Bedward 1999). All relevant information regarding community profiles is presented in **Appendix 4.1**.

4.4 ADDITIONAL SITES FOR GENERAL ADDITIVE MODELLING

As a rule of thumb a minimum of 10 sites were required to derive a modelled surface using generalised additive modelling (GAM), although general dissimilarity modelling (GDM) can use fewer sites (**Chapter 5**). The Nandewar region contains several hundred canopy-only sites in addition to full-floristic sites used in PATN. Most canopy-only site data were collected for the Nandewar Scoping Study (DeVries 2000), and many are plot-based with cover-abundance scores.

Where sufficient floristic information was associated with a canopy site, it was added to the sites representing its relevant group, thus bolstering the overall number of sites to support GAM. A total of 291 canopy sites were assigned to a total of 24 groups (**Table 4-C**). For seven groups represented by fewer than 10 sites after allocation of canopy sites, one or more "dummy" sites were expertly plotted in the landscape (**Table 4-C**). Dummy sites were only plotted in API polygons deemed likely to support the community of concern, and were only plotted in close proximity to existing plots.

TABLE 4-C

Additional sites assigned to groups to support GAM

MAP UNIT	NAME	Initial sites	Canopy sites	Dummy sites	Total sites
8	Black Pine/Orange Gum/Tumbledown Red Gum Shrubby Open Forest; south-east	55	7	-	62
19	Tumbledown Red Gum/Caley's Ironbark Shrubby Open Forest; Rock of Gibraltar	9	-	1	10
23	Black Pine/Northern Smooth-barked Apple Shrubby Open Forest; north-west	65	19	-	84
24	White Pine/Northern Smooth-barked Apple Shrubby Open Forest; north-west	15	9	-	24
30	Tumbledown Red Gum/Caley's Ironbark Shrubby Open Forest; scattered	9	-	1	10
44	White Box Grassy Open Forest; widespread (mainly southern)	20	29	-	49
55	Blakely's Red Gum/Rough-barked Apple/Red Stringybark Grassy Open Forest; tableland edge	11	15	-	26
57	Yellow Box/Blakely's Red Gum Grassy Woodland; widespread	29	38	-	67
58	Rough-barked Apple Riparian Forb/Grass Open Forest; widespread	38	9	-	47
60	Blakely's Red Gum/Yellow Box Grassy Open Forest/Woodland; tablelands	32	7	-	39
65	White Box/Silvertop Stringybark/White Pine Shrubby Open Forest; southern hilly	49	3	-	52
68	Silvertop Stringybark/Rough-barked Apple/*E. quinniorum* Shrubby Open Forest; southern tableland edge	20	21	-	41
72	Mallee Woodland; Duri Peak	8	-	2	10
77	Ribbon Gum/ Silvertop Stringybark Ferny Open Forest; Kaputar	7	1	2	10
78	Snow Gum/New England Peppermint Grassy Open Forest; tableland edge	9	-	3	12
91	Rough-barked Apple/White Box/Rusty Fig Shrubby Open Forest; Kaputar	9	1	-	10
95	Bimble Box/White Pine Grassy Woodland; western	32	4	-	36
96	Brigalow Acacia Woodland; scattered	7	3	-	10
97	Silvertop Stringybark/Bendemeer White Gum Grassy Open Forest; Kaputar and southern tableland edge	23	10	-	33
98	Grey Box/Rough-barked Apple Shrub/Grass Open Forest; northern	22	2	-	24
99	Grey Box/Blakely's Red Gum/Yellow Box Grassy Open Forest; widespread	29	47	-	76
100	Mckie's Stringybark/New England Blackbutt/Rough-barked Apple Grassy Open Forest; tableland edge	33	3	-	36
101	Western Grey Box/Pilliga Box Grassy Open Forest; north-west	17	4	-	21
104	Mugga Ironbark/Stringybark Shrubby Open Forest; southern	1	-	10	11
105	Mugga Ironbark/Blakely's Red Gum Shrub/Grass Open Forest; Bingara	13	40	-	53
106	Weeping Myall Woodland/Shrubland; scattered	6	-	4	10
109	River Oak Riparian Open Forest; widespread	57	10	-	67
110	River Red Gum Riparian Open Forest/Woodland; widespread	32	5	-	37
111	Stringybark/Spinifex Serpentine Woodlands; scattered	15	1	-	16
112	Green Mallee Mallee Woodland; scattered	9	3	-	12
	All other sites	*2172*	-	-	*2172*
		2853	**291**	**23**	**3167**

5 Vegetation Model and Map

5.1 BACKGROUND

Generalised additive modelling (GAM) and generalised dissimilarity modelling (GDM) were each used in conjunction with site data, abiotic environmental surfaces and API allocation rules to map the predicted and extant distribution of each map unit in Nandewar. A total of 106 GAMs were derived, representing groups comprising at least 10 sites. Groups 4, 51, 113, 115, 116 and 117 had fewer than 10 sites, and were not modelled using GAM, and a GAM was not derived for group 72 since its two dummy sites were not read.

A total of 109 GDMs were derived, including all groups for which GAMs were derived, as well as group 72, and two groups with fewer than 10 sites (Groups 4 and 51). Expert models were derived for four geographically restricted groups using the composite API layer. These were groups 113, 115, 116 and 117.

The GAM and GDM surfaces generated for each community were expertly compared, and the most appropriate surface chosen. All 113 individual surfaces were integrated into a combined predicted map using a new iterative replacement technique developed for this project.

5.2 PREPARATION OF ENVIRONMENTAL SURFACES

Several abiotic surfaces (**Appendix 5.1**) were used to support modelling. Each was selected on the basis of likely effect on plant growth and thus species composition. All layers were derived at 25m grid-cell resolution. The individual layers were either climatic or non-climatic, and are listed as follows:

Climatic surfaces

- precann mean annual precipitation
- precdryq mean precipitation of the driest quarter
- precwetq mean precipitation of the wettest quarter
- radhghpd mean solar radiation of the highest period
- radlowpd mean solar radiation of the lowest period
- tmpannrge annual temperature range
- tmpmncldq mean temperature of the coldest quarter
- tmpmnwrmq mean temperature of the warmest quarter

Non-climatic surfaces

▪ aspect	derived from DEM
▪ aspect-smooth	broad aspect derived from smoothed DEM
▪ dem25m	digital elevation model
▪ easting	
▪ fertestim	fertility layer derived from geology and wetness layers
▪ lithology	10 lithological classes derived from DMR geology layer
▪ northing	
▪ prescott	index of soil water balance (from Prescott 1948)
▪ rug250m	ruggedness index
▪ slope	
▪ topo250m	topographic index
▪ wetsmooth	smoothed wetness index

5.3 GENERALISED ADDITIVE MODELLING

A logistic regression model relating the probability of presence of each map unit to the abiotic environmental and geographical variables was fitted spatially using generalised additive modelling (Yee and Mitchell 1991). The modelling was conducted by the DEC Conservation Assessment and Data Unit in Coffs Harbour, via a modelling module which fitted regression models using S-PLUS statistical software (StatSci 1995). A total of 106 GAMs were generated. Each was an integer grid with probabilities 0 to 100.

5.4 GENERALISED DISSIMILARITY MODELLING

A possible weakness of GAMs is that models are fitted independently of each other. That is, generation of each model is based on the floristic data of sites representing its group, whilst ignoring floristic data of all other groups. This can potentially limit the power of GAMs, especially those groups represented by a small number of sites. GDM is an alternative procedure that measures the biological dissimilarity of each pair of survey sites in a dataset as a function of their environmental and geographical separation (Faith and Ferrier 2002, Ferrier 2002).

GDM was carried out by the GIS Research and Development Unit in Armidale to generate two alternative sets of probability surfaces with which to compare to those generated using GAM. The first step was application of a GDM to the sites-species matrix used in the PATN analysis. The compositional dissimilarity between every pair of survey sites, calculated using the Bray-Curtis measure based on presence/absence of species, was modelled in relation to the abiotic variables listed in **Section 5.2** to generate a set of transformed environmental grids. These were used to extrapolate each group into the landscape using a form of k-nearest neighbour modelling. Two types of probability surface were generated from GDM;

euclidean surfaces in which a spatial constraint was imposed using the site-group data, and non-euclidean surfaces in which no spatial constraint was imposed. The latter were generally much more widespread. Each surface was derived as an integer grid with probability values 0 to 1000 (10 times better resolution than GAMs).

5.5 CONSTRAINING MODELS USING API

5.5.1 Background

Each of the euclidean-GDM and GAM probability surfaces was constrained by the API composite layer and 100K mapsheet distribution. A unique set of candidacy rules was developed for each vegetation group based on API floristics, API understorey, and 100K mapsheet (and for grassland groups, canopy cover class). The rule sets were applied spatially through a set of candidacy matrices that acted to reduce the model probability values in some areas. For any grid-cell of a given probability surface, the final constrained value was simply a product of the original value, canopy probability, understorey probability, and mapsheet probability of that community for that grid-cell (**Figure 5-A**). The constrained probability of each grid-cell had a value between 0 and 12 000 on completion of this process. Derivation of each matrix is briefly described in the following section.

5.5.2 API canopy classes

A canopy candidacy matrix was used to assign a probability score to each vegetation group for each canopy class derived from API (**Section 2.5.1**). The matrix was developed in EXCEL and comprised a cross-tabulation of API canopy class (878 rows) by vegetation group (113 columns). Each cell in the matrix contained a value of either a 20, 15, 10, 5, 2 or 0 based the likely probability of a modelled surface occupying an API canopy polygon (‘20’ = highest candidacy, ‘2’ = lowest candidacy, ‘0’ = model set to zero probability). The matrix was developed expertly, with input from the fidelity analysis (**Section 4.3**). Fidelity provided a list of positive and negative diagnostic overstorey species for each group, which could be used in conjunction with species codes and descriptions of each API unit to assign probabilities. Areas without any existing API (over 50% of the region) were placed into a single unmapped class ‘0’ in the canopy matrix and assigned the maximum value of 20.

5.5.3 API understorey classes

An understorey candidacy matrix was also used to assign a probability to each vegetation group for each understorey class derived from API. The matrix was a simple cross-tabulation of API understorey class (rows) by vegetation groups (columns). Each cell in the matrix contained a value of either a 3 or 2 (including 3 for non-mapped areas). This had the effect of moderating the predictive power of a modelled grassy community where it clearly fell into a non-grassy understorey, and *vis versa.*

5.6.4 100K mapsheet

A mapsheet candidacy matrix was developed to assign a probability to each vegetation group for each 100K mapsheet in Nandewar. The matrix was a simple cross-tabulation of mapsheet (rows) by vegetation groups (columns). Each cell in the matrix contained either a 2, 1 or 0. This provided a final geographical constraint on models predicting over a large extent.

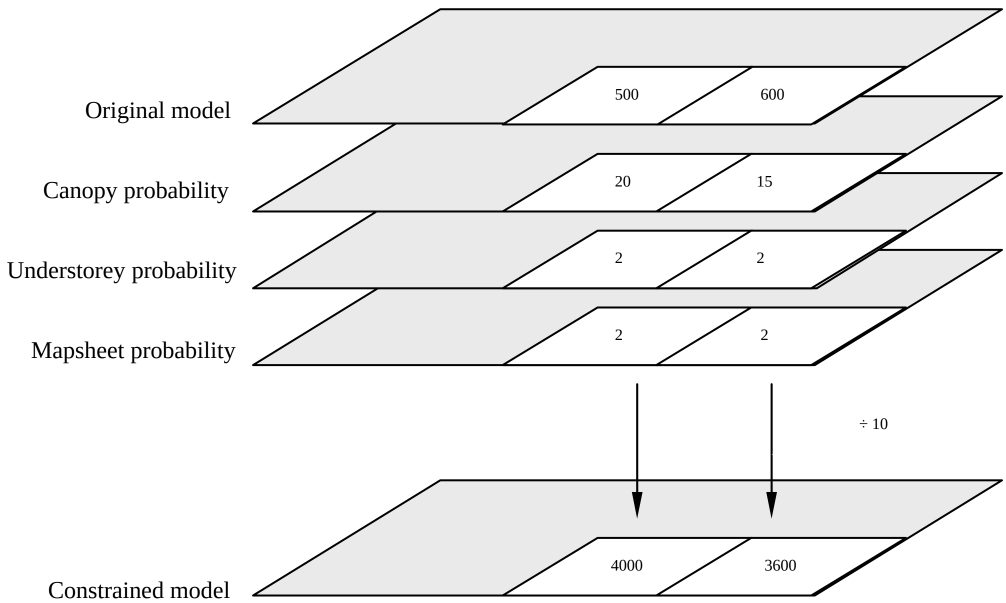

FIGURE 5-A

Application of API constraints to original model

5.6.5 Cover

A cover candidacy matrix was developed to impose a final constraint on the surfaces of each grassland group (81, 82, 85, 86 and 88). The matrix was a simple cross-tabulation of cover class (rows) by vegetation groups (columns). Each cell in the matrix contained a value of either 1 (tree cover <10%) or 0 (tree cover >10%). In this way, the final probability surface was set to '0' for each grassland community occupying API polygons with >10% tree cover.

5.6 MODEL SELECTION

This project provided a unique opportunity to compare the predicted distribution of vegetation communities generated from GAMs and GDMs using the same site and floristic data (after imposition of the various candidacy matrices). The euclidean surfaces derived from the GDM were generally observed to be superior predictors than surfaces derived from GAM. There was better correlation between sites and areas of high modelled probability in the GDM-derived surfaces than the GAMs, and in well sampled areas such as Kings Plains and Kwiambal National Parks where several groups were represented by numerous sites, the GDMs appeared to provide better environmental differentiation between groups than GAMs.

Only three GAMs were selected in preference to the GDMs; group 104 (mugga ironbark - southern), group 109 (river oak) and group 111 (serpentinite woodland). The GDM for group 104 was modelled on the basis of a single site, and was too geographically confined. The GAM surface for group 109 appeared more robust than the GDM in predicting distribution in upland watercourses. The GAM for group 111 appeared to confine the model to the serpentinite geology much better than the GDM.

In all other cases, the euclidean GDM surface was selected in preference to the GAM surface. For eight widespread groups (44, 55, 57, 68, 78, 98, 99 and 106), the euclidean GDM was appended with the residual extent of either its GAM or non-euclidean GDM to ensure adequate modelled coverage. In these cases the integrity of the original GDM was retained while the overall modelled extent was increased within the spatial extent of either its non-euclidean GDM or GAM.

As a result of model selection disfavouring GAMs, only 57 of the 291 canopy-only sites selected for possible contribution to modelling (**Section 4.4**) were eventually used. The remaining 234 canopy-only sites, in addition to others not considered for modelling, were thus available as an accuracy check against the final integrated model (**Section 5.11**).

5.7 MODEL EDITS

A sum calculation was performed on all the final surfaces to locate ‘no-model’ areas in the landscape, that is, areas in which no community was modelled. A total of about 15 000 hectares (0.5% of the Study Area) was identified, almost all of which occurred within the mapped extent of the integrated API layer. The API layer was clipped to the ‘no-model’ areas, and each polygon in the clipped layer was assigned an appropriate group number based on its canopy description and proximity to existing model distributions. These were converted to individual grids and appended to their appropriate constrained modelled surfaces. On completion of this process, fewer than 400 hectares of ‘no-model’ areas remained in the study area. These were filled as part of model integration (**Section 5.9**)

5.8 MODEL RECLASSIFICATION

Each surface was reclassified to provide a spatial coverage of relative rather than absolute probability. For each group, the relative probability of a grid-cell was simply calculated as its original probability proportional to the sum of all group probabilities of that cell, multiplied by 10 000. For example, the original value of a group may only have been 1 200 (10%), however, if no other group was predicted, the relative probability received a maximum value of 10 000 (100%). Conversely, the original probability of a grid-cell may have been 9 000 (75%), indicating a strong prediction. However, if several other groups predicted strongly for that cell, its relative probability would have been reduced appreciably.

5.9 MODEL INTEGRATION – THE COMPOSITE VEGETATION MAP

5.9.1 Background

While individual models provided maximum spatial information for each group, generation of a composite (single layer) vegetation map was also required to support interpretation and communication. A simple integration of the 113 reclassified surfaces was undertaken by assigning to each grid-cell the vegetation group possessing the highest relative probability (post API constraints). Areas possessing no model (**Section 5.7**) were filled using a 'nibble' command in ArcView. The resultant composite layer provided the best indication of which group was likely to occupy any given gridcell, however, the product also tended to mis-represent the extent of different groups. Well-sampled groups were generally over-predicted while poorly-sampled groups were under-represented. This problem was addressed in the BBS WRA by employing an iterative Bayesian technique to derive the composite layer in which the total mapped extent of each group was matched as closely as possible to the total predicted extent from the constrained probability surface for that group (ie. by summing the gridcell probabilities).

A potential disadvantage of the Bayesian technique is that the final unit assigned to a gridcell may possess a relatively low probability for that cell. An alternative analytical technique called 'iterative partial replacement' was trialed for Nandewar. Similar to the Bayesian technique, it required that the total predicted extent of each group first be determined.

5.9.2 Calculation of predicted area of each map unit

The predicted area (hectares) of each map unit or group was estimated in the BBS by analysing the relative strength of each constrained model (calculated as the sum of all its modelled gridcell probabilities, relative to the sum of all those for all other groups). This approach is useful for estimating the predicted area within the API coverage (particularly for finer-scale mapping). However, in parts of the landscape containing very broad or no API coverage, the approach may over-estimate the predicted area of map units which have been tightly constrained by existing API, but which have modelled robustly outside the extent of API. Conversely, the approach may under-estimate the predicted area of units delivering relatively weak models (eg. units possessing few sites with which to model), yet where API suggests the unit to be more extensive.

The model-only approach to calculating the predicted area of each map unit also ignores the clearing intensity of each unit. In theory, models of extensively cleared units (eg. grassy box types in fertile valleys) should predict more strongly into cleared areas than those of units with a low clearing history (eg. black cypress types). This is not always the case, and the predicted area of extensively cleared units may be under-estimated in agricultural areas.

To address these weaknesses, an alternative approach using models and API was employed to estimate the predicted area of each map unit in Nandewar. The approach used two comparable prediction indices, each calculated as a percentage value:

1. *relative model index (RMI),* calculated for a map unit as the sum of all its modelled gridcell probabilities, relative to the sum of all those for all other map units; and

2. *relative API index (RAI),* calculated for a map unit as the total area of its high-candidate API polygons, relative to the sum of all other high-candidate API polygons for all other map units (generic API polygons such as 'unknown' or 'eucalypt' were not included).

The percent predicted area (and absolute area) was calculated for each map unit by applying one of four algorithms shown in **Table 5-A**. The clearing history label in the table was expertly assigned to each map unit by considering its geology, productivity, land capability, slope and position in landscape, and visual interpretation of its model with LandSat imagery. Grassy box forest types were generally high (having been extensively cleared and modified in the past), while black pine types and other communities occurring on granitic/rhyolitic substrate were generally low. Of the 113 groups, 20 groups were assigned 'high', 45 groups were assigned 'moderate' and 48 were assigned 'low' (**Table 5-B**).

TABLE 5-A

Algorithms used to derive the predicted area of each map unit

	% Predicted Area =	
Clearing history	**for RAI > RMI**	**for RMI > RAI**
Low	RMI	RAI + (RMI – RAI) / 3
Moderate	RMI + (RAI – RMI) / 4	RMI + (RAI – RMI) / 4
High	(RMI + RAI) / 2	RMI

Where RAI (predicted extent from API) exceeded RMI (predicted extent from model), then 'low' units were assigned the RMI value, 'moderate' units were assigned a value slightly more than the RMI, and 'high' units were assigned a value equal to the mean of the RMI and RAI. Where RMI exceeded RAI, 'low' units were assigned a value slightly less than the mean of RMI and RAI, 'moderate' units were assigned a value slightly less than the RMI, and 'high' units were assigned the RMI. These algorithms enabled the models to have the major bearing on the final predicted area, while API had a lesser but important influence.

5.9.3 Iterative partial replacement technique

The iterative partial replacement technique was designed to replace the gridcells of over-predicted map units with those of under-predicted units in the composite, with the aim of achieving a final area of each unit as close as possible to its predicted area without assigning to any one gridcell a map unit of unduly low relative probability. It also aimed to provide a likely spatial representation of individual map units within the cleared landscape.

At commencement of the process, the combined extent of over-predicted units totalled about 490 700 hectares (comprising 47 over-predicted units across 15.3% of the analysis extent). Iterative partial replacement was undertaken in two stages to reduce this imbalance.

Stage 1 involved overlay of the predicted extent of the most under-predicted unit onto the composite map (starting with map unit 37), followed by the next most under-predicted unit, and so on until no areal reduction in the combined over-predicted extent was achievable. At each iteration, the predicted extent of the map unit of concern comprised a spatial selection of the maximum probability gridcells from its original smoothed model, totalling an area equal to its predicted area. To maintain integrity of the evolving composite during Stage 1, any gridcell possessing a maximum relative probability greater than 50% was not replaced (ie. where a single unit predicted more than 50% in relation to the combined probability of all other units, it was excluded from replacement).

Stage 1 involved 135 iterations, in which the combined extent of over-predicted units was reduced from 490 700 hectares to 282 500 hectares (8.8% of the analysis extent). Most iterations involved more extensive units, some of which occurred up to five times in the sequence. From **Table 5-B** it can be calculated that the number of map units within 10% of their predicted areas increased in Stage 1 from 33 (original composite) to 44 (iteration 135).

Stage 2 of iterative partial replacement involved a single replacement of over-predicted with under-predicted map units. Only the lowest probability cells of over-predicted units were eligible for substitution, as long as they were located in areas in which no single map unit predicted more than 50%. Within this domain, each gridcell was replaced by the highest probability unit from the set of under-predicted units, as long as it comprised a minimum relative probability of at least 15%. The effect of this Stage 2 is demonstrated in **Table 5-B**. The combined extent of over-predicted units was reduced to 236 500 hectares (7.4% of the analysis extent), and 57 map units were within 10% of their predicted areas.

5.10 FINAL EDITING AND CHECKING

Following completion of iterative partial replacement, a final editing process was undertaken to identify and modify potential errors in the composite vegetation model. The geographic distribution of each unit was reviewed, and its coincidence with the original API layer checked. The composite layer was modified in the following areas:

- API polygons containing inappropriate map units. This occurred when the best suited map unit for a particular API polygon failed to model strongly enough into its spatial extent, and was replaced by one or more unlikely map units.
- major water storages, where the DEM followed the water surface instead of underlying topography. Associated environmental layers such as aspect, slope, and wetness were thus inaccurate, and as a result an inappropriate unit often modelled into these areas.
- areas of cleared land containing map units deemed unlikely to have occupied these areas in respect of their recognised distribution. In particular, map units such as Howell shrubland and some of the rainforest units modelled strongly into cleared areas, and were replaced by the most suitable alternative model where necessary.
- areas of cleared land containing map units deemed unlikely to have occupied these areas in respect of their geological signature. Map units represented by sites which were confined to specific geological types (eg. granite, rhyolite, serpentinite) were replaced by the most suitable alternative model in areas where they coincided with inappropriate geological types on cleared land.
- flood channels of the major watercourses, where the predicted spatial extent of the river red gum unit was revised using LandSat imagery. The river red gum model did not predict well in the immediate flood channel of the lower reaches of major rivers in Nandewar (eq. Dumaresq, Gwydir and Namoi Rivers).
- modelled extent of derived grassland units (map units 81, 82, 85, 86 and 88), which was replaced with a composite of second best predicting map units. The grassland units were each considered to constitute derived grassland, and were thus not included in the extant or predicted distribution maps. This assumption is supported by a national assessment of native temperate grassland distribution (Carter *et al*. 2003), and by a NSW conservation assessment in which clearing rates of at least 65% were reported for Nandewar (Pressey *et al.* 2000).

On completion of all checking and modification, a spatial smoothing in ArcView was undertaken to identify blocks of cells of individual map units occupying less than 1 hectare, and to replace each with its dominant surrounding map unit. Riparian groups (49, 106, 108, 109, 110) were not included in the smooth.

Following final checking and smoothing, the combined extent of over-predicted units was reduced to 229 200 hectares (7.1% of the analysis extent), and 43 map units were within 10% of their original predicted areas. The final area of each map unit is shown in **Table 5-B**, and individual maps of each unit illustrated in **Appendix 4.1.**

TABLE 5-B

Effect of iterative partial replacement on the area of each map unit in the composite vegetation layer

					Recalculated areas (ha) following Iterative Partial Replacement					
Map Unit	**Clearing history**	**Predicted Area (ha)**	**Original Composite**	**+/-**	**Stage 1 Composite**	**+/-**	**Stage 2 Composite**	**+/-**	**Final Composite**	**+/-**
1	*low*	19361	32769	+	30962	+	26924	+	26314	+
2	*low*	12070	12459	n	10867	-	10867	-	9940	-
3	*low*	3264	2545	-	2900	-	2900	-	1983	-
4	*low*	1312	1282	n	1310	n	1310	n	1312	n
5	*low*	1438	2561	+	2538	+	2538	+	1438	n
6	*low*	14897	25790	+	21130	+	18485	+	16981	+
7	*low*	3051	21586	+	18799	+	17473	+	3369	n
8	*low*	27618	34696	+	30447	n	29062	n	25143	n
9	*low*	14683	11246	-	10541	-	12962	-	12697	-
10	*low*	23489	26381	+	23313	n	23159	n	20790	-
11	*low*	28380	39926	+	35778	+	35243	+	28048	n
12	*low*	8155	1606	-	7647	n	7647	n	7035	-
13	*low*	19788	10024	-	15030	-	16701	-	21712	n
14	*low*	19574	19413	n	17905	n	17905	n	15991	-
15	*moderate*	50568	45376	-	50679	n	50043	n	56753	+
16	*moderate*	23001	19859	-	18125	-	21006	n	19233	-
17	*low*	4240	1831	-	1450	-	1484	-	1706	-
18	*low*	4566	3213	-	2246	-	2279	-	2308	-
19	*low*	7504	9527	+	7120	n	7120	n	5651	-
20	*moderate*	33932	25546	-	27626	-	28628	-	29512	-
21	*moderate*	30343	28160	n	25319	-	25319	-	25358	-
22	*moderate*	18191	14829	-	14410	-	14908	-	12168	-
23	*moderate*	42006	44062	n	38242	n	38242	n	39281	n
24	*moderate*	22188	4521	-	18171	-	18171	-	15921	-
25	*low*	27079	21344	-	26194	n	26194	n	26032	n
26	*low*	29031	31533	n	27544	n	27544	n	27290	n
27	*low*	7179	5702	-	5311	-	5507	-	5354	-
28	*low*	15334	10732	-	13864	-	13864	-	14418	n
29	*low*	43602	67369	+	53047	+	49299	+	51428	+
30	*low*	5867	2843	-	2642	-	3514	-	3680	-
31	*moderate*	40125	38514	n	37452	n	37452	n	36378	-
32	*low*	31207	34234	n	27390	-	28514	n	30020	n
33	*moderate*	10118	7796	-	6977	-	7584	-	5433	-
34	*low*	47954	63047	+	51901	n	48539	n	42899	-
35	*moderate*	115321	151849	+	115393	n	113692	n	117855	n
36	*moderate*	61001	47483	-	54241	-	55551	n	56871	n
37	*moderate*	73487	45069	-	65300	-	67662	n	70247	n
38	*high*	152344	150118	n	138504	n	138504	n	150933	n
39	*moderate*	72420	55989	-	65061	-	69005	n	70222	n
40	*low*	37511	38842	n	31048	-	31873	-	31667	-
41	*moderate*	16717	4928	-	12687	-	12720	-	12726	-
42	*moderate*	31238	13053	-	24541	-	24541	-	22668	-
43	*high*	94282	102719	n	84314	-	90090	n	93699	n
44	*high*	121686	117490	n	115065	n	115065	n	125372	n
45	*moderate*	77565	106649	+	84104	n	79540	n	94480	+
46	*moderate*	34339	28080	-	27408	-	27881	-	33823	n
47	*moderate*	22025	21962	n	17193	-	17721	-	26103	+
48	*moderate*	50080	36454	-	49029	n	49029	n	50755	n
49	*moderate*	4078	635	-	2437	-	2437	-	883	-
50	*moderate*	3915	4059	n	3652	n	3652	n	3352	-
51	*low*	20	7	n	16	n	16	n	15	n
54	*moderate*	18029	21050	+	18529	n	18364	n	20296	+
55	*moderate*	29682	15060	-	24075	-	25230	-	27507	n
56	*moderate*	17530	4519	-	13419	-	13419	-	10923	-
57	*high*	109291	103060	n	98658	-	98658	-	115154	n
58	*high*	35234	15438	-	26869	-	27331	-	24899	-
60	*high*	72094	88166	+	80199	+	78432	n	87546	+

TABLE 5-B (*cont'd*)

Map Unit	Clearing history	Predicted Area (ha)	Original Composite	+/-	Recalculated areas (ha) following Iterative Partial Replacement: Stage 1 Composite	+/-	Stage 2 Composite	+/-	Final Composite	+/-
61	*high*	92970	112188	+	99719	n	98707	n	138086	+
62	*low*	20550	8078	-	18230	-	19555	n	19778	n
63	*moderate*	36942	41250	+	33629	n	33629	n	32170	-
64	*low*	29031	30258	n	23544	-	27996	n	25001	-
65	*high*	114507	111500	n	110903	n	109986	n	120538	n
66	*low*	7718	16971	+	16360	+	11432	+	12824	+
67	*moderate*	31156	13857	-	24786	-	26154	-	26696	-
68	*low*	15009	11727	-	10839	-	12394	-	8174	-
69	*moderate*	35559	17282	-	29891	-	29891	-	29958	-
70	*low*	15334	16640	n	10271	-	10364	-	9743	-
71	*moderate*	29275	14110	-	26610	-	26902	n	27557	n
72	*low*	325	1077	+	1130	+	839	+	423	+
73	*low*	6854	7127	n	5187	-	5520	-	5512	-
74	*low*	7616	10196	+	11408	+	11066	+	9998	+
75	*low*	5542	5265	n	5521	n	5521	n	5595	n
76	*low*	976	1071	n	1114	n	1114	n	1138	n
77	*moderate*	2532	873	-	863	-	863	-	772	-
78	*high*	8806	9164	n	9123	n	8614	n	8578	n
79	*high*	139298	174321	+	153619	n	140444	n	147497	n
80	*moderate*	21689	8251	-	19014	-	19048	-	17870	-
81	na	0	22949	+	27741	+	27741	+	0	n
82	na	0	21759	+	29047	+	30261	+	0	n
83	*high*	36535	30264	-	32334	-	34964	n	39111	n
84	*high*	43063	37641	-	38881	-	38881	-	37538	-
85	na	0	29553	+	25120	+	28151	+	0	n
86	na	0	11906	+	16507	+	18005	+	0	n
87	*high*	32946	11559	-	28381	-	28381	-	28588	-
88	na	0	69101	+	57739	+	55835	+	0	n
89	*moderate*	43389	24613	-	40241	n	40241	n	41252	n
90	*moderate*	21283	2525	-	15299	-	15299	-	15226	-
91	*low*	5542	4474	-	2959	-	3016	-	2942	-
92	*low*	834	5892	+	3427	+	1673	+	716	-
93	*low*	651	1162	+	1127	+	838	+	837	+
94	*high*	18273	19290	n	17314	n	17314	n	22077	+
95	*high*	75358	105744	+	84027	+	77758	n	100862	+
96	*high*	12070	3117	-	11343	n	11343	n	9379	-
97	*high*	57747	59351	n	49216	-	61140	n	50955	-
98	*moderate*	29682	25158	-	30213	n	29726	n	35599	+
99	*high*	96885	73900	-	91471	n	91471	n	87980	-
100	*moderate*	42331	50022	+	39397	n	39397	n	38937	n
101	*high*	23815	23153	n	20536	-	20669	-	19290	-
103	*moderate*	9782	2740	-	6133	-	6291	-	8454	-
104	*moderate*	8725	5667	-	5550	-	5811	-	5336	-
105	*moderate*	5623	1454	-	5219	n	5219	n	10395	+
106	*high*	11094	2078	-	8118	-	8118	-	6643	-
107	*moderate*	2034	2139	n	2077	n	2077	n	901	-
108	*moderate*	7098	3265	-	6663	n	6663	n	4994	-
109	*moderate*	36861	27774	-	35045	n	35045	n	37672	n
110	*moderate*	12721	7795	-	13950	n	13948	n	52040	+
111	*low*	3803	4044	n	3932	n	3857	n	4848	+
112	*moderate*	1139	773	-	2418	+	2387	+	2429	+
113	*moderate*	26	26	n	26	n	26	n	26	n
114	*moderate*	4067	9538	+	7107	+	6553	+	3202	-
115	*low*	1024	1009	n	1009	n	1009	n	1050	n
116	*moderate*	76	93	n	84	n	84	n	64	n
117	*low*	512	504	n	502	n	502	n	507	n

n - within 90% or 300 ha of original   + over-predicting   - under-predicting

5.11 MODEL ACCURACY

The predicted accuracy of modelled vegetation distributions should ideally be evaluated using independent survey data (eg. Pearce & Ferrier 2000). A total of 696 canopy-only sites not used for modelling were available to provide an evaluation against positive diagnostic canopy species listed in each community. While this is not ideal, it does enable some validation of product integrity. **Table 5-C** shows the results of model validation using canopy-only sites. A label of 'yes' was assigned to canopy sites that matched the over-storey composition of communities in which they were located. A label of 'no' was assigned to sites which, based on their canopy composition, were clearly not part of the community in which they were situated. Sites were labelled 'possible' if there was some level of similarity.

TABLE 5-C

Results of model accuracy assessment using canopy-only sites

	Extant		**Predicted**	
Equivalent	**No. sites**	***% sites***	**No. sites**	***% sites***
Yes	413	*79.3*	72	*41.2*
Possible	91	*17.5*	49	*28.0*
No	17	*3.2*	54	*30.1*

It is apparent from **Table 5-C** that model accuracy within the extent of existing vegetation is between 80% and 97%, according to coincidence of canopy sites. Outside the extent of existing vegetation the predicted model accuracy is 41 to 70%. These figures provide some level of confidence in the vegetation model. However, a more suitable approach to model validation would require comparison of model distribution against a new set of survey sites (preferably full-floristic) across the region.

6 Discussion and Interpretation

6.1 MODEL LIMITATIONS

The integrated vegetation model provides the best information to date on the current and predicted distribution of vegetation communities in Nandewar. It should be noted, however, that any modelling process has limitations, and as such, a degree of spatial error must be accepted, especially if products are interpreted at the local scale. **Section 5.11** established a good level of confidence for the extant vegetation model, and a moderate level confidence for the predicted vegetation model. However, the influence of canopy-only sites on the original API, and thus the model constraining process, will be reflected to some degree in the high level of confidence within existing vegetation.

There are several reasons for model inaccuracy and uncertainty. For example, individual models are limited by availability and quality of underlying environmental layers. The presence of a robust soils layer for Nandewar may well have increased the accuracy of models given the adaptive response of vegetation to soil productivity and depth in terms of differentiation of vegetation types. Derivation of a potential fertility layer from geological parent material provided a less appealing alternative for this project, since no soils mapping was available. A level of error is inherent in other derived environmental layers such as Prescott index, wetness index, and various climatic surfaces.

The iterative partial replacement technique adopted for this project may have been tightened given more resources and time. For example, stage 1 of the technique (**section 5.9.3**) might have been improved by reducing marginally the area of model contributing to each iteration. Similar untested methods to optimise model integration may be sought with more time. Notwithstanding, the iterative partial replacement has some merit based on results of model validation (**section 5.11**).

The sum of the predicted gross area for all vegetation models in BBS was 18.5 times the area of BBS bioregion (RACD 2003). As noted in the BBS report, this had implications about the ability of the integrated model to confidently predict the vegetation type at any point in the landscape. In Nandewar, the sum of the predicted gross area of all models is much lower, at 8.2 times the area of Nandewar. It is reasonable to summise from this comparison that there is a greater spatial exclusivity between vegetation types in Nandewar than in BBS, and that the final model is likely to predict more confidently in Nandewar. This may be explained in part by the gross number of flora sites participating in modelling. BBS comprised about 10% more flora sites than Nandewar, yet the BBS assessment area was almost twice the size of Nandewar. It may also be explained by the adoption of euclidean GDMs in Nandewar, which are apparently better at spatially differentiating vegetation groups which share similar environments.

Extant vegetation in Nandewar accounted for about 38% of the Study Area. Some areas will not contain the full suite of species of the modelled community predicted to occur there. This is not especially problematic for landscape type planning for which this product is intended. However, interpretation of models at a local scale should be conducted with some caution.

6.2 OVERVIEW OF THE GEOGRAPHIC DISTRIBUTION OF MAP UNITS

The current and predicted distribution of vegetation communities in Nandewar Study Area is shown in **Figure 6-A** and **Figure 6-B**, respectively. The map units have been grouped into broader associations (**Table 6-A**) for the purpose of visual presentation.

TABLE 6-A

Canopy associations in Nandewar

Canopy Association	Map Units
Bimble Box/Pilliga Box	95,101
Black Pine/Orange Gum	1,2,6,8
Black Pine/Tumbledown Red Gum	9,10,17
Blackbutt/Stringybark	16,66,68,74,100
Caley's Ironbark/Orange Gum	11,12,14
Caley's Ironbark/ Tumbledown Red Gum	19,28,29,30
Drainage line vegetation	49,108,115
Grassy White Box	36,38,39,44,61
Grey Box	98,99
Montane Gums	50,76,78,97
Montane Stringybarks	75,77,79,80
Mugga Ironbark	103,104,105
Narrow-leaved Ironbark	20,21,22,45,47,70,73
Northern Smooth-barked Apple	23,24,33,116

Canopy Association	Map Units
Rainforest	51,92,93,107,114
Red Stringybark	13,55,63,67
River Oak	109
River Red Gum	110
Serpentinite Woodland	111
Shrubby White Box	42,43,64,69,71,87, 91
Shrublands	3,4,5,7,72
Silver-leaved Ironbark	46,83,84,90,112
Silver-leaved Ironbark/ Tumbledown Red Gum	25,31,34,35,41
Silver-leaved Ironbark/ White Box	37,40,48,89
Tumbledown Red Gum	18,26,27,32,54,62
Western Acacia/ Casuarina Woodlands	94,96,106
White box/ Silvertop Stringybark	65,113,117

Figures 6-A and **6-B** provide spatial representations of the regional distribution of native vegetation communities in Nandewar, from which areal estimates of the current and predicted extent of each can be calculated. The maps (and underlying spatial layers) are intended to provide a regional overview from which conservation priorities for individual communities in Nandewar can be derived, to be adopted and perhaps implemented by organisations such as Catchment Management Authorities (CMAs). These products are not designed to provide fine-scale mapping of individual paddocks or properties. As such, some caution must be afforded when interpreting maps at ground level.

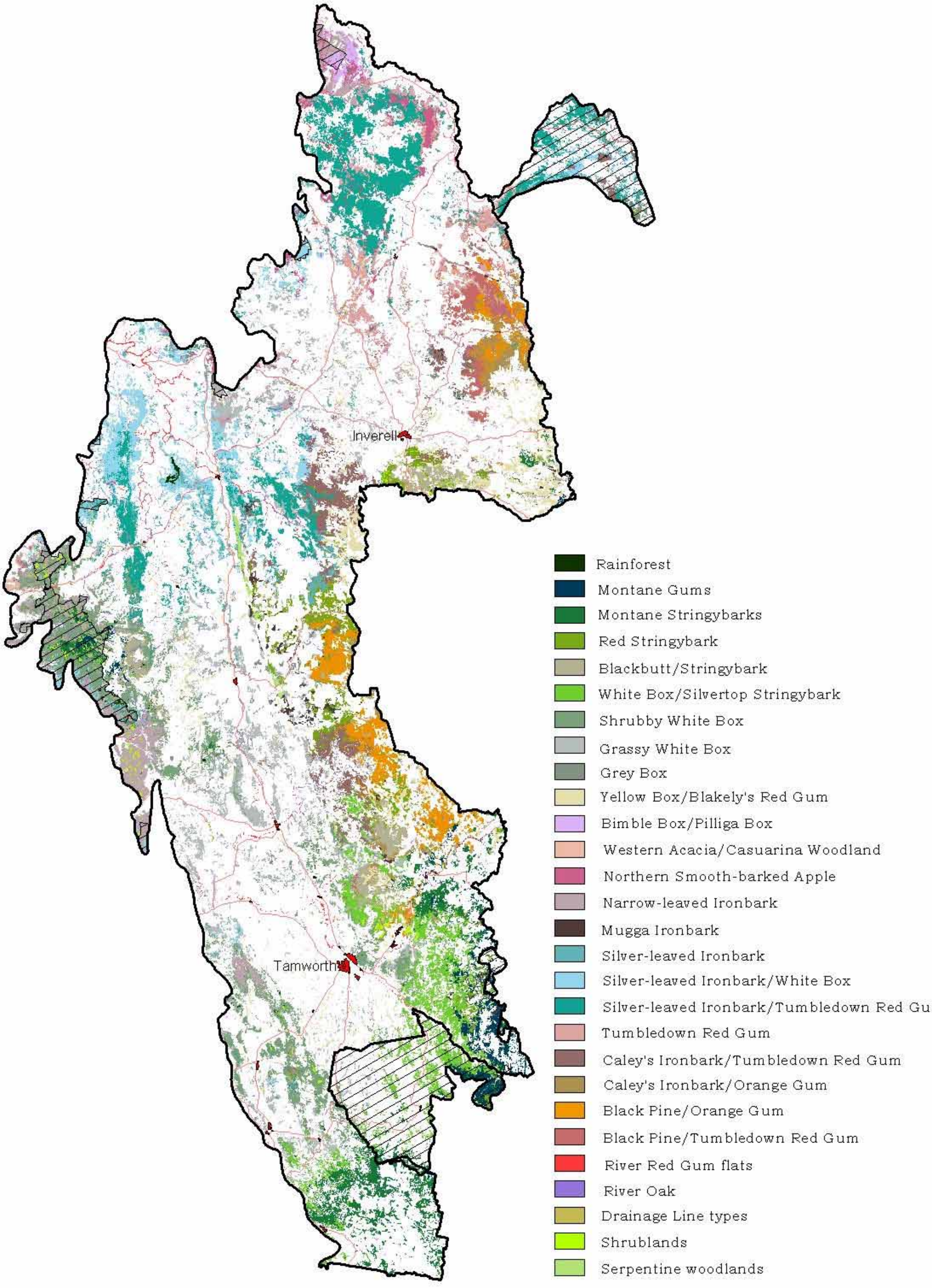

FIGURE 6-A

Current extent of canopy associations in Nandewar

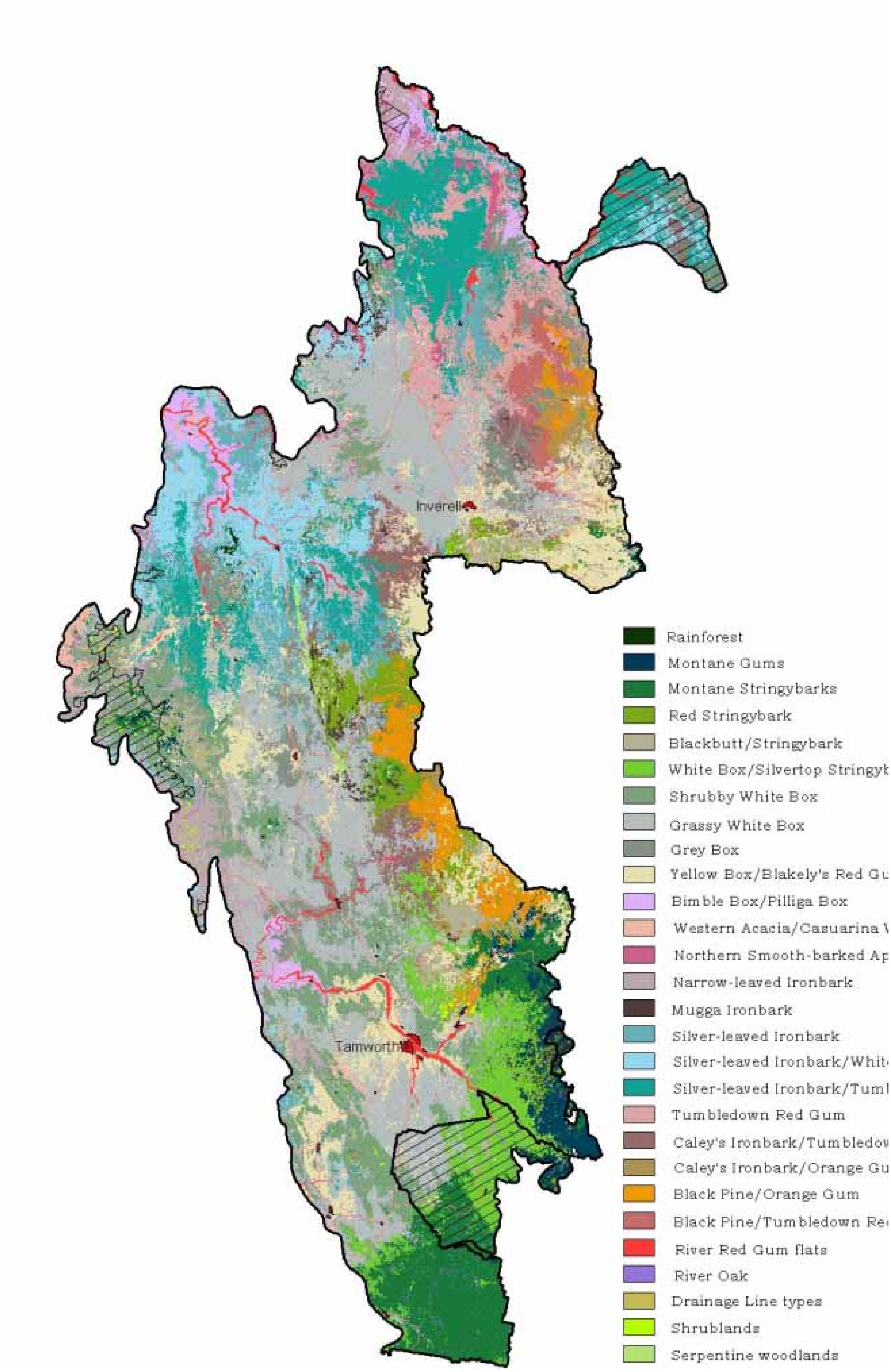

FIGURE 6-B

Predicted extent of canopy associations in Nandewar

Distribution of vegetation communities in Nandewar is influenced by geomorphology and climate. Deep fertile soils of the high elevation, high rainfall tableland plateau in the south-east (and to a lesser extent in Kaputar) support montain gum types including snow gum (*E. pauciflora*) and mountain gum (*E. dalrympleana*) (map unit 76). A number of eucalypt species that are uncommon elsewhere in the region also occur as stand dominants in the south east, including messmate (*E. obliqua*) and narrow-leaved peppermint (*E. radiata*) (map unit 50), as well as New England peppermint (*E. nova anglica*) (map unit 78). The understorey and ground layer of high elevation units is often mesic, and includes species not prominent elsewhere, including *Hymenanthera dentata, Pittosporum undulatum* and *Poa labillardierei*. Small stands of cool temperate rainforest (map unit 51) occur in the south-east, although this type is restricted to less than 20 hectares.

Several grassy open forest or woodland communities occur in undulating, moderately fertile terrain along the western edge of the New England Tableland (eg. map units 15, 55 and 60). Common tree species include Blakely's red gum (*E. blakelyi*), yellow box (*E. melliodora*), ribbon gum (*E. viminalis*), apple box (*E. bridgesiana*) and rough-barked apple (*Angophora floribunda*). The ground layer is dominated by grasses and forbs, with exotic ground species common given most areas have been modified by grazing and clearing. The understorey is usually sparse. Bendemeer white gum (*E. elliptica*) associates with silvertop stringybark (*E. laevopinea*) in the south-east, and occupies confined areas of the eastern fall of Mount Kaputar (map unit 97).

High elevation slopes of the moderately fertile tableland edge are dominated by stringybark types, mainly silvertop stringybark (*E. laevopinea*) in the south and south-east (map units 67, 79 and 80) and red stringybark (*E. macrorhyncha*) in the central and northern parts (map units 13, 55 and 63). Three geographically restricted stringybark communities include Mckie's stringybark (*E. mckieana*) - New England blackbutt (*E. andrewsii*) on the Tingha plateau of the central tablelands (map unit 100), silvertop stringybark (*E. laevopinea*)-Nandewar box (*E. nandewarica*) on the slopes of Mount Kaputar (map units 74 and 75), and Murrurundi stringybark (*E. conjuncta*) in the Upper Hunter (map unit 113).

Extensive areas of shrubby open forest and woodland occur on low fertility skeletal soils along the tableland edge, usually associated with granite substrates (map units 1, 8, 13, 14 and 28). Common overstorey species include black pine (*Callitris endlicheri*), Caley's iron-bark (*E. caleyi* ssp *caleyi*), tumbledown red gum (*E. dealbata*), orange gum (*E. prava*), Youman's stringybark (*E. youmanii*), red stringybark (*E. macrorhyncha*) and New England blackbutt (*E. andrewsii*), and valley flats may support species such as Blakely's red gum (*E. blakelyi*) and rough-barked apple (*Angophora floribunda*). A variety of shrub species occur in the understorey, including *Acacia neriifolia, Cassinia laevis, Cassinia quinquefaria, Leucopogon muticus, Melichrus urceolatus, Olearia* sp aff *elliptica* and *Olearia viscidula.* Granite outcropping occurs within most of these units, forming mosaics with granite shrubland communities (map units 2, 3 and 7).

Several shrubby woodland or open forest communities occur on fine-grained rhyolitic substrates of the Kings Plain/Severn River Nature Reserve area in the north (map units 9-12). Common tree species include black pine (*Callitris endlicheri*), orange gum (*E. prava*), tumbledown red gum (*E. dealbata*), Caley's iron-bark (*E. caleyi* ssp *caleyi*) and New

England blackbutt (*E. andrewsii*). The understorey often forms a dense shrubby layer comprising species such as *Allocasuarina inophloia, Leptospermum brevipes, Xanthorrhoea johnsonii* and *Leucopogon muticus*. The ground layer is generally sparse. A related unit comprising a number of species that have restricted distributions (map unit 19) occurs on the Rock of Gibraltar and other areas of the far north-east.

Extensive areas of sandstone geology in the low-altitude north-west part of Nandewar support a suite of unique vegetation communities (map units 20-24, 33). A number of signature tree species are confined to these areas, including northern smooth-barked apple (*Angophora leiocarpa*), brown bloodwood (*Corymbia trachyphloia* ssp *amphistomatica*), long-fruited bloodwood (*Corymbia dolicocarpa*), and dirty red gum (*E. chloroclada*). Narrow-leaved ironbark (*E. crebra*) is also common throughout.

Several grassy woodland or open forest communities dominated by box/gum species occur at low to mid elevation on undulating areas in Nandewar, usually of moderate to high soil fertility (eg. map units 36, 38, 39, 44, 56, 57, 58, 61, 95, 98, 99, 101). Dominant tree species include white box (*E. albens*), grey box (*E. molocanna*), bimble box (*E. populnea*), yellow box (*E. melliodora*) and Blakely's red gum (*E. blakelyi*). White pine (*Callitris glaucophylla*) is a common associate. The shrub layer is usually sparse and the ground layer is generally a dense sward of grass and forb species. Many areas have been modified by grazing and clearing, and exotic species, particularly Coolatai grass (*Hyparrhenia hirta*) are frequent in places. Isolated remnants of river red gum (*E. camaldulensis*) occur along the major river flats (map unit 110). Almost all of this community has been removed for cropping and irrigation.

Several prominent ranges intersect the broad Nandewar lowlands, particularly in the central parts of the region. These are often well forested and support a number of shrubby open forest communities (eg. map units 42, 43, 48 and 71) dominated by white box (*E. albens*) and white pine (*Callitris glaucophylla*), with silver-leaved ironbark (*E. melanophloia*) a common associate. Characteristic shrub species include *Olearia* sp aff *elliptica, Notelaea microcarpa* var *microcarpa* and *Cassinia quinquefaria*. The ground layer is variable. In the steeply undulating landscapes of the Liverpool Range in southern Nandewar, the major association is white box (*E. albens*)/silvertop stringybark (*E. laevopinea*).

White box (*E. albens*) communities in the central and southern parts are replaced in hilly areas at low to intermediate altitudes on the western side of Nandewar by a number of ironbark dominated shrubby open forest or woodland communities (eg. map units 35, 45, 46, 47, 70, 73, 89 and 90). Common overstorey species include narrow-leaved ironbark (*E. crebra*), silver-leaved ironbark (*E. melanophloia*), tumbledown red gum (*E. dealbata*) and white pine (*Callitris glaucophylla*). There is usually a well-developed shrub layer with *Beyeria viscosa, Dodonaea viscosa* ssp *angustifolia* and *Notelaea microcarpa* var *microcarpa* common. The ground layer is often sparse.

The higher altitude parts of Mount Kaputar support a number of distinctive vegetation types. In addition to Nandewar box (*E. volcanica*) communities at intermediate altitudes (this species does not occur elsewhere in Nandewar), this region supports a distinctive shrubland community on trachyte outcrops (map unit 5), which occurs within a matrix of snow *gum*

(*E. pauciflora*), mountain gum (*E. dalrympleana*), ribbon gum (*E. viminalis*) and silvertop stringybark (*E. laevopinea*) types, and occasionally Bendemeer white gum (*E. elliptica*). The Horton Falls area east of Mount Kaputar contains a silvertop stringybark (*E. laevopinea*) – orange gum (*E. prava*) – New England blackbutt (*E. andrewsii*) community (map unit 66).

Several **restricted communities** occur in Nandewar. Those dominated by brigalow (*Acacia harpophylla* - map unit 96), weeping myall (*Acacia pendula* - map unit 106) and belah (*Casuarina cristata* – map unit 94) occur in the far western parts of Nandewar. Scattered stands of ooline (*Cadellia pentastylis* - map unit 107) occupy parts of the north and west (Benson 1989), and patches of semi-evergreen vine thicket (map unit 114) occur on skeletal volcanic substrates of the central and western Nandewar (Curran *in prep*.), the largest in NSW occurring on Derra Derra ridge (Benson *et al*. 1996). Other dry rainforest types dominated by rusty fig (*Ficus rubiginosa*) and native olive (*Notelaea microcarpa* var *microcarpa*) occur in moist, protected locations such as rocky gullies (map units 92 and 93) (Curran *in prep.*). Mugga ironbark (*E. sideroxylon* - map units 103-105) occupies localised areas of sedimentary origin throughout Nandewar, with several large patches occurring in the Bingara – Barraba area. Isolated stands of green mallee (*E. viridis* - map unit 112) and Dwyer's red gum (*E. dwyeri* – map unit 18) occur in western Nandewar.

One of the main geomorphological features of Nandewar is the Peel Fault, which extends from Warialda to Nundle. Several areas of serpentinite geology are associated with this fault line, most notably at Woods Reef and south of Bingara. A distinctive woodland vegetation dominated by the tussock grass spinifex (*Triodia scariosa* ssp *scariosa*) occurs in shallow soils on serpentinite (map unit 111). A number of other significant plant species are also associated with these areas including an undescribed stringybark eucalypt related to red stringybark (*E. macrorhyncha*).

In addition to river red gum (*E. camaldulensis*), other riparian communities include paper-bark forest dominated by *Melaleuca bracteata* (map unit 108), which is restricted to larger streams on high fertility substrates; river oak (*Casuarina cunninghamiana)* gallery forest (map unit 109) which occurs in the unconsolidated channels of most perennial streams and rivers; teatree drainage line shrubland (map unit 49) which largely occurs in small localised moist rocky areas; and swamp/wetland (map unit 115) which are scattered throughout. One of the most frequent types of wetland occurs at high altitudes on the tableland edge, and is dominated by *Leptospermum polygalifolium* ssp *transmontanum, Carex gaudichaudiana, Scirpus polystachyus* and *Carex appressa.*

Five units of derived grassland (map units 81, 82, 85, 86 and 88) were separated from full floristic data as part of the floristic analysis (**Table 4-B**). These units were not included in the final integrated map given the probable absence of widespread areas of native grassland in Nandewar prior to clearing (**Section 5.10**). More extensive areas are likely to have occupied parts of the adjacent Liverpool Plain to the south-west, and may have occurred in localised frost hollows on the Northern Tablelands to the east.

6.3 COMPARISON WITH PREVIOUS VEGETATION CLASSIFICATIONS

6.3.1 Statewide nomenclature

Keith (2002) and Beadle (1981) each provide a broad classification of vegetation types occurring in NSW. **Table 6-B** relates the Nandewar map units to these broader units via a set of Nandewar structural groups.

TABLE 6-B

Relationship between Nandewar map units and broader NSW vegetation classifications

Keith (2002) type	Beadle (1981) Alliance or Suballiance	Nandewar Structural Group	Nandewar Map Units
87: Southern cool temperate rainforest	*Notofagus moorei*	Moist forests of the far south-east	51
10: Northern tablelands semi-mesic forests	*E. pauciflora* *E. nova-anglica* *E. delegatensis – E. dalrympleana* *E. campanulata* or *E. laevopinea*	Moist forests of the far south-east Forests of the Kaputar area	50, 78 74, 75, 76, 77, 91
41: New England Tableland grassy woodlands	*E. melliodora – E. blakelyi* or *E. laevopinea*	Grassy forests and woodlands of the western parts of the tablelands	15, 55, 56, 60, 67
27: Northern tableland dry sclerophyll forests	*E. laevopinea* *E. youmanii* *E. andrewsii* *E. caliginosa* *E. crebra* *E. melanophloia* *E. sideroxylon – E. dealbata* or *E. macrorhyncha*	Shrubby forests and woodlands on granite on the tableland edge Shrubby or grassy forests on sedimentary substrates on the tableland edge Shrubby forest and woodland on fine grained acid volcanics in the north of Nandewar	1, 2, 8, 13, 14, 16, 63, 68, 100 65, 79, 80, 97, 104 6, 9, 10, 11, 12, 19, 25, 26, 58
113:Western slopes shrub/grass woodlands	*E. crebra* *E. albens* *E. melanophloia* *E. laevopinea* *E. moluccana* or *E. sideroxylon – E. dealbata*	Shrubby or grassy forests and woodlands of central hilly areas	29, 36, 37, 41, 42, 43, 54, 66, 98, 105, 113, 117
42: Western slopes grassy woodlands	*E. melliodora – E. blakelyi* *E. moluccana* *E. melanophloia* *E. crebra* or *E. albens*	Grassy forests and woodlands on undulating terrain	38, 39, 44, 46, 47, 57, 61, 83, 84, 87, 99
4: Dry Rainforest	Rainforest-derived Communities in the Semi-arid and Arid Zones, or *Cadellia pentastylis*	Vine thicket and dry rainforest	92, 93, 107, 114
106: Yetman dry sclerophyll woodlands	*Angophora leiocarpa* *E. crebra* *Corymbia dolichocarpa – C. tessellaris* or *E. melanophloia*	Forests and woodlands on the northern sandstones	20, 21, 22, 23, 24, 31, 33, 116
29: Western slopes dry sclerophyll forests	*Angophora leiocarpa* *E. albens* *E. crebra* *E. macrorhyncha – E. rossii* *E. viridis* *E. sideroxylon – E. dealbata* or *E. melanophloia*	Shrubby forests and woodlands on low to intermediate altitude hilly areas	17, 18, 27, 28, 30, 32, 34, 35, 40, 45, 48, 62, 64, 69, 70, 71, 72, 73, 89, 90, 103, 112
51: Coast and tableland riverine forests	Communities associated with rivers	Riparian forest and woodland	109
52: Inland riverine forests	*E. camaldulensis*	Riparian forest and woodland	58, 108, 110

TABLE 6-B (*cont'd*)

Keith (2002) type	Beadle (1981) Alliance or Suballiance	Nandewar Structural Group	Nandewar Map Units
109: Central floodplain transition woodlands	*E. populnea* or *E. microcarpa*	Woodlands and grasslands of the western parts of Nandewar	95, 101
110: Western slopes grasslands	*Dichanthium sericeum* *Austrostipa aristiglumis* or *Austrostipa scabra*	Woodlands and grasslands of the western parts of Nandewar	81, 82, 85, 86, 88, 106
101: Northern clay plains woodlands	*Casuarina cristata* or *Acacia harpophylla*	Woodlands and grasslands of the western parts of Nandewar	94, 96
no equivalent	Heaths, scrubs and thickets on rocky outcrops	Serpentinite vegetation	111
no equivalent	Heaths, scrubs and thickets on rocky outcrops	Shrubland vegetation of rocky areas	3, 4, 5, 7, 49
no equivalent	Sedgelands	Swamp and Wetland	115

6.3.2 Regional Assessments

The Nandewar WRA Study Area lies between the coastal CRA area in the east and the Brigalow Belt South WRA area in the west. Vegetation communities were derived as part of both previous assessments – forest ecosystems for the coastal assessments (NPWS 1999) and vegetation units for the BBS (RACD 2003). **Table 6-C** relates map units derived for Nandewar to those derived for previous assessments. Thirty one Nandewar map units (units 3, 4,19, 25, 27, 29, 30, 34, 41, 44, 49, 54, 61, 62, 63, 66, 68, 72, 73, 84, 92, 93, 97, 99, 103, 104, 105, 111, 113, 115, and117) have no obvious CRA forest ecosystem or BBS vegetation unit equivalents.

TABLE 6-C

Relationship between Nandewar map units and those derived for coastal CRAs and BBS WRA

Nandewar Map Unit Number	BBS Map Unit Number	Forest Ecosystem Number	Nandewar Map Unit Number	BBS Map Unit Number	Forest Ecosystem Number
1	*na*	178	18	101	*na*
2	*na*	185	20	110	*na*
5	99, 100	*na*	21	123	*na*
6	*na*	185	22	76	*na*
7	*na*	178	23	110	*na*
8	*na*	175, 186	24	121	*na*
9	*na*	175, 186	26	*na*	184
10	*na*	186	28	*na*	184
11	*na*	184	31	26	*na*
12	*na*	177	32	62	*na*
13	*na*	174	33	121, 123	*na*
14	*na*	176	35	26	*na*
15	*na*	183	36	28	*na*
16	*na*	180	37	33	*na*
17	101	*na*	38	26	*na*

TABLE 6-C (*cont'd*)

Nandewar Map Unit Number	BBS Map Unit Number	Forest Ecosystem Number
39	29	*na*
40	116	*na*
42	29	*na*
43	29	*na*
45	26	*na*
46	32	*na*
47	74	*na*
48	32	*na*
50	*na*	82
51	*na*	168
55	*na*	116
56	*na*	183
57	18	*na*
58	18	*na*
60	*na*	163, 195
64	56	*na*
65	19	*na*
67	*na*	198
69	56	*na*
70	57	*na*
71	28, 29	*na*
74	13	*na*
75	14	*na*
76	15	*na*
77	8	*na*
78	*na*	2, 98

Nandewar Map Unit Number	BBS Map Unit Number	Forest Ecosystem Number
79	*Na*	43
80	*na*	43
81	35	*na*
82	35	*na*
83	26	*na*
85	188, 191	*na*
86	188	*na*
87	29	*na*
88	188	*na*
89	28	*na*
90	30	*na*
91	4	*na*
94	193, 197	*na*
95	35, 74, 199	*na*
96	198	*na*
98	*na*	190
100	*na*	180
101	90	*na*
106	180, 199	*na*
107	194	*na*
108	49	*na*
109	138, 164	120
110	158, 161	*na*
112	30	*na*
114	192	*na*
116	200	*na*

6.4 CONSERVATION SIGNIFICANCE OF NANDEWAR VEGETATION TYPES

6.4.1 Significant vegetation types

Of the 113 native vegetation communities occurring in Nandewar, 23 were considered to be related to one of eight endangered ecological communities (EECs) currently listed under the *TSC Act*, given their similar structural and floristic characteristics. These map units were referred to as **potential EECs**[2], which means that at any point throughout their geographic extent, the listed EEC may (or may not) occur, or have occurred.

[2] Any community henceforth referred to as a potential EEC is likely to contain areas of currently listed EEC. The term should not be construed to be pre-emptive of a new determination by the Scientific Committee. Nor should the entire modelled extent of a potential EEC be construed to comprise the listed EEC. On the contrary, only small areas of a listed EEC may occupy the extent of a potential EEC.

Potential EECs and their equivalent listed EECs are shown in **Table 6-D**. Six of the eight listed EECs are represented by a single equivalent map unit, while semi-evergreen vine thicket is represented by four map units, and box-gum woodland is represented by 13 map units. Potential EECs occupy a combined area of 218 300 hectares, 21.4% of existing vegetation in the Nandewar Study Area.

TABLE 6-D

Map Units identified as Potential EECs in Nandewar

Listed EEC (*TSC Act*)	**Map Units identified as Potential EECs**
Brigalow Woodland	96
Cadellia pentastylis (Ooline) community	107
Carbeen Open Forest Community	116
Howell Shrublands	7
McKie's Stringybark/Blackbutt Open Forest	100
New England peppermint woodland on basalts and sediments	78
Semi-evergreen Vine Thicket	92, 93, 94, 114
White Box Yellow Box Blakelys Red Gum Woodland (Box-Gum Woodland)	15, 36, 38, 39, 44, 48, 55, 56, 57, 60, 61, 87, 99

Figure 6-C shows the mapped distribution of potential EECs and regionally uncommon vegetation types in Nandewar, all of which have less than 10% of their predicted distribution in current reserves. Potential EECs that are unrepresented in the current reserve system include: Howell shrublands (map unit 5), white box grassy open forest (map unit 44), brigalow woodland (map unit 96), tablelands yellow box/red gum woodland (map unit 60) and northern grassy white box (map unit 61). Other potential EECs that have a combined area of fewer than 100 hectares reserved include: semi-evergreen vine thicket (map unit 114), ooline rainforest (map unit 107) and Mckie's stringybark/New England blackbutt forest (map unit 100).

An additional 19 communities were labelled **regionally uncommon** based on their restricted distribution or uniqueness. Reasons for considering communities as regionally uncommon are explained in the individual profiles of the relevant groups (**Appendix 4.1**). Regionally uncommon types are listed in **Table 6-E** (see below), and cover a combined area of 85 700 hectares, or 8.4% of existing vegetation in the Nandewar Study Area. A number of regionally uncommon types are unreserved including: Dripping Rock shrubland (map unit 4), Duri Peak mallee wood-land (map unit 72), southern mugga ironbark forest (map unit 104), spinifex woodland (map unit 111) and swamp/wetland (map unit 115).

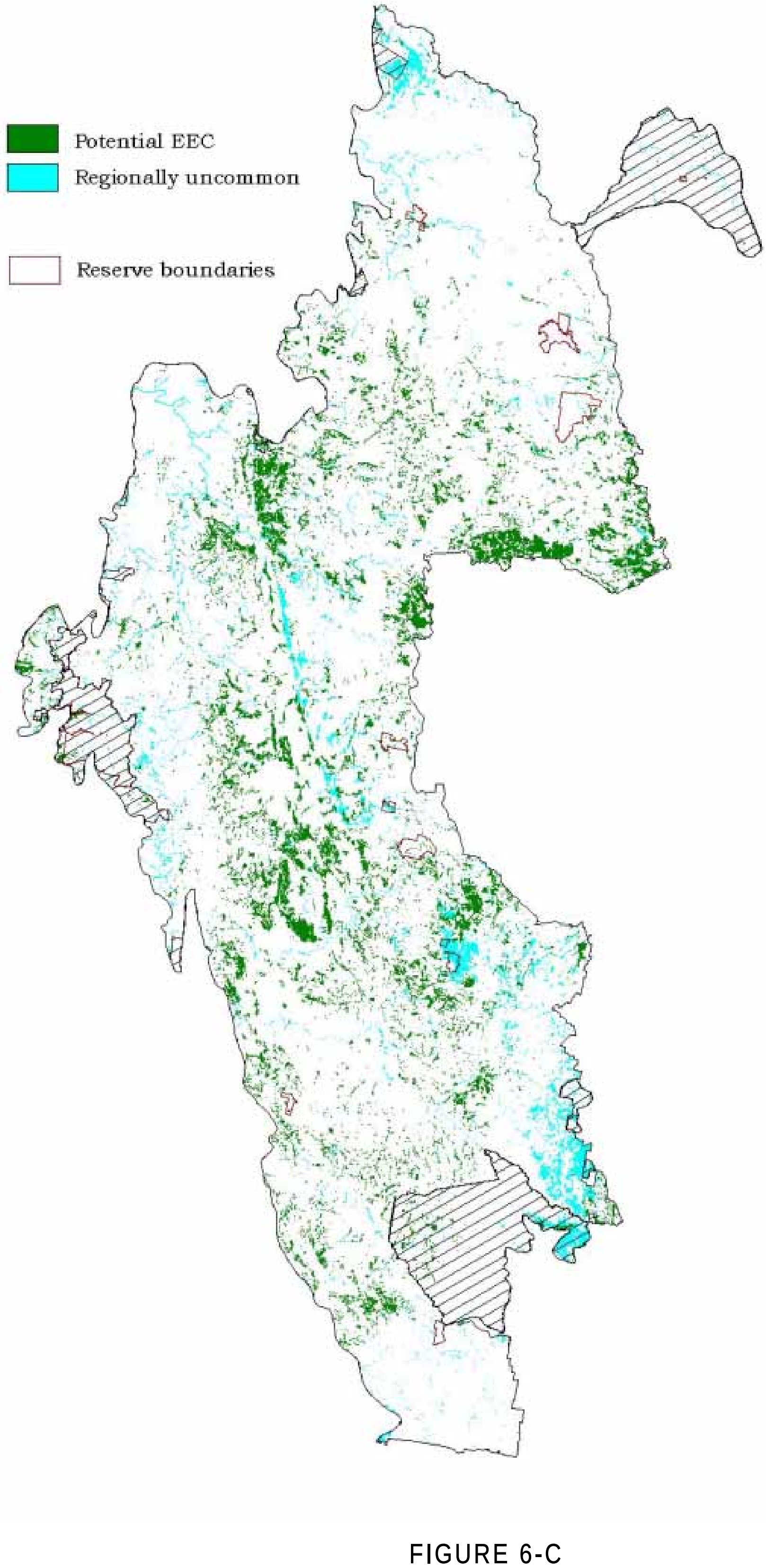

FIGURE 6-C

Current distribution of potential EECs and regionally uncommon vegetation types

6.4.2 Formal reservation levels

An assessment of the formal reservation levels of each vegetation community in the Nandewar Study Area was undertaken. The formal reserve system in the Study Area currently includes 15 reserves comprising a total area of 60,391 hectares (**Table 6-F**). Six of these reserves, including the relatively large Mount Kaputar National Park, were included in previous assessments (coastal CRAs and BBS WRA) and are included here to provide a bioregional context only. These reserves should not be reported as contributing to any conservation targets that may be developed for Nandewar in the future.

TABLE 6-F

Formal reserves in the Nandewar Study Area

Reserve	Area (ha)	% Nandewar Study Area	Previously assessed area?
Arakoola NR	1 507	0.06	Yes
Ben Halls Gap NP	16	0.00	Yes
Gibraltar NR	161	0.01	Yes
Ironbark NR	1 652	0.06	
Kings Plains NP	6 893	0.26	
Kwiambal NP	1 361	0.05	
Linton NR	667	0.03	
Melville Range NR	843	0.03	
Mount Kaputar NP	36 664	1.37	Yes
Severn River NR	4 364	0.16	
Torrington SCA	187	0.01	Yes
Wallabadah NR	1 136	0.04	
Warrabah NP	3 546	0.13	
Watsons Creek NR	1 391	0.05	
Wingen Maid NR	3	0.00	Yes
Nandewar Study Area:	**60 391**	**2.26**	
Nandewar WRA unassessed areas only:	***21 853***	***0.9***	

Table 6-G summarises the formal reservation levels of vegetation in the Nandewar Study Area. Given the current reserve system occupies just 2.6% of the Study Area, it is not surprising that 65% of vegetation communities have less than 1% of their predicted distribution within the reserve system, including a third which are completely unreserved.

TABLE 6-G

Summary of formal reservation levels of vegetation communites in Nandewar Study Area

Percent formally reserved	Number of communities	% of total communities	Combined extant area of communities (ha)	% of total extant	Includes:
0	41	38.0	281 123	27.6	11 potential EECs 11 regionally uncommon types
0 – 1	29	26.9	386 491	37.9	9 potential EECs 6 regionally uncommon types
1 – 5	16	14.8	197 413	19.4	
5 – 10	8	7.4	61 405	6.0	
10 – 15	3	2.8	23 452	2.3	
>15	11	10.2	66 369	6.5	7 occur in Mt Kaputar NP

Figure 6-D shows the current distribution of vegetation communities in the Nandewar Study Area according to current formal reservation levels. A total of 950 000 hectares of native vegetation comprises types which have less than 15% of their predicted distribution in the current reserve system. This includes 97 of the 108 mapped types, and represents over 93% of extant vegetation. Of the 11 mapped types that have more than 15% of their predicted distribution reserved, 7 of these are largely confined to Mount Kaputar National Park. So in the previously unassessed portion of the Nandewar Study Area, only 4 vegetation communities have greater than 15% of their predicted distribution formally reserved.

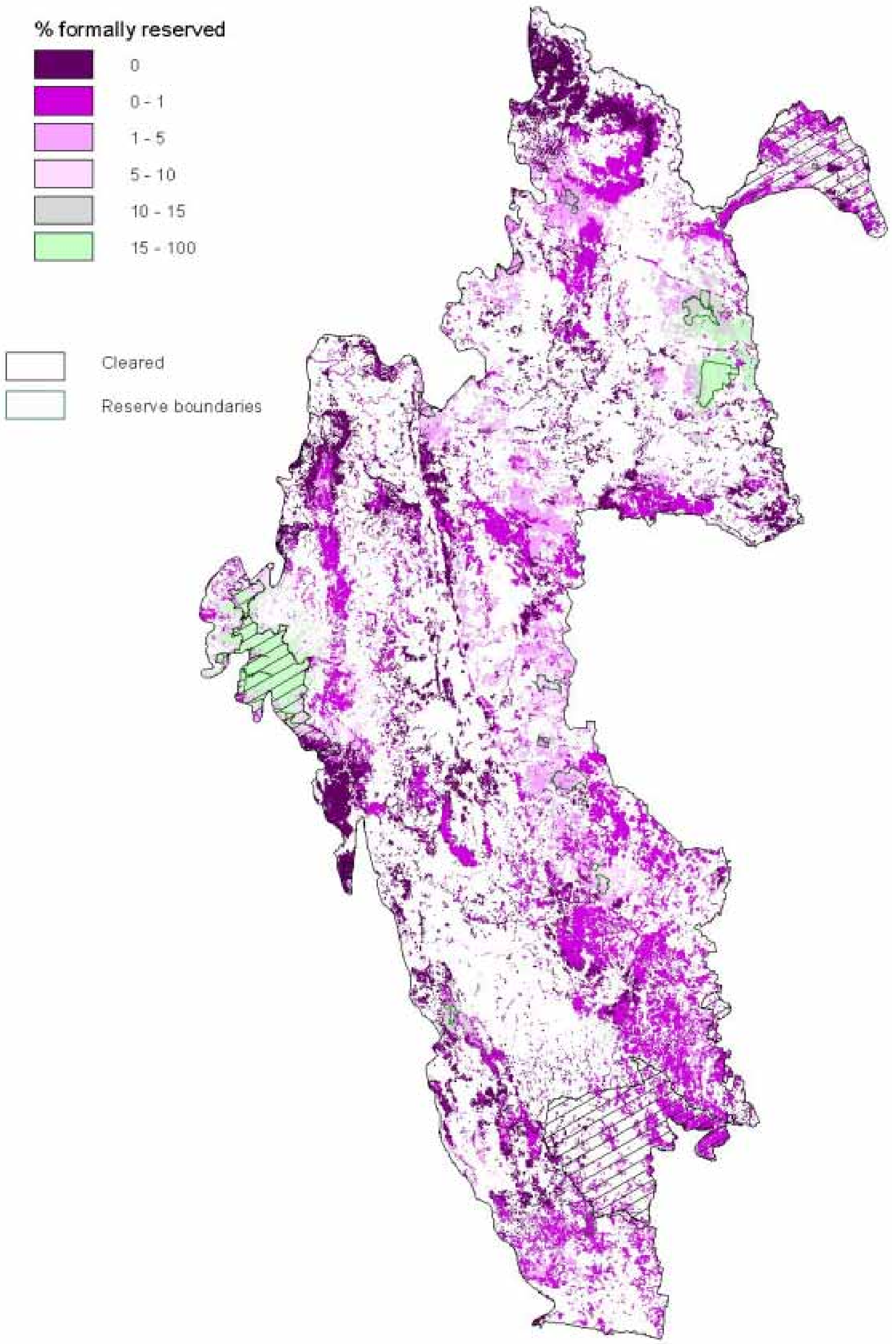

FIGURE 6-D

Formal reservation levels of current vegetation in Nandewar (based on % reservation of predicted extent of each community)

TABLE 6-E

Predicted and extant area, and formal reservation levels of Nandewar vegetation communities

No	Name	notes	Predicted Area (ha)	Extant Area (ha)	% Extant	Reserved Area (ha)	% reserved
3	White Pine/Orange Gum/Acacia Granite Outcrop Shrubland; Moonbi		1983	1519	*76.6*	0	*0*
4	Myrtle Shrubland (+- White Pine/Tumbledown Red Gum); Dripping Rock	R	1268	1258	*99.2*	0	*0*
7	Shrublands; Howell	E	737	734	*99.6*	0	*0*
13	Black Pine/Rough-barked Apple/Stringybark Shrubby Open Forest; tableland edge		7662	5514	*72*	0	*0*
18	Tumbledown Red Gum/Dwyer's Red Gum Shrubby Woodland; western		1579	845	*53.5*	0	*0*
19	Tumbledown Red Gum/Caley's Ironbark Shrubby Open Forest; Rock of Gibraltar		5528	3014	*54.5*	0	*0*
21	Black Pine/Narrow-leaved Ironbark/Dirty Gum Grassy Open Forest; north-west		10467	6279	*60*	0	*0*
22	White Pine/Narrow-leaved Ironbark Shrub/Grass Open Forest; north-west		7401	3849	*52*	0	*0*
24	White Pine/Northern Smooth-barked Apple Shrubby Open Forest; north-west		10242	5902	*57.6*	0	*0*
31	White Pine/Silver-leaved Ironbark/Tumbledown Red Gum Grassy Open Forest; far north		33936	16743	*49.3*	0	*0*
33	Dirty Gum/White Pine/Northern Smooth-barked Apple Shrub/Grass Open Forest; north-west		5105	4237	*83*	0	*0*
38	White Pine/White Box Grass/Forb Open Forest; widespread	E	142381	32134	*22.6*	0	*0*
43	White Box/White Pine Shrubby Open Forest; southern		93347	27062	*29*	0	*0*
45	White Pine/Narrow-leaved Ironbark Shrub/Grass Open Forest; south-west		42260	21864	*51.7*	0	*0*
46	White Pine/Silver-leaved Ironbark Grassy Open Forest; north-west		27542	5927	*21.5*	0	*0*
47	White Pine/Narrow-leaved Ironbark shrub/grass Open Forest; north-west		2808	674	*24*	0	*0*
48	White Pine/Silver-leaved Ironbark/White Box Shrub/Grass Open Forest; Warialda-Bingara	E	50726	16450	*32.4*	0	*0*
51	Black Olive Berry Cool Temperate Rainforest; far south-east	R	15	15	*100*	0	*0*
54	Tumbledown Red Gum/ Blakely's Red Gum Shrubby Open Forest; northern		20296	6232	*30.7*	0	*0*
60	Blakely's Red Gum/Yellow Box Grassy Open Forest/Woodland; tablelands	E	69270	15185	*21.9*	0	*0*
72	Mallee Woodland; Duri Peak	R	423	423	*100*	0	*0*
78	Snow Gum/New England Peppermint Grassy Open Forest; tableland edge	E	7969	2915	*36.6*	0	*0*
83	White Pine/Silver-leaved Ironbark Grassy Open Forest; northern		35413	3880	*11*	0	*0*
84	White Pine/Silver-leaved Ironbark Shrub/Grass Open Forest; central		37461	11044	*29.5*	0	*0*
89	White Box/White Pine/Silver-leaved Ironbark Shrubby Open Forest; western		34488	20517	*59.5*	0	*0*
90	White Pine/Silver-leaved Ironbark Shrubby Woodland; western		11493	3541	*30.8*	0	*0*
92	Rusty Fig Dry Rainforest; scattered	E	683	632	*92.5*	0	*0*
95	Bimble Box/White Pine Grassy Woodland; western		46122	2515	*5.5*	0	*0*
96	Brigalow Acacia Woodland; scattered	E	4928	131	*2.7*	0	*0*
99	Grey Box/Blakely's Red Gum/Yellow Box Grassy Open Forest; widespread	E	85126	8872	*10.4*	0	*0*
101	Western Grey Box/Pilliga Box Grassy Open Forest; north-west	R	12247	7318	*59.8*	0	*0*
104	Mugga Ironbark/Stringybark Shrubby Open Forest; southern	R	4746	757	*16*	0	*0*
106	Weeping Myall Woodland/Shrubland; scattered	R	3883	218	*5.6*	0	*0*
111	Stringybark/Spinifex Serpentine Woodlands; scattered	R	4848	3914	*80.7*	0	*0*
112	Green Mallee Mallee Woodland; scattered	R	968	965	*99.7*	0	*0*
113	Murrurundi stringybark	R	26	26	*100*	0	*0*
115	Swamp/wetland	R	588	509	*86.6*	0	*0*
116	Carbeen; far north-west	E	39	5	*12.8*	0	*0*
117	Conglomerate heathy open forest; far south-west	R	472	448	*94.9*	0	*0*

TABLE 6-E (*cont'd*)

No	Name	notes	Predicted Area (ha)	Extant Area (ha)	% Extant	Reserved Area (ha)	% reserved
61	White Box Grassy Open Forest; northern	E	137975	17461	*12.7*	2	*0*
44	White Box Grassy Open Forest; widespread (mainly southern)	E	124020	19595	*15.8*	6	*0*
57	Yellow Box/Blakely's Red Gum Grassy Woodland; widespread	E	109624	18042	*16.5*	20	*0.02*
62	Tumbledown Red Gum/Pine Shrubby Open Forest; northern		19317	7740	*40.1*	4	*0.02*
25	Tumbledown Red Gum/White Pine/Silver-leaved Ironbark Shrubby Open Forest; northern		26032	20163	*77.5*	8	*0.03*
32	White Pine/Tumbledown Gum Shrubby Open Forest ; northern		29528	14456	*49*	9	*0.03*
98	Grey Box/Rough-barked Apple Shrub/Grass Open Forest; northern		33499	7920	*23.6*	17	*0.05*
35	White Pine/Silver-leaved Ironbark/Tumbledown Red Gum Shrubby Open Forest; northern		109276	49137	*45*	62	*0.06*
114	Semi-evergreen Vine Thicket; scattered	E	2839	1046	*36.8*	2	*0.07*
94	Belah/White Pine Shrubby Woodland (with patches of Semi-evergreen Vine Thicket); north-west	E	8068	2330	*28.9*	7	*0.09*
39	White Box/White Pine Shrub/Grass Open Forest; central	E	68449	22365	*32.7*	78	*0.11*
65	White Box/Silvertop Stringybark/White Pine Shrubby Open Forest; southern hilly		115025	62137	*54*	142	*0.12*
68	Silvertop Stringybark/Rough-barked Apple/*E. quinniorum* Shrubby Open Forest; southern tableland edge		8118	7411	*91.3*	10	*0.12*
100	Mckie's Stringybark/New England Blackbutt/Rough-barked Apple Grassy Open Forest; tableland edge	E	17207	9824	*57.1*	32	*0.19*
87	White Box Shrub/Grass Open Forest; north-west	E	21800	2101	*9.6*	53	*0.24*
49	Tea-tree Drainage Line Shrubland; scattered		732	345	*47.1*	2	*0.27*
66	Silvertop Stringybark/Orange Gum Shrubby Open Forest; Horton		12824	7560	*59*	36	*0.28*
41	Silver-leaved Ironbark/White Pine/Tumbledown Red Gum Shrub/Grass Open Forest; Ashford		12466	6923	*55.5*	36	*0.29*
108	Paperbark Riparian Forb/Grass Low Closed Forest; widespread	R	4437	2495	*56.2*	13	*0.29*
110	River Red Gum Riparian Open Forest/Woodland; widespread	R	40562	10675	*26.3*	152	*0.37*
103	Mugga Ironbark/Black Pine Shrubby Open Forest; north-west	R	6539	1069	*16.3*	26	*0.4*
1	Black Pine Granite Outcrop Shrubby Woodland; tableland edge		21904	14863	*67.9*	93	*0.42*
97	Silvertop Stringybark/Bendemeer White Gum Grassy Open Forest; Kaputar and southern tableland edge	R	40146	19797	*49.3*	189	*0.47*
55	Blakely's Red Gum/Rough-barked Apple/Red Stringybark Grassy Open Forest; tableland edge	E	18867	8564	*45.4*	95	*0.5*
71	White Box Shrubby Open Forest; Melville Range		27557	17320	*62.9*	137	*0.5*
15	Rough-barked Apple/Blakely's Red Gum Grassy Open Forest; central tableland edge	E	35076	18381	*52.4*	181	*0.52*
50	Mountain Gum/Messmate/Snow Gum Montane Open Forest; far south-east	R	1405	1106	*78.7*	9	*0.64*
79	Silvertop Stringybark/Rough-barked Apple Grassy Open Forest; southern hills		137484	40882	*29.7*	899	*0.65*
42	White Box Shrubby Open Forest; widespread		22358	11691	*52.3*	148	*0.66*
107	Ooline Open or Closed Forest; scattered	E	303	148	*48.8*	2	*0.66*
27	Tumbledown Red Gum/Orange Gum/White Pine Shrubby Open Forest; Kwiambal		5028	2462	*49*	44	*0.88*
67	Rough-barked Apple/Silvertop Stringybark/Red Stringybark Grassy Open Forest; tableland edge		23788	14967	*62.9*	269	*1.13*
63	Rough-barked Apple/Red Stringybark Shrubby Open Forest; widespread		31229	11005	*35.2*	360	*1.15*
23	Black Pine/Northern Smooth-barked Apple Shrubby Open Forest; north-west		9189	5265	*57.3*	113	*1.23*
80	Rough-barked Apple/Silvertop Stringybark/Ribbon Gum Shrub/Grass Open Forest; far south		14653	6723	*45.9*	197	*1.34*
56	Blakely's Red Gum/White Pine/Rough-barked Apple Grassy Open Forest; northern drainage lines	E	8870	4256	*48*	134	*1.51*

TABLE 6-E (*cont'd*)

No	Name	Notes	Predicted Area (ha)	Extant Area (ha)	*% Extant*	Reserved Area (ha)	*% reserved*
36	White Pine/White Box Shrub/Grass Open Forest; central	E	50795	16556	*32.6*	791	*1.56*
28	Black Pine/Tumbledown Red Gum/Caley's Ironbark Shrub/Grass Open Forest; widespread		14362	5274	*36.7*	269	*1.87*
58	Rough-barked Apple Riparian Forb/Grass Open Forest; widespread		21435	6473	*30.2*	435	*2.03*
109	River Oak Riparian Open Forest; widespread	R	33969	19188	*56.5*	797	*2.35*
34	White Pine/Silver-leaved Ironbark/Tumbledown Red Gum Shrubby Open Forest; Kwiambal		41136	21631	*52.6*	980	*2.38*
37	White Pine/White Box/Silver-leaved Ironbark Shrubby Open Forest; western		29946	18353	*61.3*	719	*2.4*
26	Tumbledown Red Gum/BlackPine Shrubby Open Forest; north-east		27055	10018	*37*	725	*2.68*
29	White Pine/Tumbledown Red Gum/Caley's Ironbark Shrubby Open Forest; widespread		49898	32142	*64.4*	1352	*2.71*
105	Mugga Ironbark/Blakely's Red Gum Shrub/Grass Open Forest; Bingara	R	10364	6779	*65.4*	329	*3.17*
14	Orange Gum/Caley's Ironbark/Red Stringybark Shrub/Grass Open Forest; southern tableland edge		8807	5967	*67.8*	325	*3.69*
40	Silver-leaved Ironbark/Black Pine/White Box Shrubby Open Forest; northern		27089	12816	*47.3*	1334	*4.92*
2	Black Pine Granite Outcrop Shrubland/Open Woodland; tableland edge		7195	3716	*51.6*	470	*6.53*
16	New England Blackbutt/Youman's Stringybark Grassy Open Forest; tableland edge	R	14712	8781	*59.7*	1040	*7.07*
30	Tumbledown Red Gum/Caley's Ironbark Shrubby Open Forest; scattered		3680	3066	*83.3*	298	*8.1*
20	Narrow-leaved Ironbark/Pine/Brown Bloodwood Shrub/Grass Open Forest; north-west		14182	10266	*72.4*	1207	*8.51*
8	Black Pine/Orange Gum/Tumbledown Gum Shrubby Open Forest; south-east		24027	16681	*69.4*	2071	*8.62*
93	Alectryon/Rusty Fig/Mock Olive Dry Rainforest; scattered	E	815	611	*75*	76	*9.33*
91	Rough-barked Apple/White Box/Rusty Fig Shrubby Open Forest; Kaputar	K	2600	1602	*61.6*	249	*9.58*
64	Black Pine/White Box Shrubby Open Forest; Kaputar	K	24444	16682	*68.2*	2402	*9.83*
10	Black Pine/Tumbledown Red Gum/Narrow-leaved Ironbark/Red Stringybark Shrub/Grass Open Forest; Severn River		20772	10338	*49.8*	2457	*11.83*
9	Black Pine/Tumbledown Red Gum/Narrow-leaved Ironbark Shrubby Open Forest; north-east		12050	7828	*65*	1552	*12.88*
73	Narrow-leaved Ironbark/Tumbledown Red Gum Shrubby Open Forest; Melville Range		5512	5286	*95.9*	722	*13.1*
17	Tumbledown Gum/Black Pine/*Acacia cheelii* Shrubby Open Forest; scattered		1220	1118	*91.6*	216	*17.7*
6	Orange Gum/Black Pine Shrubby Open Forest; north-east		14438	10896	*75.5*	2711	*18.78*
11	Caley's Ironbark/Orange Gum/Black Pine Shrubby Open Forest; Severn River		9848	5440	*55.2*	2191	*22.25*
12	Orange Gum/Caley's Ironbark/New England Blackbutt Heathy Open Forest; Severn River		6130	4647	*75.8*	1403	*22.89*
70	Narrow-leaved Ironbark/Black Pine Shrubby Open Forest; Kaputar	K	8347	6141	*73.6*	2819	*33.77*
77	Ribbon Gum/ Silvertop Stringybark Ferny Open Forest; Kaputar	K	772	526	*68.1*	291	*37.69*
69	White Box/Rough-barked Apple Shrubby Open Forest; Kaputar	K	27686	21639	*78.2*	12546	*45.32*
74	Nandewar Box/New England Blackbutt/Red Stringybark Shrub/Grass Open Forest; Kaputar	K	9998	7961	*79.6*	6149	*61.5*
75	Silvertop Stringybark/Nandewar Box Shrubby Open Forest; Kaputar mid elevation	K	5595	5425	*97*	4894	*87.47*
5	Shrublands; Kaputar Trachyte	K	1438	1438	*100*	1273	*88.53*
76	Mountain Gum/Snow Gum Grassy Open Forest; Kaputar high elevation	K	1138	1138	*100*	1135	*99.74*

E = potential EEC; R = regionally uncommon; K = largely confined to Mount Kaputar National Park (assessed in BBS)

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