WILDLIFE CORRIDORS FOR CLIMATE CHANGE

Landscape Selection Process

Key Altitudinal, Latitudinal and Coastal Corridors for response to Climate Change

PRIORITIES FOR PROTECTED AREAS ON PRIVATE AND OTHER PUBLIC LANDS

A report by
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1 Introduction

This project was commissioned by the Conservation Partnerships, Parks and Wildlife Division to identify land areas to develop a strategic approach to the establishment of protected areas on private and other public lands that complements the public reserve system and enhances the CAR design principles such as representation, adequacy and comprehensiveness. The strategy will be based on improving connectivity to address potential impact of climate change. The identification of wildlife corridors for climate change will contribute to the conservation and protection of landscape scale climate change corridors. The project has strong links to the recently announced "Alps to Atherton" (A to A) Climate Change Corridor and is essentially a finer scale interpretation of the A to A concept and function at a regional scale.

2 Scope

The assessment identified those areas of the landscape that represent large scale climate change corridors of optimum habitat for wildlife. The approach is essentially a rapid assessment of best available desktop data. The corridors are significant for the movement of wildlife that may be vulnerable to the adverse effects of climate change and other threatening processes.

3 Study Area

The Study area is in North-East NSW within the Environmental Protection and Regulation Division – North East Branch boundary (DECC) including some areas on the tablelands as shown in Map 1, Appendix A. This study area was used as a guide however some areas outside the EPRD Branch boundary were included in the assessment based on available data.

4 Background

In the last few years an ever increasing volume of literature, reflecting the increasing research, on climate change has been produced. Despite this, projections regarding effects on biodiversity are of a much generalised nature. The range of predictions regarding the changes to weather patterns and the resulting effects on biodiversity are constantly being revised as new information becomes available.

The Commonwealth Scientific an Industrial Research Organisation (CSIRO) predicts that at current levels of greenhouse gas (GHG) emissions Australia will experience annual average temperature increases of 0.4-2.0 ° C by the year 2030 and 1-6 ° C by 2070. Average rainfall for the southeast Australia, in which the study area lies, is projected to decline along with increased erosion and inundation of the coastline as rainfall becomes more intense but less frequent. Higher average temperatures will cause higher evaporation and increase the incidence and intensity of bushfires (CSIRO, 2005).

As temperature and rainfall are major factors dictating the distribution of plants and animals it is expected that there will be both direct and indirect effects on species and ecosystems across Australia.

The National Biodiversity and Climate Change Action Plan 2004-2007 (NRMMC, 2004) provides a national overview of the impact of climate change and provides strategies and actions to mitigate impacts of climate change on biodiversity based on knowledge complied in 2004.

It Identifies ecosystems and species which may be particularly vulnerable to the effects of climate change. These include species and ecosystems which are: - already considered vulnerable such as those in high altitude environments, restricted to small geographic areas, vulnerable to invasive species, dependent on flowering and fruiting, low-lying coastal areas, freshwater wetlands or vulnerable to increased drought and fire.

Wildlife species are capable of adaptation to a changing climate through migration, genetic adaptation and behavioural. Biodiversity has been subject to a changing climate historically. However, climate change is now a much more significant problem than in the past due to the pervasive threats to native species from modification of land and waters by human settlements, pastoralism, and other anthropological factors that result in the fragmentation of natural vegetation (WWF, IUCN, WCPA 2007).

The identification of broad landscape corridors for adaptation to climate change is beginning to gain some attention in the scientific and government areas. The recognition and announcement of the large 'Alps to Atherton Corridor' has established a greater interest and awareness for biodiversity management in relation to the emerging threatening processes from climatic change predictions.

It is now apparent that recognised threatening processes arising from habitat fragmentation such as habitat isolation, habitat degradation, edge effects, predator/prey ratios to name a few, are now compounded by the increased needs for adaptation of wildlife to the potential pressures and threats presented by climate change. The impact of climate change scenarios on biodiversity have been briefly investigated in this report. These investigations of the current ideas and principles surrounding climate change have been integrated to establish a set of working principles and criteria which formed the basis for the design and development of the project outputs.

This approach works from within a theoretical framework that landscape connectivity will play a major role in both the adaptation to climate change effects and the continuation of wildlife ecological processes in a changing climate. This hopefully will be achieved by increasing gene flow between different populations of species to maximise their chances of exploiting changed conditions. This approach is consistent with actions identified for "the protection of habitat for terrestrial and marine species or ecosystems vulnerable to climate change" (NRMMC, 2004) and the key elements for enhancing resilience listed below.

In a the recent symposium on protected areas and climate change (sponsored by the Australian Greenhouse Office and the Department of the Environment and Water Resources), the issues of climate change resilience and the role of the National Reserve System were presented. Key directions for enhancing natural resilience were reported as

- Identify and protect climate refugia
- Conserve large-scale migration corridors
- Maintain viable populations to enable adaptation
- Reduce threatening processes at the landscape scale
- Conserve natural processes and connectivity at the landscape scale and
- Special interventions to avert extinctions

(Taylor, M and Figgis, P 2007 in "*Protected Areas: buffering nature against climate change – overview and recommendations*" page 2")

This project seeks to use best available desktop data to delineate large-scale migration corridors that can be used as a basis for addressing the above-mentioned actions and conservation priorities for climate change.

5 Rationale and Principles of Design

From the discussions above the following principles have been developed for the basis of the identification of broad wildlife corridors for adaptation to climate change pressures.

The overall rationale is to provide connectivity of similar habitats along climatic gradients and links between threatened landscapes to refugia.

The following principles of design were integrated into the analysis and decision making for corridor delineation.

- Identification of large scale migration corridors across climatic gradients.
- Reduction in edge effects on reserves and existing vegetation.
- Linking threatened landscapes
- Linking formal protected areas
- Linking key habitats
- Incorporating habitat mosaics
- Buffering and/or expansion of protected areas and linking refugia.

6 Methods

6.1 Interpretation of additional products from the Key Habitats and Corridors for forest fauna of north-east NSW (Scotts, D. and Drielsma, M.J. (2003)

The Key Habitats and Corridors for forest fauna published by Scotts (2003) was considered the most suitable model and data on which to base the assessment. This work and the associated data products (Scotts, D. and Drielsma, M.J. 2003) provided a sound basis on which to establish preliminary design and development. It is the only broad-scale network of wildlife corridors and habitats which covers the whole of the study area. The methodology has been widely reviewed and accepted.

The objectives of this project were to broadly delineate large-scale corridors based on existing mapped corridors from previous work and their significance for adaptation to climate change. To develop this approach, corridor maps for specific fauna assemblages were examined and grouped according to broad habitat requirements based on supplementary data from Scotts, D. and Drielsma, M.J. (2003). This allowed for climatic gradients and habitat mosaics to be incorporated into the design. The final 'broad' assemblages were constructed from the grouping of assemblages as shown in Table 1. This process identified three broad habitat assemblages which formed the basis of the climate change corridors delineation. These were moist habitat, dry habitat and coastal habitat assemblages. Table 1 illustrates the groups (assemblages) and their amalgamations.

Climate Corridor Assemblages	Key Habitats and Corridors – Assemblages - Scotts, (2003)
1. Moist	(UNE) Moist Escarpment – Foothills
	(UNE) Wet Eastern Tablelands
	(UNE) Wet Escarpment
	(UNE) Northern Escarpment
	(LNE) Wet Eastern Tablelands
	(LNE) Mid North Coast Wet Escarpment
	(LNE) High Elevation
	(LNE) Moist Escarpment Foothills
	(TAB) Wet Eastern Tablelands
	(TAB) Wet Escarpment Eastern Tablelands
	(SYD) Wet Coastal Ranges
2. Dry	(UNE) Eastern Tablelands
	(UNE) Dry Coastal-foothills
	(LNE) Dry Valley
	(LNE) Dry Eastern Tablelands
	(LNE) Dry Coastal Foothills
	(TAB) Dry Eastern Tablelands
	(TAB) Southern New England Tablelands
	(TAB)Dry Western Tablelands
	(SYD) Dry Valleys
	(TAB) Dry Granite Tablelands
	(SYD) Dry Western - Central
	(SYD) Dry Sandstone
3. Coastal	(UNE) Coastal Complex
	(LNE) Coastal Complex
	(UNE) Dry Coastal Foothills
	(SYD) Coastal complex
	(SYD) Dry Coastal Ranges
	(LNE) Dry Coastal Foothills

Table 1 Grouping of Scotts, D. and Drielsma, M.J. (2003) fauna assemblages into broad Habitat Assemblages for Climate Corridors

6.2 Initial delineation of Climate Change Corridors for dry, moist and coastal Assemblage fauna species

Climate Change corridors for three broad habitat assemblages were initially delineated by using a visual assessment of the landscape based on the spatial mapping of specific fauna assemblage corridors as derived by Scotts, D. and Drielsma, M.J. (2003).

The coastal delineation was based on the original mapping for the coastal complex fauna assemblage as derived by Scotts, D. and Drielsma, M.J. (2003). Extant vegetation was linked. Cleared areas and agricultural land that fit into a context of a climate change corridor was also included.

6.3 Refinement of Corridor framework

The initial corridors framework was reviewed and analysed to determine refined boundaries using more recent habitat quality models, vegetation mapping and visual checking using SPOT5 satellite imagery. The coastal corridor refinement included the additions of coastal wetlands and water-bodies.

An expert workshop was carried out on the "first cut" of areas from the process. This process used expert knowledge to refine the delineations. There was also further evaluation of the "input" map layers which formed the basis of design for proposed corridors such as:

- Mapped Fauna Assemblage Corridors specific to Moist, Dry or Coastal Assemblages (Scotts, 2003)
- Fauna assemblage habitat models (Scotts, 2003)
- Recent broad outputs from the Spatial Links Tool (Dreilsma, M, Manion, G and Ferrier, S. 2007)
- Analysis of vegetation patterns from the Forest Ecosystems remodelling (CRA – unpublished)
- Recent fauna and flora records from NSW Wildlife Atlas throughout and adjoining the study area.
- Tenure Layers
- SPOT 5 Satellite Imagery

6.4 Reference species designation

The expert review process identified reference species that were specifically associated with each corridor. These species were identified as vulnerable to climate change using a process of expert evaluation on the relative vulnerability to the adverse effects of climate change (see discussion below). In some cases two reference species were selected as climate change icons for a particular corridor. The species nominated for each corridor were species of particular conservation significance that related to each corridor location, habitat and arrangement and are intended for community recognition and awareness rather than a robust scientific indicator species.

During peer review workshops, selection and attribution of reference species for each corridor was conducted. Reference species were selected based on review of the following information;

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- Atlas fauna records
- Habitat mapping and modelling where available
- Known hotspot localities
- Expert knowledge of populations
- Vegetation mapping

The reference species serves as an icon to support community identification, awareness and understanding.

Species nominated as reference species may not be so vulnerable in other parts of their range; however the population has been assessed to have some vulnerability to threatening processes presented by climatic change predictions. It is not intended that conservation efforts should be structured solely for the benefit of the nominated reference species at the expense of other conservation values. A whole of

ecosystem approach should be undertaken with consideration of the reference species as an identifier.

6.4.1 Climate Change reference species– evaluation of "species at risk"

Fauna species with the assemblage groups developed by Scotts (2003,) were examined to evaluate those species most at risk to climate change pressures. Those selected were then 'short listed' for the selection of "reference" species to associate with particular climate change corridors. Criteria on which to base this evaluation included the following factors;

- Species which depend on landscapes predicted to be particularly vulnerable to climate change process, for example rainforest.
- restricted distribution,
- limited dispersal ability,
- specialised habitat requirements,
- small populations and/or low genetic diversity. In particular species endemic to high mountain environments, freshwater wetlands and islands are highly vulnerable. (NRMMC, 2004).

Other climate change pressures considered to impact on species at risk include;

- Vulnerability to opportunistic pest species which are adapted to take advantage of a range of climatic conditions, such as the red fox.
- Increase in virulence of viruses and parasites due to higher temperatures.
- Changes in structure and composition of vegetation communities as a result of changes in rainfall and temperature regimes will affect species adapted to existing regimes. This will directly affect nectarivores, frugivores and species dependent on hollows and fissures in old growth forests for habitat.
- Rising seal levels will mean species dependent on mangroves, coastal wetlands and seagrass will be directly affected.
- It is also expected that bushfires will increase in their frequency, intensity and extent. This will particularly affect species adapted to wetlands and rainforest as many existing moist habitats become drier (NRMMC, 2004).

6.5 Corridor names

Corridors were identified and labelled based on location, landscape features or protected areas in close proximity. This was established to facilitate community identification and "ownership' with the mapped corridors.

6.6 High Conservation Value Linkages

The Corridors networks were analysed and tagged as HCV linkages if a significant area of its extent contained key habitat. Key Habitats mapping from Scotts (2003) was utilised to calculate the areas. This outcome provides a quick reference for corridors which already support significant populations of species vulnerable to climate change. The selection of these HCV linkages was based on at least 30% mapped coverage of key habitats within the corridor.

6.7 Spatial Configuration Features

The following features were delineated within the corridors. Each corridor was split into sections based on these spatial configuration features. The sections were delineated based on the spatial configuration of the vegetation according to a visual analysis using Spot 5 satellite imagery (2005) and a consideration of the various conservation actions required over those features. The features are labelled to reflect the spatial configuration and the conservation action priorities and area summarised in Table 2 below.

Feature Label	Spatial feature	Conservation Action
Stepping Stone consolidation/development	Fragmented vegetation and remnants acting as viable corridor for selection of species.	Protection of existing vegetation and strategic re-establishment of vegetation to enhance 'stepping stone" pattern.
Valley Floor Linkages	Usually highly cleared or highly threatened fertile areas along alluvial flats.	Re-establishment of vegetation either as windbreaks or patches – in a stepping stone strategy.
Protect and Enhance	Usually extensively vegetated areas within the corridor.	Protection and rehabilitation of existing vegetation
Reserve Buffers	Predominantly extensively vegetated areas within the corridor and high proportion of mapped key habitats for wildlife.	Protection of vegetation (under covenant) to ensure buffers and expansion to formal reserve system
Reserve Buffers and Linkages	Predominantly extensively vegetated areas within the corridor and high proportion of mapped key habitats for wildlife.	As above with a view to creating strategic "linkages" of protected areas between formal reserves.
Floodplain Linkages	Sites of high fertility and productivity which were most comprehensively cleared for agriculture. The cleared floodplains of the study area represent major barriers to dispersal for many species.	Expansion of riparian vegetation, and connection to key habitats via stepping stones, creeks and ridgelines.
Linkage onto Tablelands	Extensively cleared high altitude landscapes which are predicted to become drier. East and west linkages vital to enable gene flow between rufugia.	Linking remnant vegetation along rivers and in TSRs.
Coastal connectors	Areas which are a mosaic of reserves, public lands forming stepping stone linkages of semi cleared ridges, small wetlands, and riparian strips	These will require a combination of the strategies outlined for other features
Major Wetland Areas	Function as refugia during periods of drought. May be in heavily cleared floodplain or tablelands or in forested areas.	Encourage habitat protection in and around wetland areas through bush regeneration and reduce threatening processes such as fire, water extraction, grazing and feral predators.

Table 2: Summary of Corridor Features and descriptions

7 Results and Discussion

7.1 Moist Faunal Assemblage Group

The analysis identified 39 major moist habitat assemblage corridors in the study area. The corridors link major moist habitats such as high altitudinal rainforest and wet sclerophyll and moist eastern foothills forests of northern NSW. The moist habitat assemblage corridors network links contiguous areas of forest across altitudinal gradients and latitudinal gradients. (Refer Map in Appendix B). Reference species are predominantly rainforest and high altitudinal species considered quite vulnerable to the impacts of climate change. A summary of corridors and associated reference species is provided below.

Corridor Name	Reference Species 1	Reference Species 2	HCV
Alstonville Plateau Link	Rose-crowned Fruit-dove	Pouched Frog	
Barrington to Muswellbrook	Sooty Owl		
Barrington to Myall	Grey-headed Flying Fox	Sooty Owl	
Barrington to the Hunter River west	Koala		
Billinudgel - Wollumbin	Wompoo Fruit-dove		HCV
Birriwal Bulga - Werrikimbe Connector	Yellow-bellied Glider	Sooty Owl	
Bongil Bongil - Bindarri	Koala	Yellow-bellied Glider	
Border - Toonumbar Connector - East	Wompoo Fruit-dove	Yellow-bellied Glider	HCV
Border - Toonumbar Connector - West	Wompoo Fruit-dove	Yellow-bellied Glider	HCV
Border - Upper Clarence Connector - East	Albert's Lyrebird		
Border - Upper Clarence West connector	Wompoo Fruit-dove		
Border- Wollumbin Connector	Albert's Lyrebird	Wompoo Fruit-dove	HCV
Bulga Giro Connector	Parma Wallaby	Wompoo Fruit-dove	
Byron - Tweed Range	Albert's Lyrebird	Loveridge's Frog	HCV
Coffs Coast - Escarpment	Rose-crowned Fruit-dove	Giant Barred Frog	HCV
Corindi Connector	Yellow-bellied Glider	Grey-headed Flying Fox	
Dorrigo Connector	Giant Barred Frog	Sooty Owl	
Dunoon - Hanging Rock Creek Connector	Rose-crowned Fruit-dove	Pouched Frog	
Great Lakes - Barrington	Stuttering Frog	Sooty Owl	HCV
Illuka - Richmond Range	Grey-headed Flying Fox	Black-striped Wallaby	HCV
Lower Bucca Connector	Grey-headed Flying Fox		
Macksville - Dunggir	Sooty Owl	Sphagnum Frog	
Mid North Coast Escarpment - Barrington	Giant Barred Frog	Sooty Owl	HCV
Mid North Coast Escarpment - Upper Clarence	Giant Barred Frog	Sooty Owl	HCV

Corridor Name	Reference Species 1	Reference Species 2	HCV
Mt Clunie Connector	Albert's Lyrebird	Wompoo Fruit-dove	
Nambucca - Missabotti	Yellow-bellied Glider	Wompoo Fruit-dove	
Nightcap - Nimbin Connector	Rose-crowned Fruit-dove	Pouched Frog	HCV
Oyster Creek - Escarpment	Giant Barred Frog	Little Bent-wing Bat	
Patterson to West Barrington	Koala	Grey-headed Flying Fox	
Port Macquarie - Bulga Plateau	Sooty Owl	Yellow-bellied Glider	HCV
Saltwater - Upper Manning	Yellow-bellied Glider	Sooty Owl	
Sherwood Connector	Yellow-bellied Glider	Grey-headed Flying Fox	
Tweed/Border Ranges to Mount Clunie	Fleay's Barred Frog	Albert's Lyrebird	HCV
Urunga - Escarpment	Rose-crowned Fruit-dove	Giant Barred Frog	
West Hunter River Loop	Sooty Owl		
Wet Coastal Ranges - Escarpment	Yellow-bellied Glider	Sooty Owl	HCV
Wollemi	Yellow-bellied Glider		
Yabbra - Tooloom Creek - Connector	Rose-crowned Fruit-dove		
Yamba - Nymboida	Yellow-bellied Glider	Grey-headed Flying Fox	
Yarrahappinni - Escarpment	Grey-headed Flying Fox	Wompoo Fruit-dove	HCV

Table 3: List of Moist habitat assemblage fauna climate change corridors and assigned reference species.

7.2 Dry Faunal Assemblage Group

The assessment identified 48 dry habitat assemblage corridors which are summarised below in table 4 below. The dry corridor network links major dry habitat hot spots and associated key habitats across Northern NSW in locations where moist habitat assemblages were partially or wholly absent. For example, the Hunter Valley has historically represented a 'dry' barrier to many moist habitat fauna species and will continue to be so under climate change predictions.

HCV Linkages highlight the areas where good populations of dry assemblage species should be already utilising the corridor based on the presence of areas of key habitat.

Corridor Name	Reference Species 1	Reference Species 2	HCV
Apsley River-McDonald River	Woodland Birds	Koala	
Barrington Tops	Broad-toothed Rat		HCV
Barrington Tops-Patterson	Squirrel Glider	Grey-headed Flying-fox	
Barrington-Muswellbrook	Woodland Birds	Koala	
Belford-Werakata	Woodland Birds	Squirrel Glider	
Boonoo Boonoo - Bald Rock	Woodland Birds	Wombat	HCV

Corridor Name	Reference Species 1	Reference Species 2	HCV
Cairncross	Koala	Grey-headed Flying-fox	
Carrai Plateau	Hastings River Mouse		
Carrai Plateau-Macleay Lowlands	Little Bentwing-bat	Brush-tailed Phascogale	HCV
Clarence Valley-Tablelands	Woodland Birds	Brush-tailed Phascogale	
Coastal Range	Coastal Emu		
Commissioners Waters	Woodland Birds	Koala	
Copleland Tops-Goulburn River	Woodland Birds		
Curracabundi-Barrington Tops	Wombat	Davies Tree Frog	
Ewingar-Mt Pikapene	Brush-tailed Rock Wallaby		
Garra-Cathedral Rocks	Woodland Birds	Squirrel Glider	
Garra-Mt Duval	Woodland Birds	Koala	
Glenrock-Scone	Woodland Birds	Booroolong Frog	
Goulburn River-Wollemi	Woodland Birds		
Great Eastern Tablelands Corridor	Woodland Birds	Brush-tailed Rock Wallaby	
Hillgrove-Garra	Woodland Birds	Squirrel Glider	
Jilliby-Brisbane Water	Red-crowned Toadlet		HCV
Jilliby-Yengo	Koala	Giant Burrowing Frog	HCV
Karuah-Port Stephens	Coastal Emu	Koala	HCV
Liverpool Range	Greater Glider	Wombat	
Liverpool Range-Manobalai	Woodland Birds	Wombat	HCV
Macleay River-Collombatti	Brush-tailed Phascogale		HCV
Mann River	Woodland Birds	Brush-tailed Rock Wallaby	
Mann River -Severn River	Koala	Brush-tailed Rock Wallaby	HCV
Mummel Gulf - Nowendoc	Wombat	Davies Tree Frog	HCV
Munghorn Gap-Wollemi	Woodland Birds		
Muswellbrook-Wollemi	Woodland Birds		
Pokolbin	Woodland Birds	Brush-tailed Rock Wallaby	HCV
Pokolbin-Karuah	Woodland Birds	Brush-tailed Phascogale	
Ravensworth-Wollemi	Green and Golden Bell Frog	Squirrel Glider	
Richmond Range-Bungawalbyn	Squirrel Glider		
Rocky River Valley	Hastings River Mouse	Brush-tailed Rock Wallaby	
Timbarra Plateau	Hastings River Mouse	Giant Dragon-fly	HCV
Torrington	Woodland Birds	Greater Glider	HCV

Corridor Name	Reference Species 1	Reference Species 2	HCV
Torrington - Bolivia Hill	Woodland Birds	Greater Glider	
Ulan-Munghorn Gap	Woodland Birds	Squirrel Glider	
Warra-Henry River	Eastern Pygmy Possum		HCV
Warra-New England Range	Woodland Birds	Squirrel Glider	
Werakata	Woodland Birds	Swift Parrot	HCV
Wollemi	Woodland Birds	Brush-tailed Rock Wallaby	
Woolooma-Barrington	Woodland Birds	Koala	
Yengo-Brisbane Water	Red-crowned Toadlet		HCV

Table 4 List of Dry assemblage fauna climate change corridors and assigned reference species.

7.3 Coastal Complex Faunal Assemblage Group

The Northeast NSW coastal area was divided into 24 major coastal corridors. Of these, eleven were considered to be High Conservation Value. A key faunal species for the Northeast Coast include the Koala, Grey-headed Flying-fox and the Wallum Frogs. There are important populations in the coastal forests and wetlands, however much of the habitat is fragmented. Protection of existing key habitat and buffers should be a priority conservation action on the coast. Key faunal species such as Brush-tailed Phascogale and Squirrel Gliders will also benefit from the enhancement of coastal forests on the coast.

Corridor Name	Reference Species 1	Reference Species 2	HCV
Ballina	Grey-headed Flying-fox	Rose-crowned Fruit Dove	
Ballina-Broadwater	Waders	Shorebirds	
Bellinger - Nambucca	Grey-headed Flying-fox	Coastal Shorebirds	
Broadwater - Bungawalbin	Koala	Emu	HCV
Brunswick - Chincogan	Grey-headed Flying-fox	Alberts Lyrebird	HCV
Byron - Lennox	Ground parrot	Wallum Frogs	HCV
Coffs Coast	Grey-headed Flyiing-fox	Koala	
Crescent Head - Hastings	Grass Owl	Ground Parrot	HCV
Crowdy Bay - Lower Manning	Black-necked Stork	Wallum Froglet	
Cudgen	Eastern Blossom Bat	Wallum Frogs	
Hastings - Camden Haven	Koala	Barred Cuckoo-shrike	HCV
Karuah - Hunter	Koala	Green and Golden Bell Frog	HCV
Lake Macquarie - Gosford	Koala	Wallum Froglet	HCV
Lower Clarence	Wetland Waterbirds	Emu	
Lower Manning - Wallingat	Koala	Brush-tailed Phascogale	
Macleay - Crescent Head	Wetland Waterbirds	Squirrel Glider	
Nambucca - Macleay	Eastern Blossom Bat	Grey-headed Flying-Fox	

Corridor Name	Reference Species 1	Reference Species 2	HCV
Newcastle	Squirrel Glider	Grey-headed Flying Fox	
Taree Coast	Eastern Blossom Bat	Koala	HCV
Tweed - Cobaki	Long-nosed Potoroo	Wallum Frogs	
Tyagarah - Byron	Long-nosed Potoroo	Wallum Frogs	HCV
Uralba-Tuckean Swamp	Alberts Lyrebird	Koala	
Wallingat - Karuah	Koala	Green and Golden Bell Frog	HCV
Yuraygir	Emu	Ground Parrot	

Table 5: List of Coastal habitat assemblage fauna climate change corridors and assigned reference species. (Please note: Figures for NRCMA area only at this stage)

8 SUMMARY OF OUTPUTS AND PRODUCTS

8.1 Separate digital spatial data layers for each fauna assemblage including moist, dry and coastal assemblages. Data structured in an Arcview GIS format.

The spatial data layer maps a climatic and habitat gradient corridor network to identify moist, dry and coastal faunal assemblage climate change values.

8.2 Corridor Names and Reference Species

Names are attributed to each delineated corridor based on the location in the landscape. Reference species associated with each corridor in regard to climate change values and vulnerability.

8.3 Corridor Features for Moist and Dry Fauna Assemblage corridors

A visual analysis of the SPOT5 satellite imagery and vegetation mapping data revealed various features within the corridors that will assist in strategic planning for conservation actions. These are described below.

8.3.1 Protect and Enhance

The characteristics of this corridor feature are predominantly high levels of vegetated land, presence of high conservation value forest and a level of continuity with adjacent areas of vegetation or reserves or other public land. The priorities in these areas would generally be focused on the protection of the existing high conservation value features, or some enhancement of existing vegetation through plantings, weed management and removal threatening processes.

8.3.2 Reserve Buffers and Linkages

These corridor features are predominantly delineated around or linking existing formal reserves and some other public lands. The areas are predominantly vegetated and contain large areas of key habitats and other high conservation value features such as old growth forest, wetlands, rainforest and forest that have been subject to less disturbance and fragmentation.

8.3.3 Stepping Stone Consolidation

These areas are classically fragmented and contain remnant vegetation that may be subject to edge effects. The areas are somewhat compromised in terms of viability for acting as wildlife corridors for species which will not disperse large distances over open areas but can be utilised by other species , especially bats and birds. In some instances they are more effective than narrow linear corridors which are dominated by edge loving species and thus represent important priority areas that require consolidation, maintenance and protection. The priorities in these areas would include;

- strategic re-establishment of vegetation,
- rehabilitation - weed management, feral animal removal
- protection of existing remnants
- nest boxes.
- Stepping Stone areas enhance landscape connectivity and will provide good connectivity for a subset of more mobile species such as bats, birds and insects.

8.3.4 Floodplain Linkages

The cleared floodplains of the study area represent major barriers to dispersal for many species. It is recognised that considerable resources would be required to complete these links however their importance should not be ignored. The higher productivity, access and permanent water of the major river systems will make these areas a high priority for conservation activities to address climate change. These have been refugia in past droughts and should be a high priority for future conservation efforts. Projected increased salinity in these areas may mean land becomes available for conservation as farming becomes unviable.

8.3.5 Linkage onto Tablelands

These areas are delineated as the most effective in improving connectivity for this highly threatened high altitude landscape. The extensive clearing and fragmentation of this area along with the projected higher temperatures and evaporation mean that many species and ecosystems already at risk further west may only survive along the tablelands/escarpment ecotone. Improving the connectivity along this predominately east to west gradient should be seen as a high priority.

8.3.6 Valley Floor Linkages

These are typically areas that link vegetation across the more productive, and thus heavily cleared alluvial flats and riparian areas. These areas are usually more fragmented and in poorer condition, however contain a high level of importance in terms of, productivity, connectivity and wildlife movement. Conservation actions would predominantly be associated with re- vegetation in strategic “stepping stone” locations and configurations.

8.4 Corridor Features for Coastal Complex fauna assemblage corridors

The coastal corridor has been developed using different methodology in delineating features. The geomorphology found within the long narrow coastal strip does not easily ready itself to splitting into discrete features similar to the dry and moist corridors. It also has its own unique set of climate change pressures and existing threatening processes. Sea level rises are expected to have a devastating effect on low level estuarine and freshwater wetland environments. Corridor features were

categorised as a “Linkage across Floodplains” (as described above), “Major Wetland areas” or Coastal connector”.

8.4.1 Major Wetland Areas

These areas which may be inundated with salt water and change the make of wetland communities dramatically. Cleared areas immediately adjacent to areas currently supporting wetland ecosystems should be targeted as they will be increasingly important as sea level rises.

8.4.2 Coastal Connectors

Areas which are a mosaic of reserves, public lands forming stepping stone linkages of semi cleared ridges, small wetlands, and riparian strips. These will require a combination of the strategies outlined for other features

8.5 Quantitative statistical information on conservation values:

Statistical information regarding each corridor section is built into the attribute table and can be analysed to evaluate conservation actions and funding requirements. The following information is included:

- Vegetation area (All fauna groups)
- Old growth area (All fauna groups)
- Key habitat area (All fauna groups)
- Coastal Wetland area (Coastal group)
- Rainforest area (Moist and Coastal group)

The area of these conservation features, in hectares and as a percentage of corridor area. This information is built into the attribute layers of the GIS spatial database.

9 PRIORITY TARGET CORRIDORS FOR PROTECTED AREAS ON PRIVATE AND OTHER PUBLIC LANDS

The data facilitates the assessment and prioritisation of proposed protected areas on private and other public lands in terms of climate change priorities and illustrates the value of proposals within the context of broader landscape wildlife corridors and their features.

Based on the current view of climatic change impacts, moist and coastal assemblage fauna are considered to be at greater risk to threatening processes. Therefore the moist and coastal assemblage corridors network was predominantly chosen to evaluate the highest priorities for targeting incentives and protective land management measures. In PWD regions, some components of the dry corridors network were included in the priorities.

9.1 Criteria for evaluation of priority areas.

High priority Climate Change Corridors were selected according to the following criteria:

- Corridor contains significant areas of major regional wildlife corridors as mapped by Scotts, D. and Drielsma, M.J. (2003).
- Corridor contains significant amounts of Key habitats as mapped by Scotts Scotts, D. and Drielsma, M.J. (2003).
- Majority of vegetation and potential proposals are vegetated and maintain existing connectivity to formal reserves.

- Corridor contains major opportunities for progressing reserve viability and connectivity.

9.2 Northern Rivers Region

Map 2 (Appendix C) illustrates the priority climate change corridors and fauna assemblage (Scotts, 2003) for the Northern Rivers PWD region. This area has a high number of threatened species as well as Bassian species on the edge of their ranges. Climate change pressures will necessitate a strong commitment from conservation agencies to help buffer these species from adverse effects and adjust to a changing climate.

Billinudgel to Wollumbin

This major corridor complex (refer Map 2, Appendix C) links the coastal wetlands, heaths and rainforests of the Brunswick Tweed coast with the world heritage listed Gondwanan Rainforests of the Mt Warning caldera. The nectar and rainforest fruit resource present within this corridor provide a continuous food resource for nectarivorous and frugivores bird and bat species. The coastal section of the corridor is known locally as the Marshalls Ridge wildlife corridor and has been identified in various reports and publications such as the Byron Flora and Fauna Study (BSC, 1999) and was recognised in a Pacific Highway RTA compensatory habitat land package and the construction of a fauna underpass

This corridor contains significant habitat for the following faunal assemblages (Scotts, 2003):

- Coastal Complex,
- Northern Escarpment,
- Wet Escarpment,
- Wet Escarpment Foothills and
- Moist Escarpment Foothills.

The areas mapped represent an altitudinal corridor for the Grey-headed Flying-fox, Eastern Blossom Bat, Black-flying fox, Tube-nosed bat and the rainforest dependent fruit-doves.

73% of the corridor is vegetated although invasive weeds are a significant problem in this area. 55% of the corridor has been mapped as key habitat (Scotts, 2003) and of this, 2856ha of old growth forest and 6817ha of rainforest.

The corridor links the following reserves:- Billinudgel NR, Hattons Bluff NR, Inner Pocket NR, Moball NR, Mount Jerusalem NP, Mount Nullum NP, Wollumbin NP and Wollumbin SCA.

This corridor is designed to connect and protect food and nectar resources which are under particular threat from climate change. Conservation actions to improve connectivity are needed across all tenures to allow species and ecosystems to adapt to climate change. This corridor provides a climatic gradient from sea level to the central core of the Mount Warning caldera (1156m) in an area that is host to a high number of moist endemic species and species at the limits of their distribution, indicating that that the area has been an evolutionary refugia during past climate change events.

The coastal section of the corridor is known locally as the Marshalls Ridge wildlife corridor and has been identified in various reports and publications such as the Byron

Flora and Fauna Study (BSC, 1999) and was recognised in a Pacific Highway RTA compensatory habitat land package.

Tweed – Border Ranges and Richmond Range Corridor

This group of corridors (refer Map 2 Appendix C) is considered a priority for the targeting of VCA opportunities for several of its connectivity conservation values. The area maps out major opportunities for connectivity between reserves in the area. More than 17 reserves occur along the climate change corridor representing some important refugia such as the Gondwanan rainforest core habitat values in the Border Ranges National Park. The Richmond Range is an important longitudinal corridor and contains a mosaic of habitat values for many threatened fauna and high altitude wet escarpment fauna predicted to be vulnerable to the impact of climate change. These species include the Rufous Scrub Bird, Fleay's Barred Frog, Albert's Lyrebird, Sooty Owl, Pouched Frog and Eastern Bristlebird. This area is considered a biodiversity hotspot for its diversity of flora and fauna. The refugia that the area represents will be critical to buffering the effects of climate change for many of the fauna species that occur in the Northern Rivers region.

Climate Change Voluntary Conservation Agreement (VCA) Opportunities

Map2a (Appendix C) shows several priority areas for addition to the reserve system which contain the flowing values:-

- Large areas are identified as key habitat on private property linking the caldera reserves and Billinudgel NR.
- Large tracts of key habitat south of Border Ranges National Park near Collins Creek
- Large area of key habitat on north-eastern arm of Toonumbar NP
- Areas of rainforest mapped to the east of Captains Creek NR
- Large areas of Candidate Old Growth forest adjacent to Cataract NP.

There is a high incidence of lease and former leasehold land in these areas which support high conservation value forest to be protected by covenant. Linking these areas to the reserve system by VCAs would help secure connectivity in this area.

9.3 North Coast Region

The priority corridor complex extends from the coastal parks at Minnie Water, Moonee and Repton along altitudinal gradients to the wet escapement country between Nymboida and New England's National Parks. The priority corridor occurs in areas within 30 National Parks and Reserves and includes the following identified climate change corridors.

- Bongil Bongil – Bindarri
- Coffs Coast – Escarpment
- Mid North Coast Escarpment – Upper Clarence
- Corindi Connector
- Dorrigo Connector
- Lower Bucca Connector
- Sherwood Connector Yamba Nymboida

Priorities in the North Coast Region lie within a number of identified climate corridors. The corridors link together to form broad pathways from the warmer coastal habitats to the cooler wet escarpment high altitude habitat areas. (refer to Map 3, Appendix C). These areas link further to the north and south within the Alps to Atherton Climate Change corridor (outside the North Coast Region).

Natural Heritage Values
These corridors are selected as important areas for the following fauna assemblages as derived by Scotts, D (2003):

- Moist Escarpment Foothills
- Wet Eastern Tablelands
- Wet Escarpment
- Mid North Coast Wet Escarpment

Reference fauna species for these corridors include the Sooty Owl, Yellow-bellied Glider, Giant Barred Frog, Grey-headed Flying-fox and the Rose-crowned Fruit-dove. The corridors link important habitats for these species and are primarily focused for the connectivity between vulnerable ecosystems such as rainforest and wet sclerophyll forests.

The identified areas contain approximately 173,260ha of mapped key habitats for wildlife, 155,494ha of old growth forest habitat and 86 950ha of rainforest habitat. The priority areas contain extensive records of threatened fauna vulnerable to the impacts of climate change including the Koala, Yellow-bellied Glider, Sooty Owl, Stuttering Frog, Sphagnum Frog, giant Barred Frog, Grey-headed Flying-fox and Wompoo Fruit-dove.

Landscape Connectivity and Climate Change values
The priority corridor complex connects existing reserves along altitudinal and longitudinal climatic gradients. In some of the escarpment areas, connectivity between reserves is quite good however, key coastal areas and escarpment foothills lack such connectivity in formal reserves. In these areas great opportunities for increasing connectivity along the major climatic gradients exist. Some examples include connectivity between the following reserves:

- Byrnes Scrub NR and Nymboi-Binderay NP
- Sherwood NR and Byrnes Scrub NR
- Juugawaarri NR – Ganay NR – Jaaningga NR
- Bongil Bongil NP and Bindarri NP

Other VCA Climate Change Opportunities that exist and represent achievable high priority outcomes include the following:

- Buffers to the boundaries of Reserves containing mapped key habitats including old-growth forest and rainforest values.

- Corridor of old growth forest between Bindarri National Park – west wards to Cascade National Park and Dorrigo National Park.

- Large stands of Old growth forest within “inholdings” to New England National Park.

Refer to Map 3a, Appendix C for illustration of discussion above.

9.4 Mid North Coast Region

The priority corridor complex for the Mid-North Coast region extends from the coastal parks at Minnie Water, Moonee and Repton along altitudinal gradients to the wet escapement country between Nymboida and New England's National Parks. The priority corridor complex occurs in areas within 34 National Parks and Reserves and includes the Mid North Coast Escarpment Corridor and the Port Macquarie – Bulga Plateau Corridor.

Corridor priorities in the Mid North Coast link together to form a broad pathway from the warmer moist coastal habitats around Lake Innes Nature Reserve along climatic gradients up to the cooler wet escarpment high altitude habitat areas around Cottan-Bimbang National Park. (refer to Map 4, Appendix C). These priority areas link further to the north and south within the Alps to Atherton Climate Change corridor (outside the Mid North Coast Region) as far as Barrington in the south and Mount Clunie and Richmond Range in the north.

Natural Heritage Values

This priority corridor complex is identified as important areas for the adaptation of the following fauna assemblages as derived by Scotts, D (2003):

- Moist Escarpment Foothills
- Wet Eastern Tablelands

Reference fauna species for these corridors are the Sooty Owl and Giant Barred Frog. The corridors link important habitats for these species and are primarily focused for the connectivity between vulnerable ecosystems such as rainforest and wet sclerophyll forests.

The identified areas contain approximately 108, 586ha of mapped key habitats for wildlife, 71, 279ha of old growth forest habitat and 64, 833ha of rainforest habitat. The priority areas contain extensive records of threatened fauna vulnerable to the impacts of climate change including the Koala, Yellow-bellied Glider, Sooty Owl, Stuttering Frog, Sphagnum Frog, giant Barred Frog, Grey-headed Flying-fox and Wompoo Fruit-dove.

Landscape Connectivity and Climate Change values

The priority corridor complex connects existing reserves along altitudinal and longitudinal climatic gradients. In some of the escarpment areas, connectivity between reserves is quite extensive. However the, key coastal areas and escarpment foothills lack such connectivity in formal reserves. In these areas great opportunities for increasing connectivity along the major climatic gradients exist.

Climate Change Voluntary Conservation Agreement (VCA) Opportunities

VCA Climate Change Opportunities that exist and represent achievable high priority outcomes include the following:

- Extensive areas of mapped key wildlife habitats between Mount Seaview Nature Reserve, Koorebang Nature Reserve and Werrikimbe National Park
- Large areas of mapped key wildlife adjacent to perimeter of Killabakh Nature Reserve
- Large tracts of Old-growth Forest, Rainforest and some mapped key wildlife habitats between northern boundary of Killabakh Nature Reserve and eastern boundaries of Tapin Tops National Park and Southern Birriwal Bulga National Park.

Refer to Map 4a, Appendix C for illustration of discussion above.

9.5 Hunter Region

The priority corridor complex is composed on three major climate change corridors and extends from the coastal areas of Wallingat and Sandbar along altitudinal and latitudinal gradients to the high altitude wet escapement country of Barrington Tops, Curricabundi National Park and west towards Nundle and Ben Halls Gap NP (Refer to Map 5, Appendix C). The priority corridor complex occurs in areas within 31 National Parks and Reserves and identifies key landscape connections between some of these reserves.

These priority areas link further to the north and south within the Alps to Atherton Climate Change corridor (outside the Hunter Region) as far north as Mount Clunie and the Richmond Range.

Natural Heritage Values

This priority corridor complex is identified as important areas for the adaptation of the following fauna assemblages as derived by Scotts, D (2003):

- High Elevation Tablelands
- Wet Escarpment Eastern Tablelands
- Moist Escarpment Foothills
- Wet Eastern Tablelands

Reference fauna species for these corridors include the Stuttering Frog, Sooty Owl and Giant Barred Frog. The corridors link important habitats for these species and are primarily focused for the connectivity between those ecosystems considered more vulnerable to climate change impacts such as rainforest and wet sclerophyll forests.

The identified areas contain approximately 145610ha of mapped key habitats for wildlife, 68000 of old growth forest habitat and 65858ha of rainforest habitat. The corridor complex contains extensive records of threatened fauna vulnerable to the impacts of climate change including the Koala, Rufus Scrub Bird, Yellow-bellied Glider, Sooty Owl, Stuttering Frog, Stephen's Banded Snake and Red-legged pademelon.

Landscape Connectivity and Climate Change values

The priority corridor complex connects existing reserves along altitudinal and longitudinal climatic gradients. There are many opportunities within the identified priorities where connectivity between existing reserves can and should be improved through the implementation of protective covenants or property agreements.

Climate Change Voluntary Conservation Agreement (VCA)

VCA Climate Change Opportunities that exist and represent achievable high priority outcomes include the following:

- Contiguous link of key habitats between The Glen NR and Ghin-Doo-Ee National Park
- Key habitats mapped within the Inholdings and Perimeters of Wallingat National Park
- Mapped Key habitats around boundary of Myall Lakes National Park
- Linking to and connecting key habitats south of Ben Halls Gap and Back River Nature Reserve

Refer to Map 5a, Appendix C for illustration of discussion above.

9.6 Central Coast Region

A priority moist habitat corridor connects the Jilliby SCA and Brisbane Water NP reserves on the coastal ranges with the Wollemi and Yengo escarpment and the Wategans NP to the north.

Further to the west a corridor of dry assemblage species connects the Liverpool Ranges with Manobalai NR, Goulbourn River and Wollemi NPs (Map 6, Appendix C).

Natural Heritage Values

This priority corridor complex is identified as important areas for the adaptation of the following fauna assemblages as derived by Scotts, D (2003):

- Wet Coastal Ranges
- Dry West Central

Reference species for these corridors include the Yellow-bellied Glider and Sooty Owl for the moist areas and Woodland Birds and Wombat for the dry areas.

The dry corridor contains 21 001ha of Key Habitats and 12 725ha of Old Growth forests. The moist corridor contains 91503ha of Key habitats.

Climate Change Voluntary Conservation Agreement (VCA) Opportunities

VCA Climate Change Opportunities that exist and represent achievable high priority outcomes include the following:

Liverpool Range – Manobalai

- Extensive area of old growth forest area on private property adjacent to the southern boundary of Manobalai Nature Reserve.
- Areas of key habitats on private property linking Brisbane Water NP and Jilliby SCA.
- Key habitats to the north of Jilliby SCA linking up with the special management (FMZ 2) areas of Olney State Forest.

Refer to Map 6a, Appendix C for illustration of discussion above.

9.7 Northern Tablelands Region

Torrington to Bolivia Hill and Torrington corridors

Due to the proposed study area, climate change corridors were prepared for the eastern boundary of the northern tablelands area.

The priority corridors, shown in map 7 (Appendix C), form a connection from the Great Dividing Range, across to the forested Torrington area of the northern tablelands and the eastern edge of the north-west slopes in the Nandewar Bioregion.

Natural Heritage Values

The identified area contains approximately 71,729 ha of mapped Key Habitats for fauna and over 59,408 ha of old growth forest.

These corridors are important for the following fauna assemblages as derived by Scotts (2003):

- Dry Granite Tablelands
- Dry Western Tablelands

It is predicted that habitats to west will dry out with a shift of moister habitats contracting to the east. The Torrington SCA area is part of an extensive vegetation block which is an exception in the heavily cleared tablelands. Part of this is due to the low fertility of the landscape, however taller forests occur along the eastern boundary and support species which have disappeared from much of the tablelands and north-west slopes. These corridors also provide for species which are at the western edge of their range whose habitats may become drier.

A population of Greater Gliders, possibly currently isolated from other populations, occurs in the taller old growth forests on the eastern edge of Torrington SCA. Providing connectivity to other extant populations and to the habitats further east will be crucial to ensuring the survival of this species in the area.

Other species which have become scarce further west but found in this area are the Masked and Powerful Owl. The Greater Gilder is a major prey species of the Powerful Owl. Woodland Birds are well represented in this area with some of the most easterly records of the Squatter Pigeon in NSW indicating it may be refugia for western species.

Climate Change Voluntary Conservation Agreement (VCA) Opportunities
Opposition to areas being gazetted as further reserve additions due to potential mining interests make this area a high priority for VCA targeting.

The following areas, shown on Map 7a (Appendix C), will increase connectivity and help fauna population in the area increase their natural resilience to adapt to climate change.

- Areas of key habitats mapped around Torrington SCA to the north and east which link to Gibraltar NR and Bolivia Hill Nature Reserves.

- Areas of Old Growth Forest which link smaller portions of Torrington SCA and the larger reserve area.

9.8 COASTAL PRIORITIES FOR PROTECTED AREAS ON PRIVATE AND OTHER PUBLIC LANDS

9.8.1 Northern Rivers Region

Corridors south of Ballina are considered priority in this Region as there is very little connection along the actual coast line. The corridor connecting **Uralba NR to Tuckean NR** is a significant area which connects wetland systems and other coastal habitats. Vegetation cover through this corridor is not continuous and any land management projects which seek to enhance and protect land in this corridor, for example a VCA, would have a positive effect on the viability of this corridor.

9.8.2 North Coast Region

One of the most tenuous connections along the study area in terms of continuous vegetation cover is along the **Coffs Coast**. This area should be the priority for restoration work with an emphasis of connecting and expanding areas of native coastal vegetation.

9.8.3 Mid North Coast Region

A priority area for corridor enhancement in this region is around the mouth of the Macleay River. This area supports an important large coastal wetland system and areas connecting Clybucca HS to Hat Head NP (**Nambucca – Macleay and Macleay – Crescent Head** mapped corridors) could be enhanced by management for conservation. Similarly, areas south of the mouth of the Manning River are a high priority for enhancement of lands within the mapped **Crowdy Bay – Lower Manning** coastal corridor. In particular, the Minimbah and Darawank wetlands are crucial areas for protection and restoration. Any private lands in this area, particularly low-lying or wetland areas have potential to add to the health of the coastal wetland systems and provide for a more extensive area for faunal movement.

9.8.4 Hunter Region

Areas of importance for VCA augmentation of corridors in the Port Stephens area include lands adjoining the Worimi NP and lands between Worimi NP and Medowie SCA. This area contains some important coastal wetlands and provides link across the coastal floodplain. This area is experiencing high population growth and also contains considerable rural residential small acreage landholdings. These private lands provide considerable opportunity for VCAs to add to vegetated corridors in the Port Stephens area.

9.8.5 Central Coast Region

There are large areas of key habitats identified to the east and south of Sugarloaf State Conservation Area. Other coastal priorities for VCAs in this region are the key habitats that occur south **of Arabakal NR** and **Glenrock SCA** and continue south throughout the urban areas on the eastern side of Lake Macquarie. These areas of coastal key habitats occur in vegetated areas that are contiguous with the existing reserves. A further priority area exists in the southern areas of Lake Macquarie. The areas are located adjacent to **Munmorah SCA**, Lake Macquarie SCA and **Wallarah NP**. The priority areas provide connectivity between reserves and contain coastal key habitats.

The area connecting the forests around The Entrance and Gosford are relatively intact through to Jilliby SCA, near Mangrove Mountain and then west to Yengo NP. This area comprises a significant corridor from the coast to the identified Yengo

Wilderness area. This important large relatively intact latitudinal corridor provides avenues for faunal movement through different habitat types and is important in the context of climate change. Any VCAs in this area would help to solidify the importance of this corridor.

10 Limitations to the project outcomes

10.1 Isolated vulnerable Habitats

It may not be possible to connect some vulnerable habitats, such as isolated wetlands due to geographic or geological conditions or islands by vegetative corridors. In these instances localised threatening process should be minimised and other conservation strategies explored.

10.2 Floodplain remnants and linkages

In some areas opportunities to establish Floodplain Stepping Stones may arise which are outside delineated corridors. If this occurs in heavily cleared areas it would be prudent to revegetate these areas if no other property is available in the area.

10.3 Riparian corridors

Riparian areas are natural corridors for many species and should be considered a priority to maintain and enhance. Riparian Corridors were not specifically delineated by Scotts (2003) as they are already clearly defined in the landscape.

Although riparian corridors are not extensively mapped in the project outputs, it is essential that these areas receive protection, re-habilitation and even expansion to help complement an overall landscape connectivity approach to climate change. Lindenmayer and Fisher, 2006 state that 'Riparian corridors or stream buffers are a particular type of corridor that can often be particularly effective at maintaining habitat connectivity (Kirchner et al. 2003; Hilty and Merenlender 2004). They provide habitat for large numbers of terrestrial and aquatic fauna and flora (Loyn et al. 1980: Naiman et al. 1993; Spackman and Hughes 1995). In addition, populations of several groups of species are more fecund in riparian areas (Sederquist and Mac Nally 2000), thereby providing more offspring to disperse to the less productive parts of the landscape.'

In terms of connectivity, however, Lindenmayer and Fisher, 2006 go on to state that' while riparian areas are useful for some terrestrial taxa, physical linkages outside the riparian zone are required to maintain landscape connectivity for other taxa (McGarigal and McComb 1992; Claridge and Lindenmayer 1994).

In terms of our recommendations for further corridor and landscape connectivity work, riparian corridors should feature strongly in any mapping of floodplain 'stepping stones' as an essential supplement to the existing broad corridors networks presented by this project.

11 Caveats

Lindenmayer and Fischer 2006 discuss some of the apparent disadvantages with wildlife corridors which should be considered. The discussion states that 'corridors may facilitate the spread of genes that break up co adapted gene complexes in

naturally isolated population (Knopf, 1992). They may also exacerbate the spread of weeks, pest animals, diseases, and fires (Forney and Gilpin 1989). Corridors may be dominated by negative edge effects (Sisk and Margules 1993).

These disadvantages should be considered in the allocation of resources for conservation actions. Any re-establishment or rehabilitation of vegetation should also include strategic follow up actions and resources to reduce the impacts of weeds and edge effects and allow for the area to grow spatially and structurally.

The design of this project is based on climate change projections at the lower end of the predicted changes. This is dependent on a steady reduction in carbon emissions occurring within the next 10-15 years and annual temperatures across the study area not rising by more than 2 degrees C. If emissions are not drastically reduced and temperatures rise by 3-6 degrees C then the measures outlined in this report will be ineffectual.

12 Recommendations for Further work

- This project provides for the basis broad scale network of vegetated corridors, along climatic gradients linking with the Alps to Atherton continental scale corridor, to assist threatened wildlife populations adjust as projected ecological changes due to climate change occur.

- Further work to delineate stepping stone corridors across and between the most threatened landscapes such as floodplains, wetlands, lowland forest areas and low lying coastal landscapes needs to be established as a major incentive to mitigate the increasing pressures of habitat fragmentation on fauna assemblages that rely on these landscapes and their habitat for survival.

- Further refinement is needed to define the corridor network at a local rather than regional scale to increase the effectiveness of the mapping for planning on ground conservation works at a property scale.

- Further research is needed to better understand the effects of climate change on biodiversity in the study region.

- Systematic fauna surveys are needed to determine the value of corridor linkages to different faunal assemblages.

- Research is needed on the population dynamics of vulnerable species in the study area to help improve strategies to maximise gene flow in a way which is of benefit to the species or population. This will assist in determining the effectiveness of different patch sizes for different species,

- Good baseline ecological data, such as current range and distribution, is lacking for the study area. Collecting this data should be a priority so that changes caused by climate change can be recognised. Migratory species are particularly important as changes in their arrival and departure times may signal the onset of dramatic changes.

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LIST OF EXPERTS

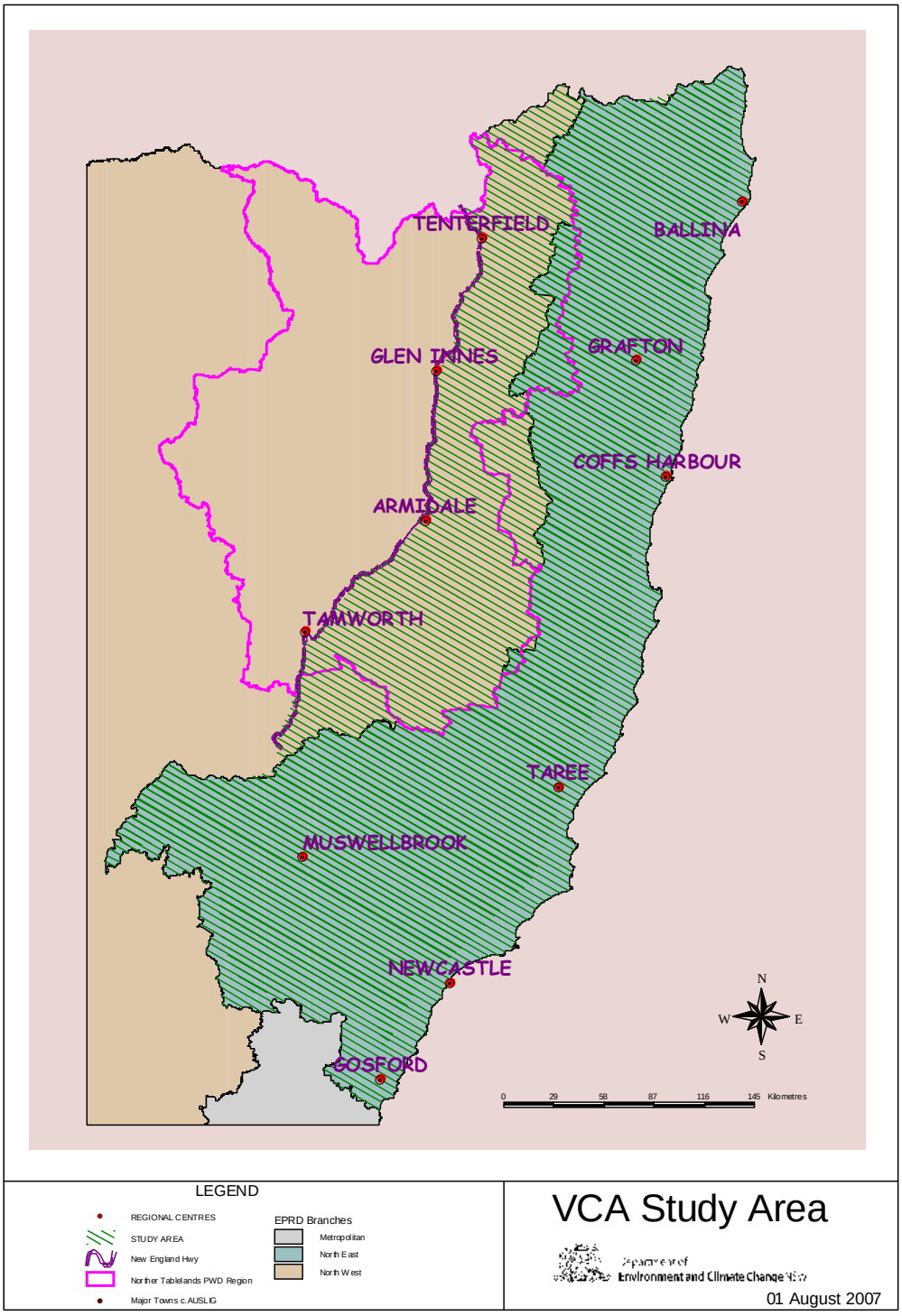
1. Dave Scotts, Consultant Ecologist
2. Mick Andren, Fauna Ecologist, Conservation Assessment Officer, Dept. Environment and Climate Change
3. Kevin Taylor, Ecologist

4. Dr Sally Townley, Fauna Ecologist

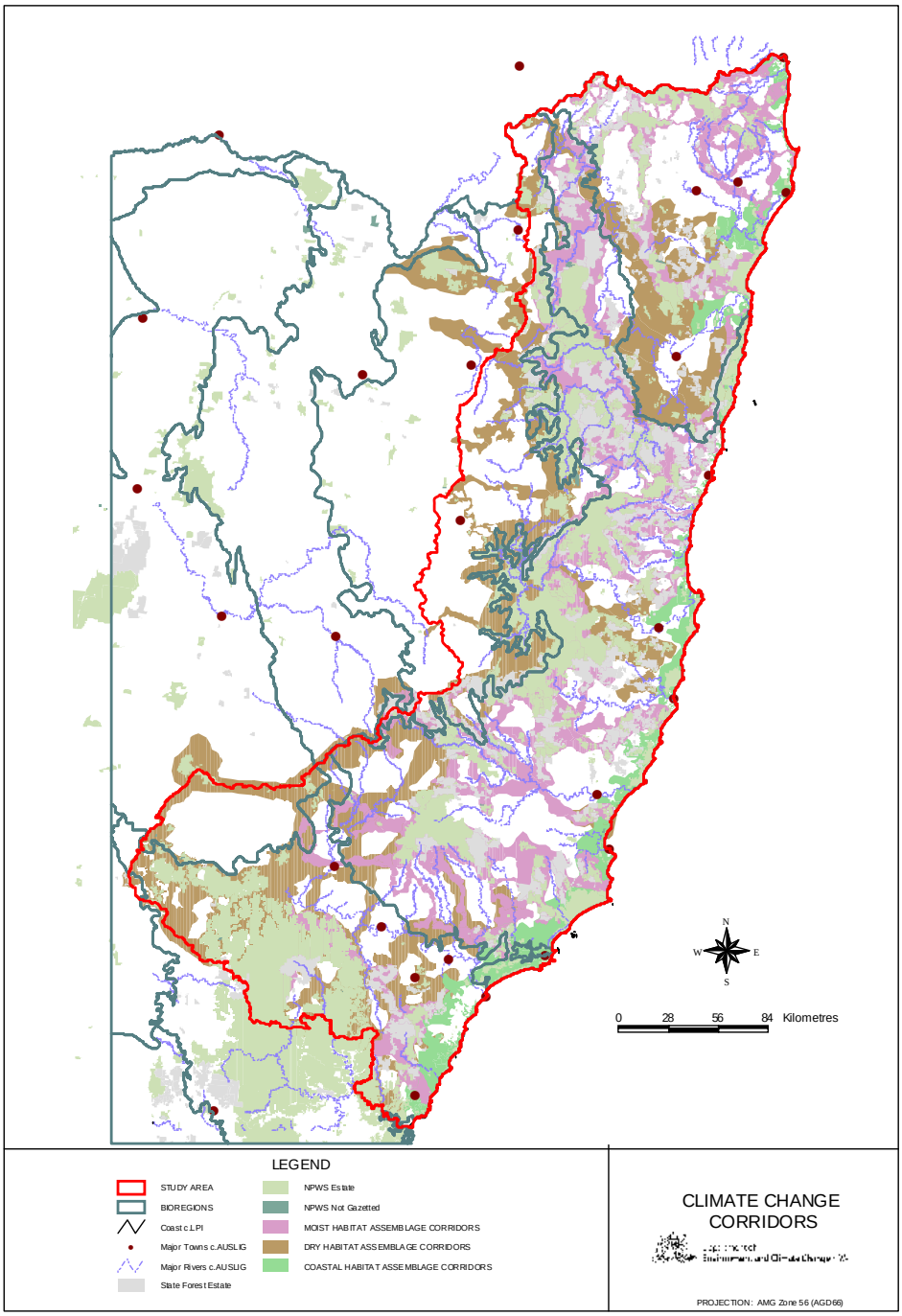
APPENDICIES

APPENDIX A

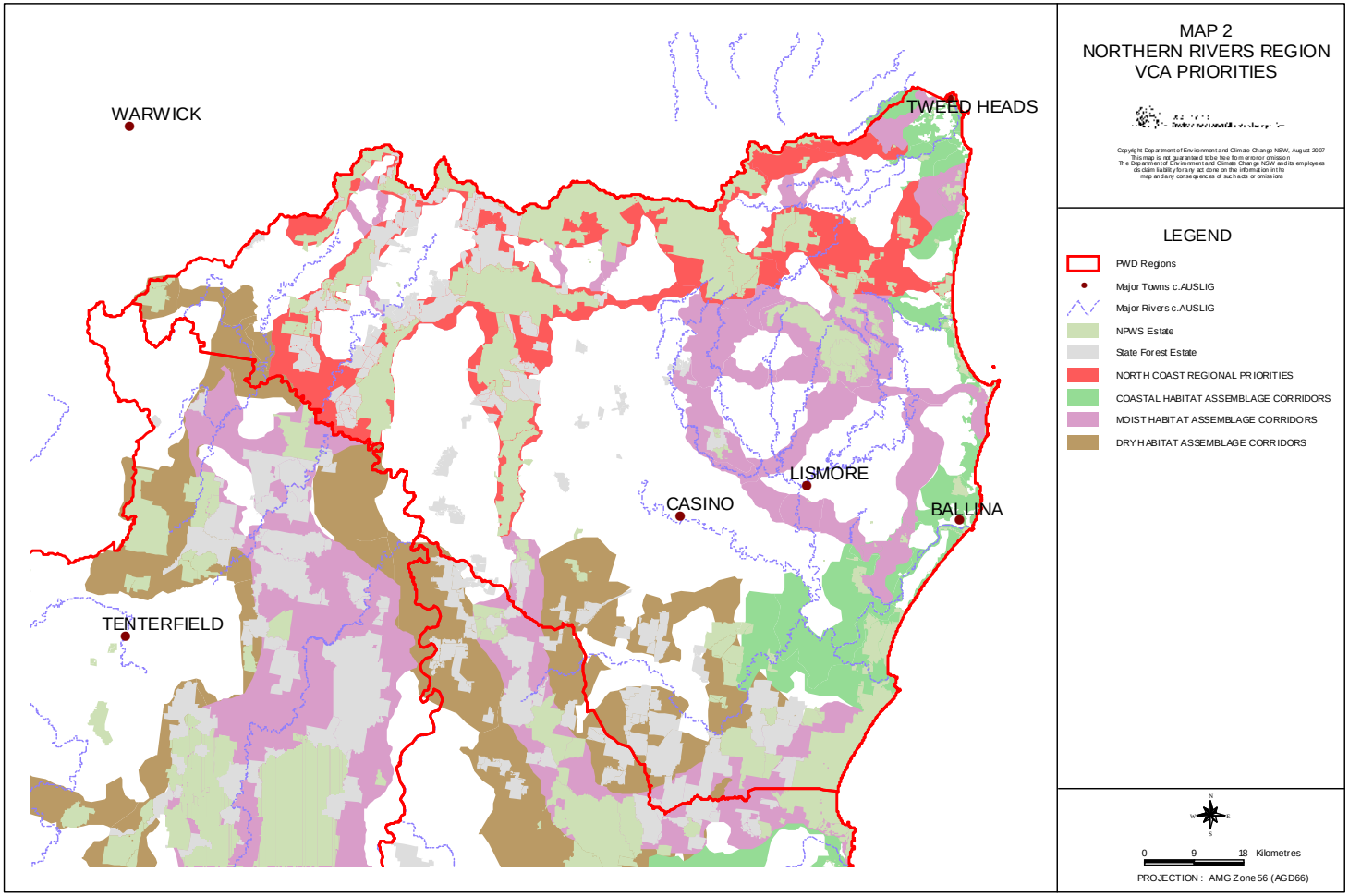
MAP 1: Map of the Study Area for Climate change Corridors project



APPENDIX B – Map of Climate Change Corridors for Moist, Dry and Coastal Habitat Assemblages.



APPENDIX C


WARWICK
TWEED HEADS
LISMORE
CASINO
BALLINA
TENTERFIELD
MAP 2
NORTHERN RIVERS REGION
VCA PRIORITIES
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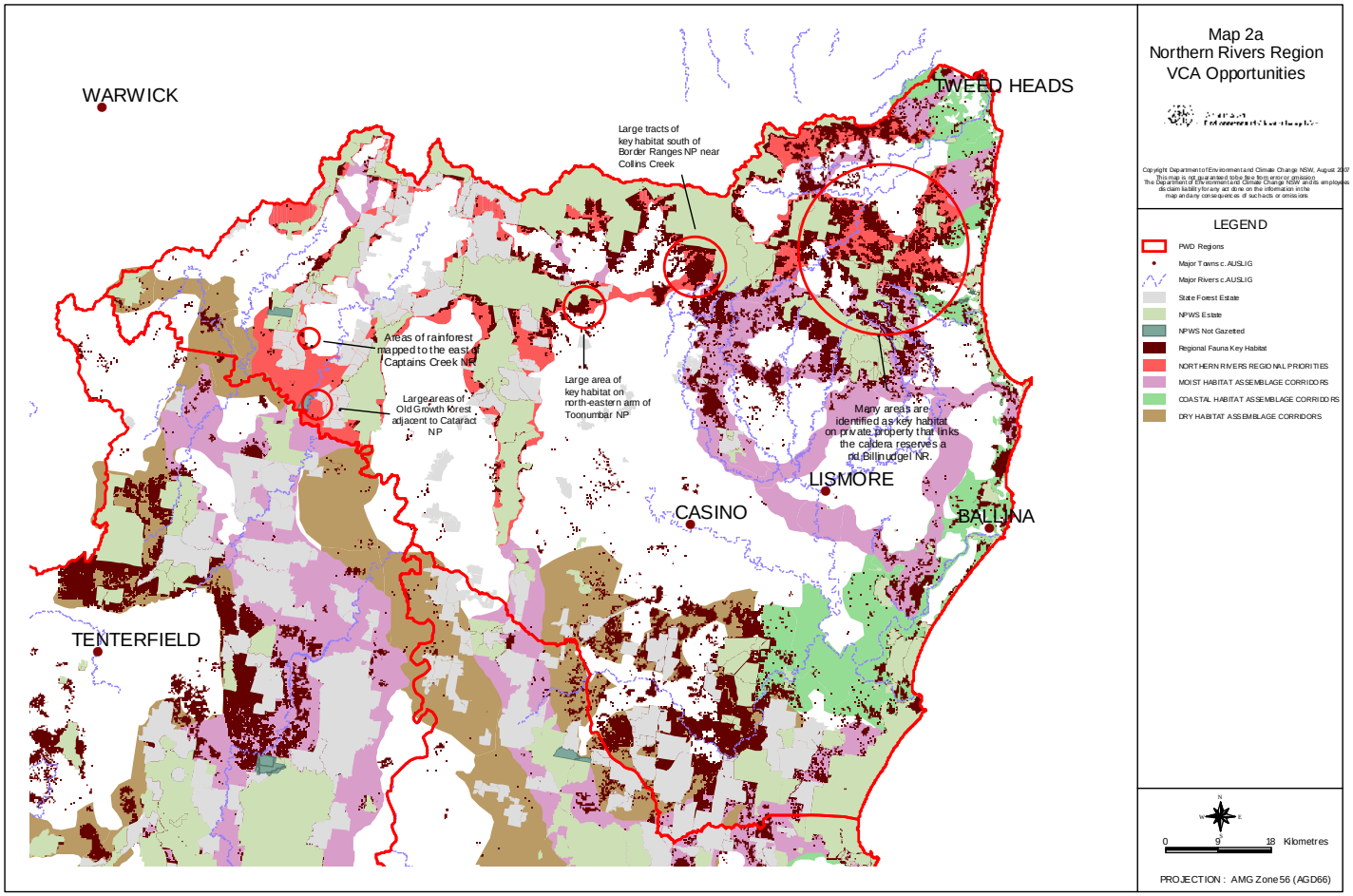
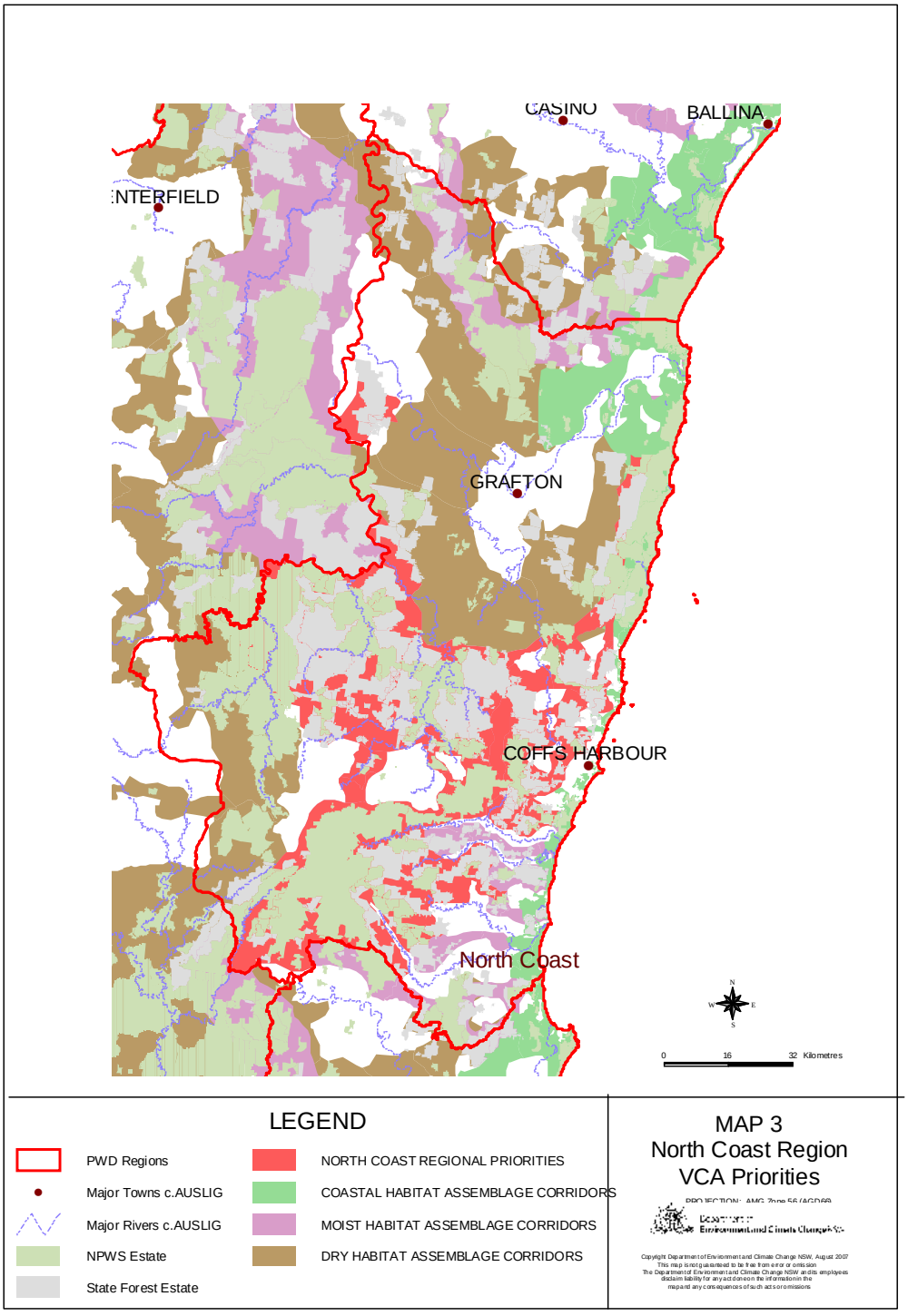
LEGEND
PWD Regions
Major Towns c.AUSLIG
Major Rivers c.AUSLIG
NPWS Estate
State Forest Estate
NORTH COAST REGIONAL PRIORITIES
COASTAL HABITAT ASSEMBLAGE CORRIDORS
MOIST HABITAT ASSEMBLAGE CORRIDORS
DRY HABITAT ASSEMBLAGE CORRIDORS
N
W
E
S
0
9
18
Kilometres
PROJECTION : AMG Zone 56 (AGD66)


WARWICK
TWEED HEADS
Large tracts of key habitat south of Border Ranges NP near Collins Creek
Areas of rainforest mapped to the east of Captains Creek NP
Large areas of Old Growth forest adjacent to Cataract NP
Large area of key habitat on north-eastern arm of Toonumbar NP
Many areas are identified as key habitat on private property that links the caldera reserves a nd Billinudgel NR.
LISMORE
CASINO
BALLINA
TENTERFIELD
Map 2a
Northern Rivers Region
VCA Opportunities
LEGEND
PWD Regions
Major Towns c.AUSLIG
Major Rivers c.AUSLIG
State Forest Estate
NPWS Estate
NPWS Not Gazetted
Regional Fauna Key Habitat
NORTHERN RIVERS REGIONAL PRIORITIES
MOIST HABITAT ASSEMBLAGE CORRIDORS
COASTAL HABITAT ASSEMBLAGE CORRIDORS
DRY HABITAT ASSEMBLAGE CORRIDORS
0
9
18
Kilometres
PROJECTION : AMG Zone 56 (AGD66)


CASINO
BALLINA
NTERFIELD
GRAFTON
COFFS HARBOUR
North Coast
N
W
E
S
0
16
32 Kilometres
LEGEND
PWD Regions
Major Towns c.AUSLIG
Major Rivers c.AUSLIG
NPWS Estate
State Forest Estate
NORTH COAST REGIONAL PRIORITIES
COASTAL HABITAT ASSEMBLAGE CORRIDORS
MOIST HABITAT ASSEMBLAGE CORRIDORS
DRY HABITAT ASSEMBLAGE CORRIDORS
MAP 3
North Coast Region
VCA Priorities
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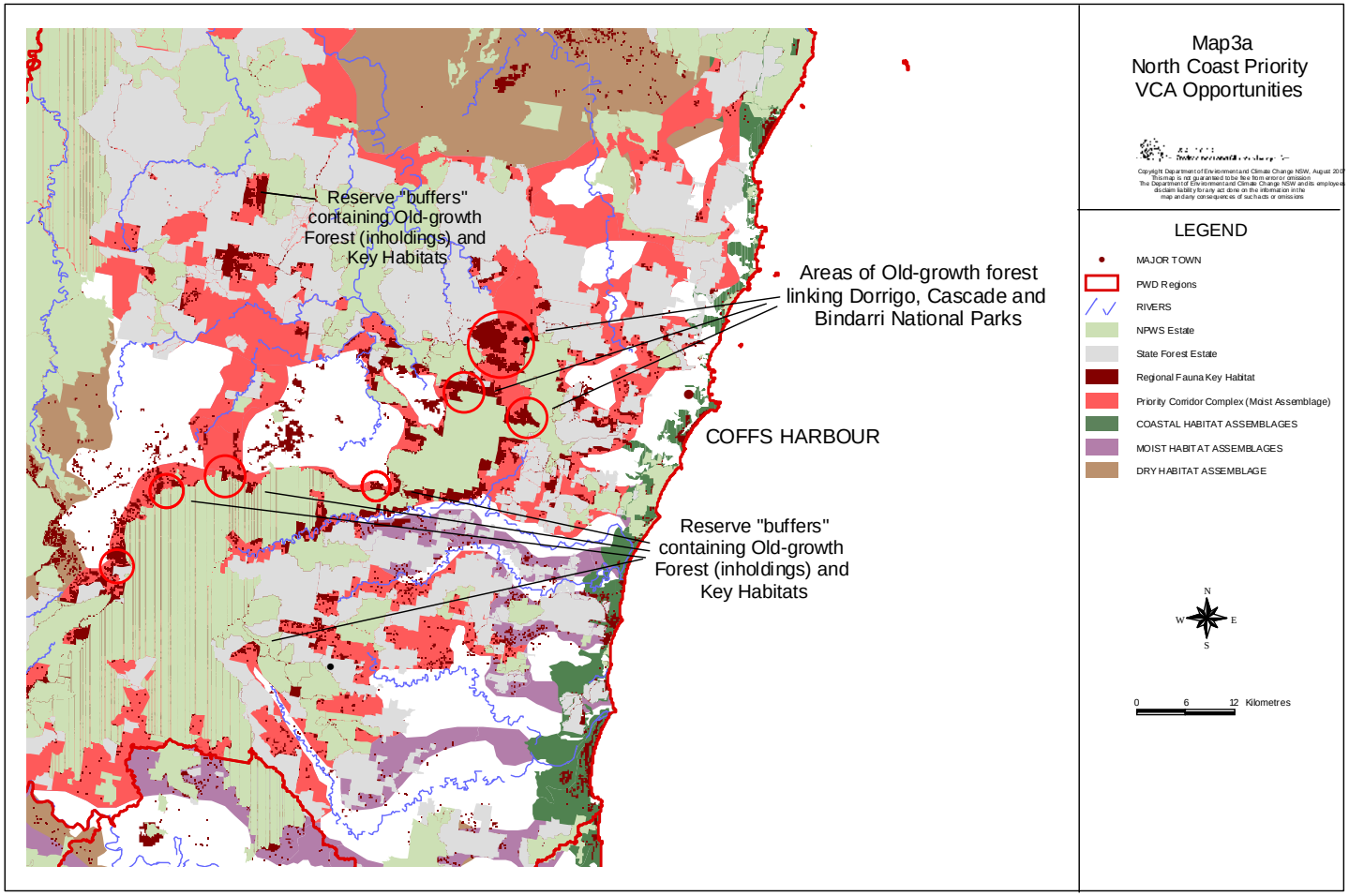
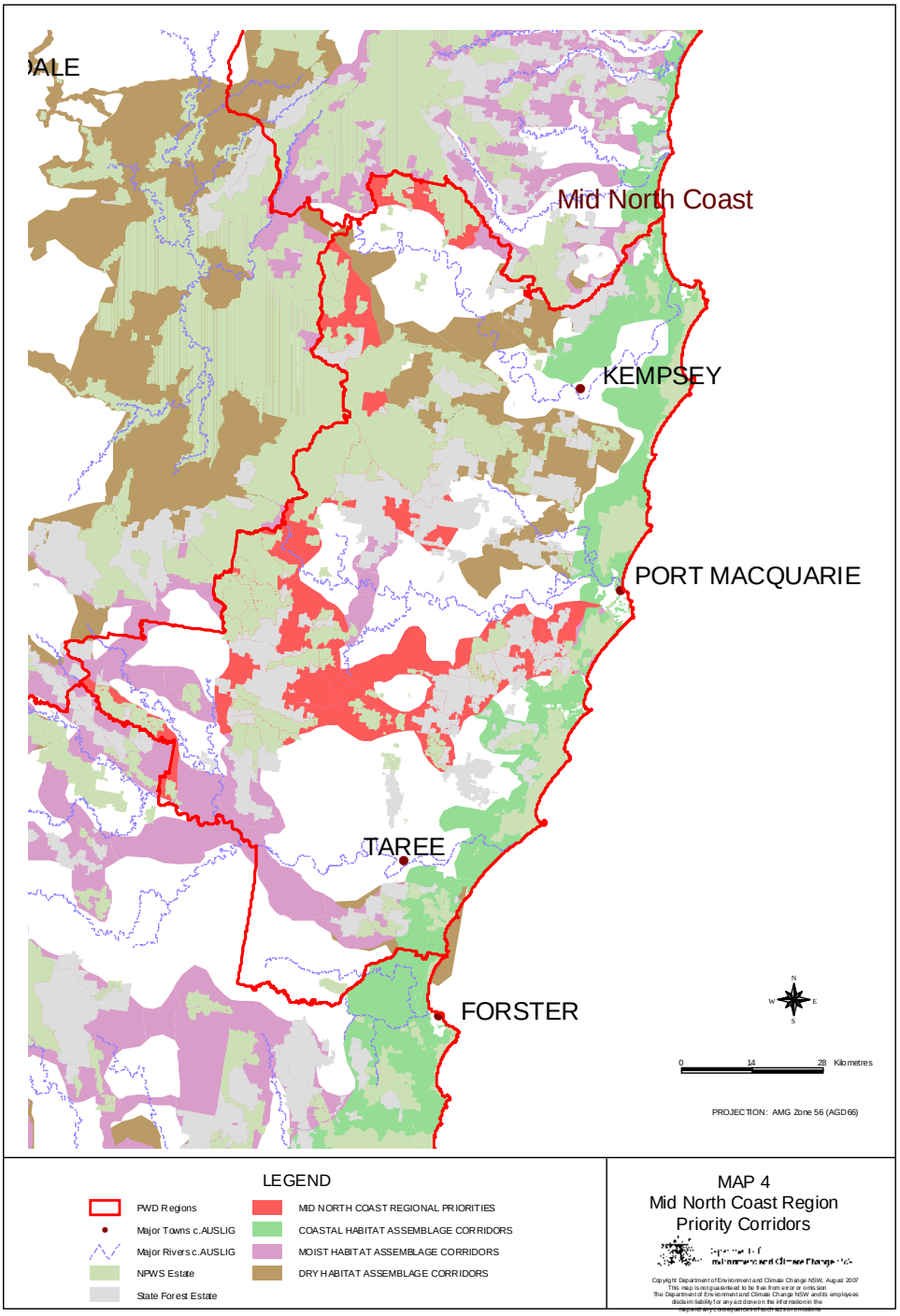
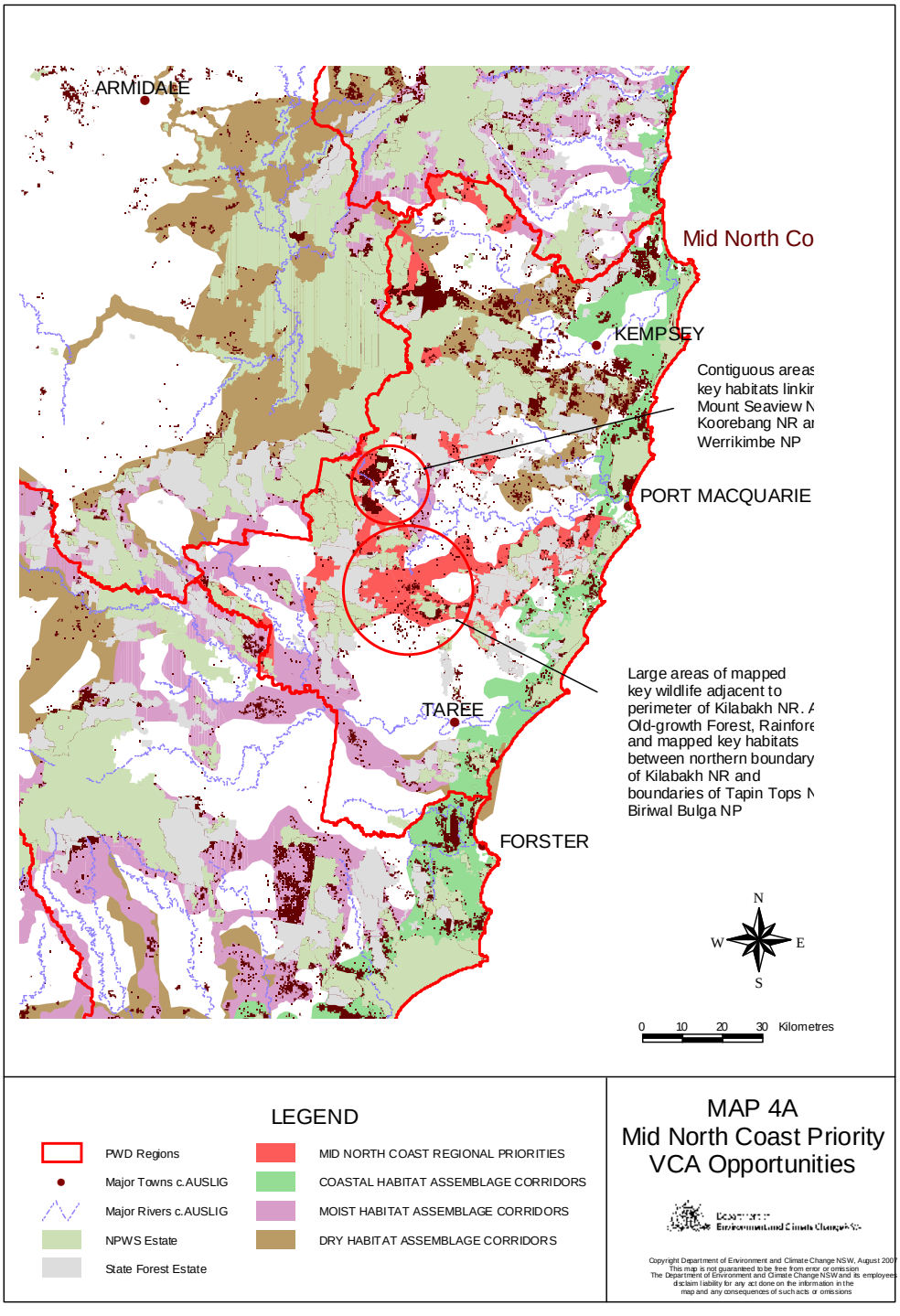

Reserve "buffers" containing Old-growth Forest (inholdings) and Key Habitats
Areas of Old-growth forest linking Dorrigo, Cascade and Bindarri National Parks
COFFS HARBOUR
Reserve "buffers" containing Old-growth Forest (inholdings) and Key Habitats
Map3a
North Coast Priority VCA Opportunities
LEGEND
MAJOR TOWN
PWD Regions
RIVERS
NPWS Estate
State Forest Estate
Regional Fauna Key Habitat
Priority Corridor Complex (Moist Assemblage)
COASTAL HABITAT ASSEMBLAGES
MOIST HABITAT ASSEMBLAGES
DRY HABITAT ASSEMBLAGE
N
W
E
S
0
6
12
Kilometres


)ALE
Mid North Coast
KEMPSEY
PORT MACQUARIE
TAREE
FORSTER
N
W
E
S
0
14
28
Kilometres
PROJECTION: AMG Zone 56 (AGD66)
LEGEND
PWD Regions
Major Towns c.AUSLIG
Major Rivers c.AUSLIG
NPWS Estate
State Forest Estate
MID NORTH COAST REGIONAL PRIORITIES
COASTAL HABITAT ASSEMBLAGE CORRIDORS
MOIST HABITAT ASSEMBLAGE CORRIDORS
DRY HABITAT ASSEMBLAGE CORRIDORS
MAP 4
Mid North Coast Region
Priority Corridors


ARMIDALE
Mid North Co
KEMPSEY
Contiguous areas
key habitats linkir
Mount Seaview N
Koorebang NR ar
Werrikimbe NP
PORT MACQUARIE
Large areas of mapped
key wildlife adjacent to
perimeter of Kilabakh NR. A
Old-growth Forest, Rainfore
and mapped key habitats
between northern boundary
of Kilabakh NR and
boundaries of Tapin Tops N
Biriwal Bulga NP
TAREE
FORSTER
N
W
E
S
0 10 20 30 Kilometres
LEGEND
PWD Regions
Major Towns c.AUSLIG
Major Rivers c.AUSLIG
NPWS Estate
State Forest Estate
MID NORTH COAST REGIONAL PRIORITIES
COASTAL HABITAT ASSEMBLAGE CORRIDORS
MOIST HABITAT ASSEMBLAGE CORRIDORS
DRY HABITAT ASSEMBLAGE CORRIDORS
MAP 4A
Mid North Coast Priority
VCA Opportunities
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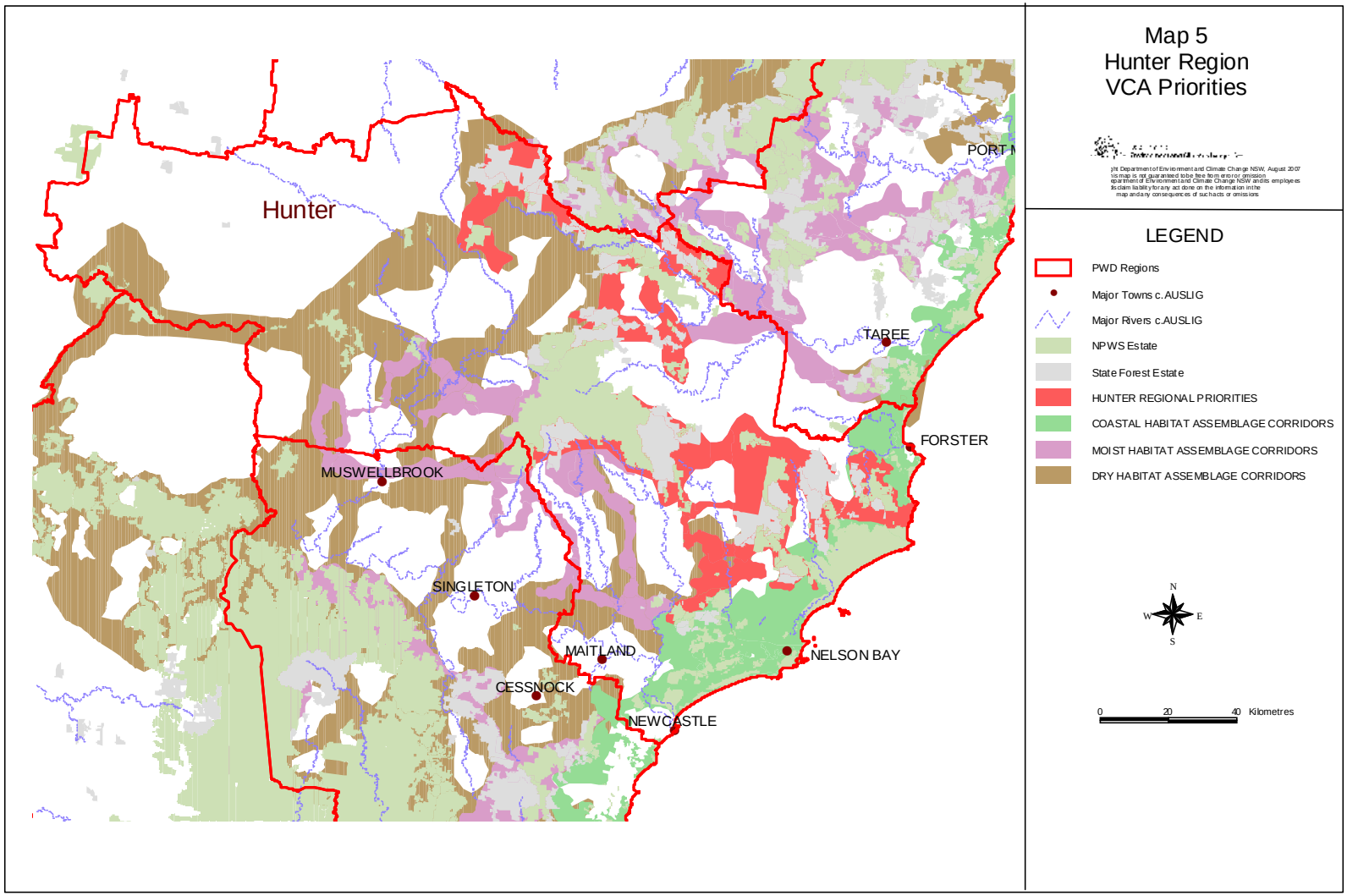
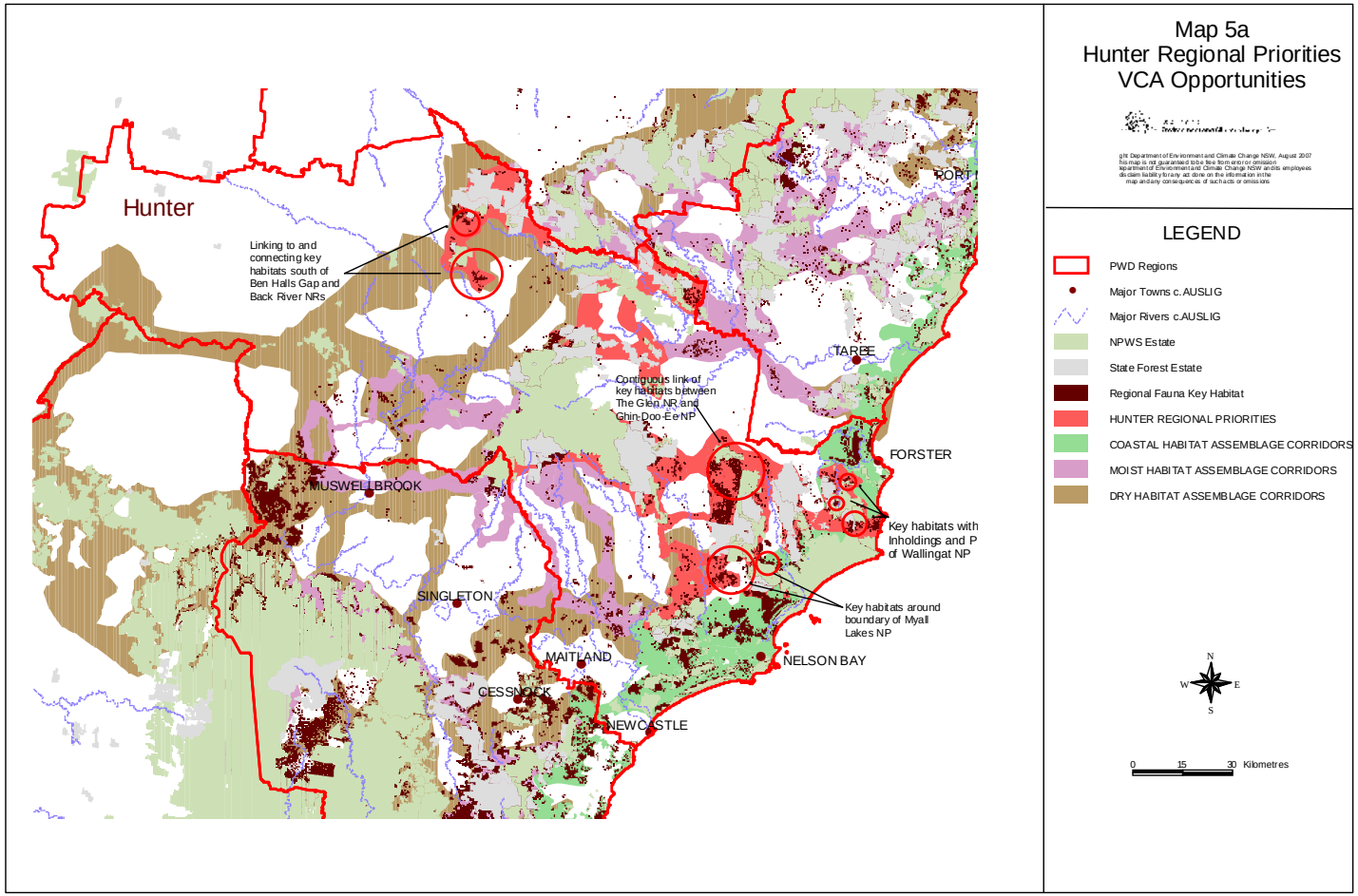
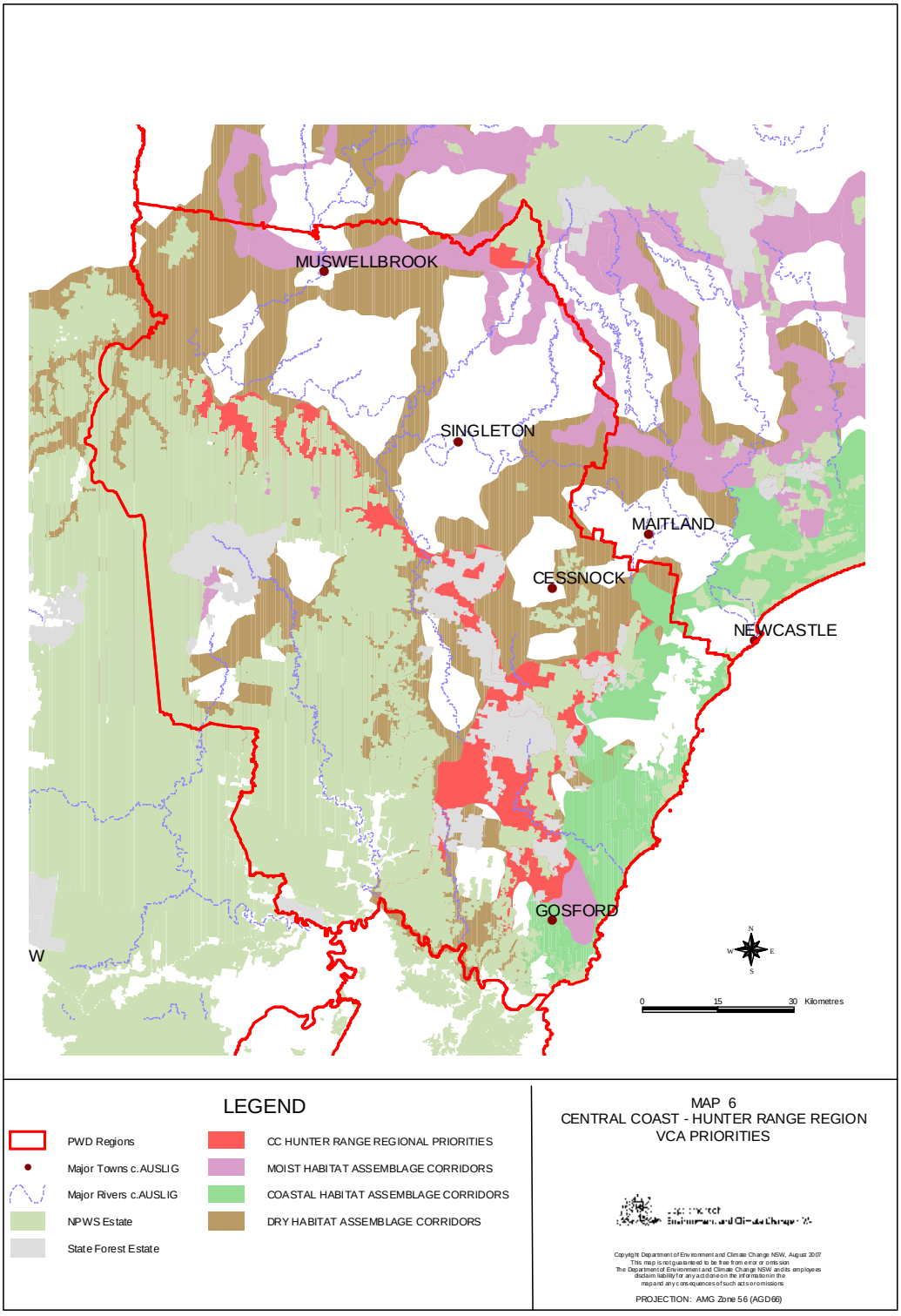

Hunter
PORT M
TAREE
FORSTER
MUSWELLBROOK
SINGLETON
MAITLAND
NELSON BAY
CESSNOCK
NEWCASTLE
Map 5
Hunter Region
VCA Priorities
LEGEND
PWD Regions
Major Towns c.AUSLIG
Major Rivers c.AUSLIG
NPWS Estate
State Forest Estate
HUNTER REGIONAL PRIORITIES
COASTAL HABITAT ASSEMBLAGE CORRIDORS
MOIST HABITAT ASSEMBLAGE CORRIDORS
DRY HABITAT ASSEMBLAGE CORRIDORS
N
W
E
S
0
20
40
Kilometres


Hunter
Linking to and connecting key habitats south of Ben Halls Gap and Back River NRs
Contiguous link of key habitats between The Glen NR and Ghin-Doo-Ee NP
Key habitats with Inholdings and P of Wallingat NP
Key habitats around boundary of Myall Lakes NP
PORT
TAREE
FORSTER
MUSWELLBROOK
SINGLETON
MAITLAND
CESSNOCK
NEWCASTLE
NELSON BAY
Map 5a
Hunter Regional Priorities
VCA Opportunities
LEGEND
PWD Regions
Major Towns c.AUSLIG
Major Rivers c.AUSLIG
NPWS Estate
State Forest Estate
Regional Fauna Key Habitat
HUNTER REGIONAL PRIORITIES
COASTAL HABITAT ASSEMBLAGE CORRIDORS
MOIST HABITAT ASSEMBLAGE CORRIDORS
DRY HABITAT ASSEMBLAGE CORRIDORS
N
W
E
S
0
15
30
Kilometres

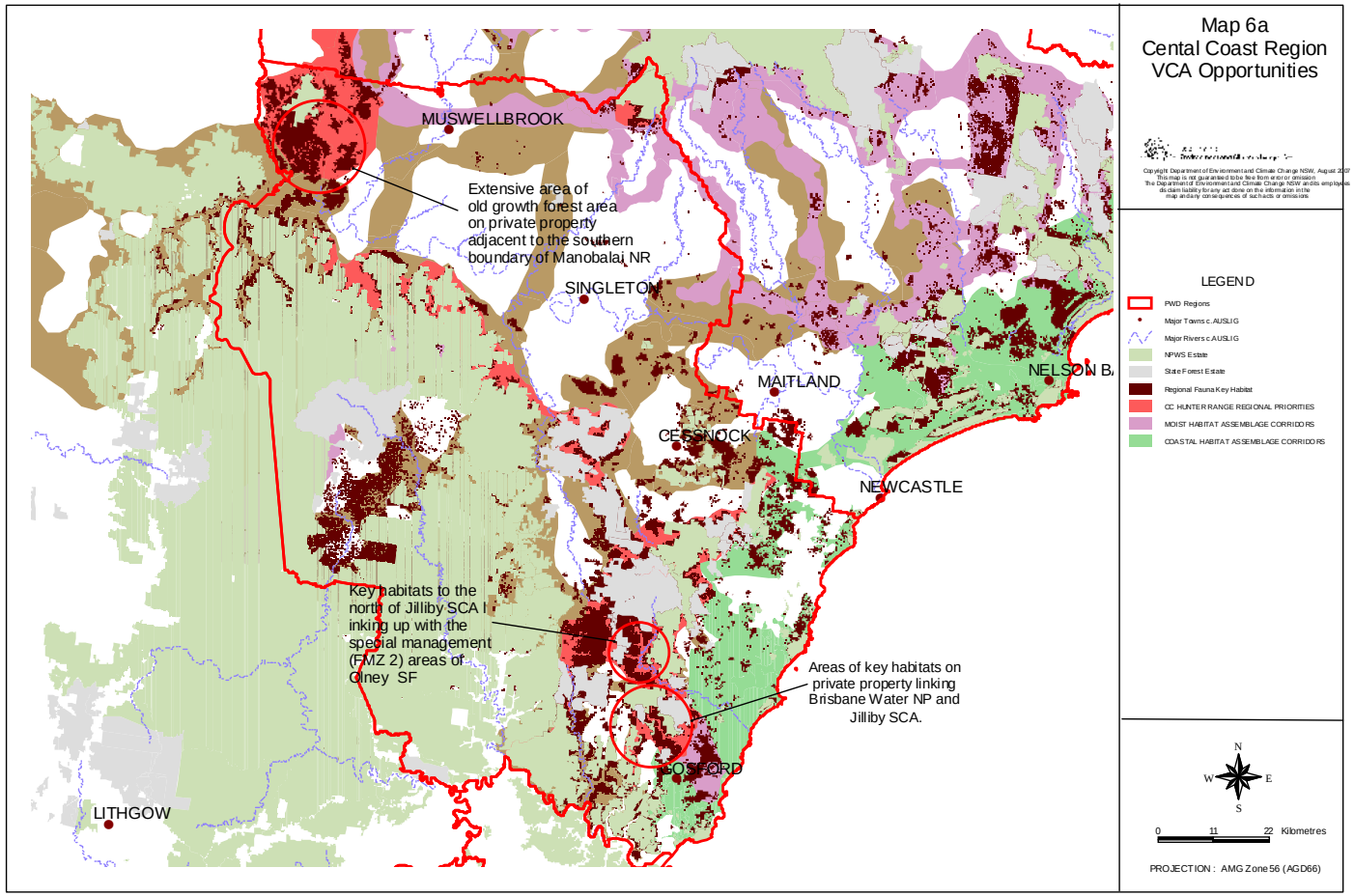


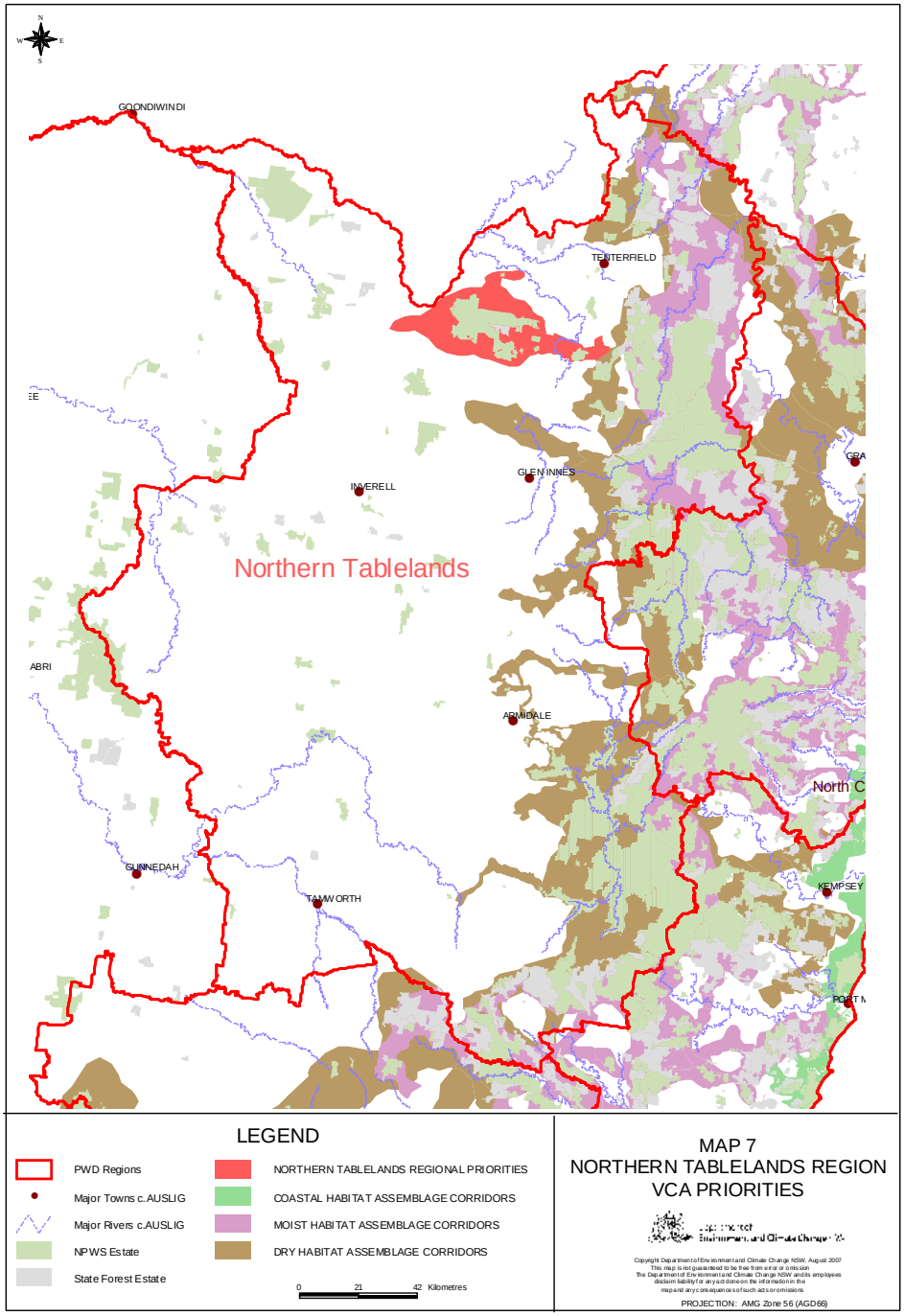
LEGEND

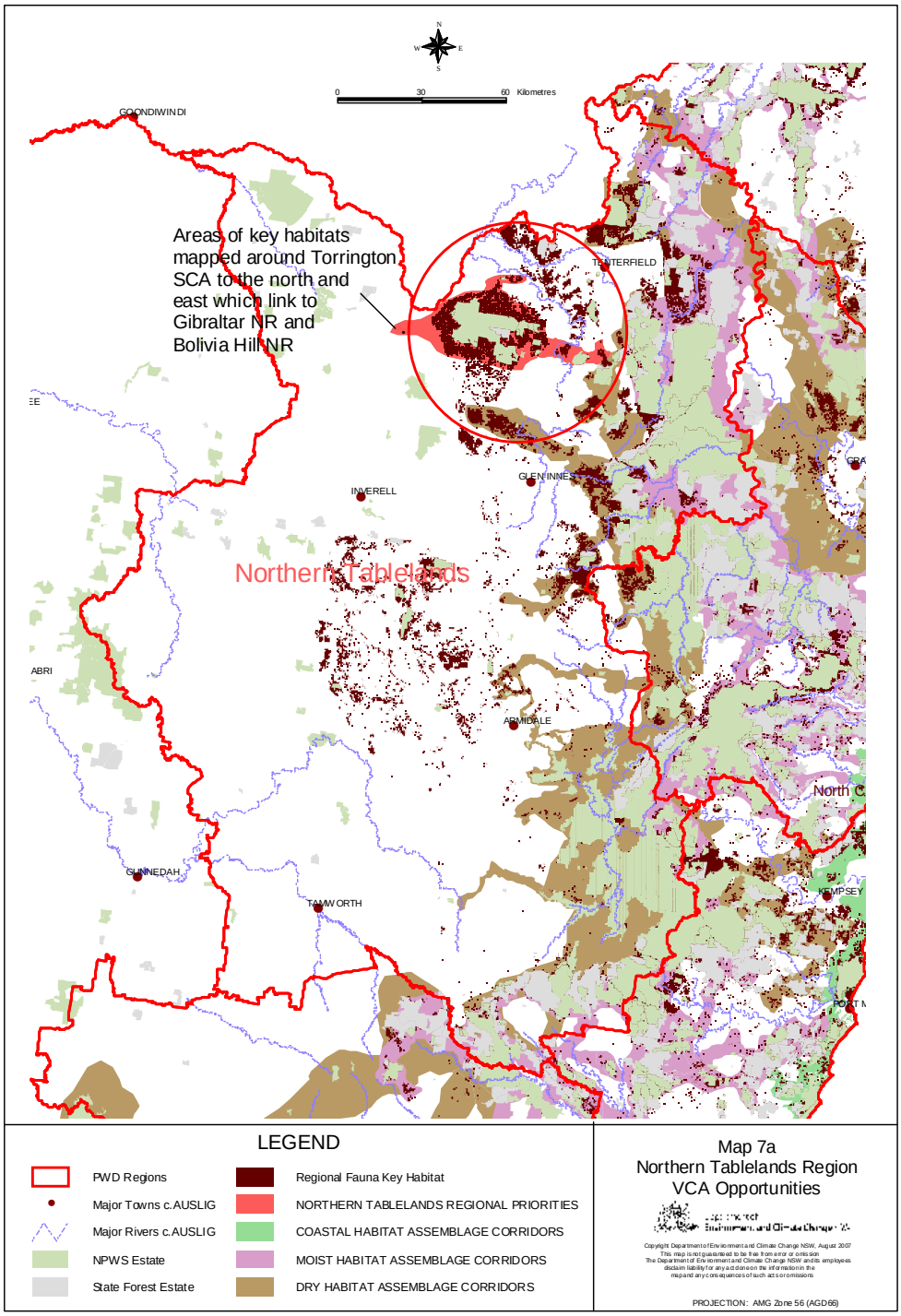
- PWD Regions
- Major Towns c.AUSLIG
- Major Rivers c.AUSLIG
- NPWS Estate
- State Forest Estate
- CC HUNTER RANGE REGIONAL PRIORITIES
- MOIST HABITAT ASSEMBLAGE CORRIDORS
- COASTAL HABITAT ASSEMBLAGE CORRIDORS
- DRY HABITAT ASSEMBLAGE CORRIDORS

MAP 6
CENTRAL COAST - HUNTER RANGE REGION
VCA PRIORITIES

PROJECTION: AMG Zone 56 (AGD66)


Map 6a
Cental Coast Region
VCA Opportunities
MUSWELLBROOK
Extensive area of old growth forest area on private property adjacent to the southern boundary of Manobalai NR
SINGLETON
MAITLAND
NELSON B
CESSNOCK
NEWCASTLE
Key habitats to the north of Jilliby SCA l inking up with the special management (FMZ 2) areas of Olney SF
Areas of key habitats on private property linking Brisbane Water NP and Jilliby SCA.
GOSFORD
LITHGOW
LEGEND
PWD Regions
Major Towns c.AUSLIG
Major Rivers c.AUSLIG
NPWS Estate
State Forest Estate
Regional Fauna Key Habitat
CC HUNTER RANGE REGIONAL PRIORITIES
MOIST HABITAT ASSEMBLAGE CORRIDORS
COASTAL HABITAT ASSEMBLAGE CORRIDORS
N
W
E
S
0
11
22
Kilometres
PROJECTION : AMG Zone 56 (AGD66)


GOONDIWINDI
TENTERFIELD
INVERELL
GLEN INNES
Northern Tablelands
ARMIDALE
GUNNEDAH
TAMWORTH
KEMPSEY
North C
LEGEND
PWD Regions
Major Towns c.AUSLIG
Major Rivers c.AUSLIG
NPWS Estate
State Forest Estate
NORTHERN TABLELANDS REGIONAL PRIORITIES
COASTAL HABITAT ASSEMBLAGE CORRIDORS
MOIST HABITAT ASSEMBLAGE CORRIDORS
DRY HABITAT ASSEMBLAGE CORRIDORS
0 21 42 Kilometres
MAP 7
NORTHERN TABLELANDS REGION
VCA PRIORITIES
PROJECTION: AMG Zone 56 (AGD66)


N
W
E
S
0
30
60 Kilometres
GOONDIWINDI
Areas of key habitats mapped around Torrington SCA to the north and east which link to Gibraltar NR and Bolivia Hill NR
TENTERFIELD
GLEN INNES
INVERELL
Northern Tablelands
ABRI
ARMIDALE
North C
GUNNEDAH
TAMWORTH
KEMPSEY
LEGEND
PWD Regions
Major Towns c.AUSLIG
Major Rivers c.AUSLIG
NPWS Estate
State Forest Estate
Regional Fauna Key Habitat
NORTHERN TABLELANDS REGIONAL PRIORITIES
COASTAL HABITAT ASSEMBLAGE CORRIDORS
MOIST HABITAT ASSEMBLAGE CORRIDORS
DRY HABITAT ASSEMBLAGE CORRIDORS
Map 7a
Northern Tablelands Region
VCA Opportunities
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PROJECTION: AMG Zone 56 (AGD66)