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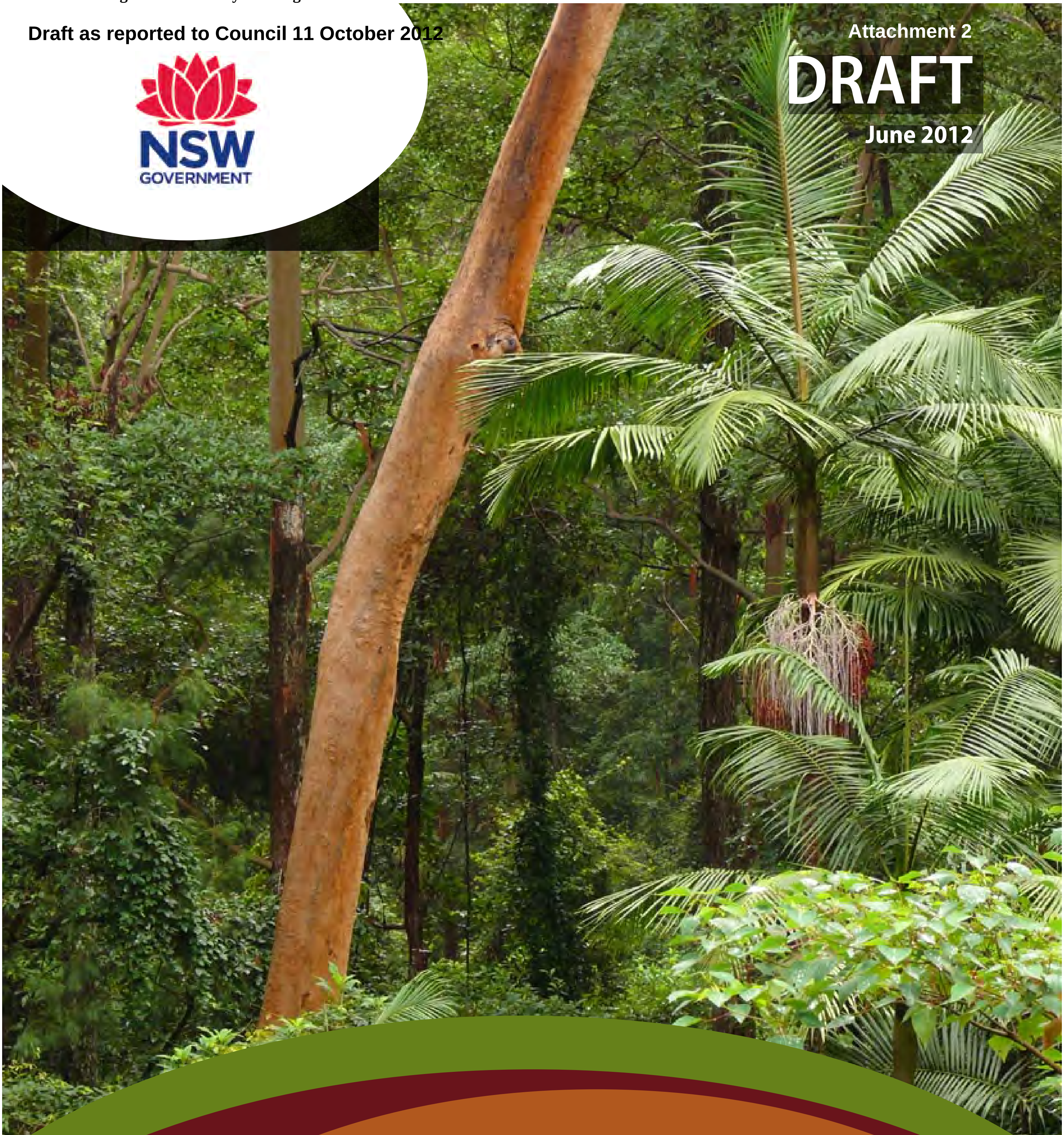

Development of a Fine-scale Vegetation Map for the Coffs Harbour Local Government Area

VOLUME 1: PROJECT REPORT

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Credits and Acknowledgements

This project was funded by the Coffs Harbour City Council, with financial assistance from the Northern Rivers Catchment Management Authority and the National Parks and Wildlife Service.

The vegetation classification and mapping project involved many people with varied and specialised skills. The Office of Environment and Heritage (OEH) would like to acknowledge the main contributors to this project.

OEH would like to acknowledge the contribution of Ernst Kemmerer (OEH) and Nigel Cotsell (Coffs Harbour City Council [CHCC]) for co-ordinating the project. The main report was prepared by Ernst Kemmerer with the assistance of Paul Sheringham, and Paul Houlder. The technical expertise of OEH staff in compiling the Vegetation Community Profiles in Volume 2 (summary) of the report and provision of the maps, figures and tables for the report is acknowledged.

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List of abbreviations

2D	two-dimensional
3D	three-dimensional
ADS40	airborne digital sensor (Leica Geosystems)
API	aerial photograph interpretation
CMA	Catchment Management Authority
EEC	endangered ecological community
LPMA	Land and Property Management Authority
LGA	local government area
LiDAR	light detecting and ranging
NPWS	NSW National Parks and Wildlife Service (which now falls within Office of Environment and Heritage)
NSW	New South Wales
OEH	Office of Environment and Heritage
PATN	pattern analysis software
ROTAP	Rare or Threatened Australian Plant
SEPP	State Environmental Planning policy
UPGMA	unweighted pair-group arithmetic averaging
YETI	flora database held by OEH

Summary

A vegetation survey and mapping program was conducted for the Coffs Harbour City Council Local Government Area (Coffs Harbour LGA) using high resolution digital imagery. The main purposes of the program were to produce a fine-scale 'Class 5' vegetation map suitable for Council's planning and project requirements, and to develop a survey and mapping methodology that could be more widely used by other local governments across coastal New South Wales.

The current native vegetation map used by Council is dated and requires upgrading to show current vegetation extant and landuses. This study sought to prepare a fine-scale vegetation map and provide up-to-date information on the type and extent of vegetation in the Coffs Harbour LGA (the study area).

The study was carried out in four main stages:

- trial and select methods to map land cover and vegetation community boundaries
- map broad land cover
- develop a vegetation community classification for Coffs Harbour LGA
- map vegetation communities.

A number of techniques were trialled to determine the most efficient process for preparing the vegetation map. It was concluded that conventional aerial photography interpretation resulted in the most accurate linework and method for attributing vegetation communities. A total of 79 different vegetation communities were classified in the study area.

Land cover was divided into 13 types, including the following cover classes and features: extant vegetation cover, cleared, horticulture/cropping, plantations, remnant trees, water bodies, estuaries and beaches. Over 88 000 hectares of extant vegetation in the Coffs Harbour LGA were mapped at 1:5000 scale using API. During the API work the vegetation patterns were mapped and polygons attributed using the codes supplied for the 79 vegetation communities.

The classification and mapping program was supported by 3475 survey sites. Data from 534 full floristic flora survey sites were used for the vegetation community classification analysis. Information on dominant plant species only was gathered at 462 rapid data sites for interpolation and mapping purposes, and 2479 API survey sites were visited to ground truth the API work. To achieve an unbiased survey effort across all tenures, private landowners were invited to voluntarily have flora surveys conducted on their land. This resulted in a sampling rate of approximately one site per 90 hectares on Crown lands and freehold lands.

Surveys conducted during this study, combined with previous work, have identified 53 significant plants and 10 endangered ecological communities within the LGA. The endangered communities are likely to occur within 24 different vegetation communities mapped in this study, and potentially cover up to 10 000 hectares in the LGA.

The new Coffs Harbour Class 5 vegetation map will underpin a range of environmental planning and vegetation management programs. The vegetation map is suitable for use at the 1:5000 scale and will support environmental planning at the whole-of-LGA level. The map may not be suitable for individual property or development plans where further flora and fauna surveys may be required to meet the requirements of the *Threatened Species Conservation Act 1995*. However, the mapping will have direct influence on the following Council strategies, planning instruments and guidelines:

- Coffs Harbour Koala Plan of Management
- Open Space Strategy

- Draft Biodiversity Action Strategy and biodiversity guidelines
- State of the Environment reporting
- Draft Coffs Harbour Local Environmental Plan 2012
- Draft Development Control Plan.

The development of the Class 5 vegetation map has been a multi-agency initiative supported by Coffs Harbour City Council, the Office of Environment Heritage and the Northern Rivers Catchment Management Authority. It is anticipated that the fine-scale vegetation map will be adopted by a range of end-users and natural resource managers.

1. Introduction

Vegetation type and vegetation condition are widely used in combination as a surrogate for biodiversity. As such, maps of vegetation type and condition form the basis of most conservation management plans and environmental planning instruments. While vegetation mapping needs may vary between government agencies, a common theme is the need for complete and consistent maps of the area of interest.

Coffs Harbour City Council ('Council') is currently using a composite vegetation map derived from a variety of sources. The primary sources are Forest Type Mapping (Forestry Commission of NSW 1989), forest ecosystem models, vegetation type mapping by Fisher et al. (1996) — with supplementary aerial photograph interpretation (API) work by Kendall (2005) — and modelling interpretation work by Eco Logical Australia (2005).

This composite vegetation map has limitations because the various map sections use different classifications systems and map scales, resulting in edge mismatches between sections. A contiguous vegetation map and classification is therefore required to overcome these issues and provide a common reference for future environmental planning and management in the Coffs Harbour City Council Local Government Area ('Coffs Harbour LGA'). For example, Council recently released a draft of its 'Biodiversity Action Strategy' (CHCC 2012) which sets the agenda and direction for biodiversity conservation planning and management throughout the Coffs Harbour LGA from 2012 to 2030 and beyond.

The development of a contiguous, fine-scale vegetation map is fundamental to a number of major programs within the Strategy, particularly for LGA-wide assessment programs such as:

- mapping Koala habitat (to contribute to the development of Council's Koala Plan of Management)
- identifying and mapping high value habitats, including endangered ecological communities (including SEPP26 areas), over-cleared vegetation communities, significant wetlands (including SEPP14), estuaries and riparian zones
- identifying and mapping threatened and significant fauna habitat
- identifying landscape connections.

These programs will ultimately contribute to Council's strategic and operational planning, including the Local Environment Plan (2012) and associated Development Control Plan. Figure A5.1 (page 26) from the draft 'Biodiversity Action Strategy' (CHCC 2012) illustrates the role of the vegetation mapping in Council's planning framework and has been included here in Appendix 1.

The National Parks and Wildlife Service (NPWS) also requires a consistent, up-to-date vegetation map of the entire Coffs Coast Regional Park, an area which is jointly managed by Council and NPWS. A contiguous, fine-scale vegetation map will support improved flora, fauna and fire management of the coastal vegetation and identify potential impacts as well as opportunities for tourism in the region. The Environment Protection Authority and Northern Rivers Catchment Management Authority (CMA) also have a vested interest in improving vegetation information to support the regulation, management, conservation and rehabilitation of vegetation.

In addition, the Office of Environment and Heritage (OEH) has been seeking to improve vegetation mapping products across New South Wales and take advantage of the opportunities for fine-scale mapping presented by the airborne digital sensor (ADS40) data captured by Land and Property Information since 2007 (Taunton 2010). The ADS40 is a high resolution, airborne digital camera that captures fine-scale, multi-spectral photography that is able to be viewed in three dimensions. Council also acquired light imaging detecting and radar (LiDAR) data for the LGA in 2005. LiDAR data produces high resolution models, including digital terrain (or ground) models, and surface models (i.e. above ground) with vertical accuracies of ±15 centimetres.

This new imagery provides an opportunity to research and develop methods to provide an integrated vegetation map for coastal New South Wales using the best available technology and data. A multi-agency vegetation mapping program was therefore initiated in 2010. The aim of the program is to develop a fine-scale vegetation map to support the requirements of the various government agencies by using the latest digital products. The project aims to explore various approaches to digital API and map production in order to recommend a model or methodology to guide future vegetation mapping projects of this nature and at this scale of resolution.

The fine-scale mapping project for the Coffs Harbour LGA is presented in two separate volumes: Volume 1 (this volume) – Project Report, and Volume 2 – Vegetation Community Profiles (summary).

1.1 Objectives of the study

The objectives of this study are to:

- produce contiguous map products at the 1:5000 scale for the Coffs Harbour LGA
- produce a land cover map for Coffs Harbour LGA
- develop a vegetation community classification for Coffs Harbour LGA
- develop a fine-scale map of vegetation communities in the Coffs Harbour LGA
- research and develop current technologies and test several approaches to fine-scale mapping

1.2 Study area

The Coffs Harbour LGA covers 117,300 hectares and is one of the few areas of coastal New South Wales where the high elevation landscapes of the Great Dividing Range are within close proximity to the coast. The diversity and extremes in landforms across the study area have produced a range of varied habitats containing a high diversity of flora and fauna. The area is within the New South Wales North Coast Bioregion and the majority of the area is within the Coffs Coast and Escarpment Subregion (Thackway & Cresswell 1995).

The overall study area can be seen as consisting of three predominant topographical landscapes: coastal plains, midland hills and escarpment ranges (see Figure 1 and Table 1).

Table 1 Landscapes of the Coffs Harbour LGA

Landscape	Area (ha)	Area (%)
Coastal plains	32 150	27
Midland hills	47 500	41
Escarpment ranges	37 650	32
Total	**117 300**	**100**

Of these three landscapes, the coastal plains landscape is home to the majority of the LGA's human population and contains the least vegetated land. Conversely the midland hills, and to a greater extent the escarpment ranges, support a much lower density of population per square kilometre because most of these areas are rural or village living. Accordingly, these landscapes — particularly the escarpment ranges — contain the highest amount of vegetated land within the study area. Major land uses in the LGA vary across the three landscapes. The coastal plains are dominated by urban and rural residential areas, with limited areas of horticulture, grazing and cropping. The midland hills and escarpment ranges are mostly rural, with some grazing and forestry, and limited areas of horticulture (primarily bananas and blueberries).

Figure 1 The study area and landscapes of Coffs Harbour LGA

1.3 Landforms

The coastal plain is a low relief landscape with little variation in altitude. It gradually rises from sea level along the shoreline to around 50 metres elevation where it transforms into the midland hills landscape, usually within 10 kilometres of the coast. Slopes are predominantly flat to gentle (0–5°) though some small hills with steeper slopes are found in this landscape. The coastline is approximately 80 kilometres in length and features a series of prominent rocky headlands and beaches.

The coastal plains landform may be divided into the Barcoongere Low Hills and Gleniffer Bonville Hills regions described by Milford (1999). These are characterised by low relief, undulating to rolling foothills and creeklines draining the coast range. Milford (1999) also names the Coffs Harbour Coast region as a landform and this contains the unconsolidated alluvial, estuarine and coastal barrier sediments.

The midland hills landscape is a moderately undulating landform and encompasses the foothills and low ranges between the coastal plains and the escarpment ranges. The western boundary roughly corresponds to the 250 metre elevation contour. Land along major river valleys is relatively flat, with associated slopes being predominantly slight to moderately steep (1–20°), though very occasional steep slopes (>40°) also occur. This landscape includes some geographic features associated with the coastal ranges, including sandstone escarpments in the north-west, and valleys, creeks and rivers draining northwards to the Clarence River.

The midland hills landscape can be further subdivided into the distinctive sandstone landforms of the Kremnos Plateau, and the steep metasedimentary and sedimentary hills of the Coast Range physiographic region. Milford (1999) also recognised the Orara, Corindi and Bellingen River Valley physiographic regions, which cross all three broad landscape classes. These regions encompass flat to gently undulating floodplains, channels and swamps. The Orara River Valley drains a large proportion of the catchment of the study area.

The escarpment ranges landscapes includes the steep hills of the Dorrigo and Orara escarpment regions as well as the flatter, more undulating terrain of the eastern Dorrigo Plateau and Bobo River Valley. The escarpment ranges extend from around the 250 metre contour in the west of the study area rising steeply to high points such as Mount Wondurrigah (820 m) and Mount Moombil (1042 m) in the south. Slopes are predominantly moderately steep to very steep (16–49°) with small areas of precipitous slopes along some cliffs associated with gorges. Some of the major gorges and canyons in this area include Wayper Creek, Shingleback Creek, Bangalore Creek, Little Nymbioda River and Urumbillum Creek.

On the elevated western fall of the escarpment range there is a combination of large and relatively flat plateaus, interspersed with slight to moderate slopes in the valleys which form the eastern Dorrigo Plateau landscape. The vegetation is influenced by the altitude and colder climate here, with significant areas of warm temperate and cool temperate rainforest. The southern boundary of the eastern Dorrigo Plateau and the LGA runs along the ridgeline of mountain ranges bordering the Gleniffer and Crossmaglen valleys.

1.4 Geology and geomorphology

The overall geological history of the study area is that of older and stable weathered Permian and Carboniferous clastic metasedimentary rocks overlain by more-recent sedimentary rocks formed in the Clarence–Moreton Basin. The only examples of volcanic or plutonic activity in the study area are intrusions of monzogranite at Diggers Point and Look-at-me-now Headland (Milford 1999). The geological history of the coast and floodplains is of recent deposition of Holocene and Pleistocene unconsolidated sediments. The rise in topography from east to west is due to uplift during the formation of the Great Escarpment which commenced about 80 million years ago (Oliver 1982).

Milford (1999) provides a more detailed account of the geology and describes the soil landscapes of the Coffs Harbour 1:100,000 map sheet. The Coffs Harbour LGA is located within three major geological divisions of sedimentary and metasedimentary rocks: the Clarence–Moreton Basin, Nambucca Block and Demon Block. Figure 2 shows the distribution of the major geological units across the landscape. Table 2 describes the main geological units of the Coffs Harbour area, and the corresponding age and geographic/geomorphic group to which they belong.

Table 2 Geological units of the Coffs Harbour LGA

Geological age	Geographic/geomorphic group	Geological unit
Holocene	Unconsolidated sediments	Dunes and beaches
		Saline tidal areas (estuarine plains)
		Floodplains (alluvial plains)
Pleistocene		Backbarrier sand plains and freshwater wallum swamps
Triassic/Jurassic	Clarence–Moreton Basin sediments	Kangaroo Creek Sandstones
		Corindi Conglomerates
		Walloon Coal Measures
	Un-named granite intrusion	Emerald Beach Adamellite
Permian	Nambucca Block metasediments	Bellingen Slates
Carboniferous	Demon Block metasediments	Coramba Beds
		Brooklana Beds
		Moombill Siltstones

The Demon Block contains Carboniferous metasediments of the Coffs Harbour Association. The Coffs Harbour metasediments are divided into three units (Milford 1999). The *Coramba Beds* is the most extensive and occurs across the plateau, escarpments and hills. The *Brooklana Beds* and *Moombil Siltstones* occur further south. These metasediments, derived from old marine and/or riverine sediments, mainly support wet and dry sclerophyll forests with pockets of rainforest in sheltered higher rainfall sites. More-exposed sites with shallow soils occasionally support open forest, woodland and shrubland vegetation.

The Nambucca Block is characterised by more-recent metasediments of Permian age. The main geological unit (the *Bellingen Slates*) is restricted to the southern section of the study area and these metasediment areas form fine-grained quartz soils which, combined with sheltered aspects and high rainfall, can support tall wet eucalypt forest and rainforest.

In the north–west of the study area are more recent Triassic and Jurassic sandstones and conglomerates of the Clarence–Moreton Basin. The *Kangaroo Creek Sandstones* form undulating to rolling plateaus on the Kremnos Plateau at Andersons Mountain and Dicks Knob. The sandstone environments support distinctive dry sclerophyll forest and woodlands growing in shallow high-quartz soils. *Corindi Conglomerate* outcrops occur throughout the north-west of the study area in Wedding Bells and Conglomerate state forests and generally support dry heathy and grassy dry sclerophyll forest, with wet sclerophyll elements in sheltered localities. The *Walloon Coal Measures* underlay the conglomerate geology and the generally steep and moist sheltered terrain provides habitat for tall wet sclerophyll forest and rainforest.

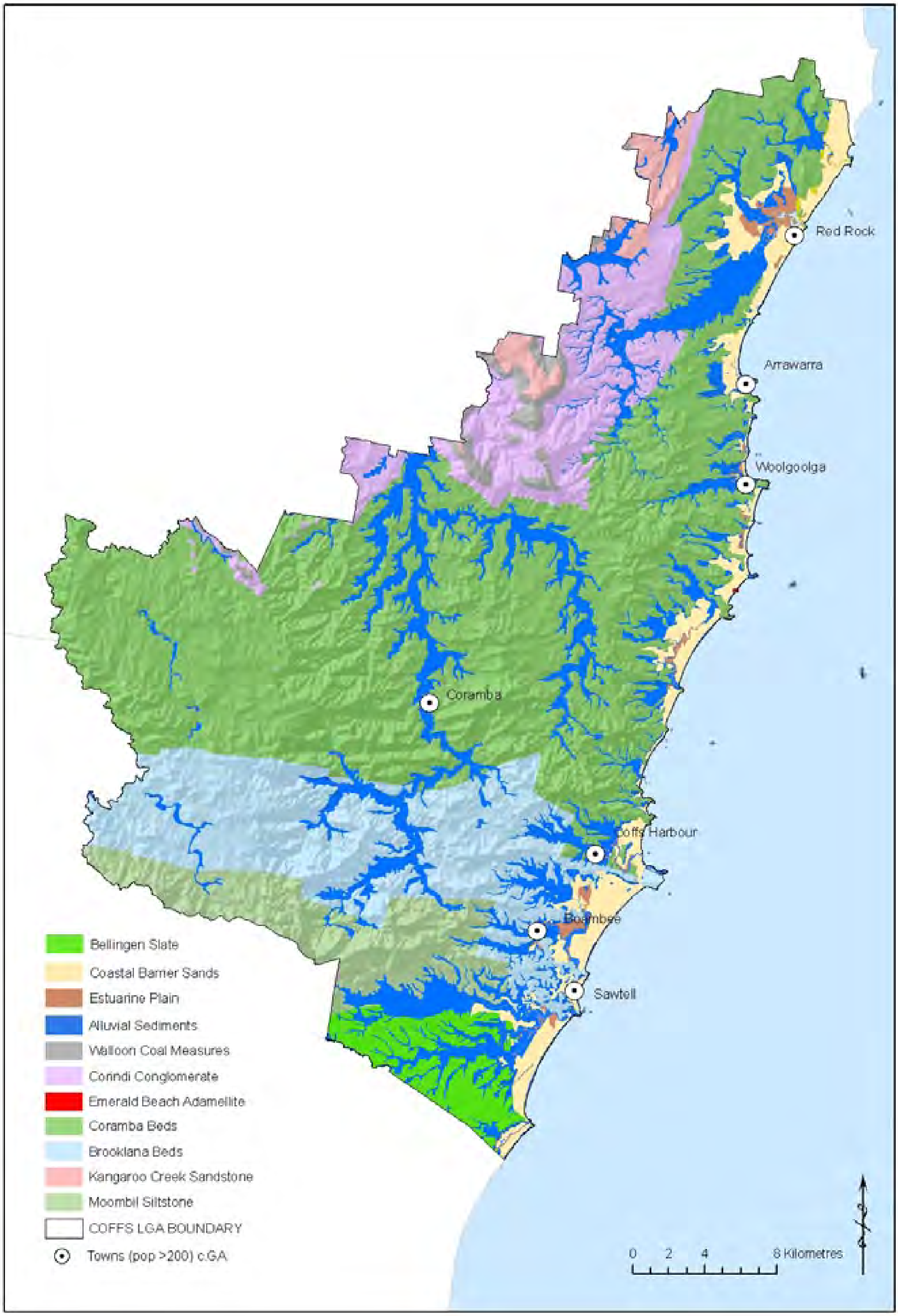

Figure 2 **Major geological units of the Coffs Harbour LGA**

A large percentage of the coastal plain is comprised of alluvial soils along major non-tidal drainage networks and valleys, and sands and muds of coastal backbarriers and estuaries. Unconsolidated alluvial sediments have been deposited in the valleys and floodplains of the Orara, Bobo and Corindi rivers and many coastal creeks. These areas support riparian forests, and forested and freshwater wetlands. Holocene estuarine sands, muds and clays have deposited in the tidally influenced main creeks and rivers of the study area. Examples include the Corindi, Pine and Boambee creek estuaries, which support areas of saltmarsh, mangrove and saline swamp forests.

Recent Holocene sand dunes have formed along the beaches. Located behind these are older, less fertile and poorly drained backbarrier sands of Pleistocene age which support wallum heathland, swamp forest/woodland, littoral rainforest, and grasslands.

1.5 Soils and soil landscapes

There are 44 soil landscapes recognised in the study area (Milford 1999). Soils have an important influence on the distribution of vegetation in the study area. Soil formation is influenced by the parent material's resistance to weathering, chemistry and mineral composition; slope and aspect; and soil moisture and permeability.

For example, the shallow coarse-grained, high-quartz soils of the *Kangaroo Creek Sandstones* support distinctive dry sclerophyll forests and woodlands with a high level of species diversity. In areas of fine-grained low-quartz metasedimentary geology, soils may vary from deep red soils in areas on sheltered slopes with high soil moisture, to shallow yellow earth on exposed slopes in drier locations. This is reflected in the distribution of tall moist forest and rainforests on the deep red soils in sheltered areas, to dry open forests on the shallow soils of exposed sites. Even the relatively infertile sandy soils of Holocene dunes may support luxuriant forms of littoral rainforest in sheltered areas.

1.6 Climate

Continental climatic patterns are controlled by the progression of high- and low-pressure systems and associated troughs across the country. Seasonal patterns of temperature and rainfall are driven by the north–south migration of high-pressure systems. The effects of tropical cyclones and landforms also have an impact on the climate of the region. Longer term trends in rainfall and temperature are influenced by the El Niño – Southern Oscillation, which determines the circulation and strength of trade winds directing moisture across eastern Australia (NRAC 1996).

In the study area, summers are generally hot and winters are moderate. The annual mean summer (February) maximum temperature for Coffs Harbour is 26.8 °C and the minimum is 19.5 °C. The annual mean winter (July) maximum and minimum temperatures at Coffs Harbour are 18.7 °C and 7.6 °C respectively (BOM 2012).

Rainfall is highest in February and March and lowest in late winter to spring, with September being the driest month. The mean annual rainfall at Coffs Harbour is 1699 mm (BOM 2012).

Topography and elevation play a significant role in the distribution of local climatic conditions across the study area — there is a clear correlation between increasing elevation and higher rainfall and lower maximum and minimum temperatures. For example, minimum winter temperatures range between 9.1 °C on the flatter, northern coastal areas and 1.8 °C on the highest parts of the escarpment ranges, while maximum summer temperatures range between 19.5 °C and 14 °C between these same locations. Annual rainfall also varies across the study area, with over 1950 mm falling on the high elevation plateaus and 1310 mm falling in the northern inland parts of the study area (some 650 mm less).

1.7 Fire history

Major fires in the Coffs Harbour LGA occurred in 1977, 1990 and 1994. Generally, similar forest types emerge after a fire, but in some cases fires can replace moist vegetation types with drier types, can convert areas of heathland to grassland, or can change the structure of a vegetation community. For example, adult plants of *Hakea actites* (an emergent shrub) are killed by fire and this changes the structure of the heathland vegetation at Garby Nature Reserve.

Most of the largest wildfires in the study area occurred in the conglomerate and sandstone landscapes in the north, and the steep gorge country in the north-west. These areas support dry sclerophyll and heathland communities that are adapted to fire and produce the major fuel loads needed for wildfires to occur. Predictably, areas that are more fertile and support wet sclerophyll vegetation have historically very low fire frequencies. Coastal areas have experienced several wildfires, particularly in Moonee Beach Nature Reserve and Bongil Bongil and Yuraygir national parks.

Fire management, including selection of fire regimes (frequency, seasonality and duration), can exert changes in vegetation patterns. There is considerable variation in the fire requirements of the communities occurring in the study area; from more fire-adapted dry sclerophyll forest and heathlands communities to those fire sensitive communities which require the exclusion of fire (e.g. littoral rainforests, forested wetlands, saltmarshes). Even the most fire-adapted communities are sensitive to inappropriate fire regimes.

2. Methods

The project was carried out in four main stages.

1. Trial and select methods to develop a land cover map and delineate vegetation community boundaries (see Section 2.1).
2. Map broad land cover types, including areas of extant vegetation, remnant vegetation and paddock trees (see Section 2.2):
   - Definiens segmentation and development of algorithms
   - edit and refine Definiens segmentation.
3. Develop a vegetation community classification for Coffs Harbour LGA:
   - conduct gap-filling flora surveys across the study area using stratified random sampling (see Section 2.3)
   - complete a numerical analysis of the flora survey site data to develop a vegetation classification for the study area (see Section 2.4)
   - refine the vegetation classification through expert review and field verification.
4. Map vegetation communities (see Section 2.5):
   - extract boundary of extant vegetation (using Stage 2 land-cover product) to define the area to be mapped
   - apply API techniques to map vegetation communities using Stereo Analyst™ and Planar monitor/viewer
   - field reconnaissance surveys to support API and refinement of vegetation classification
   - refine vegetation boundaries.

2.1 Trialling alternative mapping pathways

An overall objective of the project was to develop a survey and mapping methodology that could be more widely used by local governments across coastal New South Wales. Accordingly, a number of approaches to mapping were trialled before a final method, or pathway, was established.

Recent advances in image classification have shifted away from processing whole images to processing subsets or smaller polygons called 'objects' — this process is called object recognition and classification. This technology, together with the availability of high resolution airborne digital sensor (ADS40) imagery and light detecting and ranging (LiDAR) data, has led to the development of a number of techniques for automated or semi-automated vegetation mapping. Furthermore, API has moved away from stereoscopes to the use of digital stereo viewing (Planar stereo/3D monitor by Planar Systems Inc.) which can now take full advantage of the high resolution imagery available for interpretation. The Planar environment also allows the direct delineation and attribution of polygons in three-dimensional (3D) stereo view (Level 1 imagery) whilst simultaneously having a two-dimensional (2D) context view and any number of additional datasets to guide mapping decisions.

Discussion groups were held in the early phase of the project to explore alternative methods for developing land-cover maps (including extant vegetation cover) and delineating vegetation community boundaries.

As a result of the discussions, the following methods were trialled:

- For land-cover mapping, Definiens (see below) segmentation and development of algorithms for classification of vegetated versus non-vegetated lands.
- Crown delineation modelling using Definiens and image processing software (ERDAS Imagine™) to classify tree crown types to species level as an input to vegetation community mapping.
- Image enhancement techniques to exaggerate differences in spectral response of vegetation and thereby interpret different vegetation communities. Derived from manipulation of ADS40 multi-spectral imagery.
- Delineation of vegetation communities by interpretation of 3D ADS40 imagery using Stereo Analyst™ software (ERDAS) and Planar stereo/3D monitors (Planar Systems Inc.).

2.2 Land-cover mapping

High resolution airborne digital sensor (ADS40) imagery supplied by the Land and Property Management Authority and LiDAR data were used to map the broad land-cover types within the Coffs Harbour LGA. The ADS40 sensors recorded land surface information at 50 centimetre resolution in four bands, including near-infrared, and was flown between April 2009 and July 2010. The LiDAR data was supplied by Coffs Harbour City Council and was flown in January 2007.

The primary purpose of the land-cover mapping was to separate cleared areas from areas with extant vegetation cover. Thirteen classes for land-cover mapping were used as listed in Table 3.

Ancillary data to complete the land-cover mapping included:

- urban zone boundaries from Coffs Harbour LEP 2000
- boundary of Sapphire to Woolgoolga Pacific Highway upgrade from NSW Roads and Maritime Services
- Forests NSW plantation data as supplied in 2011
- tenure boundary data (e.g. national parks and state forest) from OEH and Forests NSW.

Definiens software (Definiens 2007a, 2007b) was used to produce the land-cover mapping. This software is based on object-based image analysis. The two fundamental principles of this analysis are segmentation and classification. Firstly, spatial data are segmented into smaller polygons (referred to as 'objects'), by a range of segmentation algorithms. Secondly, the image objects are then classified using an array of hierarchical, temporal, spectral and spatial context tools.

An important decision rule for inclusion in a Definiens rule set is the normalised difference vegetation index, especially for land cover. The effects of shadow were reduced using a combination of LiDAR parameters and Definiens rule sets.

The method chosen was to process each ADS40 tile separately in a Definiens Server framework. This required an intensive pre-processing strategy where LiDAR data were resized, formatted and collated to match ADS40 tiles so that a customised import into the Definiens Server could be performed.

After the segmentation was complete, the process of classifying the segmentations (or objects) was commenced. A rule set was developed to classify approximately 80% of an ADS40 tile's objects accurately, so that the remaining 20% could be finalised manually. The rule set was developed collectively and iteratively with experts reviewing and refining a centrally managed 'master' rule set. Experts also focussed their refinements on particular landscape features (e.g. shadows, paddocks, horticulture). To assist in the manual work of classification, additional algorithms were developed using object-orientated image processing. Further refinement was carried out using manual digitising.

Table 3 Summary of land-cover classes used in the study

Code	Description
1	Forest
1a	Urban & rural living vegetation remnant
2	Forestry plantation
2a	Hardwood plantation
2b	Softwood plantation
3	Trees–Shrubs
4	Grasslands–Pasture
5	Horticulture–Cropping
6	Impervious–Surfaces
7	Railways
8	Water
8a	Lake
8b	Reservoir–Dam
8c	River
8d	Marsh–Wetland
8e	Estuary–Coastal Waters
9	Sand–Beach
10	Headland Rock
11	Urban & rural living
12	Pacific Highway
13	Highway Upgrade 2011

2.3 Gap-filling flora surveys

Three tiers of survey were conducted during the study, as summarised in Table 4.

Table 4 Summary of flora surveys supporting this study

Survey type	No. of sites	Description of survey
Full floristic surveys	534	All vascular species recorded within a quadrat
Rapid data surveys	462	Recording of dominant species in each strata
API site surveys (see Section 2.5)	2 479	Ground truthing of API mapping and assignment of vegetation community to a site
Total	**3 475**	

Within the study area there were 393 existing full floristic survey sites from the YETI (Ellis et al. 2009) flora database, which equates to about one site per 300 hectares. This number of sites was insufficient to complete a mapping exercise for the LGA and additional full floristic surveys were required.

A stratified random sampling technique was used to evenly allocate sites across the landscape. Spatial layers used to develop the strata were a composite of geology, soil landscapes, solar radiation and topographic position. To optimise site location across the landscape, Survey Gap Analysis ™ (Manion & Ridges 2009) software was used to efficiently allocate sites to strata.

To ensure a balance of sampling across Crown lands and private property, Council invited landowners with over five hectares of land to participate in the program by allowing a survey to be conducted on their property. There was a strong and positive response to this invitation. The surveys were conducted over the spring–summer season of 2010/11.

Full floristic survey data were generally collected within 20 x 50 metre nested quadrats (or 10 x 40 metre plots in linear environments such as creeklines). The information was collected digitally and entered into an Access database compatible with the NSW Government central flora database, YETI (Ellis et al. 2009). An additional 141 full floristic survey sites were surveyed within the LGA by Eco Logical Australia, giving a total of 534 full floristic flora sites available for the floristic analysis.

During the full floristic surveys, 462 rapid data sites were also surveyed and this information was used to guide the vegetation mapping work by providing reference points for photo patterns. Rapid surveys collected information on dominant species in each strata. The aim of rapid data site surveys was to cover as much ground as possible in those areas that were easily accessible. Therefore, there is a tenure bias to that data, with limited plots collected on private land or in more remote/off-road locations. Afterwards, a vegetation community was assigned to each of these sites to guide and confirm API decision making.

2.4 Vegetation community classification

Vegetation classification involves a 'cluster' analysis which groups floristic sites that are similar (Dale 1995). In this study, a numerical PATN analysis (Belbin 1994) was undertaken using the available 534 full floristic sites to determine the main floristic groups for the study area. PATN software requires the operator to select the number of groups required in the output. A '100-group' analysis was undertaken because over 60 forest types (Forestry

Commission of NSW, 1989) occur within the forested landscapes of the study area without considering coastal heath and estuaries.

A dendrogram of the groups was produced using an unweighted pair group method with arithmetic mean (UPGMA) agglomerative hierarchical approach applied using the Bray-Curtis (Bray & Curtis 1957) association measure. In the agglomerative method, clustering is 'bottom-up' with the most similar flora sites being aggregated into larger clusters until there is a single cluster containing all sites. The dissimilarity between clusters was calculated using average values (or UPGMA), where two clusters with the lowest average distance (with a beta value setting of –0.1) were merged to form the new cluster. To support the interpretation of the results, a nearest neighbour analysis (Belbin 1994) and fidelity analysis (Bedward, unpublished software) were also carried out. Some preliminary assessments were made of the dendrogram results based on some of the known communities in the LGA. After this, most of the classification refinement and evaluation was carried out during the API mapping program and by testing the floristic communities in the field.

As field evidence was collated during the API mapping process (see Ground truthing surveys section below) the numerical vegetation classification was progressively reviewed and refined. This involved either re-allocation of flora plots to a neighbouring group in the dendrogram, or the un-allocation of plots if they were found not to be representative of the vegetation community, or the addition of a vegetation community not adequately sampled by existing flora surveys.

2.5 Vegetation mapping

API involves recognising patterns in the vegetation, understanding the species composition, delineating community boundaries, and assigning a suitable vegetation community label from the classification (Paine & Kiser 2012).

Vegetation mapping using conventional API was undertaken using the following three steps:

- Develop a draft vegetation community map (linework and attribution of data to polygons) using Stereo Analyst™ and Planar stereo/3D monitors.
- Conduct ground truthing surveys and record the API site survey information.
- Revisit vegetation map labels and refine vegetation boundaries.

This process can be iterative between developing the linework and finalising the attribution.

Develop a draft vegetation community map

Stereo API techniques were applied in this study using Planar stereo/3D monitors and Stereo Analyst™ software on an ESRI ArcGIS 10.0 platform. Additional ancillary information was used to assist in the API work, including:

- previous mapping and survey work in the study area (see Appendix 2)
- full floristic flora survey site data with the allocated floristic group
- image enhancement products — Stereo Analyst™ enhancement of ADS40 stereo imagery and a saturation stretch of ADS40 ortho-rectified imagery based on Roff (2009)
- hillshade using LiDAR-derived digital terrain model to assist interpretation of topographic variables (aspect, slope, position on slope, ridges and gullies)
- substrate information — quaternary near-surface geology where available (alluvial sediments) and soil landscapes or 1:250,000 geology in other areas.

The API decision pathway and specifications were designed to facilitate a one-to-one match with the floristic communities derived during the vegetation classification. All specifications and the API decision pathway are shown in Appendix 3.

Ground truthing surveys

Ground truthing surveys consisted of API site surveys. Ground truthing in the field undertaken extensively throughout the project with a focus on publicly accessible areas and areas that were visually accessible from public roads or tracks. Field information was collected using a geographic positioning system (Pocket PC, ASUS ™ A696) on an ArcPad™ platform and was recorded at 5–10 metre accuracy.

API site surveys collected information on the vegetation community and dominant species in order to interpret the vegetation patterns for a particular locality. The data from these points were viewed in the 3D Stereo Analyst™ mapping environment to guide and confirm decision making.

Completion of linework and attribution

Once linework was complete, a suitable vegetation community label from the vegetation classification was assigned to polygons. Additional data included a reliability score from 1 to 4, an indication of dominant species (where required), an indication of disturbance, presence of weeds and other comments as required.

Interpreters would use all available supporting data to attribute each polygon to one of the categories, and if uncertain, or a mosaic of categories existed, a dual category would be assigned.

Table 5 describes these additional attributes and their descriptions.

Table 5 API polygon attribution descriptions

Attribute	Description
Reliability	1 = Ground validation of polygon 2 = High level of confidence (adjacent polygons have survey data or distinct photo pattern) 3 = Moderate level of confidence (survey data in near vicinity) 4 = Low level of confidence (lack of nearby survey data or indistinct photo pattern)
Significant disturbance	Native vegetation with significant occurrence (30–50%) of environmental weeds or significant disturbance defined as either: • loss of or >50% disturbance to canopy • removal of >50% of understory/ground cover
Remnant trees	Significant disturbance where interpretation of vegetation community is no longer possible (significant alteration of structure and species composition)

The mapping was undertaken by six different aerial photograph interpreters. The study area was divided into manageable API tiles as shown in Figure 3, and tiles assigned to each interpreter. Consistency was achieved by having interpreters work in pairs during field surveys, and by regular calibration during the mapping exercise.

Once all API tiles were completed, they were stitched together and effectively edge-matched through manual digital editing in the 2D mapping environment with reference to the patterns in the 3D mapping environment.

Final checking for global errors, gross errors, consistency in mapping and other logical checks were made. Data was collected in the structure shown in Appendix 3. For details of the lineage of the data please refer to the metadata statement attached as Appendix 4.

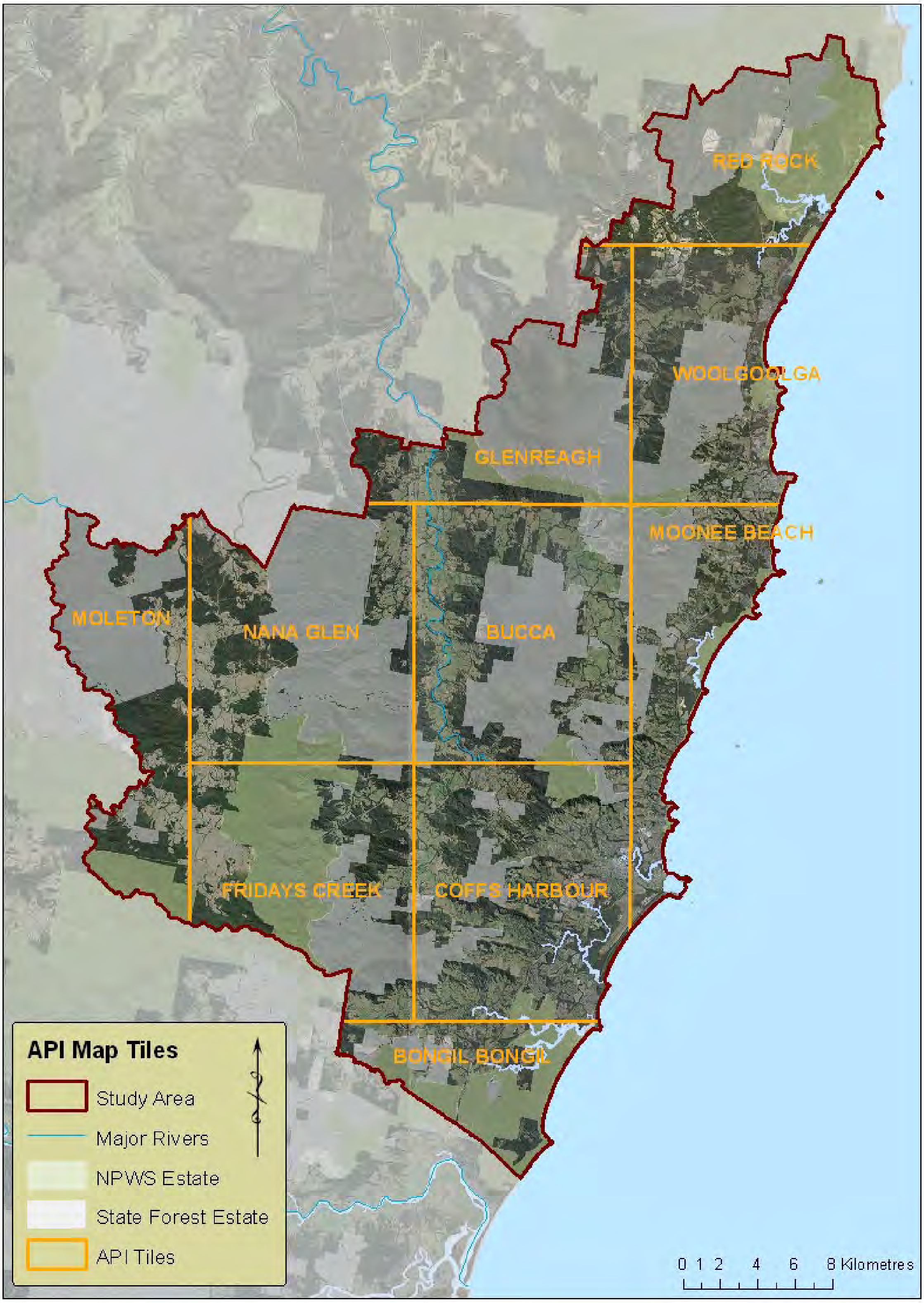

Figure 3 **API map tiles used in the study**

3. Results

3.1 Selection of mapping pathways

Alternative mapping pathways (Section 2.1) showed promise for future development in a research environment with small study areas. However, only API using Stereo Analyst™ was demonstrated to be viable for vegetation mapping in an operational sense, and as such, this is the method we used to map vegetation in this study. The Definiens-based segmentation and classification technique was used for the land-cover mapping component of the project. Crown delineation modelling was not used because of the time and costs involved in calibrating each image or tile.

3.2 Land-cover mapping

The land-cover mapping showed that 75% of the study area had extant vegetation cover and 21% was cleared (see Table 6). Horticulture and cropping was the third largest land use, covering just over 2% of the LGA, including banana plantations, blueberry farms and other crops. Land-cover mapping was completed by three geographic information system / Definiens operators within three months.

Table 6 Summary of land cover in the Coffs Harbour LGA

Land-cover codes	Land-cover class	Area (ha)	Area (%)
1a,2,2a,2b,3	Extant vegetation cover	88 826	75.73
4,11	Cleared	24 104	20.55
5	Horticulture–Cropping	2 784	2.37
8e	Estuary–Coastal Waters	390	0.33
8b	Reservoirs–Dams	377	0.32
9	Sand–Beach	270	0.23
13	Highway upgrade 2011	193	0.16
8c	River	102	0.09
7	Railway strip	83	0.07
12	Pacific Highway	76	0.06
10	Headland Rock	59	0.05
8a	Lake	28	0.02
8	Water	8	0.01
	Total	**117 300**	**100%**

Land tenure was found to be almost equally divided between Crown land (48%) and freehold land (51%), however, almost half of the freehold land has been cleared as shown in Table 7.

Table 7 Summary of study area by tenure

Tenure	Area (ha)	Area (%)
NPWS estate	14 470	12%
Forests NSW estate	40 240	34%
Other Crown lands	2 040	2%
Total Crown land	**56 550**	**48%**
Freehold vegetated	32 400	28%
Freehold cleared	28 150	24%
Total Freehold	*60 249*	*51%*
Total	**117 300**	**100.0**

The fragmentation of remnant vegetation in some areas of the LGA was apparent. In the study area, 48,307 extant vegetation polygons were less than 5 hectares (as shown in Table 8). The average remnant patch size was 2.4 hectares. There are just 71 extant vegetation polygons that are greater than 100 hectares (if roads and powerlines are considered as polygon sub-divisions). It is important to note that these results are calculated from an image analysis segmentation rather than API. The final vegetation extent was edited and re-mapped in the rural and fragmented areas to better reflect vegetation cover and the presence of significant remnant patches in those areas.

Table 8 Area of extant vegetation cover by polygon size classes (land-cover classification mapping)

Area class (ha)	No. of polygons	Area (ha)	Area (%)
0.2–5	4 647	2 877.8	3.2
5–10	147	1 030	1.2
10–100	143	3 701	4.2
100–1000	22	5 632	6.3
1 000–10 000	4	11 646.3	13.1
10 000–34 000	2	63 938.9	72
Total	**49 092**	**88 826**	**100.0**

3.3 Gap-filling flora surveys

An additional 141 full floristic sites and 462 rapid data sites were surveyed. Note that 220 rapid data sites were set aside for accuracy assessment or validation of the mapping at a later date.

Sampling rates were balanced between private property and Crown land when considering both full floristic surveys and rapid survey sites, with an average sample coverage of one site per 90 hectares as shown in Table 9.

Table 9 Average site density and tenure sampling rates for sites used in the vegetation classification

Tenure	No. of full floristic sites	No. of rapid survey sites	Total sites	% of total sites	Sampling rate (ha per site)
NPWS estate	235	26	261	26%	
Forests NSW estate	110	194	304	31%	
Other Crown lands	15	59	74	7%	
Total Crown land			**639**	**64%**	**89**
Freehold (vegetated)	174	183	357	36%	90
Total	**534**	**462**	**996**	**100%**	

The geographic spread of sites across the study area is show in Figure 4. The figure includes both flora sites collected during the mapping project and existing data for the study.

3.4 Vegetation classification

The PATN analysis was set at a 100 floristic group level. During the mapping program the PATN-derived groups were comprehensively tested and refined in the field. The result produced a list of 79 communities as listed in Appendix 5. This process was invaluable for the development of the final vegetation communities and the vegetation mapping classes.

One of the main challenges during the mapping and testing of the community list, was to ensure that vegetation communities identified by PATN analysis could be recognised and accurately delineated from the ADS40 imagery. Some map units represented potential plant communities or previously recognised communities that were not delineated by the PATN analysis due to lack of surveys or the restricted nature of the community.

These results show the value of having previous studies, numerical analysis, and mapping to inform the classification process. While it is desirable to have a fixed vegetation classification prior to mapping, deficiencies in the data used in the classification may be exposed by the mapping process. The final vegetation classification and mapped units are described in Volume 2 – Vegetation Community Profiles.

3.5 Vegetation mapping

The extent of vegetation in the study area was 88,826 hectares, with 19,045 polygons needing to be assigned to one of the 79 classified vegetation communities (see Appendix 5). The use of stereo API in combination with existing mapping products and field validation resulted in the completion of the study area in a 12 month API program. Table 10 summarises the area by vegetation formation and classes across the study area. Overall, 11 formations were mapped across 24 different classes of native vegetation. In general, it was more difficult to assign vegetation to a community in fragmented and disturbed landscapes than in contiguous forested areas.

Wet sclerophyll and rainforest formations dominate the landscape, covering over 60% (54,750 ha), and this is mainly due to the rich, fertile landscapes and high annual rainfall. Dry sclerophyll forests cover 19.6% (17,442 ha), while the coastal communities cover only 5.8% (5214 ha) of the LGA. Derived communities including plantations, exotics and regenerating pioneers cover almost 10% of the vegetated area in the LGA.

The vegetation map (see Attachment 1 or go to www.coffsharbour.nsw.gov.au) illustrates the biodiversity of the

Coffs Harbour LGA. Large areas of rainforest and wet sclerophyll forest are mapped in the west and south of the study area across the fertile areas of the eastern Dorrigo Plateau, escarpment ranges and the upper reaches of the Orara and Bucca valleys. In contrast, much of the sandstone and coastal metasediment-dominated landscapes in the north of the study area are mapped with large stands of dry sclerophyll forest, heathlands and forested wetlands. Overall, the variety of soil moisture gradients, geologies, altitudes and quaternary landscapes support a diverse array of floristic communities.

The final vegetation map shows that the major contributing influences to the floristic diversity are likely to be altitude and geology, followed by coastal/marine processes. The coastal areas have the most complex vegetation patterns and this is reflected by the number of communities mapped and the large numbers of small polygons.

Figure 4 **Flora sites used in analysis and mapping**

Table 10 Areas of formations and vegetation classes mapped across the Coffs Harbour LGA

Formation	Class	Class area (ha)	Formation area (ha)
Derived	Exotic vegetation	2 978	
	Native pioneer	213	
	Plantation	6 528	9 719
Dry sclerophyll forest	North Coast Dry Sclerophyll Forest	16 878	
	North Coast Dune Sclerophyll Forest	564	17 442
Forested wetlands	Coastal Floodplain Wetlands	289	
	Coastal Swamp Forests	2 012	
	Eastern Riverine Forests	583	2 884
Freshwater wetlands	Coastal Heath Swamps	799	
	Coastal Lagoons	27	
	Derived Freshwater Wetlands	169	995
Grasslands	Maritime Grasslands	67	67
Heathlands	Coastal Headland Heaths	867	
	Coastal Wallum Heaths	88	
	Escarpment rock outcrops	19	
	Northern Montane Heaths	21	995
Marine	Marine vegetation	3	3
Native remnant vegetation	Native remnant vegetation	1 549	1 540
Natural non-vegetated	Rock outcrop	0	
	Sand	12	12
Rainforest	Cool Temperate Rainforest	576	
	Dry Rainforest	486	
	Littoral Rainforest	233	
	Subtropical Rainforest	4 271	
	Warm Temperate Rainforest	5 098	10 664
Saline wetlands	Mangroves	157	
	Saltmarsh	205	362
Wet sclerophyll forest	North Coast Wet Sclerophyll Forest	44 134	44 134
Total		**88 826**	

3.6 Refinement of vegetation classification and map units

An iterative approach was taken to finalise the vegetation classification where the results of mapping and ground truthing surveys informed the classification. During the mapping process some grouping and splitting of the original classification occurred to better match communities identified from ground truthing.

As a result, of the 79 vegetation communities, 66 were derived from the numerical analysis (using the 534 full floristic sites), and 14 were identified from API. This step-wise method of reviewing the vegetation classification highlighted areas where further botanical work would be beneficial to adequately describe the diversity within the landscape.

Of particular note, the field ground truthing effort was extensive during the API mapping exercise with a total 2479 API sites surveyed. Together with the 534 full floristic sites and 462 rapid data sites, a total of 3475 sites were surveyed on the ground.

3.7 Native species and weeds recorded in surveys

In the gap-filling surveys, 8114 records of 689 plant taxa were made, including many species of conservation significance. Some of the most commonly recorded genera were *Eucalyptus* (23 taxa) and *Acacia* (17 taxa). The Lauraceae family (24 taxa) including *Cryptocarya*, *Endiandra* and *Neolitsea* were an abundant component of wet sclerophyll and rainforest communities. Other diverse plant families recorded across a range of wet and dry vegetation formations were Mrytaceae (74), Fabaceae (51), Poaceae (33), Cyperaceae (31) and Proteaceae (24).

In addition, 67 weed species were recorded in the surveys. Lantana (*Lantana camara*) was the most commonly recorded weed species. Other commonly recorded, highly invasive weed species included Bitou bush (Chrysanthemoides monilifera), Camphor Laurel (*Cinnamomum camphora*), Broad-leaved Paspalum (*Paspalum mandicanum*), *Senna pendula* var. *glabrata,* and Small Leaved Privet (*Ligustrum sinense*).

3.8 Threatened species of the Coffs Harbour LGA

During the gap-filling floristic surveys several threatened species were recorded in the study area, including new records of *Hakea ochroptera* and *Plectranthus cremnus*. Overall, six threatened flora species and 12 rare or threatened Australian plant (ROTAP) species were found during the Coffs Harbour LGA flora surveys. Additionally, in other recent surveys five threatened species and several ROTAP species were recorded, including *Alexfloydia repens*, *Pultenaea maritima*, *Lindsaea incisa* and *Ricinocarpos speciosus*. There are now 53 known significant plant species in the Coffs Harbour LGA. These species are listed in Table 11.

Table 11 Significant plants in the Coffs Harbour LGA

Species name	Common name	Threatened Species Conservation Act	ROTAP code
Acianthella amplexicaulis			3RC-
Acomis acoma			3RC-
Acronychia littoralis	Scented Acronychia	TSC-E	3ECi
Alexfloydia repens	Floyd's Grass	TSC-V	2K
Allocasuarina defungens		TSC-E	2E
Alloxylon pinnatum	Dorrigo Waratah		3RCa
Anetholea anisata	Ringwood		2RCa
Angophora robur	Sandstone Rough-barked Apple	TSC-V	2RC-
Austrobuxus swainii	Pink Cherry		3RCa
Arthraxon hispidus	Hairy Joint Grass	TSC-V	3VC-+
Arthrochilus prolixus			3K
Boronia umbellata	Orara Boronia	TSC-V	2VC-
Callistemon acuminatus	Tapering-leaved Bottlebrush		3RC-
Chamaesyce psammogeton		TSC-E	
Corybas undulatus	Tailed Helmet Orchid		3KC-

Species name	Common name	Threatened Species Conservation Act	ROTAP code
Cryptocarya dorrigoensis	Dorrigo Laurel		2RCa
Cryptostylis hunteriana	Leafless Tongue Orchid	TSC-V	3VC-
Cupaniopsis newmanii			2RC-
Elaeocharis tetraquetra	Square-stemmed Spike Rush	TSC-E	
Endiandra introrsa	Dorrigo Plum		3RCa
Eucalyptus ancophila			2K
Eucalyptus dunnii	Dunn's White Gum		3RCa
Eucalyptus fusiformis	Grey Ironbark		2RC-
Eucalyptus rummeryi	Steel Box		3RC-
Gahnia insignis			3RCa
Goodenia fordiana			2RC-
Hakea ochroptera			2K
Lindsaea incisa	Screw Fern	TSC-E	
Marsdenia fraseri	Narrow-leaved Milk Vine		3RC
Marsdenia liisae	Large-flowered Milk Vine		3RC-
Marsdenia longiloba	Slender Marsdenia	TCS-E	3RC-
Niemeyera whitei	Rusty Plum, Plum Boxwood	TSC-V	
Oberonia titania			
Olearia flocktoniae		TSC-E	2ECi
Olearia stillwelliae			3RCa
Parsonsia dorrigoensis	Milky Silkpod	TSC-V	2VCi
Phaius australis	Lesser Swamp Orchid	TSC-E	3VCa
Peristeranthus hillii	Brown Fairy-chain Orchid	TSC-V	
Plectranthus cremnus			3K
Plectranthus suaveolens			3KC-
Pultenaea maritima	Coast Headland Pea	TSC-V	
Quassia sp B		TSC-E	
Ricinocarpos speciosus			2RCi
Sarchochilus fitzgeraldii	Ravine Orchid	TSC-V	3VC-
Schistostylis purpuratus			3RCi
Senna acclinis	Rainforest Senna	TSC-E	3RC-
Sophora tomentosa	Silver Bush	TSC-E	
Thesium australe	Austral Toadflax	TSC-V	3VCi+
Tinospora tinosporoides	Arrow-head Vine	TSC-V	3RC-
Triplarina imbricata		TSC-E	2E
Typhonium sp aff *brownii*	Black Lily	TSC-E	
Tylophora woollsii		TSC-E	2E
Zieria prostrata		TSC-E	

TSC-E = endangered species listed on *Threatened Species Conservation Act 1995*
TSC-V = vulnerable species listed on *Threatened Species Conservation Act 1995*
ROTAP codes - see Briggs and Leigh (1996).

3.9 Endangered ecological communities of the Coffs Harbour LGA

Several of the classified vegetation communities are considered to be endangered ecological communities (EECs) or highly likely to contain EECs based on their substrate or altitudinal/landscape occurrence. Overall, 9993 hectares have floristic communities that may be EECs. Table 12 shows vegetation communities in the study area that are likely to support threatened communities.

Table 12 Vegetation communities likely to contain endangered ecological communities

EEC name / Community code and name	Area (ha)
Lowland Rainforest on Floodplain in the New South Wales North Coast Bioregion EEC	
CH_RF09: White Booyong–*Sloanea australis* Floodplain Rainforest	31
Lowland Rainforest in the NSW North Coast and Sydney Basin bioregions EEC	
CH_RF11: Yellow Carabeen–Black Booyong–Maidens Blush–*Neolitsea dealbata–Archontophoenix cunninghamiana* Subtropical Rainforest	4 240
CH_RF05: Brown Myrtle Dry Rainforest	342
CH_RF06: Grey Mrytle–Brushbox Dry Rainforest	77
Littoral Rainforest in the NSW North Coast, Sydney Basin and South East Corner bioregions EEC	
CH_RF07: Tuckeroo Beach Bird's Eye Littoral Rainforest	100
CH_RF13: Small-leaved Lilly Pilly–Pear-fruited Tamarind Littoral Rainforest (Scrub Creek)	91
CH_RF08: Headland Brush Box Littoral Rainforest	42
Themeda Grassland on Seacliffs and Coastal Headlands in the NSW North Coast, Sydney Basin and South East Corner bioregions EEC	
CH_H03: Kangaroo Grass Headland Grasslands	46
Swamp Oak Floodplain Forest of the NSW North Coast, Sydney Basin and South East Corner bioregions EEC	
CH_FrW01: Broad-leaved Paperbark–Swamp Oak–Willow Bottle Brush Floodplain Forested Wetland	936
CH_FrW10: Swamp Oak–Sea Rush Saline Swamp Forest	200
Swamp Sclerophyll Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions EEC	
Subtropical Coastal Floodplain Forest of the NSW North Coast bioregion EEC	
CH_DOF06: Swamp Box–Broad-leaved Paperbark–Forest Red Gum–Red Mahogany Transitional Dry Open Forest	2 037
Freshwater Wetlands on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions EEC	
CH_FrW01: Broad-leaved Paperbark–Swamp Oak–Willow Bottle Brush Floodplain Forested Wetland	936
CH_FW07: Jointed Twig-rush Freshwater Wetland	27
CH_FW08: *Eleocharis sphacelata–E.acuta*–Broadleaf Cumbungi Freshwater Wetland	169
CH_FrW02: Swamp Mahogany–Willow Bottlebrush Forested Wetland	182
CH_FrW03: Broad-leaved Paperbark–Willow Bottlebrush Channel Paperbark Forested Wetland	78
CH_FrW04: Broad-leaved Paperbark–*Baumea rubiginosa* Jointed Twig Rush Forested Wetland	554
Coastal Saltmarsh in the NSW North Coast, Sydney Basin and South East Corner bioregions EEC	
CH_SW03: Club Rush Dune Soak	11
CH_SW02: Twig Rush Saltmarsh	44
CH_SW04: Prickly Couch–Blue Couch ICOL Grassland/Saltmarsh	0

EEC name / Community code and name	Area (ha)
CH_SW05: Twig Rush Headland Sedgeland Soaks	4
CH_SW06: Sea Rush Saltmarsh	38
CH_SW07: Samphire–Saltwater Couch Saltmarsh	108
White Gum Moist Forest in the NSW North Coast Bioregion EEC	
CH_WSF13: Dunn's White Gum Forest	90
Total	**9 993**

3.10 Project management and costs

The mapping program commenced in October 2011 and was completed by May 2012. As a general guide, it took each interpreter around two months to map each API tile segment, including fieldwork. Additional to this, corrections, adjustments and checking took approximately one additional week per tile. Total costs of the project were $400,000, and effectively equated to $3.40 per hectare, including the floristic plots and analysis, or $2.32 per hectare for API mapping work.

Before the mapping program commenced, a significant amount of preparation work, trials, research and development was undertaken to develop the best approach for fine-scale mapping. This added significantly to the project timeframe but was, however, an invaluable exercise in determining the most appropriate use of the current technology available for Class 5 vegetation mapping. This process supported the development of a proposed methodology for Class 5 mapping projects that is the most efficient, practical and cost effective.

3.11 Research and development

Over the course of this project, several new approaches were tested for fine-scale, LGA-wide vegetation mapping. It was found that the use of conventional API techniques within the Stereo Analyst™ 3D environment with the use of high resolution ADS40 imagery and LIDAR digital terrain models was the most accurate, efficient and cost-effective approach to vegetation mapping at this scale.

The use of a computer-generated segmentation to delineate extant vegetation extent proved to be more time consuming than the conventional approach through API due to misalignment of the segmentation lines due to shadow or other anomalies with the imagery (smoke, haze or water bodies). This line work required extensive editing by traditional API methods.

Extensive work and research was carried out to determine a suitable image manipulation technique (stretch) to see if communities, tree species and vegetation patterns in general could be highlighted to allow delineation in a 2D environment or alternatively to allow automated delineation of communities. It was found that the manipulation of the ADS40 imagery, in particular the near infra-red bands, displayed the contrasting vegetation patterns well and, in some cases, illustrated the mix of species or at times the specific canopy species present in the landscape. However, the automated delineation of communities was not accurate and the process was not time-effective. Nonetheless, this research and development opportunity produced an additional highly useful data set that was referred to and utilised throughout the project to support traditional API mapping and editing.

Future research and development work could be directed towards improving multi-scale segmentation techniques for coastal complexes, especially if combined with LiDAR information. For example, coastal heaths communities can in some cases be well differentiated using height information and spectral response. Automated segmentation methods seemed to provide adequate delineation of vegetation communities, but the segmentation parameters only applied to specific areas. A multi-scale approach would enable broader landscape patterns or context to be considered to refine the scale at which segmentation is applied.

3.12 Conclusion

A fine-scale map was produced for the Coffs Harbour LGA to support environmental planning purposes at the 1:5000 scale. API was found to be the current best practice for fine-scale vegetation mapping for this coastal local government area. This was largely due to the complexity of coastal vegetation communities where significant vegetation changes occur within short distances requiring numerous small polygons to describe the vegetation patterns.

The approach of using conventional API is labour intensive and resulted in relatively high costs per hectare compared to modelled vegetation map products, but conventional API also results in significantly higher overall accuracy.

The Definiens segmentation, object-orientated approach was found to be useful for land-cover mapping but was not found to be useful for vegetation mapping over a large region. Further research is required to enable multi-scale segmentation processes to define community boundaries. This approach is most promising in coastal heath areas in conjunction with the use of LiDAR, as height differences are an important distinguishing feature.

It was found that classification and mapping go 'hand-in-hand' and mapping does not necessarily follow classification in consecutive steps. The classification process was found to inform the mapping process and the mapping process and field checking informed the classification.

Intensive field sampling effort was required to achieve the desired mapping scale and accuracy (yet to be determined) for this coastal LGA. This was largely due to the varied landscapes within the study area and the rapid changes in landform and elevation moving from east to west.

Image enhancement techniques often provide important supplementary information for the interpreter, but not all differences shown in image stretches amount to floristic changes on the ground. Availability of additional flora survey site data and ancillary information such as digital terrain models and access to previous vegetation mapping products were all found to be useful in the attribution and delineation of vegetation communities.

An accuracy assessment is yet to be completed for this map product and this will be conducted by Eco Logical Australia in July–August 2012, independently of OEH and Coffs Harbour City Council.

4. References

Austin, MP and Heyligers, PC 1989, 'Vegetation survey design for conservation: gradsect sampling of forests in north-eastern New South Wales', *Biological Conservation,* 50:13–32.

Bale, CL, Charley, JL and White, GJ 1992, *Bonville Beach Borefield Proposal: assessment of Vegetation Impacts,* Botany Department, University of New England, on behalf of Mitchell McCotter and Associates Pty Ltd, Armidale, NSW.

Bedward, unpublished software.

Belbin, L 1994, *PATN Pattern Analysis Package,* CSIRO, Canberra.

BOM—*see* Bureau of Meteorology.

Bray, JR and Curtis, JT 1957, 'An ordination of upland forest communities of southern Wisconsin', *Ecological Monographs*, 27:325-349.

Briggs, JD and Leigh, JH 1996, Rare or Threatened Australian Plants. CSIRO Australia. Canberra ACT.

Bureau of Meteorology 2012, Coffs Harbour Meteorological Office data, available at: <http://www.bom.gov.au/climate/averages/tables/cw_059040.shtml>, accessed 18 April 2012.

Cameron, MA, Sheringham, PR, Hunter RJ and Smith, M, 2010, *Survey and Mapping of the Vegetation of Bongil Bongil National Park*, Department of Environment, Climate Change and Water NSW, Coffs Harbour, NSW.

CHCC—*see* Coffs Harbour City Council

Clancy, GP 1988, 'Report on Survey of Vegetation and Fauna of Bonville Area', unpublished report.

Clode, D and Burgman, M 1997 *Joint Old-growth Forest Project: summary report,* NSW National Parks and Wildlife Service and NSW State Forests, Sydney.

Coffs Harbour City Council 2012, 'Draft Coffs Harbour Biodiversity Action Strategy 2012–2030', CHCC.

Dale, M 1995, 'Evaluating classification strategies', *Journal of Vegetation Science*, 6:437–440.

DECCW—*see* Department of Environment, Climate Change and Water.

Department of Environment, Climate Change and Water 2009, 'Native Vegetation Type Mapping Strategy 2009–2013', unpublished report, DECC, Sydney.

Definiens 2007a, *Developer 7 User Guide*, Definiens AG, Munich, Germany.

Definiens 2007b, *Developer 7 Reference Book*, Definiens AG, Munich, Germany.

Eco Logical Australia 2005, 'A Vegetation Map for the Northern Rivers Catchment Management Authority to Support Application of the Biodiversity Forecasting Toolkit', report prepared for the Northern Rivers Catchment Management Authority, Eco Logical Australia, Sutherland, NSW.

Elks, G 2006, 'Site survey for a fire response and review of environmental factors', unpublished report.

Ellis, M, Bedward, M and Gleeson, P 2009, *Yet Another Vegetation Survey Database*, Version 3.2, NSW Department of Environment, Climate Change & Water, Sydney, accessed 18 November 2010 at <http://www.environment.nsw.gov.au/research/VISplot.htm>.

Fisher, M, Body, M and Gill, J 1996, 'The Vegetation of the Coffs Harbour City Council LGA', unpublished report to Coffs Harbour City Council.

Floyd, AG 1990, *Australian Rainforests in New South Wales*, vols 1 & 2, Surrey Beatty and Sons, Chipping Norton, Sydney.

Forestry Commission of NSW 1989, *Forest Types in New South Wales*, Research Note 17, Forestry Commission of New South Wales, Pennant Hills, Sydney.

Gilmour, P, Helman, C 1991, 'Clarence Valley Rainforest Remnants Rescue', unpublished report to Clarence Environment Centre, Grafton.

Griffith, SJ and Wilson, R 2007, 'Coastal vegetation mapping project: table of communities & codes', working copy of unpublished report.

Griffith, SJ 2002, 'Pattern and process in the wallum of north-eastern New South Wales', thesis submitted for the Degree of Doctor of Philosophy of the University of New England, Armidale.

Griffith, SJ 1984, 'A survey of the vegetation of Yuraygir National Park', report prepared for the National Parks and Wildlife Service.

Kendall, P 2005, 'Environmental mapping from air photo interpretation for Corindi, Red Rock – extension to Coffs Harbour Local Government Area', report prepared for Coffs Harbour City Council, Kendall and Kendall Pty Ltd.

Manion, G and Ridges, M 2009, 'An optimisation of the survey gap analysis technique to minimise computational complexity and memory resources in order to accommodate fine grain environmental and site data', paper presented to the 18th World IMACS/MODSIM Congress, Cairns, Australia, 13–17 July 2009, accessed at: <http://mssanz.org.au/modsim09>.

Milford, HB 1999, 'Soil Landscapes of the Coffs Harbour 1:100,000 Sheet Report', Department of Land and Water Conservation, Sydney.

National Parks and Wildlife Service NSW 1994, 'Flora of north-east NSW forests', North East Forests Biodiversity Study Report No.4.

National Parks and Wildlife Service NSW 1999 'Forest ecosystem classification and mapping for the Upper and Lower NortheEast CRA regions', CRA unit, Northern Zone, NSW National Parks and Wildlife Service. Coffs harbour.

Natural Resources Audit Council 1995, *Vegetation Survey and Mapping of Upper North East New South Wales*, a report by the New South Wales National Parks and Wildlife Service for the Natural Resources Audit Council, NPWS, Hurstville, Sydney.

Natural Resources Audit Council 1996, *Regional Report of Upper North East of Upper North East New South Wales: Physical attributes*, vol. 2, chap. 1, Resource and Conservation Assessment Council, Sydney.

NPWS—*see* National Parks and Wildlife Service NSW.

NRAC—*see* Natural Resources Audit Council.

Ollier, CD, 1982, The Great Escarpment of eastern Australia: tectonic and geomorphic significance, Journal of the Geological Society of Australia, 29, 13-23.

Paine, DP and Kiser, JD 2012, *Aerial Photography and Image Interpretation*, John Wiley and Sons.

Roff, A 2009, 'Floristics, fuel load and condition: object-based, hyperspectral remote sensing of native vegetation', PhD thesis, University of NSW, Sydney, Australia.

Smith, AP, Andrews, S and Floyd A 1990, 'Flora and fauna of the Orara and Bucca valleys', a report to the Coffs Harbour City Council, Austeco Pty Ltd.

Taunton, G 2010, 'ADS40 forward program', Local Government Forward Program, Land and Property Management Authority, Local Government Spatial Seminar 15–16 March 2010.

Thackway, R and Cresswell, ID (eds) 1995, *An Interim Biogeographic Regionalisation for Australia: A Framework for Setting Priorities in the National Reserves System Cooperative Program*, version 6.0, Australian Nature Conservation Agency, Reserve Systems Unit, Canberra, accessed at: <http://www.environment.gov.au/parks/nrs/science/bioregion-framework/ibra/index.html>.

Tweedie, TD, Bruskin, S, Chapman, WS and Heyward, RW 1995, *Flora Survey, Urunga and Coffs Harbour Management Areas*, State Forests of New South Wales, Northern Region, Sydney NSW.

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Attachment 2

Appendix 1

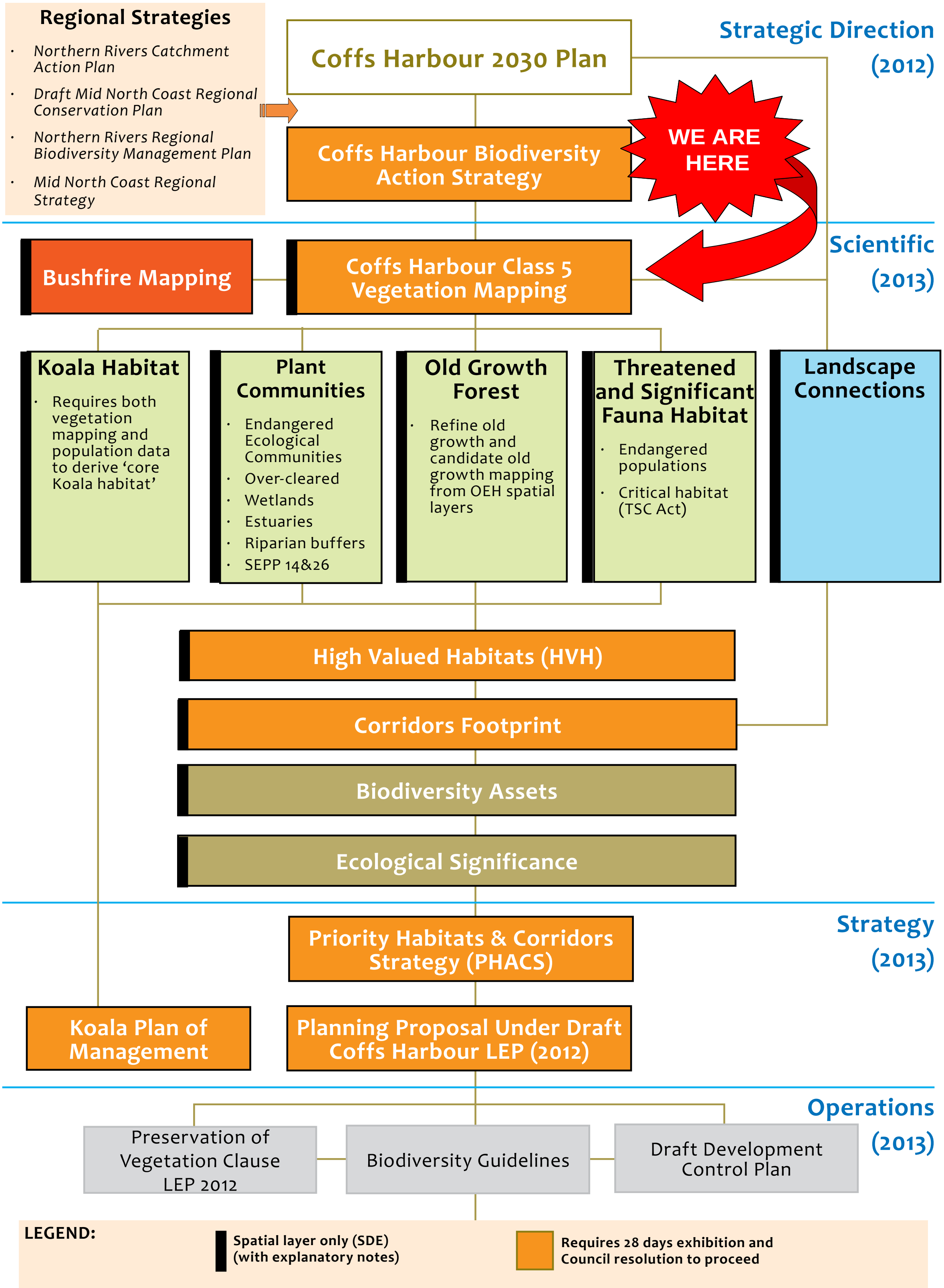


Figure A5.1 from Coffs Harbour Biodiversity Action Strategy (2012)

Appendix 2

Previous vegetation mapping and flora surveys in the study area.

See the Reference section for full publication details.

Author/Citation	Description/Method
Aerial photograph interpretation	
Forestry Commission of NSW (1989)	Research Note 17 Forest Type mapping. Complete for the following state forests: Orara East, Conglomerate, Wedding Bells, Lower Bucca, Boambee, Orara West, Pine Creek, Nana Creek and Bagawa. Method: Traditional API methods. Stereoscopic API transposed to hard copy maps then subsequently digitised.
Kendall (2005)	Vegetation mapping of the Corindi and Red Rock extension to the Coffs Harbour LGA. Mapped to classification used by Fisher et al. (1996). Method: Traditional stereoscopic API scanned, ortho-rectified and vectorised.
Griffith & Wilson (2007)	API mapping of coastal reserves and Crown land on the north coast of NSW.
Systematic survey and/or mapping	
Griffith (1984)	Systematic survey and mapping of the vegetation of Yuraygir National Park
Austin & Heyligers (1989)	A presence–absence gradsect survey of overstorey species undertaken to obtain a representative sample of the floristic variation in a forested area of about 20,000 square kilometres.
Gilmour & Helman (1991)	Rainforest survey of remnant vegetation in the Clarence Valley.
NPWS (1994)	Systematic flora survey of north-east NSW as part of the NSW North East Forest Biodiversity Study.
NRAC (1995)	Systematic flora survey and multi-attribute mapping of north-east NSW. Floristic surveys done for a regional biodiversity audit in 1995.
Tweedie et al. (1995)	Systematic survey and analysis of vegetation in the Coffs Harbour – Urunga State Forest Management Area.
Fisher et al. (1996)	Systematic survey and mapping of vegetation in the Coffs Harbour LGA.
Clode & Burgman (1997)	Systematic survey sites to characterise old-growth forest, as part of the Natural Resource Audit Council's Joint Old -growth project.
NPWS (1999)	Systematic flora survey for north-east NSW supporting the Regional Forest Agreement process.
Griffith (2002)	Systematic survey and mapping of the wallum heath of north-east NSW.
Cameron et al. (2010)	Systematic survey and mapping of the vegetation of Bongil Bongil National Park.
Office of Environment and Heritage (in prep.)	Systematic gap-filling surveys for the North Coast Vegetation Classification project.
Non-systematic survey and mapping	
Williams (1958 to 1993)	Rainforest species lists. Method: Random meanders.
Clancy (1988)	Recorded 280 plant taxa in a study area encompassing Bonville Beach.
Floyd (1990)	Surveys of littoral rainforest at Bundagen Flora Reserve and Scrub Creek. Method: Random traverse.

Author/Citation	Description/Method
Smith et al. (1990)	Flora and fauna survey of the Orara and Bucca valleys.
Bale et al. (1992)	Survey of the vegetation of the Bonville Beach Sand mass. A list of plant taxa was compiled and 19 vegetation communities were described.
Elks (2006)	Site survey for a fire-response study and review of environmental factors that included a vegetation assessment.
Lunney (in prep.)	Survey sites for Koala habitat assessment. Methods: canopy only survey.

Appendix 3

Polygon size and dimensions

Coastal lowland, alluvial plains, sands and estuaries	
Reference scale for review of linework	1:4,000
Minimum remnant size for floristic group attribution	0.2 ha
Minimum size for delineation of community within larger patch in **coastal lowland** ladscape	0.2 ha
Minimum width for linear feature in **coastal lowland** landscape	5m

Coastal foothills, escarpment and plateau forests and woodlands	
Reference scale for review of linework	1:6,000
Minimum remnant size for floristic group attribution	0.2 ha
Minimum size for delineation of community within larger patch in **forest** landscape	0.5 ha
Minimum width for linear feature in **forest** landscape	10m

Dual coding of floristic communities	
Polygons can be coded with dual floristic communities where they occur as a mosaic . Code should be denoted FGA/FGB. E.g. 17/16 where 17 is the most likely or dominant group. At least **30%** of each community should be present for a dual community code attribution.	

Polygon confidence	
Ground validation of polygon	1
High level of confidence (adjacent polygons within survey data or distinct photo pattern)	2
Moderate level of confidence (survey data in near vicinity)	3
Low level of confidence (lack of nearby survey data or indistinct photo pattern)	4

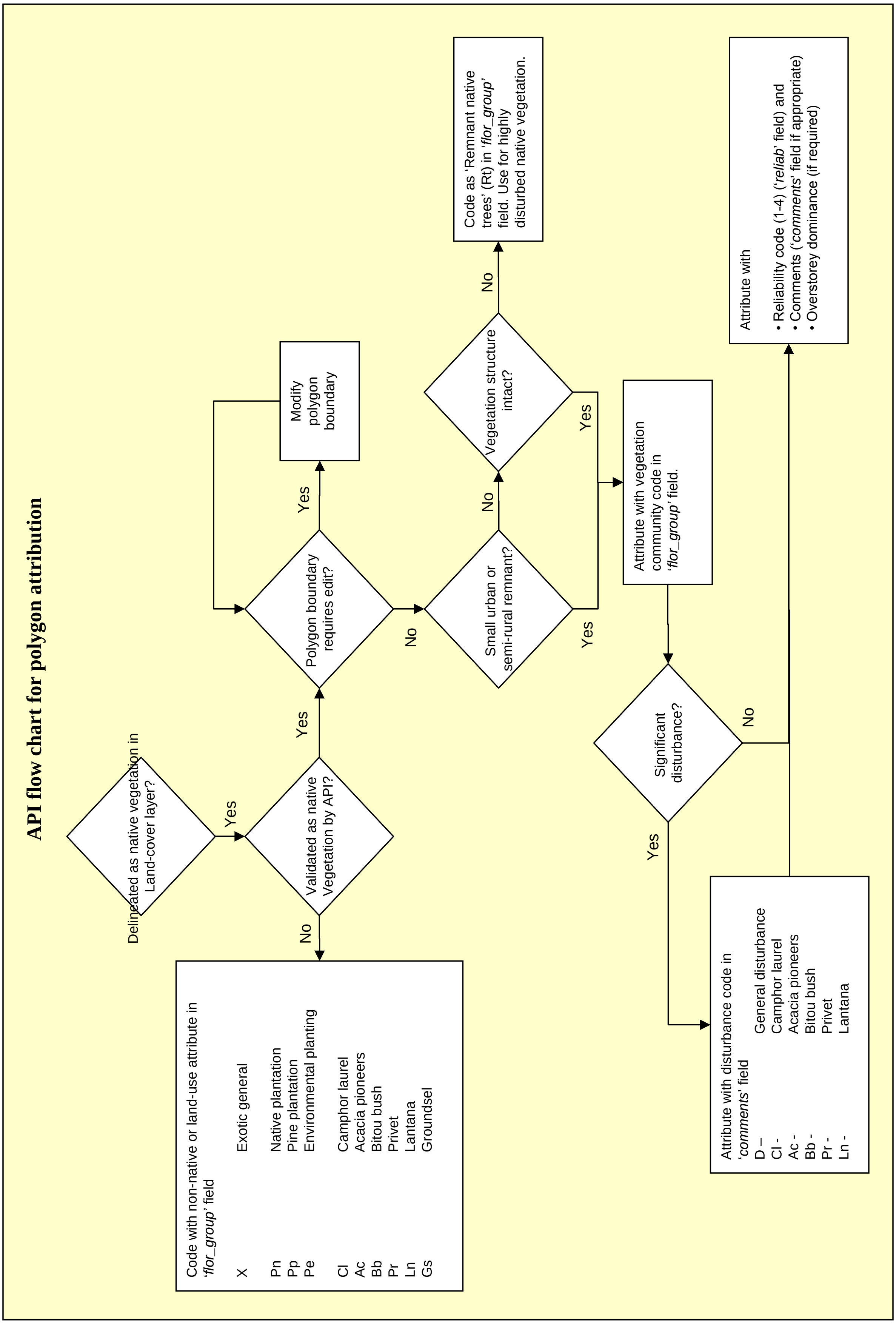
Coding of Exotic and disturbance features

Exotic dominated (>50% of polygon) features	*Flor_group* field
Exotic vegetation. Includes exotic dominated urban and rural residential vegetation which has been delineated as native vegetation in the land-cover layer.	x
Environmental weeds	See below
Native plantations	Pn
Pine / softwood planations	Pp
Environmental plantings (revegetation areas, windbreaks, raodside plantings etc.	Pe

Native vegetation with significant occurrence (30-50%) of environmental weeds or significant disturbance defined as either: a) Loss or >50% disturbance to canopy; or b) Removal of >50% of understorey/ground cover	*Comments* field
General disturbance	D
Environmental weeds	See below
Significance disturbance where interpretation of vegetation community is no longer possible (significant alteration of structure and species composition	Rt

Environmental weeds or native pioneers	
Camphor laurel	Cl
Acacia spp. Native pioneers (Not including FG 53 - Coast Wattle Shrublands). E.g. A. irrorata or A. melanoxylon.	Ac
Bitou bush	Bb
Privet	Pr
Lantana	Ln
Groundsel	Gs
Pine species	Pp
Horse-tail She-oak	Hs

Draft as reported to Council 11 October 2012 **Attachment 2**



Appendix 4

METADATA STATEMENT

Coffs Harbour Vegetation Map

DATASET Coffs Harbour City Council Floristic Vegetation Map - 2012

CUSTODIAN Coffs Harbour City Council

JURISDICTION New South Wales

DESCRIPTION Abstract

This layer is a fine-scale floristic vegetation map of the Coffs Harbour Local Government Area. There are 92 map categories in total with almost all of these being the result of statistical analysis and field-based full floristic data sites. Mapping was conducted by vegetation mapping experts in a digital three-dimensional (3D) Planar environment. Additionally, basic disturbance information was captured along with a selection of prominent weeds where discernible by interpreters.

Geographic Extent Name

GEN Category: Local Government Areas (LGA)
GEN Custodial Jurisdiction: New South Wales
GEN Name: Coffs Harbour Local Government Area
Geographic Extent Polygon
Geographic Bounding Box
Min E: 480360.3
Max E: 525096.1
Max Y: 6692556.6
Min Y: 6631522.8

DATA CURRENCY

Beginning Date 2009-09-01
Ending Date 2012-04-07

DATASET STATUS

Progress: Complete

Maintenance and Update Frequency: As required

ACCESS

Stored Data Format: ESRI ArcSDE
Available Format Type: DIGITAL - ESRI Geo-database/shapefile
Access Constraint: Contact the GIS Team Leader to discuss access and costs

DATA QUALITY

Lineage: Source data for this layer has two components, the floristic field-based site data and the other being high resolution aerial photography.

SITE DATA

An initial site data audit from the NSW VIS Flora Survey database was conducted to determine the full floristic (FF) sites of sufficient quality available for PATN statistical analysis. Statistical gap analysis and stratification identified remaining ecological gaps and a further 180 FF sites (funded by Coffs Council) were funded to target these gaps. A subsequent further review of sites determined a total of 534 FF sites for PATN analysis. PATN analysis produced 66 vegetation communities with floristic descriptions ready for mapping.

In addition, a further 462 rapid data sites were funded by Coffs Council to inform the mapping. The rapid sites collected up to 5 dominant species for 6 levels of vertical strata at each site. An enormous achievement of this project was site density is almost equal across both vegetated freehold and public tenures, a normally unavoidable bias that plagues most multi tenure mapping programs.

AREIAL PHOTOGRAPHY

The NSW Land and Property Management Authority (LPMA) captures airborne ADS40 4-band digital imagery at 50 cm resolution for most of NSW. The Coffs Harbour (Sep 09), Dorrigo (Sep 09) and Bare Pt (June 10) 1:100k ADS40 tiles covered the Coffs LGA. Two levels of imagery were utilised for the project, the 4-band 2-dimensional orthorectified images and the Level 1 Rectified stereo image pair strips. The Level 1 data was used for 3-dimensional (3D) mapping in a GIS stereo environment. Significant spatial errors up to +- 30 metres between Level 1 and the orthorectified data were discovered.

MAPPING PROCESS

Mapping was conducted by API/botanical experts in a stereo view workstation comprising of Planar stereo/3D monitors, ESRI ArcMap software and ERDAS Stereo Analyst™ software. The environment allows the direct delineation and attribution of polygons in 3D stereo view (Level 1 imagery) whilst simultaneously having a 2D context view and any number of additional datasets to guide mapping decisions. Interpreters had at their disposal all site data (733 sites) in 3D. Interpreters routinely collected field check points with geographic positioning systems to help extrapolate across areas of difficult interpretability. A total of 2479 check points were collected for the project but points were constrained to publicly accessible areas and areas that were visually accessible from public roads or tracks. This fieldwork resulted in an additional 14 map units being added to the existing 66 classified communities. The mapping was conducted on-screen at a range of scales but the final reference scale is deemed to be 1:5000. Linework was digitised using live streaming with a stream tolerance average of 5 metres (i.e. a vertex every 5 metres).

The study area was divided into 10 tiles for stereo mapping and the interpreters cross-referenced each other whenever possible to help guide their mapping decisions. The tiles were stitched together in GIS and interpreters then reviewed the edges and re-mapped any inconsistencies. A final quality review of the stitched map was conducted by examining each community in isolation and reviewing it for errors and ecological distribution anomalies. This review process fed back in further refinements. Vegetation clearing from the Sapphire-to-Woolgoolga highway upgrade was applied to the map. A Worldview2 image captured 7 April 2012 with 43 cm spatial resolution was the baseline for delineating the highway clearing footprint.

Due to the spatial accuracy issue between the Level 1 and orthorectified products, a final linework adjustment process for the study area was conducted using the orthorectified products as the accuracy reference. The focus of linework refinement was on vegetated/clearing interfaces, urban remnants, water bodies and other high contrast edges. Linework accuracy within contiguous vegetated areas were not systematically reviewed. All data stored and edited within ESRI File Geo-database format.

Positional Accuracy:

Accuracy is determined by the spatial accuracies of both the Level 1 and 2-dimensional orthorectified ADS40 imagery supplied by NSW LPMA. Orthorectified imagery is +- 2metres and Level 1 accuracy is not known.

Attribute Accuracy:

In this study, a numerical PATN analysis (Belbin 1994) was undertaken using 534 full floristic sites to determine the main floristic clusters for the study area. A 100-group analysis was undertaken. An agglomerative hierarchical approach was applied using the Bray-Curtis (Bray & Curtis1957) association measure to produce a dendrogram. In the agglomerative method, clustering is 'bottom-up' with the most similar sites being aggregated into larger clusters until there is a single cluster containing all sites. The dissimilarity between clusters was calculated using average values (or unweighted pair group method with arithmetic mean — UPGMA), where two clusters with the lowest average distance (with a beta value setting of -0.1) are merged to form the new cluster. To support the interpretation of the results a nearest neighbour analysis and fidelity was also carried out. 66 communities resulted with a further 14 map units added that resulted from findings in fieldwork. There are an additional 12 units that relate to disturbance and non-vegetated characteristics which produced 92 map categories in all. Interpreters would use all available supporting data to attribute each polygon to one of the categories and if uncertain or a mosaic of categories existed then a dual category would be assigned. Many factors affect the interpreters reliability to assign a category to a polygon (i.e. disturbance factors, clearing, regrowth, accessibility etc). For every polygon though, the interpreter was required to assign a reliability score from 1 to 4. The scoring is as follows: 1=Field survey confirmation; 2=high confidence; 3=moderate confidence; and 4=Low confidence.

In reality, some areas are disturbed to the point where none of the 92 categories reflect entirely what is present on the ground. Interpretation is then performed such that an expert needs to predict what occurred prior to disturbance in order to allocate to a category. This interpretation can occur within the 3D mapping environment or *in situ* and should be reflected within the interpreters reliability score.

Logical Consistency:

Geodatabase XY tolerance set at 0.2 metres and the resolution set at 0.1 metres. Topology validation was performed with a tolerance of 0.2 metres and all subsequent gaps and overlapping polygons fixed. Topology is correct.

Completeness:

Vegetation for the entire Coffs Harbour Local Government area has been mapped and every polygon attributed. Non-natural areas devoid of vegetation have not been mapped.

METADATA INFO

Metadata Date: 24/5/12

Appendix 5

Final vegetation community list for the Coffs Harbour LGA vegetation map.

Map code and name of floristic community		Area (ha)
CH_RF04	Hoop Pine Dry Rainforest	67
CH_RF05	Brown Myrtle Dry Rainforest	342
CH_DOF08	Pink Bloodwood–Tallowwood–Coast Banksia on Holocene Dunes	155
CH_DOF09	Pink Bloodwood–Blackbutt–Smooth-barked Apple Open Forest on Sand	409
CH_DOF01	Blackbutt–Turpentine–Pink Bloodwood Grassy Dry Sclerophyll Forest	6 697
CH_DOF02	Red Bloodwood–Needlebark Stringybark Dry Open Forest	3 707
CH_DOF04	Needlebark Stringybark–Scribbly Gum–Red Mahogany Dry Open Forest	162
CH_DOF05	Small-fruited Grey Gum–Grey Ironbark–Thick-leaved Mahogany–Tallowwood Grassy Dry Open Forest	1 997
CH_DOF06	Swamp Box–Broad-leaved Paperbark–Forest Red Gum–Red Mahogany Transitional Dry Open Forest	2 037
CH_DOF07	New England Blackbutt–Blackbutt–Thick-leaved Mahogany Dry Sclerophyll Forest of the Orara Escarpment	52
CH_DOF10	Thick-leaved Mahogany–Small-fruited Grey Gum–Grey Ironbark–Spotted Gum Dry Grassy Open Forest	2 085
CH_DOF11	Thick-leaved Mahogany Dry Grassy Open Forest	141
CH_FW01	Whites Tea-tree–Olive Tea-tree–Fern-leaved Banksia Wet Heathland/Shrubland	124
CH_FW02	Prickly-leaved Paperbark–Fern-leaved Banksia–Xanthorrhoea fulva Wet Heathland	273
CH_FW03	Leptocarpus tenax Wallum Sedgeland	33
CH_FW04	Baumea rubiginosa–Chorizandra–Lepyrodia scariosa Wallum Sedgeland	26
CH_FW05	Melaleuca sieberi–Prickly-leaved Paperbark–Wallum Heathland and/or Shrubland.	158
CH_FW06	Leptospermum polygalifolium–Whites Tea-tree Tall Shrubland	62
CH_FW07	Jointed Twig-rush Freshwater Wetland	27
CH_FW08	Eleocharis sphacelata E. acuta Broadleaf Cumbungi Freshwater Wetland	169
CH_FW09	Coral Fern Saw Sedge Freshwater Wetland	24
CH_FrW01	Broad-leaved Paperbark–Swamp Oak Willow Bottle Brush Floodplain Forested Wetland	936
CH_FrW02	Swamp Mahogany–Willow Bottlebrush Forested Wetland	182
CH_FrW03	Broad-leaved Paperbark–Willow Bottlebrush Channel Paperbark Forested Wetland	78
CH_FrW04	Broad-leaved Paperbark–Baumea rubiginosa Jointed Twig Rush Forested Wetland	554
CH_FrW05	Broad-leaved Paperbark–Swamp Box with Littoral Rainforest Elements of Hind Dunes	158
CH_FrW06	Swamp Mahogany–Broad-leaved Paperbark–Satinwood–Tassell Rush Wallum Swamp Sclerophyll Shrubland to Open Forest	103
CH_FrW07	River Oak Riparian Forest	201
CH_FrW08	Teatree–Water Gum Riparian Shrubland	382
CH_FrW09	Swamp Mahogany–Prickly-leaved Paperbark Forested Wetland on Sandy Soils	99
CH_FrW10	Swamp Oak–Sea Rush Saline Swamp Forest	200
CH_FrW11	Broad-leaved Paperbark–Twig Rush Swamp Forest	89

Map code and name of floristic community		Area (ha)
CH_G01	Strandline Grassland	59
CH_G02	Maritime Grasslands–Offshore Islands	8
CH_H01	Coast Banksia Shrubland on Holocene Dunes	400
CH_H02	Coast Wattle Shrublands	257
CH_H03	Kangaroo Grass Headland Grasslands	46
CH_H04	Black She Oak–Hakea dactyloides–Horned Sedge Clay Heath	76
CH_H05	Dagger Hakea Clay Heathlands	29
CH_H06	Coast Banksia Shrublands on Headlands	46
CH_H07	Swamp Oak Headland Shrubland	14
CH_H08	Wallum Banksia–Black She Oak Dry Heath	88
CH_H09	New England Tea-tree Rock Outcrop Shrubland	21
CH_H10	Grey Gum–Mahogany–Tea-tree Rock Outcrop Woodland	19
CH_MV01	Seagrass Beds	3
CH_RF01	Antarctic Beech Sassafras Cool Temperate Rainforest	3
CH_RF02	Antarctic Beech–Coachwood Warm/Cool Temperate Rainforest	573
CH_RF03	Coachwood–Callicoma–Sassafras with Emergent Hoop Pine Warm Temperate Rainforest	3 364
CH_RF06	Grey Mrytle–Brushbox Dry Rainforest	77
CH_RF07	Tuckeroo Beach Birds Eye Littoral Rainforest	100
CH_RF08	Headland Brush Box Littoral Rainforest	42
CH_RF09	White Booyong–Sloanea australis Floodplain Rainforest	31
CH_RF11	Yellow Carabeen–Black Booyong–Maidens Blush–Neolitsea dealbata–Archontophoenix cunninghamiana Subtropical Rainforest	4 240
CH_RF12	Coachwood Sassafras Prickly Ash Brush Box Warm Temperate Escarpment Rainforest	1 734
CH_RF13	Small-leaved Lily Pily–Pear-fruited Tamarind Littoral Rainforest (Scrub Creek)	91
CH_SW01	River Mangrove–Grey Mangrove	157
CH_SW02	Twig Rush Saltmarsh	44
CH_SW03	Club Rush Dune Soak	11
CH_SW04	Prickly Couch–Blue Couch ICOL Grassland/Saltmarsh	0
CH_SW05	Twig Rush Headland Sedgeland Soaks	4
CH_SW06	Sea Rush Saltmarsh	38
CH_SW07	Samphire–Saltwater Couch Saltmarsh	108
CH_WSF01	Flooded Gum–Bangalow Palm Riparian Wet Sclerophyll Forest	4 564
CH_WSF02	Blackbutt–Bangalow Palm–Turpentine Shrubby Wet Shrubby Forest	3 910
CH_WSF03	Turpentine–Sydney Blue Gum -Tallowwood Wet Shrubby Forest	3 306
CH_WSF04	Flooded Gum–Tallowwood–Brush Box Forest	1 459
CH_WSF05	Brush Box–Tallowwood–Blackbutt–Flooded Gum Forest	3 933
CH_WSF06	Sydney Blue Gum–Tallowwood Wet Shrubby Forest	4 041
CH_WSF07	Brush Box–Blackbutt Wet Sclerophyll/ Warm Temperate Rainforest	2 156
CH_WSF08	Blackbutt–Turpentine–Tallowwood–Forest Oak Grassy/Ferny Forest	3 527
CH_WSF09	Blackbutt Smooth-barked Apple–Rose Myrtle Ferny Forest	5 229
CH_WSF10	Tallowwood–Blackbutt–Sydney Blue Gum–Turpentine–Forest Oak Ferny Forest	4 811

Map code and name of floristic community		Area (ha)
CH_WSF11	Spotted Gum–Thick-leaved White Mahogany–Small-fruited Grey Gum Wet Shrubby Forest	2 693
CH_WSF12	Brush Box–Corkwood–Open Forest on Sand	10
CH_WSF13	Dunns White Gum Wet Shrubby Forest	90
CH_WSF14	Forest Red Gum on Headlands	39
CH_WSF15	Steel Box–Brown Myrtle Wet Sclerophyll Forest	546
CH_WSF16	White Mahogany Moist Shrubby Wet Sclerophyll Forest	67
CH_WSF17	Turpentine–Tallowwood–Small-fruited Grey Gum–Grey Ironbark–White Mahogany Wet Shrubby Forest	3 123
CH_WSF18	New England Blackbutt–Blackbutt–Smooth-barked Apple Forest of the Orara Escarpment	629