2 METHODS

2.1 REVIEW OF EXISTING INFORMATION

Prior to this study, regional scale vegetation mapping (1:100 000 scale) for the Burragorang (Fisher *et al.* 1995), Wallerawang (Benson & Keith 1990) and Katoomba (Keith & Benson 1988) and Oberon-Taralga (Fisher and Ryan 1994) mapsheets had been produced. The South Coast and Central Tablelands study (Tindall *et al.* 2004) had generated modelling and mapping for the mapsheets south and east of Lithgow. Earlier modelling work for the Southern Tablelands was completed by NPWS (2000). The descriptions of the vegetation patterns generated by these earlier studies are particularly useful, although the maps are not appropriate for use at 1:25 000 scale.

Some directed studies had been undertaken in particular areas that had been targeted for reserves and developments, or as part of either localised or more extensive assessments and regional studies. These include Gardens of Stone NP (EcoGIS 2002), Wollemi NP (Bell 1998) and the Warragamba Special Area (NPWS 2003). In addition, a number of post-graduate and master's level studies provided survey data for inclusion from the immediately surrounding areas.

2.2 EXISTING SITE DATA

Preliminary investigation of the study area suggested that 68 sites existed in the study area. These range in age from 1982 until just prior to the start of survey. However, since commencing survey, other sites were identified inside the mapping area boundaries raising total pre-existing numbers to 81. In addition, sites within the immediate vicinity of the study areas were also assessed, and altogether these come to a total of 955 sites within a 20 kilometre buffer of the study area boundaries.

Existing information has been carefully reviewed in order to collate datasets that have been collected using a comparable field survey method. There are a number of studies of relevance that have been undertaken within and surrounding the reserves. These vary in the type and methodology used to capture the information and thus their usefulness to this project. Only sites of direct use for this project were chosen (i.e. similar methodology and within close proximity to the reserves) for inclusion in analysis. Table 2.1 provides an overview of the studies of relevance to this project and the number of sites utilised from each. Surveys not included are shown to have zero sites utilised.

TABLE 2.1: EXISTING SURVEY DATA

Survey Name/Area	Sites Utilised	Total Sites Collected	Survey Method	Source
Airly Coal Mine	4	4	20 X 20 quadrat; 1-7 Braun-Blanquet	Long term vegetation monitoring, Lembit (pers. comm.)
All Sandstone	16	66	20 X 20 quadrat; 1-6 Braun-Blanquet	NPWS held data
All Wollemi	127	410	20 X 20 quadrat; 1-6 Braun-Blanquet	Bell (1998) Wollemi survey
Blue Mountains	3	15	20 X 20 quadrat; 1-6 Braun-Blanquet	Gellie & Jones, unpublished NPWS
Blue Mountains City Council	60	181	20 X 20 quadrat; 1-6 Braun-Blanquet	Steve Douglas, Blue Mountains City Council
Broad Headed Snake Potential Habitat Survey	3	25	20 X 20 quadrat; 1-7 Braun-Blanquet	Unpublished, data collected by Robert Payne (2001)
Clarence Coal Lease, swamp monitoring	4	4	20 X 20 quadrat; 1-7 Braun-Blanquet	Lembit (pers. comm.)
CRA Hunter	38	291	20 X 20 quadrat; 1-6 Braun-Blanquet	CRA LNE surveys in Hunter Region (Connolly).
EM631GLS	3	9	20x20 quadrat Separate cover / abundance and combined 1-6 BB	Steenbeeke (2005, unpublished)
Evans Crown Nature Reserve	16	16	20 X 20 quadrat; 1-6 Braun-Blanquet	Amanda Bryant, NPWS Bathurst.
Frappels Block, Sunny Corner SF	17	17	20 X 20 quadrat; 1-6 Braun-Blanquet	Amanda Bryant, NPWS Bathurst.
Gardens of Stone	81	81	20 X 20 quadrat; 1-6 Braun-Blanquet	Washington

Survey Name/Area	Sites Utilised	Total Sites Collected	Survey Method	Source
Hakea dohertyi study	58	123	20 X 20 quadrat; 1-6 Braun-Blanquet	Steenbeeke (1996)
Honours (Kowmung) Study	132	150	20 X 20 quadrat; 1-6 Braun-Blanquet	Steenbeeke (1990)
Ivanhoe North colliery rehabilitation survey	4	4	20 X 20 quadrat; 1-7 Braun-Blanquet	Lembit (pers. comm.)
Mount Werong	0	5	20 X 20 quadrat; Presence only	NPWS held data, Mjadwesch (unpubl.)
NP Southern CRA	40	40	20 X 20 quadrat; 1-7 Braun-Blanquet	NPWS southern CRA survey
Outside CRA records	1	109	20 X 20 quadrat; 1-6 Braun-Blanquet	NPWS held records
Priority 5 Management Area (P5MA)	58	800	20 X 20 quadrat; 1-7 Braun-Blanquet	Tindall *et al*. (2004)
Royal Botanic Gardens	32	51	20 X 20 quadrat; 1-6 Braun-Blanquet	Benson and Keith mapping of Katoomba (1988) and Wallerawang (1990)
Southern Zone CRA	179	250	20 X 20 quadrat; 1-7 Braun-Blanquet	NPWS held survey data, Beukers.
Steve Bell	42	43	20 X 20 quadrat; 1-6 Braun-Blanquet	NPWS held data (Bell unpubl.)
Taralga 1:25k sheet	3	42	20 X 20 quadrat; 1-6 Braun-Blanquet	NPWS held data (RBG)
Turon River NP	38	38	20 X 20 quadrat; 1-6 Braun-Blanquet	NPWS survey (Gellie unpubl.)
Warragamba Special Area	104	630	20 X 20 quadrat; 1-7 Braun-Blanquet	NPWS (2003b)
Winburndale Flora Reserve	36	36	20 X 20 quadrat; 1-6 Braun-Blanquet	NPWS survey (Bryant & Lembit)

2.3 SURVEY STRATIFICATION AND SITE SELECTION

Field surveys employed by a number of projects (e.g. NPWS 2003b) have used a stratified survey design to assist with the selection of survey sites. Stratification is a method used to reduce the landscape into more homogenous sampling units so that sampling effort can be spread across the variation in environments present. Generally strata are derived from data layers describing the geology, rainfall, elevation and aspect (NPWS 2003; Sivertsen & Smith 2001). Important considerations when developing a stratification include the following; how comprehensive the coverage is, the scale at which it is able to be used, what accuracy it shows to the expected boundaries, how well it 'dovetails' with adjacent areas when these have coverage, and whether it represents a character of the environment that is likely to have an effect upon vegetation distribution.

Initial layers considered for stratification in this project included the geology (a composite of lithology and age of the formation), aspect, altitude (in five separate elevation bands) and a simple woody – non-woody vegetation layer. However, closer examination of the distribution of geological units in the study area (particularly in the Newnes Mapping Area) revealed that the digitised mapping of the area was displaced by up to 800 metres to the northwest from its actual position. This was considered an unacceptable level of error, so this layer and those derived from it were rejected as possible stratification and mapping layers. The soil layer – one of the few layers that would yield information about the physical environment at a site – was also rejected as the coverage was inconsistent in source scale (1:250 000 and 1:100 000) and value. The mapping areas were covered by more than one classification system of soil landscape mapping and the variations were not able to be joined together easily and would have produced artificial boundaries to units along map boundaries (Kovac & Lawrie 1990; Kovac & Lawrie 1991; King 1993; King 1994).

Instead, stratification was developed from the detailed interpretation of landscape and vegetation features completed during this project. Each mapped polygon (Section 2.8) represents a homogenous combination of 'landscape' that includes geology, rock cover, dominant canopy species and understorey features. Feature codes, describing dominant canopy species and structural formations within unique substrates, were used as stratum. In this way a 1:25 000 scale map of substrate underpinned site selection across the range of climatic and altitudinal gradients present in the three distinct study areas.

Sample sites drawn from existing studies were reviewed against the stratification. Unsampled strata were highlighted in Arcview GIS against available access trails in order to identify potential sample points. Where strata fell across multiple land tenures, public lands were selected preferentially in order to expedite travel and access times. Further priorities were allocated to localities where multiple strata could be sampled in close proximity to each other. Survey of State Forest tenures was completed under permit number 21924. Access to privately owned tenure followed verbal or written permission from landowner or manager.

2.4 FIELD SAMPLING

Field survey sought to sample areas that were typical of the surrounding vegetation and were as free of obvious disturbance as possible.

Sampling was carried out in teams of two people consisting of a botanist and an assistant. Species that could not be identified in the field were recorded to the nearest possible family or genus and tagged for later identification. Species that could not be identified accurately were taken or sent to the NSW Herbarium for identification.

Field sample sites were 0.04 hectares in area. The area was marked out using a 20 by 20 metre tape-bounded quadrat, although in some communities (such as riparian vegetation) a rectangular configuration (ten metres x 40 metres) of the plot was required. Location was determined from Garmin 12 Global Positioning System to as good and accuracy as possible (usually less than 10 metres) and this point located at a corner of the plot (usually the SW corner). Within each survey plot all vascular plant species were recorded and assigned a cover abundance score using a modified six-point Braun-Blanquet scale (Poore 1955) as shown in Table 2.2 below.

TABLE 2.2: COVER ABUNDANCE SCORES

Score	Cover Abundance
1	Rare, few individuals present (three or less) and Cover <5%;
2	Common and cover <5%;
3	Very Abundant and Cover nearing 5% OR Cover from 5% to <25%;
4	Cover from 25% to less than 50%;
5	Cover from 50% to less than 75%;
6	Cover 75% or more

Estimates were made of the height range, projected foliage cover and dominant species of each structural stratum recognisable at the site. Measurements of slope and aspect were taken. Notes were also made on geology, soil type and soil depth. The percentage of outcropping rock, loose surface rock (cobbles more than 40mm on the longest dimension), litter and bare soil were estimated. Evidence of recent fire, erosion, clearing, grazing, weed invasion or soil disturbance was also recorded. The location of the site was determined using a Garmin 12 global positioning system (GPS), using the AGD66 Datum. Elevations were read from the GPS, and where not considered accurate to within 10m were augmented by a value taken off 1:25 000 topographic maps. Digital photographs were also taken at each site and are attached to the floristic site data in a database operating in Microsoft Access.

2.5 SITE NOMENCLATURE

For the purpose of managing existing and new field data, each site was initially recorded in reverse date (YYMMDD) format with a dash and the site number for the day. For instance, 050422-4 would represent the fourth site collected for the day during the survey on the date April 22nd, 2005. This allowed sites to be entered into the database in a manner that placed the sites into chronological order when stored allowing rapid updates of data and assessment of survey effort. Following the completion of intensive survey, each survey plot was given an eight-digit alphanumerical survey identification number. A separate survey identification code was also given to all data to distinguish its source. Using this system enables the reader to understand basic geographical information about the survey site.

For example, site number EDT06M1M, which is the corrected version for the site listed above:

The first three letters "EDT" refer to an abbreviation of the first characters of the 1:25 000 topographic mapsheet name, in this case the Edith mapsheet, and are usually either the first three consonants or a vowel and two consonants where that sheet name begins with a vowel.

The fourth and fifth digits "06" refer to the site number by mapsheet, ie. the sixth site on this mapsheet. Previous studies using this numbering system were taken into account and numbering of the sites was amended accordingly to follow on from previous surveys.

The sixth character "M" refers to the geological substrate evidenced at the site in this case undifferentiated metamorphic materials. The geologies found within the study area were coded as follows:

A = Alluvium (primarily gravels and organic soils, although extensive sandy soils in some parts
B = Basalt
C = Conglomerate
D = Devonian Sediments (mostly quartzite with some porphyritic rhyolite)
G = Granite
L = Limestone and marl
M = Metamorphic materials
N = Narrabeen Sandstone
O = Ordovician metamorphics
P = Permian Sediments (coal, sandstone, siltstone and shale)
R = Rhyolite and porphyry
S = Silurian metamorphics
T = Talus materials, usually downslope of Narrabeen sediments cliff-faces
Z = Quartzite

The seventh character "1" refers to the generalised aspect observed at the site (east in this case) using the following categories:

1 = 67.6 – 112.5 or E
2 = 112.6 – 157.5 or SE
3 = 157.6 – 202.5 or S
4 = 202.6 – 247.5 or SW
5 = 247.6 – 292.5 or W
6 = 292.6 – 337.5 or NW
7 = 337.6 – 22.5 or N
8 = 22.6 – 67.5 or NE

The eighth character "M" is used to describe the morphology. Morphology coding is as follows:

C = Crest
U = Upper Slope
L = Lower Slope
M = Mid Slope
V = Open Depression
D = Closed Depression
S = Simple Slope
F = Flat
R = Ridge

2.6 DATABASE STORAGE

All the data collected during field survey was entered into a Microsoft® Access97 database. This database was developed by NPWS to facilitate the storage, entry and manipulation of systematic floristic survey data. Database entry windows are similar to the format used for field proformas to minimise data entry errors. All species recorded are coded using the Census of Australian Vascular Plant Species (CAPS). New species or subspecies, as identified by the Royal Botanic Gardens, not previously listed in the CAPS were assigned new codes to the master CAPS database. An extensive data validation procedure was undertaken to ensure that the data entered into the Access database matched what had been recorded in the field. Accuracy of survey site locations was also reviewed against original field sheets. Site photographs have been electronically attached to sites and stored with the database.

2.7 TAXONOMIC REVIEW

For this project, all nomenclature was reviewed and standardised across data sets for analysis. Synonyms were updated to reflect currently accepted revisions. Nomenclature was standardised to follow Harden (1990-1993 and revised editions 2000-2002). Recent taxonomic revisions have been identified using the Flora Online Website that has been developed by the Royal Botanic Gardens (2005). The principal outcomes of the taxonomic review are as follows:

- All exotic species were identified and excluded from the analysis dataset;
- The review highlighted species that were likely to have been incorrectly identified or incorrectly entered into the database. Original field sheets were reviewed to determine the status of these species and where data entry errors were detected, changes were made to the database. Where data entry errors were not detected, species were reviewed against existing literature. Where this indicated them to be outside their likely range, and no confirmation had been made, the record was deleted from the database;
- The review highlighted inconsistently collected records of species containing subspecies or varieties. In such cases, subspecies were either lumped to species level or were assigned to a single subspecies or variant if only one sub-specific entity is present in the study area;
- The review identified groups of species within which a regular inaccuracy in clear identification could be occurring as a result of season of survey or poor ability to distinguish in the field due to missing material or life stages;
- The review identified species hybrids that are not recognised formally in the literature. These were assigned to one or other of the parent species based on the predominance of either in surrounding environments; and
- The review highlighted flora species identified to genus level only. Samples identified to genus level only which were low in number and low in cover scores (less than five percent cover) were deleted from the analysis dataset. Where genus only samples were numerous, but could not be clearly assigned to a single species, they were left unchanged.

2.8 AERIAL PHOTO INTERPRETATION

2.8.1 Objectives

Extensive Aerial Photo Interpretation (API) was required to generate a complete spatial coverage of the Western Blue Mountains (Map 1) showing the distribution of landcover elements. The API component of this project has been used to meet several objectives. These are to:

- Quantify the extent of native vegetation cover across the mapping area;
- Guide and inform the mapping of vegetation communities derived from field data; and
- Provide an index of relative vegetation condition for all native vegetation cover.

2.8.2 Area Mapped and Photography Used

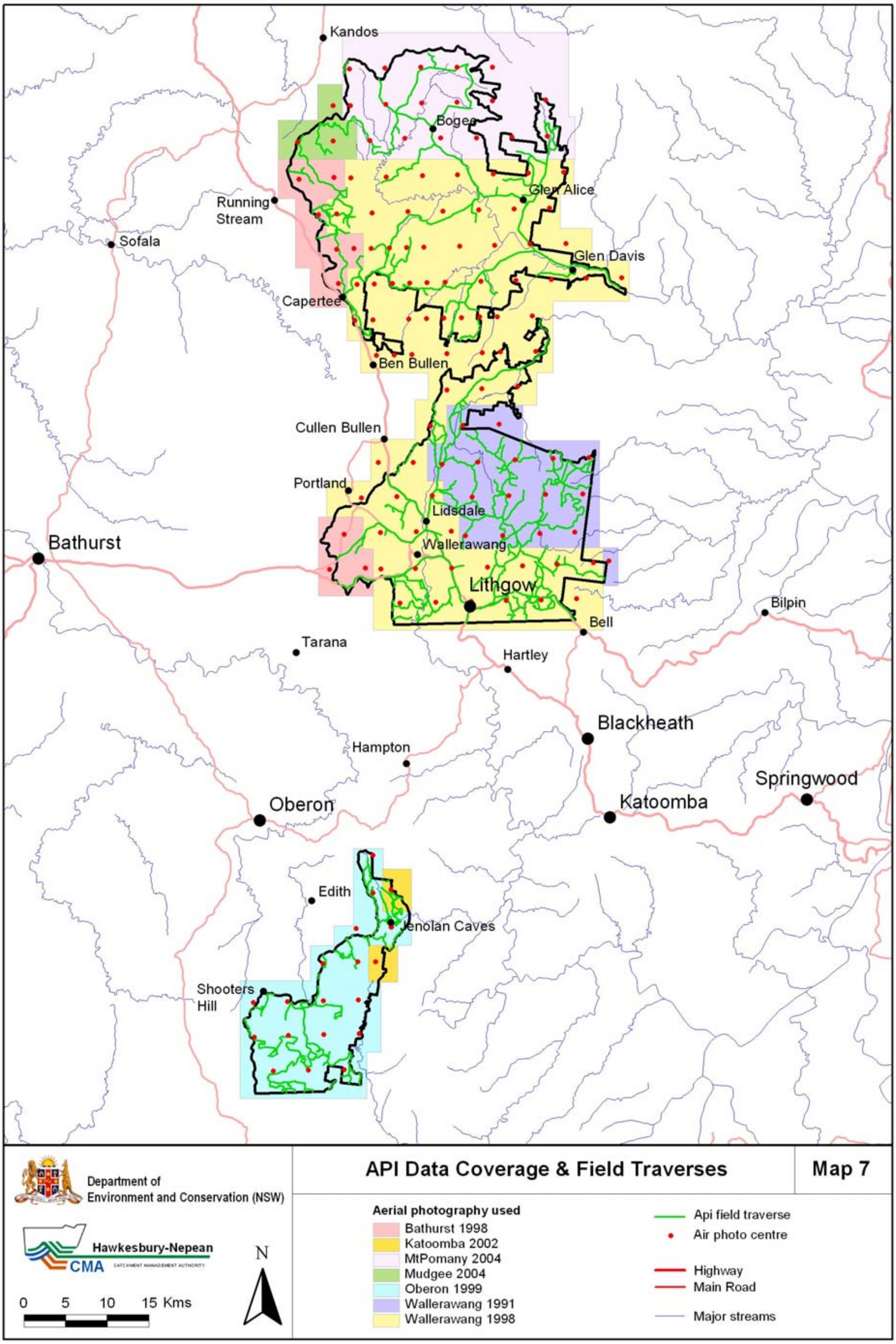
Air photo interpretation of the Western Blue Mountains was completed by a single interpreter using 1:25 000 scale aerial photos. Table 2.3 shows the aerial photographs used and Map 7 illustrates the extent of each coverage and the routes traversed.

2.8.3 Air Photo Interpretation and Landcover Classification

Air photo interpretation of landcover components as required by this project essentially involved reducing the variability in the landcover continuum according to a set of prescribed but open-ended criteria.

An API stratification of all landcover within the Western Blue Mountains was undertaken by applying the following attribute classes to each polygon. The Aerial Photos were interpreted to provide information on:

- Canopy Type
- Non-canopy Features
- Crown Cover
- Visible Rock
- API Confidence
- Understorey
- Disturbance Severity and Type of Disturbance



Map 7: API Data Coverage & Field Traverses

Attributes for each of these themes were encoded directly into ArcView GIS for each polygon. Approximately 27 000 polygons were mapped with an average patch size of 4.1 hectares. To ensure consistency in the interpretation of features across the Study Area, interpretation was tied to explicit mapping thresholds within each of the above themes.

The prescribed minimum patch size for mapping was one hectare. However, smaller patch sizes were mapped at the interpreter's discretion. Small areas considered significant enough to map included rock outcrops, rainforest patches, sedgeland and heathland. The mapping pathway is presented in Figure 2.2.

TABLE 2.3: AERIAL PHOTOGRAPHY INTERPRETED

Title	Run	Prints	Date
BATHURST	1	43-45	1998
BATHURST	2	17	1998
BATHURST	3	11-12	1998
BATHURST	4	22	1998
BATHURST	11	40	1998
BATHURST	12	44-46	1998
KATOOMBA	8	48	2002
KATOOMBA	9	29	2002
KATOOMBA	10	75	2002
MT POMANY	11	99-105	2004
MT POMANY	12	11-22	2004
MT POMANY	13	97-107	2004
MUDGEE	12	38	2004
MUDGEE	13	31-33	2004
OBERON	7	49	1999
OBERON	8	46	1999
OBERON	9	45-47	1999
OBERON	10	73-75	1999
OBERON	11	62-68	1999
OBERON	12	15-21	1999
OBERON	13	18-22	1999
WALLERAWANG	8	8-10	1991
WALLERAWANG	9	36-44	1991
WALLERAWANG	10	58-64	1991
WALLERAWANG	11	20-26	1991
WALLERAWANG	12	32	1991
WALLERAWANG	1	77-89	1998
WALLERAWANG	2	15-25	1998
WALLERAWANG	3	28-39	1998
WALLERAWANG	4	59-74	1998
WALLERAWANG	5	77-87	1998
WALLERAWANG	6	14-23	1998
WALLERAWANG	7	7-11	1998
WALLERAWANG	8	45	1998

Title	Run	Prints	Date
WALLERAWANG	9	53-55	1998
WALLERAWANG	10	77-81	1998
WALLERAWANG	11	19-23	1998
WALLERAWANG	12	3-15	1998
WALLERAWANG	13	37-47	1998

2.8.4 Feature Code

A primary requirement of the API was to map patterns of similar species composition within the upper stratum of native vegetation across the Study Area. The conventional process of delineating such areas by drawing a line of best fit between areas that are typically occupied by a species or group of species has the effect of reducing the variability of the landcover into “canopy types”. Field traverses were used to relate photo patterns with canopy species composition.

A table of canopy types was compiled throughout the course of the project from field observation and reference to other data sources such as plot based floristic survey and previous vegetation mapping (See Table 2.1). All vegetation cover classified as having a crown cover greater than three percent (crown separation ratio of less than five (Walker & Hopkins 1984)) was allocated a canopy species code based on the dominant combinations of the upper stratum species.

Canopy types were described using a two level hierarchy. The first level in the hierarchy, Level 2, described a broad, recurring pattern in upper stratum species within a unique habitat. This unique habitat most often reflected similar geological substrates and topographic positions. The second level in the hierarchy, Level 3, was allocated for distinct patterns of species that could be identified within the broader patterns described in Level 2 and retained similar environmental characteristics.

A complete list of feature codes is provided in Appendix B.

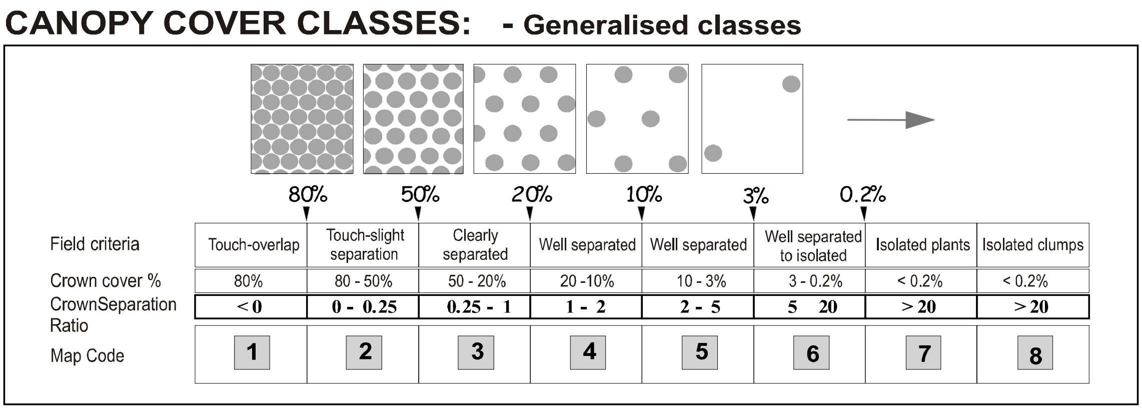
2.8.5 Non-canopy Features

Other landcover features mapped include non-vegetated and highly modified landcover such as infrastructure and cleared lands. A list of non-canopy features is provided in Appendix A.

2.8.6 Canopy Cover

An eight-scale classification of Crown Separation Ratio was utilised as a relative measure of canopy cover (Figure 2.1).

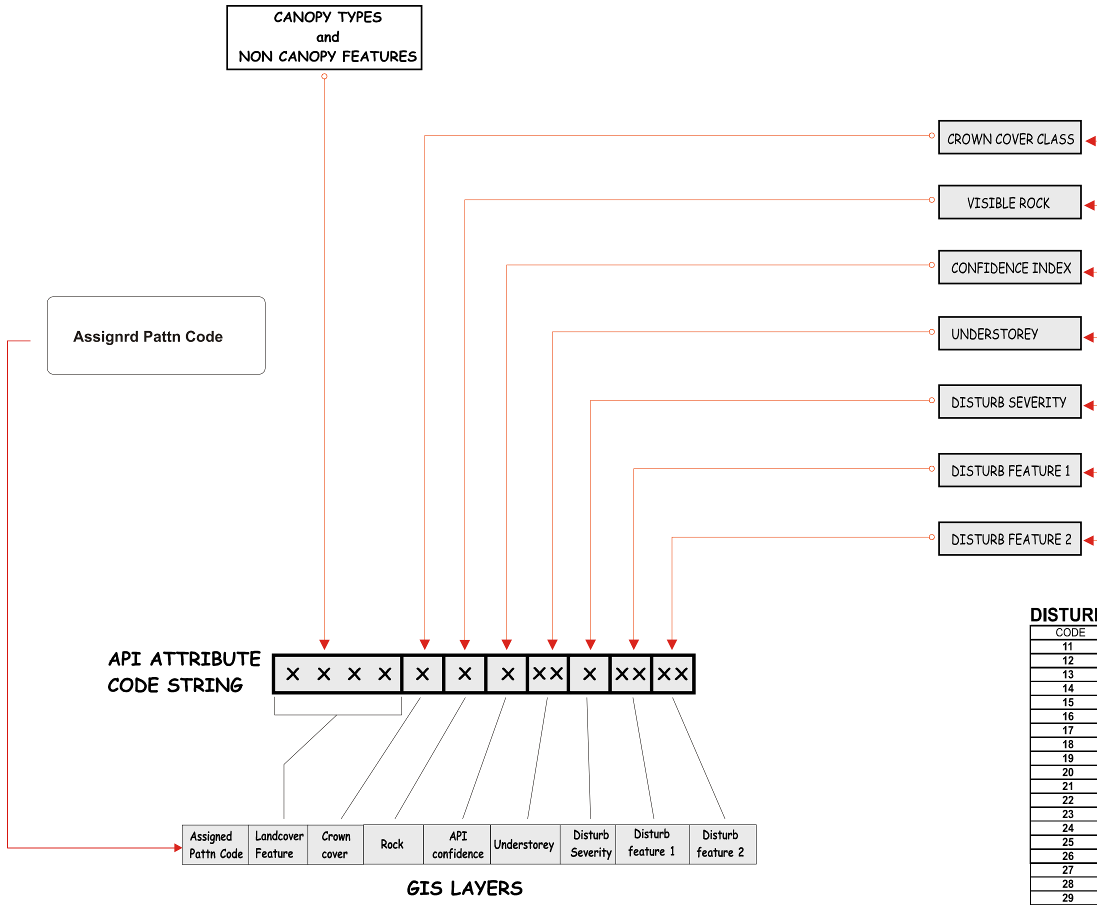
Figure 2.1: Canopy Cover Classes



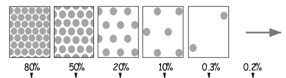
Adapted from Walker and Hopkins (1984)

Figure 2.2: API Mapping Pathway and Features

API ATTRIBUTES and GIS LAYERS



CANOPY COVER CLASSES: - Generalised classes



Field criteria	Touch-overlap	Touch-slight separation	Clearly separated	Well separated	Well separated	Well separated to isolated	Isolated plants	Isolated clumps
Crown cover %	80%	80 - 50%	50 - 20%	20 -10%	10 - 3%	3 - 0.2%	< 0.2%	< 0.2%
CrownSeparation Ratio	< 0	0 - 0.25	0.25 - 1	1 - 2	2 - 5	5 - 20	> 20	> 20
Map Code	1	2	3	4	5	6	7	8

VISIBLE ROCK

CODE	CLASS
0	NIL (<2%)
1	Visible - 10%
2	10% - 20%
3	20% - 50%
4	50% - 75%
5	75% - 100%

API CONFIDENCE CLASS

CODE	CLASS	CONTRIBUTING FACTORS
1	Very High	• Sites visited – features checked
2	High	• Confident extrapolation from localised sampling • Interpretability of features considered high, consistent with features sampled elsewhere
3	Medium	• Not visited • Some similarity with features sampled elsewhere • Uncertainty in species interpretation
4	Low	• Site or locality not visited • Remote area • Inconsistent with features sampled elsewhere • Low confidence in species interpretation

UNDERSTOREY

CODE	DOMINANT UNDERSTOREY ELEMENTS
10	Mesic / rainforest
11	Intermediate - moist, shrubs
12d	Dry - intermediate, shrubs
12r	Dry - rocky, shrubs (xeric)
12x	Dry, scrub / shrubs (xeric)
13	Dry, shrubs / grasses
14	Dry - intermediate, shrubs / grasses
16	Acacia
18a	Moist - swamp, shrubs / sedges on gully alluvium
18s	Dry - moist, shrubs / sedges assoc with seepage areas
19	Dry, mallee and shrubs (xeric)
21	Riparian complex
21a	Moist, shrubs / grasses on alluvium

DISTURBANCE SEVERITY

CODE	SEVERITY	INDICATORS
1	Lowest disturbance	Tracks may be present but not clearly evident from API Weeds not clearly evident from API Canopy gaps likely to be natural Regrowth <10%
2	Moderate disturbance	Limited areas of weed infestation evident (eg in canopy gaps) Trails clearly evident Canopy gaps and regrowth associated with trails (timber extraction) evident Moderate disturbance associated with clearing or part clearing evident Regrowth 10 - 30% Past grazing activity evident (small dams, yards, buildings etc) Scattered or clustered areas of Euc regen, Acacia, Kunzea Limited areas of erosion, bare soil or landslip
3	High disturbance	Severe disturbance associated with community or industrial infrastructures such as roads and powerline easements are clearly evident Severe weed infestation evident Regrowth >30% Continuous even aged stands of Euc regen, Acacia, Kunzea Large areas of erosion, bare soil or landslip

DISTURBANCE FEATURES

CODE	FEATURES (Features <2ha mapped as point features)
11	Roads, trails (within or adjacent)
12	Transmission line
13	Weeds (indicate in comments)
14	Canopy gaps
15	Regrowth
16	Grazing / pasture
17	Cultivation
18	Plantation / woodlot (not pine wildlings)
19	Rural residential subdivision
20	Urban / industrial development (includes mining)
21	Recreation area
22	Small dam
23	Open water (includes large dams)
24	Erosion / bare soil
25	Landslip / rock scree
26	Building
27	Pioneering shrubs / Acacia
28	Windthrow
29	Clearing / pt clearing (includes clearing adjacent polygon)
30	Recent fire
31	Viney scrub
32	Allocasuarina verticillata - Bursaria spinosa
33	Previous logging (indicators: gaps / log dumps / trails etc)
34	Pine wildings
35	Exotic trees other than pine (willow / poplar etc)

Closed, Mid dense to Sparse Vegetation Cover: canopy map codes 1-4

All vegetation cover that displays canopy integrity has been mapped. Canopy integrity has been defined as having a Crown Separation Ratio less than two (equivalent to canopy cover greater than ten percent). All vegetation cover falling within this class and with an area greater than one hectare has been mapped. This covers a range of sizes from large expanses of vegetation cover to remnant patches in cleared landscapes. They are attributed with a code describing the canopy species present, visible rock, the nature of the understorey, the severity and main types of disturbance present and an API confidence index.

Sparse Vegetation Cover: canopy map code 5

A regular feature of native vegetation cover in disturbed environments is the presence of scattered trees above an open or absent understorey, in a mosaic of cleared and remnant vegetation. Areas having a Crown Separation Ratio between two and five (equivalent to canopy cover between three and ten percent) are considered not to display canopy integrity. In view of this, attribution with a code describing the canopy species present and the nature of the understorey has been left to the discretion of the interpreter. Attributes indicating visible rock, the severity and main types of disturbance present and an API confidence index have been included.

Sparse to Very Sparse Vegetation Cover: canopy map codes 6-8

This includes obvious features such as man made structures, cleared paddocks, etc. Specific non-vegetative features attributed include landslides, rock outcrops and water bodies. Areas having a Crown Separation Ratio greater than five have not been attributed with a code describing the canopy species present and the nature of the understorey.

Visible Rock

Visible rock (Table 2.4) was interpreted for the purpose of providing information that may be of interest for further scientific survey investigation (herpetological, botanical) as well as for fire management and logistics (fuel and bushfire behaviour mapping, helicopter access points) etc.

TABLE 2.4: VISIBLE ROCK CLASSES

Code	Class
0	NIL
1	Visible – 10%
2	10 - 25%
3	25 – 50%
4	50 – 75%
5	75 – 100%

Interpretation Confidence

Four classes of interpreter mapping confidence were applied to each mapped polygon (Table 2.5). These classes enable users to understand the reliability of the mapping features.

TABLE 2.5: INTERPRETER CONFIDENCE CLASSES

Mapping Confidence Class	Confidence Assessment Criteria
1: Very High	• Sites visited, features checked
2: High	• Confident extrapolation from localised sampling • Interpretability of features considered high, consistent with features sampled elsewhere
3: Medium	• Not visited • Some similarity with features sample elsewhere • Uncertainty in species interpretation
4: Low	• Site or locality not visited • Remote area • Inconsistent with features sampled elsewhere • Low confidence in species interpretation

Understorey Classes

Understorey characteristics were interpreted where they were visible and grouped into a number of broad classes, as in Table 2.6. Understorey has been collected for a number of reasons. Firstly, it provides an additional layer of information that can be used to more accurately delineate vegetation community distribution. Secondly, it can be used to clarify habitat values for fauna. Understorey features are most reliably interpreted from mesic and sheltered forests, rocky open woodlands and through lower canopy cover vegetation formations. It is least reliable for understorey characteristics that lie between mesic and xeric.

TABLE 2.6: API UNDERSTOREY CODES

Understorey Code	Dominant Understorey Elements
10	• Mesic / Rainforest
11	• Intermediate – moist; Shrubs
12d	• Dry – intermediate; Shrubs
12r	• Dry; rocky, Shrubs / scrub (xeric)
12x	• Dry; Shrubs / scrub (xeric)
13	• Dry; Shrubs and grasses
14	• Dry – intermediate; Shrubs and grasses
16	• Acacia species
18a	• Moist – swamp; Shrubs and sedges on gully alluvium
18s	• Dry – moist; shrubs and sedges associated with seepage areas
19	• Dry; mallee and shrubs
21	• Riparian complex
21a	• Moist; shrubs and grasses on alluvium

Disturbance Severity Classes

All vegetation cover was assessed for disturbance. An initial code was applied to indicate the severity of disturbance based on a subjective assessment using a number of predefined indicators. This was a three-class system, including Low, Medium and High. The two most dominant types of disturbance were recorded in separate fields. Disturbance severity and type are displayed in Tables 2.7 and 2.8 respectively.

TABLE 2.7: DISTURBANCE SEVERITY CLASSES AND INDICATORS

Code	Severity	Indicators of Disturbance
1	Lowest Disturbance	• Tracks may be present but not clearly evident from API
		• Weeds not clearly evident from API
		• Canopy gaps likely to be natural
		• Regrowth <10%
2	Moderate Disturbance	• Limited areas of weed infestation evident (eg in canopy gaps)
		• Trails clearly evident
		• Canopy gaps and regrowth associated with trails (timber extraction) evident
		• Moderate disturbance associated with clearing or part clearing evident
		• Regrowth 10 - 30%
		• Past grazing activity evident (small dams, yards, buildings etc)
		• Scattered or clustered areas of Eucalypt regeneration, Acacia spp. • Kunzea spp. etc.
		• Limited areas of erosion, bare soil or landslip
3	High Disturbance	• Severe disturbance associated with community or industrial infrastructure • Such as roads and powerlines easements are clearly evident
		• Severe weed infestation evident
		• Regrowth >30%
		• Continuous even aged stands of Eucalypt regeneration, Acacia spp. • Kunzea spp. etc
		• Large areas of erosion, bare soil or landslip

TABLE 2.8: DISTURBANCE FEATURE TYPES

Disturbance Code	Disturbance Feature Type
11	• Roads, Trails (within or adjacent polygon)
12	• Transmission Line
13	• Weeds
14	• Canopy Gaps
15	• Regrowth
16	• Grazing / Pasture
17	• Cultivation
18	• Plantation / Woodlot (not pine wildlings)
19	• Rural Residential Subdivision
20	• Urban / Industrial Development (includes mining areas)
21	• Recreation Area
22	• Small Dam
23	• Open Water
24	• Erosion / Bare Soil
25	• Landslip
26	• Building
27	• Pioneering shrubs / Acacia
28	• Windthrow
29	• Clearing / Pt clearing
30	• Recent fire
31	• Viney Scrub
32	• Allocasuarina verticillata / Bursaria spinosa
33	• Pine wildlings
34	• Exotic trees other than pine (willow / poplar etc)

2.9 DIGITAL DATA CAPTURE AND MAP COMPILATION

The line work from the Aerial Photo Interpretation was completed on transparent overlays and delineated on every second photo frame.

The transfer of line work to a GIS format used a scanning and photogrammetric rectification process for each annotated photo. Ground control points were established using topographic maps and a 1:25 000 series of digital orthographic photos. These control points were used to rectify (the adjustment used to compensate for distortion due to change in elevation) and geo-reference (reference the spatial location by using the locations of known features) each photograph. Following this process, the raster data was converted to vectors, cleaned, and in turn converted to polygons.

A digital data layer supporting topology was cleaned and built in the ArcInfo GIS package. Polygons have been labelled with the attributes identified during interpretation process as per feature code table (Appendix A) and Tables described above.

Vegetation Pattern Code (Formation, Sub-formation, Feature);

- Crown Cover;
- Structural Formation;
- Visible Rock;
- API Confidence Class;
- Understorey;
- Disturbance Severity and Disturbance Feature (two fields).

2.10 VEGETATION CLASSIFICATION

2.10.1 Existing Vegetation Classification in the Hawkesbury – Nepean Catchment

Multiple vegetation classification systems have been applied to the native vegetation cover of the Hawkesbury – Nepean catchment (RBG 1:100 000 series) or in part NPWS (2000; 2002; 2003), Bell (1998), Tozer (2003). The scale of both the classifications of the vegetation as well as the derived map products is highly variable such that no single system can be applied to the whole region. This arises because there is a wide variety of different uses for vegetation maps ranging from site based planning associated with urban development and clearing applications through to regional planning and fire management. Detailed delineation of vegetation communities is used to highlight endangered ecological communities and is a requirement of fine-scale mapping used by councils and land managers (e.g. ESP 2001; NPWS 2002; Bell 2002) while estimates of clearing and regional vegetation patterns are sought by regional conservation planning projects (Thomas *et.al*. 2000; Tindall *et al.* 2004).

The recently completed vegetation classification of the South Coast Priority Five Mapping Area (P5MA) (Tindall *et al.* 2004) provides the most complete single-source coverage of the broad vegetation communities in the southern Hawkesbury – Nepean catchment. However, the northern catchment includes large areas of reserved lands (Wollemi, Blue Mountains and Yengo National Parks) for which there is more detailed vegetation classification though the mapping remains coarse Bell (1998) and (Bell *et al.* 1993). By contrast local council mapping adjoining the study area is detailed in both classification and mapping (ESP 2001).

2.10.2 Relationships between Vegetation Community Classifications

In order to assess the floristic relationships between vegetation classifications used in several overlapping and/or adjoining regions, all available site data within a 20 kilometre radius of the study area was included in the analysis. In this way, the allocation of sample sites to vegetation communities described by other studies (Tindall *et al.* 2004; Bell 2004; ESP 2001) could be tracked in any new analysis. Further the relationships between the addition of new sites collected by this project and these existing sites could be assessed in the same way. In all, some 1257 data points were analysed. 466 sites occurred within areas mapped as part of this project, including the Jenolan Caves Trust Reserve.

2.10.3 Analysis of Data

All data was compiled and a full list of all species recorded was examined to standardise taxonomy across the various studies. In most cases the taxa below species level (varieties and subspecies mainly) were not recorded consistently (even within surveys). Therefore all taxa below species level were collapsed upwards unless they could be shown to be reliable. Species considered unlikely to be in the area were also examined for validity, and where possible site records were examined to determine either to accept as recorded, or rejects the entry as a data error. Species that had been segregated as part of a taxonomic review within the last 20 years were collapsed under the species in the broad sense (to remove errors induced by date of sampling). Where a group of species shows poor discernability in the field these were also collapsed under a single taxon and it treated in the broadest sense.

Analysis of all data from all 1257 sites was undertaken using the analyses in the PATN suite (Belbin 1994). A number of different analyses were run in an effort to ascertain the relationships between the spatial data layer and the floristic sites. Two separate sets of analyses were conducted, and initial map construction was based on the first and confirmed with the second. The first set of runs was conducted on data containing species data as extracted from the Vegetation Survey Database, with genus-only and single occurrence species within the dataset. Masking for all species of less than two sites occurrence was applied to the dataset using the appropriate option in PATN and analyses run in accordance with the procedures outlined below. The second set of analyses were conducted using the complete data set with single-occurrence taxa and those recorded only to genus level physically removed prior to analysis.

Analysis of the data was undertaken using three different approaches. An initial non-hierarchical clustering method (ALOC) using the kulczinski coefficient was applied to the data set, using five seeds and a maximum of 100 groups with 50 iterations. In the first analysis this produced 98 groups, in the second it generated 99 groups. As the method starts with randomly chosen seeds the groups generated in one run will not necessarily be labelled the same in subsequent runs, although in most cases sites will end up in similarly-composed groups following each run.

Secondly, an association matrix displaying dissimilarity scores between all pairs of sites was produced using the ASO module in PATN. An unweighted pair group arithmetic averaging (UPGMA) clustering strategy was applied to the matrix to derive a hierarchical classification from the bottom up (FUSE) and a similar approach from the top down using Polythetic Divisive clustering (PDIV). The default beta value of –0.1 was used on all analyses, and a total of 100 groups was requested from the analyses.

A dendrogram was produced to display the hierarchical relationships between both individual sites and groups of sites from each of the three different analyses. Two sites in vegetation sampling are rarely identical given the natural continuum of vegetation patterns in the landscape. The question facing the analyst is to what degree are differences worthy of justifying unique groups of sites. These decisions are based on field observations and experience with similar vegetation. This interpretation results in either a broader or finer classification depending upon the aims and limitations of project.

Groups of sites were examined using the species that characterise the group, the structural features such as height and tree cover, along with physical characteristics such as geology, topographic position and aspect. These groups were matched to the spatial layer and communities allocated to groups of polygons based on similarity of coding strings and the frequency and similarity of floristic sites located in each polygon class.

2.11 DESCRIPTION OF VEGETATION COMMUNITIES

Vegetation communities have been described in detail using a number of features. Firstly, combinations of sites defining unique groups in the cluster analysis were used to identify the characteristic flora species of that group. These species are presented as a summary for each community in the profiles found in Volume Two. These are known as Map Units and describe the location, dominant or characteristic species (generally tree species), broad understorey description and structure. Each Map Unit is given a label to describe the vegetation present. This label is generally found only in this study in order to differentiate it from any other study unless: (a) sites used to describe a community have been used in an adjoining study that replicates the methods used here (e.g. NPWS 2003) or (b) a community defined in this study was based solely on sites collected in other studies (e.g. Tindall *et al.* 2004)

Each profile includes a brief summary of key identifying features. These include commonly occurring plant species and habitat characteristics. Example locations are also given, as is a sample photograph to guide in recognition of the community. The proportion of each disturbance class (percent) found within the mapped vegetation community is also presented along with figures highlighting the total extant area of the community within the study area. Data describing the vegetation structure (height and vegetation cover) has been generated from field sample points.

Each profile includes a list of diagnostic species. This species list is derived from the field site data and can be used to help define the floristic composition of a community in relation to all others present in the study area. A concept known as 'fidelity', developed by Keith and Bedward (1999) based on Westhoff and van der Maarel (1978) provides a systematic method for identifying 'diagnostic' or 'characteristic' species within an assemblage. This approach recognises that within given vegetation community a species may be conspicuous by the frequency and abundance with which it has been recorded. However, in other communities the same species may only occur sparsely, at low abundance or not at all. Patterns may be revealed by analysing the performance of each individual species found within each community. Table 2.9 describes the criteria used to define positive, negative, uninformative and constant species. Positive species are recorded more frequently within a community and/or at a higher median cover abundance than in all other vegetation communities. Positive species also include those that are only recorded within the target community irrespective of their frequency of detection or abundance. A species that is present in all other communities but is less common or abundant or not present at all in the target community is defined as a negative diagnostic species. A constant species is one that occurs consistently within many communities. Uninformative are those that are recorded at lower abundance and less frequently across all communities. The profile lists all species classified as positive, negative and constant. Some uninformative species have been included in the species list to aid field identification.

TABLE 2.9: DEFINITIONS OF DIAGNOSTIC SPECIES

		Occurrence of Species in Residual Map Units		
		Frequency>=35% AND C/A>=2	Frequency<35% OR C/A<2	Frequency=0
Occurrence of Species within Target Map Unit	Frequency>=35% AND C/A>=2	Constant	Positive Diagnostic	Positive Diagnostic
	Frequency<35% OR C/A<2	Negative Diagnostic	Uninformative	Positive Diagnostic
	Frequency=0	Negative Diagnostic	Uninformative	-

C/A = Cover Abundance

2.12 MAPPING VEGETATION COMMUNITIES

The mapping of vegetation communities integrated patterns in canopy and understorey from aerial photo interpretation with soil and geology mapping. Soil and geological influences are included within the aerial photograph coding as each code is structured hierarchically underneath major landscape and geological feature.

Allocation of a vegetation community to a mapped feature code was achieved using the following steps. Firstly, a number of vegetation communities appear as highly contrasting patterns on aerial photographs. These include swamps, rainforest, heaths and River Oak forests. These communities can be mapped with a high degree of reliability and correlate strongly with classified site data.

Secondly, eucalypt dominated vegetation codes were intersected with sample data. Feature codes that achieved 100 percent agreement in samples describing a single vegetation community in the analyses were allocated to that community. Feature codes that did not achieve complete agreement between sample point located within it were assessed for spatial accuracy. Sites that reached agreement within a 40 metre tolerance of the polygon boundary were subsequently allocated to the vegetation community. Sites that continued to indicate an alternative community to that described by the API feature code were investigated. Individual polygons were assessed against the mapping reliability code and, where low, were recorded to that suggested by the sample point. Feature codes that retained mixed sample allocations were allocated to the vegetated community suggested by the majority of samples and the composition of both site and polygon data strings. A small number of codes were not sampled and these were allocated to a vegetation community based on field traverses or were amalgamated with adjoining communities based on similar geological, structural and floristic attributes.

Vegetation communities defined by sites that were all located outside of the study area were excluded where they described vegetation communities found in environmental domains not present in the study area.