Assessment of Grey Box Grey Gum Wet Sclerophyll Forest TEC on NSW Crown Forest Estate

Survey, Classification and Mapping Completed for the NSW Environment Protection Authority

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1 Overview

This report interprets the final determination of Grey Box Grey Gum Wet Sclerophyll Forest threatened ecological community (TEC) listed under the NSW *Threatened Species Conservation Act, 1995* (TSC Act) and found in northern NSW. The primary purpose of the interpretation has been to assess whether this TEC occurs within 800,000 hectares of state forest in our study area. Where we consider it likely to occur, our goal has been to map the extent at a scale suitable for the regulation of forestry operations. We provide an agreed interpretation, a set of reference locations, a detailed map of extent on state forest, and a field key to aid in the identification of the TEC.

Although not explicitly stated in the final determination, Grey Box Grey Gum Wet Sclerophyll Forest (GBWS) is defined from quantitative floristic analysis of systematic plot data. Based on a strong association with the determination assemblage list and documented occurrences referenced in the determination, we have interpreted GBWS to be equivalent to a community described in a recent classification study in the Northern Rivers (OEH, 2012); 1000-1665: (Grey Gum - Grey Box - Hoop Pine shrubby open forest on hinterland hills of the Richmond and Clarence catchments, South Eastern Queensland Bioregion and NSW North Coast Bioregion).

Our analysis of plot data assigned 32 plots to community 1000-1665 and the equivalent GBWS TEC, out of 7864 plots in our north coast study area, which we assigned to other communities in the Northern Rivers Classification. Of the 32 plots, we assigned 29 with a high degree of confidence and three as possible GBWS. Most plots occurred within the range of previously documented sites of GBWS. However, we also assigned three plots to GBWS, which are disjunct from and well outside the previously known distribution, to the south. Over half of the plots that we assigned to GBWS (19 out of 32) occur in State forest, especially in Unumgar and Mount Lindesay state forests. Of the three disjunct plots, only one is in our state forest study area, in Nymboida state forest. We have no evidence that GBWS occurs south of Nymboida state forest. We recommend that Nymboida and Kangaroo River state forests are identified as plausible locations for the TEC and be diagnosed on a site-by-site basis using our field key until further survey and mapping can be completed in these forests.

For the northern occurrence areas we constructed an operational map of GBWS TEC that is at a scale commensurate with the needs of field operations. This map was developed based on plot assignments, API map polygons delineated from overstorey and understorey patterns, and results of predictive modelling. In total, we identified approximately 2936 ha of GBWS TEC in state forests north from Cherry Tree state forest.

We consider that our interpretation has reduced uncertainties associated with extent of this TEC. Our new sampling effort in potential habitat outside of known occurrences yielded only one new location. This suggests that few, if any examples are likely to occur outside of our mapped areas in this region.

Notwithstanding the results of our surveys, our mapping covers a substantially greater extent within state forest than is estimated by NPWS (1999) and cited in the final determination. These differences arise because we have analysed a larger regional dataset and mapped the species assemblage unconstrained by existing forest type mapping used to define the extent in the determination. Secondly, in areas where we have fewer data, we have mapped in a precautionary manner. Our mapping includes some areas with mixed grassy and shrubby understorey or areas highly disturbed by lantana infestation. These areas are accompanied by less certainty in our mapping assignments as we are unable to discriminate between GBWS and other closely related communities with existing data.

2 Introduction

2.1 Project Rationale

This project was initiated by the NSW Environment Protection Authority (EPA) and Forest Corporation NSW (FCNSW) as a coordinated approach to resolve long standing issues surrounding the identification, extent and location of priority NSW Threatened Ecological Communities (TECs) that occur on the NSW State Forest estate included within eastern Regional Forest Agreements.

2.2 Final Determination

The final determination of Grey Box Grey Gum Wet Sclerophyll Forest TEC (GBWS) was initially made in July 2009. Following minor amendments, a new final determination was made in July 2011. Paragraph 1 of the determination describes it as typically having a tall open canopy of eucalypts with a structurally complex understorey. The most common tree species are listed as *Eucalyptus moluccana* (Grey Box) and *Eucalyptus propinqua* (Grey Gum), with less common species *Eucalyptus biturbinata* (Grey Gum), *Eucalyptus siderophloia* (Grey Ironbark) and *Araucaria cunninghamii* (Hoop Pine). Paragraph 8 of the determination notes that it includes two previously described map units - Forest Type 81 (Baur 1989) and Forest Ecosystem 62 (NPWS 1999) - that are equivalent units mapped in identical areas. These units are used as the basis of the estimates of area of occupancy and extent of occurrence provided in paragraph 9.

Paragraph 9 notes that all known records of GBWS occur within three locations, and the extent of known distribution, (derived from the map units cited in paragraph 8), is used as one of three criteria by which the community is determined as threatened. However, the final determination does not explicitly exclude the possibility that it may occur elsewhere.

Paragraph 6 cites a report (DECC 2008), which is the nomination for the community. Based on the similarities between the final determination and this report, and on the composition of the assemblage list in paragraph 2 of the determination, the report appears to be the primary source of floristic and structural information, (although not explicitly cited as such).

Paragraph 13 cites the same report (DECC 2008) with regard to weed invasion and indicates that 19 of 20 sites of GBWS record *Lantana camara*. This reference further suggests that GBWS is a TEC that is primarily defined from quantitative analysis of floristic data.

2.3 Initial TEC Reference Panel Interpretation

Under the *Threatened Species Conservation Act 1995* (TSC Act), TECs are defined by two characteristics: an assemblage of species and a particular location. The TEC Project Reference Panel (TEC Panel), agreed that in NSW, the occurrence of GBWS is constrained to the NSW North Coast Bioregion. Based on implicit information within the final determination and nomination documents, the Panel agreed that GBWS is a TEC which has been defined from previous quantitative floristic analyses and that the analyses described in DECC (2008) form the basis of the definition, (even though that is not explicit in the final determination).

From the Final Determination for GBWS, Table 1 summarises the key determining features and how they have been used in the assessment reported here, based on the interpretation of the features by the Panel.

Table 1: Key features of Grey Box Grey Gum Wet Sclerophyll Forest TEC, including those of potential diagnostic value. Numbers in the left-hand column refer to paragraph numbers in the final determination.

	Feature	Diagnostic value and use for this assessment
1	NSW occurrences fall within NSW North Coast Bioregion.	Explicitly diagnostic.
1,4	Structure of the community '...typically has a tall open canopy of eucalypts with a structurally complex understorey including rainforest trees and shrubs, vines, ferns and herbs.'	Indicative, but general understorey structural description used, in conjunction with floristic information, to exclude vegetation with grassy understorey
2	Characterised by the listed 63 plant species, including 4 eucalypt species.	Potentially diagnostic, in the context of the extent to which these species also occur in other communities
4	'...typically dominated by an open tree canopy of *Eucalyptus moluccana* (Grey Box) and *Eucalyptus propinqua* (Grey Gum) and, less commonly, *Eucalyptus biturbinata* (Grey Gum), *Eucalyptus siderophloia* (Grey Ironbark) and *Araucaria cunninghamii* (Hoop Pine).'	Indicative, used to guide API mapping but not otherwise diagnostic.
4	Description of understorey, listing 6 small tree and shrub species, 6 vine species and 5 ground cover species which may be present	Indicative, not used
6	Description of environmental factors including elevation range and soils	Indicative, elevation thresholds used to guide API mapping but not constrain it
7	Known from two listed LGAs but may occur elsewhere.	Not used
8	Includes Forest Type 81 and Forest Ecosystem 62	Indicative; not used to constrain the occurrence of the TEC, even in areas where these vegetation units are mapped
13	20 documented sites recorded in DEC (2008)	Although not explicitly cited in the determination for definition of the TEC, we have used these sites as the primary data source to identify floristically similar vegetation likely to belong to GBWS TEC.

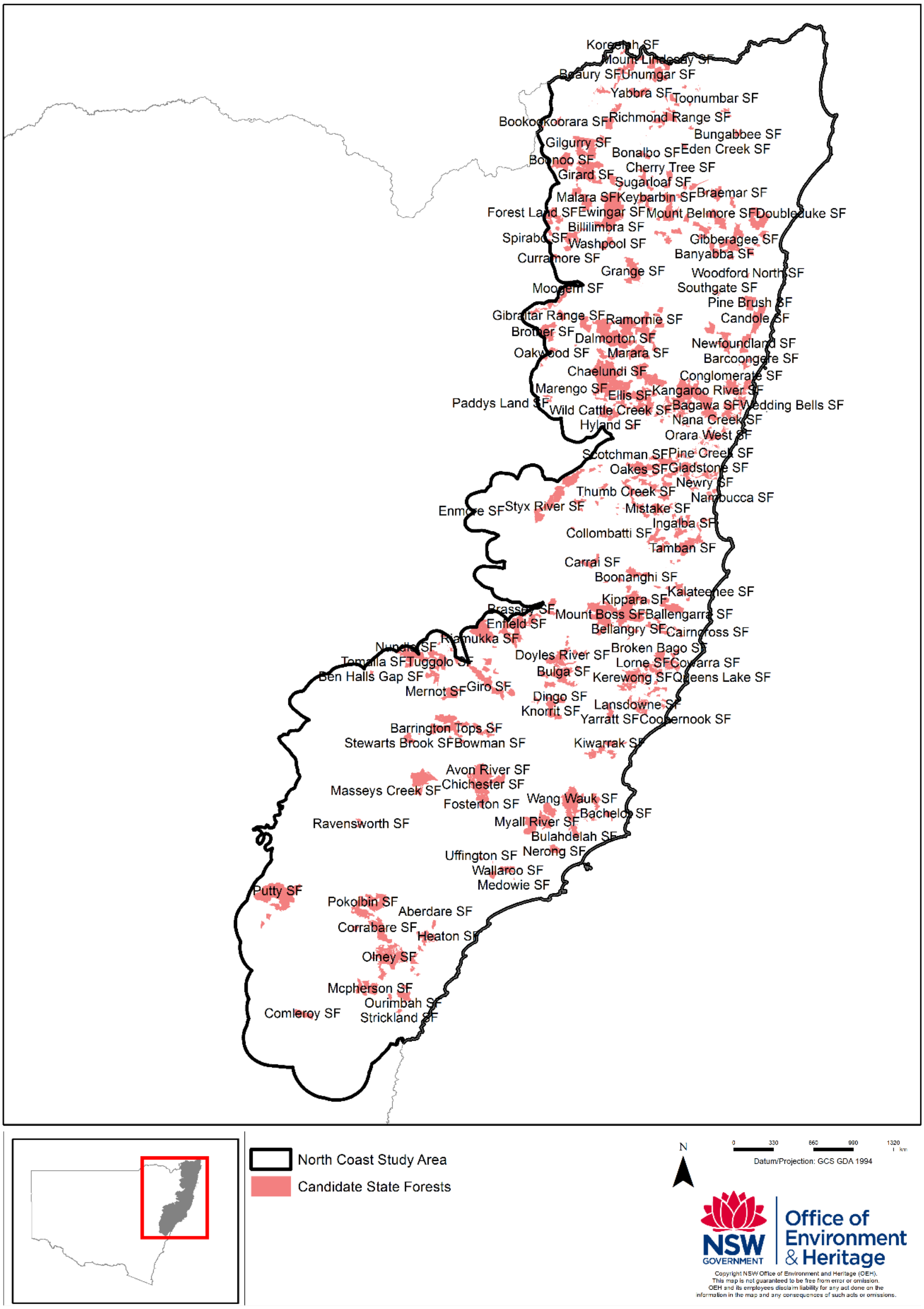
2.4 Assessment Area

2.4.1 Location and study area boundaries

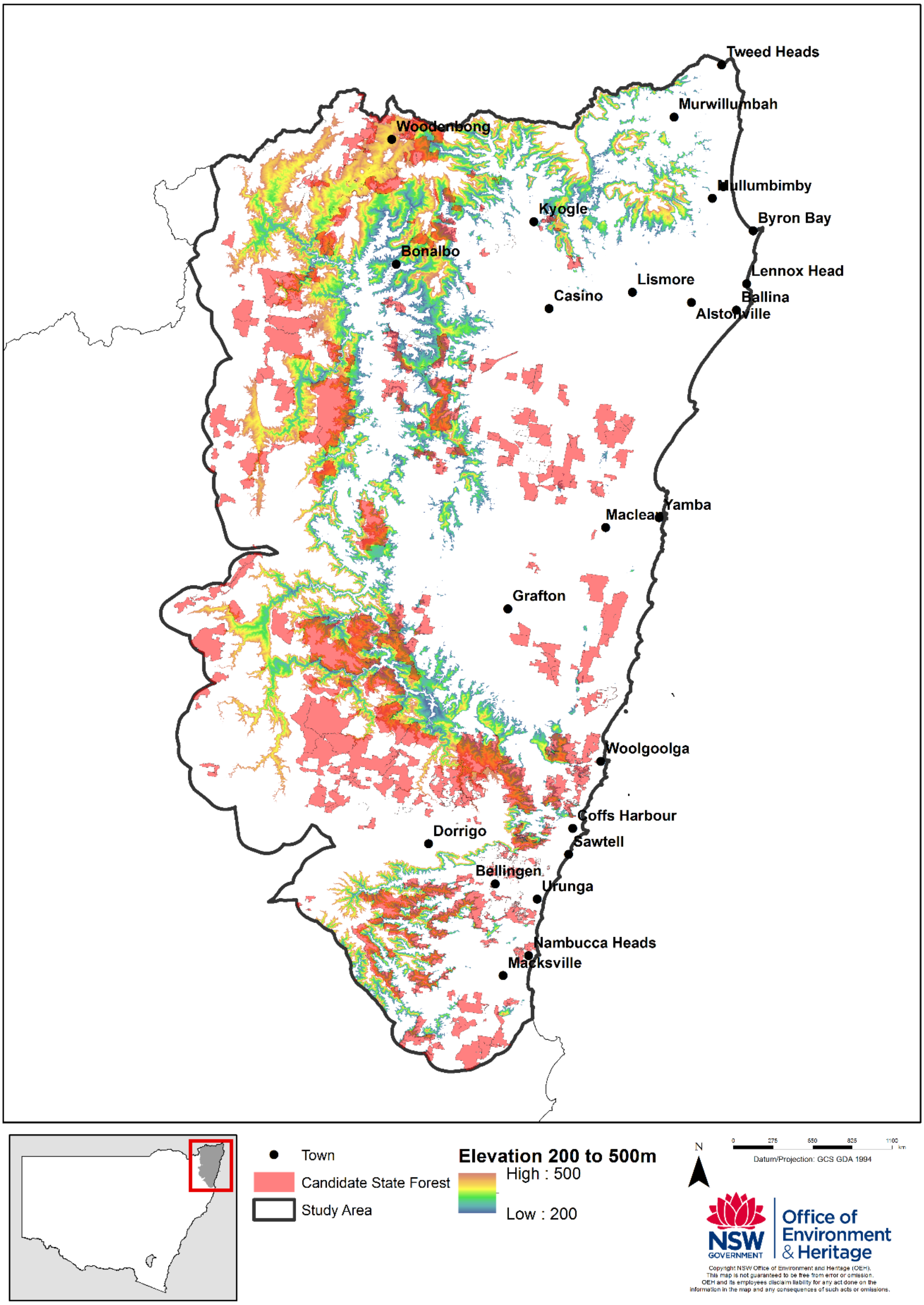
Although the determination restricts GBWS to the North Coast Bioregion, we analysed data for this TEC as part of a broader analysis of TECs (OEH, 2016) some of which also occur in Sydney Basin Bioregion. For our purpose, the Sydney metropolitan area provides a convenient study area boundary because it approximates a significant ecological boundary and because it is a highly modified landscape which does not contain any State Forest to be assessed for our project.

Our North Coast study area is shown in Map 1. This area includes all of the North Coast Bioregion and all IBRA subregions north from the Hawkesbury River in Sydney Basin Bioregion. We considered that this would include all vegetation relevant to GBWS. Map 2 shows the elevation thresholds described in the GBWS determination within the Upper North Coast region.

Map 1: Candidate State Forests in the Assessment Area



<u>Map 2:</u> Candidate State Forests within 200 to 500m elevation threshold used in GBWS determination



2.4.2 State Forests subject to Assessment

Table 2: List of candidate State Forests to be assessed and area (Ha) within the project study area

Candidate State Forest	Area (Ha)	Candidate State Forest	Area (Ha)
Aberdare SF	6	Lansdowne SF	4,118
Avon River SF	5,061	Little Newry SF	189
Awaba SF	1,784	London Bridge SF	118
Bachelor SF	2,642	Lorne SF	3,257
Bagawa SF	5,384	Lower Bucca SF	2,621
Bald Knob SF	1,695	Lower Creek SF	1,270
Ballengarra SF	6,106	Malara SF	3,352
Banyabba SF	2,674	Marara SF	5,351
Barcoongere SF	320	Marengo SF	10,128
Barrington Tops SF	12,588	Maria River SF	1,815
Beaury SF	4,568	Masseys Creek SF	3,127
Bellangry SF	6,411	Mcpherson SF	6,488
Ben Halls Gap SF	351	Medowie SF	50
Billilimbra SF	3,853	Mernot SF	4,338
Boambee SF	821	Middle Brother SF	2,131
Bom Bom SF	872	Mistake SF	5,638
Bonalbo SF	1,456	Moogem SF	1,135
Bookookoorara SF	915	Moonpar SF	1,821
Boonanghi SF	3,817	Mororo SF	379
Boonoo SF	3,968	Mount Belmore SF	9,181
Boorabee SF	914	Mount Boss SF	17,165
Boorook SF	2,990	Mount Lindesay SF	3,046
Boundary Creek SF	2,539	Mount Marsh SF	3,636
Bowman SF	3,187	Mount Mitchell SF	2,323
Braemar SF	2,002	Mount Pikapene SF	553
Brassey SF	745	Mount Seaview SF	1
Bril Bril SF	2,333	Muldiva SF	687
Broken Bago SF	3,543	Myall River SF	13,611
Brother SF	6,179	Myrtle SF	4,303
Buckra Bendinni SF	1,766	Nambucca SF	1,510
Bulahdelah SF	7,799	Nana Creek SF	1,793
Bulga SF	14,254	Nerong SF	2,173
Bulls Ground SF	2,010	Never Never SF	3
Bungabbee SF	1,097	Newfoundland SF	5,939
Bungawalbin SF	1,204	Newry SF	2,841
Burrawan SF	2,040	North Branch SF	796
Cairncross SF	4,487	Nowendoc SF	3,765
Camira SF	4,009	Nulla-five Day SF	3,370

Candidate State Forest	Area (Ha)	Candidate State Forest	Area (Ha)
Candole SF	6,574	Nundle SF	3,279
Carrai SF	3,028	Nymboida SF	6,400
Carwong SF	603	Oakes SF	7,639
Chaelundi SF	18,238	Oakwood SF	2,135
Cherry Tree SF	1,636	Old Station SF	230
Cherry Tree West SF	321	Olney SF	17,795
Chichester SF	20,539	Orara East SF	3,983
Clouds Creek SF	10,241	Orara West SF	4,459
Cochrane SF	231	Ourimbah SF	3,571
Collombatti SF	4,126	Paddys Land SF	907
Comboyne SF	2,576	Pappinbarra SF	1,181
Comleroy SF	2,904	Pee Dee SF	62
Coneac SF	777	Pine Brush SF	3,966
Conglomerate SF	5,162	Pine Creek SF	1,219
Coopernook SF	871	Pokolbin SF	14,030
Corrabare SF	5,197	Putty SF	22,252
Cowarra SF	1,687	Queens Lake SF	576
Curramore SF	84	Ramornie SF	6,175
Dalmorton SF	27,937	Ravensworth SF	901
Devils Pulpit SF	1,484	Riamukka SF	10,029
Diehappy SF	1,275	Richmond Range SF	6,340
Dingo SF	3,555	Roses Creek SF	1,790
Divines SF	1,524	Royal Camp SF	2,203
Donaldson SF	2,331	Scotchman SF	4,158
Doubleduke SF	5,824	Sheas Nob SF	4,333
Doyles River SF	7,744	Skillion Flat SF	5
Dyke SF	6	South Toonumbar SF	410
Eden Creek SF	1,179	Southgate SF	628
Edinburgh Castle SF	949	Spirabo SF	4,138
Ellangowan SF	1,179	Stewarts Brook SF	2,417
Ellis SF	9,736	Strickland SF	485
Enfield SF	12,973	Styx River SF	17,148
Enmore SF	169	Sugarloaf SF	3,151
Ewingar SF	18,433	Tabbimoble SF	2,627
Forest Land SF	6,372	Tamban SF	7,632
Fosterton SF	823	Tarkeeth SF	530
Fullers SF	1,053	Thumb Creek SF	3,944
Gibberagee SF	10,574	Tomalla SF	2,107
Gibraltar Range SF	3,113	Toonumbar SF	1,528
Gilgurry SF	9,531	Tuckers Nob SF	1,885
Girard SF	18,851	Tuggolo SF	14,004

Candidate State Forest	Area (Ha)	Candidate State Forest	Area (Ha)
Giro SF	9,933	Uffington SF	325
Gladstone SF	6,230	Unumgar SF	3,563
Glen Elgin SF	682	Upsalls Creek SF	923
Glenugie SF	4,952	Urbenville SF	3
Grange SF	7,802	Viewmont SF	702
Gundar SF	119	Wallaroo SF	3,487
Hanging Rock SF	38	Wallingat SF	1,240
Heaton SF	2,236	Wang Wauk SF	8,330
Hyland SF	4,577	Washpool SF	2,961
Ingalba SF	6,632	Watagan SF	3,502
Irishman SF	2,733	Way Way SF	1,268
Johns River SF	725	Wedding Bells SF	4,645
Kalateenee SF	1,344	Whiporie SF	1,109
Kangaroo River SF	11,399	Wild Cattle Creek SF	9,667
Kendall SF	354	Willsons Downfall SF	317
Kerewong SF	3,665	Woodenbong SF	306
Kew SF	897	Woodford North SF	219
Keybarbin SF	3,707	Wyong SF	726
Kippara SF	5,554	Yabbra SF	8,417
Kiwarrak SF	6,535	Yango SF	684
Knorrit SF	5,081	Yarratt SF	2,381
Koreelah SF	708	Yessabah SF	1,887
Grand Total			828,639

2.5 Project Team

This project was completed by the by the Ecology and Classification Team in the OEH Native Vegetation Information Science Branch. It was initiated and funded by the NSW Environment Protection Authority (EPA) under the oversight of the Director, Forestry Branch.

The project was managed by Daniel Connolly. Doug Binns undertook the floristic analysis of survey plots, and has interpreted the relationships and relatedness between relevant vegetation communities. Allen McIlwee performed the spatial analysis including fine scale modelling of alluvial floodplain extent, and broad scale predictive distribution modelling. Craig Harré undertook API mapping using 3D stereo imagery across the study area with assistance from Allen McIlwee. Flora survey plots were completed by Andy Baker.

3 Methodology

3.1 Approach

Analysis and mapping was guided by the general principles and particular interpretation of GBWS adopted by the TEC Reference Panel, described in Section 2.3. For the purpose of this project, GBWS is interpreted to be defined primarily by floristic plot data. A major part of our assessment was to allocate all relevant plot data to currently defined floristic communities, or to new communities where required. We then assessed those communities in relation to:

- the assemblage list provided in the final determination
- within the context of the nominated community (DECC 2008) which comprises the 20 documented GBWS sites and
- more recent classification of the assemblage using community *1000-1665, Grey Gum - Grey Box - Hoop Pine shrubby open forest on hinterland hills of the Richmond and Clarence catchments, South Eastern Queensland Bioregion and NSW North Coast Bioregion* (OEH 2012).

To ensure that our assessment of GBWS was comprehensive, we conducted the analyses as part of a broader set of floristic analyses for other TECs in North Coast Bioregion, to allow the possibility that GBWS may occur outside its previously known range.

Plots in which standard floristic data have been collected were compared with plots assigned to previously defined communities relevant to the final determination. These plots comprised data already held in the OEH VIS flora survey database over all tenures, and data collected specifically for this project in State forests. A number of methods were used for comparison, comprising both dissimilarity-based methods and methods based on multivariate regression. The results were then used to assess the likelihood that plots in State forests belonged to the communities referable to the final determination. There is no single preferred method of making these comparisons and no objective threshold to determine whether a plot belongs to a community (and thus a TEC). Options for different methods and thresholds represent narrower or broader interpretations of the TEC, but this approach using plot-based floristic comparison provides a means of consistently allocating plots to being either TEC or not for a range of interpretation options.

3.2 Existing Vegetation Data

3.2.1 Vegetation Classifications

A single regional vegetation classification relevant to GBWS overlaps our study area in the Northern Rivers (OEH, 2012). This classification post-dates the final determination and the vegetation communities are not cited in the determination. However, the classification describes a community, *1000-1665 Grey Gum - Grey Box - Hoop Pine shrubby open forest on hinterland hills of the Richmond and Clarence catchments, South Eastern Queensland Bioregion and NSW North Coast Bioregion*, which is referable to GBWS and includes most of the documented sites (plots) to which the final determination refers in paragraph 13. The Northern Rivers classification provides an existing framework within which we were able to analyse and assign floristic plots, including the data originally used for the classifications, existing data collected from plots not previously assigned to a vegetation community and data collected specifically for our project.

3.2.2 Vegetation Data

A recent review of OEH systematic flora survey data in eastern NSW (OEH in prep) was available for the project. The review identified a subset of data suitable for use in quantitative vegetation classification on the basis that it met a set of predefined criteria, namely that plots:

- provided location co-ordinates with a stated precision of less than 100 meters in accuracy
- covered a fixed survey search area of approximately 0.04 hectares
- supported an inventory of all vascular plants
- provided a documented method that assigns a quantitative and/or semi quantitative measure of the cover and abundance of each species recorded

A total of 23670 plots within the study area, including 520 plots surveyed specifically for our project, were in the OEH VIS Flora Survey Database at 20 June 2016. We used 15065 of these for floristic analysis, including all data assessed as suitable for quantitative vegetation classification. The data included 5521 plots previously used in the Northern Rivers classification, 3687 used in the Hunter-Central Rivers classification and 6792 used in the Sydney Basin classification. A substantial number of plots were used in more than one of these classifications. Although we considered that the Hunter-Central Rivers classification and Sydney Basin classification were unlikely to be relevant to GBWS, we included them in the overall analyses for our study area because of their relevance to other TECs and because the results would indicate the likelihood of GBWS or related vegetation occurring outside the previously known distribution of GBWS.

3.2.3 Data Preparation and Taxonomic Review

All species in the pooled dataset was standardised for analysis using a review completed for all flora survey data compiled for the Eastern NSW Classification (OEH in prep). Nomenclature was standardised to follow Harden (1990-93; 2000-2002) and updated to reflect currently accepted revisions using the PlantNETWebsite (Royal Botanic Gardens, 2002). The data was amended to:

- exclude exotic species
- exclude species identified to genus level only
- improve consistency in assignment of subspecies or varieties to species.

Cover and abundance score data extracted from the pooled data set was standardised to a six class modified Braun-Blanquet score. The transformation algorithm available within the OEH VIS Flora Survey data analysis module was applied to the analysis dataset.

3.3 New Survey Effort

3.3.1 Survey Stratification and Design

We surveyed an additional 40 plots in State forests (Map 3 and 4). The survey design was based on results of a preliminary predictive model (described in Section 3.5.3) which used all documented sites of GBWS. The main survey objective was to test the extent to which GBWS occurred within modelled areas but outside map units cited in the final determination and away from known occurrences of GBWS. We applied a systematic grid to cover the area in which prediction probabilities exceeded 0.015 and randomly selected plots in grid cells in which the maximum probability was at least 0.3. We gave priority to plots which sampled previously mapped vegetation types other than those cited in the determination and applied an exclusion zone based on existing plots by rejecting a new plot location if it was within 250 meters of an existing plot assessed as suitable for quantitative analysis.

3.3.2 Survey Method

Systematic flora survey were conducted in accordance with OEH standard methods (Sivertsen, 2009). Preselected sample points were located in the field using a global positioning system (GPS). In the field, plots were assessed for the presence of heavy disturbance (such as severe disturbance through clearing or weed infestation) and were either abandoned or moved to an adjoining location in matching vegetation.

Systematic floristic sample plots were fixed to 0.04 hectares in size. The area was marked out using a 20 by 20 metre tape, although in some communities (such as riparian vegetation) a rectangular configuration of the plot (e.g. 10 by 40 metres) was required. Within each sample plot all vascular plant species were recorded and assigned estimates for foliage cover and number of individuals. Raw scores were later converted to a modified 1-8 Braun-Blanquet scale (Poore, 1955) as shown in Table 23.

Table 3: Braun Blanquet-to-cover abundance conversion table.

Modified Braun Blanquet 6 point scale	Raw Cover Score	Raw Abundance Score
1 (<5% and few)	<5%	≤3
2(<5% and many)	<5%	≥3
3 (5-25%)	≥5 and <25%	any
4 (25%-50%)	≥25% and <50%	any
5 (50%-75%)	≥50% and <75%	any
6 (75%-100%)	≥75%	any

Species that could not be identified in the field were recorded to the nearest possible family or genus and collected for later identification. Species that could not be identified confidently were lodged with the NSW Herbarium for identification. At each plot estimates were made of the height range, projected foliage cover and dominant species of each vegetation stratum recognisable at the plot. Measurements were taken of slope and aspect. Notes on topographic position, geology, soil type and depth were also compiled. Evidence of recent fire, erosion, clearing, grazing, weed invasion or soil disturbance was recorded. The location of the plot was determined using a hand held GPS or a topographic map where a reliable reading could not be taken. Digital photographs were also taken at each plot.

Non-systematic Surveys

Non-systematic survey techniques were employed by API mappers to record observations of flora species present in likely habitat to assist in the discrimination of candidate GBWS using photo pattern.

The dominant canopy species were recorded along with understorey descriptors as free text. No fixed search area was consistently applied as the aim was to relate interpretable crown signatures to species on the ground. Observations were supported by a georeferenced position using mobile data collection applications.

3.4 Classification Analyses

3.4.1 Clustering

There is a range of methods available for quantitative classification of vegetation communities. Results may vary depending on which method is used and which parameters are chosen for a particular method. There is no single best method, but the most widely used method is clustering of plots based on pairwise dissimilarities. As results vary with varying dissimilarity measures, comparisons with previous classification require use of the same measures. Relationships among plots vary depending on the data pool used, so that introducing additional data may change the composition of previously defined groups.

Most clustering methods result in a plot being allocated to a single vegetation community. A plot may also be related to other communities, but these interrelationships are not evident from allocations. As an alternative, fuzzy clustering methods assign a membership value to each plot for each community, which provides a measure of the likelihood that a plot belongs to any particular community. For this project, Noise Clustering (De Cáceres, Font, & Oliva, 2010; Wiser & De Cáceres, 2013) was selected as the most appropriate fuzzy clustering method for three reasons: it allows specification of fixed clusters defined from previously described groups and provides direct allocations to those groups; it is relatively robust to outliers (which have a large difference from all previously defined groups or communities) and allows clustering into new groups; and it is robust to the prevalence of transitional plots with relationships to two or more previously defined communities. The latter are both characteristic of data for the study area. Noise Clustering requires specification of a fuzziness coefficient (where a coefficient of 1 is equivalent to hard clustering which allocates each plot to only one community) and a threshold distance for outliers. Following a number of trial runs with different subsets of data, different fixed groups and different parameters, we chose a fuzziness coefficient of 1.1 and an outlier threshold of 0.8. These parameters resulted in results which were relatively robust to different sets of data and which had a high degree of consistency with previous classifications. Analyses were completed using functions in the 'vegclust' package in R 3.1.1.

For our overall analyses across our study area we conducted a number of analyses using different subsets of data and different sets of previously defined communities, as follows:

1. A subset of 7864 plots which comprised all plots within our study area previously allocated to a vegetation community by Northern Rivers classification (OEH 2012), plus all previously unallocated plots north of -32° latitude (the approximate southern extent of the Northern rivers study area).
2. A subset of 9089 plots which comprised all plots within our study area previously allocated to a vegetation community by Hunter-Central Rivers classification (Sivertsen et al 2011), plus all previously unallocated plots south of -31.25° latitude (the approximate northern extent of the Hunter-Central Rivers study area).
3. A subset of 5100 plots which comprised all plots within our study area previously allocated to a vegetation community by Sydney Basin classification (OEH in prep), plus all previously unallocated plots south of -30.5° latitude.

3.4.2 Multivariate regression

We used multivariate regression to make comparisons between selected pairs of communities or groups of communities to test their degree of floristic similarity, using the 'mvabund' package in R3.1.1 (Warton, Wright, & Wang, 2012). This method does not rely on calculation of dissimilarities so provides an independent comparison with distance-based methods. For each comparison, the difference in summed AIC is calculated, summed across all species in both communities combined, between a null model and a model using community as the factor. The difference in summed AIC provides a relative measure of the extent to which recognising two separate communities or groups of communities provides a better model of species occurrence than does a single combined group. A higher difference indicates communities which are more clearly distinct. A difference close to zero, or negative, indicates no distinction between groups.

We also used the results of multivariate regression to identify species which are most strongly characteristic of difference between groups. Species with the highest difference between AIC for the group model and that for the null model are those with most diagnostic value.

3.4.3 Other methods

We made a comparison between the assemblage as listed in the GBWS final determination and each of the communities derived from analyses described in 2.4. For these comparisons we used plots which could be allocated to a community with a high degree of confidence (membership >=0,5 from fuzzy clustering results) and excluded ambiguous plots. We based the comparison on the mean proportion of the assemblage species for GBWS per plot for each community. These measures cannot be used in an absolute sense since the final determination does not provide any indication of thresholds. However, they are potentially useful in a relative sense, particularly to determine the extent to which other communities are similar to the final determination list compared to communities which comprise documented GBWS sites.

3.4.4 Assessment of vegetation communities as GBWS

We relied on the relationship between the 20 documented sites defining GBWS included in DECC (2008), communities defined by the Northern Rivers classification and the GBWS assemblage list, to assess whether communities were likely to belong to the TEC. We assigned GBWS to any vegetation community comprising plots containing the 20 plots used in DECC (2008) and for which similarity to the assemblage list can be demonstrated. We assessed all other vegetation communities to the assemblage list using the method described in 3.4.3.

3.4.5 Allocation of floristic plots to vegetation communities

We assessed plots as belonging to a previously defined floristic community if their membership of the community was 0.5 or above. We considered that plots which were assigned to new groups in all our analysis subsets, and which did not have membership >=0.5 of any existing community, belonged to potentially new vegetation communities. We have assessed these in relation to GBWS in a similar manner to previously described communities.

3.5 Indicative EEC Distribution Map

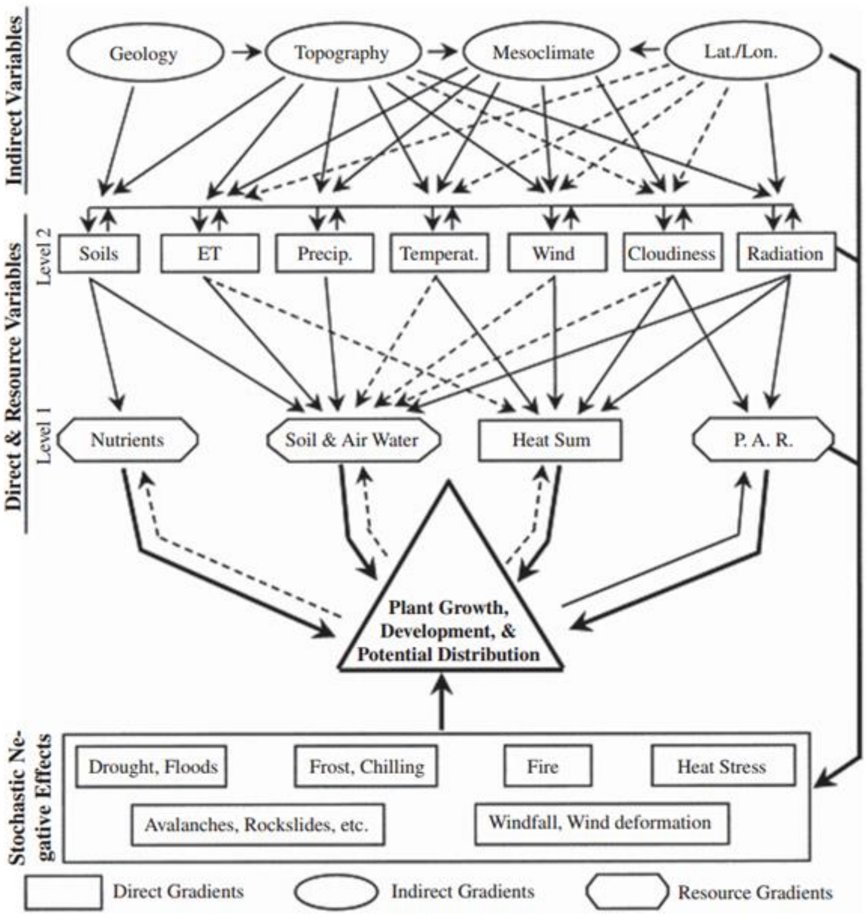
3.5.1 Background

A niche modelling approach (also known as species or habitat distribution modelling) was used to create indicative potential distribution map for GBWS. This approach attempts to extrapolate the fundamental niche of the TEC outside the locations where it is known to be present (its realized niche), by relating known occurrence and absence to environmental predictors.

Modelling the distribution of a TEC requires the characterization of environmental conditions that are suitable for the community to exist. The inclusion of the absence data from the plot allocation allows us to constrain the potential distribution model to a narrow set of favourable environmental conditions that are not occupied by other vegetation communities. Nonetheless, without API and associated on-ground validation, it is difficult to determine the extent to which potentially suitable habitat is actually occupied by the TEC.

Ecological niche modelling involves the use of environmental data describing factors that are known to have either a direct (proximal) or indirect (distal) impact on a species or ecological community. Proximal variables directly affect the distribution of the biotic entity, while distal variables are correlated to varying degrees with the causal ones (Austin, 2002). Austin & Smith (1989) differentiate between indirect gradients, which have no physiological effects on plants, and direct or resource gradients, which directly influence plant growth or distribution. Direct or resource gradients mainly concern light, temperature, water and nutrients, whereas the main indirect gradients are altitude, topography and geology (Austin & Van Niel 2011). An environmental variable may act both as a resource that provides building blocks for growth processes and as a condition that fulfils the requirements for physiological processes to function effectively.

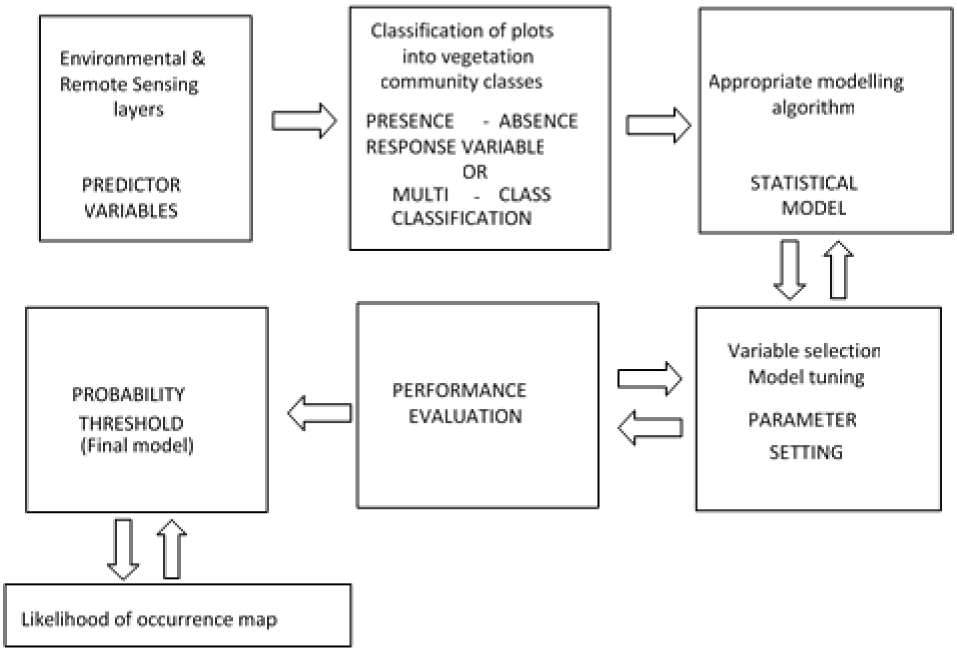
Diagram 1 provides a basic conceptual framework for how plant communities are likely to respond to their environment. Arrows in the figure show how particular indirect variables interact to generate more direct environmental drivers through biophysical processes. Note plant distributions are also influenced by stochastic processes such as extreme heat or cold, landslip or erosion, high winds, drought, flood and fire. However, in niche modelling, we assume that the composition of vegetation is primarily determined by environment rather than successional status or by time since last disturbance (Franklin 1995). It is also assumed that vegetation is in equilibrium with the environment, or at least a quasi-equilibrium where change is slow relative to the life span of the biota.



<u>Diagram 1</u>: Conceptual model of relationships between resources, direct and indirect environmental gradients and their influence on growth, performance and geographical distribution of plants and vegetation communities in general. Source: Guisan and Zimmermann (2000; Figure 3).

Diagram 2 provides an overview of the step-by-step modelling process, which involves a 'classification-then-modelling' approach (Ferrier et al. 2002) with two distinct stages. In the first stage the biological survey data are subjected to a vegetation classification and full-floristic vegetation plots are allocated to presence/absence category for the TEC. This classification is run without any reference to the environmental data. In the second stage the TEC entity as defined by the classification are modelled as a function of environmental predictors.

The statistical model refers to the choice of (i) a suitable machine learning algorithm for predicting a presence-absence response variable and its associated theoretical probability distribution, and (ii) choice of an appropriate variable selection procedure that either has the goal of optimising prediction accuracy or interpretability.



<u>Diagram 2</u>: Process for creating indicative TEC distribution maps

3.5.2 Modelling complex ecological systems

The niche modelling community has made considerable headway in developing machine learning alogrithms to predict the occurrence of species and communities using presence-absence data (Evans and Crushman 2009). The methods model vegetation patterns as continuous measures of site suitability or probability of occupancy. Non-parametric approaches such as Classification and Regression Trees (CART) have gained widespread use in ecological studies (De´ath and Fabricius 2000). However, CART suffers from problems such as over-fitting and difficulty in parameter selection. Solutions to deal with these issues have been proposed that incorporate iterative approaches (Breiman 1996). One approach, Random Forests (Brieman 2001) has risen to prominence due to its ability to handle large numbers of predictors and find signal in noisy data (Cutler et al. 2007). Another advantage of Random Forests is that, by permutation of independent variables, it provides local and global measures of variable importance.

Random Forests is an algorithm that developed out of CART and bagging approaches. By generating a set of weak-learners based on a Bootstrap of the data, the algorithm converges on an optimal solution while avoiding issues related to CARTs and parametric statistics (Cutler et al. 2007). Ensemble-based weak learning hinges on diversity and minimal correlation between learners. Diversity in Random Forest is obtained through a Bootstrap of training, randomly drawing selection of M (independent variables) at each node (defined as m), and retaining the variable that provides the most information content. To calculate variable importance, improvement in the error is calculated at each node for each randomly selected variable and a ratio is calculated across all nodes in the forest.

The algorithm can be explained by:

1. Iteratively construct N Bootstraps (with replacement) of size n (36%) sampled from Z, where N is number of Bootstrap replicates (trees to grow) and Z is the population to draw a Bootstrap sample from.
2. Grow a Random-Forest tree T_b at each node randomly select m variables from M to permute through each node to find best split by using the Gini entropy index to

assess information content and purity. Grow each tree to full extent with no pruning (e.g., no complexity parameter).
3. Using withheld data (OOB, out-of-bag) to validate each random tree T_b (for classification
OOB Error; for regression pseudo R^2 and mean squared error).
4. Output ensemble of Random-Forest trees

$$\{T_b\}\frac{B}{1}$$

To make a prediction for a new observation x_i:
Regression:

$$\hat{f}_{\mathrm{rf}}^{B}(x) = \frac{1}{B}\sum_{b=1}^{B} T_b(x)$$

Classification: Let $\hat{C}_b$ (x) be the class prediction of the *B*th Random-Forests tree then

$$\hat{C}_{rf}^{B}(x) = \mathrm{majorityvote}\left\{\hat{C}_b(x)\right\}\frac{1}{B}$$

Commonly, the optimal *m* is defined for classification problems as sqrt (*M*); and for regression *M*/3, where *M* is a pool of independent variables. It has been demonstrated that Random Forest is robust to noise even given a very large number of independent variables (Breiman 2001a; Hastie et al. 2009).

All modelling was performed in the statistical software package R version 3.3.0

3.5.3 Spatial Data and the variable selection process

A set of 175 variables were available for modelling. These include a set of 1) 130 continuous environmental variables relating to climate, topography and Euclidean distance to features such as the coastline, permanent water bodies and various stream orders, 2) 32 variables derived from Landsat and Spot 5 imagery, and 3) 13 categorical variables such as great soil group and single dominant lithology type, which were extracted from statewide corporate GIS layers. All variables were in the form of gridded Erdas Imagine rasters (*.img), with exactly the same cell size (30 x 30 m) and extent.

The raster layers were stacked in R using the Raster Package (Hijmans and van Etten 2014). The grid cell values for each of the 175 potential predictor variables were extracted for each site in the allocation file using a customised script in R, and the resulting csv file loaded into R. To improve model fit we tested for multicollinearity between the site values across the predictors using the “multicollinear” function in the rfUtilities library using a significance value of 0.001. To check whether the collinear variables were in fact redundant, we performed a "leave one out" test that identifies whether any variables are forcing other variables to appear multicollinear.

Random Forest models are a good starting point for making inferences about the factors driving the distribution of a plant species or ecological community. However, they are data driven models, whose purpose is to give the best possible predicted extent for the data available, and the complexity of spatial pattern. Variable selection is a crucial step in the modelling process. We used a variable selection procedure developed by Murphy et al. (2010) which standardizes the relative importance values of predictors to a ratio and iteratively subsets variables within a given ratio, running a new model for each subset of variables. Each resulting model is compared with the original model, which is held fixed. Model selection is achieved by optimizing model performance based on a minimization of both “out-of-bag” error and largest “within-class” error for classification. There is also a penalty for the number of variables selected in a model, resulting in a preference for the lowest number of predictors from closely competing models.

For the GBWS model, we also checked whether the shape of the fitted functions made sense based on our knowledge of the types of environments that the TEC is likely to occupy.

We ran preliminary Random Forest models using three types of predictor sets. The first used the full set of continuous environmental variables, with the aim of predicting the potential distribution (realised niche) of the TEC in its broadest sense. The second used a combination of continuous environmental and remote sensing variables. The inclusion of remote sensing variables added information about the spectral characteristics of vegetation at a site, and its dynamics through time, giving a better reflection of the actual as opposed to potential distribution of the TEC. Categorical variables were not incorporated into the models directly, but the data were occasionally used to compare frequency histograms across presence and absence sites to see if a distinct preference for a particular soil type or fertility class existed. However, given that the number of absence sites greatly outnumbered the presences, there was generally insufficient data to draw conclusions about preferences for one group of soil classes over another.

Through a series of initial trials, we found a third hybrid approach produced the best set of predictors for modelling. Here we used the variable selection process described above to identify a subset of 30 environmental predictors out of the 130 available. We then added the 32 remote sensing variables and reran the same variable selection process, selecting out two subsets, one with 15 and the other with 30 predictors. These numbers were set *a priori* since previous modelling had suggested that a minimum of around 12 predictors (those with the highest relative influence values) was generally needed to get a levelling out of the performance curves (see below). Beyond this stabilisation point, one could double or triple the number of predictors in a model, but this would have little effect on overall performance since the new predictors tended to have a very small influence on the model.

3.5.4 Model performance and TEC-Habitat relationships

As a means to assess model performance, we plotted the predicted probability of occurrence (PO) values for all plots allocated to a TEC (in descending order) against the same number of highest ranked absence plots. A good model was defined as having high PO values across the majority of TEC presence sites, with a possible drop sharply at the end for those plots that occupy marginal environmental space (and could potentially be misclassified false positives). If there was no overlap in PO values for the lowest ranked presence sites and the highest ranked absence sites, performing a classification using any number between these two values would result in the correct prediction of 100% of presence and absence sites. In such a case there was no need to present a confusion matrix describing the percentage of sites correctly classified.

In most cases, environmental variables were found to strongly dominate the set of 15 predictors, although occasionally one or two remote sensing variables were selected. However, in the set of 30 predictors, it was common for a number of the original environmental variables to reduce and be replaced by remote sensing variables. We found that models with 15 predictors generally had very good performance with 100% of sites allocated to the TEC and 100% of absence sites correctly classified. However, we also found that doubling the number of predictors generally resulted in a better model. Although a tighter fitting, finer threaded potential distribution map was produced, it was sometimes unclear as to whether the additional variables picked up important variation not captured in the main set of 15 predictors, or whether they simply account for noise in the dataset.

Too understand and evaluate the habitat relationships for GBSW, we used a combination of the scaled variable importance values for predictors and shape of the response functions in partial plots as a measure of the strength and nature of interactions. From this we assessed whether the models were likely to predict onto escarpment slopes and foothills, as we expected them to.

3.5.5 Spatial Interpolation

We used the Random Forest models with 15 and 30 variables to create two 30x30 metre GBWS probability of occurrence maps covering the upper north coast study area. Using the performance plots described above, we selected a single threshold just below the maximum PO across all absence sites to represent the cut of above which the TEC has the potential to occur, and below which, we assumed the TEC is absent. Setting the threshold at the high end of probability of occurrence values for absence sites resulted in a relatively narrow predicted extent. This created a model that matched finer habitat characteristics around known presences but was often a constrained model that also failed to capture some areas we considered likely to include presences in locations with limited survey data. To capture the broader extent, we also created a probability of occurrence map with a threshold 0.05 below the first. This had the effect of selectively extending the model out to cover a larger area (onto a number of sites classified in the site allocation as absent). However, at the slightly lower threshold, we felt more confident that we were capturing the broadest possible extent of the GBWS, allowing us to make the decision as to which State Forests had the potential to support the TEC, and which did not.

3.6 Operational EEC Map

3.6.1 Initial Aerial Photograph Interpretation

Aerial Photograph Interpretation (API) technicians, experienced in interpretation of NSW forest and vegetation types, particularly those occurring in north-eastern NSW, used recent high resolution (50cm GSD) stereo digital imagery, in a digital 3D GIS environment, to delineate observable pattern in canopy species dominance, understorey characteristics and landform elements. The distribution of documented sites (DECC, 2008) was used as a starting point for mapping the distribution of GBWS TEC on State Forest using API techniques and for defining the set of State forests for which we conducted API. API was used to detect and delineate image patterns in which any of the canopy species cited in the final determination (*Eucalyptus moluccana* , *Eucalyptus propinqua*, *Eucalyptus biturbinata*, *Eucalyptus siderophloia* or *Araucaria cunninghamii)* were present and in which the understorey included at least some shrubs or small trees (including lantana which was not consistently distinguishable from other shrub species). We also delineated areas in which *Eucalyptus rummeryi* (not listed in the determination) was present because existing classifications and plots suggested it sometimes occurred as canopy dominant in vegetation types floristically related to GBWS. Interpreters adopted a viewing scale between 1:1000 and 1:3000 to mark boundaries to infer changes in canopy and/or understorey composition.

A minimum map polygon size of 0.25 hectares was used to inform the detection and delineation of image patterns, but patterns were mapped to smaller sizes where they were readily discernable. Interpreters were supplied with a range of environmental variables to accompany interpretation including substrate and existing vegetation maps. They were also supplied with contextual layers such as roads, trails and tenure boundaries. All relevant georeferenced floristic data held in OEH databases was extracted and supplied to aid interpretation. Existing floristic data was supplemented by interpreter field traverse using an iterative process to boost interpretation confidence by relating field observations to image patterns. A crown separation ratio of 3 or greater (approx. 5% crown cover (McDonald et al, 1990)) was adopted, as the cut-off density between woody and non-woody vegetation. Areas with eucalypt crown cover of <=10% and 10-30% were mapped separately from those with >30% eucalypt cover, to allow GBWS to be distinguished from otherwise floristically similar areas of Lowland Rainforest TEC.

3.6.2 Integration of Spatial Data

We used the final API line work, in combination with prediction probabilities from the spatial model and floristic plot data (comprising data from full floristic plots and API field observation points), to develop an operational map. For each API polygon, we assessed the overstorey description, understorey description and any notes made by the interpreter from images or field assessment, in relation to features of GBWS from our interpretation of the final determination and the results of analyses of GBWS data. We classified polygons as GBWS or not GBWS based on the extent to which API polygon features matched our GBWS interpretation, the extent to which plots, which we classified as GBWS, occurred within the polygon, in similar polygons or nearby, and the extent to which polygons overlapped our predictive model.

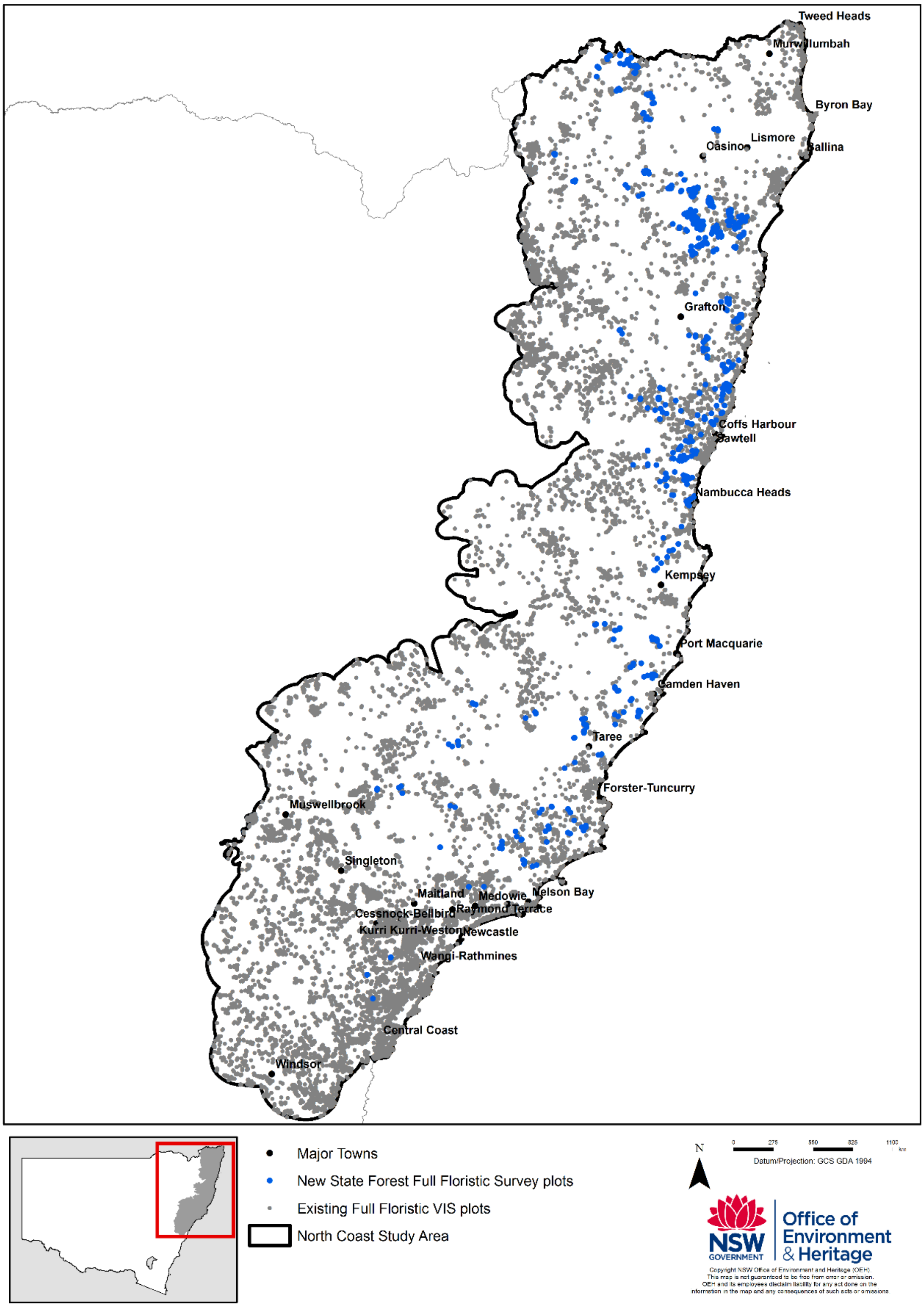
4 Results

4.1 Survey Effort

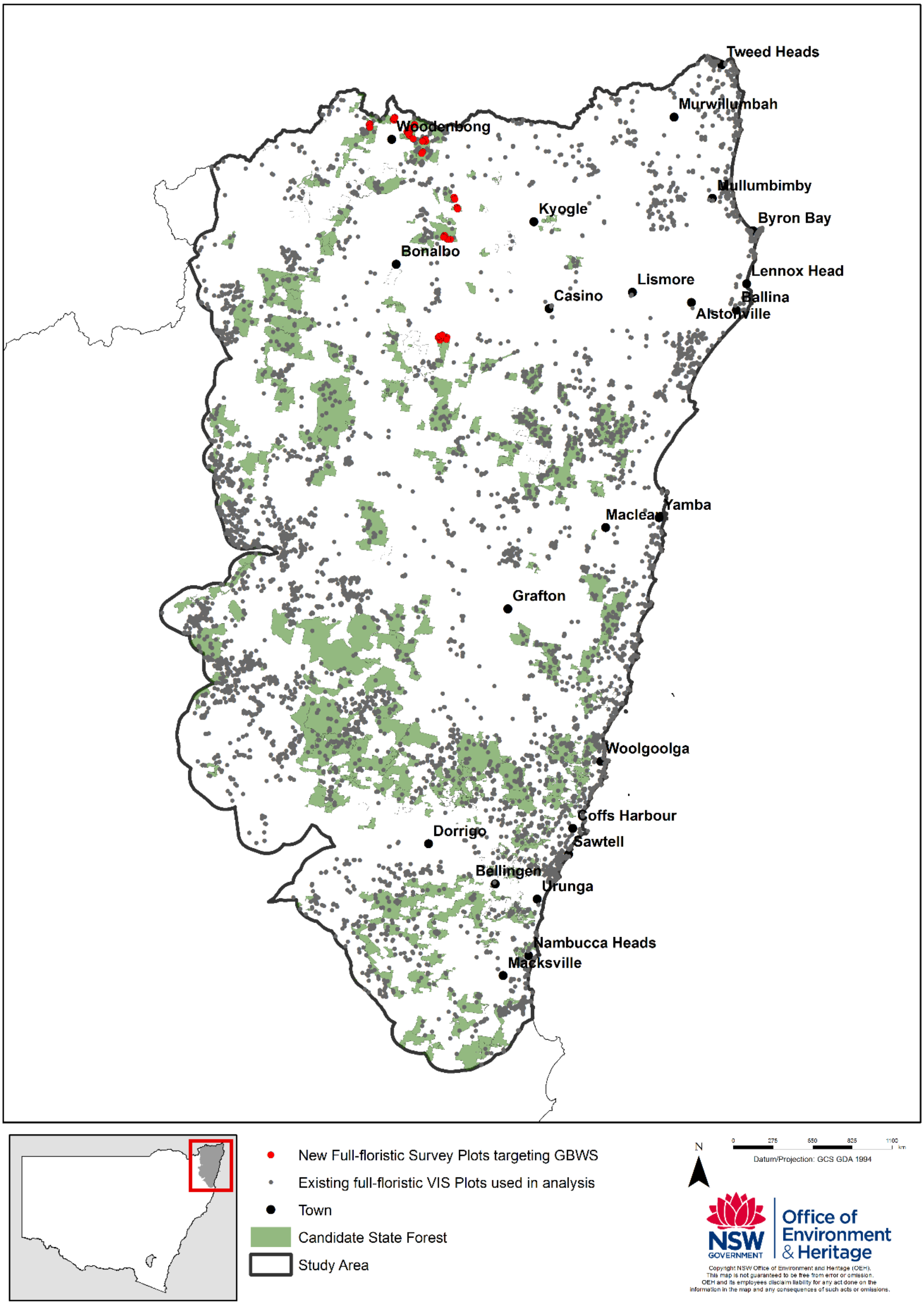
Within our study area there were 14970 standard full-floristic plots in the OEH VIS database, which we used for our initial analysis, 2009 of which are in State forest. This includes 40 systematic plots that were surveyed specifically for sampling potential GBWS area in our project (see Map 4).

We visited 233 locations within our mapping area and made georeferenced field observations of canopy species dominance and understorey characteristics to support API mapping.

<u>Map 3</u>: Location of all floristic vegetation survey plots undertaken on state forest as part of this project (blue) and other (existing) full floristic plot data (grey) used in the analysis.



Map 4: Location of new full floristic vegetation survey plots (red) undertaken on state forest targeting GBWS TEC



4.2 Classification Analyses

4.2.1 Relationships to existing classifications

Of the 14970 plots analysed (excluding floodplain validation plots), 8925 (60%) could be allocated with a high degree of confidence to an existing community described for one or more of the Northern rivers, Hunter-Central Rivers or Sydney Basin classifications. A further 1548 (10%) were not closely related to any of the communities used in the analysis, but formed additional floristic groups. Some of these most likely represent previously undescribed communities but none are relevant to our assessment of GBWS as they are floristically unrelated. The remaining plots were less strongly related to an existing community and were considered as transitional.

4.2.2 Assessment of communities and plots as TEC

From the comparisons described in 2.4.3 and considering other relevant factors and advice from the TEC Panel, we have assigned a single community as GBWS TEC: Northern Rivers community 1000-1665 *Grey Gum - Grey Box - Hoop Pine shrubby open forest on hinterland hills of the Richmond and Clarence catchments, South Eastern Queensland Bioregion and NSW North Coast Bioregion*. This community had a significantly greater degree of similarity to the determination list than any other community defined by our analyses, (results for this and other similar communities are summarised in Appendix 1). We have not assigned any other community as belonging to GBWS TEC.

From our floristic analysis we regard plots with a membership >=0.5 of a community as belonging to that community and those with membership <0.5 as having ambiguous relationships but possibly belonging to the community. We have allocated 29 plots to Northern Rivers community 1000-1665 with a high degree of confidence (membership >=0.5). These comprise 18 of the 20 documented sites of GBWS used in the nomination (DECC 2008) plus an additional 11 plots. The latter comprise 10 plots for which data were available at the time but which were omitted from the analysis used for the nomination, plus a single plot from our recent survey of 40 targeting GBWS. We allocated an additional three plots to community 1000-1665 with a lower degree of confidence (membership >=0.25 but <0.5). All plots which we allocated to NR 1000-1665 with membership >=0.5 are listed in Appendix 2. For management purposes in a precautionary context, we suggest that those plots with lower membership of 1000-1665, between 0.25 and 0.5, also be regarded as GBWS.

4.2.3 Evidence of occurrence on State Forest

Grey Box Grey Gum Wet Sclerophyll forest TEC occurs extensively in Unumgar and Mount Lindesay state forests and to a more limited extent in Bald Knob state forest (Table 4). The 19 plots in State forest have membership of 1000-1665, of at least 0.5 and are assessed as belonging to GBWS with a high degree of confidence. There are no plots in state forest which we assessed as ambiguously related to GBWS. Our results also provide evidence that GBWS occurs in Nymboida State Forest and that it may occur in Cherry Tree or adjacent state forests (based on the presence of an assigned plot nearby outside state forest). Cherry Tree State Forest is close to the previously known southern limit of GBWS TEC, and Nymboida State Forest is well outside its previously known distribution. There are limited plot data in suitable habitats in Nymboida state forest and nearby areas, and although relationships seem clear with the current limited data, we are uncertain whether the evidence for the occurrence of GBWS in that area would be sustained with more comprehensive data. It could be found to occur more extensively in that area, or additional data may indicate it is a related community which is sufficiently distinct to not be assessed as part of GBWS. We recommend that Nymboida and Kangaroo River State Forests be identified as plausible locations for the TEC until new data confirms otherwise.

We found no Hunter or Sydney Basin community which could be assessed as GBWS, and we found no evidence that GBWS occurs south of Nymboida State Forest.

Table 4. Numbers of plots of GBWS TEC on state forest.

State Forest (SF)	Number of plots
Bald Knob SF	1
Mount Lindesay SF	4
Nymboida SF	1
Unumgar SF	13

Photo 1: This reference site (GBWS69) occurs on McIntoshs Rd, just outside Unumgar State Forest. The eucalypt species here include *Eucalyptus siderophloia*, *E.moluccana* and *E.propinqua*. The understorey at this site supports a diverse mesic assemblage that features some species also associated with dry rainforest. There are a number of these present in this plot including a moderate cover of *Cupaniopsis parvifolia* with the distinctive *Araucaria cunninghamii* also present.

4.2.4 Field Key and Defining Floristic Attributes

Table 5 lists the 30 species which are most strongly characteristic of GBWS in the context of all 7860 plots, (excluding four plots with membership of 1000-1665 <0.5), used in our analysis for the Northern Rivers part of our study area, which encompasses the total extent of GBWS based on our data.

Species which are listed as characteristic in the GBWS final determination are shown with 'D' in parentheses following the name, (allowing for nomenclatural changes). It is notable that all thirty species are listed in the GBWS final determination assemblage, suggesting a strong relationship between our interpretation and the assemblage list. Of the 63 species in the determination assemblage list, we found 58 to be positively diagnostic to some degree, although seven species were only weakly diagnostic (e.g. *Acacia irrorata*, *Doodia aspera* and *Lepidosperma laterale*). We found two species (*Alphitonia excelsa* and *Dianella caerulea*) to have no diagnostic value and three species (*Imperata cylindrica*, *Lomandra longifolia* and *Eucalyptus biturbinata*) to be negatively diagnostic. In both these cases, the species are more frequent in other communities.

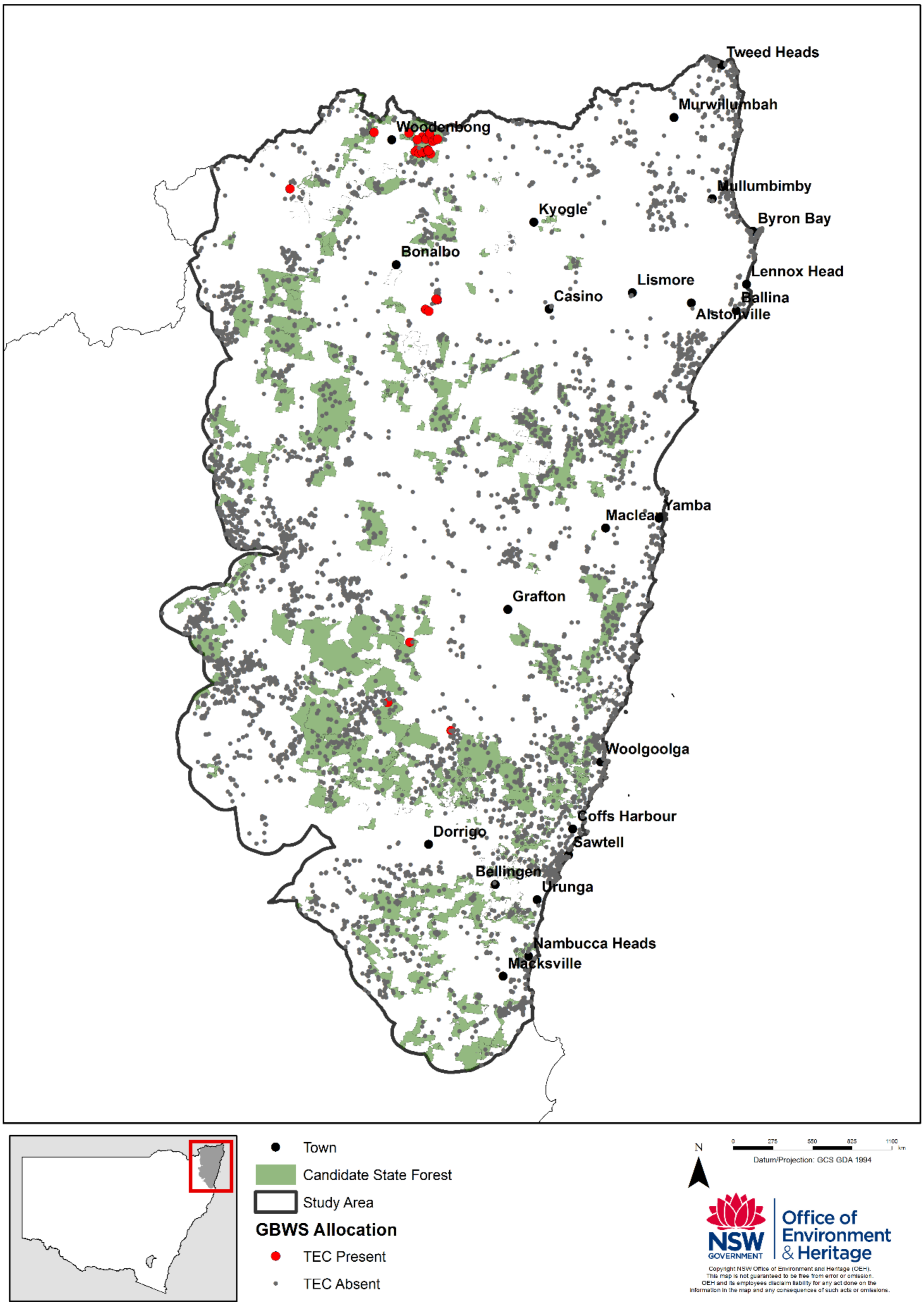
Table 5 also lists all other eucalypts which are recorded in GBWS, all of which occur with low frequency, and none of which are positively diagnostic. This is consistent with the description of canopy species in the final determination, with the exception that *Eucalyptus biturbinata* is not recorded in plot data. This discrepancy may be a result of the difficulty of distinguishing *E. propinqua* and *E. biturbinata* in the field.

Floristic field keys provide a higher degree of certainty if they are derived using datasets constrained to broadly similar communities rather than datasets, which span all communities within a large region. Appendix 3 provides a key for use in the north coast bioregion.

Table 5: The thirty most strongly characteristic species of GBWS in order of decreasing contribution to ΔsumAIC, plus all eucalypts recorded in GBWS, using 29 plots assigned to GBWS with a high degree of confidence compared to the remaining 7831 plots in the North rivers classification area, excluding those assigned to possible GBWS due to community membership value <0.5. Species annotated with '(D)' are listed in the final determination assemblage. Mean is mean cover score over all plots including zeros. Median is derived from non-zero scores only. Zeros may represent small values, due to rounding.

Species	GBWS freq	GBWS mean	GBWS median	other freq	other mean	other median	ΔsumAIC
Psydrax odorata (D)	0.69	1.1	2	0.01	0.01	1	-152
Denhamia bilocularis (D)	0.86	2.1	2	0.04	0.05	1	-138
Cupaniopsis parvifolia (D)	0.69	1.7	3	0.01	0.02	1	-131
Araucaria cunninghamii (D)	0.69	1.7	3	0.02	0.04	2	-121
Celastrus subspicata (D)	0.79	1.7	2	0.04	0.06	1	-115
Eucalyptus moluccana (D)	0.72	2.3	3	0.03	0.09	3	-105
Mallotus philippensis (D)	0.79	1.5	2	0.05	0.09	2	-104
Geijera salicifolia (D)	0.52	0.9	2	0.01	0.01	1	-96
Croton insularis (D)	0.41	1.0	2	0	0.01	1	-84
Elaeodendron australe (D)	0.62	1.3	2	0.03	0.05	1	-83
Psychotria daphnoides (D)	0.55	1.1	2	0.02	0.03	1	-80
Polyscias elegans (D)	0.69	1.3	2	0.06	0.09	1	-73
Notelaea longifolia (D)	0.83	1.7	2	0.13	0.18	1	-70
Alectryon tomentosus (D)	0.34	0.5	1.5	0	0.01	1	-69
Gahnia aspera (D)	0.72	1.2	2	0.09	0.13	1	-68
Derris involuta (D)	0.55	1.3	2	0.03	0.05	2	-68
Eucalyptus propinqua (D)	0.72	2.2	3	0.09	0.22	3	-66
Bridelia exaltata (D)	0.38	0.7	2	0.01	0.01	1	-66
Alchornea ilicifolia (D)	0.45	1.1	2	0.02	0.03	2	-66
Gossia bidwillii (D)	0.41	0.7	2	0.01	0.02	2	-66
Drypetes deplanchei (D)	0.55	0.9	2	0.04	0.06	1	-65
Alyxia ruscifolia (D)	0.59	0.9	2	0.04	0.06	1	-65
Maclura cochinchinensis (D)	0.66	1.2	2	0.07	0.09	1	-64
Croton verreauxii (D)	0.55	0.9	2	0.04	0.07	2	-63
Cyperus gracilis (D)	0.52	1.0	2	0.03	0.05	1	-62
Eucalyptus siderophloia (D)	0.72	1.8	3	0.1	0.23	2	-60
Smilax australis (D)	0.97	1.9	2	0.3	0.45	1	-58
Guioa semiglauca (D)	0.72	1.5	2	0.12	0.21	1	-54
Euroschinus falcatus (D)	0.48	0.9	2	0.04	0.06	1	-50
Tragia novae-hollandiae (D)	0.24	0.5	2	0	0	1	-49
Eucalyptus microcorys	0.10	0.2	2	0.21	0.49	2	0
Eucalyptus rummeryi	0.03	0.1	2	0.01	0.02	3	0
Eucalyptus crebra	0.07	0.1	2	0.03	0.08	3	1
Corymbia intermedia	0.10	0.2	2	0.15	0.32	2	1
Corymbia variegata	0.14	0.4	3	0.10	0.29	3	2
Angophora subvelutina	0.07	0.1	2	0.05	0.11	2	2
Eucalyptus acmenoides	0.07	0.1	2	0.08	0.22	3	2
Eucalyptus tereticornis	0.10	0.3	3	0.09	0.21	3	2

<u>Map 5</u> Plots assigned to Grey Box-Grey Gum Wet Sclerophyll Forest TEC against all plots



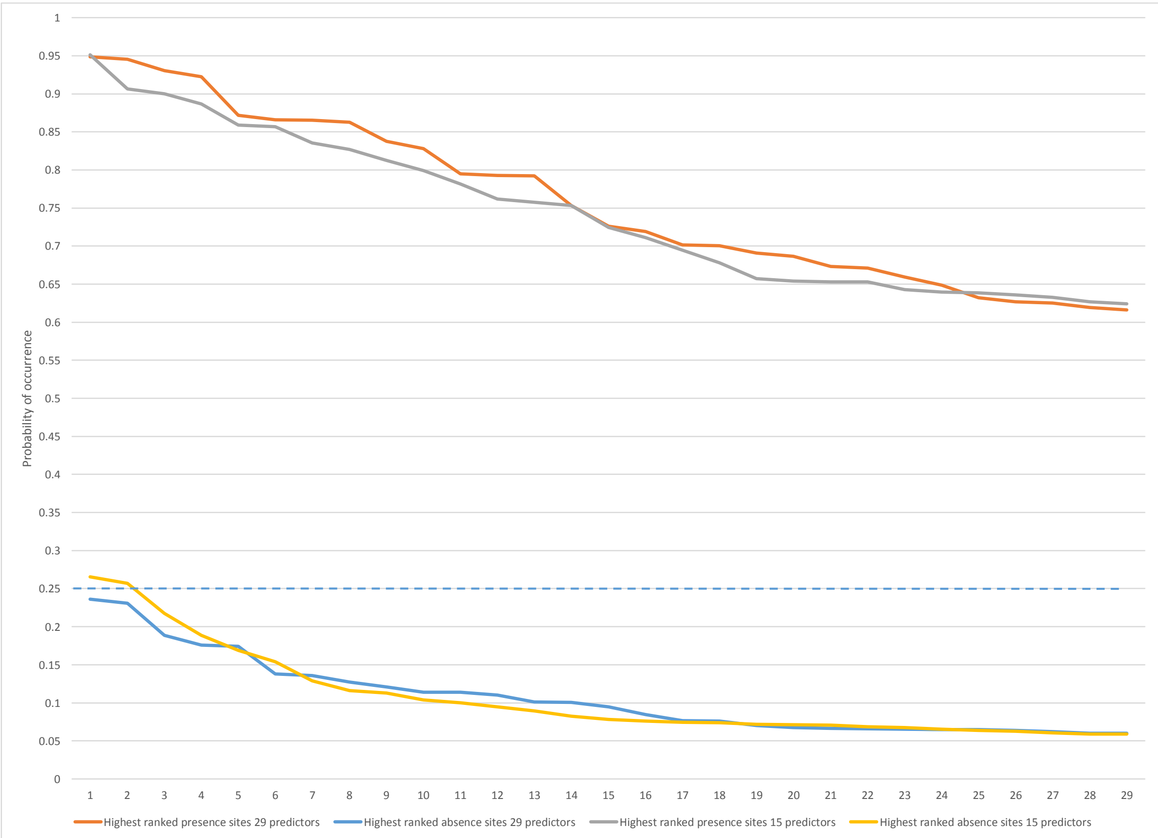
4.3 Indicative TEC Mapping

4.3.1 Model Performance

A Random Forest presence-absence model was used to predict the distribution of GBWS across its range using the site allocation results described above. We developed a model using a subset of 29 of the original 175 predictors, as well as a narrower subset of only 15 predictors.

Figure 1 shows plots of the predicted probability of occurrence for sites allocated to GBWS (in order of descending probability) plotted against the same number of highest ranked absence plots. There is no overlap between the lowest probability of occurrence value for a GBWS present site and the highest probability of occurrence for a GBWS absent site. Thus choosing any threshold between these two values results in 100% of all present and absent sites being correctly classified.

Figure 1: Predicted probability of occurrence values for sites allocated to GBWS (in order of descending probability) plotted against the same number of highest ranked absence plots.

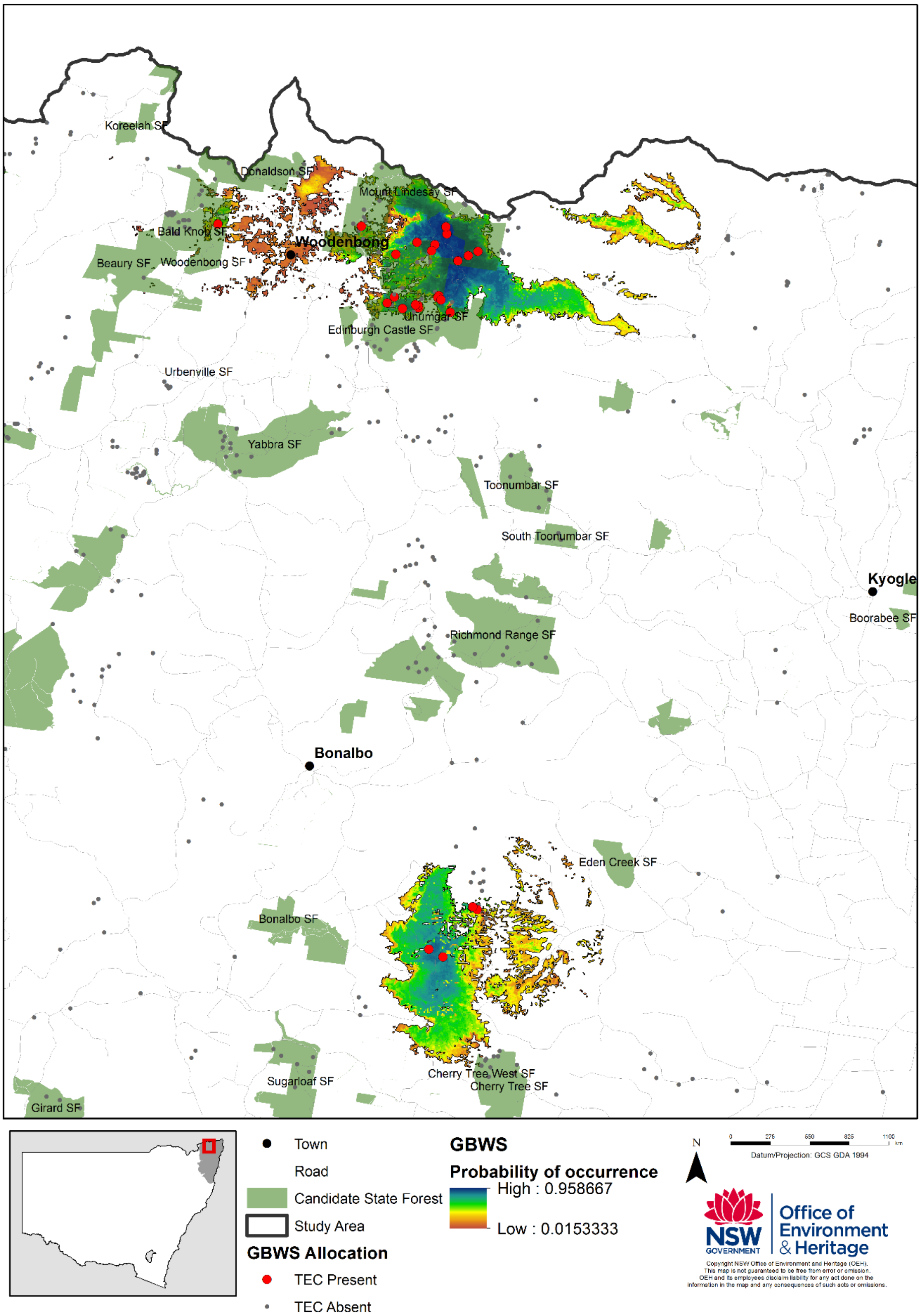


4.3.2 TEC Indicative Maps

The indicative maps predict the distribution of a TEC based on the probability of occurrence values above a particular threshold. From the modelling, we identified four possible indicative maps for each TEC. This includes two sets of models (each with 15 and 29 predictors), and two thresholds to predict the potential extent of the TEC (0.25 and 0.2). At these thresholds we accept a very small level of misclassification of absence sites (only 2-4 sites out of more than 5200). This has the effect of expanding out the model just enough to account for spatial inaccuracies that may exist in the data.

All four sets of predicted occurrence maps were examined in ArcGIS using ADS40 imagery as the backdrop, and an assessment made as to which model/threshold best discriminated the underlying habitat features and our understanding of the vegetation patterns. In this case, the model with 29 predictors and the higher of the two thresholds (narrower distribution) produced the models that aligned with our knowledge and these formed the basis for new survey and mapping efforts. Maps 6 shows the predicted distribution of GBWS across all tenure.

Map 6: Indicative map showing the potential distribution of GBWS



4.3.3 Environmental Relationships

Individual fitted functions for variables in the Random Forest models are useful for determining whether a model matches what we know about the broad distribution and habitat requirements of a TEC. For example, we know from the final determination that GBWS "*typically occurs on the escarpment slopes and foothills of north-eastern NSW, most commonly between 200 and 500m elevation, where mean annual rainfall exceeds approximately 1000mm and has a summer maximum (DECC 2008). Soils that support the community are relatively fertile and derived from a range of igneous (including acid volcanic, basic volcanic and intrusive igneous) or fine-grained sedimentary rocks.*"

Table 6 lists the variables that were selected in models with 15 and 39 predictors. The scaled variable importance values for both models are also provided in Figure 2. These give a measure of the relative contribution each variable has on the overall model, with low standardised variable importance values having relatively little impact on the probability of occurrence values.

For the RF model with 29 predictors, Temperature Annual Range and Mean Diurnal Range were the two most important climatic variables influencing the broad distribution of GBWS across the study area, followed by Highest Period Radiation and Lowest Period Radiation. Other coarse scale data of importance included distance to the coast and distance to particular stream orders. Soil pH at a range of depths has a strong influence on GBWS distribution at the local scale, followed by soil cation exchange capacity. The shape of the individual fitted functions for each of the variables are shown in Figure 3.

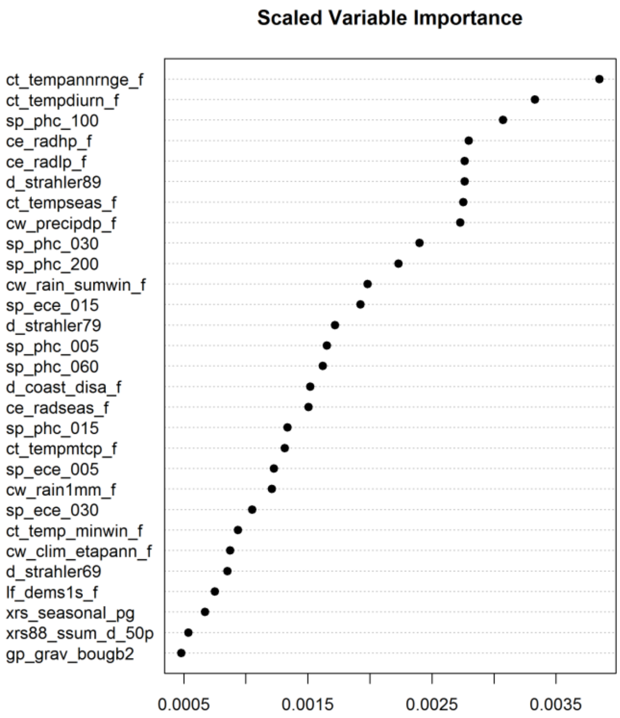
Table 6 List of variables selected in the GBWS Random Forest models with 15 and 30 predictors.

Code	Description	In model with 15 predictors
ce_radhp_f	Highest Period Radiation (bio21)	Yes
ce_radlp_f	Lowest Period Radiation (bio22)	Yes
ce_radseas_f	Radiation of Seasonality: Coefficient of Variation (bio23)	
ct_temp_minwin_f	Average daily max temperature - Winter	
ct_tempannrnge_f	Temperature Annual Range: difference between bio5 and bio6 (bio7)	Yes
ct_tempdiurn_f	Mean Diurnal Range (Mean(period max-min)) (bio2)	Yes
ct_tempmtcp_f	Min Temperature of Coldest Period (bio6)	Yes
ct_tempseas_f	Temperature Seasonality: Coefficient of Variation (bio4)	Yes
cw_clim_etapann_f	Average areal actual evapotranspiration - Annual	
cw_precipdp_f	Precipitation of Driest Period (bio14)	Yes
cw_rain_sumwin_f	Average Rainfall - Summer Winter Ratio	Yes
cw_rain1mm_f	Average Number of days with rainfall greater than 1mm Annual	
d_coast_disa_f	Distance from NSW East Coast (Euclidian)	Yes
d_strahler69	Euclidean distance to 6th order streams and above	
d_strahler79	Euclidean distance to 7th order streams and above	
d_strahler89	Euclidean distance to 8th order streams and above	Yes
gp_grav_bougb2	Bouguer gravity - band 2	
lf_dems1s_f	Elevation from 1 sec SRTM smoothed DEM (DEM-S)	

Code	Description	In model with 15 predictors
sp_ece_005	Effective Cation Exchange Capacity (%) (0 - 5cm)	
sp_ece_015	Effective Cation Exchange Capacity (%) (5 - 15cm)	
sp_ece_030	Effective Cation Exchange Capacity (%) (15 - 30cm)	
sp_phc_005	pH (calcium chloride) (0 - 5cm)	Yes
sp_phc_015	pH (calcium chloride) (5 - 15cm)	
sp_phc_030	pH (calcium chloride) (15 - 30cm)	Yes
sp_phc_060	pH (calcium chloride) (30 - 60cm)	Yes
sp_phc_100	pH (calcium chloride) (60 - 100cm)	Yes
sp_phc_200	pH (calcium chloride) (100 - 200cm)	Yes
xrs_seasonal_pg	Landsat seasonal green accumulation index - highest values are in areas that respond with high green cover for a long period after the greening event	
xrs88_ssum_d_50p	Landsat 25-year seasonal greenesss in summer (50th percentile)	

<u>Figure 2</u>: Scaled variable importance values in relation to models with a) 30 predictors, and b) 15 predictors.

a)



b)

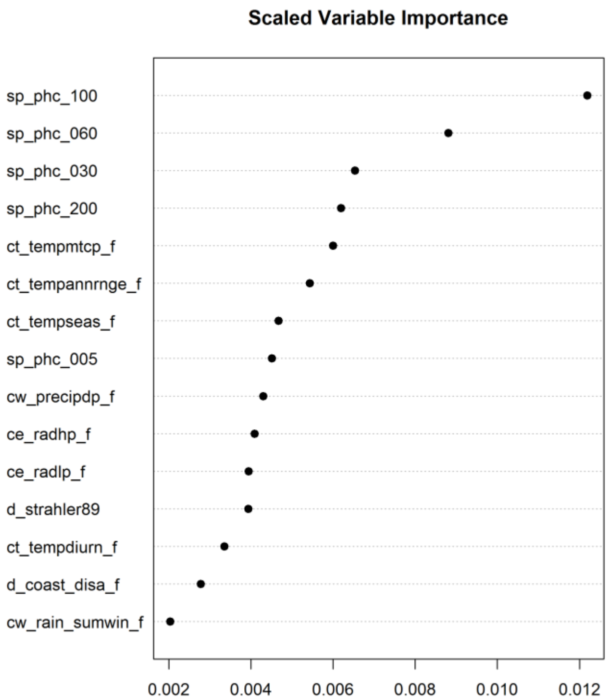
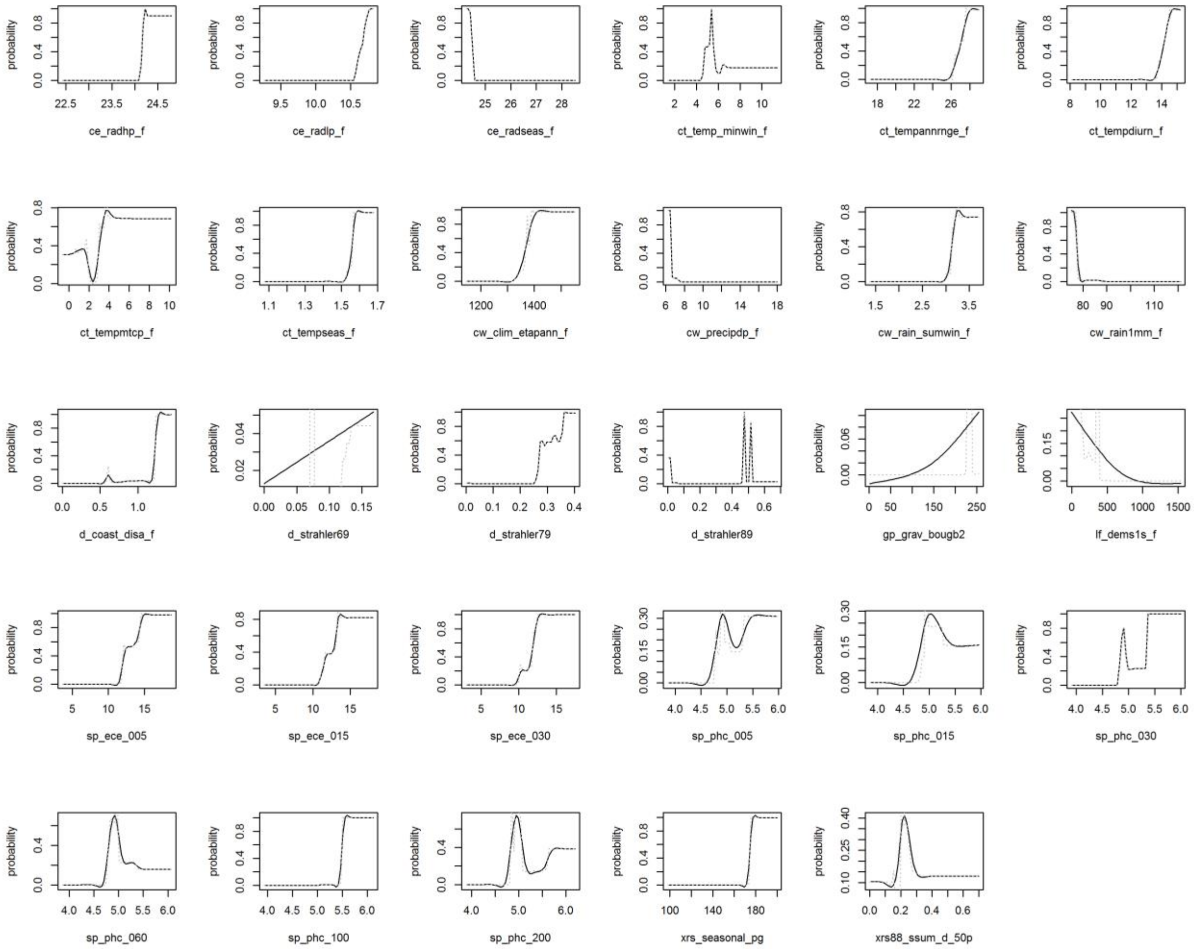
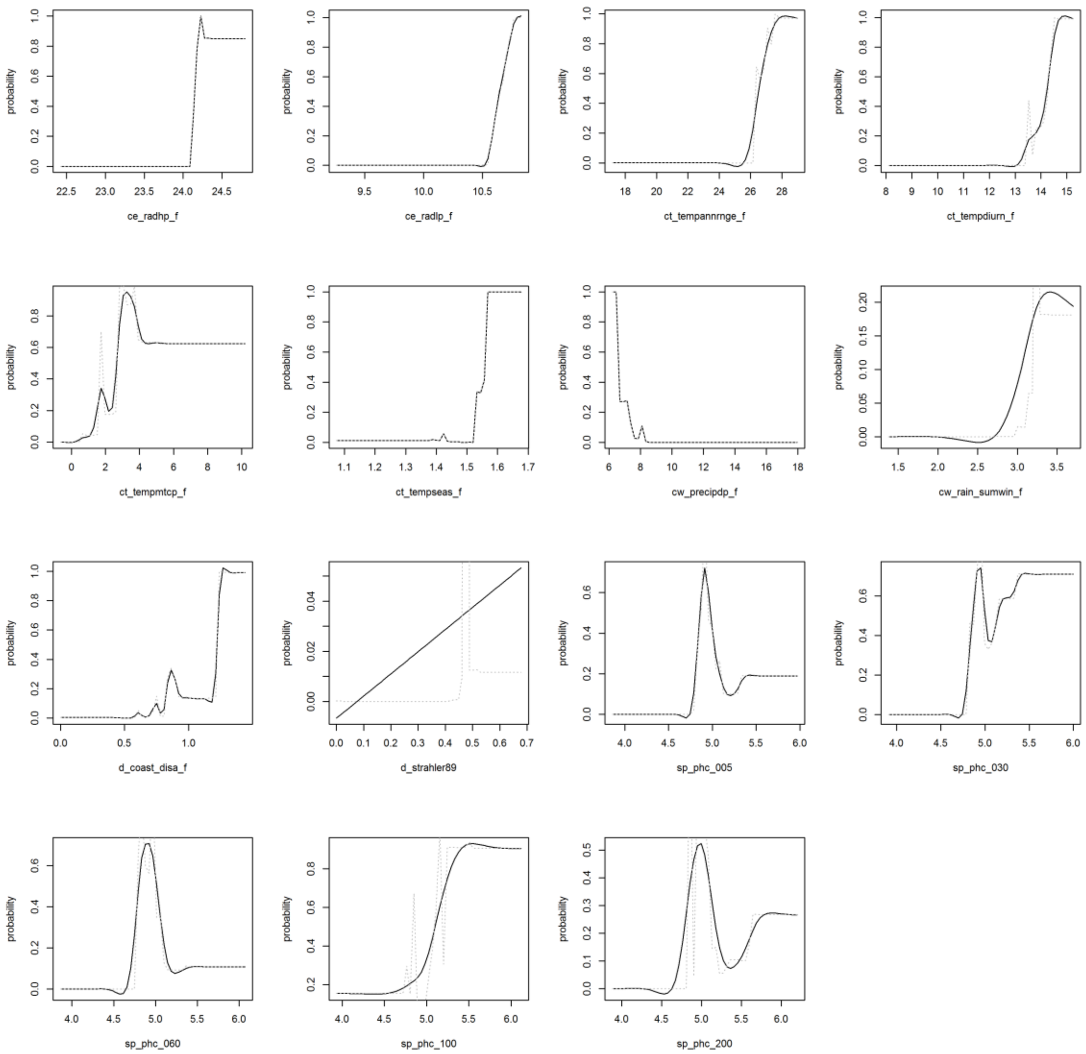


Figure 3: Shape of individual fitted functions in relation to models with a) 30 predictors, and b) 15 predictors.

a)



b)



4.4 Operational TEC Mapping

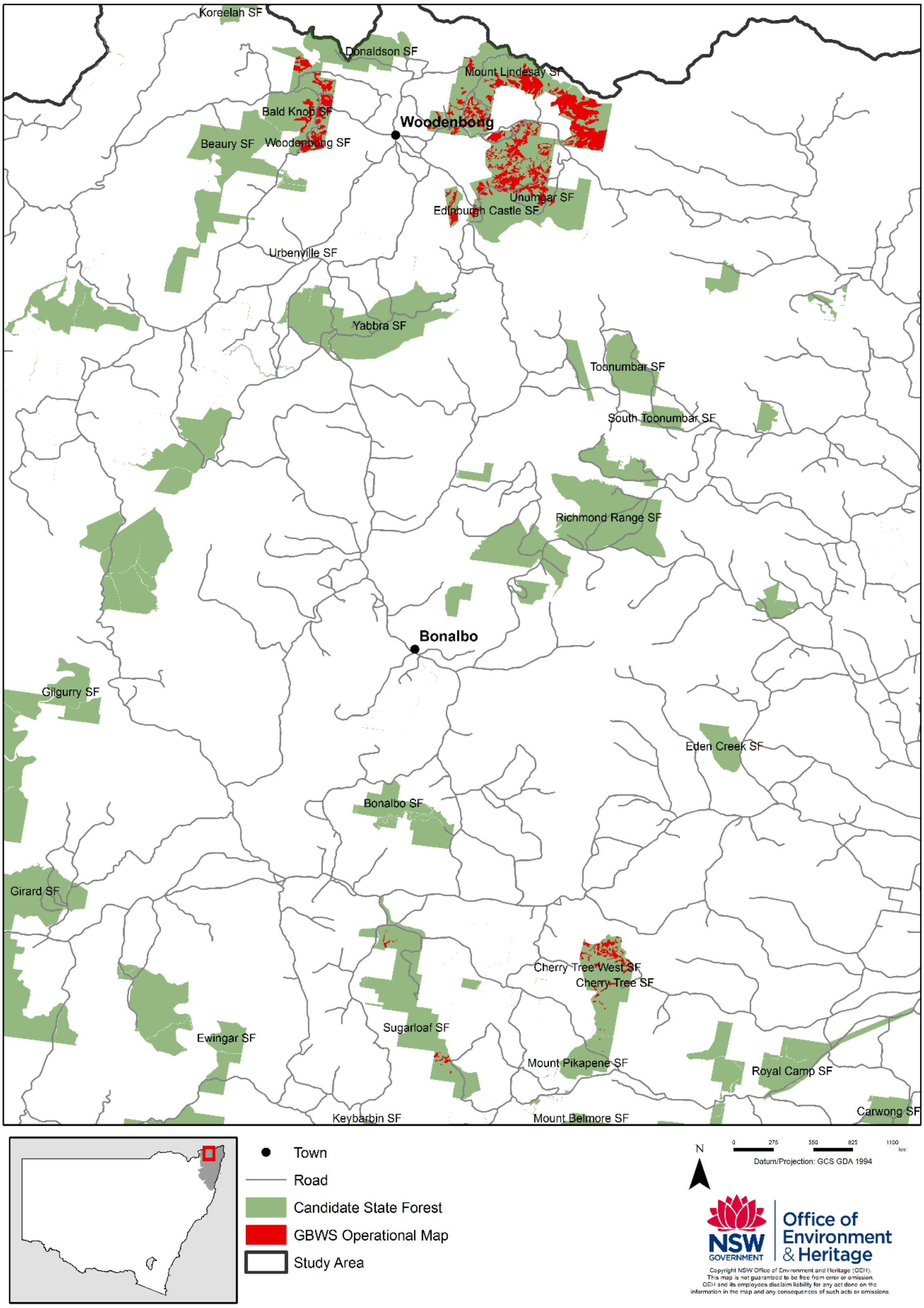
Our operational mapping covers the occurrence of GBWS north from Cherry Tree state forest, (Map 7-9). After integrating information from API results, plot data and predictive models, using the method described in Section 3.6.2, we mapped 2936 hectares of Grey Box Wet Sclerophyll Forest TEC in State forests in our study area, comprising 141 polygons with a mean size of 20.7 hecatres. We mapped as GBWS TEC the majority of API polygons with eucalypt dominants in which at least one of the listed characteristic canopy species was present, and for which the understorey was described as rainforest trees and shrubs, or mixed shrubby and grassy. The exceptions, which we did not map as TEC, were mixed shrubby and grassy polygons at the fringe of the distribution for which plot data indicated that communities other than 1000-1665 (GBWS) were present.

While we are confident that our mapping of API polygons with rainforest and mesic understorey (73%) is unlikely to include significant area that are not TEC, a proportion (23%) of our mapping is of areas with mixed grassy and shrubby understorey, including areas with a large component of lantana. Over 60% of the area supporting these understorey characteristics overlaps our predictive models. Some of these areas with mixed understorey may be found to not be GBWS, but in these areas, we are unable to map GBWS and other communities separately with existing data. Areas with dense lantana may also preclude the reliable diagnosis of GBWS if there are insufficient native species against which to apply a key.

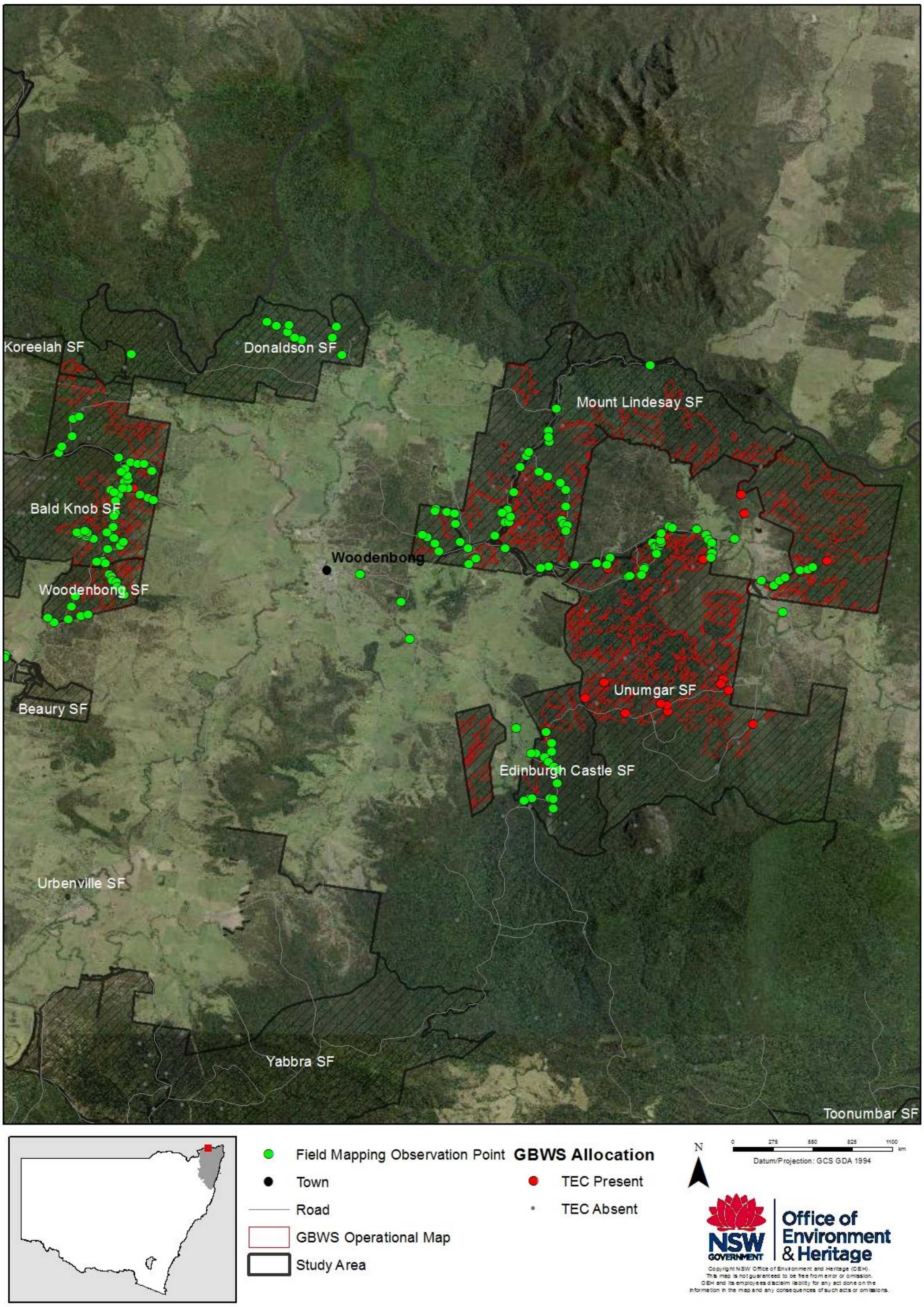
Our data also indicates that there is also a previously unrecorded disjunct occurrence south of Nymboida River. We are uncertain whether the single plot which we assigned to GBWS in Nymboida state forest is an isolated occurrence, or represents a more extensive distribution. If the latter, it is possible that GBWS may also occur in Kangaroo River state forest. We were unable to map the distribution of GBWS in these two State forests due to lack of plot data and incomplete API.

We recommend that both Nymboida and Kangaroo River state forest are considered as plausible locations for GBWS. We suggest the presence of the TEC is assessed using our field key provided until new data is available.

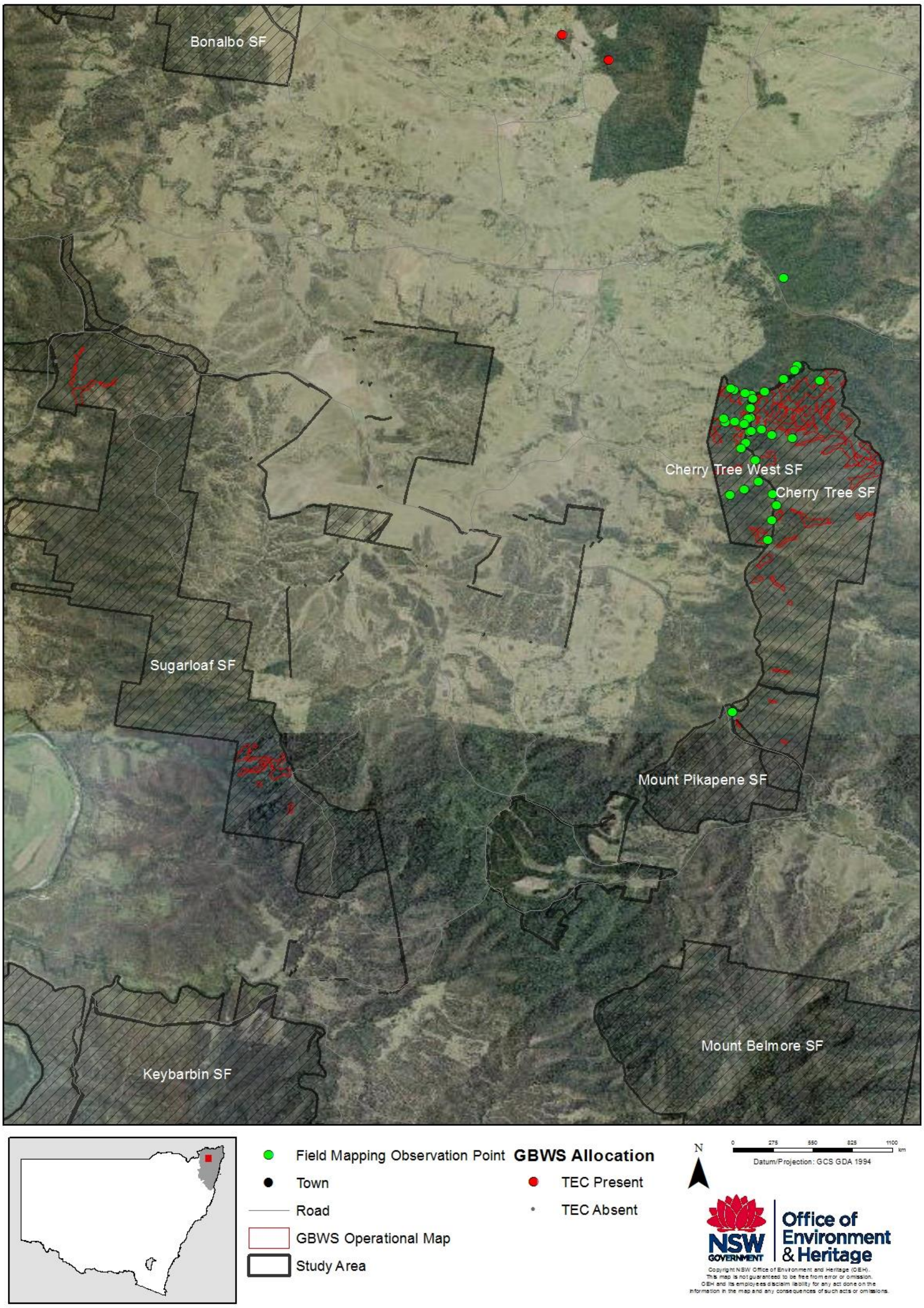
<u>Map 7:</u> Operational map for GBWS



Map 8: Example of operational map in the Woodenbong area showing reference plots and field observation points.



<u>Map 9:</u> Example of operational map in the Bonalbo area showing reference plots associated field observation points



5 Discussion

5.1 TEC Panel interpretation

Based on our results, the TEC Panel has interpreted GBWS as being equivalent to Northern Rivers community 1000-1665, a relatively distinct and well-defined floristic community. The interpretation of various features of the GBWS final determination, which the TEC Panel adopted, are summarised in Appendix 4. Additionally, the Panel's resolution of a few minor inconsistencies or uncertainties in the final determination are also noted in Appendix 4.

Possibly the most significant feature for the Panel to resolve, was whether the related community 1500-155 *Small-fruited Grey Gum - Grey Box - Grey Ironbark - Spotted Gum shrub/grass open forest of sub-coastal claystone hills of the Clarence Basin, South Eastern Queensland Bioregion*, a community with predominantly grassy understorey, belonged to GBWS. The Panel resolved that 1500-155 did not belong to GBWS for three main reasons. Firstly, although 1500-155 had the third highest proportion of final determination assemblage species of those communities analysed, the proportion was substantially lower than that for 1000-1665. Secondly, although acknowledging variation in structure, the determination describes GBWS as a wet sclerophyll forest and emphasises its structurally complex understorey which includes rainforest species. Thirdly, notwithstanding the variable relationships of a very few plots as discussed below, 1500-155 is most closely related to a floristic group which was explicitly excluded by the nomination for GBWS.

The interpretation adopted in this project, omits two plots which were included as GBWS in the original nomination (one of which is in Unumgar state forest), and which we found were more clearly related to community 1500-155. Our result is consistent with the results of the Northern Rivers classification, which also assigned these two plots to 1500-155. Conversely, both our results and the Northern Rivers classification assigned substantially more plots (13 and 12, respectively) to the GBWS floristic community (1000-1665) than did the nomination. Data for all except one of these additional plots were available at the time of the analysis conducted for the nomination, but were omitted because the scope of that analysis beyond target map units was limited to a small random sample of data. We believe that the more comprehensive scope of analyses conducted for Northern Rivers classification, and of our analyses, provides a more accurate indication of floristic relationships than that provided by the original nomination.

5.2 Canopy composition and estimates of extent

Our plot data and analysis indicates that there are canopy dominants present within GBWS which are not among those species listed by the final determination. This has likely arisen as the nomination data included a smaller pool of data than was otherwise available. Our maps typically include at least one of the listed canopy species but it is not necessarily dominant as it is described in the determination. These differences will also arise because plots and mapped polygons are discriminating patterns at different spatial scales.

We have also mapped large areas as GBWS, which are outside the previously mapped areas of Forest Type 81 or Forest Ecosystem 62. These units are cited in the determination as 'included' within GBWS, and are used as the basis for estimates of area of occupancy, extent of occurrence, and to make the assessment of threat status. We note that this leads to both our predictive models and our operational maps being larger by an order of magnitude than the area estimated provided in the determination, which excluded substantial areas which are known to occur in reserves (based on floristic plot data). If our records from Nymboida state forest and nearby areas are sustained with the collection of further data from that area, the estimate of extent of occurrence for GBWS would also be significantly greater than that given in the determination. We have not attempted to assess the effect that these revised estimates would have on the assessment of threat status.

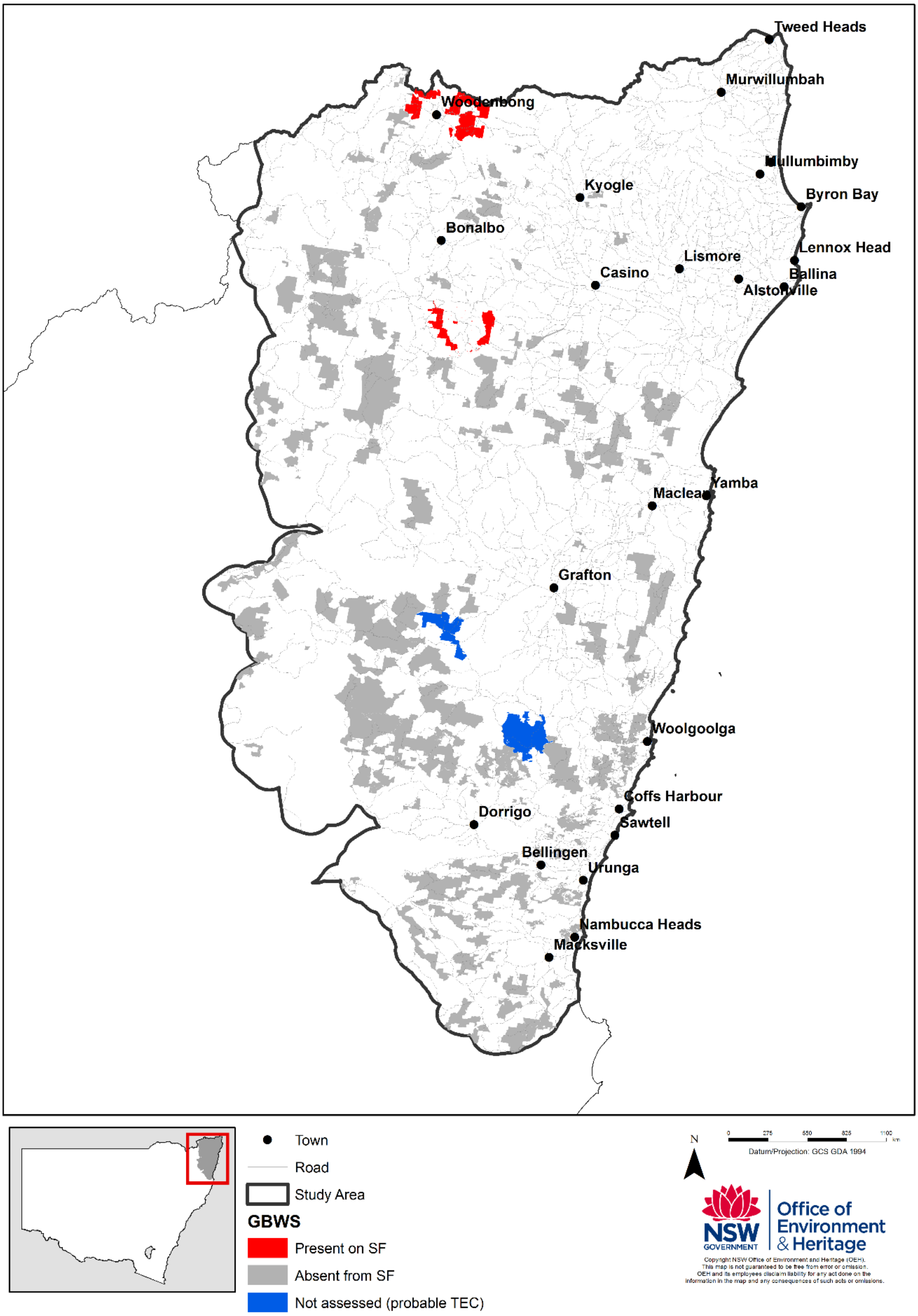
5.3 Final State Forest-EEC Occurrence Matrix

Table 7 provides a summary of the area of GBWS mapped on State Forest within the IFOA Study area. The total area mapped as the TEC includes 2,936 hectares, which represents 16.7% of the total are of the 12 state forests in which it is mapped. Map 9 identifies the state forests where GBWS was mapped, and the two state forests which plausibly may include the TEC for which there is currently no mapping.

Table 7: Total Area mapped across all State Forests in the study area.

State Forest	SF Area (Ha)	GBWS Mapped Area (Ha)	% GBWS
Bald Knob SF	1,695	344	20.32%
Cherry Tree SF	1,636	176	10.78%
Cherry Tree West SF	321	35	10.90%
Donaldson SF	2,331	129	5.52%
Edinburgh Castle SF	949	151	15.88%
Kangaroo River SF	11,399	Indicative	
Mount Lindesay SF	3,046	1,150	37.74%
Mount Pikapene SF	553	0.4	0.07%
Nymboida SF	6,400	Indicative	
Sugarloaf SF	3,151	41	1.31%
Unumgar SF	3,563	775	21.74%
Woodenbong SF	306	135	44.08%
Total	35,340	2,936	16.73%

<u>Map 9:</u> State Forests which include mapped occurrences of GBWS (red) and those which plausibly may include the TEC for which there is currently no mapping (blue)



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Appendix 1

Summary of vegetation communities with similarity to the Grey Box Grey Gum Wet Sclerophyll Forest TEC final determination assemblage list

This appendix lists all communities in the highest decile of similarity to the final determination assemblage list. It is based on vegetation communities described in both Northern Rivers classification and Hunter classification, but plot allocations may vary slightly from original allocations for plots used in these regional classifications and communities may also include plots which have been surveyed since that classification was developed. Mean proportions of species in the assemblage list are calculated as described in Section 3.4.3 and are based on plots allocated to communities using fuzzy clustering methods described in Section 3.4.1.

Community or group	Community name or description	Number of plots	GBWS mean
1000-1665	Grey Gum - Grey Box - Hoop Pine shrubby open forest on hinterland hills of the Richmond and Clarence catchments, South Eastern Queensland Bioregion and NSW North Coast Bioregion	32	0.61
1000-1666	Small-leaved Tuckeroo - Red Kamala dry rainforest with emergent Hoop Pine and Steel Box on the northern hinterland ranges, South Eastern Queensland Bioregion and NSW North Coast Bioregion	23	0.44
1000-1700	Small-fruited Grey Gum - Steel Box tall open forest with dense Brown Myrtle mid-storey on coastal foothills between Coffs Harbour and Grafton, South Eastern Queensland Bioregion and NSW North Coast Bioregion	3	0.43
1500-155	Small-fruited Grey Gum - Grey Box - Grey Ironbark - Spotted Gum shrub/grass open forest of sub-coastal claystone hills of the Clarence Basin, South Eastern Queensland Bioregion	12	0.42
MU 027	Giant Stinging Tree/ Sandpaper Fig dry subtropical rainforest at Mt Yengo	3	0.41
700-536	Whalebone Tree - Sweet Myrtle - Thorny Pea dry riparian rainforest on basaltic alluvium in the Richmond River valley, South Eastern Queensland Bioregion	3	0.37
700-8	Moist shrubby E. acmenoides E. largeana open forest	14	0.35
1500-154	Steel Box - Small-fruited Grey Gum - Tallowwood - Turpentine moist shrubby open forest of Coffs Harbour hinterland hills, NSW North Coast Bioregion and South Eastern Queensland Bioregion	11	0.35
1000-1699	Choricarpia leptophylla with emergent Eucalyptus propinqua Eucalyptus microcorys Eucalyptus rummeryi (Madmans Creek Talawahl NP)	3	0.35
1500-1157	Forest Red Gum tall to very tall moist open forest/rainforest transition with on the coastal plain north of the Richmond River, South Eastern Queensland Bioregion	5	0.35
MU 020	Brown Myrtle/ Lilly Pilly dry rainforest on ranges of the Central and lower North Coast	9	0.33
1500-967	Brush Box - Tallowwood - Pink Bloodwood - Sydney Blue Gum shrubby wet open forest of the far North Coast hinterland, South Eastern Queensland Bioregion	29	0.33
700-398	Brush Box - Grey Myrtle - Water Gum dry rainforests of poorer soils of gorges and river valleys, NSW North Coast Bioregion and South Eastern Queensland Bioregion	5	0.32
700-455	Rough Leaved Elm - Hoop Pine - Tuckeroo - Three-veined Laurel subtropical lowland rainforest of the lower Richmond and Tweed River valleys, South Eastern Queensland Bioregion	3	0.32
MU 048	White Mahogany/ Turpentine moist shrubby tall open forest	37	0.31

Community or group	Community name or description	Number of plots	GBWS mean
MU 019	Tuckeroo/ Yellow Tulipwood/ Red fruited Olive Plum Littoral Rainforest of the lower North Coast	25	0.31
700-406	Dunn's White Gum tall wet forest on basalt-derived or enriched soils on hinterland ranges, NSW North Coast Bioregion and South Eastern Queensland Bioregion	31	0.31
40-505	Brush Box - Curracabah - Acacia blakei - Plectranthus graveolens - Wiry Panic open woodland or shrubland of steep rocky slopes of escarpment ranges, NSW North Coast Bioregion	5	0.31
1000-1613	Brush Box - Tallowwood moist shrubby tall open forest of the escarpment ranges, South Eastern Queensland Bioregion and NSW North Coast Bioregion	8	0.31
MU 018	Tuckeroo/ Lilly Pilly/ Coast Banksia littoral rainforest	26	0.3
1000-1615	Wild Quince - Yellow Persimmon - Red Kamala - Hoop Pine dry rainforests on sedimentary substrates, NSW North Coast Bioregion and South Eastern Queensland Bioregion	13	0.3
700-410	Brush Box Mallotus philippinensis with E. siderophloia and Corymbia intermedia very high covers + presence of weeds (unallocated)	3	0.3
MU 023	Whalebone Tree/ Red Kamala dry subtropical rainforest of the lower Hunter River	21	0.3
MU 102	Grey Ironbark/ Broad-leaved Mahogany/ Smooth-barked Apple coastal headland low open forest of the Central Coast	2	0.3
700-436	Shatterwood - Stinging Tree - Yellow Tulipwood dry rainforest on steep stony slopes, NSW North Coast Bioregion and South Eastern Queensland Bioregion	9	0.29
700-480	Brush Box +/ - Blackbutt +/ - Pink Bloodwood tall forest of the coast and ranges of the NSW far north coast in the South Eastern Queensland Bioregion	3	0.29
700-481	Pink Bloodwood - Blackbutt - Grey Ironbark shrubby open forest on basalt hills of the far North Coast, South Eastern Queensland Bioregion	10	0.29
700-435	Shatterwood - Whalebone Tree dry rainforests on metasediments, NSW North Coast Bioregion and South Eastern Queensland Bioregion	54	0.29
MU 024	Shatterwood dry rainforest on ranges of the lower North Coast	4	0.28
1500-1142	Brush Box - Pink Bloodwood - Grey Ironbark - Blackbutt open forest on sandstone and alluvial sediments along the far North Coast of NSW, South Eastern Queensland Bioregion	14	0.28
700-485	Cupaniopsis anacardioides - Guioa semiglauca Regenerating Littoral Rainforest on Basalt and Metasediment North of the Richmond River, NSW North Coast Bioregion	21	0.28
700-432	Grey Myrtle - Rough-leaved Elm - Water Gum dry vine rainforest of seasonally dry gullies and hills, NSW North Coast Bioregion and South Eastern Queensland Bioregion	12	0.28
700-512	Coast Cypress Pine open forest to closed forest with littoral rainforest elements, South Eastern Queensland Bioregion	4	0.28
MU 032	Small-fruited Grey Gum/ Turpentine/ Tallowwood moist open forest on foothills of the lower North Coast	33	0.27
700-459	Small-leaved Lilly Pilly - Broad-leaved Lilly Pilly - Lilly Pilly littoral rainforest mainly on sands, NSW North Coast Bioregion and South Eastern Queensland Bioregion	12	0.27

Community or group	Community name or description	Number of plots	GBWS mean
700-431	Grey Myrtle - Brush Box dry rainforest on metasediments and lower nutrient volcanics, NSW North Coast Bioregion and South Eastern Queensland Bioregion	25	0.26
700-4	E. saligna E. laevopinea E. campanulata open forest	18	0.26
700-473	Coast Banksia - Tuckeroo closed forest/shrubland of coastal Holocene dunes, NSW North Coast Bioregion and South Eastern Queensland Bioregion	37	0.26
700-397	Syncarpia - E. microcorys - E. propinqua	13	0.26
1500-939	Brush Box - Turpentine - Spotted Gum shrub/grass tall open forest of the escarpment foothills, NSW North Coast Bioregion and South Eastern Queensland Bioregion	21	0.26
700-488	Swamp Box - Forest Red Gum - Pink Bloodwood seasonal swamp forest on floodplains and low rises, NSW North Coast Bioregion and the South Eastern Queensland Bioregion	35	0.26
1000-1627	Tuckean Wet Sclerophyll Forest (Lophostemon confertus - Livistona australis - Corymbia intermedia - Eucalyptus siderophloia)	3	0.26
MU 016	Black Booyong/ Giant Stinging Tree/ Rosewood/ Moreton Bay Fig lowland subtropical rainforest of the lower North Coast	31	0.26
MU 066	White Mahogany/ Spotted Gum/ Grey Myrtle semi-mesic shrubby open forest of the central and lower Hunter Valley	28	0.26
MU 045	Sydney Blue Gum/ New England Blackbutt/ Whitetop Box moist shrub/ grass tall open forest of the lower North Coast	20	0.26

Appendix 2

List of all plots assigned to Grey Box Grey Gum Wet Sclerophyll Forest TEC

This list comprises all plots assessed as Grey Box Grey Gum Wet Sclerophyll Forest TEC based on strong membership of floristic group NR 1000-1665, which we have assessed as belonging to the TEC. It excludes four plots with ambiguous membership.

Plot number	Latitude	Longitude	GBWS (1000-1665) membership	State forest
BUC14	-29.7808	152.6619	0.59	Nymboida SF
CUT23-3	-28.4251	152.6978	0.71	Unumgar SF
GBWS69	-28.4235	152.6976	0.74	
KAN01501	-30.0253	152.7760	0.8	
NEF2010	-28.8321	152.7376	0.95	
NEF2014	-28.8303	152.7346	0.93	
NEF2064	-28.3807	152.6969	0.99	Unumgar SF
NEF2065	-28.4177	152.6815	0.55	Unumgar SF
NYM41	-29.9477	152.6008	0.9	
REV62-01	-28.3822	152.7090	1	Unumgar SF
REV62-02	-28.3864	152.7067	1	Unumgar SF
REV62-03	-28.3749	152.7171	0.92	
REV62-04	-28.3701	152.7164	1	
REV62-06	-28.3932	152.7246	1	Mount Lindesay SF
REV62-07	-28.3897	152.7315	1	Mount Lindesay SF
REV62-08	-28.3868	152.7381	0.91	Mount Lindesay SF
REV62-10	-28.4217	152.6768	0.86	Unumgar SF
REV62-11	-28.4254	152.6870	0.99	Unumgar SF
REV62-12	-28.4229	152.6959	1	Unumgar SF
REV62-13	-28.4168	152.7117	0.98	Unumgar SF
REV62-14	-28.3697	152.6594	0.99	Mount Lindesay SF
REV62-15	-28.3684	152.5623	0.99	Bald Knob SF
REV62-18	-28.4281	152.7194	0.95	Unumgar SF
REV62-19	-28.4180	152.7111	1	Unumgar SF
REV62-20	-28.8589	152.7049	0.95	
UNE05046	-28.3888	152.6826	0.98	Unumgar SF
UNE05048	-28.4195	152.7131	0.94	Unumgar SF
UNE05059	-28.8641	152.7145	0.97	
UNE05063	-28.5243	152.3301	0.63	

Appendix 3

Field key for identifying Grey Box Grey Gum Wet Sclerophyll Forest TEC

This key assumes the vegetation to be assessed is in an area north of Taree and between 100 m and 600 m elevation. There is no indication that Grey Box Grey Gum Wet Sclerophyll Forest TEC (GBWS) occurs outside these parameters. Assessment should be done in 20m x 20m plots or areas of similar size. The more plots assessed, the more reliable the result. Likelihoods given below are mean proportions based on a single plot and have been rounded to the nearest 5%. This key and the likelihoods provided are based on distinguishing GBWS from vegetation not currently listed as any TEC. Vegetation identified as GBWS by this key may also, or alternatively depending on degree of floristic overlap, belong to Lowland Rainforest TEC.

To use this key, apply the following steps:

1. count the number of species present which are in the list of positive diagnostic species (Table A, first column) and the number of species present which are in the list of negative diagnostic species (Table A, second column).
2. using the results of step 1, refer to the row and column counts in Table B, to obtain an estimate of the likelihood that the vegetation is Grey Box Grey Gum Wet Sclerophyll Forest TEC.

Likelihoods for the case where no positive diagnostic species are present use the upper 95% confidence limit. In other cases, mean likelihoods are given and have an uncertainty of approximately +/- 5%.

Table A Diagnostic species

Positive diagnostic	Negative diagnostic
Psydrax odorata	Allocasuarina torulosa
Cupaniopsis parvifolia	Themeda triandra
Araucaria cunninghamii	Hardenbergia violacea
Denhamia bilocularis	Glycine clandestina
Croton insularis	Desmodium varians
Mallotus philippinensis	Syncarpia glomulifera
Celastrus subspicatus	Imperata cylindrica
Elaeodendron australe	Hibbertia scandens
Eucalyptus moluccana	Vernonia cinerea
Alchornia ilicifolia	Pteridium esculentum

Table B Estimates of likelihood that vegetation is GBWS

		Number of negative species					
		0	<=1	<=2	<=3	<=4	<=5
Number of positive species	0	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	>=1	0.25	0.15	0.1	0.1	0.1	0.05
	>=2	0.45	0.35	0.25	0.25	0.25	0.2
	>=3	0.65	0.55	0.45	0.4	0.4	0.4
	>=4	0.85	0.8	0.7	0.65	0.65	0.65
	>=5	0.9	0.9	0.85	0.85	0.85	0.85

Appendix 4

Summary of issues and Panel review, meeting held 17 May 2016

Final Determination	TEC Panel Principles	Our Project	TEC Panel Review
Occurs in NSW North Coast Bioregion	Accept Bioregional Qualifier	Adopted.	
'...typically has a tall open canopy of eucalypts with a structurally complex understorey including rainforest trees and shrubs, vines, ferns and herbs. Structural characteristics of the community may vary, depending on the intensity and nature of past disturbances including fire, logging and partial clearing.'	Assess vegetation structure descriptors that may constrain or allow a range of structural forms	Used to exclude related communities with predominantly grassy understorey, where this is consistent with results of floristic analysis. We assume that at the community level, grassiness is due to a combination of fire and physical environment and not fire alone; EEC may include individual stands with grassy understorey due to fire effects. Grassy vegetation with similar eucalypt dominants is floristically distinct and is recognised as one or more of several separate communities (but see note below regarding plots included in the nomination). We have excluded these from the TEC.	Endorsed the assessment of the related grassy community, NR 1500-155, as not GBWS TEC
Characterised by the list of 63 plant species	Be guided by the species lists presented in the Final Determination	Compare species assemblage data drawn from source classifications, other existing classifications and new classifications developed by our project with that presented in the Determination. A single community, NR 1000-1665, clearly has the highest proportion (0.61) of assemblage species of any community. The next highest has a substantially lower proportion (0.44) and is floristically a rainforest community. NR 1000-1665 is a robust community which varies little in composition with different analyses. We have included all of NR 1000-1665 as GBWS TEC. We have not included any other communities in this TEC.	Agreed that the assemblage list supports the description of the TEC as a shrubby wet sclerophyll forest and that 1500-155, a related grassy community, be excluded
Description of frequent, widespread or common species in canopy and other vegetation strata. In particular, '…is	Assess statements regarding the characteristics of the floristic composition	Use descriptive statements to assist in assessing how classifications described since the final determination, including new classifications	Accepted the inclusion of areas with canopy dominants other than cited species

Final Determination	TEC Panel Principles	Our Project	TEC Panel Review
typically dominated by an open tree canopy of Eucalyptus moluccana (Grey Box) and Eucalyptus propinqua (Grey Gum) and, less commonly, Eucalyptus biturbinata (Grey Gum), Eucalyptus siderophloia (Grey Ironbark) and Araucaria cunninghamii (Hoop Pine).'		developed by our project, relate to the EEC. Include only communities for which at least one cited canopy species is present, usually as a dominant. No constraint on canopy composition at the plot or sample scale. At the plot scale, a few plots in NR 1000-1665 are dominated by eucalypts other than those listed. These may also represent different eucalypt dominants at a map scale. We have included these as GBWS TEC. Our current mapping does not include areas with other canopy dominants except as part of image patterns where cited canopy species are present.	
'...typically occurs on the escarpment slopes and foothills of north-eastern NSW, most commonly between 200 and 500m elevation, where mean annual rainfall exceeds approximately 1000mm and has a summer maximum (DECC 2008). Soils that support the community are relatively fertile and derived from a range of igneous (including acid volcanic, basic volcanic and intrusive igneous) or fine-grained sedimentary rocks.'	Assess habitat descriptors and whether these constrain or define the limits of the TEC which otherwise may have a broader distribution	Used indicatively but not to constrain occurrence of TEC.	Noted
EEC 'includes' Forest Type 81 and the equivalent FE62. No other source is cited.	Assess references to existing vegetation classification sources in the Determination. The panel will note whether the existing classifications are "included within" are "part of" or "component of" the Final Determination. Classifications developed using traceable quantitative data will be recognised as primary data upon which to assess floristic, habitat and distributional characteristics. Where data has been sourced	There are no traceable primary quantitative data based on the vegetation types which are explicitly cited. Traceable data are available from the nomination, which is cited in reference to conservation assessment but not in reference to the definition of the EEC. We use allocations from the nomination as our primary data source, because the threat assessment in the final determination implies that the EEC is equivalent to the community defined by the nomination. This may not be consistent with the inclusion	Agreed that more recent analyses with broader scope provide a more accurate indication of relationships and that the two plots which belong to 1500-155 should not be included as GBWS TEC

Final Determination	TEC Panel Principles	Our Project	TEC Panel Review
	and used in alternate regional or local classification studies the results will be considered by the panel to assist in the development of the TEC definitional attributes.	of some interpretations of FT 81. Omission of citation of any other Forest Types implies that only communities dominated by E. moluccana and E. propinqua/E. biturbinata are EEC, but this constraint is not applied at the plot or sample scale. Mapped FT81 includes grassy forest belonging to communities other than NR 1000-1665. Of the 20 plots attributed to GBWS in the nomination, 2 have since been included in a separate community, 1500-155, characterised by more grassy understorey, in the NR analysis. This change is consistent with our more recent analyses and likely occurred because of the limited scope of the analysis done for the nomination, which included only a small subset of non-target plots. These two plots are in mapped type 62a, not FT81. Community 1500-155 is floristically related to GBWS, but has a much lower proportion of species in the assemblage list than 1000-1665 (0.42 compared to 0.61). We propose to exclude 1500-155 from GBWS TEC. Alternative options are to include just the two nominated plots, or to include all of 1500-155. The latter would affect the conservation assessment of the TEC. Our current mapping pathway does not include grassy forest.	