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J.6 Conservation Zone Management Plan

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CONSERVATION ZONE MANAGEMENT PLAN

New Acland Coal Mine Stage 3 Project

JANUARY 2014

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1. Introduction

1.1. Background

This Conservation Zone Management Plan (CZMP) has been developed to ensure the protection of significant landscape features, and the enhancement of associated environmental values, during the implementation of the revised New Acland Stage 3 Project (revised Project) at the New Acland Coal Mine (Mine). In particular, the CZMP focusses on two key landscape features, namely Lagoon Creek and nearby Bottle Tree Hill.

Under this plan, New Acland Coal Pty Ltd (NAC) will develop and implement strategies and activities that fall within the revised Project and existing Mine areas, protect and enhance ecologically significant areas of remnant vegetation, and promote restoration of the Lagoon Creek riparian zone.

The CZMP builds upon ecological investigation and planning, and also the Conservation Management Plan associated with Stage 2 of the Mine. The earlier Plan was developed and implemented to address Condition F2 of the Mine's Environmental Authority (EA) EPML00335713.

It is proposed that the CZMP will be distinct from the Final Landuse and Rehabilitation Plan (FLURP). The CZMP will however be administered through NAC's Plan of Operations, and be referred to in that key document. It will also be referenced to and coordinated with the rehabilitation and conservation activities of the FLURP.

NAC will concentrate conservation and rehabilitation efforts on selected sections of Lagoon Creek that are contained within the boundaries of the revised Project. NAC will also undertake additional conservation and rehabilitation measures around Bottle Tree Hill.

1.2. Plan Scope

The scope of this CZMP includes:

- An assessment of current native vegetation status;
- Identification of suitable areas for rehabilitation;
- Determination of mechanisms for rehabilitation;
- Description of rehabilitation methods; and
- Development of native vegetation rehabilitation criteria.

1.3. Plan Objectives

The overall objectives of this CZMP are to ensure the protection of significant landscape features near the New Acland Coal Mine, and to enhance the associated environmental values, during the implementation of the revised Project. In particular, the CZMP focusses on two key landscape features, namely Lagoon Creek, and nearby Bottle Tree Hill.

More specifically, the CZMP aims to meet these objectives by providing guidance on the protection, rehabilitation and management of significant vegetation and habitat associated with the landscape features, including existing stands of regional ecosystems (REs) 11.8.5 and 11.8.3 located on Bottle Tree Hill and remnant patches of REs 11.3.1, 11.3.2, 11.3.17, 11.3.21, 11.9.5, 11.9.10 and 11.9.13 located within the riparian zone of Lagoon Creek.

2. Current Status of Native Vegetation

2.1. Overview of the Existing Environment

Most of the original vegetation has been cleared in the Mine and revised Project areas for agriculture, grazing and mining operations. The original pre-European vegetation within these areas would have consisted of woodlands and open forests of Poplar Box *Eucalyptus populnea*, Brigalow *Acacia harpophylla* and Belah *Casuarina cristata* on low lying alluvial plains and low hills on clay soils.

The presence of Forest Red Gum *Eucalyptus tereticornis* in low numbers suggests that this species was probably more common in the pre-European vegetation. Igneous soils on higher parts of the Mine and revised Project areas are likely to have supported Mountain Coolibah *Eucalyptus orgadophylla* woodlands and dry rainforest vine thickets while native grasslands comprising mostly Queensland Bluegrass *Dichantheum sericeum* are likely to have dominated heavy clay soils and interspersed amongst woodland vegetation.

Extant remnants of these vegetation types currently consist of small isolated patches of woodland amongst grazing and cropping lands and narrow strips retained along road reserves (Figure 2-1). The condition of the remnant vegetation is variable, with most areas being subjected to long-term grazing impacts, and as a consequence, present moderate to low diversity of native flora. Native grassland occurs in paddocks not subject to regular ploughing, cropping and grazing, with better quality examples occurring in lightly grazed areas.

The general topography comprises low undulating hills and alluvial plains with a small number of rocky hillocks. Lagoon Creek is ephemeral, and flows across the Mine and revised Project areas from the north-east corner to the south-west corner, supporting numerous man-made, in-stream dams and a patchy distribution of remnant vegetation. Some semi-permanent waterholes exist, however farm dams are the only permanent source of water on the site.

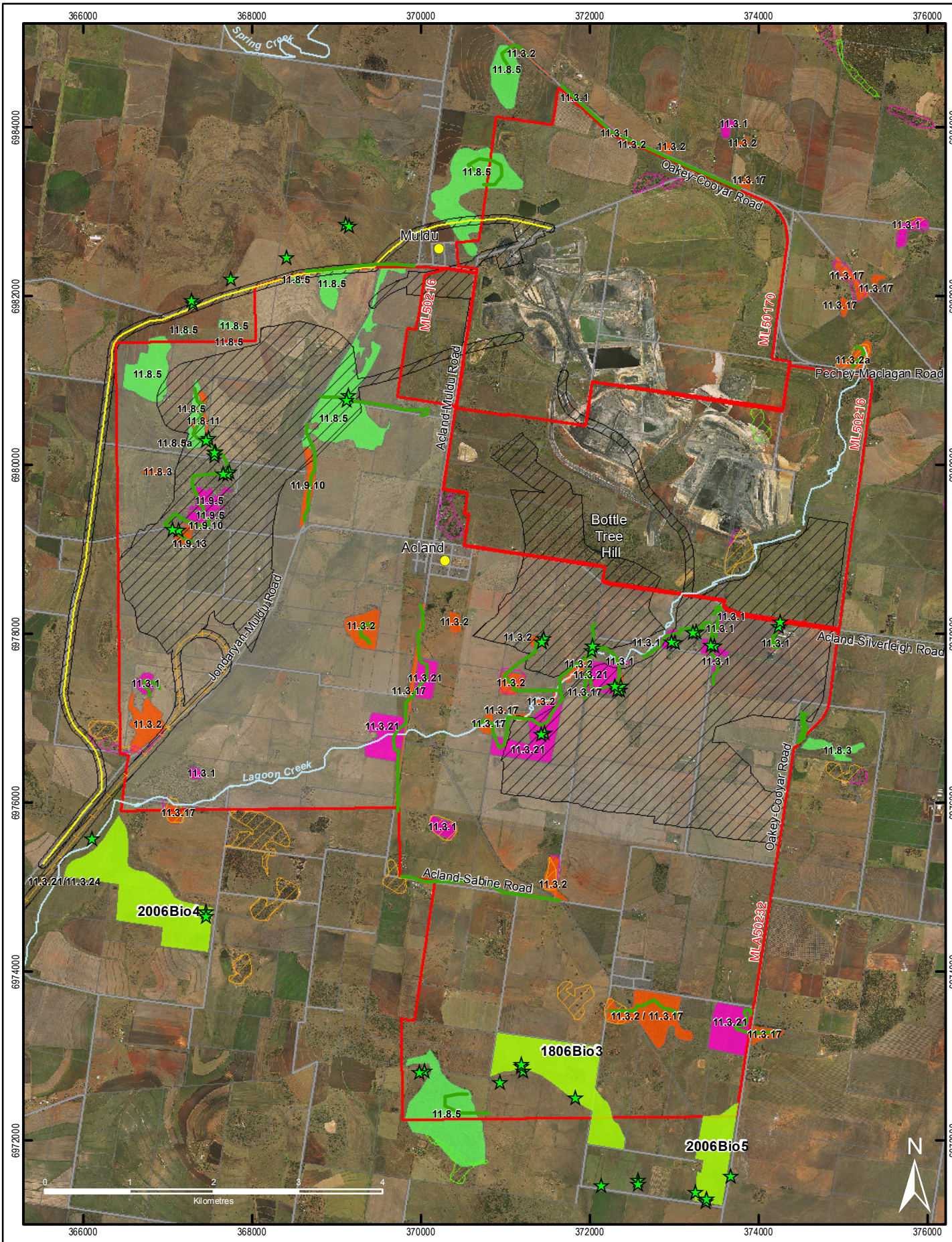
Numerous vegetation communities have been identified within the Mine and revised Project area, as determined by regional ecosystem mapping and field verification.

The Mine is positioned high in the Lagoon Creek catchment, and as a result, the Creek possesses a relatively small upstream catchment area of approximately 300ha and only flows after significant rainfall events. A majority of Lagoon Creek's channel is poorly defined and difficult to ascertain in areas without detailed topographical survey information.

The ecological and physical status of Lagoon Creek as part of the Oakey Creek sub-catchment was classed as 'poor' to 'very poor' in all the key parameters surveyed by the Department of Natural Resources and Water (NRW) for its last 'State of the Rivers' report on the Upper Condamine River catchment. The Lagoon Creek system has suffered a long history of disturbance from agricultural activities, such as grazing, and as a result, riparian and aquatic vegetation, channel diversity and bank stability are highly impacted and exotic weed species invasions are common.

2.2. Vegetation Communities present within the revised Project area

The three regional ecosystems found in the revised Project area are described in Table 2-1 and their distribution mapped in Figure 2-1. The location and extent of the community, a general description of species, structure and assessment of the conservation values of the community at a national, state and regional level are included.



LEGEND

- Towns and Localities
- Flora Transects
- Rail Spur
- Roads
- Creeks
- Jondaryan-Muldu Road Diversion
- Cadastre
- Mining Tenements
- Disturbance Footprint Area
- Proposed Extent of Surface Rights Area

High Value Regrowth

- Containing Endangered regional ecosystems
- Containing Of Concern regional ecosystems
- Is a Least Concern regional ecosystem
- Biocondition Assessment Sites

Observed Regional Ecosystems

- Endangered
- Of Concern
- Least Concern

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Figure 2-1 - Extent of Remnant Regional Ecosystems

Scale 1:60,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Table 2-1 Vegetation communities of the revised Project area

No.	Regional Ecosystem Code	Biodiversity Status	VM Act Status	Description
1	11.3.1	Endangered	Endangered	*Acacia harpophylla* and/or *Casuarina cristata* open forest on alluvial plains
2	11.3.2; 11.3.2a	Of Concern	Of concern	*Eucalyptus populnea* woodland on alluvial plains
3	11.3.17	Endangered	Of concern	*Eucalyptus populnea* woodland with *Acacia harpophylla* and/or *Casuarina cristata* on alluvial plains
4	11.3.21	Endangered	Endangered	*Dichanthium sericeum* and/or *Astrebla spp.* grassland on alluvial plains. Cracking clay soils
5	11.8.3	Of Concern	Of Concern	Semi-evergreen vine thicket on Cainozoic igneous rocks. Steep hillsides
6	11.8.5; 11.8.5a	No concern at present	Least Concern	*Eucalyptus orgadophila* open woodland on Cainozoic igneous rocks; *Eucalyptus orgadophila* woodland with a dense understorey of low trees species
7	11.9.10	Endangered	Of Concern	*Acacia harpophylla, Eucalyptus populnea* open forest on Cainozoic fine-grained sedimentary rocks
8	11.9.3	Of Concern	Of Concern	*Eucalyptus moluccana* or *E. microcarpa* open forest on fine grained sedimentary rocks
9	11.9.5	Endangered	Endangered	*Acacia harpophylla* and/or *Casuarina cristata* open forest on fine-grained sedimentary rocks

2.3. Pre-clearing Regional Ecosystem Extents

Pre-clearing vegetation mapping was obtained from the Queensland Herbarium to ascertain likely historical patterns of vegetation across the study area. The mapping indicates that a single Regional Ecosystem dominated the floodplain of Lagoon Creek, RE 11.3.17 – *Eucalyptus populnea* woodland with *Acacia harpophylla* and/or *Casuarina cristata* on alluvial plains.

This regional ecosystem is described in the Regional Ecosystem Description Database as follows.

"*Eucalyptus populnea* woodland with *Casuarina cristata* and/or *Acacia harpophylla* clumps or scattered trees and a low tree layer dominated by *Geijera parviflora*. *Eucalyptus populnea* predominates forming a distinct but discontinuous canopy (15-18m high). *E. populnea* alone may form the canopy at a density of 25-75 trees/ha, or *Acacia harpophylla* and/or *Casuarina cristata* may be part of the canopy.

Most frequently, *A. harpophylla* predominates a lower tree layer (8-14m high). A moderately dense, tall shrub layer is usually present, and dominated by species such as *Eremophila mitchellii, Geijera parviflora, Acacia melvillei* (Darling Downs), *Alectryon oleifolius* and *Acacia pendula*. Localised areas may be dominated by *Acacia harpophylla* or other understorey species.

A sparse to open, low shrub layer is frequently present. The ground layer is usually sparse, and composed of grasses most frequently *Bothriochloa decipiens, Aristida ramosa, Enteropogon acicularis* and *Paspalidium* spp. with *Chloris ventricosa, Eragrostis lacunaria, Aristida jerichoensis, Paspalidium constrictum*, and *Tripogon loliiformis* on scalded areas. Occurs on back plains, levees and terraces formed on Quaternary alluvial deposits. Soils are generally deep texture contrast with thin sandy surfaces."

2.4. Current Condition

The riparian zone of Lagoon Creek within the revised Project area currently supports limited isolated patches of mapped remnant vegetation. Field surveys found that this area contains patches of two REs listed as Endangered under the VM Act (11.3.1 and 11.3.21), and another two mapped as Of concern (11.3.2 and 11.3.17). The riparian zone also contains several clumps of near-remnant vegetation, including stands of Poplar Box *Eucalyptus populnea* and Brigalow *Acacia harpophylla* with scattered Belah *Casuarina cristata*.

In some areas, particularly towards Acland Road, there is significant recruitment of Brigalow and Poplar Box, whilst other areas support a dense growth of Wilga *Geijera parviflora*, with no canopy elements.

Lagoon Creek contains many man-made, in-stream impoundments which have compromised natural flows.

2.5. Potential Vegetation Clearing

Disturbance to vegetation within the immediate riparian zone (within 50 metres) of Lagoon Creek is only planned at one location within the revised Project area (Mining Lease Application 50232), located to the south of the existing Mine (Mining Leases 50170 and 50216). This disturbance will be associated with the construction of a creek crossing for a planned mine haul road from the Willaroo Pit area to the Coal Handling and Processing Plants. The exact location of the crossing will be planned to avoid unnecessary disturbance to patches of remnant REs present, mapped as either Endangered (primarily 11.3.21), or as Of concern (primarily 11.3.2).

To date, there has only been some limited clearing of the eastern margins of Bottle Tree Hill, associated with the construction of a radio repeater station and access track. This clearing has been offset by excluding stock from the area and restricting vehicular access to the confines of the track. The conservation area will be extended beyond the existing vegetation boundary to the western edge of the patch.

The following sections of the Plan review a number of potential rehabilitation methods which may be applied to the Lagoon Creek and Bottle Tree Hill conservation areas, an action plan for implementing the conservation measures and a monitoring program and assessment criteria for determining the efficacy of the conservation measures.

3. Potential Rehabilitation Methods

3.1. Introduction

Natural regeneration, direct seeding and planting of seedlings are the three main techniques used in revegetation. Each technique has advantages and factors to consider when deciding whether it is suitable. These methods are discussed in the following sections.

3.2. Natural Regeneration

If remnant vegetation is present, whether as isolated trees in a paddock or grassland along a roadside, it is often the ideal starting point to encourage natural regeneration. For nature conservation on farmland, the priority is to fence off and manage these areas first, including encouraging natural regeneration events from seed dispersal and the existing soil seed bank (i.e. under the appropriate climatic conditions).

Natural regeneration is an effective, low cost method of establishing large numbers of plants in a random design. It is an important part of the succession and ecology of vegetation. Characteristics of natural regeneration include the following:

- genetics are appropriate for the site (except for isolated trees with no out-crossing potential);
- low cost in terms of labour and dollars;
- specialised equipment is not usually necessary;
- can be adapted for large and small scale projects;
- a large number of plants can be produced (they will self-thin over time or can be actively managed if required);
- ensures indigenous species are established rather than weeds;
- plants develop deep, strong root systems which help them establish quickly and withstand drought and wind;
- the random spacing of established plants will result in the re-creation of a clumped self-sustaining habitat; and
- usually used with remnant vegetation areas and provides further protection for these areas.

Without fencing to exclude livestock, new seedlings will not be established. Livestock readily eat young seedlings, particularly when there is no other food available, for example, during the autumn feed gap. Trampling and compaction by livestock also exacerbate this problem.

The seedbed can be improved in different ways to suit different species. Light cultivation, scalping, fire and the removal of weeds to increase light and soil moisture may be appropriate options.

3.3. Direct Seeding

Direct seeding involves the sowing of treated seeds directly onto a site to achieve germination and establishment and can be carried out mechanically or by hand. Advantages of direct seeding are as follows.

- This technique involves a plant growing from seed rather than propagated material. Direct seeded trees and shrubs develop deep, strong root systems that help them establish quickly and withstand drought and wind.
- The patchy spacing of established plants enables the re-creation of a 'natural' self-sustaining habitat.
- If conditions are not favourable for seeding, (for example, too dry), the seed can be stored for future sowing. Seedlings are harder to look after until the next season.
- Mechanical direct seeding is the most efficient technique for broad scale revegetation.
- Mechanical direct seeding is cost effective and labour efficient. Assuming the appropriate site preparation is completed, it is possible, with current technology, for one person to revegetate 10 to 15 hectares in one day (approximately 30 to 45 kilometres of seed line).

There are a range of direct seeding machines available for direct seeding native vegetation. Direct seeding machines are commonly mounted on tractor linkage or drawn by 4WD vehicles. The critical issue is ensuring the machine is suited to the site conditions and that it is set up to provide the right seedbed and seed placement.

Direct seeding by hand is another option for native vegetation establishment, and can be used for a range of purposes and in many different situations.

3.4. Planting

The planting of indigenous seedlings can be undertaken by machine or by hand. While there is an increase in labour, time and money with this technique compared to natural regeneration and direct seeding, a high level of efficiency can be achieved with the use of planting equipment and when planting is preceded by good planning and ground preparation, and follow up maintenance to reduce weed and grass competition during establishment.

Advantages of mechanical planting include the following:

- mechanical planting provides an efficient option for large-scale revegetation in the right conditions - flat to undulating country with friable soil conditions;
- suitable for planting specimens grown from cuttings or tissue culture or open-rooted seedlings;
- it is particularly suitable for projects which require regular, known, spacings of tree seedlings, such as farm forestry or narrow shelterbelts;
- for use in planting selected, high performance, provenance seedlings which would be too wasteful of seed or too expensive to direct seed;
- can commonly achieve planting rates of 500 to 1,000 plants per hour;
- enables older or infirm people to participate in planting;
- some machines water-in planted seedlings;
- it is a useful technique for establishing recalcitrant species that may possess special germination or other requirements; and

- much less tiring than manual planting.

Hand planting is a technique most suited to revegetation projects that:

- require selected plants at regular spacings, for example, farm forestry;
- require species that are difficult to direct seed;
- are establishing species for which there is a limited seed supply; hand planting can be valuable in setting up seed production areas to rectify this problem for the future;
- aim to provide a high level of community education at the planting stage;
- are inaccessible by machinery;
- are of a small scale;
- use a wide range of species; or
- require the planting of specimen trees.

4. Action Plan

4.1. Introduction

The following sections outline vegetation conservation measures planned for Lagoon Creek and Bottle Tree Hill. The plan identifies areas which are:

- Remnants and require protection;
- Non-remnant areas that will be encouraged to regenerate naturally; and
- Those areas which may require active revegetation through direct seeding and/or planting.
- The conservation areas and likely methods of management are shown in Figure 4-1.

4.2. Remnant Protection

4.2.1. Lagoon Creek

When it comes to recreating a 'natural' landscape, the protection, enhancement and management of existing remnant native vegetation is the highest priority. Remnant vegetation will contain the remaining biodiversity and the elements of functioning ecosystems that are often the hardest to recreate through revegetation: the fungi and soil microorganisms, lichens, mosses, herbs and ground covers. Remnants, whether in good condition or degraded, are in most cases much easier and cheaper to restore than recreating new areas from scratch.

For the vast majority of revegetation, fencing is the most cost-effective way of protecting plants from livestock.

4.2.2. Bottle Tree Hill

Vegetation on Bottle Tree Hill is in relatively good condition, with limited weed invasion, a high level of natural recruitment and many elements of remnant vegetation. Minimal intervention is required across this area.

Vegetation will continue to be protected by the exclusion of stock and the restriction of vehicular access/disturbance within the area. A radio repeater station and access track that have been constructed on Bottle Tree Hill, which has resulted in some limited disturbance of vegetation. The area outside this limited disturbance footprint has been designated as a conservation zone.

As stock are restricted from the larger area due to mining operations, fencing of the conservation zone is not considered to be necessary. The boundary of the zone will be adequately signposted to ensure no accidental disturbance within the conservation zone. NAC also possesses a 'permit to disturb' system to prevent accidental disturbance at the Mine for cultural heritage and other purposes. This practice will be continued for the revised Project.

4.3. Natural Regeneration

4.3.1. Lagoon Creek

Several non-remnant areas exhibit strong natural recruitment of seedlings, and these areas are suited to natural regeneration with minimal intervention. Such areas will be monitored to

determine the level of seedling recruitment over time. If required, some stimulation of soil seed banks may be appropriate by excluding grazing pressure, controlling weeds and light cultivation.Figure 4-1 shows areas of Lagoon Creek which will be allowed to naturally regenerate.

4.3.2. Bottle Tree Hill

The clearing of vegetation on the north-eastern side of Bottle Tree Hill for the repeater station access track (approximately 5 metres wide), has been offset by the extension of the conservation zone on the western side of the remnant. The cleared areas have been mapped and maintained on a site plan.

The exclusion of stock from this area, as part of the broader mine area, is now allowing natural regeneration.

4.4. Direct Seeding and Planting

4.4.1. Lagoon Creek

Areas currently lacking a remnant or near-remnant canopy and showing limited recruitment potential may require direct seeding and/or planting with appropriate groundcover, shrub and tree species. Initially, these areas should be fenced off to prevent stock assess and rates of natural regeneration assessed. Direct seeding/planting should then be undertaken in areas where natural regeneration is limited. A list of suitable species is provided in Section 4.5.

4.4.2. Bottle Tree Hill

No direct seeding or planting is proposed for Bottle Tree Hill.

4.5. Action Plan Timetable

4.5.1. Lagoon Creek

Stock exclusion has taken place since 2009. A program of direct planting along Lagoon Creek with appropriate groundcover, shrub and tree species is on-going. This program has commenced in the north-east corner of the current Mine site, and is progressing towards the south-west corner.

It is intended that the active restoration of Lagoon Creek will progress at a rate of approximately 1-2 km of creekline per year. This rate may be influenced by climatic conditions, for example, during drought periods.

4.5.2. Bottle Tree Hill

The exclusion of stock access to the conservation zone surrounding Bottle Tree Hill to allow natural regeneration has occurred since 2009.

4.6. Species for Seeding/Planting of Lagoon Creek

The suggested species list (Table 4-1) has been compiled from vegetation survey plot data obtained from reference sites for Regional Ecosystem 11.3.17.

This list should not be considered comprehensive, but provides a reasonable guide to species selection. Where possible, seed would be sourced locally (local provenance) to maintain the genetic integrity of the flora. The final species selection used in the seeding/planting program will be determined by a number of factors including the availability of local provenance seed/plant stock, and local site conditions.

LEGEND

- Towns and Localities
- Proposed Rail Spur
- Roads
- Stage 3 Pit Areas
- Mining Tenements

Rehabilitation Zones

- Direct seeding/planting
- Natural regeneration
- Remnant protection

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Figure 4-1 - Rehabilitation Plan

Scale 1:43,000 on A4
Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Table 4-1 Suggested Species for Revegetation

Scientific Name	Common Name	Life form	Propagation Best From	Months from Propagation to Field-Ready	Best Method of Establishment
Acacia harpophylla	Brigalow	Large Tree	Seed	3	Soil seedbank
Acacia melvillei	Myall	Small Tree	Seed	3	Direct Seeding
Casuarina cristata	Belah	Large Tree	Seed	3	Seedlings
Eucalyptus populnea	Poplar Box	Large Tree	Seed	No data	Seedlings
Eucalyptus orgadophila	Mountain Coolibah	Large Tree	Seed	No data	Seedlings
Geijera parviflora	Wilga	Small Tree	Seed	No data	Seedlings
Acacia salicina	Sally Wattle	Small Tree /shrub	Seed	3	Soil seedbank
Acacia pendula	Weeping Myall	Small Tree /shrub	Seed	3	Soil seedbank
Alectryon oleifolius	Western Rosewood	Small Tree	Seed	No data	Seedlings
Eremophila mitchellii	False Sandalwood	Small Tree	Seed	No data	Seedlings
Aristida leptopoda	White spear grass	Groundcover	Seed	No data	Direct Seeding
Aristida ramosa	Three-awned spear grass	Groundcover	Seed	No data	Direct Seeding
Aristida jerichoensis	Jericho Wiregrass	Groundcover	Seed	No data	Direct Seeding
Chloris ventricosa	Tall Chloris	Groundcover	Seed	No data	Direct Seeding
Enteropogon acicularis		Groundcover	Seed	No data	Direct Seeding
Eragrostis lacunaria	Purple Love Grass	Groundcover	Seed	No data	Direct Seeding
Paspalidium constrictum	Knottybutt Grass	Groundcover	Seed	No data	Soil seedbank

Scientific Name	Common Name	Life form	Propagation Best From	Months from Propagation to Field-Ready	Best Method of Establishment
Tripogon loliiformis	Fiveminute Grass	Groundcover	Seed	No data	Soil seedbank
Bothriochloa decipiens	Pitted Blue grass	Groundcover	Seed	No data	Direct Seeding
Panicum decompositum	Native Millet	Groundcover	Seed	No data	Direct Seeding

5. Native Vegetation Rehabilitation Criteria

5.1. Introduction

A useful way of evaluating the progress of a revegetated site is to compare the monitoring results with:

(a) baseline data (describing the condition of a site before the revegetation was established); and

(b) survey data from one or more reference sites (i.e. sites representing the 'target condition', such as remnant forests of the type that may have occurred on a site prior to clearing).

Comparison with baseline data will show how much a site has changed following revegetation, while comparison with forest reference (benchmark) site(s) can show whether the revegetated site has achieved the target condition, and if not, what attributes require further development. Comparisons with reference sites are particularly useful, because many structural attributes vary between different forest types and regions.

This section presents information, protocols and proformas for monitoring 'basic indicators' at revegetated sites. Basic indicators include various aspects of forest structure which have been selected for survey because they:

- provide information on important stages of development of a revegetation project;
- can be measured relatively easily and rapidly, without specialist knowledge; and
- are correlated with the use of sites by wildlife.

5.2. Assessment Parameters

5.2.1. Recruitment of Woody Perennial Species

Recruitment or regeneration is essential to the sustainability of any ecosystem. Some land management practices such as burning and grazing, and natural processes such as drought, can degrade the ability of natural regeneration processes to take place. Regeneration is therefore an important component in assessing the health or condition of each zone.

The recruitment attribute will be used to assess the presence of recruitment of the dominant overstorey species. For ease and reliability of assessment, assessment of recruitment will be restricted to the dominant woody perennial species within the tree layer, due to the seasonal and therefore ephemeral nature of the lower layers.

Recruitment will be assessed as the proportion of overstorey species present at a site that are regenerating (<5 cm diameter at breast height [dbh]), for example, if four overstorey species occur at the site, but only two of these species are present as regeneration, then the proportion is 50%.

5.2.2. Native Plant Species

To simplify assessment, native plant species richness will be estimated for five life-forms: trees, shrubs, grass, forbs and others. Assessment will be based on the number of native species observed in the 50 x 10 m plot for each life form group. A total score for native plant species richness will be derived by adding together the scores identified for each of the five life-form groups, and dividing by 5.

5.2.3. Tree Canopy Cover

The vertical projection of the tree canopy over a 100 m transect will be recorded. The total length of the projected canopy will then be divided by the total length of the tape to give an estimate of percentage canopy cover, which will be compared with the benchmark data.

The tree canopy cover attribute score will be qualified by the health of the canopy of the trees assessed along the 100 m transect. Trees assessed along the transect, with canopies that fit into health categories 3, 4 and 5, having lower scores than those with scores of 1 or 2.

5.2.4. Tree Canopy Height

Tree canopy height refers to the median canopy height in metres, estimated for the tree layer within the 100 m x 50 m assessment area. The median canopy height is the height that has 50% of canopy trees larger and smaller than it. This is generally synonymous with average height, except when there are some trees that are substantially higher or lower than the median (Neldner *et al.* 2005).

5.2.5. Shrub Cover

Shrub canopy cover refers to the estimate of the percentage cover of native shrubs recorded along the 100 m transect (similar to the estimation of tree canopy cover using a vertical projection downwards).

5.2.6. Ground Cover

There is one ground layer, which may contain graminoids, forbs, sprawling vines and other plants that are short in stature and overlap in height with the grasses. Seedlings of trees and shrubs will be included in this layer, if not already allocated to a separate shrub layer. The ground layer most frequently extends from 0 cm to 100 cm (Neldner *et al.* 2005). The ground cover is measured by a vertical projection downwards of the living plant material.

Three components of the ground cover will be scored: perennial grass species cover; perennial herb and forb (non-grass) species cover and; annual grass, herb and forb species cover. Perennial ground cover species will be scored as a separate attribute from annual ground cover species.

5.2.7. Large Trees

Large trees are an important resource within forest and woodland ecosystems. They provide greater leaf material, nectar and bark-surface area for foraging purposes, and are more likely to contain hollows and crevices for nesting and sheltering purposes.

Large trees are defined as the number of large living trees per hectare. These trees will be counted within the 100 x 50 m assessment area to give a density per hectare. This number can then be compared with the RE benchmark, and placed in the appropriate category. Any large trees located during the assessment will also be assessed regarding its habitat value for hollow-dependent wildlife. If a large tree also contains an observable hollow with an opening > 10 cm diameter, then a higher score is given.

5.2.8. Fallen Woody Material

Fallen woody material is an important component in many aspects of ecosystem functioning. It is primarily measured as a habitat surrogate for ground dwelling fauna, but can also be used as a variable in the estimate of carbon biomass, and as an indicator of fire disturbance.

Fallen woody material refers to coarse woody debris or dead timber on the ground > 10 cm diameter and > 0.5 m in length. Assessment will be conducted by counting the number of

fallen woody logs and other debris that are found within the 50 m x 10 m plot. To be counted as in, 50% or greater of the log will have to be located within the plot.

5.2.9. Weed Cover

Weed cover refers to the percentage cover of non-native plant species, assessed within the 50 m x 10 m sub-plot. Where there are weeds present in more than one layer, e.g. a grass in the ground layer and shrub in the shrub layer then the percentage in each layer are added together to give a percentage weed cover for the site. The benchmark for weed cover in RE 11.3.17 is 18%.

5.2.10. Organic Litter

Organic Litter includes both fine and coarse organic material such as fallen leaves, twigs and branches < 10 cm diameter. Organic litter cover refers to the average percentage cover assessed within each of the five 1 m x 1 m quadrats. Within a quadrat, the sum of the native ground cover, weed ground cover, organic litter (including any coarse woody material) and bare ground/ rock cover, must equal 100 per cent.

5.3. Reference Sites

5.3.1. Rationale

Quantitative benchmark data can be derived by locating and setting up a local reference site. Reference site assessment does require good botanical and habitat assessment skills, and entails measurement and recording of vegetation floristics and structure.

The assessment methodology detailed in this document is for the location, establishment and recording of floristic and structural vegetation attributes specifically for the generation of benchmarks for rehabilitation.

The appropriate location and establishment of a reference site is paramount to the derivation of relevant benchmarks. Canopy height and cover vary within RE's according to environmental conditions. Therefore areas to be assessed should be compared with a reference site that occurs as close as possible to the area to be assessed and has similar environmental conditions, i.e. the same regional ecosystem, vegetation community, similar climate (same subregion), similar landscape conditions (soil, slope, position in the landscape, geology, etc.) and similar natural disturbance (cyclone impacts or fire history).

For this reason, field measurements of the height, canopy cover and species composition of the area of interest are compared, where possible, to measurements from a local reference area, i.e. a nearby area of comparable vegetation that is known to be remnant, such as a shadeline or road reserve.

Reference sites are selected in RE's with no extensive chemical or mechanical disturbance to the predominant canopy evident on the aerial photograph archive (from 1960s to recent) or on the ground.

5.3.2. Methodology for Establishing the Reference Site

The assessment site constitutes a 100 m x 50 m nested plot design as per the BioCondition Assessment Methodology (Eyre *et al.* 2011), developed by the former DERM. The layout of the site and nested subplots is shown in Figure 5-1 with further detail provided in Appendix A.

A series of subplots is used to sample the floristic, habitat and disturbance components, and is summarised as follows:

- 100 m x 50 m area: records all potential large trees > 20 or >30 cm diameter at breast height (DBH): depending on the tree species;
- 50 m x 10 m area: record all fallen woody material > 10 cm diameter, and number of floristic species by lifeform group i.e. Tree, Shrub, Grass, Forbs and other species;
- 100 m transect: record tree and shrub canopy cover; and
- five 1 m x 1 m subplots: record ground cover, litter, rock cover, and bare ground.

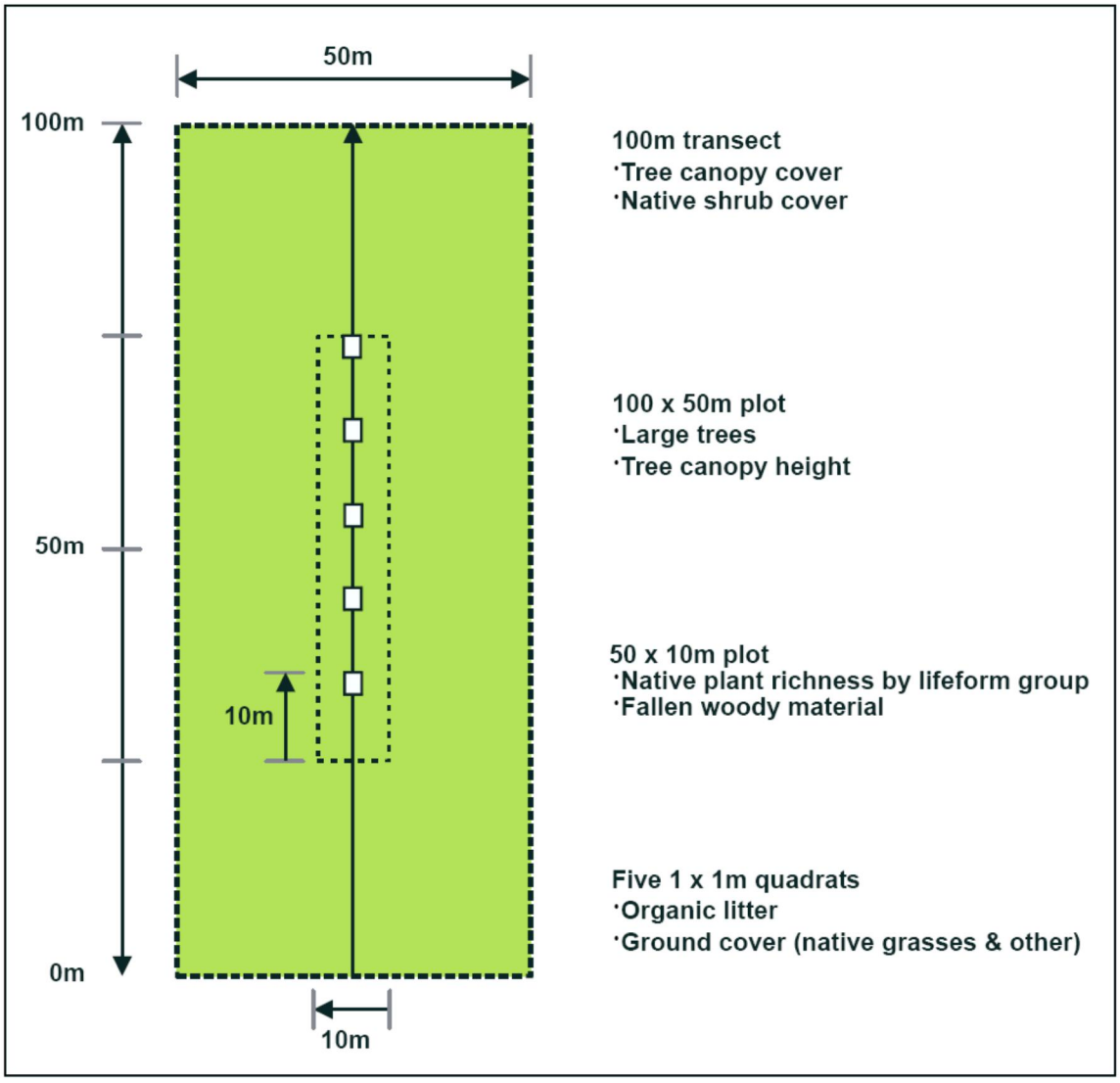
Demarcation of the reference site is established by positioning a 100 m tape, which constitutes the centre line of the plot. Flagging tape can be used to identify the outer boundaries of the plot, which is 25 m each side of the centre transect.

The plot boundary must be a minimum distance of 50 m from a major disturbance or discontinuity such as a road or disturbed edge. In topographically diverse areas, the plot should be oriented so that its long axis follows the contour, or topographic position (e.g. gully, midslope, ridge).

Plot location is recorded at its centre point (the 50 m point along the 100 m transect). A global positioning system (GPS) is recommended to record the position of the centre point in the field. This position should be checked against a 1:100 000 or larger scale topographic map for the area.

The altitude recordings on GPS can be inaccurate and are better derived from the topographic map. The use of star pickets or pegged down tyres at the beginning and end of the 100m transect will aid in relocating the site for future monitoring.

Figure 5-1 Configuration of Reference Sites



A full methodology for data collection for reference sites is provided in Appendix A.

5.3.3. Lagoon Creek Reference Site Results

Based on the best available information (ie: pre-clearing RE mapping maintained by the Department of Environment and Heritage Protection) and site observations, the alluvial plains of Lagoon Creek within the study area historically supported a single regional ecosystem, characterised by Poplar Box *Eucalyptus populnea* and Brigalow *Acacia harpophylla*.

A reference site transect was established within a remnant patch of RE 11.3.17, to establish benchmark data. This reference site was located on Myall Creek, on the Maclagan-Cooyar Road (368858 E, 7007998 S), and it displayed the condition attributes listed below in Table 5-1.

Table 5-1 Benchmark data for RE 11.3.17

Site Based Condition Attributes	RE 11.3.17
Recruitment of woody perennial species	100% of overstorey species present as natural recruitment, three species present
Native plant species richness	18
Tree canopy cover (%)	30-40%
Tree canopy height	19m
Shrub layer cover (%)	10%
Native perennial grass cover (%)	65%
Native perennial forb and non-grass cover (%)	15%
Native annual grass, forb and non-grass cover (%)	5%
Large trees	35
Fallen woody material	12
Weed cover (%)	18%
Litter cover (%)	10%

5.4. Rehabilitation Criteria

5.4.1. Background

The development of species composition in restored sites toward a state that resembles appropriate reference sites is, at best, extremely slow and as such there is little to be gained by setting unrealistic rehabilitation targets.

A full species survey or census to quantify the biodiversity values of a patch of vegetation is expensive to conduct and requires high levels of technical expertise. As such, use of indicators of biodiversity, or measurable surrogates of biodiversity, is a relatively reliable and cost effective approach to assess or monitor biodiversity.

At the site scale, biodiversity indicators are either based on key or 'indicator' species or structural aspects of the vegetation that are known to be important for biodiversity. The approach using key indicator species is limited because relationships between species and biodiversity are yet to be established, as well as other inherent issues with survey conditions and how these can influence detectability of species.

However, indicators based on key vegetative structural elements are proving to be a more reliable and cost effective approach for the assessment of biodiversity, and form the basis of assessment of vegetation condition elsewhere in Australia.

5.4.2. Targets for Site-based Condition Attributes

Targets for site-based condition attributes have been derived from the benchmark data obtained for RE 11.3.17.

Target values adopted are the minimum values which would score greater than zero, using the Biocondition Assessment Manual (Eyre *et al.* 2011), for each attribute (Table 5-2).

Table 5-2 Lagoon Creek Rehabilitation Targets

Site Based Condition Attributes	Rehabilitation Targets	Target Values (after 10 years)
Recruitment of woody perennial species	100% of overstorey species present as regeneration	3 species present
Native plant species richness	35% of benchmark species	6 species present
Tree canopy cover (%)	30% of benchmark canopy cover	10.5%
Tree canopy height	25% of tree canopy height	5m
Shrub layer cover (%)	30% of benchmark shrub cover	3%
Native perennial grass cover (%)	40% of benchmark perennial grass cover	26%
Native perennial forb and non-grass cover (%)	50% of benchmark perennial forb cover	7.5%
Native annual grass, forb and non-grass cover (%)	50% of benchmark annual grass, forb and non-grass cover	2.5%
Large trees	50% of benchmark number of large trees (comprised of species which will eventually become large trees)	17 large trees
Weed cover (%)	Similar to benchmark weed cover	<20% weed cover

6. Monitoring program

6.1. Establishment of Monitoring Sites

Survey plots to monitor basic indicators will be established and permanently marked in a revegetated site, prior to the commencement of any on-ground works. The same plots will then be surveyed each time the site is monitored. A metal peg or star-picket will be used to permanently mark the location of the 0 m points on each transect and the location of the start and finish points will be recorded using a GPS.

6.2. Monitoring Frequency

Natural regeneration areas will be inspected at approximately six monthly intervals, to determine the extent of weed invasion and natural recruitment, and to assess the requirement for further intervention or management.

Revegetation (active seeding/planting) areas will be visually monitored monthly for the first six months (or until the plants are self-sufficient), then annually thereafter until rehabilitation targets are reached for the first 10 years. The qualitative visual monitoring will include the following: presence of active rill/gully erosion and weed species, general assessment of seedling establishment, and any general failure of rehabilitation works.

Reference sites and revegetation areas will be quantitatively assessed (including species composition), every 3 years after establishment of the reference sites.

7. Maintenance program

7.1. Rehabilitation maintenance

If monitoring demonstrates that natural regeneration or revegetation sites along Lagoon Creek or around Bottle Tree Hill are not achieving their designated rehabilitation criteria, NAC will investigate the cause of the negative variance or failure. Based upon the findings of these investigations, NAC will conduct specific maintenance rehabilitation activities to correct or improve the overall performance of the deficient sites, to ensure that the long term objectives of the CZMP are achieved. If required, NAC may also adjust its standard revegetation techniques to correct any identified technical or other failings.

Maintenance activities may include supplementary plantings of selected species from one or more of the five identified life forms (using either direct seeding or planting), or the implementation of a targeted weed eradication program (herbicide spraying, mechanical removal, etc.).

7.2. General maintenance

General maintenance will involve a range of measures as required, including erosion and sedimentation maintenance, repair of any damaged infrastructure (e.g. fencing, signage, etc.), general weed control, and control of fire fuel loads following good growing seasons.

To control fire fuel loads efficiently, targeted grazing may be employed within the revised Project's conservation management zone. This specific use of grazing will be very limited in terms of application (timing and extent), and will not be applied to any newly planted areas. NAC's sister company, the Acland Pastoral Company, will provide advice and management of all targeted grazing undertaken for this purpose within the revised Project's conservation management zone.

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Appendix A – Methodology for data collection – reference sites

Department of Environment
and Resource Management

Method for the Establishment and Survey of Reference Sites for BioCondition

Version 2

July 2011

ISBN 978-1-7423-0916

This work may be cited as: Eyre, T.J., Kelly, A.L., and Neldner, V.J. (2011). Method for the Establishment and Survey of Reference Sites for BioCondition. Version 2.0. Department of Environment and Resource Management (DERM), Biodiversity and Ecological Sciences Unit, Brisbane.

Acknowledgements
Within the Department of Environment and Resource Management (DERM), the development, testing and improvement of the BioCondition reference site method has been greatly enhanced through contributions by Melinda Laidlaw (reviewed draft), Andrew Franks, Peter Taylor (Figure 9), Tony Bean, Don Butler, Bill McDonald, and Jian Wang.

Prepared by:Biodiversity and Ecological Sciences

Department of Environment and Resource Management

Published by the Queensland Government, July 2011

July 2011

#29814

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1 Introduction

Recent policy demands and expectations have conceptualised vegetation condition as a major component of native vegetation management, primarily to assist decision making for developmental approvals, incentive payments, market-based investments and demonstration of environmental duty of care (Keith & Gorrod 2006; Neldner 2006). Methods to assess vegetation condition are therefore required, with a simple, rapid assessment approach highly desirable, as it facilitates widespread application by a range of users (Andreasen et al. 2001). Accordingly, most condition assessment tools utilise key attributes or surrogates of biodiversity values that can be rapidly measured in the field (Gibbons & Freudenberger 2006). In Australia, the 'Habitat Hectares' approach in Victoria (Parkes et al. 2003) instigated development of similar vegetation condition assessment frameworks such as BioMetric in New South Wales (Gibbons et al. 2008), TASVEG in Tasmania (Michaels 2006) and BioCondition in Queensland (Eyre et al. 2011). The frameworks vary in accordance with jurisdictional legislation and policy, however they all share four properties: a set of weighted assessable attributes thought to be important to biodiversity; methods to assess the attributes; comparison against benchmark values based on the same communities under 'reference' conditions; and a final overall metric or 'score' that represents a condition state.

BioCondition is an assessment framework that provides a measure of how well a terrestrial ecosystem is functioning for the maintenance of biodiversity values. It is a site-based, quantitative and therefore repeatable assessment procedure that provides a numeric score along a continuum of 'functional' through to 'dysfunctional' condition. The BioCondition score is based on a comparison between measurements of specific site-based attributes and a benchmark value for each of those attributes, specific to a particular Regional Ecosystem (RE). A benchmark value is based on the average or median value obtained from mature and long undisturbed sites or from Best on Offer (BOO) sites, given few ecosystems are totally free of impacts of threatening impacts (Michalk and Norton, 1980; Landsberg and Crowley, 2004). These BOO sites are termed 'reference sites'.

Benchmarks for REs in Queensland will be derived from quantitative data and expert elicitation and will be posted on the DERM BioCondition website. However, due to the large number of REs, many have not yet been benchmarked. Where benchmarks are not yet available, or an assessment needs to be conducted during less than optimal conditions, then quantitative benchmark data can be derived by locating and setting up a local reference site. Reference site assessment does require good botanical and habitat assessment skills, and entails measurement and recording of vegetation floristics and structure.

The assessment method detailed in this manual is for the location, establishment and recording of floristic and structural vegetation attributes specifically for the generation of benchmarks for BioCondition. The benchmark data derived using this method is to be used in conjunction with the companion manual: BioCondition – A condition assessment framework for terrestrial biodiversity in Queensland (Eyre et al. 2011). Feedback on the methods is sought and will help improve future versions (See Appendix 1 for contacts).

There are 10 attributes in BioCondition that require benchmarks for the scoring system (Table 1). However, not all attributes require measurement at reference sites. This is because their benchmarks are either effectively zero or scores are qualified in the BioCondition scoring system. Attributes that do not require assessment at reference sites include recruitment of canopy species, non-native plant cover and the attributes relating to landscape context.

Table 1: Site-based attributes that are compared against benchmark values in BioCondition, and hence measured at reference sites

Attribute	Measure
Native plant species richness	number
Tree canopy cover (%)	percentage
Tree canopy height (m)	median
Shrub layer cover (%)	percentage
Native perennial grass cover (%)	percentage
Large trees	number
Coarse woody debris (m)	number
Litter cover (%)	percentage

BioCondition provides an assessment of the condition of an ecosystem in relation to its functioning for the maintenance of biodiversity values, but will not provide the answer to all your assessment and monitoring needs. Practitioners need to evaluate their objectives, as there may be additional information required in order to meet the data requirements of their study. If more detailed assessments are required for biodiversity survey or monitoring by appropriately skilled operators, then the following methods are recommended:

- **Flora:** Neldner, V.J., Wilson, B.A., Thompson, E.J. and Dillewaard, H.A. (2005). Methodology for survey and mapping of regional ecosystems and vegetation communities in Queensland. Version 3.1. Department of Environment and Resource Management, Brisbane <www.derm.qld.gov.au>.
- **Fauna:** Eyre, T.J., Ferguson, D. J., Hourigan, C.L., Kelly, A.L., Venz, M.F., Mathieson, M.T., Smith, G. C. (in prep.). Terrestrial Fauna Survey Assessment Guidelines for Queensland.Version 1.0. Department of Environment and Resource Management, Brisbane.

2 What is required for the assessment?

The assessment takes place within a 100 x 50 m area. Ideally you will need:

- 100 m transect tape
- 50 m transect tape
- compass
- diameter tape or tree callipers
- this current manual
- clinometer or hypsometer for measuring tree heights
- digital or print film camera
- 1 m^2 quadrat
- 2 x star pickets or tyres and wire (to peg down tyre) to mark out each end of the transect line (if continual monitoring of site is desired).
- clipboard, pencils and eraser.
- pocket calculator
- flagging tape
- global positioning system (GPS)
- plant press for collecting specimens
- plant identification guides (see Appendix 2).

3 Locating reference sites

The appropriate location and establishment of reference sites is essential to the development of relevant and effective benchmarks. Canopy height and cover vary within RE's according to environmental conditions. Therefore areas to be assessed should be compared with a reference site that occurs close to the area to be assessed and has similar environmental conditions, i.e. the same regional ecosystem, vegetation community, similar climate (same subregion), similar landscape conditions (soil, slope, position in the landscape, geology etc) and similar natural disturbance (cyclone impacts or fire history). For this reason, field measurements of the height, canopy cover and species composition of the area of interest are compared, where possible, to measurements from a local reference area, i.e. a nearby area of comparable vegetation that is known to be remnant, such as a shadeline or road reserve.

As much as practicable, a reference or BOO site should:

- be homogenous with regard to RE and condition status
- be selected in RE's with no extensive chemical or mechanical disturbance to the predominant canopy evident on the aerial photograph archive (from 1960s to recent) or on the ground
- represent an undisturbed, late mature or BOO of the required RE. That is, the site must have minimal modification through timber harvesting, grazing, fire, erosion, dieback, flood, and/or weed infestation

- be located within a reasonably large (> 5 ha) intact patch of remnant vegetation (to avoid issues of edge effects)
- be located at least 50 m from a roadside, track, or other major disturbance
- be remote from artificial water sources e.g. > 6 km from permanent water (Fensham and Fairfax 2008)
- exclude areas subject to recent major management change.

An effective strategy for locating reference sites, that best represent a BOO state for the RE of interest, is to first look at the extent remaining of the RE using the latest available Queensland Herbarium Regional Ecosystem mapping. Free RE maps are available as downloadable pdf/printable maps for properties and as digital data from the Regional Ecosystems area of DERM's website <www.derm.qld.gov.au>. The hardcopy maps and digital data can be used to produce a map specific for the area representing the extent of the RE or the local area from which you are trying to obtain your local reference sites[1] . The applicability of the RE mapping should be assessed in the field to check if it is relevant at the scale at which the assessment is being conducted. REs are defined at scales which range from 1:50 000 (e.g. South East Queensland) to 1:100 000 (e.g. rangeland bioregions) and a single polygon may contain several mapped REs (heterogeneous polygons).

Large patches of the RE of interest located in public land reserves such as national parks, state forests, and road reserves can often represent the RE in an undisturbed or BOO state. In addition, staff from the Queensland Herbarium and/or local natural resource managers can often provide information about suitable locations representing the least disturbed patches remaining of the RE of interest.

To obtain a reasonable representation of the natural variation inherent in vegetation condition attributes within the geographic range of an RE, there must be a minimum of three local reference sites located and measured. It is preferable that the reference sites are not located proximally, and are established at least 3 km apart to account for potential geographic variation. In some cases, particularly in highly fragmented bioregions, it may not be possible to collect benchmark data for all attributes within the one reference site, e.g. a recent fire may have impacted upon shrub cover and the number of understorey species present, but not the number of large trees. It is acceptable to establish a reference site that provides benchmark data for one or more attributes only. However, it will need to be made clear on the datasheets that it is a partial reference site only.

4 Field assessment

4.1 When to assess

Reference site assessment during the peak of summer or following a period of drought is not recommended, as there is likely to be a reduction in plant diversity during these times, particularly in the forb and grass life form groups. Seasonally, the best time of year for assessment, in the rangelands in particular, is during the growing season of May to June, when plant diversity is generally at its greatest. However, this is a general rule and the appropriate time to assess should be guided by local climate and knowledge.

In regions north of the tropic of Capricorn, site assessment should be conducted after the wet season, ideally between March and May to ensure adequate sampling of ground cover species (Neldner et al. 2004). South of the tropic of Capricorn, site assessment should be generally conducted in May or June following the wetter summer months. An exception would be following an unseasonably wet winter or spring when plant species are flowering.

[1] If using a Geographic Information System (GIS) to look for reference sites see Appendix 3 for coding to include in a query to pull out the dominant (where >50% of the polygon contains the RE of interest) and subdominant (<50% of polygon) extent of the RE of interest.

4.2 Setting up the assessment site

The assessment site constitutes a 100 m x 50 m nested plot design. The layout of the site and nested subplots are shown in Figure 1. Demarcation of the reference site is established by positioning a 100 m tape, which constitutes the centre line of the plot. Flagging tape can be used to identify the outer boundaries of the plot, which is 25 m each side of the centre transect. The plot boundary must be a minimum distance of 50 m from a major disturbance or discontinuity such as a road or disturbed edge. In topographically diverse areas, the plot should be oriented so that its long axis follows the contour, or topographic position (e.g. gully, midslope, ridge). Plot location is recorded at its centre point (the 50 m point along the 100 m transect). A global positioning system (GPS) is recommended to record the position of the centre and start points of the transect line in the field. This position should be checked against a 1:100 000 or larger scale topographic map for the area. The altitude recordings on GPS can be inaccurate and are better derived from the topographic map. The use of star pickets, metal tags attached to trees or pegged down tyres at the beginning and end of the 100 m transect will aid in relocating the site for future monitoring.

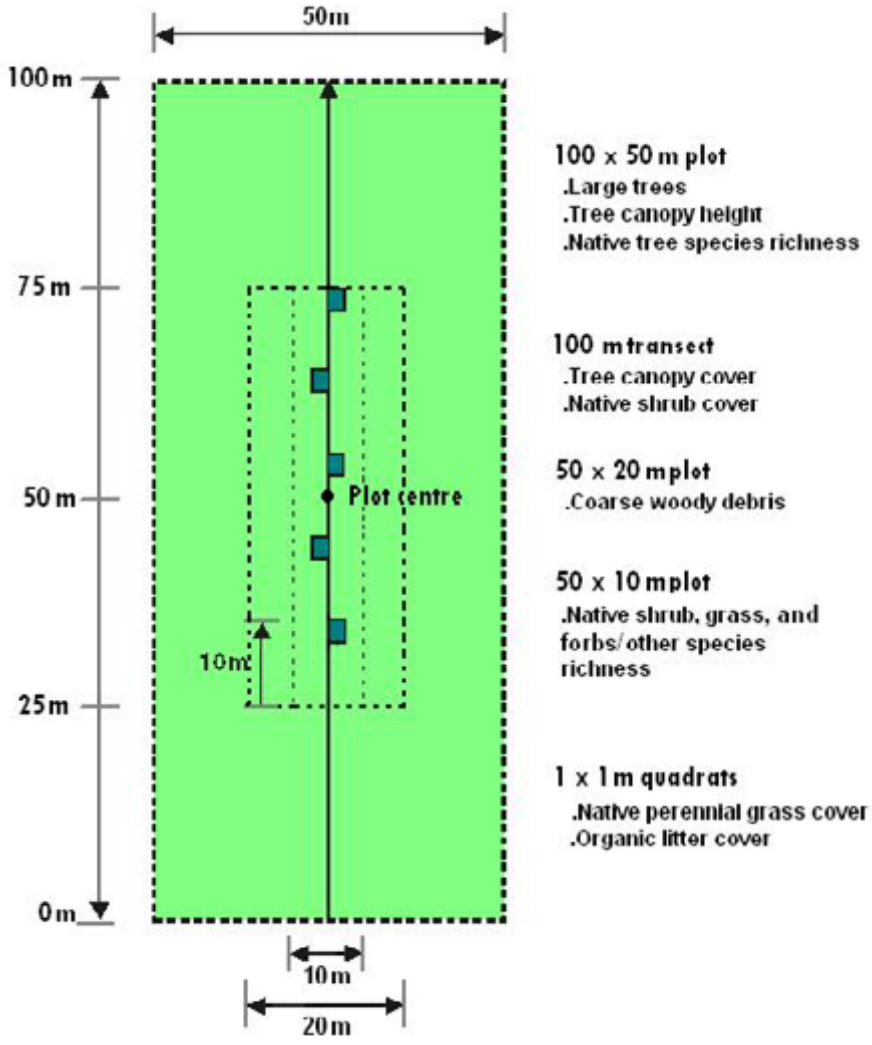


Figure 1: BioCondition reference site area and layout

4.3 Data collection

Five sampling areas form the basis for and approach to data collection. A series of subplots are used to sample the floristic, habitat and disturbance components, and are summarised as follows;

(1) **100 x 50 m area:** records all potential large trees >20 or >30 cm diameter at breast height (DBH); depending on the tree species, see Large tree section 4.3.1. Site information and disturbance, tree species richness and tree canopy height are also assessed in the 100 x 50 m area.

(2) **100 m transect:** records tree and shrub canopy cover.

(3) **50 x 20 m area:** records the length of all coarse woody debris >10 cm diameter and >50 cm in length.

(4) **50 x 10 m area:** records the number of floristic species by lifeform group (Native plant species richness) for Shrub, Grass, and 'Forbs and Other' species. This area can also be used as a Secondary Site for the detailed survey of RE's if desired following Appendix 2 in the Method for Survey and Mapping of Regional Ecosystems and Vegetation Communities in Queensland (Neldner et al. 2005).

(5) **1 x 1 m subplots:** records Native Perennial Grass cover and Organic Litter cover.

A datasheet to aid the collection of reference site data is provided in Appendix 4. It is important to ensure that the plot remains within the regional ecosystem to be sampled. Therefore it may be necessary to reduce the width of the plot for narrow ecosystems, eg. riparian ecosystems. In these situations the length of the plot may be increased to enable the sampling of an adequate area.

4.3.1 100 x 50 m assessment area

4.3.1.1 Site information and Disturbance

Within the greater 100 x 50 m assessment area assess the site location, general physical characteristics and disturbance information relevant to the site.

Location and site information

Plot location Record three locations, one at a convenient road point, another at the start of the 100 m central transect and another at the plot centre, the distance and bearing from the road to the plot centre and the plot alignment (to aid future relocation of the plot). Record location to the nearest metre using a Global Positioning System (GPS) receiver. Record the datum to which the GPS is set. It is recommended that GDA94 or if not available WGS84 is used as the datum.

Plot bearing Refers to the compass bearing or direction the plot is oriented from the start of the transect.

Locality description Record a general description of where the plot is situated. Include the state forest/national park number and/or name, or a property name or description, the name of the nearest road if applicable and any other information relevant to the locality. Include the tenure of the land parcel on which the plot occurs by reference to the Digital Cadastral Data Base (DCDB) which is maintained by Department of Environment and Resource Management (DERM) <www.derm.qld.gove.au>

Bioregion Record the Queensland bioregion name.

Regional Ecosystem

Habitat description

Record a detailed description of the site including the key species and density of all tree, shrub and ground layers. Aim to include its structural form type (Table 2), as per the Queensland Herbarium (BRI) which uses the characteristic stratum, or the layer that contributes most to overall above-ground biomass (Neldner et al. 2005).

Regional Ecosystem

REs were defined by Sattler and Williams (1999) as bioregional vegetation communities that are consistently associated with a particular combination of geology, landform and soil. The RE description database (REDD) is updated regularly and is available on the DERM website along with mapping that you can download.

A total of 1375 REs are currently defined (REDD v.6.0) in Queensland with mapping updates occurring frequently. RE maps are currently available for over 90 per cent of Queensland. The RE for the site can be determined by firstly querying the RE mapping and comparing the descriptions of the mapped REs for the location, in order to decide which RE the site represents. If the description is not a good match with any of the mapped REs, then check others in the appropriate bioregion and land zone. Occasionally the specific RE may not be mapped because:

- Regional ecosystem mapping is usually at 1:100 000 scale, but in some cases mapped at 1:25 000 scale.
- Vegetation mapping often uses the concept of mosaics where, again because of scale restraints, a single vegetation polygon is classed as being a mix of several different vegetation types (and thus REs).
- Not all of Queensland has mapping available.

For this reason the regional ecosystem maps should be used as a guide and the habitat description should be detailed enough to enable the classification of the actual community into a single RE.

Land form

Slope position Record the slope position, using codes given on the datasheet.

Slope degree Measure the general slope of the plot using a clinometer and record in degrees. For flat areas record slope as 0 degrees.

Slope aspect Record the compass direction, in degrees, of the downward slope of the plot. For flat areas record a dash (-).

Site photos

At the 50 m centre point of the plot collect four photos, north, south, east and west, and at the commencement of the central transect. In addition, spot photos can be useful to capture the variability in ground cover within the five 1 x 1 m quadrats. See Appendix 5 for description on how to take photos.

Disturbance

Disturbance is visually assessed over the whole reference site. These data are not actually required for benchmarking, but it is helpful to have a record of any disturbance if present as information on the current condition of the site at the time of assessment. As outlined earlier, ideally the reference site should have minimal disturbance.

For each disturbance type a code is used to rank its relative severity (from 0 = no discernible disturbance to 3 = severe). Codes are also used to record an estimated time since the last event for each disturbance (A: <1 year; B: 1-3 years, C: 5-10 years, D: 10-20 years, D: > 20years), and how the disturbance was estimated (1 = visual estimate, 2 = from historical records, 3 = from informant, 4 = from imagery or mapped source). Assessment of disturbance should be considered in the context of impact on the RE's structure, composition and function. Assessment needs to take into account the capacity of the community to recover after the event – that is, disturbances can appear to be severe soon after their occurrence. It is important to try to gauge how this event will affect the community beyond the short term.

Wildfire	Refers to major previous hot fire disturbance, the severity of which can be based on the extent of fire scars on standing trees relative to their height and diameter. Time since such an event can be estimated on the height of any post-burn regeneration, charring on ground woody debris which may have fallen since the event, diameter growth around fire scars on standing live trees, extent of crown recovery or from the aerial photograph or satellite imagery archive or web fire mapping sites such as Northern Australian Fire Information (NAFI) website, or the CSIRO Sentinel website. Record also the mean height of fire scars on standing stems.
Prescribed Burn	Refers to the cool, frequent (annual or biennial) burns used to reduce fuel loads and/or increase grazing potential of the grassy understorey. The nature of these burns dictates that the intensity of this disturbance would rarely be recorded as severe. However, if the fire regime is too frequent then impact on the ground and shrub layers can be deemed severe.
Logging	Record information on past logging events. Severity should be the total of all logging events and time for the latest event. If there have been several logging events record details in the notes section.
Treatment	Treatment is defined as the destruction of individual trees by ringbarking or poisoning, in contrast to 'logging' of individual trees for product harvesting and 'clearing' by mechanical means. Standing dead and fallen trees should be examined closely for marks indicating past treatment. These can be at waist height (ringbarking or axe cuts) or near ground level for basal injection treatment.
Grazing	Grazing impact can be assessed by the presence of manure, compaction, presence of stock trails, and eaten off grasses. It will probably not be possible to estimate grazing severity for older grazing events. However, inspection of fencing and stock infrastructure in the vicinity may give some indication of the time since grazing activity.
Non-native plants	Non-native plants include all exotic species, and those declared or assumed to be noxious (e.g. lantana, balloon cotton bush), but not native 'woody weeds' such as *Dodonaea, Eremophila*.
Erosion	Record information on erosion seen in the plot, e.g. gully erosion. Erosion outside the plot but in the vicinity should be noted.
Regeneration	Record information about regeneration resulting from disturbance e.g. *Acacia* following wildfire or regrowth following clearing. Detail in notes as required.
Other	Specify any other disturbance types noted e.g. dieback, soil disturbance, snig tracks.

Table 2: Structural formation classes qualified by height

Projective foliage cover	70-100 %	30-70 %	10-30 %	<10 %
Crown separation	closed or dense	mid-dense	sparse	very sparse
Field criteria	touching-overlap	touching – slight separation	clearly separated	well separated
Crown separation ratio[2]	<0	0-0.25	0.25-1	1-20
CROWN COVER %[3]	81-100 %	52-81 %	20-52 %	0.2-20 %
GROWTH FORM[4] ↓	**Structural Formation Classes (qualified by height)**			
Trees[5] > 30 m	tall closed-forest TCF	tall open-forest TOF	tall woodland TW	tall open-woodland TOW
Trees 10 – 30 m	closed-forest CF	open-forest OF	woodland W	open-woodland OW
Trees < 10 m	low closed-forest LCF	low open-forest LOF	low woodland LW	low open-woodland LOW
Shrubs[6] 2 – 8 m	closed-scrub CSC	open-scrub OSC	tall shrubland TS	tall open-shrubland TOS
Shrubs 1 – 2 m	closed-heath CHT	open-heath OHT	shrubland S	open-shrubland OS
Shrubs <1 m	-	Dwarf open-heath DOHT	dwarf shrubland DS	dwarf open-shrubland DOS
Succulent shrub	-	-	succulent shrubland SS	dwarf succulent shrubland DSS
Hummock grasses			hummock grassland HG	open hummock grassland OHG
Tussock grasses	closed-tussock grassland CTG	tussock grassland TG	open-tussock grassland OTG	sparse-tussock grassland STG
Herbs[7]	closed-herbland CH	herbland H	open-herbland OH	sparse-herbland SH
Forbs	closed-forbland CFB	forbland FB	open-forbland OFB	sparse-forbland SFB
Sedges	closed-sedgeland CV	sedgeland V	open-sedgeland OV	

Neldner et al. 2005, modified from Specht (1970)

2 Equivalent to Specht (1970) projective foliage cover (pfc) classes from Walker and Hopkins (1990) Table 14a.
3 Equivalent crown cover from Walker and Hopkins (1990) Table 17
4 Growth form of the predominant layer (the ecologically dominant layer).
5 Tree is a woody plant more than 5m tall usually with a single stem.
6 Shrub is a woody plant less than 8m tall either multi-stemmed or branching close to the ground, occasionally with a single stem.
7 Herbland refers to associations in which species composition and abundance is dependant on seasonal conditions and at any one time grasses or forbs may predominate

4.3.1.2 Large trees

Large trees are an important resource within forest and woodland ecosystems. They provide greater leaf material, nectar and bark-surface area for foraging purposes, and are more likely to contain hollows and crevices for nesting and sheltering purposes. What is considered 'large' will vary between species and communities. Trees growing under poor environmental conditions can never obtain the diameter of trees growing in more productive environments, and other species are slow growing or short-lived and so are unlikely to obtain the relatively large diameters. A method for determining a meaningful threshold for what is considered large is therefore required.

The threshold above which a tree is considered large is obtained by assessing the average stem size of all live trees over a certain stem size, depending on the community or species group. The data is used in two ways; 1/ to derive a threshold value of what is considered to be a large tree in the ecosystem that you are sampling in and 2/ to derive a benchmark of the number of large trees per hectare to be used in your BioCondition assessment. As a general guide, the trees included in the assessment should include all the living mature trees in a stand (standing dead trees are not included).

In eucalypt forests and woodlands and rainforests (excluding vine thickets), the threshold diameter at breast height (DBH) from which to start recording trees and their diameters is 30 cm. In *Melaleuca, Acacia, Callitris* and all other non-eucalypt and vine thicket dominant ecosystems, the threshold is 20 cm DBH. Where communities are mixed those species that have a greater capacity to reach a larger size such as the *Eucalyptus, Corymbia, Syncarpia, Lophostemon* and larger rainforest trees will be included in the data if greater than 30 cm DBH, whilst the smaller stemmed trees, generally sub-canopy trees such as *Melaleuca, Acacia, Callitris, Eremophila* and *Casuarina* will be included if >20 cm DBH.

In some cases there will be exceptions to this rule, where it is acceptable to increase or decrease the threshold in response to the inherent structural characteristics of the ecosystem being assessed. For example, in most *Acacia harpophylla* dominated ecosystems the 20 cm threshold is appropriate, however in the *A. harpophylla* low woodland RE 4.9.19 mature trees rarely exceed 20 cm, therefore a 15 cm threshold may be more appropriate from which to start recording the trees for the large tree sample. In BOO *Melaleuca viridiflora* low open-woodlands on Cape York Peninsula, the average tree DBH is only 12 cm, therefore all trees greater than 10 cm DBH need to be included to determine the appropriate large tree threshold.

It is important to note that the ‘large tree’ benchmark is derived from calculating the average DBH of trees greater than the threshold, and then counting the number of trees greater than this average value (see section 5). Therefore, selecting an inappropriate threshold, which either over- or under-represents the mature tree component will lead to the derivation of an inappropriate benchmark for the large tree attribute.

The species and DBH of larger trees are recorded within either a 100 x 50 m; 100 x 20 m; or 100 x 10 m plot area (Figure 2) depending on the evenness and distribution of the stems, i.e. the selection of plot area to record the number of large trees will be determined by the inherent stand structure of the RE being assessed.

In general, the 100 x 50 m plot area should be used for most eucalypt dominant REs such as woodlands and open forests and in rainforest communities with larger unevenly distributed trees, as the large, mature trees are often widely dispersed. The smaller plot areas can be used for REs with many, and/or uniform sized trees. For example, the 100 x 20 m plots should be used for rainforest communities with a greater level of variability in the stems, and in open mallee communities. The 100 x 10 m plot should be used in communities with uniform stem sizes and even distributions of stems such as in vine thickets, and in closed mallee. The selection of the plot area can be guided by an aim to obtain a reasonable sample (> 25) of the stand (note that all trees above the threshold within the plot area selected are measured. i.e. don’t cease measuring when 25 trees are recorded).

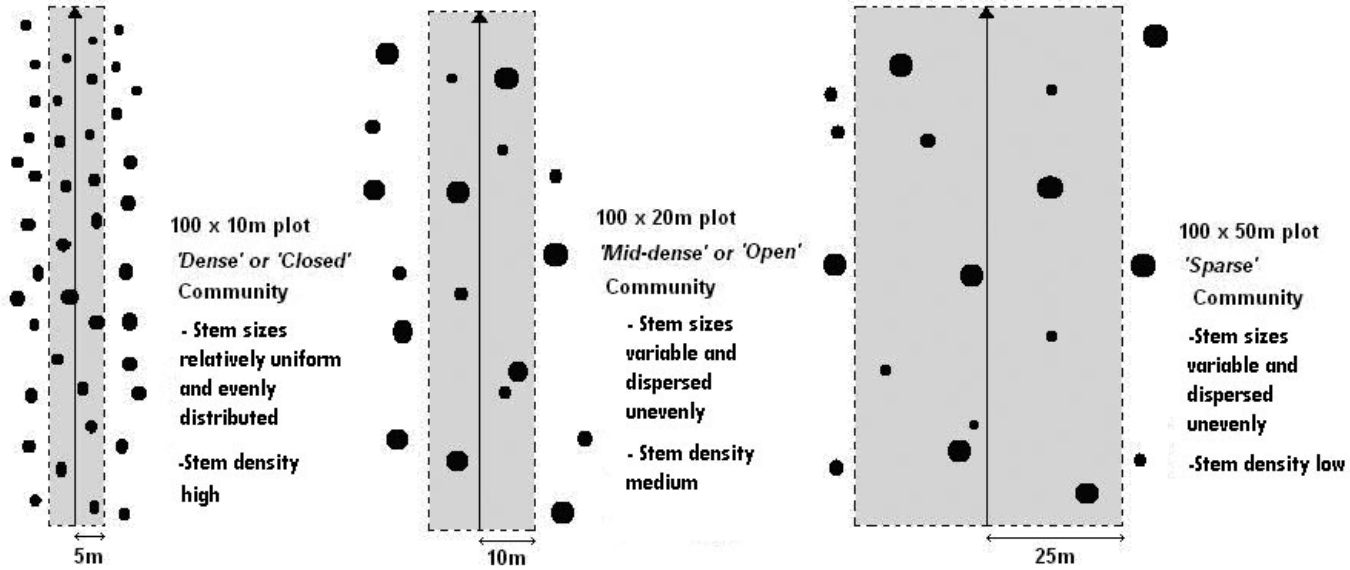


Figure 2: Plot size selection for large tree threshold attribute

Regional ecosystem 11. 4.3a - Black tea-tree (*Melaleuca bracteata)* woodland. The evenness and density of stems would suit a 100 x 10 m plot. All trees greater than 20cm DBH would be measured in the 100 x 10 m plot.

Regional ecosystem 12.5.13 – Vine forest. The unevenness of stem sizes and distribution of stems would suit a 100 x 20 m plot. All trees greater than 20cm DBH would be measured in the 100 x 20 m plot.

Regional ecosystem 11.8.15 – Poplar box (*Eucalyptus populnea*) woodland. The unevenness of stem sizes and open random distribution of stems would require a 100 x 50 m plot to assess the large tree attribute. All 'eucalypt' trees greater than 30cm DBH and all 'non-eucalypt' trees greater than 20cm DBH would be measured in the 100 x 50 m plot.

4.3.1.3 Tree canopy height

Tree canopy height refers to the median canopy height in metres estimated for trees in the ecologically dominant layer (EDL) (canopy layer) (Appendix 6). If there are emergent and/or subcanopy layers present, then median height of these layers needs to be assessed also. The median canopy height is the height that has 50 per cent of canopy trees larger and smaller than it (Figure 3). The height of woody vegetation is measured from the ground to the tallest live part of the tree (Neldner et al. 2005).

The maximum heights of the crown of at least three trees that are estimated to represent the median canopy height are measured for height, using a hypsometer or clinometer and tape measure (measured to the top of the highest leaves).It is recommended that a clinometer or hypsometer be used if available. When using a clinometer, adjustments are also made for the height of the recorder and any slope in the land surface. A method for assessing tree heights is provided in Appendix 7.

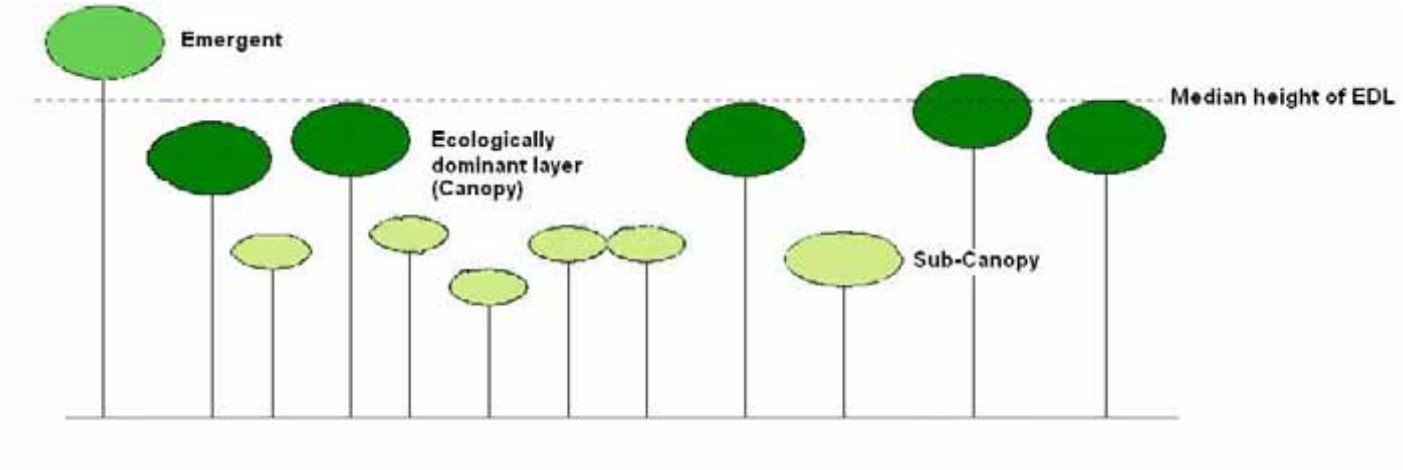


Figure 3: Median height of the Ecologically Dominant Layer (EDL)

4.3.1.4 Tree species richness

Native tree species richness is assessed by slowly criss-crossing each half of the plot from the centre-line and tallying the number of tree species within the 50 x 100 m plot area.

4.3.2 100m transect

4.3.2.1 Tree canopy cover

Tree canopy cover refers to the estimation of the percentage canopy cover of the living, native tree layer along the 100 m transect, using the line intercept method (Greig-Smith 1964). For this attribute, only the cover of the species making up the EDL or tree canopy cover is assessed for the majority of REs. Canopy cover equates to crown cover as defined by Walker and Hopkins (1990). The vertical projection of the tree canopy over the 100 m transect is recorded (Figure 4 and Box 1). The total length of the projected canopy of each layer is then divided by the total length of the tape to give an estimate of percentage canopy cover on the site.

If there is a distinct emergent or subcanopy layer (See Appendix 6 for identifying strata), then the canopy cover of each of these layers (EDL, emergent and subcanopy) is assessed separately.

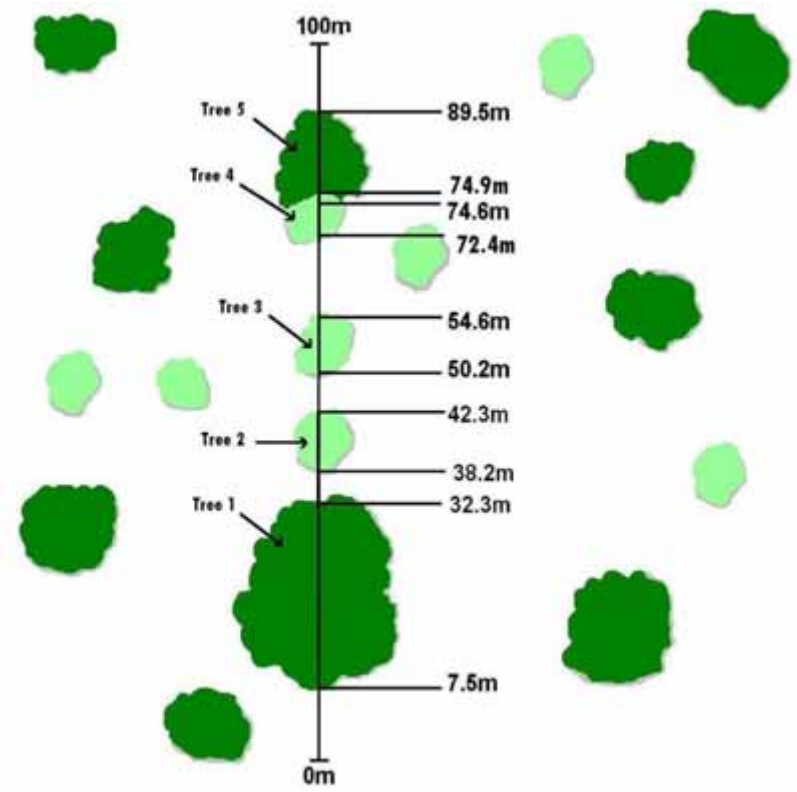


Figure 4: Example of assessing tree canopy cover (%).

Box 1: Calculation of tree canopy cover

In this regional ecosystem there is a canopy (EDL) (dark green) and a subcanopy (light green)

The canopy cover (EDL) is 39.7%, calculated as:
= (canopy cover Tree 1) + (canopy cover Tree 5)
= (32.3–7.5) + (89.5–74.6) = 24.8 + 14.9 = 39.7%.

The subcanopy cover is 11%, calculated as:
= (cover Tree 2) + (cover Tree 3) + (cover Tree 4)
= (42.3 – 38.2) + (54.6 - 50.2) + (74.9 –72.4) = 4.1 + 4.4 + 2.5 = 11%

4.3.2.2 Shrub canopy cover

Shrub canopy cover refers to the estimate of the percentage cover of native shrubs recorded along the 100 m transect (similar to the estimation of tree canopy cover using a vertical projection of shrub crowns downwards and above the centre line transect).

4.3.3 50 x 20 m plot area

4.3.3.1 Coarse woody debris

Coarse woody debris (CWD), for the purpose of the BioCondition reference site assessment, refers to logs or dead timber on the ground that are >10 cm diameter and >0.5 m in length (and more than 80 per cent in contact with the ground). Note: branches that are attached to the log, are measured if they meet the size thresholds, regardless of whether they are touching the ground. All CWD within the assessment area are measured to the boundary of the 50 x 20 m plot (i.e. 0.1 hectare). The total measured value is multiplied by 10 to generate the benchmark and is expressed as metres per hectare. Any woody debris smaller than this is included as litter cover.

4.3.4 50 x 10 m plot area

4.3.4.1 Native plant species richness

Native plant species richness for shrubs, grass and forbs/other species are recorded within the 50 x 10 m plot. The number of native plant species are assessed into one of four life-form groups, to assist assessment and benchmarking; trees, shrubs, grass, and forbs/other (see Appendix 8 for groupings). Native plant species richness is assessed by slowly walking along each side of the centre-line and tallying the number of species in each of three life-forms: shrubs, grasses and forbs/other. NB: Tree species richness is assessed in the 50 x 100 m plot.

4.3.5 1 x 1 m quadrats

Ground cover data is recorded from each of the five 1 x 1 m subplots centred along the central transect. For benchmarking purposes, quantitative data are required only for native perennial grass cover and organic litter cover. However, it is recommended that all components of the ground cover are recorded, to ensure 100 per cent of the ground cover is estimated. Ideally the botanical names of the species observed are recorded, however this is dependent on the knowledge of the observer (for more detailed procedures for recording of floristic data see Neldner et al. 2006). The datasheet provides space to record cover estimates for; native perennial ('decreaser') grass cover, native other grass cover (if relevant, see below), native forbs and other species, native shrubs (< 1m height), non-native grass, non-native forbs and shrubs, litter, rock, bare ground and cryptogams (NB: the total cover for a quadrat equals 100 per cent).

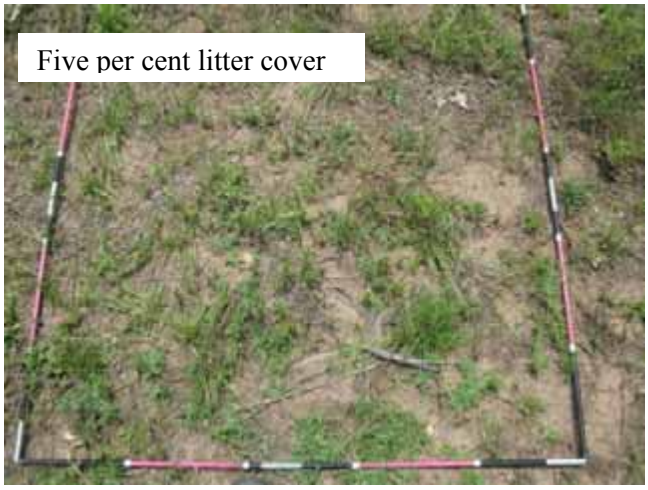
4.3.5.1 Native perennial grass cover

Perennial grass cover refers to the average percentage cover of native perennial grasses, assessed within each of the five 1 x 1 m quadrats and averaged to give a benchmark value for the site. The ground cover is measured by a vertical projection downwards of the living and attached plant material. A stylised guide is provided in Figure 5 to help estimate cover percent. This cover equates to the projected foliage cover in Walker and Hopkins (1990). A value for the reference site for each component is obtained by averaging the values from the five sub-plots. The sum of all ground cover components will equal 100 per cent in each subplot.

Where possible (predominantly in rangeland, or western Queensland REs), it is preferable to constrain the assessment of perennial grasses to those known as 'decreaser' species if identified in the benchmark documents, or listed as native 'preferred and intermediate' species in the land type sheets (Whish 2010) . This will then align the BioCondition assessment with land condition assessments conducted for Delbessie (DERM 2009) and Stocktake monitoring for grazing land condition (Aisthorpe and Paton 2004). Native preferred and intermediate species have been identified and listed specifically for each described land type in Queensland, based on local expert ecological knowledge and the concept of increaser species and decreaser species. Research has shown that there are a set of grass species (known as decreaser species) that are sensitive to grazing because they are palatable to stock. Many decreaser species are particularly important to the grazing industry, because they are palatable, perennial and productive ('3P', or 'preferred' or 'intermediate'), but also act as indicators of overgrazed landscapes, which is relevant to the aim of BioCondition.

4.3.5.2 Organic litter cover

Litter is defined as including both fine and coarse organic material such as fallen leaves, twigs and branches <10 cm diameter. Organic litter cover refers to the average percentage cover assessed within each of the five 1 x 1 m quadrats. Note: in areas with high cover of living plant material, it is only the organic litter cover that is observed through the living plant material that is included.



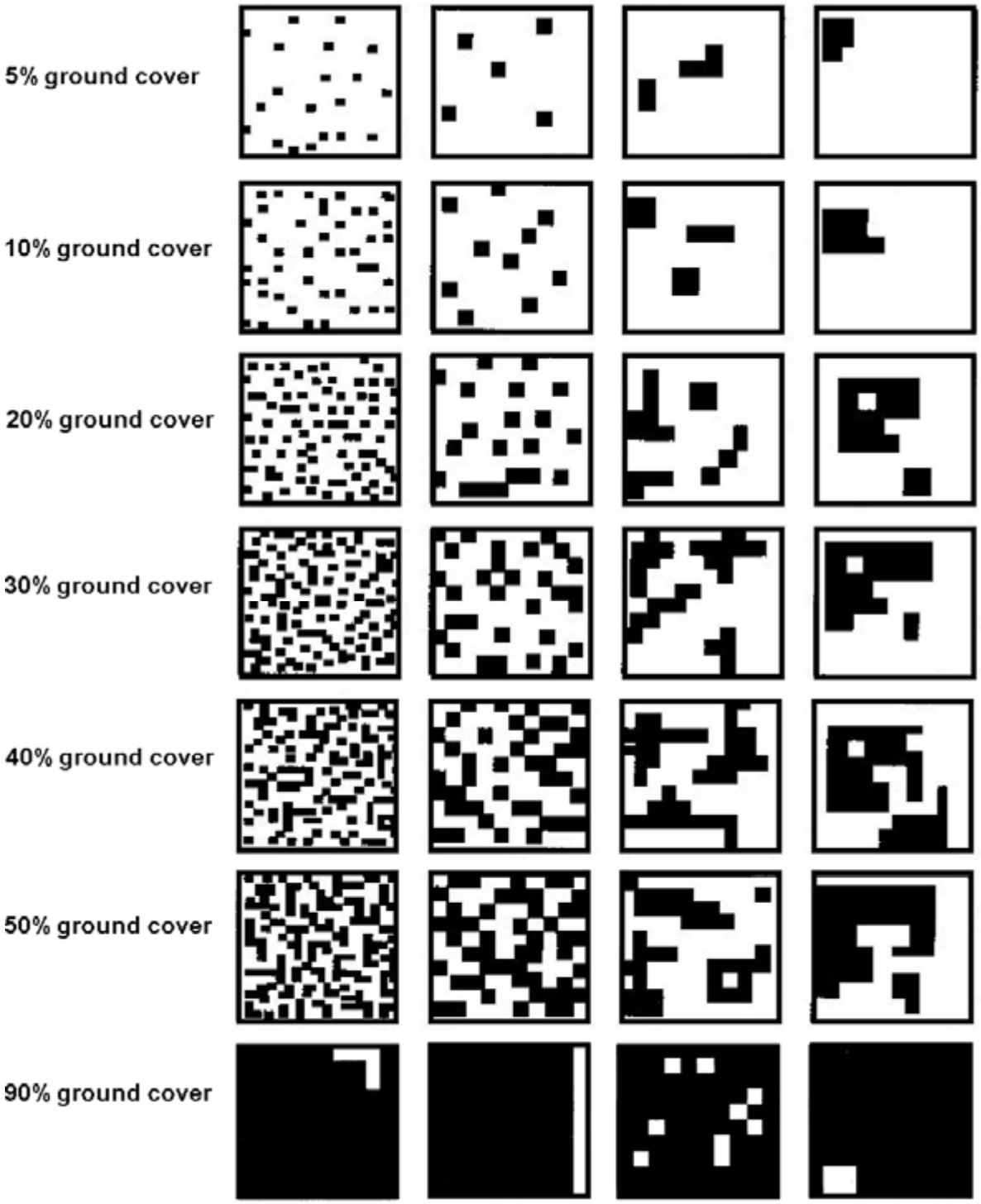


Figure 5: Stylised examples of ground cover proportions (DERM 2010). Various ground cover amounts (as a percentage) can be evenly spread across the quadrat or distributed in patches.

5 Deriving Benchmarks from the data

If reference site data are collected and collated from more than one plot in a particular RE, then the benchmark for an attribute is derived by taking the average value for each attribute from the range of sites (Box 2). If however, there is data from more than 3 reference sites then the benchmark is derived by taking the median value for each attribute from the range of sites. The median is a measure of central tendency, and is the 50th percentile of the data collected from more than one site for a particular attribute. It is the value for which 50 per cent of the values fall below the median and 50 per cent of the values are greater than the median.

Box 2: Example for deriving benchmarks from reference site data

Reference site data has been collected from three sites in the one RE in a local area. The values collected for tree height, tree canopy cover, shrub canopy cover and perennial grass cover for the three sites, and the average values are shown below. The average values are the benchmark values for each attribute, rounded down to the nearest whole number.

Values collected for four attributes across three reference sites within one RE, and the median values obtained:

Site	Tree height	Tree canopy cover	Shrub canopy cover	Perennial grass cover
1	33	25	12	25
2	30	25	10	35
3	32	23	7	20
Average	31.6	24.3	9.6	26.6

Therefore, for this RE, the benchmark for tree height = 31 m; tree canopy cover = 24 %; shrub canopy cover = 9 %; and perennial grass cover = 26 %.

To derive benchmarks for the large tree attribute (see Box 3), first the threshold DBH at which a tree is considered 'large' needs to be determined. This threshold can be determined by calculating the average DBH for each genus measured from one or more reference sites within an RE. It is important to have a 'large tree' threshold for each genus recorded in the reference site as different genera have varied growth habits e.g. in a mixed forest of cypress pine (*Callitris glaucophylla*) and poplar box (*Eucalyptus populnea*) (RE 11.10.11), a large cypress pine tree may be > 25 cm DBH, whereas a large poplar box may be > 50 cm. Trees are then grouped into eucalypts and non-eucalypts for simplicity of assessment.

Once the large tree DBH threshold has been determined, the median value from a range of sites can be calculated as outlined above for other attributes.

Box 3: Example for determining a large tree threshold

Plot size: 100 x 50 m plot

Regional Ecosystem: 11.10.11

Data:

Species	Diameter at breast height (DBH)
Eucalyptus populnea	30.4, 30.1, 30.6, 31.4, 35.4, 35.7, 35.4, 36.5, 36.2, 36.3, 37.2, 37.1, 38.1, 39.3, 41.8, 41.2, 43.8, 44.2, 47.1, 51.7, 52.2, 62.2, 63.1
Callitris glaucophylla	20.4, 20.9. 20.2, 20.6, 21.4, 21.6, 22.4, 22.6, 24.4, 24.4, 24.3, 24.7, 25.4, 24.2

Determining the large tree DBH threshold:

Average DBH for *E. populnea* trees > 30 cm DBH = 940/23 = 40.8

Average DBH for *C. glaucophylla* trees > 20 cm DBH = 317.5/14 = 22.7

Therefore, for this reference site, the DBH threshold indicating a 'large' tree is 40 cm DBH for the Eucalypts and 22 cm DBH for Callitris. (threshold is rounded off for simplicity in application)

Determining the large tree benchmark from this reference site:

Number of eucalypt trees > 40 cm = 18 trees per hectare (9 trees in 100 x 50 m plot x 2)

Number of non-eucalypt trees > 22 cm = 16 trees per hectare (8 trees in 100 x 50 m plot x 2)

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7 Glossary of terms

Benchmark	A description of a regional ecosystem that represents the median characteristics of a mature and relatively undisturbed ecosystem of the same type.
BioCondition Score	The score assigned to the assessed site that indicates its condition relative to the benchmarks set for the regional ecosystem being assessed. The score can be expressed as a percentage, on a scale of zero to one, or as a category of 1, 2, 3, or 4.
Biodiversity	The diversity of life forms from genes to kingdoms and the interactions and processes between.
Canopy	The layer formed collectively by the crowns of adjacent trees or shrubs in the case of shrublands. It may be continuous or discontinuous. The canopy usually refers to the ecological dominant layer.
CORVEG	Queensland Department of Environment and Resource Management Herbarium database for field data.
Cryptogam	A collective term referring to biological soil crusts, a highly specialized community of cyanobacteria, mosses, and lichens.
Diameter at Breast Height (DBH)	DBH is a measure of the size of the tree and is consistently measured at 1.3 m. On sloping ground, DBH is measured on the high side of the tree from bare earth ground level. Try and ensure that the tape is straight when reading the diameter. On leaning trees, on level ground, 1.3 m is measured from the underside of the lean. If a whorl, bump scar or other abnormality occurs at the 1.3m mark, measure the diameter at a nominated height (measured in whole 0.1m increments) above the defect. If a representative measure as described above cannot be taken (e.g.: presence of strangler figs), a reasonable estimate of the diameter should be made viewing the tree from two different directions. For multiple stems, a diameter is recorded for each stem, when it forks below 1.3m.
Dominant species	A species that contributes most to the overall above-ground biomass of a particular stratum (= predominant species).
Ecologically Dominant (predominant) layer or species (EDL)	The EDL contains the greatest amount of above-ground vegetation biomass, usually referred to as the canopy layer.
Emergent layer	The tallest layer/stratum is regarded as the emergent layer if it does not form the most above-ground biomass, regardless of its canopy cover e.g. poplar box (Eucalyptus populnea) trees above a low woodland of mulga (Acacia aneura).
Eucalypt species	Under BioCondition, a eucalypt species is any species from the following genera: Eucalyptus, Corymbia, Angophora, Lophostemon, Syncarpia, Tristaniopsis, Welchiodendron and Xanthostemon.

Forb	Herbaceous or slightly woody, annual or sometimes perennial plant that is not a grass or life form defined under 'Other species'. Note: members of the Cyperaceae, Juncaceae and some other families may have a grass-like (graminoid) appearance but are recorded as forbs rather than grasses.
Grass	A collective term for the following plant life forms: tussock grass which forms discrete but open tussocks usually with distinct individual shoots; hummock grass which are coarse xeromorphic grasses with a mound-like form often dead in the middle e.g. genus *Triodia*; other grasses of the family Poaceae, but having neither a distinctive tussock nor hummock appearance.
Grassland RE	A remnant RE described as having a structure code that does not include the terms 'forest', 'scrub', 'vineland', 'shrubland', 'heath' or 'woodland' in the Regional Ecosystem Database found at <www.derm.qld.gov.au>.
Large tree	A living tree identified as 'large' by a DBH threshold as defined in the benchmark document relevant to a RE. In some REs a different large tree threshold will be identified for eucalypt and non-eucalypt species due to the variation in potential size of these two tree types. For the purpose of defining large trees eucalypts include trees of genera *Angophora, Eucalyptus, Corymbia* and *Lophostemon.* If a large DBH threshold is not provided in the benchmark document, then generic thresholds of >20 cm DBH for non-eucalypts and >30 cm DBH for eucalypts can be used.
Native species	A native species is one that is considered to have evolved in Queensland unaided by humans or has migrated to and persisted in Queensland without assistance from humans (Bostock and Holland 2010).
Non-eucalypt species	Under BioCondition, a non-eucalypt species is defined as any species that is not listed as a eucalypt.
Non-native plant	Any plant that is not a native species.
Non-remnant vegetation	Non-remnant vegetation is vegetation that fails to meet the structural and/ or floristic characteristics of remnant vegetation. It may include regrowth, heavily thinned or logged and significantly disturbed vegetation, and cleared areas. Non-remnant vegetation may retain significant biodiversity values and includes areas mapped as 'high-value' regrowth.
Organic Litter	Includes both fine and coarse organic material such as fallen leaves, twigs and branches <10 cm diameter.
Other species	All plant life-forms that are not trees, shrubs, grasses or forbs.
Perennial species	Perennial species are long-lived plants, tending to persist for three or more years. Generally perennial grasses are characterised by larger bulk than annual grasses i.e. forming tussocks and large root mass with evidence of previous seasons growth i.e. remains of last years tiller bases, and presence of stolons or rhizomes.

Reference Site	An area that represents an example of a Regional Ecosystem in 'Functional ' Condition, i.e. in a relatively undisturbed and mature state. As not all RE's will have examples of totally undisturbed states, sites of this kind are meant to represent the 'Best On Offer ' for that RE in that area. Data obtained from Reference sites will be used to establish benchmarks for each of the attributes used within BioCondition.
Regional Ecosystem (RE)	Regional ecosystems were defined by Sattler and Williams (1999) as vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil. For up to date descriptions of regional ecosystems go to the Regional Ecosystem Description Database at <www.derm.qld.gov.au>.
Remnant vegetation	Remnant vegetation is defined in the Vegetation Management Act 1999 as vegetation shown on a regional ecosystem or remnant map. A map showing remnant regional ecosystem is the same as a 'remnant endangered (or of concern or not of concern) regional ecosystem map' defined under the Vegetation Management Act 1999. Where there are no maps available, remnant vegetation is defined as vegetation where the dominant canopy has greater than 70 per cent of the height and greater than 50 per cent of the cover relative to the undisturbed height and cover of that stratum and dominated by species characteristic of the vegetation's undisturbed canopy. Free regional ecosystem maps for most of Queensland can be obtained from the DERM website <www.derm.qld.gov.au>. If RE maps are not available, then remnant vegetation maps can be obtained from the same website.
Shrub	Woody plant that is multi-stemmed from the base (or within 200 mm from ground level) or if single stemmed, less than 2 m tall.
Shrub canopy cover	The estimation of the percentage canopy cover of the living shrub layer (see Shrub).
Shrub canopy height	The median canopy height in metres, as estimated for the shrub layer (see Shrub canopy cover).
Stratum	A layer in a community produced by the occurrence at approximately the same level (height) of an aggregation of plants of the same habit (Beadle and Costin 1952).
Tree	Woody plants, more than 2 m tall with a single stem or branches well above the base.
Tree canopy cover	Refers to the estimation of the percentage canopy cover of the canopy tree layer
Tree canopy height	The median canopy height in metres, as estimated for the canopy tree layer (see Tree canopy cover).

Appendix 1: Contacts for further information

Dr Teresa Eyre, Principal Ecologist
Biodiversity and Ecological Sciences DERM
Queensland Herbarium Brisbane Botanic Gardens
Mt Coot-tha Road Toowong Q 4066
Ph. 07 3896 9834
teresa.eyre@derm.qld.gov.au

Annie Kelly, Senior Ecologist
Biodiversity and Ecological Sciences, DERM
Queensland Herbarium Brisbane Botanic Gardens
Mt Coot-tha Road Toowong Q 4066
Ph. 07 3896 9878
annie.kelly@derm.qld.gov.au

Dr John Neldner, Chief Scientist
Biodiversity and Ecological Sciences, DERM
Queensland Herbarium Brisbane Botanic Gardens
Mt Coot-tha Road Toowong Q 4066
Ph. 07 3896 9322
john.neldner@derm.qld.gov.au

Appendix 2: Plant identification guides

General plant collecting guidelines

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Santos (2007) Field Guide to Trees and Shrubs of Eastern Queensland Oil and Gas Fields. Santos Ltd. Adelaide, South Australia.

Appendix 3: Using GIS to search for reference sites

Consulting local experts can be the best way to locate suitable Best On Offer (BOO) examples of the RE that you are interested in. The Queensland Herbarium[8] staff who undertook the mapping in the area you are working in can be a useful starting point. Local Department of Environment and Resource Management, Queensland Parks and Wildlife Service, Natural Resource Management groups or Department of Employment, Economic Development and Innovation and Employment officers can have also have local knowledge of REs in BOO condition.

Knowing the extent of the RE of interest can also be a useful tool in the location of suitable sites. Data can be obtained[9] on the Queensland Government Information Service website or by sending an e-mail to <NRScDataCoordinator@derm.qld.gov.au> (Information on the DERM website on the Regional Ecosystem page).

Vegetation mapping often uses the concept of mosaics where because of scale restraints, a single vegetation polygon is classed as being a mix of several different vegetation types (and thus REs). Polygons containing a mixture of vegetation types are known as heterogeneous polygons. In order to increase your chances of finding larger patches of your RE of interest it can be useful to make a selection of those polygons that are dominated (>50 per cent) by the RE of interest. In the case of some RE's however the remaining extent of that community maybe so small that it is worth investigating polygons where the RE is present in less than 50 per cent of the polygon (Sub-Dominant), in order to find patches of the RE for assessment (e.g. Box 4 and Figure 6).

Box 4 Method for mapping the extent of a Regional Ecosystem where the proportion of the polygon is dominant or sub-dominant.

Using ESRI's GIS software ArcGIS use the 'Selection' drop down menu and 'select by attributes';

For a selection where the RE of interest is Dominant (>50% of polygon of RE of interest) e.g. ("RE1" = '12.5.13' AND "PC1" >= 50) OR ("RE2" = '12.5.13' AND "PC2" >= 50)

Or Sub-Dominant (50% of polygon of RE of interest) e.g. ("RE1" = '12.5.13' AND "PC1" < 50) OR ("RE2" = '12.5.13' AND "PC2" < 50) OR ("RE3" = '12.5.13') OR ("RE4" = '12.5.13') OR ("RE5" = '12.5.13').

[8] Queensland Herbarium Brisbane Botanic Gardens
Mt Coot-tha Road Toowong Q 4066
Tel: (07) 3896 9326

[9] Charges may apply

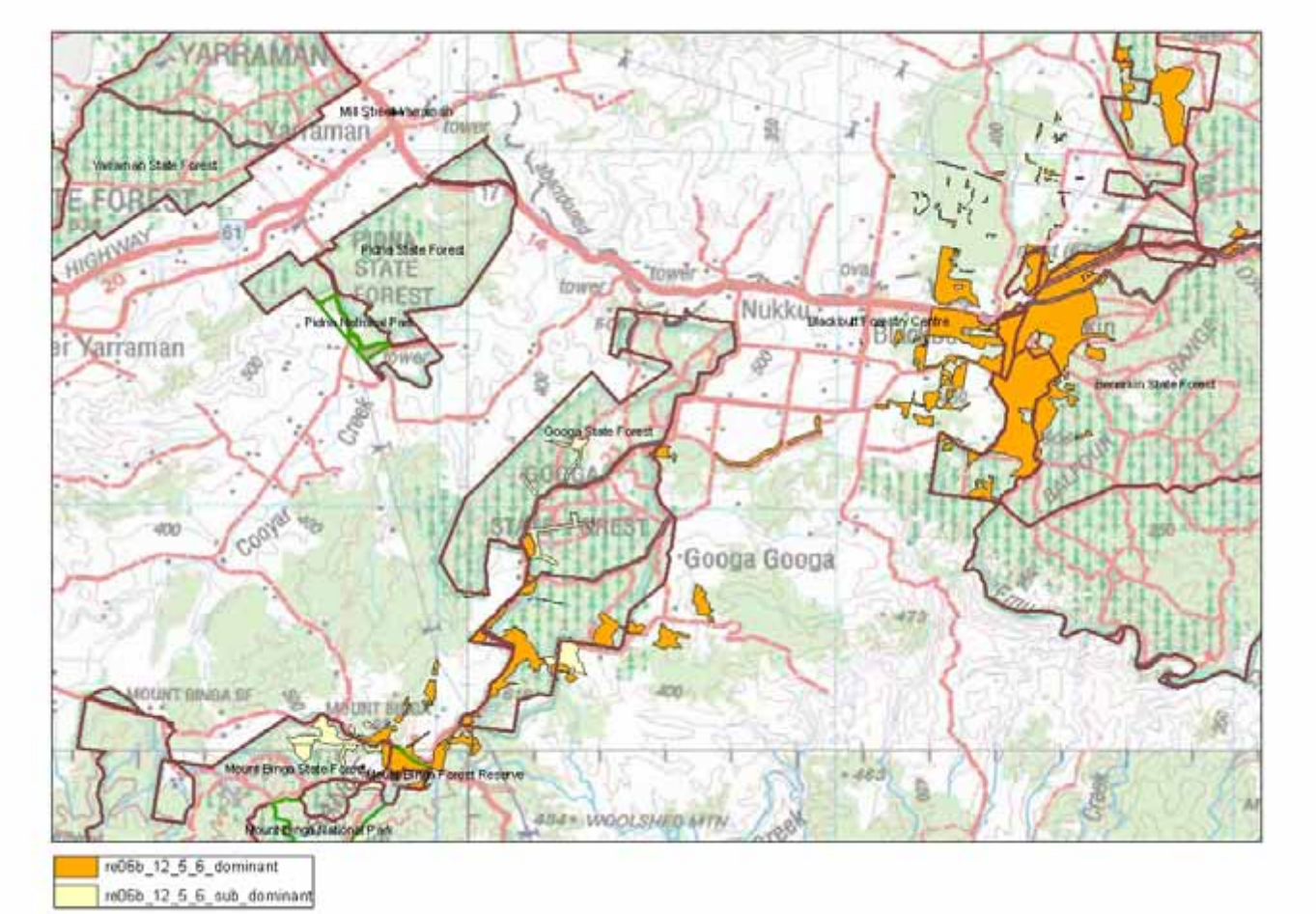
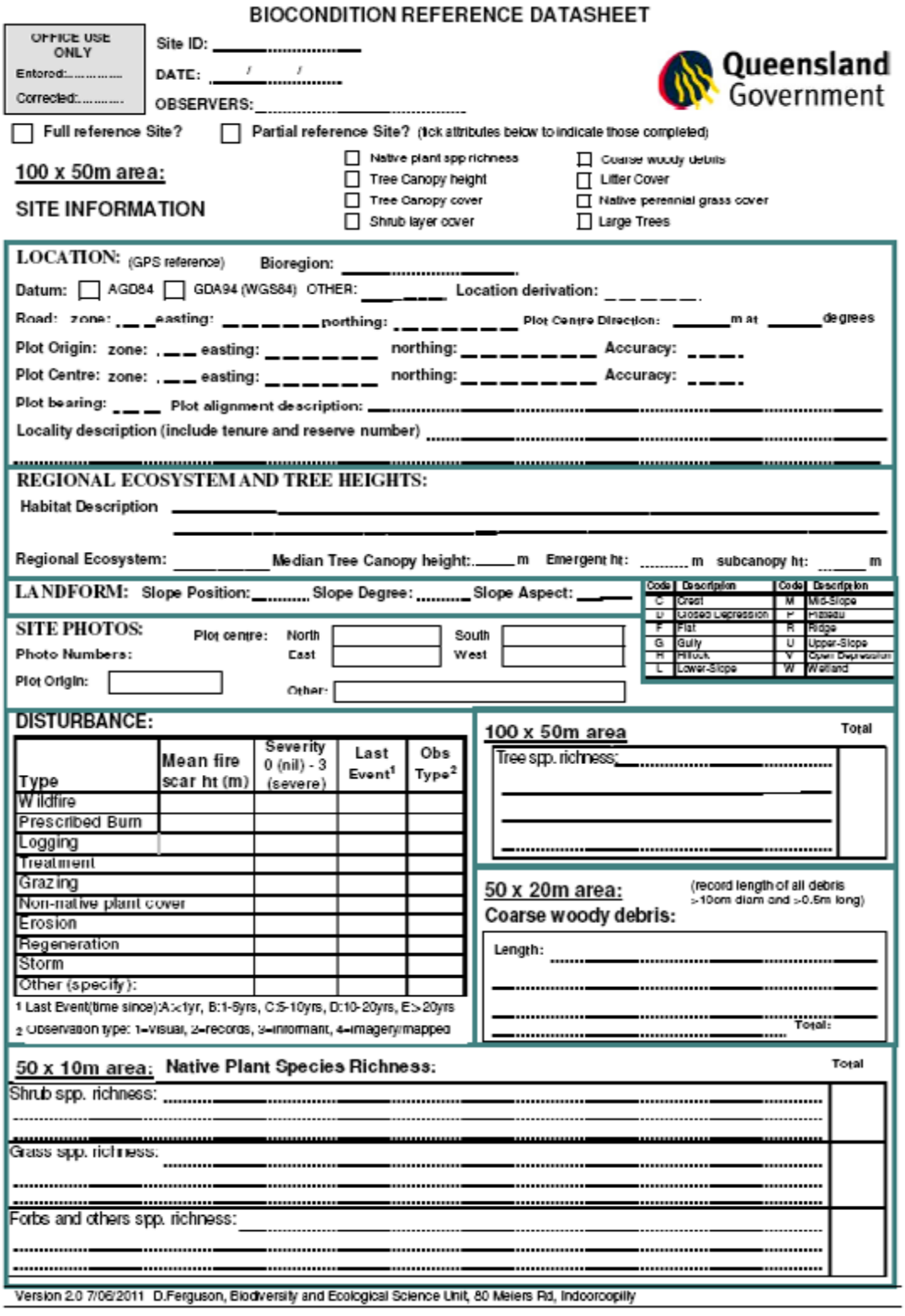


Figure 6: Mapped example showing the extent of RE 12.5.6, where it is the dominant RE in a polygon and where it is sub-dominant within a local area.

Appendix 4: Reference site datasheets[10]



BIOCONDITION REFERENCE DATASHEET

OFFICE USE ONLY
Entered:.....
Corrected:.....

Site ID: _____
DATE: __/__/____
OBSERVERS: _____

Queensland Government

☐ Full reference Site? ☐ Partial reference Site? (tick attributes below to indicate those completed)

100 x 50m area:
- ☐ Native plant spp richness
- ☐ Tree Canopy height
- ☐ Tree Canopy cover
- ☐ Shrub layer cover
- ☐ Coarse woody debris
- ☐ Litter Cover
- ☐ Native perennial grass cover
- ☐ Large Trees

SITE INFORMATION

LOCATION: (GPS reference) Bioregion: _____

Datum: ☐ AGD84 ☐ GDA94 (WGS84) OTHER: _____ Location derivation: _____

Road: zone: __ easting: _____ northing: _____ Plot Centre Direction: _____ m at _____ degrees

Plot Origin: zone: __ easting: _____ northing: _____ Accuracy: ____

Plot Centre: zone: __ easting: _____ northing: _____ Accuracy: ____

Plot bearing: ___ Plot alignment description: _____

Locality description (include tenure and reserve number) _____

REGIONAL ECOSYSTEM AND TREE HEIGHTS:

Habitat Description _____

Regional Ecosystem: _____ Median Tree Canopy height: ____ m Emergent ht: ____ m subcanopy ht: ____ m

LANDFORM: Slope Position: _____ Slope Degree: _____ Slope Aspect: ____

Code	Description	Code	Description
C	Crest	M	Mid-Slope
D	Closed Depression	P	Plateau
F	Flat	R	Ridge
G	Gully	U	Upper-Slope
H	Hillock	V	Open Depression
L	Lower-Slope	W	Wetland

SITE PHOTOS:
Photo Numbers:
Plot Origin:
Plot centre: North ____ South ____ East ____ West ____
Other: _____

DISTURBANCE:

Type	Mean fire scar ht (m)	Severity 0 (nil) - 3 (severe)	Last Event[1]	Obs Type[2]
Wildfire				
Prescribed Burn				
Logging				
Treatment				
Grazing				
Non-native plant cover				
Erosion				
Regeneration				
Storm				
Other (specify):				

1 Last Event(time since):A:<1yr, B:1-5yrs, C:5-10yrs, D:10-20yrs, E:>20yrs
2 Observation type: 1=visual, 2=records, 3=informant, 4=imagery/mapped

100 x 50m area — Total
Tree spp. richness: _____

50 x 20m area: (record length of all debris >10cm diam and >0.5m long)
Coarse woody debris:
Length: _____ Total:

50 x 10m area: Native Plant Species Richness: — Total
Shrub spp. richness: _____
Grass spp. richness: _____
Forbs and others spp. richness: _____

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[10] For a pdf copy of the datasheet see Appendix 1 for contacts.

BIOCONDITION REFERENCE cont....

1 x 1m plots: Ground Cover:

Ground Cover type	1	2	3	4	5	Mean
Native perennial (preferred and intermediate) grass						
Native non-preferred grass (if relevant)						
Native forbs and other species (non-grass)						
Native shrubs (<1m in height)						
Non-native grass						
Non-native forbs & shrubs						
Litter						
Rock						
Bare ground						
Cryptograms						
Total	100%	100%	100%	100%	100%	

100 x 50m area: Large Trees: Plot size: ☐ 100 x 50m ☐ 100 x 20m ☐ 100 x 10m

Species	Eucalypt (E) or Non-Eucalypt (N)	Diameter at Breast height (1.3m) (cm) (Measure all Eucalypts >30cm dbh and all Non-eucalypts >20cm)
Eucalypts:		Average DBH (threshold) = cm
		Number of trees >= benchmark:
Non-eucalypts:		Average DBH (threshold) = cm
		Number of trees >= benchmark:

100m transect: Tree and Shrub Canopy Cover: Type - C = canopy tree, SC = subcanopy tree, E = Emergent tree or S = shrub)

type	distance	total	type	distance	total	type	distance	total	type	distance	total	type	Distance	total
													Subcanopy total:	
													Canopy total:	
													Emergent total:	
													Shrub total:	

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Appendix 5: Taking Photos

(Adapted from Land Manager's Monitoring Guide Photopoint Monitoring, and Land Management Agreement - Rural Leasehold Land Self-Assessment Guideline <www.derm.qld.gov.au> and BioCondition v 1.6.)

Taking photographs of site features from a fixed point is a great way to keep a permanent visual record of how attributes have changed over time. Photographs can be the most reliable and useful record collected in any monitoring program, as they best represent how things were over time, in comparison to our memories which aren't as reliable as we think.

Two photo types are recommended to be taken at each site, each time you do an assessment.

1. The Spot photo

This is a photo taken from head height looking nearly vertically down on a spot marked with a one square metre frame or quadrat, as shown in Figure 7. You can use the base of your plot centre marker, to relocate the same spot each time you visit. Spot photos provide a detailed picture of the ground cover, organic litter and plant species for a standard sized area. Commonly there is great variety in ground cover at any given site, so taking more spot photos will help record this variation. It is important to have a system that allows you to take the spot photos in the same place each time you do an assessment. For example, spot photos could be taken along the transect line where you are doing your ground and litter cover assessments (i.e. 35, 45, 55, 65 and 75 metres).

Figure 7: Taking the spot photo – try and keep the top of your feet out of the frame and angle the camera down as straight as possible

2. The Landscape photo

The landscape photos are taken of features in the intermediate distance or further to provide an overview of the entire site and its surrounds. They illustrate the general condition of the site, showing changes in tree, shrub and ground layers over time. These site specific landscape photos can also be used to record particular disturbance events such as flood levels and damage or the impacts of a bushfire.

The landscape photo is taken from the plot centre and the origin of the 100m centre line, holding your camera so that the image is taken with a 'landscape' perspective – that is where the picture is wider than it is high. Stand next to the plot centre marker (Figure 8), facing south (recommended direction – see 'photo tips'), and position the horizon so it cuts the photo frame in half (half above the horizon and half below). Then take the photo focusing on infinity. Recording how the photo was lined up or simply taking a copy of the picture with you on future visits will make lining up the shot easier. Alternatively and preferentially, taking a series of plot centre landscape photos in a north, south, east and west direction (with the aid of a compass), allows you to pick up more of the variation across the site and is easy to replicate next time an assessment is done.

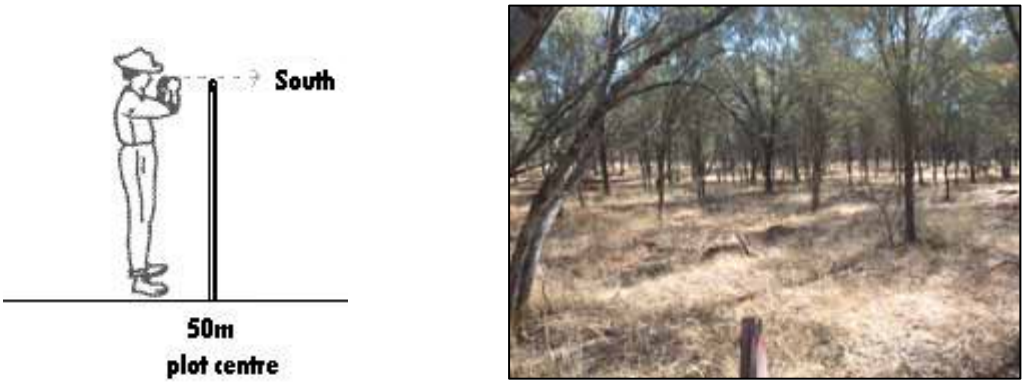

Figure 8: Taking the landscape photos – record the bearing or direction of the photo in order to assist replicate photos on subsequent visits.

Photo tips

Any type of camera from colour print film to a digital camera can be used to take these photos. Digital cameras are ideal, allowing instant review of an image for clarity and colour; making sure you always have a good photo for your records.

The best photos are generally taken on a clear day between 9am and 3pm. Before 9am and after 3pm will generally result in more shadowing and different colour cast which may conceal some important features. Overcast days are great for photography in closed communities such as rainforests, scrubs and thickets, as the even light removes much of the shadowing.

A common problem is too much light blanking out the colour and detail of the image. If you have control over your camera settings, this can be reduced by setting the exposure compensation to a negative setting; using the auto-exposure lock (AE lock); or by using spot metering. Your camera's user guide will explain how to use these functions on your particular camera – the troubleshooting section is often a good place to find these and other useful solutions.

You will always get a better photo by having the sun behind you with the sunlight shining on the landscape facing you. So, if you are only taking one photo it is best to be facing south, avoiding having the sun shining into your lens.

For each photograph record the relevant area, land type and site; the date the photo was taken; and the direction the photo was taken (N/S/E/W). The date stamp feature on your camera may be useful if it does not obscure important components of a photograph. Photos can be stored in a database (scanned if not digital) and/or printed and kept on file with the monitoring records.

Appendix 6: Stratifying vegetation

The assessment of the tree height and tree canopy cover attributes require consideration of the distinct vegetation layers or strata that make up the community. In general, site-based assessment of vegetation uses structure (vertical and horizontal distribution of vegetation: its growth form, height, cover and strata) and floristics (dominant genera or species in various strata and characteristic species) (Hnatiuk et al. 2009). In Queensland, the structural and floristic characteristics of the vegetation are used in defining and describing REs. Details of the methods used to classify vegetation and regional ecosystems in Queensland are described in Neldner et al. (2005).

Determining the ecologically dominant layer

Once the vegetation community has been classified into strata (see Figure 9 when strata are not obvious), the determination of the ecologically dominant layer (EDL) is made. The EDL contains the greatest amount of above-ground vegetation biomass (Neldner 1984).

Example 1: EDL; RE 3.5.24, Eucalyptus chlorophylla open-woodland (EDL), Cape York Peninsula

Here the above-ground biomass of the trees is estimated to be larger than the grass layer, and is the EDL. Generally if the tree layer in these situations has a canopy cover of 8 per cent or more, then the trees will form the EDL.

Here the above-ground biomass of the trees is estimated to be larger than the grass layer, and is the EDL. Generally if the tree layer in these situations has a canopy cover of 8 per cent or more, then the trees will form the EDL.
In the majority of cases in wooded communities, it is the tallest layer that forms the most above-ground biomass, except in the case of widely scattered emergent trees. Therefore, in most cases only the EDL layer is assessed for the attributes tree canopy cover and height in BioCondition. Exceptions include rainforest canopies with emergent species and mixed genus woodlands (e.g. poplar box and mulga woodlands).

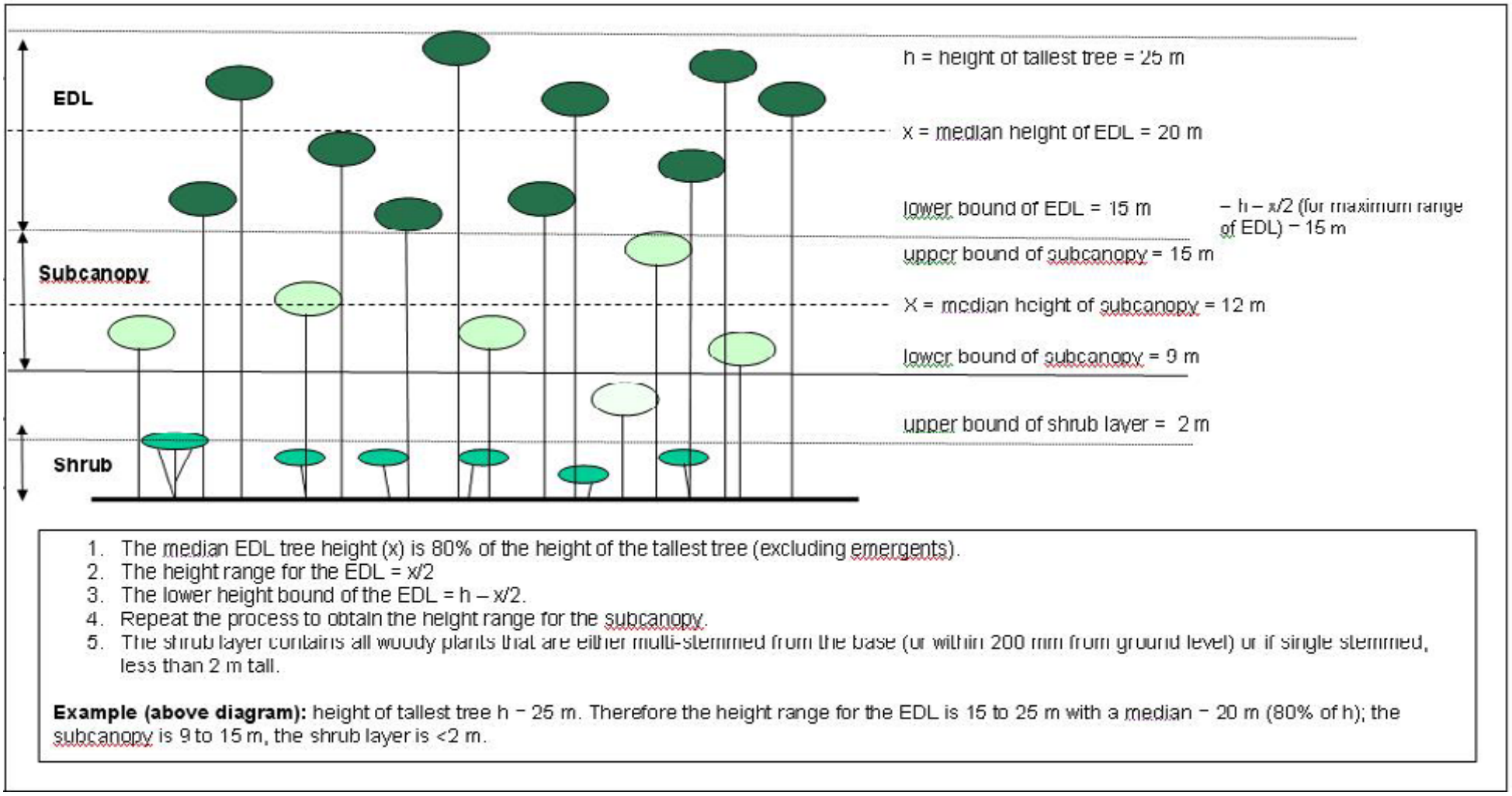

Figure 9: Method for determining vegetation strata, when not obvious

Example 2: Emergent layer and EDL; RE 5.7.2, Acacia catenulata low woodland (EDL) with emergent Eucalyptus thozetiana.

Example 3: EDL and shrub layer; RE 2.5.15, Melaleuca viridiflora low woodland (EDL) with a distinct shrub layer of Petalostigma banksii on western Cape York Peninsula.

Example 4: EDL and shrub layer; RE 2.5.12, Eucalyptus pruinosa low woodland (EDL) with low shrub layer of Acacia spp.

Example 5: Multi-layers: RE 8.5.1, coastal Corymbia spp. woodland (EDL) with a subcanopy layer of Melaleuca viridiflora and immature canopy trees. The layers in some forest communities can be relatively indistinct.

The impact of disturbance on vegetation structure

While in an undisturbed state, a vegetation community will develop a distinct structure (height and cover) based on the growth forms of the species present and their abundance. Frequently different species define and dominate different layers. However, within an ecosystem the structural attributes (height and cover) will frequently vary depending on the environmental conditions at the site (e.g. rainfall and soil depth). Where there has been significant natural (e.g. cyclones, fires or floods) or human disturbance (e.g. clearing or logging), the structure and floristics of the vegetation can be significantly altered. At these sites, the development of distinct layers may not occur or be indefinite, and the resultant communities may develop a number of structural outcomes (see below). In these situations, it is important to compare the heights and canopy covers of the vegetation at the site to the defined layers in the benchmark documents. For example, in the RE 6.5.3 Eucalyptus populnea predominates forming a distinct but discontinuous canopy (10 - 20 m tall). A lower tree layer (subcanopy) of Acacia aneura is sometimes present. After disturbance, at least three structures may develop (1) E. populnea woodland with little or no subcanopy, (2) A. aneura woodland with none or only scattered E. populnea emergents, or (3) regenerating woodland of both species. In each structural type it is important to compare the heights and covers of both E. populnea and A. aneura with the layers they dominate in the benchmark site.

RE 6.5.3: *Eucalyptus populnea* **predominates forming a distinct but discontinuous canopy (10 – 20 tall) (EDL). A subcanopy of** *Acacia aneura* **is sometimes present.**

Example of benchmarks for REs with more than one layer

RE 6.5.3 *Eucalyptus populnea* woodland with *A. aneura* subcanopy.

Canopy (EDL) of *Eucalyptus populnea*: Benchmark height = 15 m. Benchmark canopy cover = 18 per cent

Subcanopy of *Acacia aneura*: Benchmark height = 8 m. Benchmark canopy cover = 30 per cent

Appendix 7: Measuring Tree Height

Clinometer Method (extracted from Abed and Stephens 2002)

The Suunto clinometer (clino) is a tool commonly used by foresters to measure tree heights and also slope angles. At the rear of the clino is a peephole, which shows a percentage scale and a horizontal line (see Figure 10).

1. First measure the horizontal distance between the base of the tree and the operator.
2. Looking through the peephole (see Figure 10 and 11), line up the horizontal line with the top of the tree (the highest part of the tree, usually foliage) and read off the corresponding number from the percentage scale, which is on the right hand side. The scale on the left is in degrees and should not be used.
3. Line up the horizontal line with the base of the tree and again read off the corresponding number from the percentage scale.
4. If the base of the tree is above you (i.e. you're on the downward slope) then subtract the number from step 3 from the number in step 2 and multiply by the horizontal distance to get a total tree height.
5. If the base of the tree is level with you or below you (i.e. you're on the upward slope) then add the numbers together and multiply by the horizontal distance to get a total tree height.
6. If the tree is leaning, stand at right angles to the lean so the tree isn't leaning towards or away from you. If the highest part of the tree is not directly above the trunk, then adjust the horizontal distance so that it relates directly to the highest part of the tree.

Hint: If you can't see the bottom of the tree because of branches or understorey, sight to a point up the stem that can be seen and treat this as the base of the tree and continue with the procedure as described above. Then add the height from the base to the point you could see to get your estimate of total height.

Figure 10: Looking through a clinometer

Figure 11: Using a clinometer

The heights of the crown can also be measured using a laser instrument called a hypsometer. Where the top of the tree is not directly above the base of the trunk, it is important to also measure the point directly below the highest point of the tree canopy to get an accurate crown height.

Appendix 8: Life-forms used in BioCondition

(modified from ESCAVI 2003).

Code	Name	Description	BioCondition Category
T	**TREE**	Woody plants, more than 2 m tall with a single stem or branches well above the base	Tree
M	**TREE MALLEE**	Woody perennial plant usually of the genus Eucalyptus. Multi-stemmed with fewer than 5 trunks of which at least 3 exceed 10 cm diameter at breast height (DBH). Usually 8 m or more.	Tree
S	**SHRUB**	Woody plant multi-stemmed from the base (or within 200 mm from ground level) or if single stemmed, less than 2 m.	Shrub
Y	**MALLEE SHRUB**	Commonly less than 8 m tall, usually with 5 or more trunks, of which at least three of the largest do not exceed 10 cm DBH.	Shrub
Z	**HEATH SHRUB**	Shrub usually less than 2 m, commonly with ericoid leaves (nanophyll or smaller). Often a member of one of the following families: Ericaceae, Myrtaceae, Fabaceae and Proteaceae. Commonly occur on nutrient-poor substrates.	Shrub
C	**CHENOPOD SHRUB**	Single or multi-stemmed, semi-succulent shrub of the family Chenopodiaceae exhibiting drought and salt tolerance.	Shrub
U	**SAMPHIRE SHRUB**	Genera (of Tribe Salicornioideae, viz: Sarcocornia, and Tecticornia) with articulate branches, fleshy stems and reduced flowers within the Chenopodiaceae family, succulent chenopods. Also the genus Suaeda.	Shrub
G	**TUSSOCK GRASS**	Forms discrete but open tussocks usually with distinct individual shoots, or if not, then forming a hummock. These are the common agricultural grasses.	Grass
H	**HUMMOCK GRASS**	Coarse xeromorphic grass with a mound-like form often dead in the middle; genus Triodia	Grass
W	**OTHER GRASS**	Member of the family Poaceae, but having neither a distinctive tussock nor hummock appearance.	Grass
V	**SEDGE**	Herbaceous, usually perennial erect plant generally with a tufted habit and of the families Cyperaceae and Restionaceae.	Other
R	**RUSH**	Herbaceous, usually perennial erect plant. Rushes are grouped into families Juncaceae, Typhaceae, Restionaceae and the genera Lomandra and Dianella.	Other
F	**FORB**	Herbaceous or slightly woody, annual or sometimes perennial plant; not a grass, and including ground orchids.	Forbs

D	**TREE FERN**	Spirally arranged crowns on erect trunks several metres high (U.N.E 1989), characterised by large and usually branched leaves (fronds), arborescent and terrestrial; spores in sporangia on the leaves.	Shrubs
E	**FERNS AND FERN ALLIES**	Characterised by large and usually branched leaves (fronds), herbaceous to arborescent and terrestrial to aquatic; spores in sporangia on the leaves.	Other
B	**BRYOPHYTE**	Mosses and Liverworts. Mosses are small plants usually with a slender leaf-bearing stem with no true vascular tissue. Liverworts are often moss-like in appearance or consisting of a flat, ribbon-like green thallus.	Other
N	**LICHEN**	Composite plant consisting of a fungus living symbiotically with algae; without true roots, stems or leaves.	Other
K	**EPIPHYTE**	Epiphytes (including orchids), mistletoes and parasites. Plant with roots attached to the aerial portions of other plants. Often could also be another growth form, such as fern or forb.	Other
L	**VINE**	Climbing, twining, winding or sprawling plants usually with a woody stem.	Other
P	**PALM**	Palms and other arborescent monocotyledons. Members of the Arecaceae family or the genus Pandanus. (Pandanus is often multi-stemmed).	Trees
X	**XANTHORRHOEA**	Australian grass trees. Members of the family Xanthorrhoeaceae.	Shrubs
A	**CYCAD**	Members of the families Cycadaceae and Zamiaceae	Shrubs
J	**SEAGRASS**	Flowering angiosperms forming sparse to dense mats of material at the subtidal and down to 30m below MSL. Occasionally exposed.	Grass
Q	**AQUATIC**	Plant growing in a waterway or wetland with the majority of its biomass under water for most of the year. Fresh, saline or brackish water.	Other
O	**LOWER PLANT**	Alga, fungus.	Other
UNK	**UNKNOWN**		Other