Ground-based survey methods for The Living Murray assessment of condition of river red gum and black box populations

Version 12 (11th January 2010)

Murray-Darling Basin Authority (2010)

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Document Outline

Assessment of river red gum (*Eucalyptus camaldulensis* Dehnh.) and black box (*Eucalyptus largiflorens* F.Muell) condition is fundamental to informing progress toward the ecological objectives of The Living Murray program across the majority of the Icon Sites. To ensure consistent reporting of river red gum and black box condition throughout The Living Murray, this suite of standard methods is to be incorporated into the Icon Site Condition Monitoring plans and all field assessments of river red gum and black box condition are to be carried out using these methods.

Figure 1 outlines how the ground survey data collected at the Icon Sites is analysed and reported. Condition monitoring of river red gum and black box is reported in two ways, Stand Condition and Tree Condition.

Stand condition of river red gum and black box is determined using the TLM stand condition model. The TLM stand condition model uses the relationship between ground surveys of condition at permanent monitoring sites and remotely sensed data, which covers the whole Murray River floodplain, to predict the condition of river red gum and black box stands. The model estimates stand condition across all Icon Sites supporting river red gum and black box populations, allowing stand condition to be mapped across the distribution of these vegetation types and categorised into stand condition classes (good, moderate, poor, degraded and severe).

Tree condition of river red gum and black box is determined from ground survey only, and determines the condition of 30 trees within a particular assessment site. The condition of trees at each site is determined by combining the assessment of crown extent and crown density. Additional condition indicators include new tip growth, epicormic growth, extent of bark cracking and leaf die-off, which may indicate the future direction of tree condition. The tree condition assessment also collects contextual information at both the scale of the individual tree and the assessment site scale to aid in the interpretation of the condition assessments.

The methods outlined in this document for determining stand and tree condition are recommended as the standard methods for assessing condition of river red gum and black box populations in the Murray-Darling basin.

This document is split into three sections:

- **Section 1** provides background information on the natural history and ecology of the two species.
- **Section 2** outlines the field surveys required to inform the **TLM Stand Condition Model** for river red gum and black box.
- **Section 3** outlines the field surveys required to conduct the **TLM Tree Condition Assessment** for river red gum and black box.

The methods presented here have been collated, in consultation with ecologists and Icon Site monitoring staff, by the Murray-Darling Basin Authority to provide a standard approach to assessing condition of river red gum and black box populations within The Living Murray Icon Sites. This will allow consistent reporting across The Living Murray and allow direct comparison among Icon Sites.

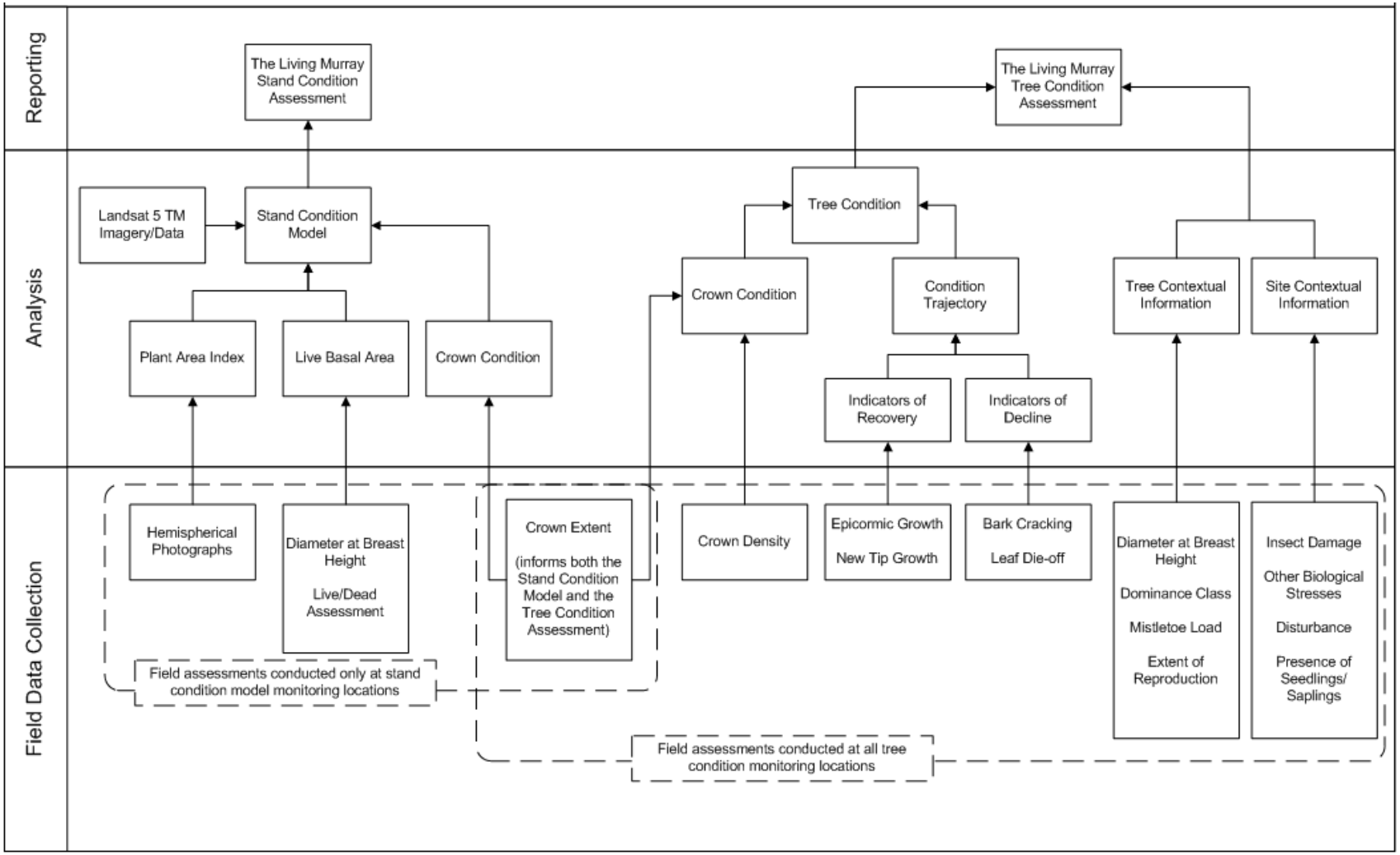

Figure1: Collection of data, analysis and reporting for The Living Murray river red gum and black box condition assessments.

Acknowledgements

The authors wish to thank David Hohnberg and Lex Cogle from the Murray-Darling Basin Authority for their comments on the numerous drafts of this report. Thanks also to Gary Miller (Forests NSW) and Mark Schultz (South Australian Murray-Darling Basin Natural Resource Management Board) for their early input into this method document.

Thanks also to Cherie Campbell and Mel Tucker (Murray-Darling Freshwater Research Centre), Mark Walter (Department of Water, Land and Biodiversity Conservation) and Danielle McAlister (Forests NSW) for their assistance in conducting the field workshop to test and refine the methods outlined in this document.

These survey methods have been reviewed as part of the 2009 scientific review of Icon Site Condition Monitoring Plans. Thank you to the review team Keith Walker, Ben Gawne, Angus Webb, John Porter and Shaun Meredith.

Our thanks also go to the numerous people who attended the workshops hosted by the Murray-Darling Basin Authority to discuss and develop vegetation monitoring techniques and who also supported the drive towards a consistent method to monitor trees under The Living Murray initiative.

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Section 1 – Background information on river red gum and black box

River red gum (*Eucalyptus camaldulensis* Dehnh.)

Adapted from Taxon Attribute Profiles Eucalyptus camaldulensis Dehnh. (CSIRO, 2009).

Eucalyptus camaldulensis is a common and widespread tree along watercourses over much of mainland Australia. It is frequently a dominant component of riparian communities, and is an iconic and important species of the Murray-Darling Basin.

Figure 2: Eucalyptus camaldulensis *Dehnh. Werta Wert, Chowilla Floodplain S.A.*

Taxonomy and Ecology

(Nicolle, 1997; Brooker and Kleinig, 1999)

Family: Myrtaceae, Genus: *Eucalyptus*, Subgenus: *Symphyomyrtus*
Section: *Exsertaria*, Series: *Exsertae*

Life form

Eucalyptus camaldulensis is a perennial, single-stemmed, large-boled, medium-sized to tall tree to 30 m high (Bren and Gibbs, 1986), although some authors (e.g. Boland et al., 1984; Brooker et al., 2002) record trees to 45 m. According to Jacobs (1955) river red gum may reach ages of 500 to 1000 years but trees are difficult to age due to irregular formation of tree rings.

Distribution

Eucalyptus camaldulensis is found over most of the Australian mainland, except for southern Western Australia, south-western South Australia and the eastern coastal areas of Queensland, New South Wales and Victoria (Chippendale, 1988). It is widespread along rivers of all continental Australia (Brooker and Slee, 1996).

Habitat

Eucalyptus camaldulensis commonly grows on sandy alluvial soils in riverine sites, which have permanent or seasonal water (Brooker et al., 2002). It is most extensive along river banks and on floodplains subject to frequent or periodic flooding (Costermans, 1989). It also lines the channels of sandy watercourses and creeks (Boland et al., 1984); commonly forming ribbon stands but sometimes extending over extensive areas of regularly flooded flats. It can also occur in the higher reaches of creeks in major valleys of hilly country (Cunningham et al., 1981).

"Status" in community

Eucalyptus camaldulensis is generally dominant in the community, often forming pure open forests or woodlands (Costermans, 1989). On lower levels of the floodplain, it is usually the only tree species present. On higher areas, it may occur in association with black box (*Eucalyptus largiflorens*) in the south or coolibah (*E. microtheca*) in the north of Australia (Dalton, 1990).

Physiological traits and adaptations

Trees possess deep sinker roots, which provide access to ground water (Bren 1990) and are highly effective in conducting water (Heinrich, 1990). *Eucalyptus camaldulensis* will also reduce water demand by shedding leaves and thereby reducing leaf area. This adaptation also reduces heat load under dry conditions when transpiration is reduced (Gibson et al., 1994).

Reproduction and Establishment

Flowering

Eucalyptus camaldulensis flowers in most years from late spring to mid-summer (July to February according to Brooker and Kleinig, 1999, December to February according to Boland et al., 1984). Flowering intensity is variable and unpredictable from year to year. About 45% of flowers fail to mature (Dexter, 1978).

Fruit development and maturation time can be as short as four months (CAB International, 2000). Eucalyptus species store little or none of their seed in the soil (see McEvoy, 1992).

Germination

Floods historically receded in spring-early summer and consequently these conditions are optimal for recruitment. Winter floods with winter recession are unfavourable due to conditions being too cold for successful germination. Spring-summer floods followed by summer recession provide suitable germination conditions but subsequent heat and water stress can cause massive seedling mortality (Roberts and Marston, 2000).

Establishment

Eucalyptus camaldulensis is a prolific producer of seed under favourable conditions. Dense stands of young plants appear over extensive areas after floods, at times forming impenetrable thickets. Seedling survival depends on maintenance of soil moisture through the first summer after germination (Jensen et al. 2008). These saplings gradually thin out as stands develop (Cunningham et al., 1981). A long-term planting trial at Barmah forest, suggests high density stands (> 1000 trees ha^{-1}) are more susceptible to dieback (Horner *et al.*, 2009). However, an extensive survey

along the Victorian Murray River only found stands of moderate density (< 800 trees ha^{-1}), suggesting that these high-density stands are rare due possibly to past logging practices and the rarity of flooding events (Cunningham *et al.*, in press).

Hydrology and salinity

Eucalyptus camaldulensis obtains its water from three main sources: flooding, ground water and rainfall. River flooding enables the species to survive in semi-arid areas where rainfall is too low. Some provenances of *E. camaldulensis* demonstrate moderate salt tolerance but increasing salinity is associated with reduced tree growth (Benyon et al., 1999). *Eucalyptus camaldulensis* is not physiologically adapted to either drought or salinity, although these stresses can be tolerated for short periods or at low levels.

Flooding regimes

Eucalyptus camaldulensis grows best in areas with a flooding frequency ca 1 in 2 years (Roberts and Marston, 2000). Changes in river flow in regulated systems (such as the Murray River) have led to dieback of river red gum and changes in understorey composition. Reduced flooding has also resulted in less water being available for recruitment. Permanent inundation of the floodplain (such as weir pools) has led to death of river red gum stands (Dalton, 1990).

Black box (*Eucalyptus largiflorens* F.Muell)

Based on the format of Taxon Attribute Profiles Eucalyptus camaldulensis Dehnh. (CSIRO, 2009)

Eucalyptus largiflorens occur on low-lying, outer floodplain areas and often coincide with the presence of river red gums. Black box woodlands usually have an understorey consisting of shrubs and grasses. Black box is more drought resistant than river red gum but still requires floods of a certain frequency and duration for their growth and survival.

Figure 3: Eucalyptus largiflorens *F.Muell near Wallpolla Island, Vic.*

Taxonomy and Ecology

(Nicolle, 1997; Brooker and Kleinig, 1999)

Family: Myrtaceae, Genus: *Eucalyptus*, Subgenus: *Symphyomyrtus*
Section: *Adnataria*, Series: *Buxeales*, Sub series: *Amissae*, Subraspecies: *Opacae*

Life form

Eucalyptus largiflorens is a perennial, medium sized tree, 10 m or sometimes to 20 m high, with a large spreading crown and drooping branches. The bark is persistent throughout except on the smallest branches and is hard, dark, rough and somewhat furrowed (DPI, 2009).

Distribution

Eucalyptus largiflorens occurs throughout Queensland, New South Wales, Victoria and South Australia, primarily in the Murray-Darling Basin, although some populations do exist outside the basin. (Chippendale et al., 1981).

Habitat

Eucalyptus largiflorens typically grows at higher elevations on the floodplain than *E. camaldulensis* (Roberts and Marston, 2000). *Eucalyptus largiflorens* commonly grows on heavy clay soils of periodically flooded alluvial plains and along dry lake margins, occurring in monospecific stands, or in association with river red gum, cooba (*Acacia stenophylla*) or occasionally *Melaleuca lanceolata* (Henderson pers. comm.).

"Status" in community

In black box woodlands, *E. largiflorens* forms a canopy over an understory of chenopods, short-lived herbs and grasses, and patches of lignum (*Muehlenbeckia florulenta*). In some areas *E. largiflorens* are widely-spaced and a chenopod shrubland develops between the patches of woodland.

Physiological traits and adaptations

Eucalyptus largiflorens is ecologically flexible and opportunistic in its water use, using both soil water and deeper groundwater, including water that is saline (Roberts and Marston, 2000).

Reproduction and Establishment

Flowering

The phenology of flowering and seed fall vary geographically. Main flowering period is August to January. However, flowering is reported to occur earlier (May-October) on the Chowilla floodplain (Roberts and Marston, 2000).

Germination

Large scale regeneration occurs after flooding (Treloar, 1959) due to suitably moist conditions that ensure widespread germination (Roberts and Marston, 2000). In the Murray system, ideal conditions for germination would historically occur in spring, whilst in the Darling system germination was most effective in the cooler months (Roberts and Marston, 2000).

Establishment

Seedlings usually appear after flooding and seldom appear in response to rainfall (Trelour 1959). Large scale floods provide the moisture conditions necessary for widespread germination and successful seedling establishment (Roberts and Marston 2000). The period of time that it takes for sapling release to occur has an effect on maturation time, where dense even-aged cohorts of seedlings/saplings occur, active growth is delayed until self-thinning occurs (Smith and Long, 2001). Black box seedlings are not tolerant of the root-zone anoxia that is caused by extended surface flooding (Roberts and Marston, 2000). Time for reproductive maturation may range from decades to centuries. Under adverse conditions, maturation may be delayed or may not occur (George 2005).

Hydrology and salinity

Eucalyptus largiflorens has the ability to use both soil water and deeper groundwater, including water that is saline (Roberts and Marston, 2000). Depth to groundwater and salinity of groundwater are the main factors affecting groundwater uptake (Jolly and Walker, 1996)

Flooding regimes

The required flooding regime for maintenance of *E. largiflorens* varies widely according to adequacy of groundwater and rainfall resources. Flooding is more important for maintenance in semi-arid environments. Black box is more tolerant of prolonged dry periods and less tolerant of flooding, than river red gum (Roberts and Marston, 2000).

Eucalyptus largiflorens can persist for extensive periods without flooding if soil moisture is maintained (up to 10 years (Jensen et al., 2008); 16+ years (Henderson et al., 2009)). In the Lower Murray, trees become stressed after 4 years without soil moisture being reset by flooding or significant rain. Tree stress is also observed in areas where where saline groundwater (> 40,000 EC) is within 4 m of the soil surface (Jensen et al. 2008).

Section 2 – Surveys to inform the TLM Stand Condition Model for river red gum and black box

1 Introduction

The Living Murray Stand Condition Model, reports on the condition of river red gum, black box and mixed box populations across all Icon Sites supporting river red gum and black box populations. The model produces stand condition maps for river red gum, black box and mixed box vegetation at each Icon Site, which can be used to estimate the proportion of each vegetation type in different condition classes, reveal spatial patterns in forest dieback and through repeated mapping quantify the effect of management actions.

Developed by the Australian Centre for Biodiversity at Monash University, The Living Murray Stand Condition Model models tree condition based on a combination of remotely sensed data (LANDSAT) and on-ground measurements of monitoring stands (Cunningham *et al.* 2009). The on-ground measurements required for the model are live basal area (m^2 ha^{-1}), plant area index (area of leaves and stems per unit of ground area, m^2 m^{-2}) and crown extent (percentage of crown that contains foliage).

The outputs of The Living Murray Stand Condition Model will be provided to the MDBA and Icon Site ecologists for interpretation and reporting each year.

Upon completion of the existing contract with Monash University, the MDBA will be provided with a modelling tool that can accurately predict stand condition on an annual basis. The tool will use current LANDSAT and ground assessment data from the monitoring sites as inputs, as well as relationships between LANDSAT and ground assessment data from previous years, to predict current condition across the Murray River floodplain. It will output a current stand condition layer as an ER Mapper file, which can be imported into Arc GIS for manipulation.

2 Establishing assessment sites

(developed from Cunningham et al. 2007)

The stand condition model relies on accurate field survey data at permanent monitoring locations throughout the Icon Sites. The locations for permanent monitoring are representative of each Icon Site and are detailed in Appendix 7. Monitoring locations are stratified to cover the range of vegetation types (e.g. forests, woodlands) landscape position (riverside, creekline, floodplain, wetland) and stand condition (severe to good) occurring at an Icon Site. This allows accurate mapping of condition across each Icon Site, comparisons among landscape positions, and assessment of the effectiveness of management actions for stands in different locations and conditions. Where possible, the permanent monitoring locations are locations that have been previously used for TLM condition monitoring.

The data collected at these monitoring locations will be used to build the Stand Condition Model and provide reference data to validate the model's predictions each year. The model requires a clearly defined spatial area so that ground survey data can be modelled against the same area of remotely-sensed data.

An assessment site has been established at each monitoring location. The following sections provide an overview to establishing assessment sites and Appendix 1 outlines

the methodology in detail should new or additional monitoring locations be required into the future.

2.1 Defining the spatial area of an assessment site

An assessment site of 0.25 ha is to be established at each monitoring location. The shape of the assessment site can be varied according to the distribution of trees within the area. Optimum site shape should be a 50 m × 50 m square, or circular site with a radius of 28.2 m. However, to assess linear stands along riverbanks and creeklines where a 50 m x 50 m square is not representative, a 100 m x 25 m rectangular shape may be used. GPS locations of each of the corners of a site, or centre of a circular site, are to be recorded to calculate accurate point locations for each monitoring location. Where transects already exist, a polygon of the appropriate dimensions can be overlain to capture the majority of currently assessed trees. A tree is to be included in the assessment if its trunk originates wholly or partly from within the boundaries of the assessment site.

2.2 Tree selection & photo point locations

The following sections provide an overview of tree selection and location of photo points to collect hemispherical photographs. Appendix 1 provides additional detail.

2.2.1 Live Basal Area – tree selection

For the Live Basal Area assessment, all trees, live or dead, of any species with diameter at breast height (DBH) ≥ 10 cm within the 0.25 ha are to be assessed. The number of trees inside the site should be recorded to determine density of trees per unit area.

2.2.2 Crown extent – tree selection

When conducting the assessment of crown extent, a total of 30 representative trees with DBH ≥ 10 cm are selected within the site. These trees are given a unique identifier and permanently marked using plastic cattle tags or stamped metal tags. Trees are selected to represent the size distribution and range of condition found within the site. This includes, in poorer condition sites, a proportional sample of dead trees among the 30 trees to ensure an accurate assessment of stand condition for comparison with remotely-sensed data. When sites contain fewer than 30 trees, additional representative trees are to be chosen within 20 m of the edge of the site until the 30 tree quota is reached. These additional trees must be noted on the datasheet as ‘outside’ the 0.25 ha area of the site.

At monitoring locations where both stand condition assessments and tree condition assessments are conducted (i.e. all sites listed in Appendix 7), trees used solely for the stand condition assessment will have the prefix “S” before the tree number. Trees used for both the stand condition and the tree condition assessments will be marked with “C” as a prefix to the tree number, whilst trees used solely for the tree condition assessment (see Section 3) will have the prefix “T” before the tree number.

2.2.3 Plant Area Index – locating photo points

Plant area index is estimated from digital hemispherical photographs taken using a digital camera and fisheye lens. Photographs should be taken from fixed positions at the centre of the site. A single photograph will be sufficient for sites < 70 m in length

whereas two photo points should be established in sites of greater length. In longer sites, these photo points should be spaced evenly across the site. The position of the photo point(s) should be recorded and permanently marked with a stake.

3 Attributes to be assessed

Table 2.1 outlines the variables assessed at each site during the ground survey to inform the TLM Stand Condition Model for river red gum and black box. Refer to Appendices 1, 2 and 3 for specific details on collecting attribute data.

Table 2.1: Attributes and variables assessed to inform the TLM Stand Condition Model.

Attribute	Variables	Sample Size
Live Basal Area %	DBH; Live/Dead Assessment	All trees ≥ 10 cm DBH within the 0.25 ha site.
Crown extent	Crown extent	30 permanently marked trees ≥ 10 cm DBH within the 0.25 ha site
Plant Area Index	Hemispherical Photographs	1 or 2 photographs per site (as outlined in 2.2.3)

4 Methods for assessment

All assessments should be undertaken by experienced observers to maintain consistency over time. New observers should be provided with thorough training and reference materials prior to undertaking monitoring surveys, including calibration against experienced observers to ensure standardisation of measurements.

4.1 Live Basal Area

Percentage Live Basal Area is a fundamental component of the Stand Condition model. Two field assessments enable Percentage Live Basal Area to be calculated: Diameter at Breast Height (DBH) and Live/Dead Assessment. Every stem within the site (DBH ≥ 10 cm) must have DBH measured and be assessed as live or dead. Refer to Appendix 2 for specific detail on applying this methodology.

4.1.1 Diameter at Breast Height (DBH)

Record the DBH of every tree, regardless of species, within the site to the nearest millimetre at 1.3 m above the ground. Where a tree has multiple stems at 1.3 m, the DBH of each stem is to be recorded and noted they belong to the same tree to allow calculation of tree density.

4.1.2 Live/Dead Assessment

(Cunningham et al., 2007)
Record the live/dead status of every tree within the site. For this assessment, a "dead" tree is defined as a tree that has no live foliage and a "live" tree is classed as a tree that does have live foliage. If a tree has been ringbarked, it is not included in the calculations of Live Basal Area.

4.1.3 Calculations to determine Live Basal Area

Percentage of Live Basal Area is calculated as follows:

1. Calculate the Basal Area (BA) of each stem using the following formula:

$$BA(cm^2) = \pi \times [DBH(cm)/2]^2$$

2. Calculate total Live Basal Area for the site by calculating the sum of the basal areas for all "Live" trees
3. Calculate total Dead Basal Area for the site by calculating the sum of the basal areas for all "Dead" trees
4. Calculate % LBA for the site using the following formula:

$$\%LBA = [\text{total live BA} / (\text{total live BA} + \text{total dead BA})] \times 100$$

4.2 Crown extent

(Souter et al. 2009)

For the TLM Stand Condition Model, the visual assessments of crown extent as outlined below will be used as inputs to the model. Refer to Appendix 2 for specific detail on applying this methodology.

4.2.1 Definition of Assessable Crown

In order to measure Crown Extent, the observer must first determine the 'Assessable Crown'. The 'Assessable Crown' is defined as the crown that is/was supported by all existing branches on the tree. This includes live branches, recently dead branches, and long-term dead branches. By including all existing branches on the tree in the assessable crown, issues of consistency between observers are minimised as no decision is required as to whether a branch is recently or long-term dead. Fallen branches are not considered part of the assessable crown. Figure 2 shows a stylised tree with the assessable crown defined.

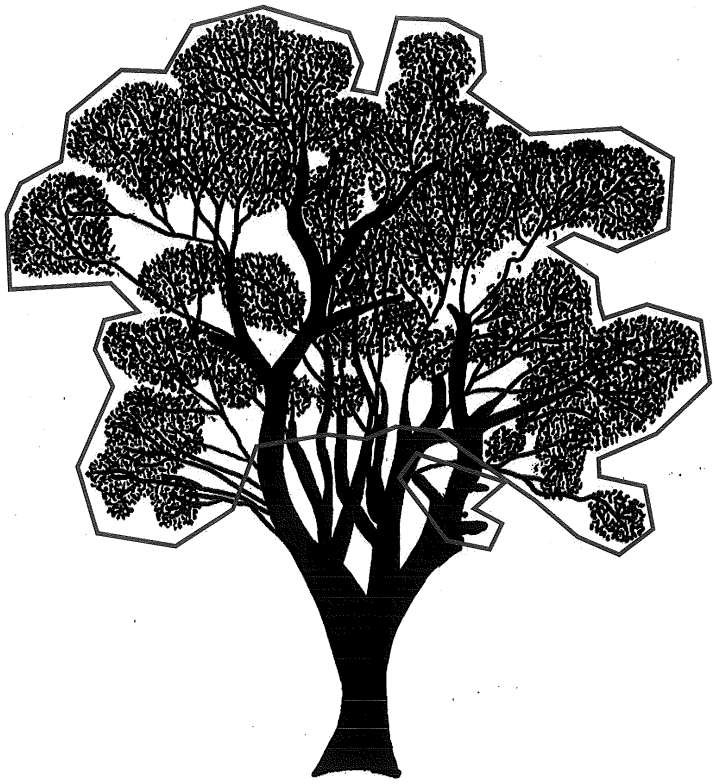

Figure 4: Stylised tree with the Assessable Crown defined by the red line (adapted from Souter et al., 2009).

4.2.2 Assessing crown extent

Crown extent is the percentage of the assessable crown in which there are live leaves. This includes branches that have leaves at their base and middle but not at their tips. Crown extent will diminish as foliage is progressively lost from the branches. The assessment of crown extent includes epicormic growth. Crown extent is reported according to the categories outlined in Table 2.2. In the data analysis for the Stand Condition Model, the minimal and sparse categories will be combined (1-20%) and the major and maximum classes will be combined (81-100%).

Table 2.2: Category scale for reporting crown extent assessments.

Score	Description	Percentage of assessable crown containing leaves
0	None	0 %
1	Minimal	1-10 %
2	Sparse	11-20 %
3	Sparse - Medium	21-40 %
4	Medium	41-60 %
5	Medium - Major	61-80 %
6	Major	81-90 %
7	Maximum	91-100 %

4.3 Plant Area Index

(adapted from Cunningham et al., 2007)

Plant area index (PAI) is defined as the area of leaves and stems per unit ground area without adjustment for clumping of canopy components (also defined as effective PAI by Chen, 1996). Plant Area Index is estimated from digital hemispherical photographs taken using a digital camera and fisheye lens or adaptor. Refer to Appendix 3 for specific detail on how to collect hemispherical photographs in the field.

The hemispherical photographs of the canopy are then assessed using the image analysis program Winphot 5.0 (ter Steege 1996) to estimate Plant Area Index. Refer to Appendix 6 for specific detail on applying this methodology.

5 Data Protocols

It is expected that the agency conducting the assessment will collect and store data according to best practice (Refer also to Appendix 6). Data return to the MDBA will be conducted in a similar manner to current Sustainable Rivers Audit (SRA) data return protocols, which will be distributed to Icon Site monitoring staff.

Section 3 – Surveys to inform the TLM Tree Condition Assessment for river red gum and black box

1 Introduction

The Living Murray Tree Condition Assessment, reports on the condition of river red gum and black box trees at the individual monitoring location scale. The monitoring locations may represent a particular vegetation type or landscape position. The tree condition assessment provides an assessment of the number of trees within a particular condition class at each monitoring location.

2 Assessment sites

TLM tree condition assessments are conducted at monitoring locations within the Icon Site. The locations selected for permanent monitoring are representative of each Icon Site and stratified so that the full range of vegetation types and landscape positions are covered (riverside, creekline, floodplain, wetland). This allows comparisons of tree condition among landscape positions, and assessment of the effectiveness of management actions for stands in different conditions.

Where possible, monitoring locations and assessment sites that have previously been used for condition monitoring should be retained to ensure continuity of data. Assessment sites for TLM tree condition assessments do not require a defined spatial area and hence can be transects, polygons or circular plots of any dimension provided data for 30 representative trees with DBH greater than 10 cm is captured.

2.1 Tree selection & photo point locations

2.1.1 Condition assessment

When conducting the assessments, a total of 30 live trees with DBH ≥ 10 cm are to be selected within the assessment site, given a unique identifier and permanently marked using plastic cattle tags or stamped metal tags. These trees should be selected to represent the size distribution and range of condition found within the site.

At monitoring locations where both stand condition assessments and tree condition assessments are conducted (i.e. all sites listed in Appendix 7), trees used solely for the tree condition assessment will have the prefix “T” before the tree number. Trees used for both the stand condition and the tree condition assessments will be marked with “C” as a prefix to the tree number, whilst trees used solely for the stand condition assessment (see Section 2) will have the prefix “S” before the tree number.

2.1.2 Photo point monitoring

The purpose of photo points is to provide a visual assessment of changes in vegetation condition over time. Consistency in photographs is essential to provide a valuable observational record of trends in condition over time. A minimum of one photo point shall be established for each assessment site. The photo points should be representative of the landscape, and the locations must be clearly identifiable.

The position of each photo point should be such that:

- the images will be representative of the condition of those trees surveyed;
- maximise the number of transect trees captured in the image; and
- maximise the resolution of the tree crowns captured.

3 Attributes to be assessed

Table 3.1 outlines the attributes to be assessed as part of the TLM Tree Condition assessments. These attributes have been selected so that reporting of tree condition is consistent among Icon Sites.

Table 3.1: Attributes and variables assessed to inform the TLM Tree Condition Assessment.

	Attribute	**Variables**	**Sample Size**
Tree Condition Assessment	Crown Condition	• crown extent, crown density	30 permanently marked trees ≥ 10 cm DBH at each site
	Additional Condition Indicators	• new tip growth • epicormic growth • leaf die-off • extent of bark cracking.	30 permanently marked trees ≥ 10 cm DBH at each site
Contextual Information for Tree Condition	Tree information	• DBH • dominance class • extent of reproduction • mistletoe load.	30 permanently marked trees ≥ 10 cm DBH at each site
	Site information	• disturbance • insect damage • other biological stresses • presence of seedlings and saplings	Assessment of the Site as a whole
Photo points		• digital photographs	At least one photo point per site.

4 Methods for assessment

Within each assessment site, the individual condition of 30 marked trees is to be measured to provide an on-ground assessment of tree condition. All assessments, where possible, should be undertaken by the same experienced observers to maintain consistency over time. New observers should be provided with thorough training and reference materials prior to undertaking monitoring surveys, including calibration against experienced observers to ensure standardisation of measurements.

4.1 Tree Condition

Visual assessments of crown condition are based on methodology developed by Souter et al. (2009). Two tree condition attributes, crown extent and crown density, are assessed.

4.1.1 Definition of Assessable Crown

In order to measure crown extent, the observer must first determine the 'Assessable Crown'. The 'Assessable Crown' is defined as the crown which is/was supported by all existing branches on the tree. This includes live branches, recently dead branches,

and long-term dead branches. By including all existing branches on the tree in the assessable crown, issues of consistency between observers are minimised as there is no decision required as to whether a branch is recently dead, or long-term dead. Fallen branches are not considered part of the assessable crown. Figure 3 shows a stylised tree with the assessable crown defined.

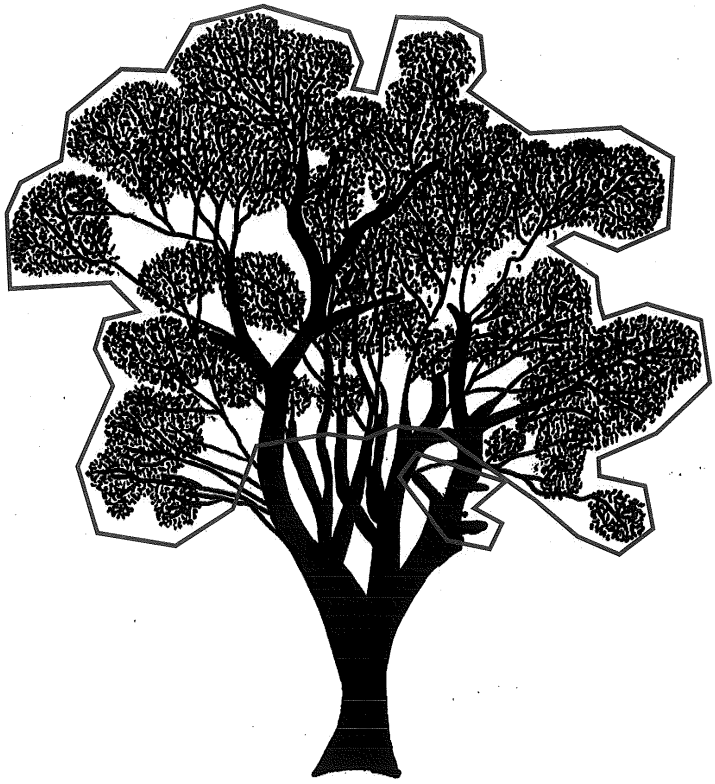

Figure 5: Stylised tree with the Assessable Crown defined by the red line (adapted from Souter et al., 2009).

4.1.2 Assessing crown extent and crown density

The protocol uses a combination of descriptive terms and percent divisions (e.g. sparse = 11-20%). This is intended to assist assessment of condition, particularly where difficulty in defining differences at the edges of categories exists. It should also be noted that data may need to be re-categorised in future as knowledge and practices improve. Consequently, it is required that observers also record an actual estimate of both crown extent and crown density percentage value. This approach allows for expansion or contraction of the number of divisions (or to retrospectively analyse data using other scales) if desired. Refer to Appendix 4 for specific detail on applying this methodology.

4.1.3 Crown extent assessment

Crown extent is the percentage of the assessable crown in which there are live (green) leaves. This includes branches that have leaves at their base and middle but not at their tips. Crown extent will diminish as foliage is progressively lost from the branches. The assessment of crown extent includes epicormic growth. Crown extent is reported according to the categories outlined in Table 3.2. Observers must also record an estimated percentage value of crown extent.

4.1.4 Crown density assessment

Crown density is assessed as the amount of skylight blocked by portion(s) of the crown containing live leaves i.e. the higher the density of live leaves, the higher the amount of skylight blocked by the foliage. Only live leaves in the crown contribute to the estimate of density (see Figure 4). Crown density is reported according to the categories outlined in Table 3.2. Observers must also record an estimated percentage value of crown extent.

Table 3.2: Category scale for reporting crown extent and crown density assessments.

Score	Description	Percentage of assessable crown holding leaves
0	None	0 %
1	Minimal	1-10 %
2	Sparse	11-20 %
3	Sparse - Medium	21-40 %
4	Medium	41-60 %
5	Medium - Major	61-80 %
6	Major	81-90 %
7	Maximum	91-100 %

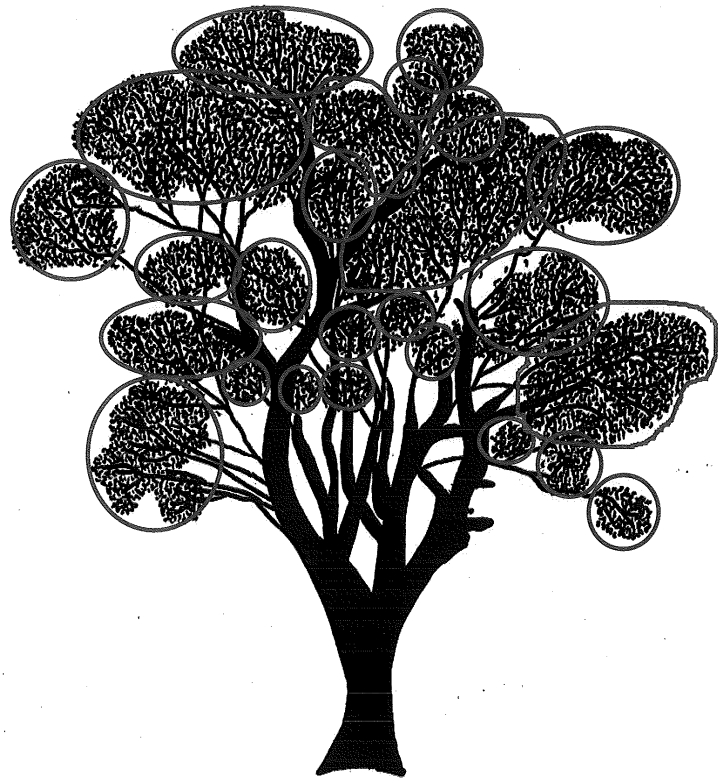

Figure 6: Stylised tree showing areas for crown density assessments circled in red (adapted from Souter et al., 2009).

4.2 Condition Indicators

The attributes of new tip growth, epicormic growth, leaf die-off, and extent of bark cracking may provide additional information on tree condition. Trees producing new tip growth suggest either a maintenance in condition for healthy trees or recovery from stress and a possible future increase in condition (if suitable environmental conditions are maintained) in unhealthy trees. Trees producing epicormic growth

suggest a recovery from stress and a possible future increase in condition (if suitable environmental conditions are maintained) in unhealthy trees. In contrast, trees that have leaves dying off, and/or deeply cracked bark may be under stress and may continue to decline in condition. Once a temporal sequence of data has been collected the relationship between these indicators and future condition of the tree can be quantified. Refer to Appendix 4 for specific detail on assessing Condition Indicators using this methodology.

4.2.1 New tip growth

Growth of new shoots from branch tips (i.e. not epicormic growth) is classed as new tip growth and indicates that environmental conditions are currently suitable for tree growth. New tip growth is readily identified in the field as it is typically yellow/light green in colour in contrast to the darker green of older foliage. Assessment of new tip growth records the presence and visual effect of new shoots, when assessed over the entire assessable crown, as per the categories presented in Table 3.3.

4.2.2 Epicormic growth

Growth of new shoots from the main trunk, or major support branches of the tree is classed as epicormic growth and indicates that environmental conditions are suitable for tree growth. Epicormic growth is identified in the field by observing the trunk and major support branches and looking for new shoots growing directly from those major branches. Second year growth from epicormic shoots is still considered epicormic until the base of the shoot is 3 cm or more in diameter.

Assessment of epicormic growth records the presence and abundance of live epicormic shoots, when assessed over the entire assessable crown, as per the categories presented in Table 3.3. When trees have lost their entire crown prior to responding to favourable environmental conditions, epicormic growth may constitute the entire crown of the tree, this should be noted as part of the assessment.

Table 3.3: Category scale for reporting new tip growth, epicormic growth, and leaf die-off.

Score	Description	Definition
0	Absent	Effect is not visible
1	Scarce	Effect is present within the assessable crown but not readily visible
2	Common	Effect is clearly visible throughout the assessable crown
3	Abundant	Effect dominates the appearance of the assessable crown

4.2.3 Leaf Die-Off

The relative abundance of dead leaves on the tree is assessed as leaf die-off and indicates poor environmental conditions for tree growth. Assessment of leaf die-off records the presence and visual effect of dead and partially dead leaves, when assessed over the entire assessable crown, as per the categories presented in Table 3.3. If a tree has lost all leaves and continues to be placed under significant water stress, cracking of bark and exposure of the heartwood may begin to occur. Continued water stress will lead to tree death.

4.2.4 Extent of bark cracking

Bark condition is assessed by observing areas of smooth bark on the main stem(s) and lower branches of the tree and rating the extent of cracking as per the categories presented in Table 3.4. The assessment only scores bark cracks that go into the sapwood, regardless of whether they have been repaired with sap. Shallow 'growth' cracks should be excluded from this assessment.

Trees showing minor or moderate cracking may have the potential to improve or recover condition should environmental conditions improve. Trees exhibiting extensive cracking have deep vertical cracks in the bark, generally found on the main stem, which expose the sapwood. Trees under this level of stress generally have lost all of their leaves or only have dead leaves. Long term dead trees have no bark and have lost all of their medium and fine branches.

It should be noted that the extent of bark cracking index is most applicable to river red gum, in contrast, once black box show signs of bark cracking, they are typically well beyond recovery (T. Wallace *pers comm.*).

Table 3.4: Categories for the assessment of bark cracking.

Score	Description
0	Intact Bark
1	Minor cracking i.e. cracks limited in number and bark still held in place
2	Moderate cracking i.e. numerous cracks but bark still held in place
3	Extensive cracking i.e. numerous deep cracks which are lifting the bark off the sapwood
4	No bark (long term dead)

4.3 Contextual Information for Tree Condition

These assessments will provide additional information on the condition of trees assessed as part of The Living Murray Tree Condition Assessment. The assessments listed are not core components, however, they provide additional context for the tree condition at the Icon Sites and, therefore, must be recorded and reported in the initial implementation of this methodology. Future analysis will determine the usefulness of these variables in assessing tree condition, and hence, the requirement for continued monitoring of these variables. Refer to Appendix 4 for specific detail on applying this methodology.

4.3.1 Diameter at Breast Height (DBH)

Record the DBH in centimetres at 1.3 m above the ground. Where a tree has multiple stems at 1.3 m, the DBH of each stem is to be recorded.

4.3.2 Dominance class

Forest structure may have an effect on the condition of individual trees. Dominance class information is particularly important at Icon Sites with forests, to provide additional context to the condition of individual tress. Dominance class data can be interpreted to determine if the condition of particular individuals is declining due to its position in the forest structure e.g. a subdominant tree being out-competed by dominant and codominant trees. Descriptions of dominance categories are presented in Table 3.5.

Table 3.5: Categories for assessing tree dominance (Forests NSW Operations, G. Miller pers. comm.; 2008).

Category	Description
Dominant	Tree with a crown extending above the general canopy, receiving full light from above and partly from the sides; a larger than average tree in the stand.
Codominant	Tree with crown forming part of the general canopy, receiving full light from above but comparatively little from the sides.
Subdominant	Tree shorter than the previous classes, but with a crown extending into the canopy of the Codominant trees, receiving little light from above but none from the sides.
Suppressed	Tree with a crown entirely below the canopy, receives no direct light from above or from the sides.

4.3.3 Extent of reproduction

Trees used in the condition assessment are to be assessed for extent of reproduction. Extent of reproduction is recorded as the combined relative abundance of buds, flowers and fruit assessed within the assessable crown. Combining the different reproductive states increases the speed of assessment and removes the confounding nature of seasonality and the cyclical nature of bud crops common to eucalypts. Extent of reproduction is assessed against on the category scale presented in Table 3.6.

Table 3.6: Category scale for reporting extent of reproduction.

Score	Description	Definition
0	Absent	Reproductive behaviour is not visible
1	Scarce	Reproductive behaviour is present but not readily visible
2	Common	Reproductive behaviour is clearly visible
3	Abundant	Reproductive behaviour dominates the appearance of the tree

4.3.4 Mistletoe load

The relative abundance of live mistletoe on the tree is assessed as mistletoe load and indicates poor environmental conditions for tree growth. Assessment of mistletoe records the presence and visual effect of live mistletoe within the assessable crown, as per the categories presented in Table 3.7.

Table 3.7: Category scale for reporting mistletoe load.

Score	Description	Definition
0	Absent	Mistletoe is not visible
1	Scarce	Mistletoe is present but not readily visible
2	Common	Mistletoe is clearly visible
3	Abundant	Mistletoe dominates the appearance of the tree

4.4 Contextual Information on the Condition of the Assessment Site

These assessments will provide additional information on the condition of the assessment site. The assessments listed are not core components, however, they provide additional context for the tree condition at the Icon Sites and, therefore, must also be recorded and reported in the initial implementation of this methodology. Future analysis will determine the usefulness of these site assessments in assessing and reporting tree condition. Refer to Appendix 4 for specific detail on applying this methodology.

4.4.1 Disturbance

Recording natural and man-made disturbances that have occurred at a site allows changes in condition that may be due to influences other than those of The Living Murray to be assessed. Disturbances such as logging, grazing, flooding and fire can have significant impacts on tree condition. Similarly, biological stresses such as insect damage, disease and weed infestation may also impact on tree condition, masking the effect of actions undertaken as part of The Living Murray.

4.4.2 Insect damage

Numerous insects will feed on river red gum and black box leaves. The most commonly observed forms of leaf damage are irregular shaped leaves with jagged edges and skeletonised leaves. Insect attack is assessed over the site as a whole and categorised as per Table 3.8.

Table 3.8: Insect damage categories for site assessment.

Category	Description
Absent	Not visible or minor damage to some trees
Scarce	Some trees have scattered damage within the crown
Common	Most trees have significant damage within the crown
Abundant	All trees have significant damage within the crown

4.4.3 Other biological stresses

Other biological stresses could include disease, parasites or significant weed infestation. The site is assessed for any visible sign of stress. The type of stress is identified and rated based on the categories in Table 3.9.

Table 3.9: Categories for other biological stresses observed during site assessment.

Category	Description
Absent	Not visible or minor presence within the site
Scarce	Scattered occurrence throughout the site
Common	Present throughout the majority of the site
Abundant	Present throughout the entire site

4.4.4 Presence of seedlings and saplings

An assessment of the presence of seedlings and saplings across the site whilst conducting tree condition assessments provides important contextual information. The presence of seedlings and saplings within the site is recorded according to the categories presented in Table 3.10. This assessment is not a substitute for assessing

recruitment, a comprehensive assessment of recruitment for black box and river red gum should be undertaken as part of Icon Site Condition Monitoring, as it is a key indicator of the success of The Living Murray.

Table 3.10: Category scale for reporting presence of seedlings and saplings.

Description	Definition
Absent	No seedlings/saplings found
Scarce	Less than 10 seedlings/sapling present
Common	10-50 seedlings/saplings present
Abundant	Greater than 50 seedlings/saplings present

4.5 Photo Points

The purpose of photo points is to provide a visual assessment of changes in vegetation condition over time. Digital photography is the recommended method for photo points, as it provides a method to capture high resolution images that are easily stored and incorporated into reports. The Living Murray Communications Unit may also use such photographs in brochures, reports, websites, etc.

4.5.1 General guidelines

Consistency in photographs is essential to provide a valuable observational record of trends in condition over time. A minimum of one photo point shall be established for each site. The photo points should be representative of the landscape, and the locations must be clearly identifiable.

Photographs should be taken on the same day that vegetation sampling is conducted and at a similar time of day to previous assessments to maximise comparability of images.

A single photo point should be established for each transect to document change through time. The position of each photo point should be such that:

- the images will be representative of the condition of those trees surveyed.
- maximise the number of transect trees captured in the image; and
- maximise the resolution of the canopies of the trees captured.

The camera should be positioned on the same point, pointing along the same bearing, at the same height and set to the same zoom level on each occasion. When taking photographs, care should be taken to prevent direct sunlight creating glare on the lens.

4.5.2 Methodology

Photo points should be established for each transect to document change through time. Photo points should be permanently marked (e.g. using a survey peg/stake) and their location recorded on a hand-held GPS unit. The peg should be labelled with the site number. Insert a “sighter” peg 10 m away from primary survey peg. The photographer should be positioned at the base of the photo point peg and, where possible (due to elevation and aspect), the viewfinder should be centred on the sighter peg (see Figure 7).

A small white board (e.g. 0.3 x 0.3 m) with the site name, site number, and date (dd/mm/yyyy) placed at the base of the “sighter” peg will assist with site-photograph identification.

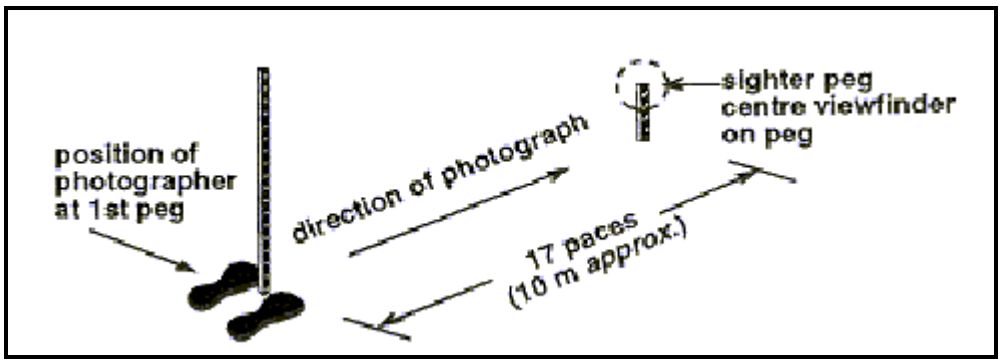

Figure 7: Position of photograph at photo point (Tatnell 1987).

All photographs should be taken with a high resolution (>5MP) digital camera with image quality set to ‘HQ', focus set to ‘auto’, zoom set to ‘off/zero’, and flash set to ‘off’. If necessary, the camera should be shaded to prevent glare on the lens. Blue-tooth enabled GPS and blue tooth enabled cameras, which imbed GPS coordinates into the photographs and synchronise with GIS software are recommended.

4.5.3 Data management and analysis of Photo points

Appropriate metadata must be recorded with all photographs. Essential metadata for photographs are: date and time, direction bearing in degrees (from compass), GPS coordinates, and name of site and name of photographer. Additional metadata should be recorded as required to document special or unusual conditions.

5 Data Protocols and Analysis

It is expected that the agency conducting the assessment will collect and store data according to best practice.

The combinations of attributes which best inform the condition assessment is currently under revision. It is important to collect data for all of the attributes that form the condition assessment whilst the revision continues. The data collected over time at the sites may be used to determine if these variables are reliable indicators of positive or negative trajectories.

6 Back Compatibility

The proposed method differs in how it assesses crown condition from some past methods used at the Icon Sites. There will be some data that has not been collected in the past (e.g. crown density, extent of bark cracking) and there will be some incompatibility between previous categories and the proposed categories. Previous assessments may contain sufficient raw data to enable this new method to be applied (eg. crown extent recorded as percentages rather than categories). If photographs of individual trees have been kept on file, trees could also be reassessed using the new assessment scales to provide uniformity of data.

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Appendix 1: Protocol for establishing TLM stand condition monitoring assessment sites

Assessment sites for TLM Stand Condition monitoring were established in 2009 (see Appendix 7 for location details). The established sites are intended to be revisited each year. However should a site be deemed unsuitable, and a new site is established, the following protocol for establishing a TLM Stand Condition Monitoring assessment should be followed.

Equipment

- GPS and spare batteries
- Compass
- Maps of Icon Site including monitoring location information
- 100 m surveyor's measuring tape(s)
- DBH tape
- Plastic cattle tags or stamped metal tags pre-prepared as unique identifiers of surveyed trees
- Aerosol can of blue tree marking paint
- Small hammer or mallet + fasteners
- Permanent marker pens
- Datasheets and/or field computer

Protocol:

1. Find the monitoring location using the location information provided.
2. Identify an assessment site of 0.25 ha at each site. The shape of the site can vary according to the vegetation distribution at the site being assessed. Optimum shape and size should be a 50 x 50 m square, or circle with a radius of 28.2 m (i.e. from pre-established Bench tree star picket). However, rectangular sites of 100 m x 25 m can be used to assess linear stands, which are common along riverbanks and creeklines in the Lower Murray.
3. Mark the corners of the assessment site (a short length of orange conduit is a suitable marker) and record the GPS locations of all corners of a site, or centre of a circular area.
4. Identify all trees (including other species assessed as part of Live Basal Area assessment) that are located within the assessment site. A tree is to be included in the assessment if its trunk originates wholly or partly from within the boundaries of the assessment site.
5. Allocate positions where digital hemispherical photographs will be taken. A single photo point is sufficient for assessment sites < 70 m in length. Two photo points should be selected for assessment sites > 70 m in length. Photo points should be evenly spaced along the length of the site so that they provide representative coverage (e.g. at 100 x 25 m sites photo points should be at 33.3 and 66.6 m). Photo points should not be established within 3 m of the trunk of a large tree. Record the location of photo point(s) and permanently mark with a stake.
6. Select a total of 30 trees of the species being assessed for the individual crown extent assessment as follows:
    - All trees used in previous surveys within the 0.25 ha are to be included

- Additional trees (where required) are to be randomly selected from within the quadrat area to reach the 30 tree quota.
- When sites contain fewer than 30 trees, additional representative trees are to be chosen within 20 m of the edge of the assessment site until the 30 tree quota is reached. These additional trees must be noted on the datasheet as 'outside' the 0.25 ha area of the site.
- Each tree is given a number (1-30) and permanently marked using plastic cattle tags or metal tags. Trees used solely for the stand condition assessment have the prefix "S" before the tree number. Trees used for both the stand condition and the tree condition assessments are marked with "C" as a prefix to the tree number.
- GPS locations of the 30 individual trees should also be recorded.

Appendix 2: Protocol for surveys to inform the TLM stand condition model for river red gum and black box

Every tree greater than 10 cm DBH within the defined sampling site must be assessed as live or dead and have DBH recorded. The 30 marked trees at the site must also be assessed for crown extent.

Equipment:

- GPS and spare batteries
- Compass
- Maps of Icon Site including site location information
- Diameter tape (d-Tape)
- Photographic guide to Crown Assessment (under development)
- Aerosol can of blue tree marking paint
- Datasheets and/or field computer
- Attribute assessment categories (methodology)

Protocol:

Note: crown extent and Live Basal Area assessment can be conducted concurrently – as outlined below – or crown extent can be assessed separately if the survey being conducted includes TLM Tree condition assessments (refer to Section 3).

1. Locate the established assessment site using the location information provided.
2. Conduct a rapid assessment of disturbance at the site noting the presence and extent of natural and/or man-made disturbances within the site (e.g. fire, logging, grazing, flooding etc.) on the datasheet.
3. Select the first tree to be assessed. Trees used for the stand condition assessment have the prefix “S” or “C” before the tree number. Trees used only for the tree condition assessments are marked with “T” and should not be assessed using this protocol.
4. Measure the DBH of the tree according to the following rules:
    - Breast height is 1.3 m above ground measured along the stem.
        - Where the tree is on a slope, 1.3 m is measured on the uphill side of the tree.
        - Where the tree is on a lean, 1.3 m is measured on the underside of the lean.
        - Where a swelling occurs at 1.3 m, two points unaffected by swellings or limbs equally spaced above and below 1.3 m should be selected, measured then averaged to give an estimate of DBH.
    - The tape must be at 90° to the axis of the stem at 1.3 m.
    - Lichen or loose bark should be gently cleared so as not to remove any firm bark from the tree.
    - Measure DBH to the nearest mm.
    - If DBH is less than 10 cm, ignore and move to the next tree.
    - If DBH is at least 10 cm record the measurement on the datasheet.
    - If the tree has multiple stems, the DBH of each stem is to be recorded.

- The measurer should paint the point(s) on the tree where the diameter measurement(s) have been made.

Every tree in the 0.25 ha is to be assessed as above, regardless of species and the species noted.

5. Assess the tree as live or dead based on the following definitions and record the assessment on the datasheet.
   - "Dead" tree is defined as a tree that has no live (green) foliage;
   - "Live" tree is classed as a tree that does have live foliage.
   - Every tree in the 0.25 ha is to be assessed as above, with the exception of ringbarked trees, which are not included in the calculations of Live Basal Area.
6. If the tree is one of the 30 trees tagged for crown extent assessment, apply the following method to assess crown extent:
   - 'Assessable Crown' is defined as the crown that is/was supported by all existing branches on the tree. This includes live branches, recently dead branches, long-term dead branches, and branches in the lower crown that possibly died because they were redundant.
   - Crown extent is the percentage of the assessable crown in which there are live leaves. This includes branches that have leaves at their base and middle but not at their tips, including epicormic growth.
   - Consider the tree from several angles and make your final decision standing where you have a clear view of the whole crown.
   - Crown extent is assessed using the scale presented in Table A2.1 and the category recorded on the datasheet.
   - Observers should also record an actual estimate of crown extent percentage value (e.g. to within 5 %).

Table A2.1: Category scale for reporting crown extent.

Score	Description	Percentage of Assessable Crown
0	None	0 %
1	Minimal	1-10 %
2	Sparse	11-20 %
3	Sparse - Medium	21-40 %
4	Medium	41-60 %
5	Medium - Major	61-80 %
6	Major	81-90 %
7	Maximum	91-100 %

7. Move to the next tree until all trees within the defined sampling site have been assessed as live or dead, DBH measured and the 30 tagged trees assessed for crown extent.

Appendix 3: Protocol for collecting hemispherical photographs for Plant Area Index (PAI) assessment

Plant area index (PAI) is estimated from digital hemispherical photographs taken using a digital camera and fisheye lens adaptor. The hemispherical photographs of the canopy are then assessed using image analysis software to estimate PAI.

Equipment:

- GPS and spare batteries
- Maps of Icon Site including site location information
- Digital camera and spare batteries
- Fisheye lens or adaptor
- Tripod
- Datasheets and/or field computer

Protocol:

1. Photographs must be taken during the 90 minutes after sunrise or the 90 minutes before sunset to avoid direct sunlight on the canopy. Photographs with excessive sunlight in the canopy or on the trunks will lead to substantial underestimates of PAI. Excessive sunlight can sometimes be removed by positioning the camera such that the sun is behind the trunk of a large tree.
2. Locate the established assessment site using the location information provided.
3. Locate the marked camera position.
4. Set up and level the tripod and camera at 1.3 m height.
5. Photographs must be taken with the lens pointing at 90° to the horizontal plane
6. Capture the photograph and record the required information including the filename/number on the hemispherical photograph record sheet
7. Move to the next camera position and repeat.

Appendix 4: Protocol for TLM Tree Condition Assessments of river red gum and black box

Two attributes comprising a set of six core variables form the minimum requirements for reporting river red gum and black box tree condition for The Living Murray. Additional attributes also provide context to the changes in condition observed at each site and therefore, must be recorded and reported in the initial implementation of this methodology. Future analysis will determine the usefulness of these variables in assessing tree condition, and hence, the requirement for continued monitoring of these variables. Within each assessment site, the individual condition of 30 marked trees is measured to provide an on-ground assessment of tree condition.

Equipment:

- GPS and spare batteries
- Compass
- Maps of Icon Site including site location information
- Permanent marker pens
- Diameter tape (d-Tape)
- Photograph guide to Crown assessment (under development)
- Binoculars
- Aerosol can of blue tree marking paint
- Tags
- Fasteners
- Hammer
- Attribute assessment categories (methodology)
- Datasheets and/or field computer

Protocol:

1. Locate the established assessment site using the location information provided.
2. Locate the first tree to be assessed. Trees used for the tree condition assessment have the prefix “T” or “C” before the tree number. Trees used only for the stand condition assessments are marked with “S” and should not be assessed using this protocol.
3. Measure the DBH of the tree according to the following protocol:
    - Breast height is 1.3 m above ground measured along the stem.
        - Where the tree is on a slope, 1.3 m is measured on the uphill side of the tree.
        - Where the tree is on a lean, 1.3 m is measured on the underside of the lean.
        - Where a swelling occurs at 1.3 m, two points unaffected by swellings or limbs equally spaced above and below 1.3 m should be selected, measured then averaged to give an estimate of DBH.
    - The tape must be at 90° to the axis of the stem at 1.3 m, if there is lichen or loose bark it should be gently cleared so as not to remove any firm bark from the tree.
    - Measure DBH to the nearest cm and record the measurement on the datasheet.
    - If the tree has multiple stems, the DBH of each stem is to be recorded.

- The measurer should paint the point(s) on the tree where the diameter measurement(s) have been made.

4. Assess the extent of bark cracking by observing the smooth barked areas of the main stem and lower branches of the tree and rating the extent of cracking as per the categories presented in Table A4.1.

Table A4.1: Categories for the assessment of bark cracking.

Score	Description
0	Intact Bark
1	Minor cracking i.e. cracks limited in number and bark still held in place
2	Moderate cracking i.e. numerous cracks but bark still held in place
3	Extensive cracking i.e. numerous deep cracks which are lifting the bark off the sapwood
4	No bark (long term dead)

5. Assess crown extent according to the following rules:
   - The assessable crown is defined as the crown which is/was supported by all existing branches on the tree. This includes live branches, recently dead branches, long dead branches, and epicormic growth.
   - crown extent is the percentage of the assessable crown in which there are live (green) leaves. This includes branches that have leaves at their base and middle but not at their tips.
   - Consider the tree from several angles prior to making your final decision.
   - Crown extent is assessed using the scale presented in Table A4.2 and the category recorded on the datasheet.
   - Observers must also record an actual estimate of crown extent percentage value.

Table A4.2: Category scale for reporting crown extent assessments.

Score	Description	Percentage of Assessable Crown
0	None	0 %
1	Minimal	1-10 %
2	Sparse	11-20 %
3	Sparse - Medium	21-40 %
4	Medium	41-60 %
5	Medium - Major	61-80 %
6	Major	81-90 %
7	Maximum	91-100 %

6. Assess crown density according to the following rules:
   - Crown density is the amount of skylight blocked by the foliated portion(s) of the crown. i.e. the higher the density, the higher the amount of skylight blocked by the foliage.
   - All live leaves in the crown, including epicormic, contribute to the estimate of density.
   - Values of crown density can exceed values of crown extent e.g. fully epicormic trees will have low extents but the existing foliage will have a high density.

- Consider the tree from several angles prior to making your final decision. Use binoculars if required.
- Crown density is assessed using the scale presented in Table A4.3 and the category recorded on the datasheet.
- Observers should also record an actual estimate of crown density percentage value.

Table A4.3: Category scale for reporting crown density assessments.

Score	Description	Percentage of skylight blocked by foliated portions of the crown
0	None	0 %
1	Minimal	1-10 %
2	Sparse	11-20 %
3	Sparse - Medium	21-40 %
4	Medium	41-60 %
5	Medium - Major	61-80 %
6	Major	81-90 %
7	Maximum	91-100 %

7. Assess the main branching structure for epicormic growth, using binoculars. Epicormic growth is assessed against the categories in Table A4.4 based on the following rules.
   - Epicormic growth is the growth of new shoots from the main trunk or major support branches of the tree.
   - Shoots are to be considered as epicormic if they have initiated from old stems and are less than 3 cm in diameter.
   - In cases where trees that have lost their entire crown respond to favourable conditions, epicormic growth will constitute the entire crown of the tree. This should be recorded separately as a comment and/or in a tick box on the datasheet.
   - Assessment of epicormic growth records the presence and visual effect of new shoots, when assessed over the entire assessable crown

Table A4.4: Category scale for reporting epicormic growth.

Score	Description	Definition
0	Absent	Epicormic growth is not visible
1	Scarce	Epicormic growth is present but not readily visible
2	Common	Epicormic growth is clearly visible
3	Abundant	Epicormic growth dominates the appearance of the tree

8. Assess the crown using binoculars for new tip growth based on its visibility using the categories in Table A4.5.
   - New tip growth is defined as the growth of new shoots from the tips of the tree branches at the edge of the crown.
   - New tip growth is readily identified in the field as it is typically yellow/light green in colour in contrast to the darker green of older foliage.
   - Assessment of new tip growth records the presence and visual effect of new shoots, when assessed over the entire assessable crown

Table A4.5: Category scale for reporting new tip growth.

Score	Description	Definition
0	Absent	New tip growth is not visible
1	Scarce	New tip growth is present but not readily visible
2	Common	New tip growth is clearly visible
3	Abundant	New tip growth dominates the appearance of the tree

9. Use binoculars to visually assess leaf die-off in the crown using the categories in Table A4.6.
    - Leaf die-off is the relative abundance of dead and partially dead leaves on the tree.
    - Assessment of leaf die-off records the presence and visual effect of dead leaves, when assessed over the entire assessable crown

Table A4.6: Category scale for reporting leaf die-off.

Score	Description	Definition
0	Absent	Leaf die-off is not visible
1	Scarce	Leaf die-off is present but not readily visible
2	Common	Leaf die-off is clearly visible
3	Abundant	Leaf die-off dominates the appearance of the tree

10. Provide a dominance class for the tree based on its position in the forest structure according to the descriptions outlined in Table A4.7. Dominance is particularly important at Icon Sites with forest to provide additional context to the condition of individual tress.

Table A4.7: Categories for assessing tree dominance (Forests NSW Operations, G. Miller pers. comm.; 2008).

Category	Description
Dominant	Tree with a crown extending above the general canopy, receiving full light from above and partly from the sides; a larger than average tree in the stand.
Codominant	Tree with crown forming part of the general canopy, receiving full light from above but comparatively little from the sides.
Subdominant	Tree shorter than the previous classes, but with a crown extending into the canopy of the Codominant trees, receiving little light from above but none from the sides.
Suppressed	Tree with a crown entirely below the canopy, receives no direct light from above or from the sides.

11. Use binoculars to visually assess extent of reproduction in the crown. Extent of reproduction is recorded as the combined relative abundance of buds, flowers and fruit assessed within the assessable crown, reported against the categories outlined in Table A4.8.

Table A4.8: Category scale for reporting extent of reproduction.

Score	Description	Definition
0	Absent	Reproductive behaviour is not visible
1	Scarce	Reproductive behaviour is present but not readily visible
2	Common	Reproductive behaviour is clearly visible
3	Abundant	Reproductive behaviour dominates the appearance of the tree

12. Assess the crown to determine the trees live mistletoe load. Assessment of mistletoe records the presence and visual effect of live mistletoe within the assessable crown, as per the categories presented in Table A4.9.

Table A4.9: Category scale for reporting mistletoe load.

Score	Description	Definition
0	Absent	Mistletoe are not visible
1	Scarce	Mistletoe are present but not readily visible
2	Common	Mistletoe are clearly visible
3	Abundant	Mistletoe dominates the appearance of the tree

13. Repeat the assessments (Steps 3-12) for each of the 30 individual trees at the assessment site.
14. Conduct a rapid assessment of disturbance at the site noting the presence and extent of natural and/or man-made disturbances within the site (e.g. fire, logging, flooding, grazing, etc.) on the datasheet.
15. Record levels of insect damage as observed over the whole site. Observers may require binoculars to conduct the assessment. Level of Insect damage is categorised as per Table A4.10.

Table A4.10: Insect damage categories for site assessment.

Category	Description
Absent	Not visible or minor damage to some trees
Scarce	Some trees have scattered damage within the crown
Common	Most trees have significant damage within the crown
Abundant	All trees have significant damage within the crown

16. Record levels of other biological stresses as observed over the whole site. Observers may require binoculars to conduct the assessment. Extent of biological stress is categorised as per Table A4.11.

Table A4.11: Biological stress categories for site assessment.

Category	Description
Absent	Not visible or minor presence within the site
Scarce	Scattered occurrence throughout the site
Common	Present throughout the majority of the site
Abundant	Present throughout the entire site

17. Conduct a rapid assessment of the presence of seedlings and saplings by observing the number of saplings present within the site. Record the presence

of seedlings and saplings category as per Table A4.12 and provide comment on the appearance of the recruits (i.e. healthy, stressed, dead).

Table A4.13: Category scale for reporting presence of seedlings and saplings.

Description	Definition
Absent	No saplings found
Scarce	Less than 10 sapling present
Common	10-50 saplings present
Abundant	Greater than 50 saplings present

Appendix 5: Protocol for Collecting Photographs for Photo Point Monitoring

Photo points of vegetation sites should be taken to document change through time. The TLM Communications Unit may also use such photographs in brochures, reports, websites, etc.

Equipment:

- GPS and spare batteries
- Maps of Icon Site including site location information
- Digital camera and spare batteries
- Tripod
- Datasheets and/or field computer
- Small (30 x 30 cm) Whiteboard
- Whiteboard Marker

Essential Instructions:

- Photographs should be taken at a minimum resolution of 300 dpi.
- Photo points should be selected so that they provide representative coverage of each site.
- The camera should be positioned on the same point, pointing along the same bearing, at the same height and set to the same zoom level on each occasion.
- Photographs must be taken with the lens pointing parallel to the horizontal plane.
- Photo points should be clearly marked to ensure photographs are consistent.
- Ideally photographs would be taken on the same day that vegetation sampling is conducted and at a similar time of day to complement vegetation data and to maximise comparability of images.

Protocol:

1. Locate the established assessment site using the location information provided.
2. Locate the marked camera position.
3. Set up and level the tripod and camera. The photographer should be positioned at the base of the photo point peg and, where possible (due to elevation and aspect), the viewfinder should be centred on the sighter peg. Setup the camera so that it is at the same height and set to the same zoom level as previous occasions.
4. The white board with the site name, site number, and date (dd/mm/yyyy) should be placed at the base of the “sighter” peg.
5. Capture the photograph. When taking photographs, care should be taken to prevent direct sunlight creating glare on the lens by shading the lens with a hat or folder. All photographs should be taken with a high resolution (> 5 MP) digital camera with image quality set to ‘HQ', focus set to ‘auto’, zoom set to ‘off/zero’, and flash set to ‘off’.
6. Record the required information including the filename/number on the data collection sheet. Additional metadata should be recorded as required to document special or unusual conditions.
7. Move to the next camera position and repeat.

Appendix 6: Data protocols, analysis and calculations

Appendix 6.1 Data protocols for field datasheets and photographs

1. Datasheets and notes should be copied as soon as possible after leaving the field site.
2. All photographs and electronic data are to be downloaded to back up media the same day.
3. Transfer data from the datasheet to electronic database/spreadsheet as soon as possible.
4. Survey data is to be safely filed and backed up.

Appendix 6.2 Calculating Diameter at Breast Height from circumference measure

If a diameter tape is not available, measure the circumference of the stem using a standard measuring tape and convert circumference at Breast Height to DBH using the following equation:

$$\text{DBH (cm)} = \text{Circumference (cm)} / \pi \qquad \text{NB: } \pi \text{ (pi)} = 3.14159$$

Appendix 6.3 Calculating Live Basal Area

Calculation of Live Basal Area (LBA %) as follows:

1. Calculate the Basal Area (BA) of each stem using the following formula:
   $$\text{Basal Area (cm}^2\text{)} = \pi \times [\text{dbh (cm)}/2]^2$$
2. Calculate total Live Basal Area for the site by calculating the sum of the BA for all "live" trees
3. Calculate total Dead Basal Area for the site by calculating the sum of the BA for all "dead" trees
4. Calculate LBA for the site using the following formula:
   $$\text{LBA (\%)} = [\text{total live BA} / (\text{total live BA} + \text{total dead BA})] \times 100$$

Appendix 6.4 Image analysis of hemispherical photographs

Plant Area Index is calculated from digital hemispherical photographs using the program Winphot 5.00 (ter Steege, 1996). This program is freeware and can be downloaded from: http://www.bio.uu.nl/~herba/Guyana/winphot/wp_index.htm

1. Winphot 5.00 requires that images are bitmaps (.bmp), 256 colour (8 bit) and no greater than a 1000 pixels in length. Using Microsoft Photo Editor (or an equivalent photographic program), crop the black areas either side of the circular image and convert the camera image to the required format.
2. Open the Converted images in Winphot 5.00.
3. Set the Threshold (Edit>Threshold b/w) so that all areas of sky are white, but the majority of the vegetation is black.
4. Define the extent of the hemispherical photograph using the 'align image' tool (arrow pointing at circle symbol) by clicking at the top edge of the circle and dragging down.
5. Calculate the PAI of an aligned image by clicking on the 'LAI' tool (leaf symbol). Further information can be found in the Help menu of the program.

Appendix 7: Location data for the TLM Stand Condition Model monitoring locations

Location data is given in the Universal Transverse Mercator projection and WGS84 coordinate system. The reference sites have been named (site number – location, forest type) for the Stand Condition survey and the original names of existing sites and those used in previous selection maps are given for reference.

Appendix 7.1: Chowilla Floodplain Monitoring Locations

Reference Site	Original name	Forest Type	ZONE	EASTING	NORTHING
S1-CRF	WWW0301	RF	54H	487784	6244950
S2-CRF	CRF02	RF	54H	499170	6234541
S3-CRW	MIH0501	RW	54H	488956	6241565
S4-CRW	PUN401	RW	54H	494329	6244654
S5-CRW	KKA0301	RW	54H	504177	6234325
S6-CRB	CWH0401	RB	54H	485452	6239986
S7-CRB	CMN03	RB	54H	488178	6245405
S8-CRB	CMN02	RB	54H	488755	6238154
S9-CRB	CRB01	RB	54H	490339	6249414
S10-CRB	PIH0501	RB	54H	498200	6242513
S11-CBB	CCX0601	BB	54H	485496	6238955
S12-CBB	CCX0101	BB	54H	486246	6241977
S13-CBB	BNU09	BB	54H	487470	6240889
S14-CBB	BNH02	BB	54H	490235	6244133
S15-CBB	BN126	BB	54H	492210	6241113
S16-CBB	BN68	BB	54H	493069	6245426
S17-CBB	BNU01	BB	54H	494094	6249814
S18-CBB	BND03	BB	54H	495592	6249398
S19-CBB	BNH04	BB	54H	498429	6237137
S20-CBB	GFL0101	BB	54H	498585	6245919
S21-CBB	BNU08	BB	54H	499514	6243090
S22-CBB	BNU06	BB	54H	500709	6233372
S23-CBB	BNU05	BB	54H	503362	6241120
S24-CBB	KKB0701	BB	54H	503632	6234145
S25-CBB	BNU07	BB	54H	503732	6238163

Forest types: RF = river red gum forest, RW = river red gum woodland, RB = river red gum – black box woodland and BB = black box woodland

Appendix 7.2: Lindsay, Mulcra and Wallpolla Islands Monitoring Locations

Reference Site	Original name	Forest Type	ZONE	EASTING	NORTHING
S26-LRW	R8	RW	54H	506021	6231864
S27-LRW	R5	RW	54H	512950	6228137
S28-LRW	R9	RW	54H	515099	6227469
S29-LRW	R6	RW	54H	520967	6226291
S30-LRW	RN46	RW	54H	532789	6224753
S31-LRW	R12	RW	54H	536736	6222989
S32-LRW	R22	RW	54H	567212	6226744
S33-LRW	R20	RW	54H	573028	6224597
S34-LRW	R24	RW	54H	578495	6222422
S35-LRB	R2	RB	54H	512593	6224169
S36-LRB	RN07	RB	54H	522511	6223670
S37-LRB	R19	RB	54H	571310	6225789
S38-LBB	B1	BB	54H	505823	6229108
S39-LBB	B2	BB	54H	509859	6227284
S40-LBB	B7	BB	54H	512534	6227317
S41-LBB	B3	BB	54H	515437	6226203
S42-LBB	B8	BB	54H	521570	6228153
S43-LBB	B4	BB	54H	525375	6226621
S44-LBB	B15	BB	54H	539782	6220808
S45-LBB	BN110	BB	54H	559412	6224066
S46-LBB	BN52	BB	54H	563271	6224440
S47-LBB	BN87	BB	54H	576722	6218665
S48-LBB	BN106	BB	54H	577036	6222818
S49-LBB	BN53	BB	54H	577354	6220328
S50-LBB	BN127	BB	54H	580904	6220526

Forest types: RW = river red gum woodland, RB = river red gum – black box woodland and BB = black box woodland

Appendix 7.3: Hattah-Kulkyne National Park Monitoring Locations

Reference Site	Original name	Forest Type	ZONE	EASTING	NORTHING
S51-HRF	R21	RF	54H	629771	6173139
S52-HRF	R25	RF	54H	634045	6166199
S53-HRF	R26	RF	54H	638306	6158653
S54-HRW	R12	RW	54H	623995	6156564
S55-HRW	R17	RW	54H	625803	6164583
S56-HRW	R11	RW	54H	627642	6161084
S57-HRW	R16	RW	54H	630084	6168375
S58-HRW	R9	RW	54H	631464	6171460
S59-HRW	R10	RW	54H	634807	6156947
S60-HRB	R5	RB	54H	624509	6155892
S61-HRB	R7	RB	54H	627113	6162766
S62-HRB	R3	RB	54H	631340	6160558
S63-HRB	B14	RB	54H	633976	6156727
S64-HRB	B13	RB	54H	634402	6165413
S65-HBB	B4	BB	54H	624227	6152537
S66-HBB	B8	BB	54H	625615	6172485
S67-HBB	B5	BB	54H	625720	6160123
S68-HBB	B6	BB	54H	626470	6165382
S69-HBB	B9	BB	54H	631711	6172848
S70-HBB	B3	BB	54H	631814	6158038
S71-HBB	B7	BB	54H	632228	6167689
S72-HBB	B12	BB	54H	633684	6165894
S73-HBB	B1	BB	54H	636809	6153606
S74-HBB	B2	BB	54H	637145	6158776
S75-HBB	B11	BB	54H	639294	6151873

Forest types: RF = river red gum forest, RW = river red gum woodland, RB = river red gum – black box woodland, BB = black box woodland and BX = box woodland

Appendix 7.4: Koondrook-Perricoota Forest Monitoring Locations

Reference Site	Original name	Forest Type	ZONE	EASTING	NORTHING
S76-KRF	PAD155	RF	55H	246885	6050522
S77-KRF	PAD152	RF	55H	249544	6052571
S78-KRF	PAD150	RF	55H	250276	6055903
S79-KRF	PAD149	RF	55H	250418	6045925
S80-KRF	PAD154	RF	55H	250887	6050323
S81-KRF	N55	RF	55H	251768	6054679
S82-KRF	PAD156	RF	55H	254762	6047239
S83-KRF	PAD157	RF	55H	257039	6043446
S84-KRF	PAD171	RF	55H	259147	6041921
S85-KRF	PAD164	RF	55H	259286	6044697
S86-KRF	PAD170	RF	55H	262290	6040989
S87-KRF	PAD138	RF	55H	263457	6042351
S88-KRF	PAD133	RF	55H	263446	6039129
S89-KRF	PAD130	RF	55H	263532	6034210
S90-KRF	N126	RF	55H	265173	6028576
S91-KRF	N122	RF	55H	265970	6035401
S92-KRF	PAD166	RF	55H	269886	6024602
S93-KRW	N62	RW	55H	246109	6058177
S94-KRW	PAD158	RW	55H	251849	6042992
S95-KRW	PAD163	RW	55H	254163	6049157
S96-KRW	PAD165	RW	55H	265922	6031045
S97-KRW	N126	RW	55H	268763	6043283
S98-KBX	N50	BX	55H	264524	6043628
S99-KBX	N125	BX	55H	266670	6026075
S100-KBX	N92	BX	55H	271956	6020966

Forest types: RF = river red gum forest, RW = river red gum woodland and BX = box woodland

Appendix 7.5: Gunbower Forest Monitoring Locations

Reference Site	Original name	Forest Type	ZONE	EASTING	NORTHING
S101-GRF	1A	RF	55H	242126	6051056
S102-GRF	7A	RF	55H	245020	6048009
S103-GRF	10A	RF	55H	245334	6045423
S104-GRF	N62	RF	55H	247954	6043568
S105-GRF	110A	RF	55H	251145	6037886
S106-GRF	34A	RF	55H	253893	6039390
S107-GRF	41A	RF	55H	255634	6036987
S108-GRF	101A	RF	55H	256356	6035694
S109-GRF	62A	RF	55H	257582	6034692
S110-GRF	52A	RF	55H	258797	6035944
S111-GRF	98A	RF	55H	259379	6032278
S112-GRF	N40	RF	55H	261140	6030106
S113-GRF	78A	RF	55H	261222	6031540
S114-GRF	N61	RF	55H	261226	6034115
S115-GRF	N75	RF	55H	264809	6028344
S116-GRF	100A	RF	55H	265166	6024060
S117-GRW	RL1B	RW	55H	247373	6042663
S118-GRW	18A	RW	55H	251746	6041444
S119-GRW	37A	RW	55H	257432	6038891
S120-GRW	132A	RW	55H	267152	6024029
S121-GBB	29A	BB	55H	247556	6039923
S122-GBB	47A	BB	55H	250883	6036134
S123-GBB	N38	BB	55H	259632	6031082
S124-GBB	95A	BB	55H	266305	6021587
S125-GBB	N119	BB	55H	268782	6020279

Forest types: RF = river red gum forest, RW = river red gum woodland and BB = black box woodland

Appendix 7.6: Millewa Forest Monitoring Locations

Reference Site	Original name	Forest Type	ZONE	EASTING	NORTHING
S126-MRF	N50	RF	55H	310154	6015948
S127-MRF	PAD122	RF	55H	312167	6018317
S128-MRF	N57	RF	55H	312640	6013324
S129-MRF	N63	RF	55H	312889	6045707
S130-MRF	N78	RF	55H	313180	6050436
S131-MRF	PAD126	RF	55H	313383	6039405
S132-MRF	PAD129	RF	55H	313677	6046958
S133-MRF	N118	RF	55H	314191	6028679
S134-MRF	N75	RF	55H	315535	6038292
S135-MRF	N89	RF	55H	316233	6025167
S136-MRF	PAD102	RF	55H	319190	6039120
S137-MRF	PAD106	RF	55H	323050	6032627
S138-MRF	PAD107	RF	55H	325479	6033384
S139-MRF	N83	RF	55H	326114	6039246
S140-MRF	PAD109	RF	55H	326834	6034958
S141-MRF	N90	RF	55H	333740	6036884
S142-MRF	N97	RF	55H	334476	6033671
S143-MRF	PAD112	RF	55H	336948	6037392
S144-MRF	PAD114	RF	55H	342429	6033644
S145-MRF	PAD117	RF	55H	347228	6030897
S146-MRW	PAD128	RW	55H	311075	6044649
S147-MRW	PAD101	RW	55H	316992	6037068
S148-MRW	N95	RW	55H	341247	6034708
S149-MBX	N76	BX	55H	316189	6049656
S150-MBX	N127	BX	55H	321353	6037779

Forest types: RF = river red gum forest, RW = river red gum woodland and BX = Box woodland

Appendix 7.7: Barmah Forest Monitoring Locations

Reference Site	Original name	Forest Type	ZONE	EASTING	NORTHING
S151-BRF	BFN93	RF	55H	313961	6014351
S152-BRF	BFN96	RF	55H	315217	6016080
S153-BRF	BFU15	RF	55H	315990	6023888
S154-BRF	BN127	RF	55H	317062	6019802
S155-BRF	BN116	RF	55H	317139	6029481
S156-BRF	BFN91	RF	55H	318703	6015852
S157-BRF	BFU20	RF	55H	319148	6020985
S158-BRF	BFU30	RF	55H	319423	6025787
S159-BRF	BFU28	RF	55H	324026	6024253
S160-BRF	BFN75	RF	55H	324310	6021838
S161-BRF	BFN85	RF	55H	324286	6030134
S162-BRF	BN131	RF	55H	326037	6032794
S163-BRF	BN123	RF	55H	328470	6028629
S164-BRF	BFN92	RF	55H	328495	6024526
S165-BRF	BFU31	RF	55H	331976	6026681
S166-BRF	BFU26	RF	55H	333254	6029998
S167-BRF	BFU24	RF	55H	335901	6028201
S168-BRF	BFU22	RF	55H	339249	6030203
S169-BRF	BFN84	RF	55H	341583	6032490
S170-BRF	BN130	RF	55H	351031	6029822
S171-BRW	BWN88	RW	55H	319582	6023685
S172-BRW	BWU14	RW	55H	320135	6029804
S173-BRW	BWN86	RW	55H	329976	6033395
S174-BRW	BWU02	RW	55H	346495	6030000
S175-BRW	BN114	RW	55H	358872	6032575

Forest types: RF = river red gum forest and RW = river red gum woodland

Appendix 8: Stand Condition Assessment Data collection sheet

Site ID:		*Dimensions:*		*Date:*	
Observer 1:			*Observer 2:*		
Disturbance(s):					
Notes:					

Key:
Tree Species: RRG = river red gum; BB = black box; GB = grey box; C = ooba
Live/Dead Assessment: L = Live; D = Dead
Crown extent:

Score	*Category Description*	*Percentage of Assessable Crown*
0	*None*	*0 %*
1	*Minimal*	*1-10 %*
2	*Sparse*	*11-20 %*
3	*Sparse - Medium*	*21-40 %*
4	*Medium*	*41-60 %*
5	*Medium - Major*	*61-80 %*
6	*Major*	*81-90 %*
7	*Maximum*	*91-100 %*

*Note: Trees outside the 0.25 ha when less than 30 trees occur within the site are marked with an * next to the tree number.*

Tree No. (inc. prefix)	*Tree Species*	*DBH*	*Live / Dead*	*Marked tree? (Y/N)*	*Crown extent category*	*Crown extent value %*

Tree No. (inc. prefix)	*Tree Species*	*DBH*	*Live / Dead*	*Marked tree? (Y/N)*	*Crown extent category*	*Crown extent value %*

Appendix 9: Hemispherical photograph record sheet

Site ID	*Date*	*Time*	*Photograph 1 Filename*	*Photograph 2 Filename*	*Photographer*

Appendix: 10: Tree Condition Assessment Data Collection Sheet

Site ID:		*Date:*	
Observer 1:		*Observer 2:*	

	Type	*Category*
Disturbance (1)		
Disturbance (2)		
Disturbance (3)		
Insect damage		
Other biological stresses (1)		
Other biological stresses (2)		
Presence of Seedlings/Saplings		
Additional Observations/ Comments:		

Photo Point Monitoring:
Filename: *Bearing:* *Time:* *Photographer:*

Quick reference to Condition Indicators

Crown extent & Crown density						
Score	Description	% Assessable Crown		Score	Description	% Assessable Crown
0	None	0%		4	Medium	41-60%
1	Minimal	1-10%		5	Medium-Major	61-80%
2	Sparse	11-20%		6	Major	81-90%
3	Sparse-Medium	21-40%		7	Maximum	91-100%

Condition Indicators (new tip growth, epicormic growth, leaf die off, mistletoe load, extent of reproduction)		
Score	Description	Definition
0	Absent	Response not visible
1	Scarce	Response present but not readily visible
2	Common	Response is clearly visible
3	Abundant	Response dominates appearance of tree

Condition Indicators (Extent of bark cracking)		
Score	Description	Definition
0	Intact Bark	Intact bark
1	Minor cracking	Cracks limited in number and bark still held in place
2	Extensive cracking	Numerous and/or deep cracks which are lifting the bark off the sapwood
3	No bark	Long term dead trees having no bark

Prefix	*Tree No.*	*DBH (separate multiple stems with a comma)*	*Crown Extent Category*	*Crown Extent Value %*	*Crown Density Category*	*Crown Density % value*	*New Tip Growth*	*Epicormic Growth*	*Bark Condition*	*Leaf Die Off*	*Mistletoe Load*	*Extent of Reprod.*	*Dominance Class*
	1												
	2												
	3												
	4												
	5												
	6												
	7												
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