Eyre Peninsula Groundwater Dependent Ecosystem Data Analysis: Red Gum tree condition data (five sites)

A report for Natural Resources Eyre Peninsula, Department of Environment and Water, Port Lincoln, South Australia.

Prepared by: Kerri Muller NRM Pty. Ltd.

Authors: Dr. Kerri Muller and Dr. Nick Souter with Water Technology Pty. Ltd.

Revision 1

Date: 28 July 2020

Reference: 7219/CE394

Document Management

Version	Date Released	Author	Released by	Released to
Data analysis progress report	18 Feb 2019	K.L. Muller & N.J. Souter	K.L. Muller	A. Freeman
Updated data analysis	19 May 2019	K.L. Muller, N.J. Souter & S. Evans	K.L. Muller	A. Freeman
Draft for discussion	17 June 2019	K.L. Muller, N.J. Souter & A. Charles	K.L. Muller	A. Freeman
Final	20 June 2019	K.L. Muller, N.J. Souter & A. Charles	K.L. Muller	A. Freeman
Revision 1 – Updated RCI results	28 July 2020	K.L. Muller, N.J. Souter & A. Charles	K.L. Muller	M. Clanahan

Acknowledgements:

The authors wish to thank the staff of Natural Resources Eyre Peninsula, especially Andrew Freeman and Ben Smith, who collected the field data, provided valuable insights, reviewed our initial data analysis and assisted with report finalisation.

To contact the authors:

Dr. Kerri Muller
Kerri Muller NRM Pty. Ltd.
PO Box 203 Victor Harbor SA 5211

E: km@kmnrm.com.au

Citation:

Muller K.L., N.J. Souter and Australian Water Technology (2020). *Eyre Peninsula Groundwater Dependent Ecosystem Data Analysis: Red Gum tree condition data (five sites). Revision 1.* A report for Natural Resources Eyre Peninsula, Department of Environment and Water, Port Lincoln, South Australia.

Executive Summary

Many Red Gums on the southern Eyre Peninsula rely on groundwater for some or all of their water needs. This makes them Groundwater-Dependent Ecosystems (GDEs) that need to be considered under the Southern Basins and Musgrave Prescribed Wells Areas Water Allocation Plan (the WAP). Principles and policies for water-sharing aim to maintain these Red Gums at a low level of risk with regard to possible impacts of groundwater extraction.

Adaptative management of our groundwater resources relies on regular and strategic monitoring. The Eyre Peninsula Natural Resources Management Board have previously invested in extensive investigations into regional groundwater dynamics, but this is the first time that the WAP has required the monitoring of GDEs due to community feedback as part of the WAP consultation process.

Red Gum condition was assessed at five monitoring sites. Two of these five sites are near current licensed groundwater extractions (Bramfield and Uley/Wanilla), one site is located where licensed extraction occurred until 2015 but has since ceased (Polda) and two sites are 'control sites', being outside of the expected zone of influence of any current or known historic licensed extraction (Bellevue and Coulta).

Changes in the average Redgum Condition Index (RCI) were detected at most sites with significant declines at Bellevue (7% change), Bramfield (5%) and Polda (10%), significant increases at Coulta (5%) and no change at Wanilla between 2016 and 2018. All Red Gum stands were, however, in *Good* to *Moderate* condition in both years. There were only seventeen trees (3%) in the highest health category, *Very good*.

Analysis of long-term rainfall across all the sites showed that cumulative winter rainfall has steadily declined since 1990, whilst cumulative summer rainfall has increased over this time. The sites in the Southern Basins PWA (Wanilla and Coulta) have been significantly wetter in both winter and summer than those in Musgrave PWA (Bellevue, Bramfield and Polda). Groundwater levels varied across the sites, with evidence of long-term declines at Bellevue, Polda and Wanilla, but in all cases groundwater was shallow enough to be within the assumed zone that the Red Gums deep roots could access for the full length of record (1963 to 2019).

Eyre Peninsula Red Gums were found to have lower minimum and maximum health scores than comparative trees on the River Murray in South Australia. This may reflect an adaptive strategy by 'healthy' trees to grow fewer leaves and thus have lower water demands in the relatively drier conditions or that they are on the drier edge of the species' distribution and thus are unable to attain canopies that are as extensive or dense as trees on the River Murray. Long-term climate factors may also be adversely affecting their health and their condition is lower than it would have been historically.

There were no consistent differences in Redgum Condition Index scores in 2016 and 2018 between sites with or without nearby groundwater extraction, which suggests that climate is a major driver of Red Gum health. These data suggest that the trees are likely to be vulnerable to climate change and that current licensed groundwater extraction, at the rates permitted by the WAP, is not a source of significant risk to the Red Gums condition compared to that predicted for climate change over coming decades.

1. Introduction

Red Gum woodlands (*Eucalyptus camaldulensis*) in the area covered by the Southern Basins and Musgrave Prescribed Wells Areas Water Allocation Plan (the WAP) are considered to be *phreatophytes*, plants that depend on groundwater for some or all of their water needs to be healthy. There are some exceptions, such as the Red Gums growing around Big and Little Swamps, that are dependent on surface water catchments. This means that the WAP needs to consider the environmental water requirements of the groundwater-dependent Red Gums through its water-sharing policies and principles (EP NRMB 2016).

Red Gums need more water than just that provided by the typical annual rainfall on Eyre Peninsula. These trees are deep-rooted, which enables them to supplement the water they get from rainfall by growing in areas where the groundwater level is shallow enough to allow capillary rise to reliably bring it into the unsaturated soil zone where the roots are (Figure 1). The health of these Red Gums is, therefore, likely to be linked to groundwater availability and responsive to changes in groundwater quantity or quality, that are in turn, linked to climate variables such as wet periods that lead to raising of groundwater levels or dry periods that lead to lowering of groundwater levels (Doeg et al. 2012; Stewart et al. 2012).

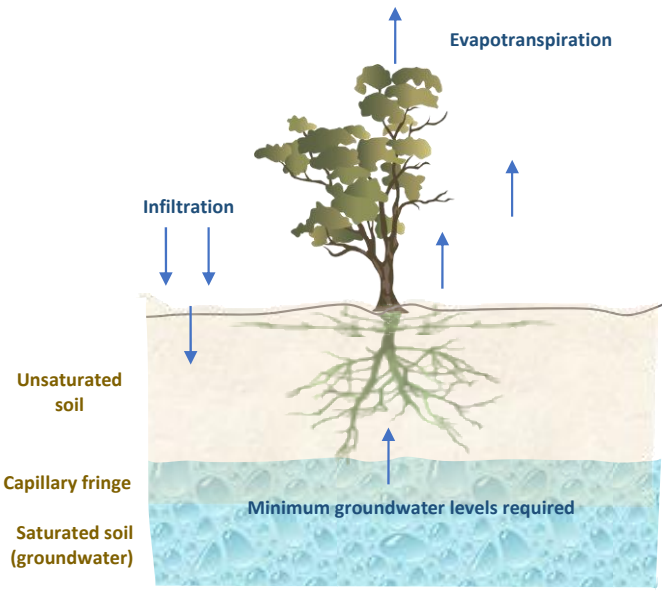


Figure 1: A conceptual model of the groundwater dependence of deep-rooted Red Gums on Eyre Peninsula.

Adaptive management of the taking and use of groundwater, as outlined in the WAP, depends on regular and strategic monitoring. Groundwater dynamics on Eyre Peninsula have been extensively studied and are thought to be strongly affected by recharge from recent rainfall (Stewart et al. 2012). Limits for extraction in the WAP have been set at levels that will maintain groundwater-dependent ecosystems (GDEs), such as Red Gums, at a low level of risk. It is acknowledged, however, that GDE health may be more strongly linked to climatic variables than the impacts of the limited groundwater extraction permitted under the WAP and that adverse climate impacts (e.g. high temperatures, lower or more variable recharge rates) are likely to increase over coming decades due to climate change.

Rainfall and groundwater monitoring in the PWAs has been undertaken for decades but this is the first time the WAP has required targeted GDE monitoring. Natural Resources Eyre Peninsula (NREP) staff collected Red Gum tree condition data at five WAP monitoring sites in 2016 and 2018 following the methods developed by Souter (2018) and groundwater at these same sites in 2018 and 2019. Two new observation wells were installed at Coulta in May 2018 for this project and thus groundwater data is only available since 2018 for this site. It should also be noted that other new wells were installed at this same time being two wells at Bellevue, one well at Bramfield and one at Wanilla. Additional long-term groundwater data for the period 1963 to 2019 for the other four sites was sourced from DEW.

Two of these five sites are near current groundwater licensed extractions (Bramfield and Uley/Wanilla), one site is located where licensed extraction occurred until 2015 but has since ceased (Polda) and two sites are 'control sites', being outside of the expected zone of influence of any current or known historic licensed extraction (Bellevue and Coulta). It must be noted that at all sites there is extraction of water for stock and domestic purposes without a water licence, which is assumed to be low compared to extraction for licensed consumptive purposes.

NREP engaged Kerri Muller NRM Pty. Ltd. to analyse and evaluate the Red Gum tree condition against relevant rainfall and groundwater data to set a baseline for tree condition that can be used to evaluate WAP policies and inform the ten-year review of the WAP in 2027. In this report, tree condition data has been assessed to place each tree and each site into health categories specific to Eyre Peninsula Red Gums, against which future trends can be evaluated. Rainfall and groundwater data were analysed and graphed to show long-term rainfall patterns at or near the five sites and to establish groundwater baseline levels. Differences in tree condition between sites is discussed with regard to the rainfall and groundwater data. Results from these data analyses will be used on the Red Gum report cards periodically published by NREP in accord with the Monitoring, Evaluation, reporting and Improvement (MERI) Plan developed for the WAP (EP NRMB 2016).

2. Methods

Redgum Condition was assessed for 50 trees using the multi-variable Redgum Condition Index (RCI) developed by Souter (2018) at each of the following five Eyre Peninsula WAP MERI monitoring sites at two time periods, spring 2016 and spring 2018:

- Bellevue Roadside Reserve (Musgrave PWA Bramfield Lens – Control site)
- Red Gum GDE south of Bramfield (Musgrave PWA Bramfield Lens – Groundwater extraction site)
- Red Gum GDE at Polda Trench (Musgrave PWA Polda Lens – Historical Groundwater extraction site)
- Red Gum GDE just south of Coulta (Outside PWA's Control Site – No extraction)
- Red Gum GDE at Northern end of Uley/Wanilla (Southern Basin PWA Uley/Wanilla Lens – Groundwater extraction site)

All of the tree condition variables collected in the field were included in the data analysis except for leaf condition, which was excluded because it is not collected as a part of *The Living Murray* methods (Souter et al. 2010) and thus was not included in the RCI inputs. The tree condition data recorded bark condition as either intact or cracked and these qualitative descriptions were assigned the values of 0 and 1 respectively, to align with *The Living Murray* method.

For each site, mean ±95% confidence intervals were calculated for RCI in 2016 and 2018 to determine overall stand condition and determine if there had been any change in condition over

time. To examine the change in individual tree condition delta RCI was calculated, which is the difference in the condition of each tree between the two dates. These data were summarized for each site as mean delta RCI ±95% confidence intervals. A significant change was recorded as an RCI value of either greater or less than zero where the 95% confidence intervals also did not cross zero. The raw data set has been provided to NREP as a separate xls file for further analysis and the R Software program used to calculate the RCI along with an instructional vignette is available at https://www.researchgate.net/profile/Nicholas_Souter.

Groundwater hydrographs have been compiled using data from Water Connect and supplemented by more recent data provided by Natural Resources Eyre Peninsula (May 2018-May 2019). Hydrograph data is presented as depth to water table below natural surface for wells documented in the GDE Survey Site Establishment report (EP NRMB 2018). Hydrograph trends are presented in two ways: short-term trends (i.e. 2016-2018) are presented for ease of comparison to vegetation condition data and long-term historical monitoring data are also presented for historic context (Figures 5 and 6 below).

Monthly rainfall data was downloaded from the Bureau of Meteorology for the stations at Elliston (#18069) for Bramfield and Bellevue, Port Lincoln – Big Swamp (#18017) for Wanilla and Coulta and Mount Wedge (#18056) for Polda. This data used to calculate the long-term mean rainfall for summer (November to March) and winter (April to October) for each of the stations. Deviation and cumulative deviation from the mean seasonal rainfall was then calculated and is presented in Figure 4. Where data gaps existed in the monthly rainfall records, the long-term monthly mean was used. Data gaps only represent between 0.06% and 2.4% of the total data, across the three sites used for the rainfall analysis.

3. Results and Discussion

3.1: Changes in Red Gum condition index (RCI)

Over the two time periods (spring 2016 to spring 2018), mean Redgum Condition Index (RCI) declined significantly at Bellevue (7% change), Bramfield (5%) and Polda (10%). There was no significant change in RCI at Wanilla, whilst at Coulta there was a 5% increase in RCI (Figure 2). The delta RCI results mirrored the changes observed in mean RCI.

A decline in RCI was evident at Bellevue with a delta RCI of -0.07 (-0.10, -0.04). Similarly, Bramfield showed a negative change (-0.05 {-0.08, 0.02}), as did the trees at Polda (-0.10 {-0.14, -0.07}). There was no significant change at Wanilla (0.01 {-0.02, 0.03}) and an increase in delta RCI was observed at Coulta (+0.05 {0.03, 0.08}).

It must be noted that a large storm event in September 2016 caused leaf dieback on the western side of some Red Gum stands on Eyre Peninsula. It is thought this event had little impact on the 2016 monitoring results as only some of the trees monitored are found on the western side of the particular Red Gum stands.

3.2: Assessment of appropriateness of health categories

The RCI categories defined in Souter (2018) are: *Very Good* (RCI > 0.85), *Good* (RCI 0.65-0.84), *Moderate* (RCI 0.4-0.64), *Poor* (RCI 0.1-0.39), *Very poor* (RCI 0.01-0.09), *Extremely poor* (RCI 0).

These categories were based on Red Gum condition at Chowilla floodplain on the River Murray. If these categories were applied to the Eyre Peninsula data, the condition of the five sites would all be *Moderate* (RCI: 0.40 – 0.64).

The RCI scores across all five Eyre Peninsula sites and both dates ranged from a relatively low minimum value of 0.20 (Bellevue B40 in 2018) to a relatively low maximum of 0.76 (Polda P50 in

2016) compared to those at Chowilla (Souter 2018). For instance, no dead or defoliated trees were reported nor were there any *Very good* trees in the Eyre Peninsula data set based on Souter (2018) categories. This suggests that different, regionally-tailored tree health categories are warranted for Eyre Peninsula.

In defining condition classes for Chowilla, Souter (2018) examined the relationship between RCI and the six secondary variables taken as part of the field assessment. This has been repeated here for the Eyre Peninsula Red Gum condition data (Figure 3).

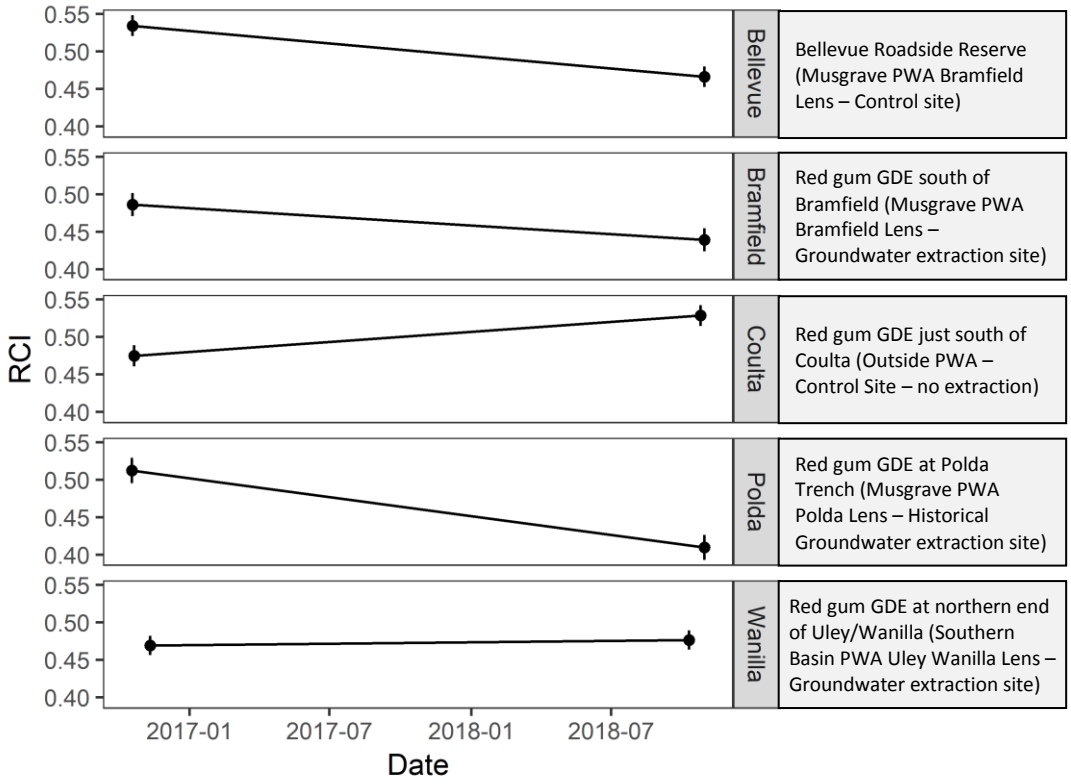


Figure 2: **Mean change in Red Gum condition index (delta RCI) at each of the five monitoring sites between 2016 and 2018** (± 95% confidence intervals are shown as error bars).

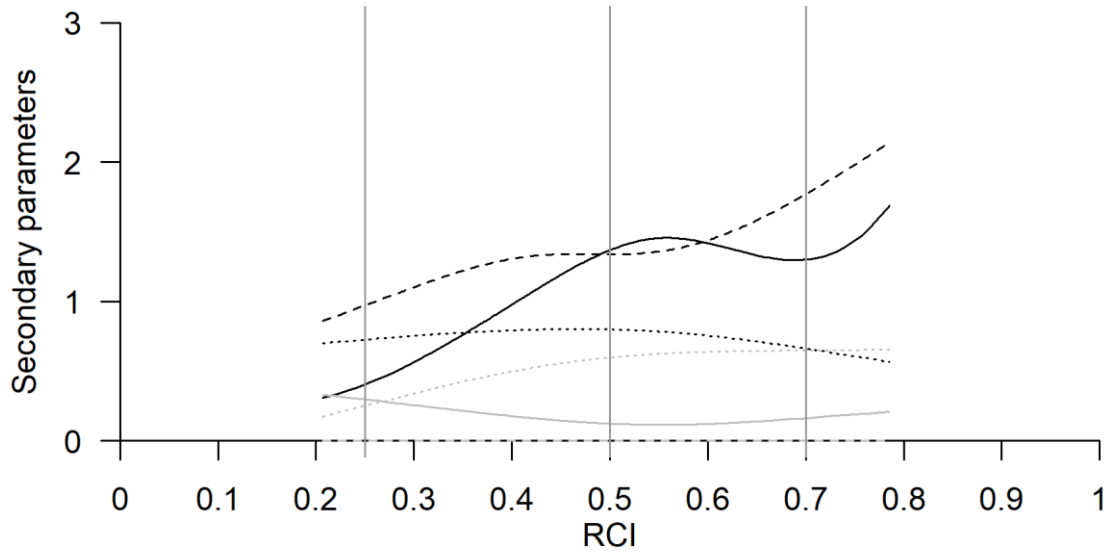


Figure 3: Relationship between RCI and secondary variables as cubic smoothing splines.
Secondary variable legend: new tip growth, black solid line; reproduction, black dashed line; epicormic growth, black dotted line; dieback, grey solid line; mistletoe, grey dashed line; bark condition, grey dotted line. Vertical grey lines demarcate proposed Eyre Peninsula categories (*Very Poor* to *Very Good*).

This analysis shows that there is a non-linear response in the secondary classes as RCI increases. New tip growth, for example, declined across the *Good* range (Figure 3, solid black line). The variation in the Eyre Peninsula secondary variables was also much less than that for Chowilla.

This further strengthens the argument that different health categories are warranted for phreatophytic Red Gums on Eyre Peninsula, particularly given that the purpose of undertaking this monitoring is to set a baseline against which trends in Red Gum health over time will be evaluated and thus the categories need to be set such that there is room for the health condition to go up or down over time.

It is, therefore, proposed that the following Red Gum tree condition categories are used for Eyre Peninsula Red Gum monitoring sites instead of those detailed in Souter (2018):

Very good (RCI >0.70)	Seventeen trees were classed as *Very good*, a score which corresponds with an increase in new tip growth and reproduction (see Attachment A).
Good (RCI 0.50 – 0.69)	Trees with an RCI of 0.50 to 0.69 saw a plateau in dieback and decline in epicormic growth, increase in reproduction; decline in new tip growth and improved bark condition at higher RCI values (n=187, 38%). This band seems to represent trees able to respond to water.
Moderate (RCI 0.25 – 0.49)	This category was more difficult to delineate, but represents the band between trees that seemed to be *Good* and those that seemed to be *Poor*. Approximately 58% of the 500 tree samples were in this category (n=291). All variables were relatively stable across this band except for New tip growth which increased.
Poor (RCI ≤ 0.24)	Trees in the data set with an RCI of ≤0.24 (n=4) generally had low crown densities (1 or 2).

Examples of trees in each of these categories are shown in Attachment A. The trees in these photos were chosen as examples of each category but are not necessarily 'representative'.

The high density of trees at many of the sites (presumably clustered around areas where groundwater is available) means that the tree canopies are often constrained by close neighbouring trees. This high density of trees may also reflect the characteristics of their germination and early establishment, possibly following heavy rainfall events that caused rainfall to pool on the soil surface prior to infiltration (Doeg et al. 2012).

Application of these new tree condition categories to the Eyre Peninsula monitoring data shows that all sites were in *Good to Moderate* condition

It should be noted that the condition score is based on the mean score for all 50 trees sampled at that site and does not consider the confidence limits or the range in tree condition at the site. All sites showed a similar spread of individual tree RCI scores from *Poor* to *Very Good* with Coulta having the smallest range and highest minimum value in 2018 (shown in Attachment B). The RCI value bands for each category are based on analysis of the data (as described above) but some categories were more difficult to see breaks between than others in the data or in the photos of the Red Gums (Figure 3, Attachments A and B).

Table 1: Mean Redgum Condition Index (RCI) scores for the five surveyed sites in 2016 and 2018 (range of values in brackets).

Site	2016		2018	
	RCI	Condition	RCI	Condition
Bellevue	0.53 (0.52 – 0.55)	Good	0.46 (0.07 –- 0.69)	Moderate
Bramfield	0.49 (0.0.47 – 0.50)	Moderate	0.44 (0.08 – 0.62)	Moderate
Coulta	0.48 (0.47 – 0.50)	Moderate	0.53 (0.3 – 0.7)	Good
Polda	0.51 (0.50 – 0.53)	Good	0.41 (0.14 – 0.69)	Moderate
Wanilla	0.47 (0.46 – 0.484)	Moderate	0.48 (0.2 – 0.68)	Moderate

Over time, the distinction between the *Good*, *Moderate* and *Poor* categories may become more obvious and confirm that these categories are appropriate (or not). If changes in tree condition are observed and these categories are found to not be sensitive enough or too sensitive, it may be necessary to alter the range and/or number of categories. There would also be merit in reviewing the category ranges if the distribution of RCI scores at the sites markedly increased or if a significant proportion of trees dropped to RCI scores below 0.3, especially if this was not detected in the trend analysis at the site scale.

There were only seventeen trees (3%) across all five sites that were in the *Very good* category. This could be indicative of a historic decline in trees over time, when more trees were in the *Very Good* category, although the dieback scores would be expected to be higher if this were the case. Alternatively, the *Very Good* category could represent a "theoretical maximum" that very few groundwater-dependent Red Gums on Eyre Peninsula will ever achieve without additional water (e.g. growing at an old well site or next to irrigated crops or roads).

3.3: Links between Red Gum health, rainfall and groundwater availability

Elliston rainfall records were used for both Bellevue and Bramfield Red Gum monitoring sites (nearest station with longest record) where RCI values significantly declined between spring 2016 and spring 2018.

Winter rainfall in 2017 and 2018 was below the long-term mean (351 mm) and cumulative winter rainfall steadily declined at this site since the early 1990s, although winter rainfall in 2016

(69.1 mm) was above the mean (Figure 4). Summer rainfall, conversely, was higher than the long-term mean (75.7 mm) in 2016 and 2017 and cumulative rainfall has been increasing at this site since 1990. Rainfall at Mount Wedge used for the Polda Red Gum monitoring site, where RCI also declined between 2016 and 2018, showed a similar pattern in cumulative rainfall and had similar long-term means for winter (316 mm) and summer (73 mm; Figure 4).

Groundwater data showed that in May 2018 groundwater was available at between 1.7 and 5.8 m below ground level at Bellevue, between 4.24 and 9.6 m at Bramfield and between 2.8 and 3.9 m at Polda (Figure 5). These depths are all within the soil profiles that it is assumed Red Gum roots will occupy and thus it is highly likely that groundwater was available to these trees to supplement rainfall if it was insufficient to meet their needs.

At Bellevue and Bramfield, only recent groundwater monitoring data was available for the wells within the GDE monitoring sites (from mid-2018). There was no significant change in groundwater over the 12 months since May 2018 at the GDE monitoring sites.

A longer groundwater monitoring record is available for wells located approximately 1.5km to 4.5km from the Bellevue GDE and indicates a declining trend (increased depth to water table) from 1989 to present. Two monitoring wells show some recovery between 2010 and 2017, before the downward trend continues in late 2017. This trend is consistent with annual rainfall patterns and lower winter rainfall (Figure 4).

At Bramfield, historical monitoring data is available for wells located approximately 1.5km to the north of the GDE site, where a number of stock and domestic bores are located. The monitoring record for the Bramfield wells is interrupted and variable, with most bores now dry. This does not necessarily indicate a declining trend in groundwater levels as the total depth of the bores is now significantly shallower than their original construction.

At Polda, additional monitoring data is available adjacent to the GDE site and also indicates a decline in groundwater levels between spring 2016 (2.68m) and spring 2018 (3.18m), however, the water table remains within a depth accessible to Red Gum trees. The longer monitoring record for bores located at a greater distance from the GDE site is similar to that observed at Bellevue, with a declining trend between 1989 and 2009, some recovery between 2009 and 2017, before declining again from late 2017. However, at Polda this does not appear to be as strongly correlated with annual rainfall data. The same pattern in groundwater levels was also evident at Wanilla although the magnitude of change was relatively less than at Polda.

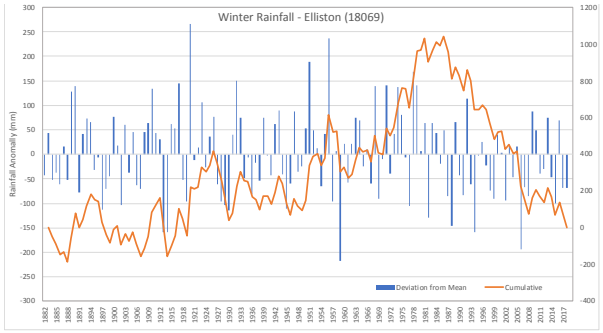
The decline in RCI values at Bellevue, Bramfield and Polda may be indicative of several interacting Red Gum responses rather than a linear response. For example, the relatively wet summer in 2016 may have led to a growth spurt that raised the RCI to a short-term peak that was not sustained over the hot summer of 2018 when leaves may have dropped due to high canopy temperatures.

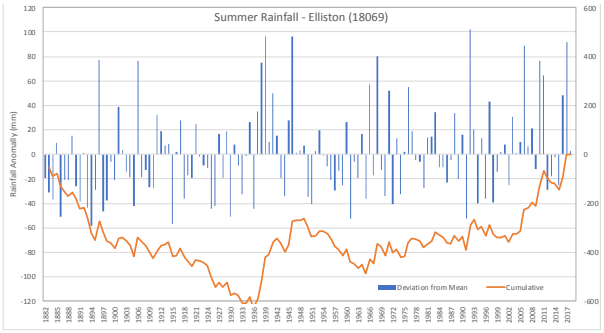
The overall rainfall patterns at the Port Lincoln (Big Swamp) BoM station used for the Coulta and Wanilla Red Gum monitoring sites were similar to those observed at Elliston and Mount Wedge, although the winter and summer means were 1.4 times higher (459 and 98 mm, respectively; Figure 4). This is consistent with the Southern Basin Prescribed Wells Area being generally 'wetter' than the Musgrave Prescribed Wells Area. Groundwater was also available within the assumed capillary rise zone at both sites, occurring at depths between 6.8 and 8.1 m at Coulta and between 6.1 and 12 m at Wanilla in May 2018 (Figure 5). Deeper wells at Bellevue and Wanilla showed that groundwater was also available at 16.7 and 24.2 m depth in 2018, respectively, which may also be accessible by deep Red Gum roots.

Redgum Condition Index at Wanilla did not change between 2016 and 2018, whilst Red Gums at Coulta, one of the wetter sites and not subject to extraction, were the only ones to show a significant increase in RCI between 2016 and 2018. This may be linked to short-term differences

in other climatic factors (e.g. lower canopy temperature) that enabled these trees to retain leaves across these two years and may or may not represent a longer-term trend. Red Gum condition for the stand of trees at Coulta was *Moderate,* as it was for the other sites, and RCI values for individual trees at Coulta varied across the same range in both years (Attachment B).

Overall, the tree condition scores were not consistently higher at either of these 'wetter' sites than at the 'drier' sites (Bellevue, Bramfield and Polda). Furthermore, there were no significant differences in RCI values or groundwater depths at the site scale or for individual trees at the control sites compared to the sites with current extraction nearby (Figures 2 and 5, Table 2 and Attachment B).

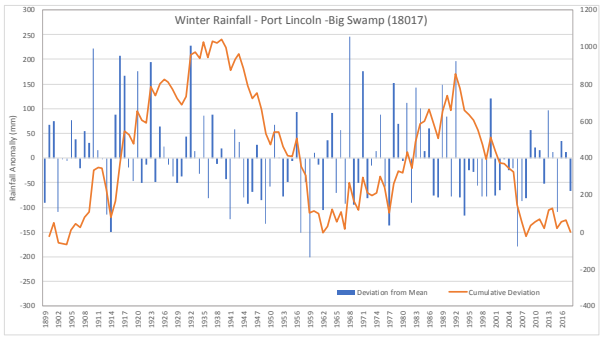


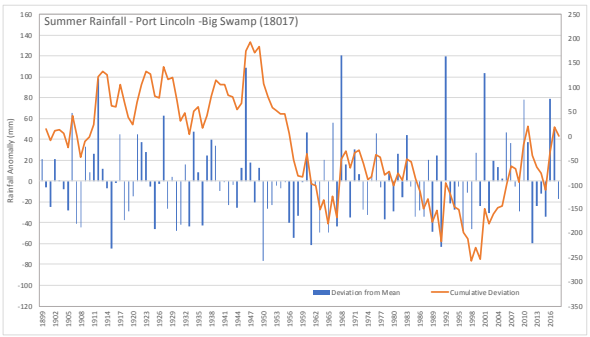


Bellevue & Bramfield

Elliston BoM station #18069 (1882 to 2018)
Winter Long-term Mean Rainfall 351 mm
(April to October)

Summer Long-term Mean Rainfall 75.7 mm
(November to March)

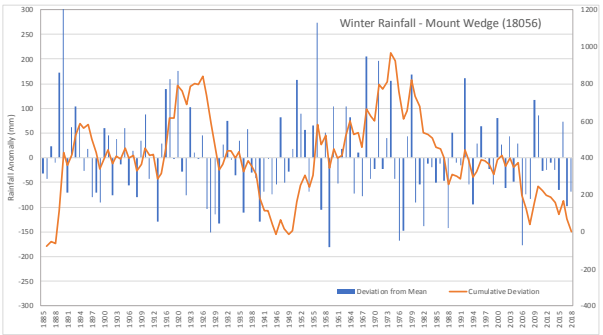


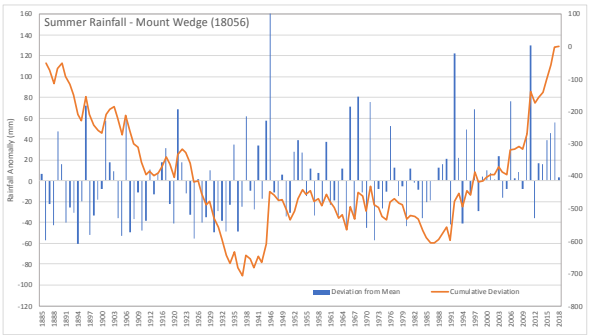


Coulta & Wanilla

Port Lincoln (Big Swamp) BoM station #18017 (1899 to 2018)
Winter Long-term Mean Rainfall 459 mm
(April to October)

Summer Long-term Mean Rainfall 98 mm
(November to March)



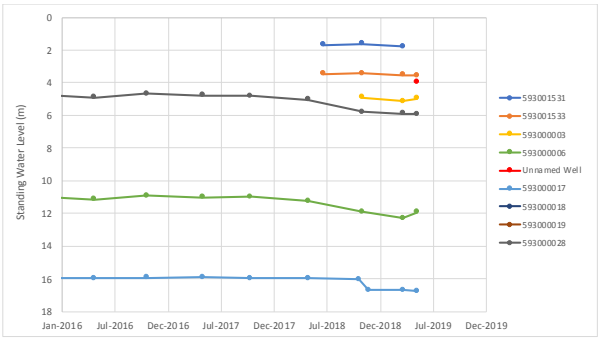


Polda

Mount Wedge BoM station #18056 (1885 to 2018)
Winter Long-term Mean Rainfall 316 mm
(April to October)

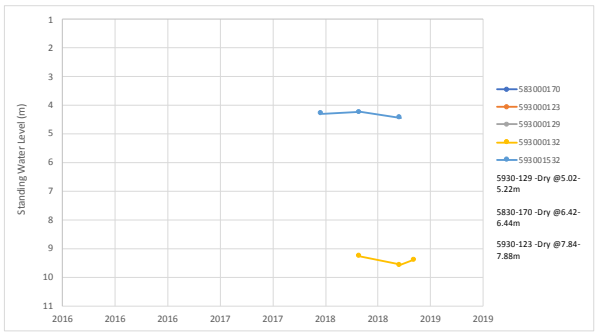
Summer Long-term Mean Rainfall 73 mm
(November to March)

Figure 4: **Rainfall for Elliston, Port Lincoln (Big Swamp) and Mount Wedge expressed as cumulative deviations from the long-term mean rainfall for winter (April to October) and summer (November to March).**



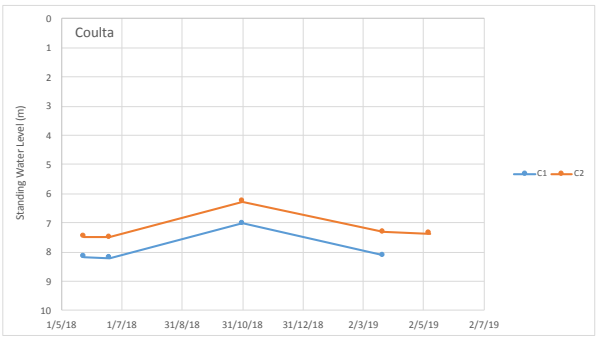
Bellevue Roadside Reserve (Musgrave PWA Bramfield Lens – Control site)

Bellevue



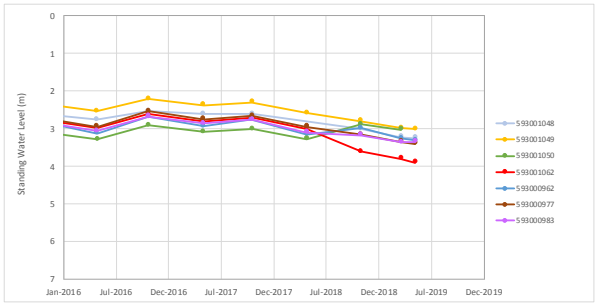
Red gum GDE south of Bramfield (Musgrave PWA Bramfield Lens – Groundwater extraction site)

Bramfield



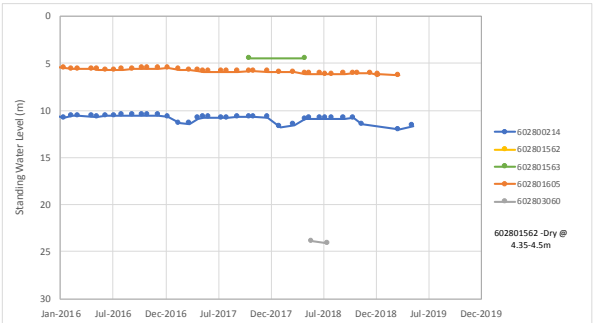
Red gum GDE just south of Coulta (Outside PWA Control Site – No extraction)

Coulta



Red gum GDE at Polda Trench (Musgrave PWA Polda Lens – Historical Groundwater extraction site)

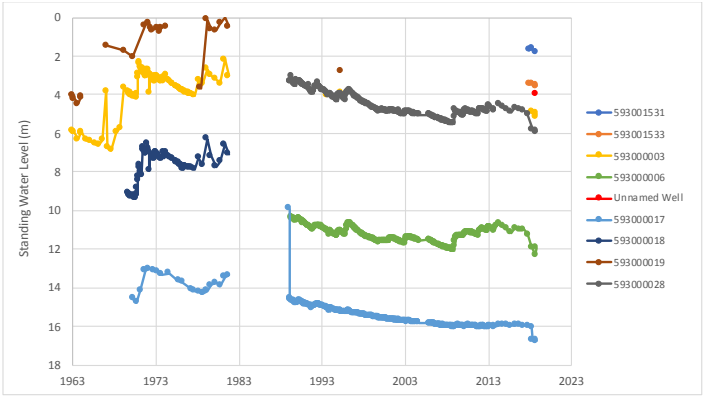
Polda



Red gum GDE at Northern end of Uley/Wanilla (Southern Basin PWA Uley/Wanilla Lens – Groundwater extraction site)

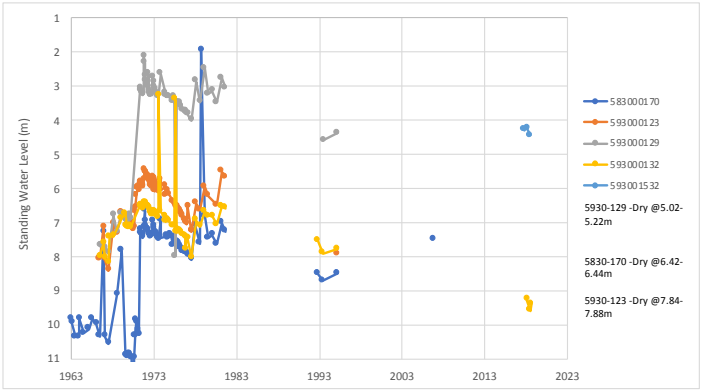
Wanilla

Figure 5: Current depth to groundwater for the five Red Gum monitoring sites (May 2018 to May 2019).



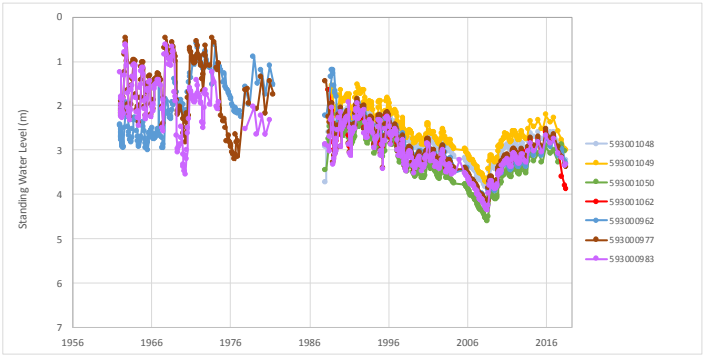
Bellevue Roadside Reserve (Musgrave PWA Bramfield Lens – Control site)
Full record: 1963-2019

Bellevue



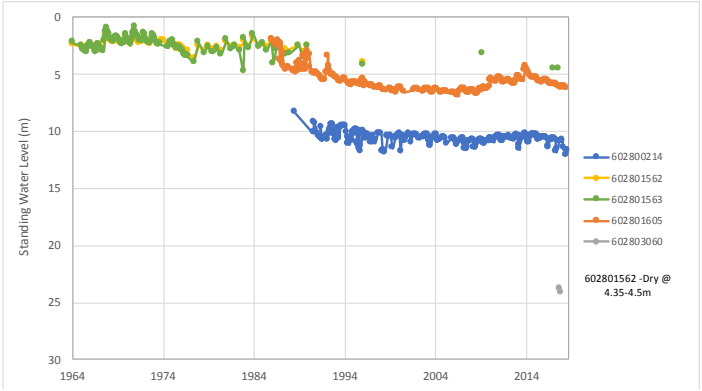
Red gum GDE south of Bramfield (Musgrave PWA Bramfield Lens – Groundwater extraction site)
Full record: 1963-2019

Bramfield



Red gum GDE at Polda Trench (Musgrave PWA Polda Lens – Historical Groundwater extraction site)
Full record: 1963-2019

Polda



Red gum GDE at Northern end of Uley/Wanilla (Southern Basin PWA Uley/Wanilla Lens – Groundwater extraction site)
Full record: 1963-2019

Wanilla

Figure 6: Long-term trends in depth to groundwater for four Red gum monitoring sites (1963-2019)
(all available data, note charts have different scales and no additional data is available for Coulta).

4. Next steps to fill knowledge gaps

1. Collect surface elevation data for Red Gums at each site to improve our assessment of actual groundwater levels as 'seen' by individual trees. Priority to be given to trees that have the lowest and highest RCI values at each site to obtain a range of actual depth to groundwater. Better resolution of effective groundwater depth may explain some of the variation in tree condition and help with assigning RCI bands relevant to assessing the WAP.

2. Use the data acquired from new monitoring infrastructure installed in early 2019. In January 2019 rainfall gauges were installed at all five sites to obtain more localised rainfall information. In April 2019 dataloggers were placed in an appropriate well at each of the five sites to obtain more detailed groundwater depth information.

3. Evaluate the proposed new Redgum Condition Index categories. Some stands at Big Swamp are likely to have close to ideal growing conditions and could be used to test the RCI categories. The community may also be able to identify the 'best' Red Gums on Eyre Peninsula to evaluate the threshold for the *Very good* category (RCI <0.70). Other condition categories could also be tested (e.g. the thresholds between Good, *Moderate* and *Poor*) by field observations and analysis of RCI values over time.

4. Evaluate alternate tree condition assessment methods that could be used to match tree condition to climate data and groundwater levels e.g. 3D tree imaging with drone technology. Existing remote sensing data could be analysed by DEW Science, Information and Technology to show changes in "greenness" of Red Gum stands over time to identify periods of higher or lower photosynthetic activity and link them to climatic variables, such as rainfall (Figure 6), periods of effective recharge based on assumed recharge thresholds (e.g. daily rainfall of 10 mm or more) or periods of very hot and dry weather.

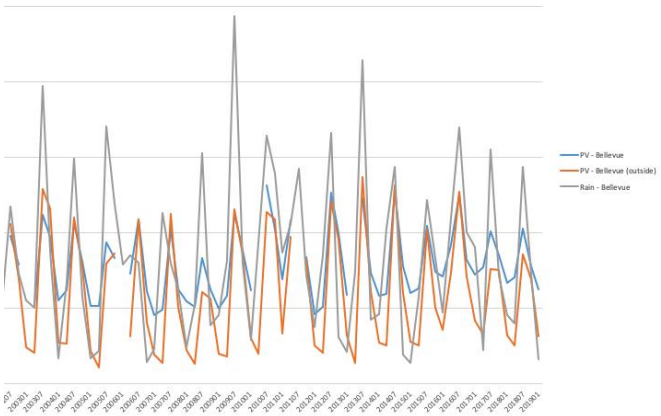


Figure 6: Rainfall (grey line) and Landsat Fractional Cover Greenness measures for trees on the inside (red line) and outside (blue line) of the stand at Bellevue.

5. Analyse more climate variables to determine the 'effective' water availability and probable canopy temperatures to better understand any observed changes in RCI values, especially at sites where groundwater is reliably available but there has been a decline in RCI over time. Canopy temperatures could be based on BoM station air temperatures but would ideally be tested in the field. There would be merit in requesting that DEW Science, Information and Technology prepare regional climate reports of key climatic variables that are likely to change markedly and are linked to ecosystem health (e.g. cumulative seasonal rainfall, minimum and maximum seasonal temperatures, ocean temperature, effective recharge).

6. Consider knowledge gained from undertaking Red Gum site monitoring and specific research projects to fill the knowledge gaps listed above with regard to the WAP MERI Plan.

5. Conclusions

Significant declines in Red Gum Condition Index (RCI) were recorded between spring 2016 and spring 2018 for stands of trees at Bellevue, Bramfield and Polda. No change was observed at Wanilla and a significant increase in RCI values was recorded at Coulta. The nature of these changes and their long-term significance will become more evident once more years of Red Gum condition data are available and a trend can be analysed.

Long-term rainfall analysis indicated that cumulative winter rainfall has declined steadily since c. 1990 and that cumulative summer rainfall has increased over this period. It may be that these changes will become stronger over coming decades. More analysis of the correlations between Red Gum health on Eyre Peninsula and extreme climatic factors that could have a negative impact (e.g. very hot summer days), as well as those that could have a positive impact (e.g. heavy rainfall onto warm soil), is needed to improve management.

Analysis of long-term groundwater levels found changes over the last six decades that were generally consistent with changes in rainfall patterns. Groundwater levels at Bellevue, Polda and Wanilla showed decline between 1989 and 2019 with some increases in the wetter period between 2009 and 2017. Groundwater levels at Bramfield were more variable over time and the frequency of sampling was less frequent and thus the pattern was not as distinct. Long-term groundwater data were not available for Coulta but it can be assumed that the overall patterns would have been similar given the strong linkages to climate.

It is too early to detect trends in Redgum Condition Index values but the data presented here can be used as a sound baseline against which future changes in tree condition and local groundwater levels can be referenced. Regardless of these changes in condition, all sites were in the *Good* to *Moderate* health classes and the individual tree scores from each site were spread across similar ranges of RCI values. There were no significant differences between Red Gum sites in the two Prescribed Wells Areas or between sites with and without nearby licenced groundwater extraction. This indicates that the baseline condition of all the Red Gum monitoring sites are similar and that the licenced taking of groundwater was not having a detectable effect on Red Gum health at the site scale in spring 2016 and spring 2018. This further suggests that there is a stronger correlation between Red Gum health and climate factors than licenced groundwater extraction rates, although long-term RCI values are not available to analyse against long-term groundwater trends. Filling of key knowledge gaps, as described above (e.g. analysis of long-term greenness values) may assist with better understanding of long-term trends in Red Gum health.

The Red Gums at the five monitoring sites had relatively low maximum and low variance in RCI values compared to trees on the River Murray. Comparative analysis of the two Red Gum data sets led to development of different RCI bands for the different condition classes specific to the Eyre Peninsula Red Gums. It is likely that phreatophytic Red Gums on Eyre Peninsula are at the climatic edge of the species' range (temporal and spatial) and thus may not develop very large or full crowns compared to Red Gums on the River Murray, especially given the high densities of trees at most of the sites. This may mean that they are more vulnerable to climate change than trees along the River Murray that have access to groundwater that is permanently recharged by the river, especially when the strong connections between groundwater levels and recent recharge on the Eyre Peninsula are considered.

Overall, there were no consistent differences in Redgum Condition Index scores in 2016 and 2018 between sites with or without nearby groundwater extraction, which suggests that climate is a major driver of current Red Gum health. These data suggest that the trees are likely to be vulnerable to climate change and that current groundwater extraction at the rates permitted by the WAP is not a source of significant risk to the Red Gums condition compared to that predicted for climate change over coming decades.

6. References

Doeg T, Muller KL, Nicol J, and VanLaarhoven J (2012). Environmental Water Requirements of Groundwater Dependent Ecosystems in the Musgrave and Southern Basins Prescribed Wells Areas on the Eyre Peninsula. Technical Report DFW 2012/16, Department for Water, Government of South Australia.

EP NRMB (2016). Water Allocation Plan for the Southern Basins and Musgrave Prescribed Wells Areas. Prepared by Eyre Peninsula Natural Resources Management Board, Port Lincoln, South Australia.

EP NRMB (2018). Groundwater Dependent Ecosystem (GDE) Survey Site Establishment. Internal Document. Prepared by Eyre Peninsula Natural Resources Management Board, Port Lincoln, South Australia.

Stewart S, Alcoe D, and Risby L (2012). Science Support for the Musgrave and Southern Basins Prescribed Wells Areas Water Allocation Plan, DFW Technical Report 2012/15, Department for Water, Government of South Australia

Souter, N. J. (2018). The red Gum condition index: a multi-variable tree condition index for visually assessed river red Gum (*Eucalyptus camaldulensis*) trees. *Transactions of the Royal Society of South Australia*, 00(00), 1–19. https://doi.org/10.1080/03721426.2018.1557994

Souter, N. J., Cunningham, S., Little, S., Wallace, T., McCarthy, B., & Henderson, M. (2010). Evaluation of a visual assessment method for tree condition of eucalypt floodplain forests. *Ecological Management & Restoration,* 11(3), 210–214. https://doi.org/10.1111/j.1442-8903.2010.00551.x

Attachment A: Photos of Red Gums from different RCI categories.

Very Good. **Tree P50 at Polda in 2016 (RCI =0.76)**

Good
Coulta 2016 Tree C49 (RCI = 0.55)

Moderate
Bellevue 2018 Tree B29 (RCI = 0.41)

Moderate
Polda 2018 Tree P21 (RCI= 0.35)

Poor
Bramfield Tree A28 (2018, RCI = 0.21)

Bellevue Tree B40 (2018, RCI =0.20)

Bellevue Tree B10 (2018, RCI =0.22)

Attachment B:
Range in individual Redgum tree RCI values in 2016 and 2018.

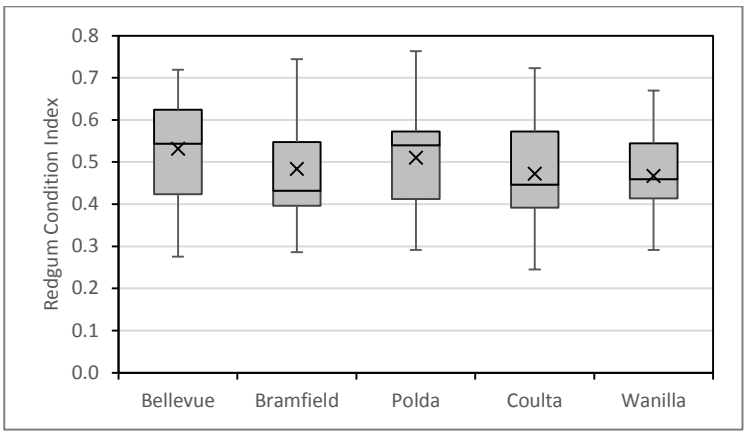


Figure B1: Individual tree RCI scores in 2016.

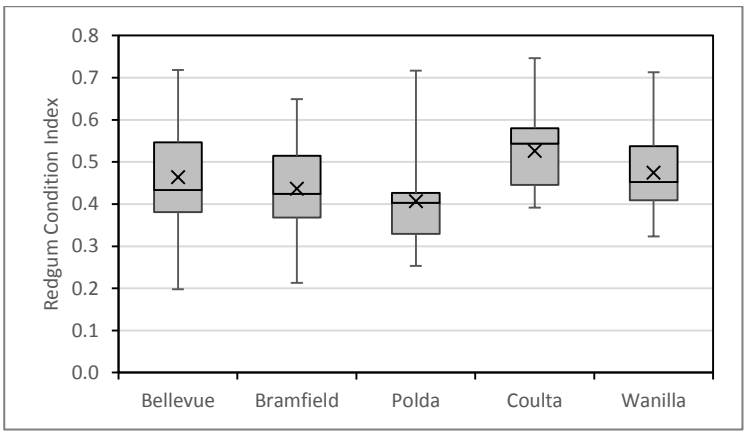


Figure B2: Individual tree RCI scores in 2018.

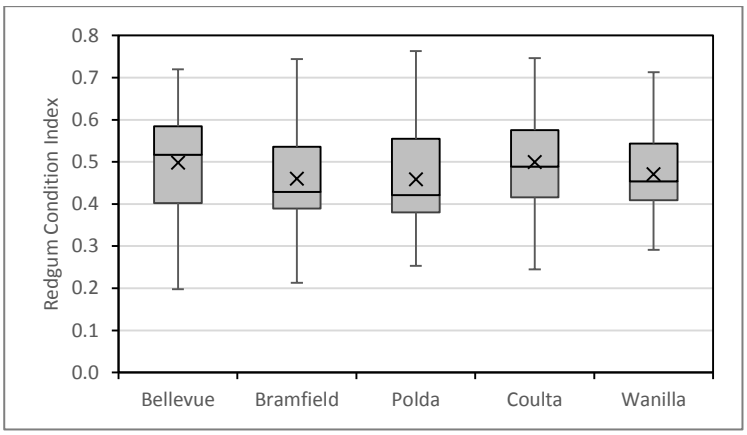


Figure B3: Individual tree RCI scores in 2016 and 2018 combined.