Monitoring of Die Back in River Red Gum (*Eucalyptus camaldulensis)* Communities in the Northern & Yorke Region 2008-2015

Update for *Natural Resources Northern & Yorke*

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by
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River Red Gum Die-Back Monitoring Program 2008-2015
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Photographs by Anne Jensen
Cover photo: Many streams were flowing during the 2015 survey, including the rare sight of Crystal Brook flowing, upstream of the town (September 2015)

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Executive Summary

The eighth monitoring survey since 2008 found significant improvement in the degree of stress and die-back in red gum communities of the Northern and Yorke region, but also found continuing critical recruitment failure due to lack of germination, as reported since 2012.

Healthy seed crops are still being produced, but this is not translating into successful germination. Water availability in 2015 was more widespread than in previous years, as indicated by the high number of flowing streams. This suggests that there was a higher likelihood of adequate soil moisture being available to sustain any germination from seed fall in summer 2014-15. However, once again, there was no mass germination of seedlings at any of 62 monitored locations across four catchments, and only two individual new seedlings were found while traversing more than 1200 km across the region.

The primary factor inhibiting successful germination appears to be lack of bare, moist soil below mature trees for seeds shed from aerial seedbanks to land on and germinate. There is competition from dense grassy weed cover emerging at the same time as conditions are suitable for seed fall and germination. In watercourses, reduced flows mean that reedbeds commence their summer growth earlier, covering potential red gum germination sites with dense growth.

In spite of improved canopy condition, red gum die-back continues to be significant across the region, and the primary cause of die-back in mature river red gums is reduced water availability. The monitoring results indicate that reduced access to water sources can be a very localised problem, with the level of stress across a community of trees varying widely among individual trees. Local variations occur due to uneven access to water sources from fractured rock aquifers and varying transmissivity and storage capacity of soils.

Conditions in 2015 were remarkable for the areal extent of flows sustained into early September. Flows were observed in many watercourses for the first time in all surveys, but the extent and duration of flows did not show up in water monitoring data. As reported in 2014, the existing monitoring stations are very limited, and these are insufficient to document the flow events which have occurred. The need remains to obtain a minimum data set at least for Broughton, Wakefield and Willochra catchments for future management, and proposals presented in 2014 to upgrade the water monitoring network should be listed as a priority if funding becomes available. The flows in 2015 demonstrated the potential value of a program of citizen science, as recommended in 2014, to encourage individuals to report information on flow events, to supplement data from official monitoring sites.

Levels of insect attack were generally mild in 2015, compared to severe insect attacks in 2012 and 2013. The exception was in locations around Clare which suffered severe lerp infestation, including severe decimation of the survey monitoring site on Spring Gully Road near the Caravan Park. In 2015, recovery growth post-bushfires near Wirrabara and on Telowie Creek appeared to be stable but not as advanced as expected.

As stated in previous monitoring reports, urgent intervention is needed to facilitate germination and survival of red gum seedlings. This requires preparation of suitable seed beds by clearing weeds and creating bare soil to coincide with maximum seed rain (Nov-Dec), or by broadcasting seed onto prepared beds to coincide with useful rainfall events (>10 mm). Seed falling from trees needs to land on bare moist soil to germinate, and seedlings need to be protected from stock grazing until at least 1.2 m high.

As recommended in the 2014 report, actions to save river red gums fit best within actions for sustainable management of the wider landscapes, and could be incorporated into a wider project with the aim of restoring 20% of native vegetation to the general landscape.

The overall prospect for the long-term survival of red gum communities is unchanged. As stated in previous reports, without active intervention to promote germination and to protect minimum water sources for red gums, the Northern & Yorke region is in danger of losing its distinctive red gum landscapes in the next 30-50 years. Concerted action is needed to save red gum communities, to obtain better water data, to engage community members in a program of citizen science to record flow events and red gum germination, and to develop a revegetation and protection program to sustain a minimum 20% native component in regional landscapes. The benefits of these actions will not only include improved health of red gum communities, but also sustainable management of landscapes, maintenance of a full range of environmental services and adaptation to expected drier and hotter conditions due to climate change.

Figure 1 Single red gum seedling found in Willochra Creek near Melrose (site WL006A)

Background

An investigation into die back in river red gum (*Eucalyptus camaldulensis)* populations in the Northern & Yorke region was commenced in August 2008. Concerns about the decline of river red gum health dated from 2005, when the river red gums lining the Booleroo Whim Creek north-east of Melrose deteriorated alarmingly into a state of severe stress.

The initial assessment in 2008 found that local data were lacking on the status of water sources, changes in tree health and changes in secondary impacts, and this information was needed to provide feedback on the effects of management actions. Therefore, the monitoring program was established to gather important local data to monitor changes in tree condition over time and to understand the possible causes of die-back in the region. The four target catchments are Broughton, Mambray Coast, Wakefield and Willochra catchments (Figure 1, Appendix 1) and annual surveys have been completed up to September 2015, with eight surveys completed.

The data from previous surveys is incorporated into the graphs presented in this report. In addition to seven new sites added in 2013 to link red gum die-back monitoring with the *Four Catchments* project, and a further three sites were added in 2014. Eight new sites were added in 2015, and four previous sites were suspended (Appendix 2).

Brief for 2015 Monitoring Survey

A further monitoring survey was contracted to evaluate conditions in September 2015 and provide an assessment of trends in vegetation condition.

The monitoring tasks included:

- Visit 50 ongoing monitoring sites in 4 catchments (Broughton (21), Mambray Coast (10), Wakefield (10) and Willochra (9), recording data as per the monitoring guidelines
- Visit 3 new sites established in 2013 (Broughton 1, Willochra 2), record data
- Visit 2 new sites established in 2014 (Wakefield), record data
- Establish 8 new sites (Wakefield 6, Willochra 2), record location and baseline data on condition
- Analysis of data and comparison to previous monitoring surveys
- Update of monitoring manuals and guidelines
- Update report on monitoring results for NY NRM Board
- Update recommendations for future monitoring activities
- Provide e-copy of report, updated manuals and data to Project Officer.

Methodology

The methodology and results have been described in previous reports (Jensen *et al.* 2008a, Jensen 2010, 2011, 2012, 2013, 2014a). The rapid assessment scoring system for site condition was continued as per previous surveys at the revised list of 62 sites, using health rankings for each parameter to generate scores to measure the risk of decline and the chance of recovery for each site (Appendices 1-3; Jensen *et al*. 2008a, Jensen 2014a). Low scores indicate a high risk of decline and low chance of recovery, while high scores indicate sites with low risk of decline and high chance of recovery, ie sites in good condition.

At 34 special monitoring sites with 5 target trees, additional parameters were scored to assess the stage and crop volume of the phenological cycle (buds, flowers, fruits, leaves), to assess canopy condition, and to evaluate the extent of epicormic growth.

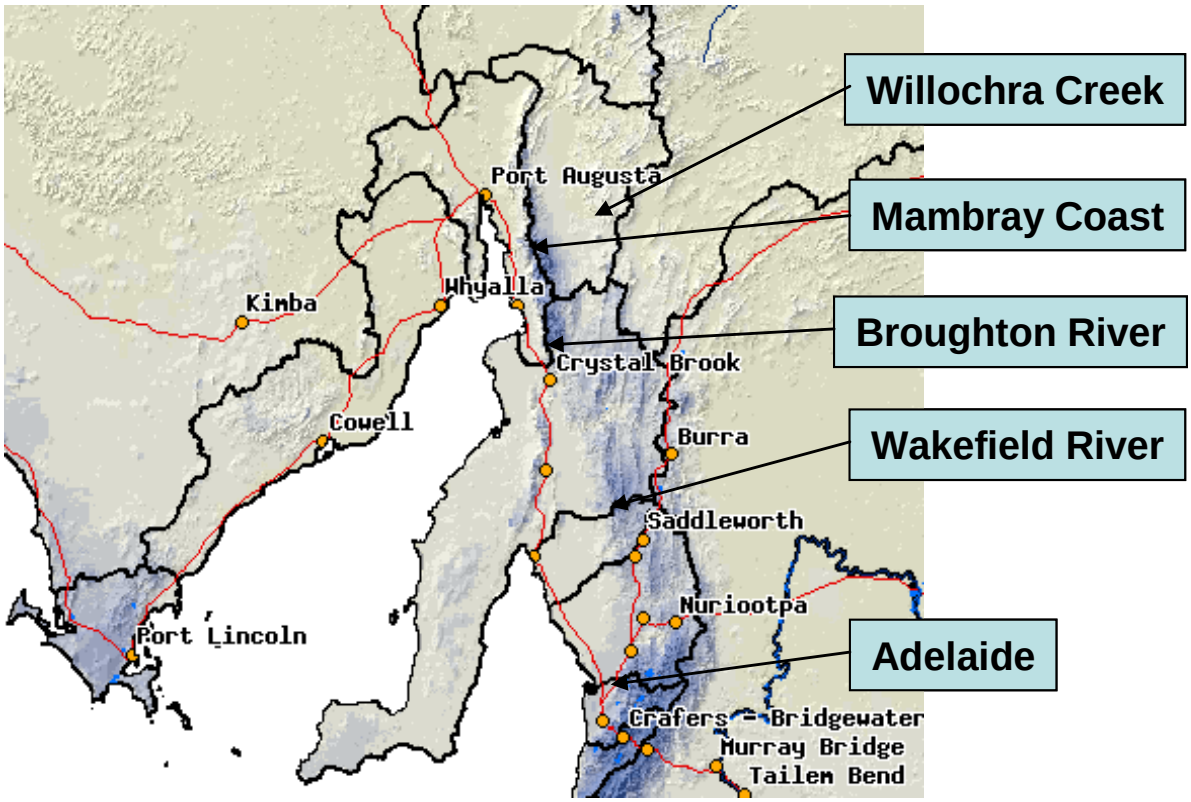


Figure 3 Location of monitored catchments. Base map: Rural Water Maps http://adl.brs.gov.au/water2010/mapserv/

Figure 2 Spring Creek flowing at new monitoring site on Pengilly Road near Wilmington, September 2015

Factors Influencing Growth and Health of Red Gums

As reported previously, water availability for river red gum regeneration and maintenance has reduced significantly since 1970, due to regional decline in rainfall and increased water abstraction for agricultural and domestic use (eg Jensen 2013).

The key question for sustainable natural resources management is an understanding of surface water resources and the closely-linked groundwater resources. This includes data on the seasonality, duration and extent of inundation from flows, run-off from catchments, and the relationship to rainfall in the catchments.

A report for the NY Lower North Group in 2014 found that the Northern & Yorke region has limited historical collection of water data and monitoring of seasonal conditions related to flows (Jensen 2014b). The number of active streamflow monitoring stations is extremely limited, with no stations in the lower reaches of the Broughton and Wakefield catchments, no stations at all in Mambray Coast catchments, and no upstream stations in the Willochra catchment.

This lack of data makes it very difficult to monitor the extent and duration of individual flow events which might produce germination events in river red gums, or replenish shallow fractured rock aquifers which could supply a water source for existing trees. In particular, good seasonal flows to the lower end of the Broughton and Wakefield Rivers in 2014 and 2015 were not detected by the current monitoring network. Peak flows in winter and early spring were recorded in 2014 in the upper reaches of the Broughton and Wakefield Rivers, but not in 2015. A late peak in October appears in the Broughton record at Mooroola. Flows in the Willochra Creek reached the site of the now closed monitoring station at Pinda Bridge in September 2015 (Figure 4).

Available data on water sources and flows in 2015 is summarized below.

Figure 4 Flows in Willochra Creek at Pinda Bridge, Orrorroo Road, September 2015

Rainfall Data

Rainfall across the four catchments continues to record average to below-average volumes, except for Koolunga, noting that the 2015 figures are only to 30 September (Figures 5 & 6). The rainfall patterns in 2015 continue to show unusually high rainfall peaks in January, April and August but below average rain in September, when significant rains would be expected to fall (Figure 7). The red gum survey was undertaken early in September, prior to extreme weather conditions which included frost and hail in mid-September, followed by a short period of extreme heat at the beginning of October, which may have affected red gum health.

It has previously been noted that predictions for the impacts of climate change for the region including the mid-North include a shift to more peak summer rainfall events and fewer spring rainfall events (Jensen 2010), and this would appear to be the case in the rainfall pattern for the past three years. As noted in previous monitoring reports, a 1% decline in rainfall translates to 3% decline in run-off in a semi-arid catchment, so the predicted future decline in rainfall due to climate change would also result in a significant decline in run-off, leading to an associated decline in water availability for red gums.

Flows Data

During the previous red gum survey in mid-September 2014, flowing water was recorded in the Lower Broughton for the first time since these surveys commenced in 2008. Flows were observed again in the lower Broughton in mid-September 2015, and more water was recorded across the Northern and Yorke region than ever seen in all surveys.

Sites observed with flowing water in 2015 included Telowie Creek at Top Track (MB010, just downstream of Telowie Gorge), Mambray Creek at National Highway 1 (MB007), Beautiful Valley Creek linking to Willochra Creek east of Wilmington (WL012), Willochra Creek at Melrose and sites further downstream (WL006a, WL006, WL009), Wild Dog Creek at Murraytown (WL003), and Rocky River at Wirrabara and upstream of Laura (BR008), as well as the Lower Broughton flowing again at Cockys Crossing (BR014), Butler Bridge (BR015) and Lower Broughton Road (BR016). Flows observed in the upper Wakefield River and downstream as far as Auburn and 'Nyowee' (WK004) did not continue downstream beyond 'The Rocks', and there were no signs of any flows in 2015 in the lower reaches at Whitwater (WK008) and Bowmans (WK010).

As reported in 2014, the monitoring stations for the Wakefield River near Rhynie and the Broughton River at Mooroola give the longest data sets for stream flows in these catchments (Jensen 2014b), and the flows for 2015 are given in Figures 8 & 9. However, these data do not indicate any significant flows at all to the end of September 2015. In particular, there is no indication of the extent or duration of flows in the upper catchments or the lower reaches of these rivers.

The surprising absence of flows recorded by the primary monitoring stations fails to support the suggestion in the 2014 monitoring report that flow volumes at Rhynie and Mooroola can be used as indicators of the likelihood of flows in the lower reaches (Jensen, 2014a). This reinforces the need for more monitoring stations spread across catchments for more accurate assessment of the extent, duration and frequency of annual flows. It also reinforces the potential value of engaging the local riparian community in a citizen science project to record local flows.

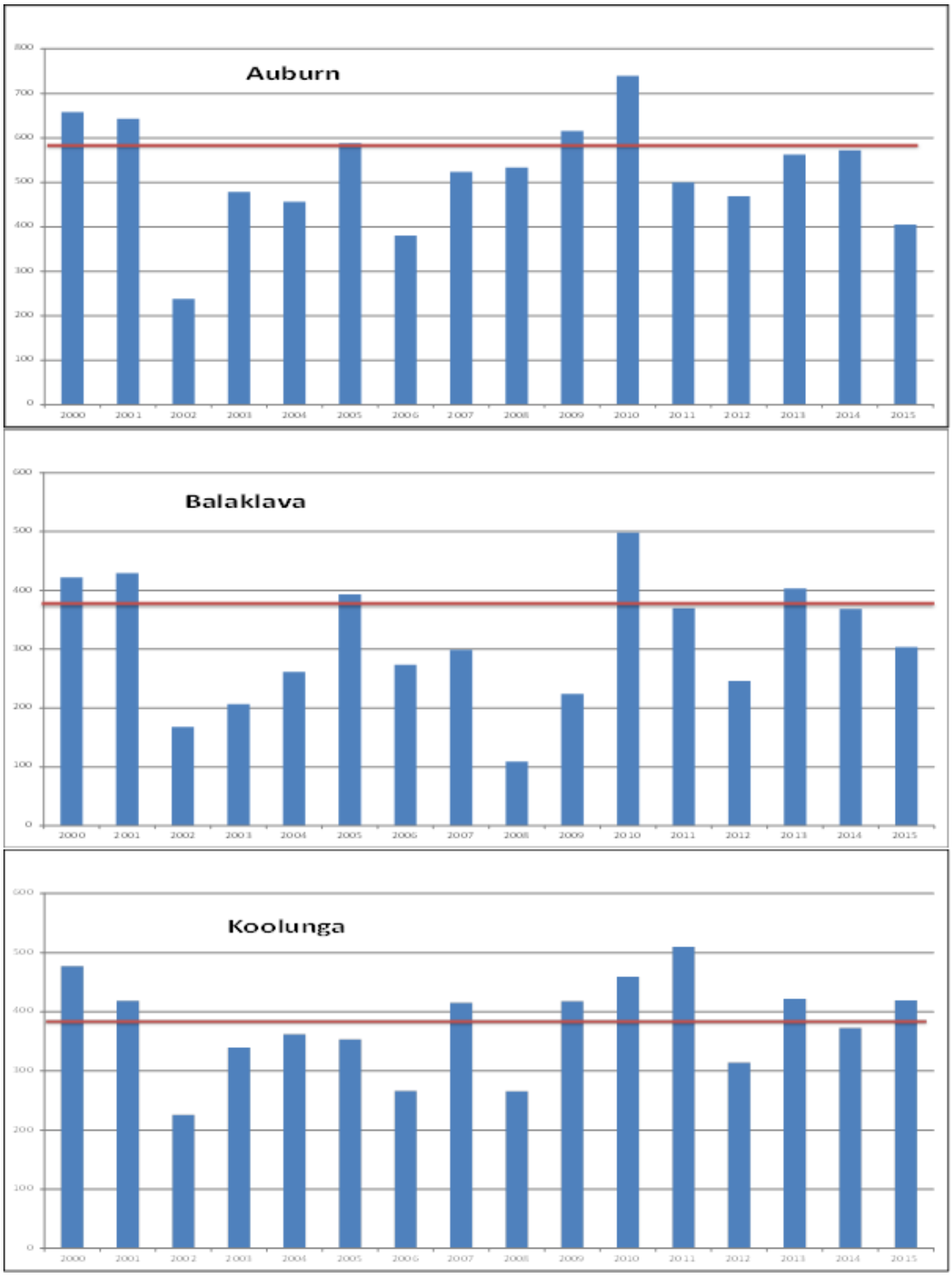


Figure 5 Average annual rainfall for Auburn, Balaklava and Koolunga, with long term average volume shown by red line. Note that 2015 volume is to 30 September only, covering rainfall in the period prior the survey.
(Source: Bureau of Meteorology)

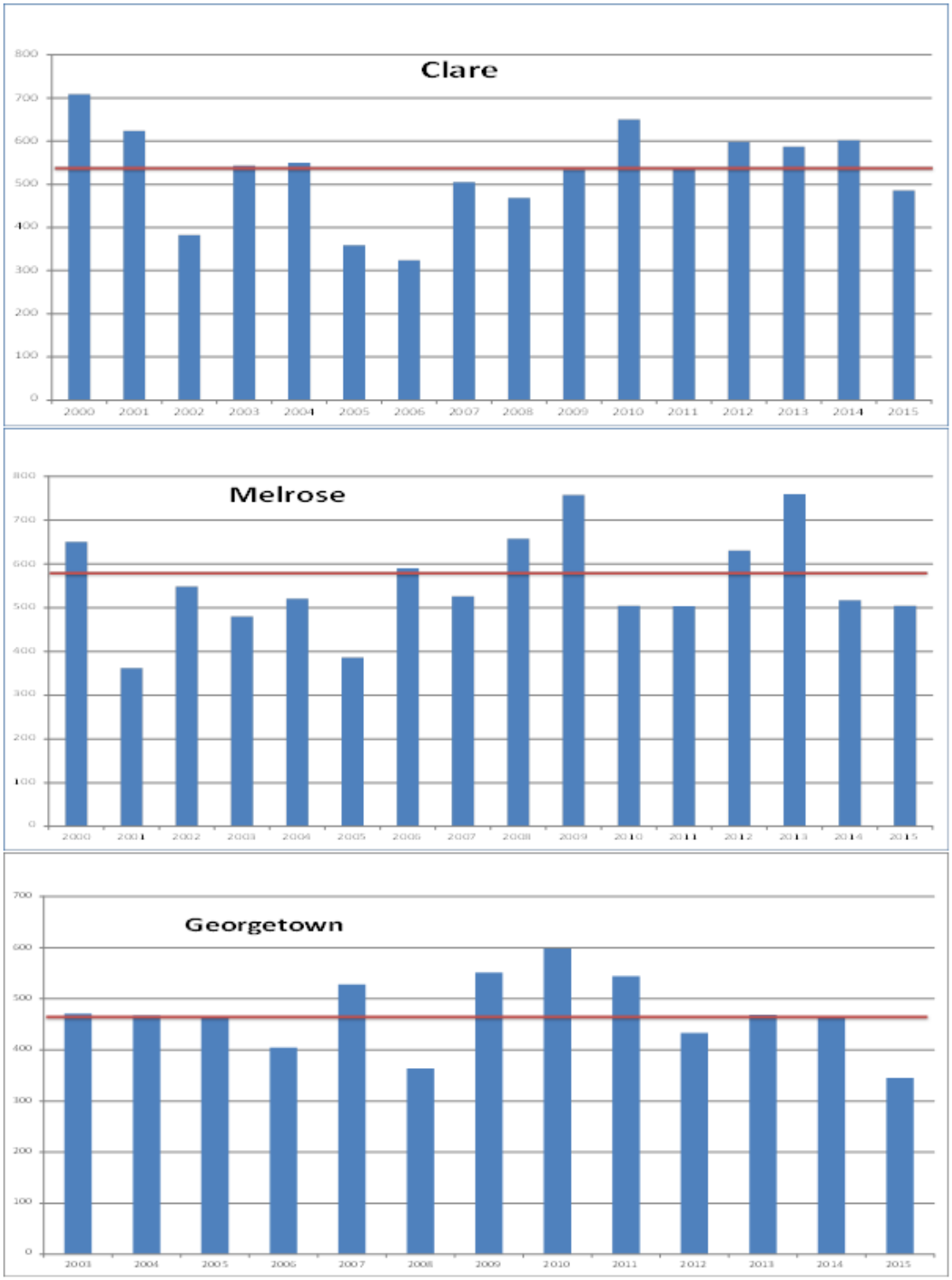


Figure 6 Average annual rainfall for Clare, Melrose and Georgetown, with long term average volume shown by red line. Note that 2015 volume is to 30 September only, covering rainfall in the period prior to the survey.
(Source: Bureau of Meteorology)

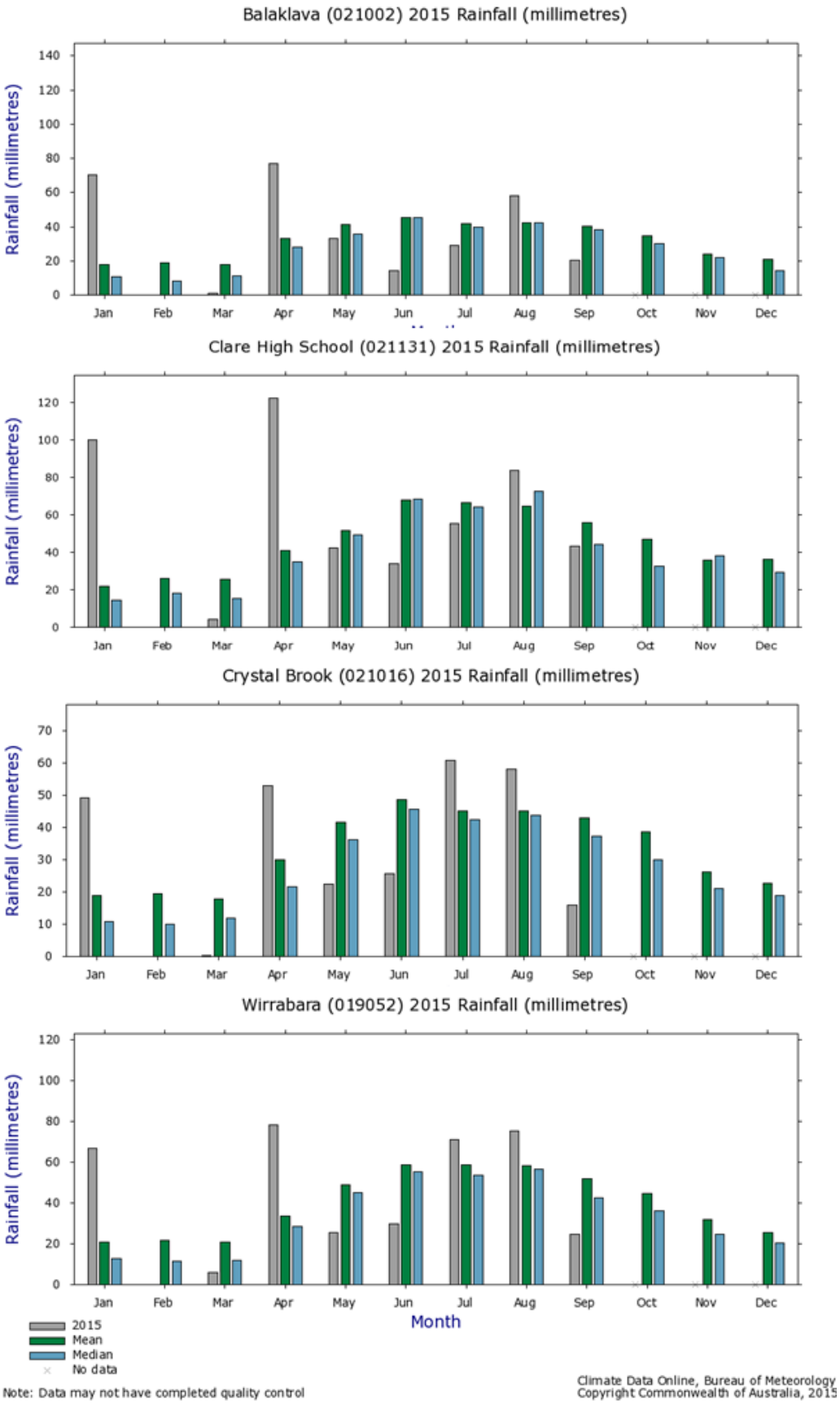


Figure 7 Monthly rainfall pattern January to September 2015 for regional stations, showing unusual peak rainfall in January, April and August (Source: Bureau of Meteorology)

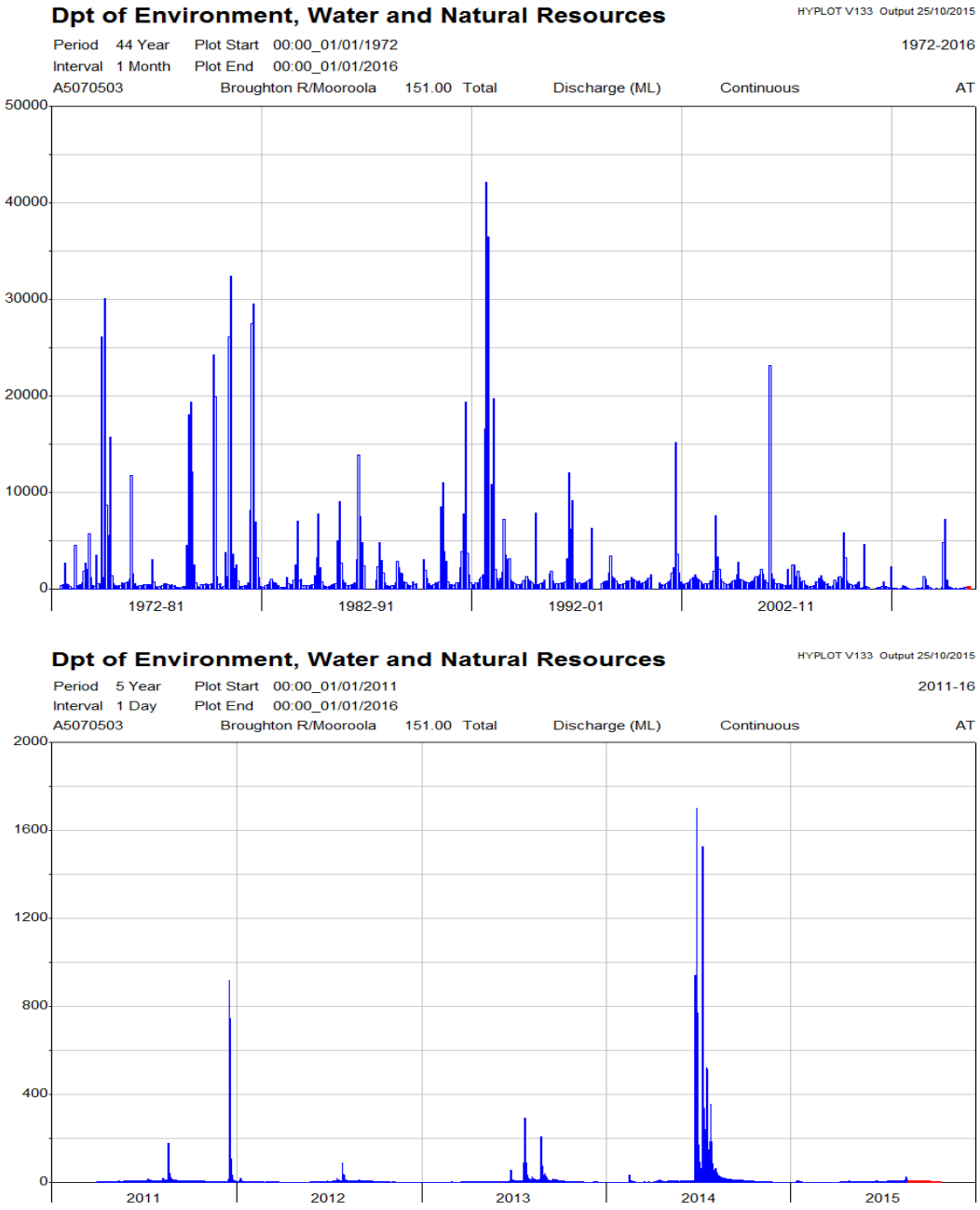


Figure 8 Stream flow data from the monitoring station on the Broughton River at Mooroola, showing monthly data from 1972-2015, and daily data from 2010-2015 (updated 25 Oct), with no flow peak prior to the September red gum survey. (Source: DEWNR WaterConnect database)

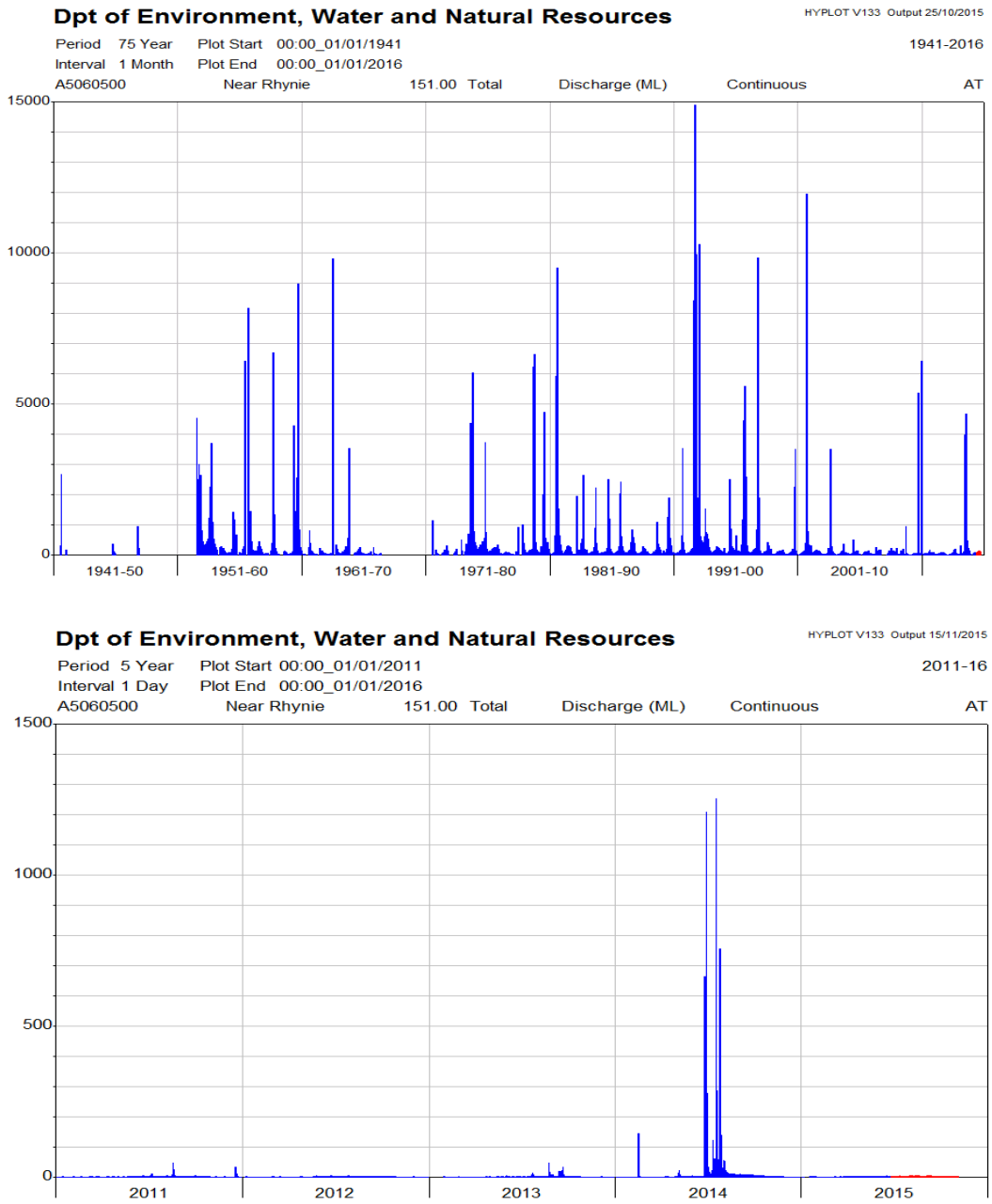


Figure 9 Stream flow data from the monitoring station on the Wakefield River near Rhynie, showing monthly data from 1941-2015 (updated 25 Oct), and daily data from 2010-2015 (updated 22 Nov) with no flow peak prior to the September red gum survey. (Source: DEWNR WaterConnect database)

Figure 11 Water flowing at Threadgolds Crossing, September 2015

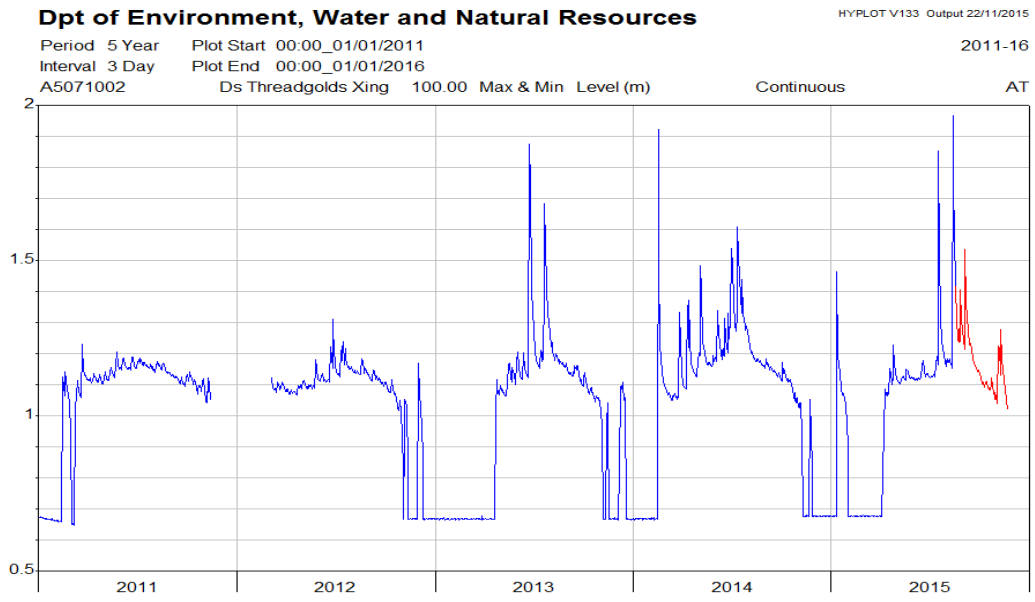


Figure 10 Level records at Threadgolds Crossing on the Rocky River better reflect the flows observed across the Broughton Catchment in 2014 and 2015 than data from the Mooroola monitoring site (Source: DEWNR WaterConnect database)

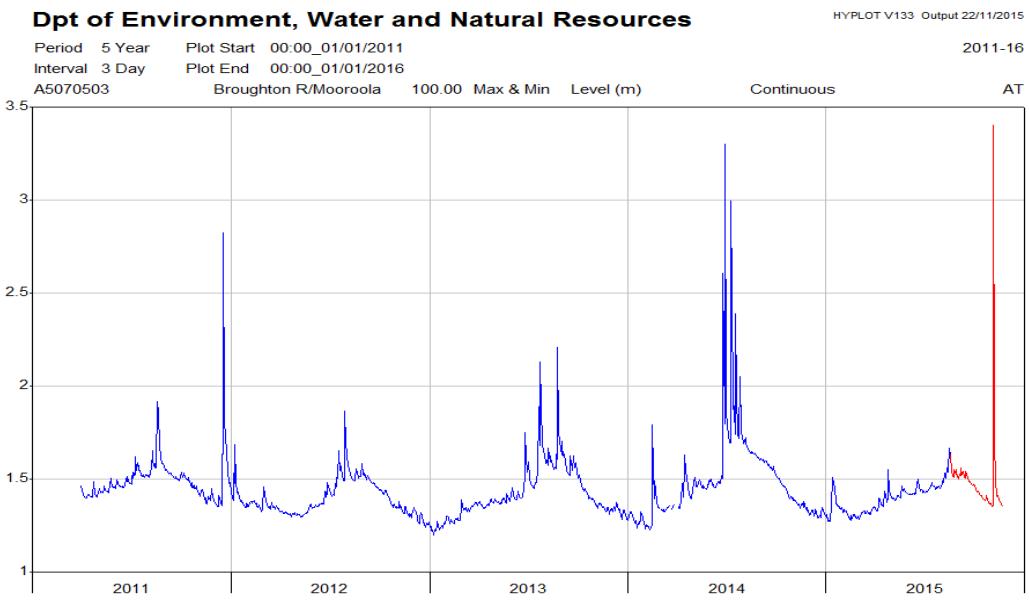


Figure 12 Levels at Mooroola on the Broughton River do not show any significant flows prior to the September red gum survey, but include a flash flood in November (updated 22 Nov)
(Source: DEWNR WaterConnect database)

Figure 13 Broughton River flowing at Lower Broughton Road in September 2015 (monitoring site BR016)

Site Condition Results

Previous Condition

From the initial stressed condition of 2008, red gum communities in the Northern & Yorke region partially recovered at most sites in 2010 and 2011, following two years of average or above average rainfall (Jensen 2010, 2011). However, most trees still exhibited a significant level of stress and site condition deteriorated again in 2012, coupled with heavy insect attack on recovering epicormic growth (Jensen 2012). Recovery in 2013 was again compromised by significant insect attack, although it did not trigger new epicormic growth (Jensen 2013). Levels of insect attack in 2014 were insignificant, and canopy condition improved as epicormic growth converted to normal tip growth (Jensen 2014a).

Current Condition

Climatic conditions in 2015 were again improved, with widespread seasonal flows in streams and rivers. Results for tree condition in 2015 indicate continued recovery in mature trees with medium stress, with negligible insect attack. However, individual trees with severe stress still only have extremely limited recovery.

Recovery with continued underlying stress in 2015 is seen in individual catchments in Figures 14-15. Broughton continues to be the catchment in best condition, with low risk of decline and medium chance of recovery. Mambray has improved significantly in its risk of decline scores, but continues to have a low chance of recovery. Wakefield has a low risk of decline but only a low-medium chance of recovery. Willochra has a medium to low risk of decline and a medium chance of recovery.

Condition scores for the new sites added in 2013 and 2014 are shown separately in Appendix 4, and will be processed separately until there are three data points for each site. Phenological data for these sites have been included in the overall catchment scores in Figure 22.

Photographs of site conditions since 2008 for selected individual locations are given in Figures 17-19, to illustrate the high variation between individual trees and sites.

Canopy Condition and Epicormic Growth

Canopy condition improved in Mambray from spring 2014 to spring 2015, was maintained in Broughton and Willochra, and declined in Wakefield (Figure 20), in spite of widespread stream flows which might have been expected to support improved canopy condition in all catchments.

The primary factor contributing to improved condition is the minimal extent of epicormic growth, compared to the high levels of epicormic growth in 2011 and 2012. Epicormic growth continued to be very low, as in 2013 and 2014, reflecting mostly normal growth from tips as recovery continues (Figure 21).

Seasonal Phenological Cycles

The phenological data for 2015 are dominated by mature bud crops as well as mature closed fruit, indicating significant numbers of trees carrying dual crops, with seed ready for release in summer 2015-16 and a further crop of seed developing for summer 2016-17 (Figure 22). Trees in Willochra catchment also have open mature fruit, indicating that some seed has already been shed. All catchments have trees with dual crops, indicating healthy phenological cycles, and healthy seed sources available.

Figure 14 Comparison of Risk of Decline Scores for individual Catchments (2008-2015), showing the highest risk of decline is still in Mambray Coast catchments and the lowest risk is in Broughton catchment

Figure 15 Comparison of Chance of Recovery Scores for individual Catchments (2008-2015)

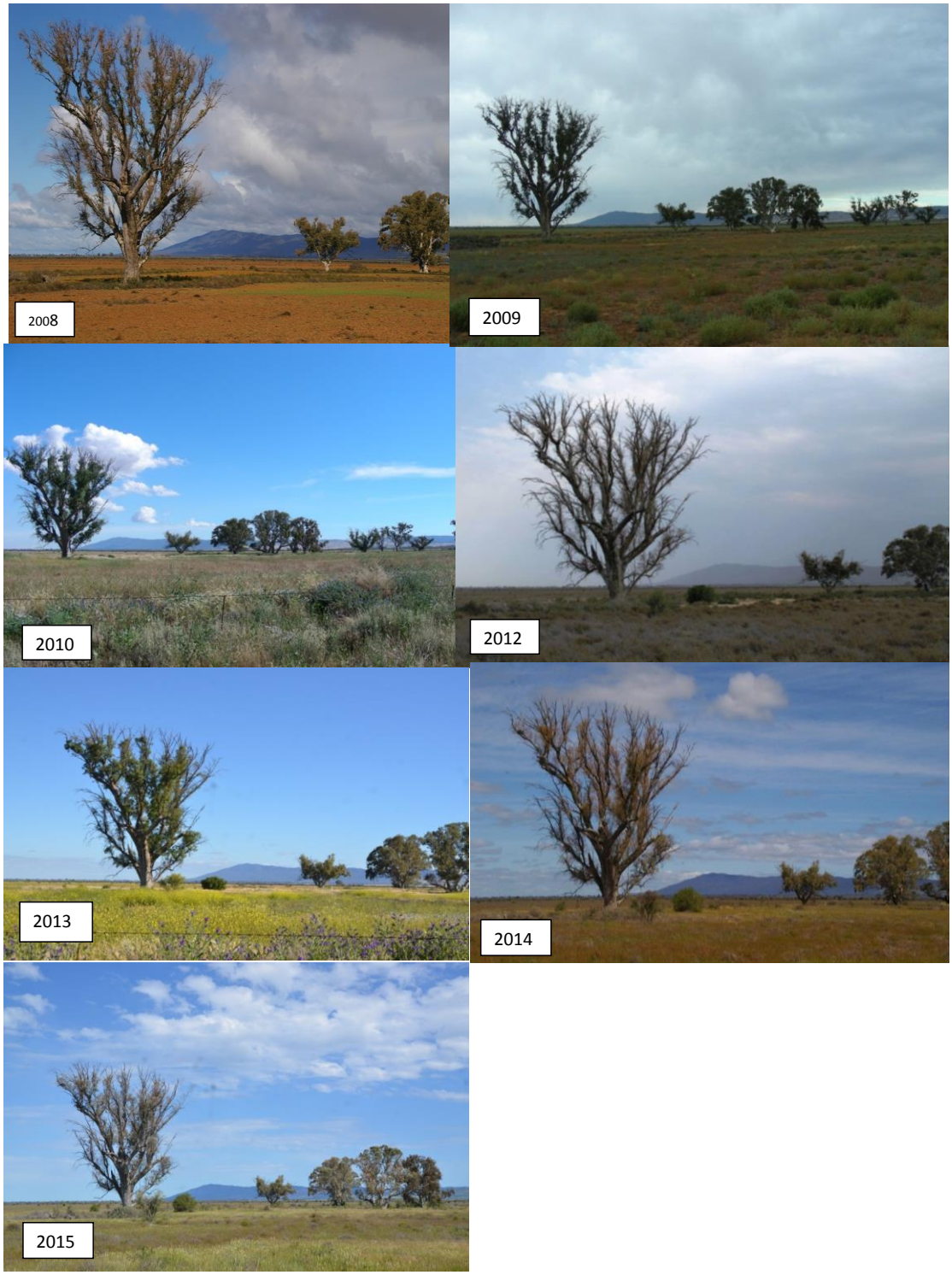


Figure 16 Declining health of indicator tree in lower reaches of Beautiful Valley Creek, east of Wilmington; the tree appeared dead in 2012, then put on new epicormic growth in 2013, declined again in 2014, with little surviving foliage, but has new epicormic growth in 2015, with water flowing to the end of Beautiful Valley Creek and beyond, towards Willochra Creek

Figure 17 Some recovery of stressed trees on Lower Telowie Creek, but a large stand of mature trees has died in this reach, and no regeneration has been found. No flows reached this point in 2015.

Figure 18 Continued decline in health of trees on Horrocks Creek, Mambray Coast, with no regeneration and no sign of flows in 2015.

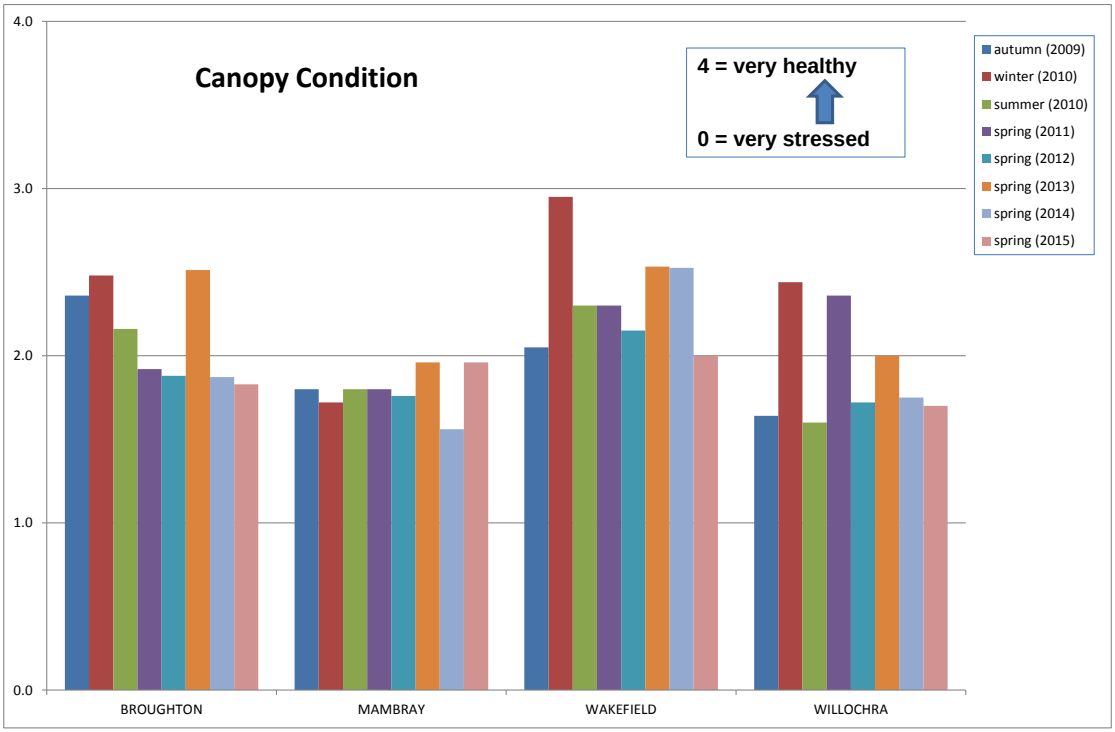


Figure 20 Trends in Canopy Condition for all catchments 2009-2015

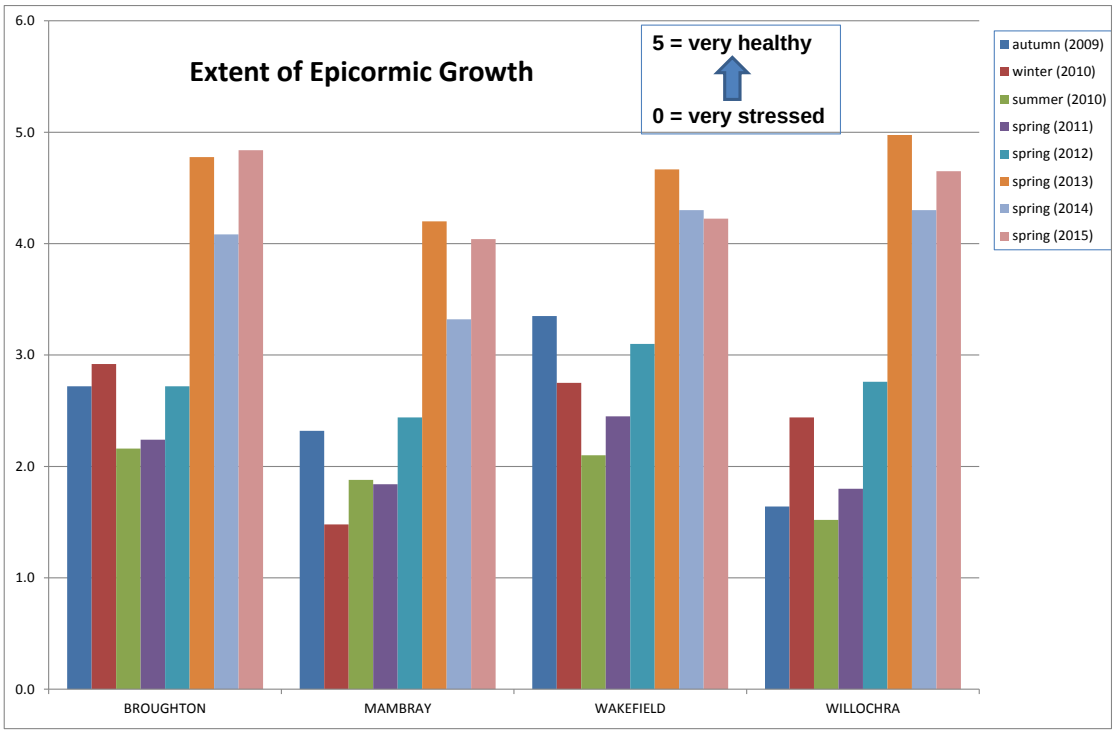


Figure 19 Trends in Epicormic Growth for all catchments 2009-2015

Figure 21 Phenological Cycles for all Catchments (2009-2015), with closed mature fruit crops dominant in 2015

Critical Lack of Regeneration

The issue of regeneration continues to be of urgent concern, with no change in 2015. No effective regeneration of red gum seedlings has been found at any monitoring sites on any surveys since 2008. This represents a critical recruitment failure, with the long term survival of red gum communities threatened if they fail to replace themselves.

Sampling sites were deliberately placed near existing regeneration (already established in 2008), including the Rocky River between Wirrabara and Laura, Broughton River near Merriton, and isolated patches of regeneration on the Hutt River north of Clare, Horrocks Creek, Nectar Brook and Crystal Brook. However, only two new seedlings were found anywhere across the region in 2015, this time at a sample site on Willochra Creek (WL006a). Just a handful of seedlings has been found over eight surveys, mostly on roadsides or in vineyards, and few of them have survived slashing or poisoning. Five seedlings which emerged at a sample site in Armagh Creek near Clare continue to survive (BR023), but seedlings which grew in the adjacent vineyard were poisoned. No mass regeneration has been found at any site, although it would be expected at some suitable locations in any season with widespread stream flows and average rainfall.

As reported previously, seedlings need open space, preferably bare ground, control of competing weeds and pasture species, and control of grazing stock in order to survive. Regeneration within riparian zones is clearly being limited by competition from dense weeds and pasture species, and by grazing stock. In addition, reduced flows have had the effect of allowing annual regeneration of reedbeds to occur earlier, creating competition with red gum seedlings when seeds land in watercourses, with only a few seedlings surviving to sapling stage (Figure 20).

Figure 22 **Red gum regeneration competing with *Phragmites* reedbeds in the Wakefield River near Nyowee, downstream of Rhynie**

Bushfire Impacts

Only one fire-affected site was visited, at Upper Telowie Creek (Figure 21). The development of epicormic growth and development of a new canopy continues to be much slower than expected, with very limited regrowth.

Figure 23
Initial epicormic growth at Telowie Creek in April following February 2014 bushfires and floods (top picture) was stalled in September 2014 (middle picture) and there is little improvement in September 2015 (bottom picture)

Discussion

The 2015 survey confirms continued recovery and improved canopy condition in river red gum across the Northern & Yorke region but there is continuing under-lying significant die-back and stress. It also confirms the continuing critical recruitment failure which threatens the long-term survival of red gum communities in the region. No new broad-scale regeneration has now been found since 2008, either at monitoring sites or in observing the landscape generally.

Seasonal stream flows were more widespread and of longer duration than seen in any previous survey. There has been some improvement in the 'risk of decline' scores across catchments, reduced from 40% to 30% of sites at high to medium risk of decline from 2014, but 70% of sites have only low to medium 'chance of recovery' scores. Canopy condition continues to sustain normal growth, with minimal epicormic growth, with low levels of insect attack.

In the Broughton catchment, there continues to be a relatively low and stable risk of decline but only a medium chance of recovery. In the Mambray Coast catchments, there are major variations in the risk of decline in individual catchments, with reducing risk of decline, but only a low to medium chance of recovery. In the Wakefield catchment, the risk of decline is low but there is only a low to medium chance of recovery. In the Willochra catchment, there continues to be a low-medium risk of decline with an ongoing medium chance of recovery.

Lack of regeneration

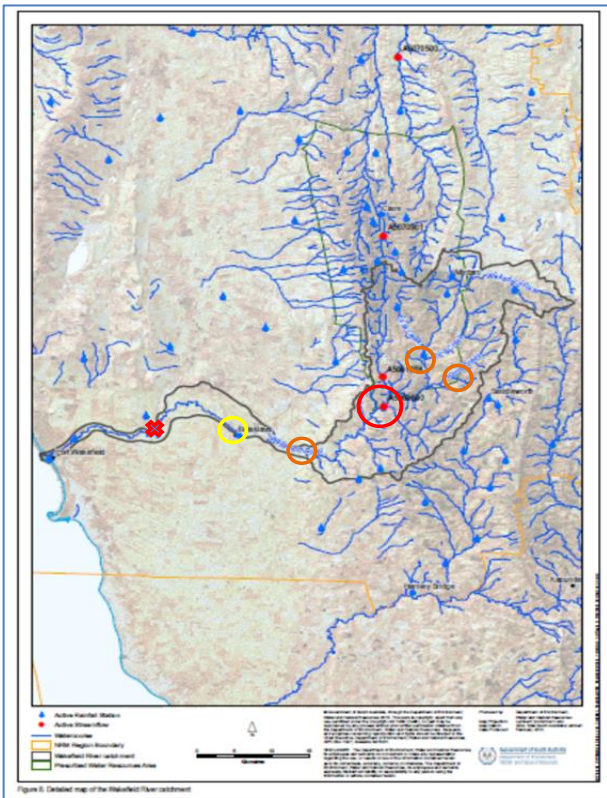
There are now extreme concerns about the lack of regeneration across the region. No natural examples of mass germination have been found, in spite of good potential for regeneration from rainfall during the past three years and the availability of significant volumes of seed. The very few examples of individual seedlings germinating are insignificant and will have no effect on the long-term survival of red gum communities at a landscape scale.

Active intervention is required to assist regeneration in the region, as has been outlined in previous reports (Jensen 2012, 2013, 2014a). This would include preparation of suitable bare soil seed beds, weed control, addition of seed if required, control of grazing, and watering during the first two summers if natural water sources are not available. Mass germination and survival of red gum require adequate water availability until the seedlings have established a root system, bare moist soil for initial germination, seeds falling from the trees, no weeds competing with the seedlings for moisture, and no grazing for two years until the growth tips are above grazing level for stock.

Lack of Monitoring of Water Sources

Seasonal flows occurred in the catchments in 2015, lasting for up to three months, with many sites still flowing in early September. However, measured flow data from five stations in the Broughton and two stations in the Wakefield, all in the upper catchment, did not capture these flows. The two flow stations in the Willochra catchment are both at the extreme downstream end of the catchment, and did not capture flows data on in the upper catchment. It is more critical to measure flows at Melrose to obtain useful flow data. Flows in 2015 reached the former monitoring station at Pinda Bridge, now discontinued and no longer recording flows.

Lack of local rainfall data and flow data is an ongoing issue. The recommendations that additional monitoring stations be installed and some closed stations be re-activated, made to the NY Lower North Group and the Board of *Natural Resources Northern & Yorke* in 2014, remain relevant (Figures 23 & 24; Jensen 2014b). Priority should be given to seeking funding to install telemetry to develop local flow data for the main watercourses, and particularly to monitor key flow events.

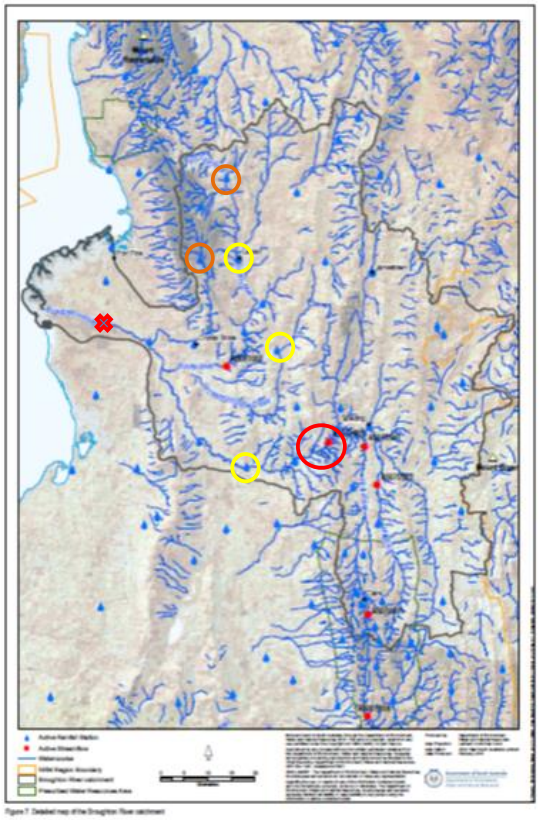


Existing monitoring stations:
Rhynie 73 y
Skillogalee 11y

Essential addition:
✖ Whitwarta

Desirable additions:
○ *new* ○ *re-activate*
- Balaklava
- The Rocks
- Eyre Creek
- Pine Creek

Figure 24 Recommended additional monitoring sites for the Wakefield River catchment



Existing monitoring stations:
Broughton River @ Mooroola 42y
Hutt River nr Spalding 45y
Hill River nr Andrews 45y
Hutt River @ Clare 25 y
Rocky River @ Thredgolds 11 y

Essential addition:
✖ Cockys Crossing

Desirable additions:
○ new ○ re-activate
- Wirrabara
- Laura
- Beetaloo
- Koolunga
- Yackamoorundie Creek

Figure 25 Recommended additional sites for the Broughton River catchment

Recommendations for Data Projects using Citizen Science

In addition to monitoring stations, a system of citizen science to record local river flows, levels, duration and timing should be developed to gather local data from landholders and community members, as recommended to the NY Lower North Group and the Board of *Natural Resources Northern & Yorke* in 2014 (Jensen 2014b).

Proposal for Landscape Scale Revegetation

As described in 2014, the issue of river red gum health and lack of regeneration is part of a wider problem, the general lack of native vegetation across regional landscapes. It was recommended that the solution for river red gum health be incorporated into a broader approach to sustainable landscapes, linking to aims to increase regional biodiversity.

Briefly, the proposal is to aim for a target of 20% native vegetation (alongside 80% agricultural uses) in regional landscapes, to be achieved in 10 years, including:

- water reserves, road reserves, public reserves, rocky hilltops
- one side of 5-chain roads (allow width for farm machinery to pass)
- riparian zones along watercourses
- fencelines & driveways
- develop corridors of bushes only, or mix trees and bushes
- develop 'golden corridors' of acacias and sennas, particularly along tourist routes
- involvement of community groups, local government, landholders, conservation volunteers in active regeneration projects and citizen science projects to monitor local flows and any regeneration events.

Figure 26 **Willochra Creek flowing at Ken Walters Road, September 2015**

Conclusions

The condition of river red gum communities across the Northern & Yorke region continues to give cause for concern, with no significant regeneration since 2008. Canopy condition has improved 2013-2015, with minimal epicormic growth, but the long term chance of recovery for red gum communities remains low as long as there is no mass regeneration.

The primary cause of die-back in mature trees continues to be reduced water availability, due to the combined effects of water extraction from catchments, regional decline in rainfall over the past 30 years and the impacts of severe drought conditions from 2000 to 2010. Seasonal flows in 2014 and 2015 in many streams supported improved canopy condition at most sites. The level of insect attack in 2014 and 2015 was minimal, so this was not inhibiting canopy growth or affecting condition, except in a localized area near Clare which suffered a sustained severe lerp attack which decimated foliage.

The lack of any germination events is attributed primarily to weed competition in riparian zones, and competition with reeds in watercourses. Good fruit crops have been present in the last three seasons, so sufficient seed is present in the landscape and there have been rainfall events and stream flows which potentially could have triggered and supported germination. There have not been any instances found of germination which has been grazed off by stock, and only a very few isolated seedlings have been found on road and stream edges.

Seasonal flows occurred in 2015 at many locations, with water still flowing to the lower Broughton in early September 2015 (Figure 26). However, as noted in 2014, the lack of water monitoring stations means that these events are not recorded in the water data network, and it is recommended that additional monitoring be implemented, along with a program of citizen science to capture the knowledge of local community members.

In addition to action to stimulate regeneration, a general solution is recommended, by including river red gums in a broadscale revegetation target of 20% native vegetation, using a mixture of trees, bushes and groundcover and targeting roadsides, council reserves, fencelines and riparian zones. Red gums should be included in all appropriate locations, especially iparian sites. Funding could be sought for a package of actions for management of sustainable landscapes, incorporating the 20:80 landscapes vision proposal together with the proposals for improved water data instrumentation, leading to improvement of regional red gum recruitment and health.

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Appendix 1 Monitoring Site Locations

NORTHERN & YORKE RIVER RED GUM MONITORING: BROUGHTON CATCHMENT					
Reach	**Site No**	**grid (GPS waypoint)**	**Photos**	**Directions**	**Subject**
Broughton Catchment: Crystal Brook upstream towards Brookman Park, Crystal Brook in Beetaloo Valley					
	BR001*	0242994 6314046 (8)	1	Crystal Brook Valley Road (upstream of town), north from	healthy trees, regeneration
	BR004	0242057 6308189 (7)	1	Crystal Brook Valley Road, view along escarpment from	stressed trees
	BR005	0241921 6317796 (11)	1	Tributary to Beetaloo Creek, at ford on Beetaloo Valley	stressed tributary creek
	BR006	0241801 6318953 (13)	1	Tributary to Beetaloo Creek, at ford on Beetaloo Valley	healthy tributary creek
Broughton Catchment: Rocky River upstream to Appila Springs (Crystal Brook to Gladstone, Laura, Wirrabara, Appila)					
	BR007a		1	Rocky River pool, Threadgolds Crossing	mature trees, no regeneration
	BR007	0252530 6316215 (20)	2	Rocky River floodplain (upstream & downstream)	mature trees, regeneration
	BR008*	0247542 6330696 (23)	3	Rocky River opposite Laura Golf Club, ford on side road	reported fertilizer impact, stress
	BR009	0252968 6341333 (27)	2	Rocky River Creek (upstream & downstream), at ford	regeneration
	BR009a		1	Rocky River, upstream of Wirrabara	weed removal
	BR010	0260620 6341791 (28)	2	Appila Creek (upstream & downstream), at road bridge	erosion impact, regeneration
	BR011	0264572 6345581 (29)	1	Appila Springs, looking south-west	stressed trees, healthy riparian
Broughton Catchment: Lower Broughton River downstream to Lower Broughton (Crystal Brook west to Lower Broughton)					
	BR012	0239300 6306776 (90)	1	Crystal Brook, entrance to Golf Club (under railway	stressed mature, no regeneration
	BR013*	0231301 630581 (91)	1	Crystal Brook, ford on Frith Road from floodway sign	stressed floodplain
	BR015	0238770 6306598 (139)	1	Butler Bridge, Old Broughton Road	lower reach, mild stress
	BR016	0774311 6310907 (93)	1	Broughton River floodplain, Lower Broughton Road	floodout zone, Cassytha vines
Broughton Catchment: Mid-Broughton River, upstream to Hutt River tributaries (Crystal Brook to Merriton, Red Hill, Koolunga, Yacka Spalding,					
	BR017	0235172 6297097 (99)	1	Broughton River at old Merriton Bridge on Highway 1	healthy trees, regeneration
	BR020*	0258314 6280119 (105)	1	Broughton River, White Cliff Corner Crossing, Yacka	regeneration
	BR021	0277335 6289633 (110)	1	Broughton River (old bridge on Spalding to Clare Road)	limited regeneration
	BR022	0276650 6266317 (111)	2	Hutt River (Cornwall Rd at culvert)	regeneration, overgrazing
	BR023	0276645 6255238 (113)	2	Armagh Creek (St George Terrace at culvert)	weeds, gorse, regeneration
	BR024*	0279657 6249974 (115)	1	Hutt Creek (Spring Gully Road at culvert)	weeds, broom

Table 1 Monitoring Sites in Broughton Catchment

NORTHERN & YORKE RIVER RED GUM MONITORING: MAMBRAY COAST CATCHMENT					
Reach	**Site No**	**grid (GPS waypoint)**	**Photos**	**Directions**	**Subject**
Mambray Coast Catchment: north to south tributaries					
	MB003*	0781010 6387247 (83)	1	Horrocks Creek ford (track off Horrocks Pass road, Nectar Brook Road)	mildly stressed creekline
	MB004	0780736 6384704 (84)	1	Tattiwa Creek (side view from track, Nectar Brook Road)	mildly stressed creekline
	MB005	0777252 6378587 (85)	1	Nectar Brook (view from track near homestead, Nectar Brook Road)	healthy creekline, regeneration
	MB006*	0778429 6364847 (86)	1	Mt Gullet Creek (side track at creek crossing east of Highway 1)	relatively healthy creekline
	MB007*	0779128 6361788 (87)	1	Mambray Creek at railway line (parking area east of Highway 1)	very stressed floodplain
	MB008	0775876 6360990 (134)	1	Mambray Creek downstream reach (Spencer Road west 3 km of Highway 1, gate at corner of Colin Mudge Road)	downstream floodout zone, stressed floodplain
	MB010*	0228158 6341893 (97)	1	Telowie Creek road crossing on Top Track, south of Telowie Gorge park entrance track	medium stress in creekline
	MB011	0228820 6338114 (96)	2	North End Well Creek, upstream and downstream from ford on Top Track	very stressed creekline
	MB012	0224147 6337748 (138)	1	Telowie Creek downstream reach, Noel Smith Road 1 km east of Highway 1 at ford	very stressed floodplain

*= special sites for intensive tree monitoring

Table 2 Monitoring Sites in Mambray Catchment

NORTHERN & YORKE RIVER RED GUM MONITORING: WAKEFIELD CATCHMENT					
Reach	**Site No**	**grid (GPS waypoint)**	**Photos**	**Directions**	**Subject**
Wakefield Catchment: Skillogalee Valley					
	WK001*	0280530 6243341 (117)	1	Upper Skillogalee Creek, from Upper Skilly Road	sheep grazing, no riparian zone
	WK002*	0281037 6237498 (119)	1	Upper Skillogalee Creek, from Upper Skilly Road	cattle grazing, contours
	WK003	0280871 6234706 (121)	1	Lower Skillogalee Creek, from Lower Skilly Road	regeneration, grazing
Wakefield Catchment: Lower Wakefield Valley					
	WK004	0280150 6223400 (122)	1	Wakefield River (junction of Nyowee & Rhynie to Balaklava Roads, from road)	healthy trees, permanent pool
	WK005	0266081 6218367 (123)	1	Wakefield River (Whitings Ford), from track south of ford	stressed trees
	WK006a		1	Wakefield River downstream of Balaklava	healthy trees, weeds
	WK006*	0258366 6221880 (124)	1	Wakefield River (Werocata Rd between Balaklava & Whitwarta, from north of ford)	stressed trees, recovery
	WK007	0256349 6223625 (125)	1	Wakefield River (from Rifle Range Road near Whitwarta cemetery)	stressed trees
	WK008*	0254544 622978 (126)	1	Wakefield River (old bridge at Whitwarta)	healthy trees
	WK009	0252484 6222363 (127)	1	Wakefield River (distant view to river from Angels Road)	stressed trees, possible salinity
	WK010	0247373 6217653 (129)	1	Wakefield River (upstream from old bridge north of Bowmans on Bowmans Beaufort Road)	stressed trees, weeds

* = special sites for intensive tree monitoring

Table 3 Monitoring Sites in Wakefield Catchment

NORTHERN & YORKE RIVER RED GUM MONITORING: WILLOCHRA CATCHMENT					
Reach	**Site No**	**grid (GPS waypoint)**	**Photos**	**Directions**	**Subject**
Willochra Catchment: Melrose Loop -- Campbell Creek, Wild Dog Creek, Willochra Creek					
	WL001	0235631 6359500 (39)	1	Peach Tree Hill, Melrose – Pt Germein Road	mature trees, no regeneration
	WL001a*		1	Mt Remarkable Creek	native woodland, creek
	WL004	0241692 6355110 (46)	1	Wild Dog Creek	floodbank blocking flows
	WL005*	0241777 6356582 (47)	1	Wild Dog Creek	stressed mature, regeneration
	WL006a*		1	Willochra Creek	grazed riparian, mature trees
	WL006*	0238552 6367619 (51)	1	Willochra Creek	very stressed, 2007 recovery
Willochra Catchment: Willochra Creek --Booleroo Whim Creek to Beautiful Valley Creek					
	WL008*	0250269 6369636 (53)	1	Booleroo Whim Creek (from south)	very stressed, 2007 recovery
	WL009*	0239908 6369771 (54)	1	Willochra Creek	medium stress in creekline
	WL011*	0239294 6379223 (58)	1	Spring Creek	stressed floodout zone
	WL012	0236025 6389275 (61)	1	Beautiful Valley Creek	stressed creekline

* = special sites for intensive tree monitoring

Table 4 Monitoring Sites in Willochra Catchment

Appendix 2 New Monitoring Site Locations 2013-2015

NORTHERN & YORKE RIVER RED GUM MONITORING						
Reach	**Site No**	**grid (GPS waypoint)**	**No of Photos**	**Directions**	**Subject**	**Date**
Broughton Catchment: Rocky River mid-valley, upstream of Crystal Brook						
	BR007a*		1	Thredgold Crossing	die-back, insects	2013
Broughton Catchment: Rocky River upstream to Appila Springs (Crystal Brook to Gladstone, Laura, Wirrabara, Appila)						
	BR009a*		2	Wirrabara Creek (Pilmore)	removal of weeds	2013
	BR011*		1	Appila Springs, looking south-west	stressed trees, no regeneration	2013
	BR018a		1	Broughton River, Redhill, opposite hotel	regeneration, pool, Broughton willow	2013
	BR019a		1	Broughton River, Koolunga – Hope Crossing	regeneration, reeds	2013
Wakefield Catchment: Wakefield River Valley						
	WK003a*		1	Wakefield River, Mintaro (Riley Road Reserve)	planted trees, reserve, weeds	2014
	WK003b*		2	Wakefield River, Mintaro (Hare Road)	remnant mature riparian trees	2014
	WK003c		3	Wakefield River, Mintaro (Holm Park)	weeds, healthy trees	2015
	WK004a*		1	Wakefield River, Auburn (Agostino)	weeds, healthy trees	2013
	WK004b		2	Wakefield River Auburn (Vandeleur)	bare riparian zone, red gum planting	2014
	WK004c		1	Wakefield River, Auburn (Taylors)	fenced riparian zone	2015
	WK004d		1	Wakefield River, Auburn (river walk)	introduced species, mature red gums	2015
	WK004e		2	Wakefield River, Auburn (Saddleworth bridge)	mature red gums, weeds	2015
	WK004f		2	Wakefield River, Auburn (Undalya bridge)	reedbeds	2015
	WK005a		3	Wakefield River, The Rocks (McInerny)	regeneration, reeds	2015
	WK005b*		3	Wakefield River, Whiting Ford (Shepherd)	mature red gums, river bed	2015
	WK006a*		1	Wakefield River, Balaklava (Fisher)	weeds, healthy trees	2013
Willochra Catchment: Upper Willochra Valley						
	WL001a*		2	Mt Remarkable Creek, Melrose (NP)	conservation site, insects	2013
	WL001b*		1	Campbell Creek, Melrose (Lello)	grazed riparian	2013
	WL001c*		1	Melrose	weeds, riparian zone	2015
	WL006a*		1	Willochra Creek, Melrose (McCallum)	grazed riparian	2014
	WL011a*		1	Spring Creek, Pilliga Road	grazed mature woodland	2015

* = special sites for intensive tree monitoring

Appendix 3 Field Guidelines for Scoring Site Condition

QUICK GUIDELINES FOR SCORING SHEET D

Chance Of Decline	5	4	3	2	1	0
Past Die-Back	0%	<25%	25-50%	50-75%	>75%	100%
Recovery	100%	>75%	50-75%	25-50%	<25%	0%
% Dead Trees	0%	<25%	25-50%	50-75%	>75%	100%
% Stag Ends	0%	<25%	25-50%	50-75%	>75%	100%

Chance Of Recovery	5	4	3	2	1	0
Regeneration	--	VH	H	M	L (few)	0
Multiple Ages	--	4	3	2	1	0
Riparian	--	--	H	M	L (few)	0
% Healthy Trees	100%	>75%	50-75%	25-50%	<25%	0%
% Epicormic Growth	0%	<25%	25-50%	50-75%	>75%	100%

QUICK GUIDELINES FOR SCORING CANOPY CONDITION ON SHEET F

Condition	Indicators	Score
Healthy	Intact without die-back or epicormic growth	4
Low Stress	<10% of canopy died back	3
Medium Stress	10-33% of canopy died back	2
High Stress	33-66% of canopy died back	1
Extreme Stress	>66% of canopy died back	0

DIE-BACK = branches or branchlets without full leaf cover, exposed bare branches (stag ends), dead branches

CONVERSION OF EPICORMIC SCORES ON SHEET F

% Epicormic Growth In Canopy	Score
100	0
80-90	1
60-70	2
40-50	3
20-30	4
0-10	5

Appendix 4 Site Condition Scores for Four Catchments Sites (2013-2015)