Review of historical subsidence areas and impacts on vegetation

Ulan West Extension EPBC Referral

Prepared for
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Cover photo	Clockwise from top: Ironbark Open Forest Complex (x 2); Ironbark Cypress canopy; E. dwyeri in flower. Photo credit: Sarah Dickson-Hoyle

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Abbreviations

Abbreviation	Description
CEEC	Critically Endangered Ecological Community
EPBC Act	*Environmental Protection and Biodiversity Conservation Act 1999*
ELA	Eco Logical Australia
HSD	Honest significant difference (Tukeys test)
UCML	Ulan Coal Mines Limited

1 Introduction

Eco Logical Australia (ELA) was engaged by Ulan Coal Mines Limited (UCML) to undertake a detailed study of remnant forest and woodland vegetation above previously mined longwalls.

This study was required in response to further information requested by the Department of the Environment (DotE) for the Ulan West Extension *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC) Referral regarding potential degradation or destruction of the *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland*, a Critically Endangered Ecological Community (CEEC) listed under the EPBC Act.

This report presents the results of a study comparing vegetation structure, health and associated habitat values above three mined longwall panels and a related control (non-subsided area). The longwall panels were selected to represent a wide time span (1, 10 and 20 years) to help understand if there were any notable recovery or decline trajectories in vegetation condition following longwall mine subsidence.

The results of this study will inform an assessment of whether there is a difference in variables measured in vegetation communities and habitat values between subsided and non-subsided areas and over a range of timescales.

1.1 Previous Studies

ELA in collaboration with UCML developed a multi-temporal multi-data source method to quantify the impacts of longwall mine subsidence on native vegetation over the Ulan Underground No. 3 mine West 1 and West 2 longwall areas, north-east of Mudgee (Eco Logical Australia, 2011).

Analysis was conducted using a combination of remotely sensed data (LiDAR and satellite imagery), directed field survey and rigorous statistical analysis.

A multiple dataset approach was undertaken assessing key vegetation parameters available from LiDAR data, high resolution satellite imagery and field survey. Both the LiDAR data and satellite imagery were captured at two separate times permitting before and after subsidence comparison with the LiDAR data and post subsidence 'lag effect' comparisons with the satellite imagery. Impact zones were mapped using surveyed results to derive areas of maximum subsidence (longwall) and maximum change in slope (transition) as well as areas of little subsidence (pillar) and assumed no subsidence (control). For the remote sensing analysis variability from different vegetation communities was accounted for by comparing change in condition parameters between the two capture dates and by selecting proportionally based on the area of a particular vegetation community within each zone. Field survey was confined to three impact and one control zone within the Ironbark Open Forest Complex. All data were compared using robust statistical comparison techniques. In addition the remotely sensed data were assessed using visual assessment techniques.

Results showed that subsidence generally occurred as predicted with maximum subsidence up to 1.5 metres (m) occurring in the centre of the longwall panels, maximum change in slope occurring in the transition areas and greatly reduced or no subsidence in the pillar and control areas.

Field data from all zones were compared via single factor ANOVA. In general there were no significant differences between any of the samples with the exception of the percent foliar cover where the control sample had significantly less cover than the pillar sample. This result is considered an artefact of either the relatively small sample size and/or natural variability within woodland communities as it is unlikely that subsidence had such as significant positive effect on the foliar density within the pillar impact area in the 2 year time period.

Comparison of all impact zones showed no significant negative differences in any zone at any time with any dataset. In no case did the vegetation condition in the control area exceed that shown within the impact zones. Visual assessment confirmed this statistical comparison as no trends in changed vegetation condition could be seen on any of the datasets.

2 Methods

2.1 Study area

The Ulan Coal Complex straddles the Great Dividing Range and is located at the headwaters of the Goulburn River catchment (draining to the east) and the Talbragar River catchment (draining to the west) (Umwelt 2009). The study area is located within the Goulburn River catchment and is characterised by transitional rocky uplands with gentle to medium slopes of less than 10 per cent.

The Ulan Coal Complex is at the western limit of the Sydney Basin geological formation and at the southern end of the Gunnedah Sub-basin. Ten coal seams occur within the Permian Coal Measures, ranging in thickness from approximately 0.4 to 10 m (Umwelt 2009).

Vegetation mapping of the Ulan Coal Complex has occurred previously as part of the Environmental Assessment undertaken for the Ulan Coal Continued Operations Project (Umwelt, 2009). Desktop analysis of this mapping indicated that while there is 413 ha (Umwelt 2009) of *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland* CEEC present throughout the Ulan Coal Complex, the majority of this is located in areas that have not been subject to subsidence. No CEEC was present above 20 year longwalls. The limited areas of CEEC mapped above subsided longwalls occur as either highly fragmented patches, or in grassland formation; the latter of which would have precluded assessments of woodland condition, canopy health or habitat value. As such, it was determined that there was insufficient extent of CEEC above the targeted longwalls to allow for a statistically valid study to be undertaken as per the request of DotE.

Ironbark Open Forest Complex on Sandstone was found to be the most extensive vegetation community (4,160 ha of a total of 13,435 ha (Umwelt, 2009)), and is present across all target longwalls (**Table 2-1** to **Table 2-3; Figure 2** and **Figure 3**). Ironbark Open Forest Complex on Sandstone is also the dominant vegetation community in the referral area (48.7 % of referral area). Given this extent, and the limitations in assessing CEEC as described above and the similarity between potential impacts of subsidence upon on the CEEC and surrounding vegetation, Ironbark Open Forest Complex on Sandstone was identified as being the most appropriate vegetation community within which to assess the impacts of subsidence on native forest and woodland vegetation within the study area.

A description of the Ironbark Open Forest Complex on Sandstone is found in **Appendix A**.

Table 2-1: Vegetation communities and their corresponding areas above 1 year longwall (LW27)

Vegetation community	Area (ha)
Ironbark Open Forest Complex on Sandstone	29.94
Rough-barked Apple Open Forest on Alluvium/Colluvium	18.12
White Box Woodland Grassland	15.87
Unimproved Pasture	12.73
Derived Native Grassland	8.81
Improved Pasture	7.71
Modified White Box Woodland	5.65
Rough-barked Apple Open Forest on Alluvium/Colluvium (regenerating)	0.97
Yellow Box - Red Gum Woodland	0.00
Total area	**99.81**

Table 2-2: Vegetation communities and their corresponding areas above 10 year longwall (LW22)

Vegetation community	Area (ha)
Ironbark Open Forest Complex on Sandstone	28.64
Modified White Box Woodland	12.61
Stringybark-Ironbark Open Forest on Sandstone Slopes	7.80
Blakely's Red Gum Open Forest	7.70
Derived Native Grassland	7.64
Improved Pasture	2.82
Rough-barked Apple Open Forest on Alluvium/Colluvium	1.03
Ironbark Open Forest Complex Grassland	0.14
Derived Native Grassland	0.11
Box Woodland	0.02
Total area	**68.50**

Table 2-3: Vegetation communities and their corresponding areas above 20 year longwall (LW08)

Vegetation community	Area (ha)
Scribbly Gum Woodland – Heathland on Sand Plateaux	37.39
Ironbark Open Forest Complex on Sandstone	11.32
Stringybark-Ironbark Open Forest on Sandstone Slopes	4.32
Black Cypress Forest on Sandstone	2.91
Rough-barked Apple Open Forest on Alluvium/Colluvium	2.90
Narrow-leaved Ironbark Open Forest on Alluvium/Colluvium	2.22
Total area	**61.07**

2.2 Experimental design

The study was designed as a Control-Impact study to compare the control sites (areas not within the subsidence footprint) with impact sites (areas that have been previously subsided) subsided over a range of timescales. No Before-After comparisons were possible as before subsidence data of sufficient detail are not available.

2.2.1 Impact Hypothesis

The impact hypothesis used for this study was that subsidence as a result of longwall mining activities has a detrimental impact on the condition of native vegetation communities and habitat values.

2.2.2 Site stratification and sampling design

Longwalls that had been previously mined were targeted for field survey, in addition to control sites located within the targeted vegetation community outside of the subsidence areas (**Figure 1 to Figure 3**).

Original discussion with UCML placed impact sites above longwalls that had been mined 1, 5 and 10 years previously. Further discussion with DotE and UCML relocated these sites into longwall panels that had been mined 1, 10 and 20 years previously (**Figure 1**). The longwalls surveyed, years since mining and summary of subsidence are shown in **Table 2-4**.

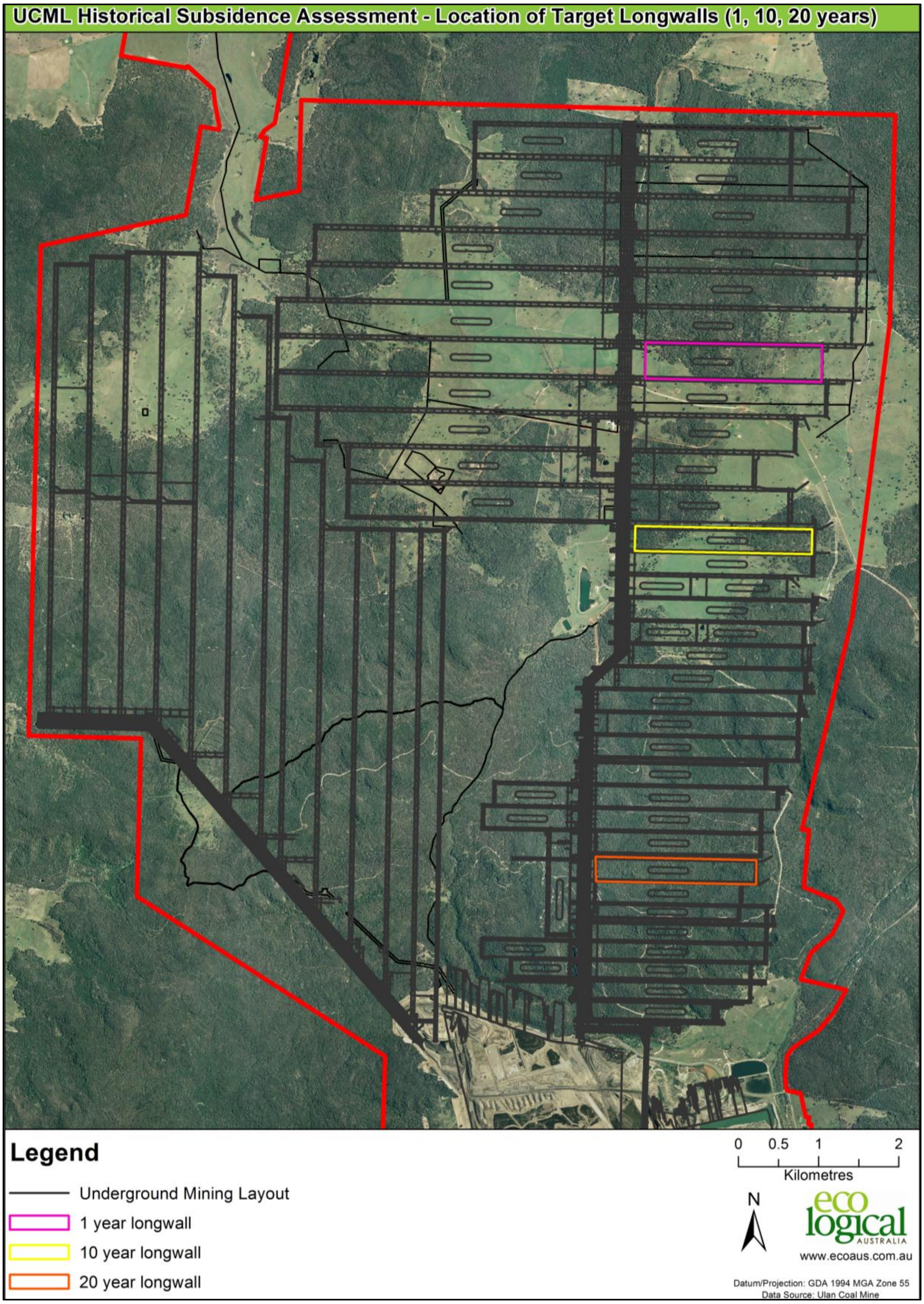

Figure 1: Overview of longwall panels studied

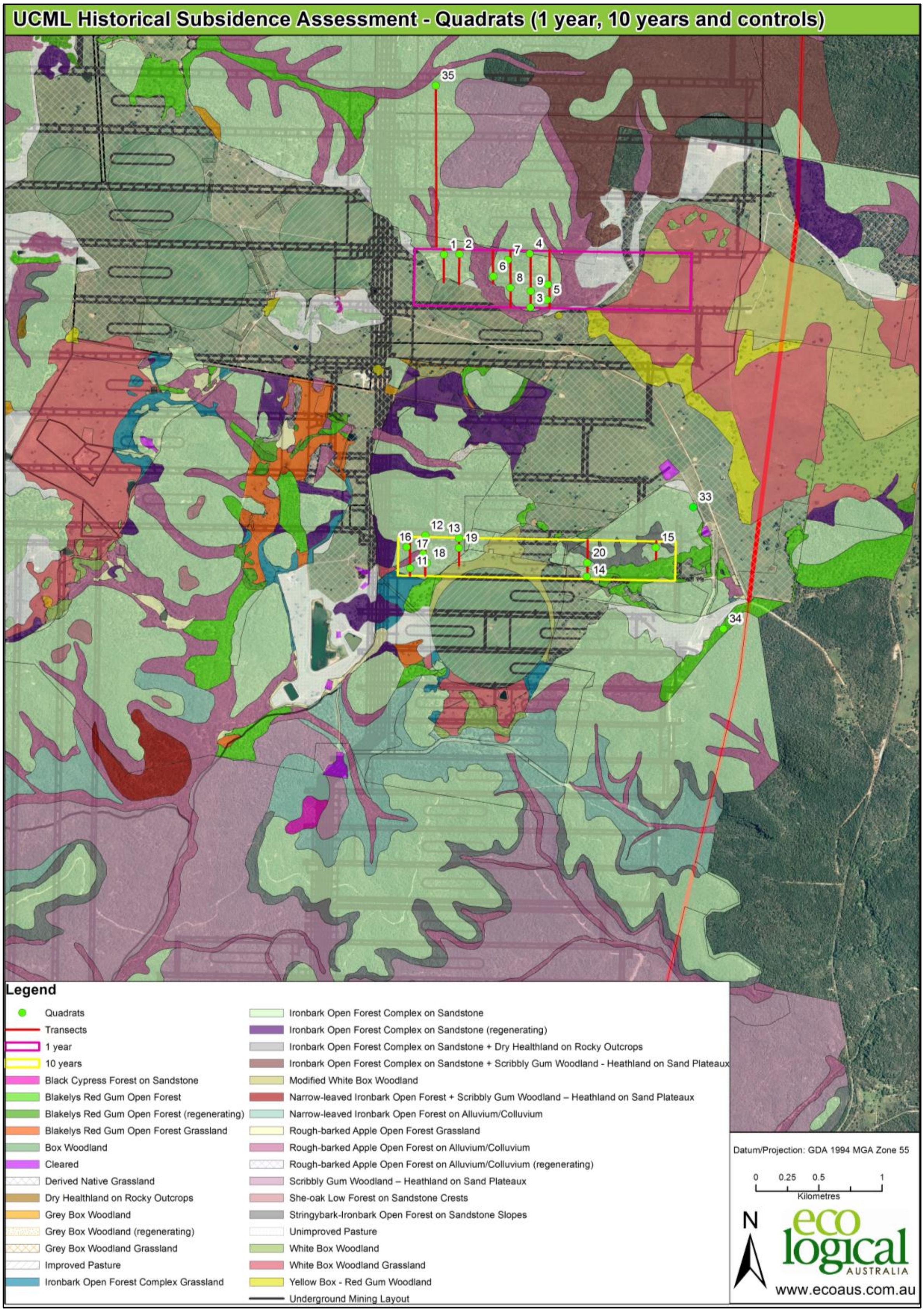

Figure 2: Location of quadrats & transects – Years 1 & 10

Figure 3: Location of quadrats & transects – Year 20

Table 2-4: Longwalls surveyed and summary of subsidence

Longwall	27	22	8
Years since mining	1	10	20
Depth (m)	253 to 276	220 to 285	160
Maximum subsidence (m)	1.47	0.8	1.0
Goaf edge subsidence (mm)	290	not known	87
Angle of draw (°)	45	not known	29
Maximum tilt (mm/m)	13	10	15
Maximum strain (mm/m)	3.1	3	9
Horizontal displacement (mm)	600	100	300

Each longwall panel surveyed varied in width and was separated into 3 ‘impact zones’ (longwall, transition and pillar). The pillar zone is located between each longwall panel in an area where longwall mining does not occur, therefore with only minor subsidence occurring. The transition zone was determined to be from the centre of the pillar to approximately 75 m into the panel. The longwall zone is located within the centre of the panel and varies in width, depending on the width of the panel.

The location of transects were identified through desktop analysis of the Ulan Underground #3 mine plan and the mapped vegetation communities. Transect locations were identified in each zone at random sites.

Quadrat locations were designed to be randomly spaced along each transect, with a minimum of 50 m between each site and a minimum of 10 m from each site to the mapped boundary of the target vegetation community. A total of 35 quadrats were identified for survey in order to allow sufficient data to be collected to make a statistical interpretation of the results. These included:

- Five quadrats in each longwall zone
- Five quadrats in each transition zone
- Five quadrats in control sites.

There were no quadrats placed within the pillar zone due to the minor nature of subsidence that may occur in this zone.

2.3 Field survey

The field survey was undertaken over four days by ELA ecologists David Allworth and Sarah Dickson-Hoyle on the 24 to 29 September 2015, with one additional site surveyed on the 1 October 2015. Additional field survey assistance was provided by Tom Frankham of UCML. A summary of the ELA field staff qualifications and experience is outlined in **Appendix A**.

Weather conditions during the field survey showed temperatures ranging from 0.5 to 24.3 degrees Celsius (Bureau of Meteorology, 2015). There was no rainfall recorded during the period of the field survey.

In the field, the location of each quadrat (identified via desktop analysis) was validated to ensure sites were located within the appropriate vegetation communities and geological formations. Sites were located in areas with Triassic and Jurassic sandstone geology, and where vegetation was dominated by one or more of *Eucalyptus fibrosa* (Broad-leaved Ironbark), *Eucalyptus agglomerata* (Blue-leaved Stringybark), *Eucalyptus crebra* (Ironbark) and/or *Eucalyptus sparsifolia* (Stringybark) in varying combinations.

At each site a 20 m x 20 m quadrat was established, with the north-west corner of the quadrat positioned at the intended site coordinates (locations adjusted in field where necessary, as outlined above).

Photographs were taken across each quadrat, and of the canopy at each corner. A general site description was recorded for each quadrat, including a description of the geology, soils, landscape position and vegetation community, as well as any observation of disturbance (historical or current) or evidence of management actions.

The following data were recorded for each quadrat:

Canopy health and defoliation (all in 5% increments) (adapted from DSE 2012):

- Percentage of epicormic foliage in relation to total tree foliage;
- Proportion of primary branches within canopy that have died back;
- Percentage of current canopy foliage as a proportion of the estimated canopy foliage volume/potential canopy; and
- Percentage of canopy foliage discoloured.

Vegetation structure:

- Projected foliage cover (PFC – 1-5% then 5% increments) of native grass/ground cover; native shrubs <1 m height; native shrubs/small trees >1 m height;
- PFC (5% increments) of upper canopy (assessed at each quadrat corner and averaged);
- Exotic species
- Number of stags, estimated time since and cause of death;
- Lower, estimated median and upper height of canopy (m);
- Lower, estimated median and upper diameter at breast height (DBH) over bark of canopy stems (cm); and
- Abundance of each canopy species (identified to species level); calculated total stems per hectare.

Habitat features:

- Length of fallen logs > 10cm diameter (0.5 m increments); and
- Number of hollow-bearing trees and stags (hollows > 5 cm diameter);

2.4 Data analysis

Data was analysed separately for health, structure and habitat, with health as key indicator of subsidence related impacts/overall vegetation community health.

Data was tested for normality using the Shapiro-Wilk test. Where data was not normally distributed, log transformations were used. A one way analysis of variables (ANOVA) design was used to assess whether there were significant changes between control and impact sites, and between longwall panel zones, as field data was collected at 1 point in time.

The null hypothesis for the comparison was that all sites and all longwall panel zones were the same and that any differences were the result of subsidence impacts. Where the P factor was <0.05, a Tukey's honest significant difference (HSD) Test was undertaken to determine the differences amongst means for the variable.

2.5 Limitations

The area has a history of multiple land use and disturbance types. Much of the area has undergone historical logging, clearing for agriculture or fire. These disturbances have resulted in changes to the structure of the vegetation surveyed, and present potential indirect effects on other variables examined within this study.

3 Results

3.1 Field Observations

Field-based expert evaluation showed no clear difference in tree health between control and impact sites

There was evidence of clearing, selective logging and/or fire in the majority of areas surveyed indicating that these areas have been subject to historical disturbances.

Across the entire study area the canopies of Stringybark individuals present within the survey area were seen to be healthier than Ironbark or *Angophora floribunda* species (the latter observed within the broader Ulan Coal Complex). Extensive branch dieback and sparse canopies were seen in Narrow-leaved Ironbark and Broad-leaved Ironbark individuals, as well as *Angophora floribunda*. Signs of tree stress have been observed within these species throughout the Mudgee region recently. Investigations have been undertaken in areas of *A. floribunda* dieback within the Ulan Coal Complex, however results of soil analysis show no evidence of fungal pathogens and the cause is still unknown. Signs of tree stress were considered to be more extensive and pronounced within all sites surveyed at UCML as part of this study. These signs of stress were found in both control and impact sites.

The canopies of Ironbark individuals were observed to have signs of dieback and evidence of defoliation with up to 50% canopy loss in some trees assessed. There was evidence of psyllids within vegetation surveyed in LW 8. However, these may not be the primary or sole cause of the decline in canopy health within these areas as trees are generally more susceptible to infestation when a tree is in a stressed condition. The canopies of Stringybark trees were largely considered to be at full health.

3.2 Statistical analysis of field data

Field data from all sites and zones was compared via single factor ANOVA. Data were compared between each longwall and the control area (**Table 3-1** and **Table 3-3**) and between each zone within each longwall and the control area (**Table 3-2**). In general there were no significant differences between any of the samples. Where a P-value was less than 0.05 a difference was considered to be significant.

A significant difference was observed between sites for the PFC of native shrubs <1 m and > 1 m between sites as shown in **Table 3-3** as a green highlight. A Tukey’s HSD Test was undertaken for each of these variables. The results of the Tukey’s HSD Test are shown as a superscript letter above each of the means for the variables tested. Where a result shares a superscript letter, the result is not considered to be significantly different. Where results do not share a superscript letter, the results are considered to be significantly different. The results for PFC for native shrubs < 1 metre showed that for the Control, Year 10 and Year 20 sites the results were not statistically different. The results also showed that for the Control, Year 1 and Year 20 sites the results were not statistically different. However, between Year 1 and Year 10 sites the results showed that the PFC for native shrubs < 1 m were statistically different.

The results for PFC for native shrubs > 1 m showed that the results for Year 20 were statistically different from all other years. The results for all other years were not statistically different.

Table 3-1 - Health results between years since mining, regardless of impact zone.

Health parameter (%)	Summary Statistic	Years since mining			
		Control	1	10	20
Epicormic foliage	Min	0.0	0.0	0.0	5.0
	Max	25.0	40.0	5.0	10.0
	Mean	8.0	8.0	4.5	5.5
	P-value	**0.3304**			
Branch dieback	Min	0.0	5.0	0.0	5.0
	Max	15.0	15.0	20.0	20.0
	Mean	6.0	6.0	9.0	9.0
	P-value	**0.0903**			
Canopy foliage	Min	70.0	50.0	65.0	50.0
	Max	95.0	95.0	95.0	95.0
	Mean	87.0	77.5	82.0	77.0
	P-value	**0.4837**			
Discolouration	Min	0.0	0.0	0.0	0.0
	Max	5.0	10.0	5.0	30.0
	Mean	2.0	4.0	3.0	8.0
	P-value	**0.1400**			

Table 3-2 - Health results between impact zones and years since mining.

Health parameter (%)	Summary Statistic	Years since mining								
		1			10			20		
		Control	Transition	Longwall	Control	Transition	Longwall	Control	Transition	Longwall
Epicormic foliage	Min	0.0	5.0	0.0	0.0	0.0	5.0	0.0	5.0	5.0
	Max	25.0	40.0	5.0	25.0	5.0	5.0	25.0	5.0	10.0
	Mean	8.0	13.0	3.0	8.0	4.0	5.0	8.0	5.0	6.0
	P-value	**0.6195**			**0.3541**			**0.4488**		
Branch dieback	Min	0.0	5.0	5.0	0.0	0.0	5.0	0.0	5.0	5.0
	Max	25.0	15.0	5.0	25.0	20.0	15.0	25.0	15.0	20.0
	Mean	6.0	7.0	5.0	6.0	7.0	11.0	6.0	8.0	10.0
	P-value	**0.1716**			**0.4687**			**0.8536**		
Canopy foliage	Min	70.0	50.0	60.0	70.0	75.0	65.0	70.0	75.0	50.0
	Max	95.0	95.0	90.0	95.0	95.0	85.0	95.0	95.0	95.0
	Mean	87.0	73.0	82.0	87.0	87.0	77.0	87.0	82.0	72.0
	P-value	**0.289**			**0.1886**			**0.2413**		
Discolouration	Min	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0
	Max	5.0	10.0	5.0	5.0	5.0	5.0	5.0	10.0	30.0
	Mean	2.0	5.0	3.0	2.0	2.0	4.0	2.0	5.0	11.0
	P-value	**0.6007**			**0.3966**			**0.6404**		

Table 3-3 - Parameter results between years since mining, regardless of impact zone.

Parameter		Summary Statistic	Years since mining			
			Control	1	10	20
PFC - 1-5% then 5% increments	Native grass/groundcover	Min	1.00	1.00	1.00	1.00
		Max	15.00	15.00	75.00	4.00
		Mean	6.00	8.40	14.70	2.30
		P-value	**0.0967**			
	Native shrubs <1 m	Min	1.00	1.00	2.00	2.00
		Max	5.00	10.00	25.00	10.00
		Mean	2.60^{AB}	2.70^{B}	8.60^{A}	5.50^{AB}
		P-value	**0.0065**			
	Native shrubs >1 m	Min	1.00	1.00	0.00	3.00
		Max	10.00	10.00	10.00	25.00
		Mean	5.00^{B}	4.80^{B}	1.67^{B}	14.80^{A}
		P-value	**0.0000**			
	Exotics	Min	0.00	0.00	0.00	0.00
		Max	0.00	1.00	10.00	0.00
		Mean	0.00	0.20	1.90	0.00
		P-value	**0.4298**			
	Average Canopy	Min	1.00	1.00	1.25	3.00
		Max	5.75	8.75	22.25	7.50
		Mean	3.40	4.03	6.86	5.65
		P-value	**0.1727**			
Abundance	Canopy species stems/ha	Min	100.00	25.00	75.00	100.00
		Max	300.00	250.00	675.00	375.00
		Mean	175.00	147.50	225.00	212.50
		P-value	**0.3320**			
Height of canopy (m)	Upper	Min	15.00	17.00	15.50	13.00
		Max	23.00	24.00	24.00	22.00
		Mean	19.60	19.35	18.50	17.00
		P-value	**0.1840**			
	Lower	Min	9.00	11.00	11.00	10.00
		Max	18.00	21.00	18.00	16.00
		Mean	13.60	15.75	14.70	12.50
		P-value	**0.0664**			
	Median	Min	12.00	13.00	8.00	12.00
		Max	22.00	21.00	21.00	18.00
		Mean	16.20	17.00	15.20	14.90
		P-value	**0.4727**			
Diameter at breast height (cm)	Upper DBH	Min	20.20	37.50	26.80	29.50
		Max	67.00	73.00	56.00	52.70
		Mean	55.70	50.30	43.71	44.40
		P-value	**0.1686**			
	Lower DBH	Min	11.70	14.20	13.50	10.80

Parameter		Summary Statistic	Years since mining			
			Control	1	10	20
		Max	38.00	55.00	35.00	23.10
		Mean	22.36	26.29	22.16	16.38
		P-value	**0.1422**			
	Median DBH	Min	16.00	19.00	15.00	11.00
		Max	53.00	55.00	36.00	40.00
		Mean	37.80	31.48	26.95	25.82
		P-value	**0.1701**			

Note: P>0/0.05 indicates no significant difference; where there is a significant difference cells have been shaded green

Note: Common superscript in mean row indicative of no significant difference between sites (p>0.05). All other variables are significantly different.

Table 3-4 - Health results between impacts zones and years since mining.

Parameter		Summary Statistic	Years since mining								
			1			10			20		
			Control	Transition	Longwall	Control	Transition	Longwall	Control	Transition	Longwall
PFC - 1-5% then 5% increments	Native grass/ ground cover	Min	1.00	1.00	3.00	1.00	1.00	3.00	1.00	1.00	2.00
		Max	20.00	15.00	15.00	15.00	75.00	20.00	15.00	4.00	3.00
		Mean	7.00	6.20	10.60	6.00	16.80	12.60	6.00	2.20	2.40
		P-value	**0.4045**			**0.366**			**0.4351**		
	Native shrubs <1 m	Min	1.00	1.00	1.00	1.00	2.00	2.00	1.00	3.00	2.00
		Max	5.00	3.00	10.00	5.00	25.00	15.00	5.00	10.00	10.00
		Mean	2.40	1.80	3.60	2.60	8.80	8.40	2.60	5.20	5.80
		P-value	**0.6679**			**0.135**			**0.1341**		
	Native shrubs >1 m	Min	1.00	1.00	2.00	1.00	0.00	0.00	1.00	5.00	3.00
		Max	10.00	10.00	10.00	10.00	2.00	10.00	10.00	25.00	25.00
		Mean	4.60	3.60	6.00	5.00	0.60	3.00	5.00	15.00	14.60
		P-value	**0.4463**			**0.4421**			**0.0599**		
	Exotics	Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Max	2.00	1.00	0.00	0.00	10.00	5.00	0.00	0.00	0.00
		Mean	0.40	0.40	0.00	0.00	2.40	1.40	0.00	0.00	0.00
		P-value	**0.5034**			**0.4088**			**N/A**		
	Average Canopy	Min	0.00	0.00	0.00	1.00	1.25	5.75	1.00	3.00	3.75
		Max	2.00	1.00	0.00	5.75	22.25	7.33	5.75	7.50	7.50
		Mean	0.40	0.40	0.00	3.40	7.15	6.57	3.40	5.60	5.70
		P-value	**0.3443**			**0.2903**			**0.1191**		
Abundance	Canopy species stems/ha	Min	1.00	1.00	1.75	100.00	75.00	75.00	100.00	100.00	125.00
		Max	6.75	4.75	8.75	300.00	375.00	675.00	300.00	300.00	375.00
		Mean	3.60	3.00	5.05	175.00	190.00	260.00	175.00	175.00	250.00
		P-value	**0.7356**			**0.8845**			**0.2877**		

Parameter		Summary Statistic	Years since mining								
			1			10			20		
			Control	Transition	Longwall	Control	Transition	Longwall	Control	Transition	Longwall
Height of canopy (m)	Upper	Min	100.00	75.00	25.00	15.00	15.50	16.00	15.00	13.00	14.00
		Max	300.00	250.00	225.00	23.00	20.00	24.00	23.00	22.00	20.00
		Mean	175.00	160.00	135.00	19.60	17.50	19.50	19.60	17.00	17.00
		P-value	**0.894**			**0.4237**			**0.3183**		
	Lower	Min	15.00	17.00	0.00	9.00	13.00	11.00	9.00	10.00	10.00
		Max	23.00	24.00	0.00	18.00	18.00	18.00	18.00	15.00	16.00
		Mean	19.60	19.70	0.00	13.60	14.80	14.60	13.60	11.80	13.20
		P-value	**0.5081**			**0.7574**			**0.5408**		
	Median	Min	9.00	11.00	11.00	12.00	8.00	12.00	12.00	12.00	13.00
		Max	18.00	18.00	21.00	22.00	18.00	21.00	22.00	18.00	18.00
		Mean	13.60	16.00	15.50	16.20	13.40	17.00	16.20	14.80	15.00
		P-value	**0.7737**			**0.2984**			**0.7194**		
Diameter at breast height (cm)	Upper DBH	Min	12.00	13.00	15.00	20.20	26.80	39.00	20.20	29.50	35.50
		Max	22.00	20.00	21.00	67.00	56.00	54.00	67.00	52.50	52.70
		Mean	16.20	16.40	17.60	55.70	41.12	46.30	55.70	44.68	44.12
		P-value	**0.6494**			**0.2732**			**0.3361**		
	Lower DBH	Min	11.70	15.80	14.20	11.70	15.00	13.50	11.70	10.80	11.80
		Max	38.00	49.40	55.00	38.00	34.60	35.00	38.00	22.80	23.10
		Mean	22.36	25.00	27.58	22.36	23.48	20.84	22.36	16.20	16.56
		P-value	**0.8749**			**0.8927**			**0.3712**		
	Median DBH	Min	16.00	19.00	23.00	16.00	19.50	15.00	16.00	11.00	21.50
		Max	53.00	50.00	55.00	53.00	36.00	35.00	53.00	40.00	32.00
		Mean	37.80	28.86	34.10	37.80	27.50	26.40	37.80	26.30	25.34
		P-value	**0.581**			**0.2126**			**0.2017**		

Table 3-5 – Habitat value results between years since mining, regardless of impact zone.

Parameter	Summary Statistic	Years since mining			
		Control	1	10	20
Length LWD (m)	Min	17.00	0.00	3.00	3.00
	Max	38.00	45.00	38.00	65.00
	Mean	24.80	17.20	23.85	27.11
	P-value	**0.4721**			
Number of hollow bearing trees	Min	0.00	0.00	0.00	0.00
	Max	4.00	1.00	2.00	2.00
	Mean	1.40	0.30	1.10	0.80
	P-value	**0.0975**			

Table 3-6 - Habitat value results between impacts zones and years since mining.

Parameter	Summary Statistic	Years since mining								
		1			10			20		
		Control	Transition	Longwall	Control	Transition	Longwall	Control	Transition	Longwall
Length LWD (m)	Min	17	7	0	17	3	23	17	10	3
	Max	38	45	29	38	34	38	38	40	65
	Mean	24.8	19.4	15	24.8	19.4	28.3	24.8	27.5	26.8
	P-value	**0.4754**			**0.3737**			**0.9709**		
Number of hollow bearing trees	Min	0	0	0	0	0	0	0	0	0
	Max	4	1	1	4	2	2	4	2	1
	Mean	1.4	0.4	0.2	1.4	0.8	1.4	1.4	1	0.6
	P-value	**0.432**			**0.8626**			**0.2519**		

4 Discussion & Conclusion

This project aimed to determine whether longwall mine subsidence has had an impact upon the condition of vegetation communities within the Ulan Underground No. 3 mine area. The field survey occurred within 3 previously mined longwall areas, and within 2 impact zones within those longwalls. Control sites were established in areas where underground mining had not been undertaken and where subsidence was not expected to occur. All data were analysed using statistical comparisons and qualitative assessment from experienced ecologists.

For the majority of woodland condition parameters assessed there was no significant difference between the longwalls and the control area or the longwall zones and the control area. Only the PFC of native shrubs (<1 m and >1 m) showed any statistical differences and in these cases the control area was either lower or similar to the other values.

Examination of the field results for the sites surveyed for Year 20 showed that there was a higher PFC of native shrubs > 1 metre recorded at these sites in comparison to the other longwalls surveyed. The conditions present at these sites supported the increased PFC seen for shrub species as there was evidence of fire present which would encourage shrub regeneration, and the sites were predominantly located on ridges with shallow sandy soils; a landscape position and substrate observed within the region to be associated with higher densities of shrub species.

The results for habitat values included as part of this study showed that there was no statistical difference for the parameters studied, and therefore no difference between the control and impacts sites surveyed.

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Appendix A Vegetation Community Description

A.1 Ironbark Open Forest Complex on Sandstone

Ironbark Open Forest Complex is typically a dry, mid-high to tall open forest-woodland, generally 10 to 18 metres tall (however only 6 metres on rocky sites), with 20 to 30 per cent cover. The community occurs on a variety of substrates ranging from sandy-loams and conglomerates to sands. Dominant canopy species include broad-leaved ironbark (*Eucalyptus fibrosa*), narrow-leaved stringybark (*E. sparsifolia*) and narrow-leaved ironbark (*E. crebra*). Other common canopy trees include blue-leaved stringybark (*E. agglomerata*), Dwyer's red gum (*E. dwyeri*), red stringybark (*E. macrorhyncha subsp. macrorhyncha*) and occasionally inland scribbly gum (*E. rossii*). Grey gum (*E. punctata*) is common in this community in the southern part of the proposed Ulan West mining area. Black cypress pine (*Callitris endlichen*), narrow-leaved wattle (*Acacia linearifolia*), and Allocasuarina gymnanthera are widespread in the canopy and sub-canopy of Ironbark Open forest Complex.

The understorey typically comprises a sparse to mid-dense sclerophyllous shrub stratum generally up to 2 metres in height with between 5 and 40 per cent cover, which becomes dense in small patches often on skeletal soils where trees are less dominant. Common and dominant shrubs recorded were blunt beard-health (*Leucopogon muticus*), *L. attenuatus*, pink five-corners (*Styphelia triflora*), narrow-leaved geebung (*Persoonia linearis*), *Goodenia hederacea* subsp. *Hederacea*, prickly shaggy pea (*Podolobium ilicifolium*), *Pultenaea cinerascens*, sifton bush (*Cassinia arcuate*), *C.* species *D, C. quinquefaria*, common fringe-myrtle (*Calytrix tetragona*), *Leptospermum parvifolium*, tantoon (*L. polygalifolium*), urn heath (*Melichrus urceolatus*), ruby urn heath (*M. erubescens*), *Melaleuca erubescens*, *Pultenaea laxiflor*a, vanish wattle (*Acacia verniciflua*), box-leaved wattle (Acacia buxifolia), *Platysace enricoides* and *Harmogia densifolia*.

The ground cover is typically dry and sparse to very sparse, with generally up to 10 per cent cover. A range of forbs, ferns and grasses characterise the community including poison rock fern (*Cheilanthes sieberi* subsp. *Sieberi*), *Phyllanthus hirtellus*, pomax (*Pomax umbellata*), *Hydrocotyle peduncularis*, *Pseudanthus divaricatissimus*, silky purple-flag (*Patersonia sericea*), orchids (*Caladenia* spp. and *Pterostylis* spp), blue flax lily (*Dianella revolute var. revolute*), threeawn speargrass (*Aristida vagans*), weeping grass (*Microlaena stipoides var. stipoides*), forest hedgehog grass (*Echinopogon ovatus*), purple burr-daisy (*Calotis cuneifolia*), Poranthera microphylla, Oxalis exilis, hairy stinkweed (*Opercularia hispida*), rough saw-sedge (*Gahnia aspera*), Lepidosperma laterale, wattle mat-rush (*Lomandra filiformis*), mat-rush (*L. confertifolia subsp. Pallida*), pale mat-rush (*L. glauca*) and many flowered mat-rush (*L. multiflora subsp. Multiflora*).

Ironbark Open Forest Complex is closely related to Stringybark – Ironbark Open Forest, with which it intergrades, particularly in slope positions and on shallow soils with a high percentage of sandstone outcropping. Ironbark Open Forest Complex is also closely related to She Oak Low Forest, the latter of which develops in areas that are often on level, crest positions. In many cases, small stands of She Oak Low Forest occur in Ironbark Open Forest Complex that are too small to be mapped separately. Species that characterise She Oak Low Forest also commonly occur in Ironbark Open Forest Complex.

Both Black cypress forest and Acacia Forest are closely related to Ironbark Open Forest complex. These two communities are relatively common within the Ulan Coal Complex (Umwelt, 2009a), but were not recorded within the proposed Ulan West mining area. Black cypress pine (*Callitris endlicheri*) is a common tree in the Ironbark Open Forest complex that sometimes occurs in small, monospecific stands within the Ironbark Open Forest Complex, which are too small to be mapped separately. Similarly, narrow-leaved wattle (*Acacia linearifolia*), which is characteristic and dominant tree in Acacia Forest, forms stands within Ironbark Open Forest Complex that are too small to be mapped separately as Acacia Forest.

Areas of sclerophyllous heath become dominant in the Ironbark Open Forest Complex where the tree stratum declines to a very sparse-absent level and, if present, are often in a mallee or stunted habit. These heaths are consistent with the Dry Heathland community but are too small and spatially entwined with Ironbark Open Forest Complex to be mapped separately.

Where the community occurs on low rises in the Bobadeen region which have been previously cleared and grazed, it occurs in a regenerating form. The floristic composition is similar to that of the mature and intact community however; the canopy is dominated by low trees or occasionally colonising shrub species.

Ironbark Open Forest Complex is the most widespread vegetation community in the proposed Ulan West mining area. It is a diverse community comprising a number of variants and a variety of structural forms such as dry open forests, low forests, woodlands and heathlands that occur in mosaic patterns across the sandstone hillslopes and crests, with a high diversity of species in varying abundance.

References

Umwelt (Australia) Pty Ltd (2009). *Ulan Coal – Continued Operations Ecological Assessment.* Prepared by Umwelt (Australia) Pty Ltd on behalf of Ulan Coal Mines Limited.

Appendix B ELA Staff Experience

CURRICULUM VITAE

David Allworth

ECOLOGIST

QUALIFICATIONS

- Bachelor of Natural Resources (Honours) – University of New England
- Final year thesis of "*The role of cover and tillage on runoff on Vertosols of north-western New South Wales cropping lands*".

David has been involved in-field delivery of large scale tree plantings, the translocation and propagation of rare plant species, plant species selection for planting, vegetation surveys, and provision of management of plants for grasslands, woodlands and closed forest areas. His work has mainly been within the inland cereal cropping belt of eastern Australia.

David has written technical articles, and has also produced a wide range of extension materials for rural landholders and others. Extension work has involved one-on-one advice, the planning and presenting at field days and workshops, and provision of material for electronic and print media outlets.

EXPERIENCE

Eco Logical Australia (2012 – present)

Ulan Coal Mines Limited

- Floristic monitoring (spring & autumn, 2012 – 2015)
- Pre-clearing surveys & clearing supervision (2012 – 2015)
- Supervision of revegetation works (2015)
- Revegetation contractor supervision (2015)
- Targeted surveys for threatened species (2014, 2015)

Moolarben Coal Operations

- Floristic monitoring (2012 – 2015)
- Pre-clearing surveys & clearing supervision (2012 – 2014)
- Impact Assessments to support Modification(s) (2014)
- Rehabilitation monitoring (2012 – 2015)
- Offset Area floristic monitoring (2012 – 2015)

Other projects include works at Charbon Coal, Energy Australia and the Bylong Exploration Project.

Other Significant Projects

- Mid-Western Regional Council Saleyards Land Flora & Fauna Impact Assessment (2013)
- Edgell Land Biodiversity Sensitivity Review (2013)
- Warrego-Darling Long Term Intervention Monitoring Stage 2 (2015)
- Warrego Passing Lanes Preliminary Documentation (2015)
- BHP Caroona Native Vegetation on Cracking Clay (2015)
- Barwon-Darling & Condamine-Balonne floodplain & wetland vegetation mapping (2015)
- Locating rare plants in Central Queensland, *Dichanthium queenslandicum* and *Digitaria porrecta* for

offset areas.

- Surveys to determine the presence of *Eucalyptus cannonii* in the Lithgow-Wallerawang area.

Self-employed (2006 - 2012)

Provision of vegetation identification and management advisory services. Works completed relevant to vegetation include:

- Regional Ecosystem description of vegetation communities & production of plant species list for plant selection database (Logan City Council).
- Study of biodiversity values (including surveys for rare and threatened plant species) and investigation of issue of rehabilitation (Friends of Felton).
- Review of natural regeneration in 60 Regional Ecosystems & database establishment (Condamine Alliance).
- Assessment of sites against natural grassland criteria of the *Commonwealth Environment Protection & Biodiversity Conservation Act 1999* (National Farmers Federation (private landholders)).
- Vegetation assessments (various) for QLD Government Department of Transport and Main Roads.
- Vegetation survey and assessment of grassland and woodland sites with respect to the *Commonwealth Environment Protection & Biodiversity Conservation Act 1999* (Toowoomba City Council).
- Review of distribution of grasslands on the Darling Downs using historical images and current soils information for the development of case for Regional Ecosystem 11.8.11 in the southern Brigalow Belt (Queensland Murray Darling Committee).

Allworth Trees & Timber (2000 – 2005)

- Tree planting program (~350,000 trees) between Roma and Gatton, QLD, plus maintenance of trees one year post planting.
- Sale of trees for planting (~150,000 trees), plant rescue programs, vegetation surveys, training services.
- Survey for rare plant species and transplanting for Powerlink infrastructure.

Greening Australia (1996-1999)

Smallholders Education Project Officer, Eastern Darling Downs.

NSW Soil Conservation Service, Riverina Region (1989-1993)

Information and Public Relations Officer & Acting Regional Landcare Officer.

Queensland Conservation Council (1984-1987)

Research/administrative assistant for Australian Heritage Commission – Southeast QLD Reference Panel.

Sample Publications

Allworth, D. (1998), Distribution of some rare plant species of the Darling Downs, in *Native Vegetation of the Darling Downs,* ed. I. Menkins, Toowoomba Field Naturalists.

Allworth, D. (1998), Extension of smallholders: the use of night time field days, *Managing and Growing Trees – farm forestry and vegetation management conference*. Kooralbyn Hotel Resort, South East Queensland (editor A. Grodeki) Queensland Department of Natural Resources, Queensland Environment Protection Agency, Queensland Department of Primary Industries, and Greening Australia.

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Barker, P. and Allworth, D. (1990), *Detecting dryland salinity in the Riverina and south-western slopes of New South Wales.* Soil Conservation Service of NSW.

CURRICULUM VITAE

Sarah Dickson-Hoyle

ECOLOGIST

QUALIFICATIONS

- Bachelor of Arts/Bachelor of Science(Geography/Botany), University of Melbourne
- Master of Forest Ecosystem Science, University of Melbourne
- Final year thesis of ‘*Risk, remnants and roadsides: understanding fire and conservation management along a rural road, western Victoria*’.

Sarah has over four years’ experience in forestry and environmental consulting, research, and natural resource management. She has experience in conducting flora surveys, forest assessment and monitoring, carbon forestry, and community based conservation management, as well as social research.

Prior to this her work with ELA, Sarah worked for two years in carbon forestry and associated services, involving plantation inventory, biomass assessment, and project and methodology development under the Carbon Farming Initiative.

She has also led a series of flora surveys as part of the Victorian Forest Monitoring Program, gaining experience in forest assessment and a sound knowledge of the flora of western and northern Victorian Mallee and heathy-woodland communities. She has worked with Landcare and other community groups on reforestation and land restoration projects throughout Victoria and NSW, and has conducted in depth research on roadside grassland conservation and fire management in western Victoria.

EXPERIENCE

Eco Logical Australia (2014 – present)
Ulan Coal Mines Limited

- Floristic Monitoring Program (Spring 2014, Autumn 2015)
- Pre-clearing surveys & clearing supervision (2012 – 2014)

Moolarben Coal Operations

- Floristic Monitoring (Spring 2014, Autumn 2015)
- Modification 9 Targeted EPBC Surveys
- Rehabilitation Monitoring (Spring 2014, Autumn 2015, Spring 2015)

Other Significant Projects

- Energy Australia - Pinedale Mine Purple Copper Butterfly survey
- Mid-Western Regional Council Caerleon Pipeline and Sewage Pump Station Review of Environmental Factors
- BHP Caroona Project Offset Properties Flora Survey and Fauna Expert Reports
- Oberon Quarry Pre-Clearing Survey
- Mid-Western Regional Council Targeted Survey – *Leucochrysum albicans* var. *tricolor*

University of Melbourne (February - May 2014)
Sessional academic tutor

International Student Volunteers (April 2012 – February 2014)
Project Leader – Australia & Thailand

CO2 Australia (March 2011 – May 2013)
Project Officer

- Lead botanist and deputy team leader, statewide forest monitoring and reporting project for the Department of Environment and Sustainability, Victorian Government
- Assistant to project managers and Director (Carbon Farming Initiative projects)
- Field team member (plantation inventory and biomass sampling)

The University of Melbourne (June 2010 – May 2013)
Laboratory class demonstrator; field and research assistant

- Demonstrating in first year level biology practical classes
- Assisting lecturers in conducting undergraduate field trips (presentations and logistics)
- Assisting post-doctoral and research fellows with field and laboratory based research projects

PUBLICATIONS

Dickson-Hoyle, S. and Reenberg, A. 2009. “The shrinking globe: globalisation and the changing geographies of livestock production’. *Danish Journal of Geography*. 109(1): 105-112

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