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Mine site rehabilitation report

Oakleigh Mine, November 2007

Report Number 22078.22852

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1. Introduction

To comply with its environmental authorities, New Hope Coal Australia is required to rehabilitate land disturbed by open-cut mining at its West Moreton mine sites. In the main, the disturbed areas consist of overburden or spoil which, at the cessation of mining, had been land-formed prior to sowing with common pasture species. For compliance with the conditions in the environmental authorities, it is necessary for pasture in these rehabilitated areas to be of a condition similar to that at a nearby reference or analogue site, which has not been disturbed by mining. The nominated post-mining capability of the rehabilitated land is low intensity grazing – the same as the analogue site.

A copy of previously agreed criteria for assessing consistency between the rehabilitation and analogue sites is provided in Appendix A. The criteria relate to the following:

- Species diversity,
- Foliage projective cover,
- Standing dry matter, and
- Soil erosion.

This report provides an assessment of progress in rehabilitating sites at the Normanton Dump, at the Oakleigh Mine, to the north of Rosewood. The nominated analogue site is located nearby, in Keates Road, Ashwell, and is described as L566 CH31740. The total area of the lot is 32.375 hectares.

This report relates to field work undertaken in November 2007.

2. Assessment methods

2.1 Sampling intensity

The sampling intensity at each of the assessment sites was determined on the following basis:

- Variance observed in previous assessments,
- In-field assessment of the within and between sampling site variance, and
- Sampling intensities in previous assessments.

The applied sampling intensities are shown in Table 1.

Table 1: Sampling intensities at each rehabilitation site and the analogue site

Site	Area	Sampling sites	Locations	Sampling intensity
Normanton Dump	12 ha	4	10 per site	3.0 ha/site
Analogue	32 ha	10	10 per site	3.2 ha/site

2.2 Sampling site locations

2.2.1 Normanton Dump

The approximate location of the 4 sampling points at the Normanton Dump rehabilitation site is shown in Figure 1.

Figure 1: Location of sampling sites used at the Normanton Dump in November 2007

2.2.2 Analogue site

The approximate location of the 10 sampling points at the analogue site is shown in Figure 2.

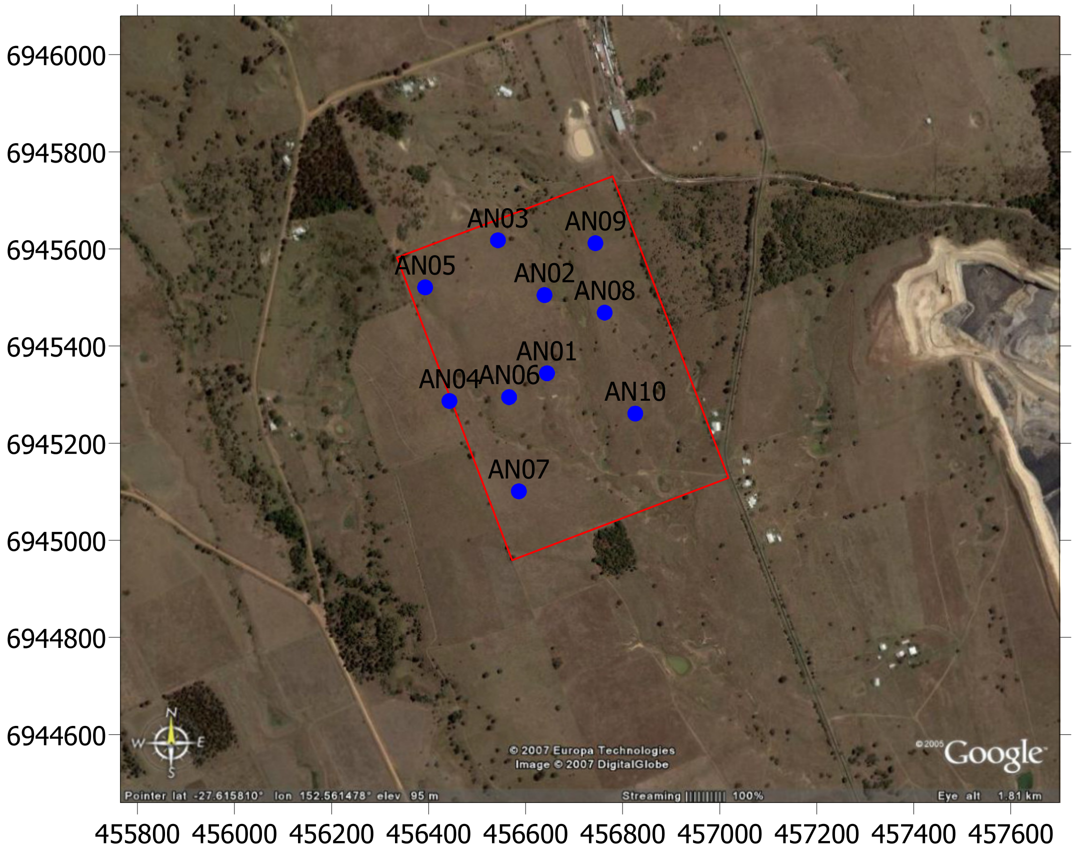

Figure 2: Location of sampling sites used at the analogue site in November 2007

2.3 Vegetation sampling

2.3.1 Sampling quadrats

Point frame quadrats, similar to the one shown in Figure 3, were used to determine foliage projective cover and total cover at ten locations at each of the various sampling sites in the rehabilitation area and in the analogue area.

Figure 3: A point frame quadrat used in the assessments

The ten sampling locations at each sampling site were selected on the basis of a random left-right walk. The random walk was initiated from the point logged with a handheld GPS unit and shown as the location of the sampling site in Figure 1 and Figure 2. The ten sampling locations at each sampling site were selected be pacing distances given by ten site-specific pairs of randomly selected, single digit numbers (*i.e*. *x*-paces to the left & *y*-paces to the right where *x* & *y* are the two random numbers). The random numbers had been generated beforehand using Microsoft® EXCEL™.

Once the sampling location was identified the point frame quadrat was placed at 90° to the tip of the foremost of the sampler's feet.

2.3.2 Plant cover & botanical composition

Projective cover was recorded in each quadrat on the basis of the uppermost contact each of the quadrat points made when lowered following placement of the frame. The cover (or lack of cover) was recorded on the following basis:

- Live plant material (*i.e*. 'green' foliage),
- Dead foliage and surface litter, and
- Bare ground.

Where contact was made with live plant material, an attempt was made to identify the plant and the taxa recorded. To avoid recording superfluous data, some minor components of the sampled swards were only identified to family or genus level, rather than species. Further, in some cases the vegetative state of the plants (*e.g*. pre-flowering) precluded accurate species identification and these plants were also only identified at genus level.

2.3.3 Standing vegetative dry matter

A visual assessment of standing dry matter was made at each sampling point (but not each sampling location).

To provide consistency with previous reporting the assessment was made using the photo-standards in Hacker *et al*. (2005); supplemented by those in Forrester (2007). However as in the April 2007 assessment, the standing dry matter was scored using the ordinal scale shown in Table 2. This avoided the subjectivity and inaccuracy inherent when estimating intermediate values from photo-standards (*e.g*. estimating standing dry matter at 550 kg/ha from a photo-standard depicting 300 – 600 kg/ha).

Table 2: Scores applied in assessing standing dry matter against photo-standards

Score	Standing dry matter (kg/ha)
1	50 – 100
2	100 – 300
3	300 – 600
4	600 – 900
5	900 – 1 200
6	1 200 – 1 500
7	1 500 – 2 000
8	>2 000

2.3.4 Photographic record

A photograph was taken at each sampling point. Copies of the photographs are provided in Appendix B.

2.4 Soil erosion

2.4.1 Universal Soil Loss Equation

The Universal Soil Loss Equation (USLE) is a well recognised method and widely accepted method of estimating erosive soil loss. Algorithms for the revised form of the USLE provided by Rosewell & Loch (2002), Lu *et al*. (2003) and Foster (2005) were used to compute soil loss estimates representative of each sampling site in this assessment. The USLE equation used in these assessments is given by:

$$A = R \times K \times LS \times P \times C$$

Where:

A = average annual soil loss (t/ha/yr),
R = rainfall erosivity factor (MJ.mm/ha.hr.yr),
K $= 2.766 \times M^{1.14} \times 10^{7} \times (12 - OM) + 4.28 \times 10^{-3} \times (SS - 2) + 3.28 \times 10^{-3} \times (PP - 3)$
M $= (\%\text{ silt} + \%\text{ very fine sand})/(100 - \%\text{ clay})$
OM = organic matter (%),
SS = soil structure code (1 – 4),
PP = profile permeability code (1 – 6),
LS = slope length factor,
P = soil conservation practice factor,
C = vegetation factor.

$$= e^{\left(\left(-0.002 \times A^{2} - 0.0256 \times A - 0.8775\right) \times \left(1 - \frac{FPC}{100} \times e^{(0.1 \times H)}\right) \times \left(0.45 + e\left(-3.314 \times \left(0.184 + \left(\frac{T_d}{20}\right)^{1.439}\right)\right)\right)\right)}$$

A = soil cover (%),
FPC = foliage projective cover (%)
H = foliage height (m), and
T_d = time since disturbance (years).

The rainfall intensity is a 2-year average recurrence interval (ARI), 6-hour design storm at Rosewood is 11.9 mm/hr (Pilgrim, 2001). The corresponding value for the rainfall erosivity factor, R, in the Universal Soil Loss Equation is 3 061.

2.4.2 Slope gradient

Slope gradients at each sampling site were measured using a Suunto™ handheld inclinometer.

2.4.3 Slope length

The length of the slope (± 10 m) at each sampling site was estimated.

2.4.4 Soil texture

A field assessment of texture of the surface soil was undertaken at each sampling site.

2.4.5 Soil chemical characteristics

In the previous assessment the soil organic carbon, electrical conductivity, cation exchange capacity and exchangeable sodium values applied were generic values for spoil from Queensland mines as provided in So *et al*. (2003).

For this assessment more specific values was obtained from analyses undertaken on soils collected at Oakleigh Mine an analysed in September 2007. Cation exchange capacities in the tested Oakleigh samples were used to infer the likely textural characteristics of the sampled soils, and these were in turn related to the soil textures recorded during this field assessment. Thus for example, soils of each textural class were assigned the attributed values for the same texture soils at Oakleigh. While site-specific data would be better, the adopted approach should be better than that used in previous assessments.

2.4.6 Soil cover

Estimates of soil cover were taken from the plant cover data obtained in the vegetation sampling described in Section 2.3.2

2.4.7 Canopy height

A visual estimate (±0.1 m) was made of the average canopy height at each sampling site.

2.5 Statistical analysis

The STATISTICS® software package (Analytical Software, 1996) was used to undertake the statistical analyses provided in this assessment.

3. Results

3.1 Antecedent weather conditions

3.1.1 Meteorological data

The meteorological station at the Amberley airfield is the closest Bureau of Meteorology station recording a comprehensive suite of data. The airfield is approximately 14 kilometres east of the mine office at Oakleigh.

3.1.2 Precipitation

Figure 4 provides plots of the following for Amberley airfield:

- The total monthly precipitation November 2006 to October 2007 (*i.e.* the 12 months preceding this assessment), and
- The long term average precipitation for the same months.

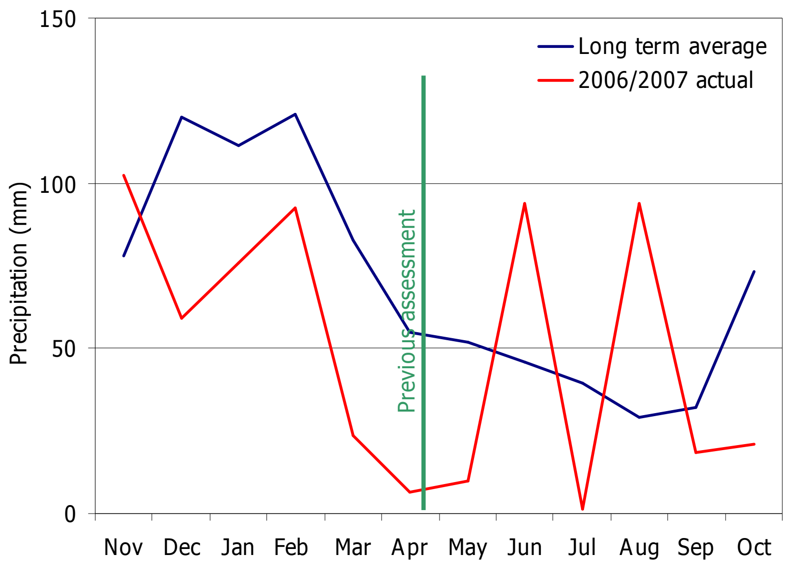

Figure 4: Total monthly precipitation recorded at Amberley between November 2006 and October 2007 and the long term averages for the same months

It can be seen from Figure 4 that following five months of below average rainfall prior to the last assessment in April 2007, monthly rainfall totals have subsequently been quite erratic. This is seen in precipitation in June and August being very much higher than average – mindful though that total rainfall in these months is normally relatively low (*i.e.* <50 mm). Conversely, rainfall in May, July, September and October has been lower than normal – particularly in July when only 1.2 mm was recorded.

Total precipitation for the preceding 12 month has been 598 mm, or nearly 30% less than the long term mean of 839 mm.

3.1.3 Temperature

Figure 5 provides plots of the following for Amberley airfield:

- Mean monthly values for daily maxima from November 2006 to October 2007,
- Mean monthly values for daily minima for the same period,
- The long term averages maxima and minima for the same months.

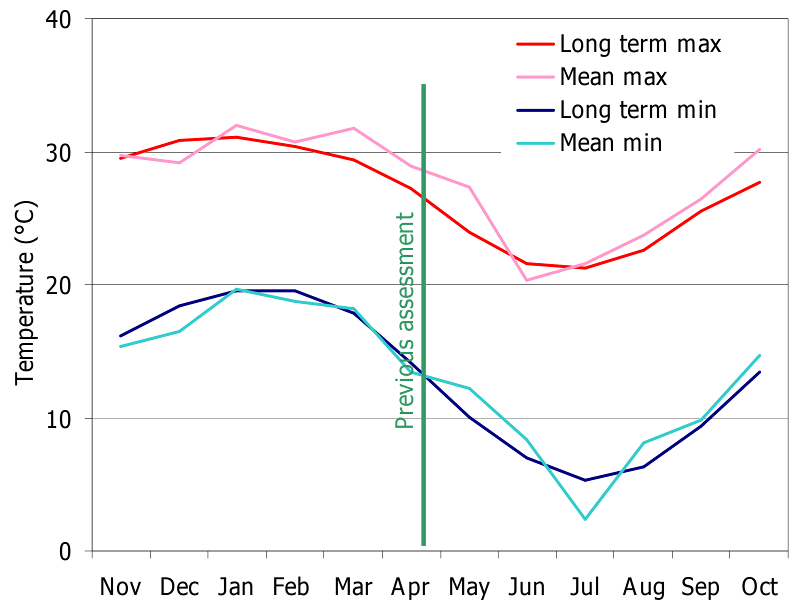

Figure 5: Mean daily maximum and minium temperatures at Amberley between November 2006 and October 2007 and the long term averages for the same months

From Figure 5 it is evident that subsequent to the April 2007 assessment, maximum and minimum temperatures have generally been slightly above average. The exceptions to this generic pattern were the mean maximum temperature in June and the mean minimum in July, which were both below average (markedly so in July). It is noteworthy that the lowest air temperature ever recorded at Amberley (1943 – present) was recorded on 19 July 2007[1]. This temperature was -4.8°C. An air temperature of this magnitude is liable to have caused severe frost damage in susceptible plant species (*e.g.* perennial tropical and sub-tropical pasture species), and even species some normally considered frost tolerant

[1] The lowest ground temperature of -9.1°C occurred in August 1995

3.2 Vegetation

3.2.1 Species present

Table 3 provides a list of taxa observed during the assessment.

Table 3: List of taxa observed at the rehabilitation and analogue sites

Family & species	Common name	Normanton Dump	Analogue
Poaeace			
Aristida spp.	Wire grasses		X
Bothriochloa decipiens	Pitted blue grass		X
Chloris gayana	Rhodes grass	X	X
Chloris virgata	Feather-top Rhodes grass		X
Dichanthium spp.	Bluegrasses	X	X
Digitaria didactyla	Blue couch	X	X
Panicum maximum var. *trichoglume*	Green panic	X	
Paspalum dilatatum	Paspalum		X
Rhynchelytrum repens	Red Natal grass		
Urochloa sp.	Urochloa	X	
Amaranthaceae			
Achyranthes aspera	Chaff flower		X
Alternanthera pungens	Khaki weed		
Gomphrena celosioides	Gomphrena weed		X
Asclepiadaceae			
Asclepias sp.	A balloon cotton		
Asteraceae			
Cirsium vulgare	Spear thistle	X	X
Conyza sp.	A fleabane	X	
Gnapalium spp.	Cudweed		X
Lactuca spp.	Prickly & willow lettuce	X	
Sonchus spp.	A sow thistle		X
Brassicaceae			
Lepidium sp.	Peppercress	X	X
Various Brassicaceae	Mustards, turnips & rockets		X
Cactaceae			
Opuntia spp.	Tree and prickly pears		X
Campanulaceae			
Pratia concolor	Poison pratia		X
Wahlenbergia sp.	A native bluebell		X

Family & species	Common name	Normanton Dump	Analogue
Cuscutaceae			
Cuscuta sp.	A dodder		X
Cyperaceae			
Cyperus gracillis	Slender sedge		X
Euphorbiaceae			
Euphorbia drummondii	Asthma plant		
Fabaceae			
Crotalaria palida	A rattlepod		X
Various Fabaceae	Various native legumes	X	
Macroptilium atropurpureum	Siratro		
Macroptilium lathroides	Phasey bean	X	
Medicago polymorpha	Burr medic		
Melilotus alba	Bokhara clover	X	
Melilotus indica	Hexham scent		X
Oxalidaceae			
Oxalis spp.	Oxalis & soursobs		X
Primulaceae			
Anagallis arvensis	Scarlet pimpernel		
Solanaceae			
Solanum nigrum	A blackberry nightshade		X
Verbenaceae			
Lantana camara	Lantana	X	
Verbena sp.	A verbena		
Verbena tenuisecta	Maynes pest		X

= present at sampling site
X = recorded in sampled quadrats

3.2.2 Species numbers

Table 4 shows the number of different taxa recorded in sampled plots at each site.

Table 4: Number of taxa recorded at each site

Site	Taxa
Normanton Dump	13
Analogue	23

Forty-four percent fewer taxa were recorded at the Normanton Dump rehabilitation site in comparison to the analogue site.

3.2.3 Species diversity index

Species diversity at the rehabilitation and analogue site was assessed by applying the Shannon diversity index[2] (H') to frequency data for each area (*i.e.* species presence or absence at every sampling site). The results are shown in Table 5, along with the values for a variant of the *t*-test (Zar, 1999) that can be used to assess differences between the index scores for the analogue site and those for the rehabilitation site.

Table 5: Observed and maximum values for the Shannon diversity index and the *t*-test values for the difference between the analogue and the rehabilitation site

Site	n	H'	H'_{max}	s^2	t	df
Normanton Dump	4	2.38	3.30	0.77	0.28_{ns}	13
Analogue	10	2.93	4.61	3.12	—	—

Values for the *t* statistic followed by 'ns' subscript are not significant at P = 0.10, α = 1

The values for H' in Table 5 are all substantially less than the theoretic maximum values (H'_{max})[3], suggesting that none of the sites are particularly rich in terms of the diversity of species present. Consistent with the comparable numerical values for the H' statistic obtained for the two sites, the *t*-test values in Table 5 are not statistically significant. Thus, it can be concluded that species diversity at the rehabilitation site did not differ significantly from that at the analogue site at the time of this assessment.

[2] The index is sometimes referred to as the Shannon-Weaver or Shannon-Wiener index of diversity. Refer to standard statistical texts, such as Zar (1999), for the computational methods. *n.b.* natural or base *e* logarithms were used in these calculations.

[3] The index is not a linear relationship hence a site, with a H' value of 2.93 does not have 64% of the theoretic maximum diversity where H'_{max} is 4.61 (as in the analogue site data in Table 5).

3.2.4 Foliage projective and total cover

Figure 6 shows the proportions of total cover at the various sites attributable to the following:

- Foliage of live Poaceae (grasses),
- Foliage of live dicotyledonous plants (herbs and forbs),
- Plant litter and dead foliage, and
- Bare ground.

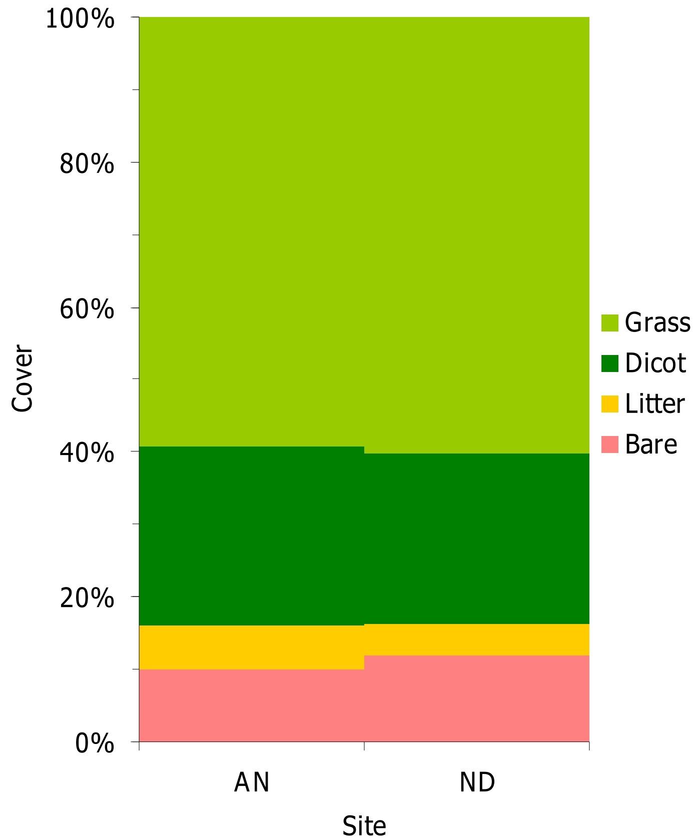

Figure 6: Mean proportions of total cover provided by foliage of live grasses and dicotyledonous plants, litter and dead foliage, and bare ground in the analogue and rehabilitation areas[4]

Compared to the previous assessment in April 2007, there has been a marked increase in the grass component of the foliage cover at both sites. Likewise there has been a very large increase in the cover of dicotyledonous plants at both sites. There has been a modest decrease in the proportion of bare soil at the Normanton Dump site, with a commensurate decrease in the proportion of the projective cover that is dead foliage and plant litter at both sites.

Figure 7 provides a box and whisker plot of foliage projective cover in the assessment areas[5].

[4] In Figure 6, ND = Normanton Dump and AN = Analogue

[5] Median values are represented by the horizontal lines bifurcating the red boxes. The box ends correspond to the first and third quartiles. The 'whiskers' show the extreme values

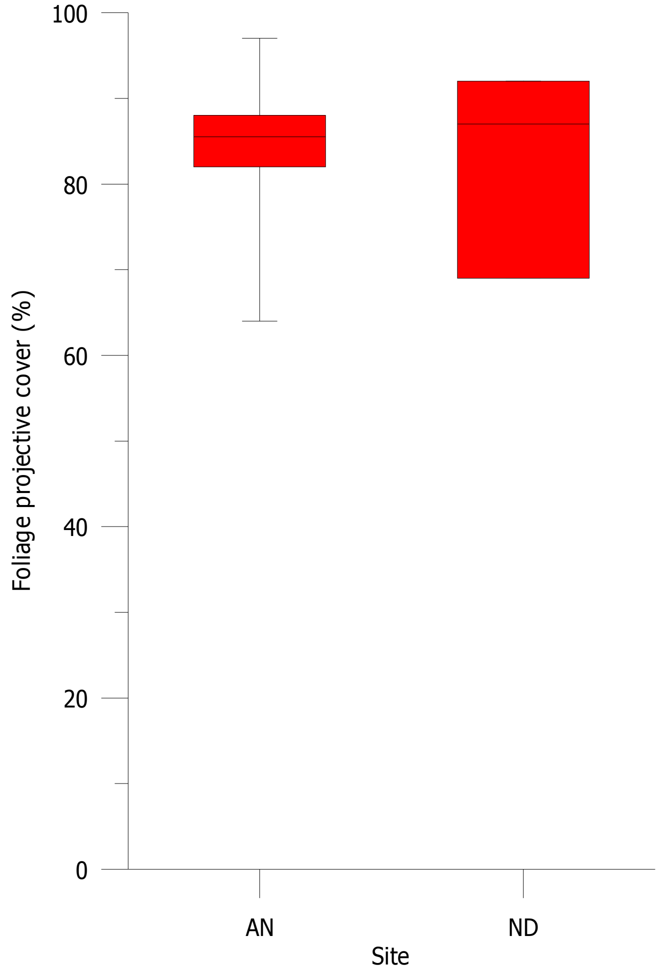

Figure 7: Box & whisker plot of foliage projective cover

From Figure 7 it would appear that the foliage projective cover at both sites is very similar. To investigate this further the foliage protective cover data for the two sites was statistically analysed using the Kruskal-Wallis nonparametric analysis of variance (ANOVA). The results are shown in Table 6.

Table 6: Results of Kruskal-Wallis nonparametric ANOVA of foliage projective cover data

Site	Sampling sites	Mean FPC (%)	Mean rank
Normanton Dump	4	83.7	7.3 $_{ns}$
Analogue	10	83.8	7.9 $_{ns}$
Total	**14**	**83.8**	**7.7**
Kruskal-Wallis statistic			**0.83^{ns}**

ns = not significant at P = 0.05

The ANOVA would indicate that there is no statistically significant difference between the foliage projective cover at the two sites. The mean cover at the rehabilitation site was in excess of 70%.

3.2.5 Standing dry matter

A box and whisker plot of the standing dry matter scores is provided in Figure 8.

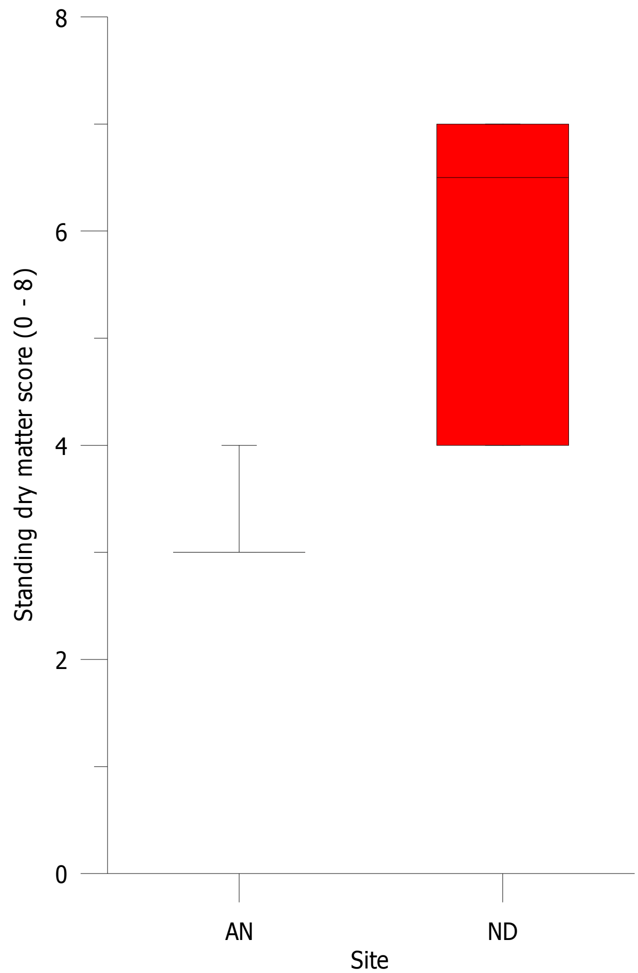

Figure 8: Box & whisker plot of standing dry matter scores

It would appear from Figure 8 that there is a substantial quantitative difference in the standing dry matter scores for the two sites, and only minimal overlap of extreme values in the datasets. Again, a Kruskal-Wallis nonparametric ANOVA was undertaken on the standing dry matter scores to establish whether a quantitative difference of this magnitude is statistically significant. The results are shown in Table 7.

Table 7: Results of Kruskal-Wallis nonparametric ANOVA of standing dry matter scores

Site	Sampling sites	Mean SDM	Mean rank
Normanton Dump	4	6.0	12.3 $_a$
Analogue	10	3.2	5.6 $_b$
Total	**14**	**4.0**	**7.5**
Kruskal-Wallis statistic			**8.98***

* = value significant at P = 0.05
Mean ranks followed by the same letter do not differ at P = 0.05

From Table 7 it is clear that the median standing dry matters score for the Normanton Rehabilitation site is significantly greater than that for the analogue site (at P = 0.05). The practical significance of this result needs to be considered in view of the quite obvious differences in grazing management of the two sites.

3.3 Soil erosion

Figure 9 shows a box and whisker plot of the estimated annual rates of soil loss at the various assessment sites.

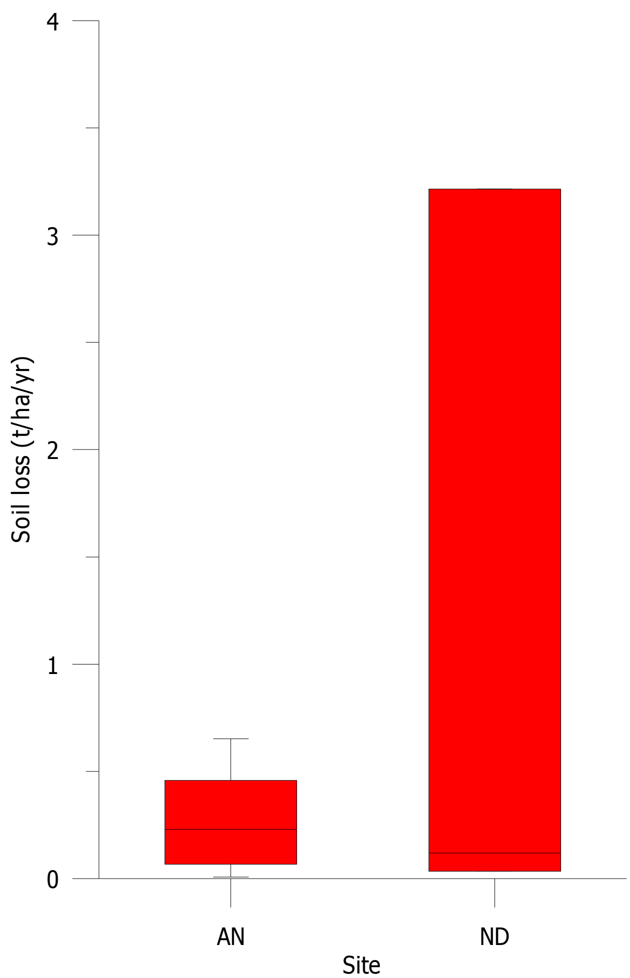

Figure 9: Box & whisker plot of USLE soil loss estimates

While belied somewhat by the *y*-axis scale in Figure 9, the estimated annual soil loss at both sites is very low and generally within the range that would be considered acceptable for a grazed area in the West Moreton. Importantly the median value for the Normanton Dump site is actually less than that for the analogue site.

Table 8 provides the results of a Kruskal-Wallis ANOVA undertaken on the soil loss estimates.

Table 8: Results of Kruskal-Wallis nonparametric ANOVA of USLE soil loss estimates

Site	Sampling sites	Mean soil loss	Mean rank
Normanton Dump	4	0.9	6.5 ns
Analogue	10	0.3	7.9 ns
Total	**14**	**0.5**	**7.5**
Kruskal-Wallis statistic			**0.32** ns

ns = not significant at $P = 0.05$

The results of ANOVA in Table 8 confirm that there is no statistically significant difference in the soil loss estimates at the two sites.

4. Conclusion

4.1 Acceptance criteria 1

This criteria requires *foliage projective cover* to be greater than 70%.

At the time of this assessment, the mean foliage projective cover at the Normanton Dump site was 83.7% and was equivalent to that at the analogue site.

4.2 Acceptance criteria 2

Standing dry matter at rehabilitation sites has to be within ±10% of that at the analogue site to satisfy this criteria.

The mean standing dry matter score for the rehabilitation site at this assessment was significantly greater than the score for the analogue site. However different grazing regimes make any meaningful interpretation of this result difficult.

4.3 Acceptance criteria 3

To meet this criteria, *species diversity* (species number) at the rehabilitation sites has to be within ±20% of that at the analogue site.

At the time of this assessment, 44% fewer taxa were represented on the Normanton Dump site when compared to the number recorded at the analogue site. However, the Shannon diversity index is a more robust indicator of species diversity. This index value indicated that there was no significant statistical difference between the sites.

4.4 Acceptance criteria 4

This criteria would be met if erosive soil loss from the rehabilitation areas, as estimated using the USLE, was within ±10% of that from the analogue site.

Arithmetically the mean soil loss at the rehabilitation site was more than 10% greater than that at the analogue site. However the ANOVA indicated that the difference was not statistically significant. This result is consistent with both levels of soil loss being in the range of acceptable losses for grazed land in the West Moreton.

4.5 Recommendations

After two assessments, under varying seasonal conditions, it is evident that a number of the current acceptance criteria have serious deficiencies in respect to desirable outcomes for a rehabilitation site. Consideration should thus be given to either (1) seeking a review of the acceptance criteria, or (2) instigating a grazing management regime that might better deliver acceptable outcomes – although the later cannot be necessarily guaranteed to provide such an outcome. It would appear exceedingly unlikely the current acceptance criteria will be met within any practical timeframe under the current grazing management system.

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6. Appendices

Appendix A.	Acceptance criteria	A
Appendix B.	Site photographs	C

Appendix A. Acceptance criteria

Acceptance Criteria for Rehabilitation Areas (Grazing) at Jeebropilly Coal Mine

The EPA has approved the following Acceptance Criteria with respect to the rehabilitation of lands disturbed by mining to a grazing landuse.

> <u>Acceptance Criteria 1:</u> FPC of Monitoring rehabilitation sites is at or above 70% understorey FPC
>
> *Monitoring:*
> Biennial monitoring of randomly selected plots within mine rehabilitation areas proposed for the "grazing outcome" and the analogue site using methods described in section 3.
>
> <u>Acceptance Criteria 2:</u> Standing Dry Matter to be within +/- 10% of the analogue sites production rate over a period of 12 months
>
> *Monitoring:*
> Biennial monitoring of randomly selected plots within mine rehabilitation areas proposed for the "grazing outcome" and the analogue site using methods described in Campbell and Hacker (2002).
>
> <u>Acceptance Criteria 3:</u> Grazing species diversity on the mine rehabilitation sites to be on average within +/- 20% of the analogue site
>
> *Monitoring:*
> Biennial monitoring of randomly selected plots within mine rehabilitation areas proposed for the "grazing outcome" and the analogue site using methods described in section 3.
>
> <u>Acceptance Criteria 4:</u> Erosion rates of the mine rehabilitation areas, as determined by the Revised Universal Soil Loss Equation (RUSLE) (Renard *et al*. 1994), to be within +/- 10% of the rates of the analogue site.
>
> *Monitoring:*
> Biennial monitoring of randomly selected plots within mine rehabilitation areas proposed for the "grazing outcome" and the analogue site using methods described in Renard *et al*. (1994).

Due to the nature of the historical mining operations at Oakleigh Mine areas disturbed by mining are at different stages of rehabilitation. Areas of older rehabilitation are being monitored against the above selection criteria.

Appendix B. Site photographs

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Normanton Dump

ND01

ND02

ND03

ND04

Analogue site


AN01


AN02


AN03


AN04


AN05


AN06


AN07


AN08


AN09


AN10