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Sibelco - Silica Sand Mine

Rehabilitation Monitoring Report for ML1124 2017 Rehabilitation Area

September 2019

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Executive Summary

The Sibelco Silica Sand Mine Lease ML1124 has been operational since 2007 and is situated approximately 4 km north-east of the township of Dunwich on North Stradbroke Island, Southeast Queensland.

In order to determine the condition of the 2107 rehabilitation block, Ausecology Pty Ltd was engaged by Sibelco to conduct vegetation monitoring between on the 13th of September 2019 in conjunction with monitoring on the adjoining ML1108 lease.

The monitoring aims to assess the state of rehabilitated areas relative to reference sites. The monitoring was conducted within 50 m x 10 m transects across one rehabilitation site and two reference sites. The rehabilitation site was analysed and assessed against 22 criteria which focused on three categories comprising diversity, density and cover. Additionally, Sorenson's index of similarity (SIS) was used to calculate the similarity of species richness between the rehabilitation and reference sites and their respective benchmark data. Benchmarks were set for each of the rehabilitation criteria based on the 2019 data collected from the reference sites.

Overall rehabilitation site V4 achieved 10 of the 22 criteria with criteria in the diversity category passing 80% of the benchmark followed by the cover category at 25% and scoring lowest was the density category at 12.5%. This is typical of rehabilitation sites as cover can be expected to increase with the age and height of the vegetation communities whilst density will increase through in-situ reproduction and ex-situ immigration processes.

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Abbreviations

Acronym	Description
EMP	Environmental Management Plan
Ha	Hectares
EA	Environmental Authority
EPBC Act	*Environmental Protection and Biodiversity Conservation Act 1999*
ESR	Environmental Studies Report
ht	height
Km	Kilometres
m	Metres
RE	Regional Ecosystem
SIS	Sorensen's Index of Similarity

1 Introduction

The Sibelco Silica Sand Mine Lease ML 1124 has been operational since 2007 and is situated approximately 4 km north-east of the township of Dunwich on North Stradbroke Island, Southeast Queensland.

The construction, reinstatement and rehabilitation of the Mine is authorised under the QLD Department of Environment and Heritage Protection Environmental Authority MIM9000220203 (EA), the Commonwealth Department of Environment Environmental Protection and Biodiversity Conservation (EPBC) Act Approval EPBC2007/3464 and associated Environmental Management Plans (EMP).

Ausecology Pty Ltd (Ausecology) has been engaged by Sibelco to establish and measure a monitoring site within 2017 rehabilitation efforts undertaken in a block on mine lease ML 1124, and to also conduct monitoring concurrently at the adjoining mine lease ML1108 and associated reference sites, sensitive area sites and rehabilitation monitoring sites situated throughout the ML1108 mine lease area. Ausecology conducted the monitoring of the new reference site on ML1124 on 13th of September 2019 and at the reference sites between 10th and 13th September 2019.

This report details the methodology used to conduct these activities and presents results for the rehabilitation area with reference to the requirements under the EA for ML1108 as surrogate criteria.

Documents used for methodology, reference information and baseline data in compiling this report include:

- Environmental Management Plan – North Stradbroke Island Silica Sand Mining Operations – ML1108, UNIMIN Australia Limited, December 2008;
- Environmental Studies Report – Flora Assessment – Vance Mining ease ML 1108, North Stradbroke Is, Queensland, URS, October 2007;
- Scope of Works – 2015 Flora Monitoring, Sibelco Australia Limited;
- 2012 Annual Vegetation Monitoring Report, Vance 1108, Biodiversity Assessment and Management Pty Ltd;
- 2013 Annual Vegetation Monitoring Report, Vance 1108, Biodiversity Assessment and Management Pty Ltd;
- 2014 Annual Vegetation Monitoring Report, Vance 1108, Biodiversity Assessment and Management Pty Ltd;
- 2015 Sibelco - Silica Sand Mine, Rehabilitation Monitoring Report, Ausecology Pty Ltd;
- 2016 Sibelco - Silica Sand Mine, Rehabilitation Monitoring Report, Ausecology Pty Ltd;
- 2017 Sibelco - Silica Sand Mine, Rehabilitation Monitoring Report, Ausecology Pty Ltd; and
- 2018 Sibelco - Silica Sand Mine, Rehabilitation Monitoring Report, Ausecology Pty Ltd

2 Methodology

2.1 Survey sites

A total of two primary reference sites within ML1108 and one rehabilitation monitoring site located on ML1124 were surveyed (Appendix 3). Reference sites were established during compilation of the original Environmental Studies Report (ESR) (URS, 2007) and Environmental Management Plan (EMP) (UNIMIN, 2008), for the purpose of providing reference site data (sites P2 and P7) with which to compare the progression of rehabilitated areas on the adjoining mine lease ML1108. These methodologies and criteria were used in the absence of such criteria for ML1124.

Rehabilitation site V4 was established in order to sample rehabilitation undertaken in 2017, with a single site representative for that year of rehabilitation works. The details of each monitoring site are summarised in Table 2-1. Site P2 was established during the ESR surveys for ML1108, whereas P7 was added in 2008 to meet additional baseline assessment requirements identified in the ML 1108 EMP (pg. 19).

Table 2-1 Monitoring site details

Site	Site Type	Description	Monitoring purpose
V4	Rehabilitation site	Rehabilitation established 2017. Regenerating open heath with a sparse shrub layer of regenerating canopy species currently reaching 2.5 m with a shrub layer to 2 m. Consistent with regenerating RE12.2.10.	Comparable to reference sites: P2 and P7
P2	Reference site	Mallee shrub land, regenerating following fire disturbance, with a sparse canopy reaching 6 m. RE12.2.10.	Reference site for V4.
P7	Reference site	Woodland with a canopy to 14 m and a dense ground layer. Disturbed by fire. RE 12.2.10	Reference site for V4.

2.2 Monitoring criteria

The monitoring program aims to:

- Assess the state of rehabilitated areas relative to reference sites, against specific criteria set out in the EMP for ML1108.

The EMP criteria specify conditions that must be reached in the establishment of rehabilitated flora. For rehabilitated areas, three categories of criteria are to be met, these being species diversity, density and cover as presented in Table 2-2.

In the absence of sufficient sample points (only one sample representing each rehabilitation year), the 'statistically significantly less than' criteria stipulated in the EMP is not applied at this point, and an 'achieved' or 'not yet achieved' determination is made relative to the applicable percentage of the benchmark.

Table 2-2 Monitoring criteria and standard methodology for rehabilitation and reference sites

Measure Category	Stratum	Revegetation Criteria	Standard methodology
Diversity	Trees	All tree species present in representative baseline reference sites are present in the rehabilitated block for the same vegetation community.	Tree species list - 50 x 10 m quadrat
	Trees and understorey	The mean number of native plant species is not statistically significantly less than 75% of mean value recorded baseline reference sites for the vegetation community.	Tree and shrub species list - 50 x 10 m quadrat
		All Significant Species* present in representative baseline reference sites are present in the rehabilitated areas for the same vegetation community.	Tree and shrub species list - 50 x 10 m quadrat
Density	Trees	Total density of all trees greater than 2 m in height is not statistically significantly less than 75% of the mean value recorded in baseline reference sites for the vegetation community.	Total stem count of all trees >2 m in 50 x 10 m quadrat.
	Trees	Density of individual trees greater than 2 m in height for each species is not statistically significantly less than 50% of the mean value recorded in baseline reference sites for the vegetation community.	Stem count per species of all trees >2 m in 50 x 10 m quadrat.
	Trees and understorey	Mean number of individual trees is not statistically significantly less than 75% of the mean value recorded in baseline reference sites.	Total stem count for all trees (in 50 x 10 m quadrat) and all shrubs (in 50 x 2 m quadrat).
Cover	Trees	Tree foliage projective cover (FPC) of the canopy is not statistically significantly less than 75% of the mean value recorded in baseline reference sites	FPC of tree cover using Transect Intercept Method.

Measure Category	Stratum	Revegetation Criteria	Standard methodology
	Understorey	Tree foliage projective cover (FPC) of the understorey is not statistically significantly less than 75% of the mean value recorded in baseline reference sites.	FPC of shrub layer using visual estimation (50 m x 2 m transect).
	Ground	FPC of ground layer is not statistically significantly less than 65% of the mean value recorded in baseline reference sites.	FPC of ground cover using five 1x1m quadrats (as per baseline ESR survey).

* Significant species are listed in the EMP (UNIMIN, 2008). Three species were identified by the Minjerribah Moorgumpin Elders in the EMP as being of cultural significance to the traditional owners of North Stradbroke Island. These were: *Boronia rosmarinifolia* (forest boronia), *Boronia safrolifera* (safrole boronia) and *Boronia falcifolia* (wallum boronia). One state conservation significant species, *Acacia baueri* sub sp. *baueri*, is located within ML 1108. The fauna report (Appendix G of the ESR) also identified species such as *Eucalyptus pilularis* and *Banksia aemula* as providing potential foraging habitat for the grey-headed flying fox.

2.3 Field measurement methodology

At the monitoring location a 50 m x 10 m plot is delineated by permanent hardwood stakes. Two steel star pickets mark the start and end points of a centreline to guide the cover transect. The quadrat and transect dimensions are summarised in Table 2-3.

Table 2-3 Specific site measurement dimensions

Site	Type	Measured parameter	Plot/transect Dimensions
V4	Rehabilitation site	Tree species Foliage Projective Cover (FPC) transect length	50 m
		Shrub species FPC transect length:	
		• Stems >1 m tall	50 m
		• Stems <1 m tall	50 m
		Tree species stem density quadrat dimensions	50 m x 10 m
		Shrub species stem density quadrat dimensions	50 m x 1 m
		Ground cover species stem density quadrat dimensions	1 m x 1 m
P2	Reference site	Tree species Foliage Projective Cover (FPC) transect length	50 m
		Shrub species FPC transect length:	
		• Stems >1 m tall	25 m
		• Stems <1 m tall	25 m
		Tree species stem density quadrat dimensions	50 m x 5 m
		Shrub species stem density quadrat dimensions	25 m x 1 m
		Ground cover species stem density quadrat dimensions	1 m x 1 m
P7	Reference site	Tree species Foliage Projective Cover (FPC) transect length	50 m
		Shrub species FPC transect length:	
		• Stems >1 m tall	50 m
		• Stems <1 m tall	25 m
		Tree species stem density quadrat dimensions	50 m x 10 m
		Shrub species stem density quadrat dimensions	1 m x 1 m
		Ground cover species stem density quadrat dimensions	

Site structural details were acquired from visual assessment of the vegetation within the 50 m x 10 m plot. The locality was described in relation to the lease area. Coordinates for the start and end stakes were captured using a Trimble GeoExplorer GPS and corrected to sub metre accuracy. Site details included vegetation community structure and diversity, estimated foliage projected cover (FPC) per strata, minimum, maximum and median height of each strata and the dominant species in each stratum, as per BioCondition assessment methodology (Eyre *et al*., 2015). A short description of the vegetation type was made and EVNT species present, disturbances and wetland features noted. Community structural formation classes were applied as per Specht (1970). The geology, landform and regional ecosystem were then determined.

The FPC of each species intercepting the transect was recorded using standard opaque canopy intercept method as per BioCondition assessment methodology (Eyre *et al*., 2015). Each entry for FPC was recorded as species name, metres distance along the centreline (to 5 cm accuracy), and either greater or less than 1 m in height. Continuous canopy intercept made up of numerous individuals of the same species were counted as one canopy.

Stem densities for each species were recorded within a quadrat of varying dimensions (as set out in Table 2-3) depending on the visual assessment of density. Individual plants exceeding 2 m in height were recorded separately to stems under 2 m. Density measurements for stems >2 m involved recording the species, height and diameter at breast height (DBH) of each individual, whereas attributes for stems <2 m only included a tally/count of each species.

The percentage cover of each ground cover type was estimated within five 1 m x 1 m quadrats. Ground cover types included litter, native vegetation, exotic vegetation, bare ground, cryptogams. The stem densities of each species were also recorded within each groundcover quadrat for all stems with no live parts exceeding 1 m in height. For a stem to be counted, the stem base must be within the quadrat and have no living parts exceeding 1 m in height. A photo of each quadrat was captured.

Photo point monitoring was commenced, with a photo taken of each site from the start and end point of the centre transect and taken from a height of 1.6 m.

Detailed data recorded at the site is presented in Appendix 1.

2.4 Benchmark scores

In order to measure the performance of the rehabilitated area against the release criteria, benchmark scores were determined by collecting the same data attributes in analogue vegetation communities similar to the desired vegetation to be achieved through rehabilitation. Two primary sites were used to provide this analogue data for comparison to the rehabilitation site. This process of comparison is set out in the EMP and includes the ten attributes listed in Table 2-4.

Table 2-4 EMP-1108 Criteria

Performance indicators
Density all trees >2 m
Density tree species >2 m
Stem count
FPC >1 m
FPC <1 m
Ground Cover
Species Diversity

Performance indicators
Tree Species
Significant species
Ground cover species richness

The EMP also states the required revegetation criteria for each of these ten attributes, as detailed in Table 2-2. The revegetation criteria allow a buffer of 65-75% of the benchmark value in order to achieve performance.

2.5 Sorensen index of similarity

Sorensen's index of similarity (SIS) provides a measure of the consistency in species richness between two sites; the closer the index is to 1, the greater the similarity.

SIS was used to compare rehabilitation sample data with reference site data. In this case the comparison provides an indication of the progress of rehabilitation towards the desired species diversity, compared to the reference sites, and whether supplementary planting is required to achieve the species diversity and composition targets. The calculation uses total species present at both locations, number of species present only in the rehabilitation site, and number of species present only in the reference site.

The formula is:

$$Cs = \frac{2a}{(2a + b + c)}$$

Where:

- Cs = index of similarity;
- a = total number of species present at both sample sites;
- b = number of species present only in sample 1; and
- c = the number of species present only in sample 2.

3 Results

3.1 Reference sites

Benchmark scores are calculated from data captured at suitable reference sites P2 and P7 then averaged to obtain combined scores for RE 12.2.10. Benchmark scores for 2019 data are presented alongside 2018, 2017, 2016 and 2015 data for comparison in Table 3-1. The increase in density of trees above 2m observed in the previous years of monitoring has stabilised in 2019 with an equal total number of 3180 stems per hectare to the 2018 survey. A decline of 27% FPC from the shrub strata was recorded whilst the lower shrub layer (<1m) maintained a high FPC at 75.8%.

Table 3-1 Benchmark scores calculated from the mean of site P2 and P7 results

Performance Criteria	Benchmark Sites (P2 & P7 - RE 12.2.10)				
	2015	2016	2017	2018	2019
Density					

Performance Criteria	Benchmark Sites (P2 & P7 - RE 12.2.10)				
	2015	**2016**	**2017**	**2018**	**2019**
Density all trees species >2 m (stems per ha)	1120	1340	1410	1590	1590
Density tree species >2 m (stems per ha)					
Banksia aemula	460	470	450	490	450
Corymbia gummifera	160	70	290	310	230
Eucalyptus planchoniana	360	480	430	410	490
Eucalyptus racemosa sub sp. *racemosa*	20[1]	50[1]	10[1]	40[1]	40
Leptospermum trinervium	120[1]	270	230	360	400
Cover					
FPC >1 m (%)					
Trees	58	64.6	51	55	53.9
Shrubs	34.4	52.2	48.8	50	23
FPC <1 m (%)	73	72	72.2	75	75.8
FPC – ground cover – native vegetation (%)	83.5	72.5	66.1	58.2	58.2
Diversity					
Species diversity	42	40	37.5	38.5	46
Ground cover species richness (1 m x 1 m quadrats)					
All	34	35	22.5	32	22
Herbaceous	10	7	4.5	5	4.5
Tree species present:					
Banksia aemula	✓	✓	✓	✓	✓
Corymbia gummifera	✓	✓	✓	✓	✓
Eucalyptus planchoniana	✓	✓	✓	✓	✓
Eucalyptus racemosa subsp. *racemosa*	✓	✓	✓	✓	✓
Leptospermum trinervium	✓	✓	✓	✓	✓

Performance Criteria	Benchmark Sites (P2 & P7 - RE 12.2.10)				
	2015	2016	2017	2018	2019
Monotoca sp. *(Fraser Island P. Baxter 777)*	✓	✓	✓	✓	✓
Significant species present:					
Acacia baueri subsp. *baueri* - Vulnerable NC Act	✓	✓	✓	✓	✓
Banksia aemula – Foraging source for grey-headed flying fox	✓	✓	✓	✓	✓
Corymbia gummifera – Foraging source for grey-headed flying fox	✓	✓	✓	✓	✓
Boronia rosmarinifolia – Cultural significance	✓	✓	✓	✓	✓

[1] The mean for these results was affected by a value of zero at one of the two sites used in the average.

3.2 Rehabilitation site

4.2.5. Rehabilitation site V4

Rehabilitation of site V4 was completed in 2017 and was surveyed for the first time this year. The site supports regenerating open heath with a planted canopy layer to 2.5 m and a shrub layer to 2 m. As with the other rehabilitation sites, V4 is also consistent with RE12.2.10 and is comparable to reference sites P2 and P7.

There were 36 native species recorded at V4 comprising 8 tree species, 14 shrub species and 14 ground layer species. There were a further 3 weed species recorded on site, *Crotalaria pallida* (rattlepod), *Megathyrsus maximus* (guinea grass) and *Melinis repens* (red natal grass).

The dominant canopy species regenerating at this site were *Eucalyptus planchoniana, Corymbia gummifera*, and *Banksia aemula*.

As show in Table 3-2 the shrub species displaying the greatest density included *Acacia ulicifolia, Acacia suaveolens, Baloskion tetraphyllum* subsp*. meiostachyum* and *Eriachne pallescens*.

Table 3-2 Densities of dominant flora species at V4

Species	Stem Density (stems per ha)
	2019
Trees	
Eucalyptus planchoniana	720
Corymbia gummifera	300
Banksia aemula	200
Shrubs	
Acacia ulicifolia	8800
Acacia suaveolens	1800
Ground covers	
Baloskion tetraphyllum subsp. *meiostachyum*	1800
Eriachne pallescens	1400

Shown in Table 3-3 the dominant shrub species *Acacia ulicifolia* and *Acacia suaveolens* provided the most FPC at site V4 whilst *Eucalyptus planchoniana* provided the highest FPC from the canopy layer species.

Table 3-3 *Species providing the dominant FPC at V4*

Species	2019 FPC (%)
Acacia ulicifolia	31.6
Acacia suaveolens	8.8
Eucalyptus planchoniana	6.2
Corymbia gummifera	2

The results of ground cover assessments recorded in five 1 m x 1 m quadrats were averaged across the five samples and presented in Table 3-4 below.

Table 3-4 Mean percent ground cover quadrat results for V4

Dataset	Native vegetation (%)	Exotic vegetation (%)	Litter (%)	Bare ground (%)	Cryptogams (%)
2019	55.7	0	22.68	21.62	0

3.2.1 Comparison of rehabilitation sites to reference sites

The results for the rehabilitation site V4 are measured against a benchmark values derived by calculating the averages obtained for the reference sites (P2 and P7). Table 3-5 shows the progress of the rehabilitation area towards each of the performance criteria detailed in Section 2.2 (Table 2-2).

Results of the rehabilitation site scores compared to the required release values (applicable to ML1108) are presented in Table 3-5.

Table 3-5 Comparison between reference and rehabilitation site scores

Performance Criteria	Benchmark Scores RE 12.2.10 (P2 & P7)	V4
Density		
Density of trees, greater than 2 m in height, per ha	1590	140
Tolerance 75%	1193	12%
Density of trees, less than 2 m in height, per ha: 50 m x 10 m/ 25 m x 2 m quadrat data	2280	1380
Tolerance 75%	1710	81%
Density of shrubs, less than 2 m in height, per ha (1m^2 quadrat data)	183000	34000
Tolerance 75%	137250	25%
Density tree species >2 m/ha		
Banksia aemula	1590	0
Tolerance 50%	795	0%
Corymbia gummifera	230	40
Tolerance 50%	115	35%
Eucalyptus planchoniana	490	40
Tolerance 50%	245	16%
Eucalyptus racemosa subsp. *racemosa*	20	20
Tolerance 50%	10	200%
Leptospermum trinervium	200	0
Tolerance 50%	100	0%
Cover		
FPC >1 m (%) Trees	53.9	4.4
Tolerance 75%	39.8	11%
FPC >1 m (%) Shrub species	23	9.4
Tolerance 75%	17.3	54%
FPC <1 m (%) All species (50 m x 10 m quadrat)	75.8	96
Tolerance 75%	56.9	169%
FPC – Ground cover – Native vegetation (%)	58.2	30.2
Tolerance 65%	37.83	70%

Performance Criteria	Benchmark Scores RE 12.2.10 (P2 & P7)	V4
Diversity		
Species diversity	46	36
Tolerance 75%	34.5	104%
Tree species		
Banksia aemula	✓	✓
Corymbia gummifera	✓	✓
Eucalyptus planchoniana	✓	✓
Eucalyptus racemosa subsp. *racemosa*	✓	✓
Leptospermum trinervium	✓	×
Monotoca sp. (Fraser Island P. Baxter 777)	✓	×
Significant species:		
Acacia baueri subsp. *baueri* - Vulnerable NC Act	✓	✓
Banksia aemula – foraging source for grey-head flying fox	✓	✓
Boronia rosmarinifolia - cultural	✓	✓
Ground cover species richness (1m^2 quadrats):		
All species (shrubs and ground covers)	22	11
Herbaceous (ground covers)	4.5	3

3.2.2 *Sorensen's index of similarity for rehabilitation areas*

Sorensen's index of similarity (SIS) provides a measure of the consistency in species richness between two sites. This formula was used to compare the species richness between site V4 and the two reference sites. The results presented in Table 3-6 show an averaged SIS score of 0.5 which may seem low when one considers the total number of species at V4 achieved the benchmark at 36 species (shown in 3.2.1).. This suggests the low SIS score is a reflection of the different successional states of the vegetation communities as V4 is yet to develop a canopy and is therefore dominated by shrub and ground cover species that favour high exposure to the sun. In contrast, the reference sites are more developed vegetation communities with an enclosed canopy and understory species adapted to shade.

Table 3-6 Sorensen's Index of Similarity comparing primary and rehabilitation sites

	P2	P7
V4	0.46	0.53

4 Discussion

4.1 Benchmark sites

The benchmark scores derived from reference sites P2 and P7 shown in Table 3-1 remain consistent across all criteria except for the shrub coverage which recorded a significant drop to 23% and species diversity which increased from 38.5 to 44 species. This is the highest score of species diversity recorded since monitoring began and is due to the additional presence of *Styphelia viridis* and *Phyllota phylicoides* at site P2 and *Dodonaea triquetra, Leucopogon margarodes, Leucopogon virgatus, Zieria laxiflora* and *Phyllota phylicoides* at site P7. The density of tree species 'greater than 2 m' has stabilised at 1590 after a consistent increase of density for this stratum was recorded throughout the previous 4 years that followed the fire in 2015.

4.2 Rehabilitation site

Rehabilitation site V4 was consistent with the other rehabilitation sites on lease area ML1108 in that it passed 80% of the diversity criteria whilst the cover and density of the site are well below the benchmark passing just 25% and 12.5% respectively as shown in *Table 4-1* below. This is typical of rehabilitation sites as cover can be expected to increase with the age and height of the vegetation communities whilst density will increase through in-situ reproduction and ex-situ immigration processes

It was noted that site V4 was the only rehabilitation site to have the vulnerable *Acacia baueri* subsp. *Baueri* which is regarded as a significant species in the EMP.

Table 4-1 Proportion of benchmark criteria achieved per site and attribute

Year	Site	Density (%)	Cover (%)	Diversity (%)	Average (%)
2019	V4	12.5	25	80	39.2

As highlighted in previous rehabilitation monitoring reports, the current reference site data may be an inadequate benchmark with which to compare the performance of vegetation. Variability between the two reference sites is substantial, exemplified by the removal of reference site P6 due to its dissimilarity. Given the strict nature of some of the success criteria, it is improbable that the rehabilitation sites will establish vegetation communities identical to the reference sites.

4.3 Recommendations

Three invasive weed species including one shrub *Crotalaria pallida* (rattlepod) and two species of grass *Megathyrsus maximus* (guinea grass) and *Melinis repens* (red natal grass) were present on the newly added rehabilitated site V4 and removal should be considered to prevent their competition on native species. Moreover, the site lacks *Leptospermum trinervium* and *Monotoca* sp. (Fraser Island P. Baxter 777) which is a requirement of the diversity category in the ML1108 EMP. Enrichment planting of these will likely improve future results.

5 Conclusion

Monitoring of the 2017 rehabilitation area was commenced and compared to existing reference site data captured during concurrent surveys undertaken for the ML1108 rehabilitation.

The results of the monitoring show 10 of the 22 release criteria (relevant to ML 1108 EMP) for revegetation have been achieved with four of the six tree species present , and all of the significant species present. FPC less than 1 m in height is well above the requirement, whereas density and FPC criteria of trees and shrubs greater than 1 m in height yet to be achieved.

Rehabilitation site V4 contained three exotic plant species which may pose a threat to the vegetation community through competition and their removal should be considered.

6 References

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7 Appendix 1

7.1 General Results

7.1.1 Site coordinates

Table 7-1 Corrected GPS coordinates

Site	Peg	Latitude	Longitude
P2	Start	-27.48201977	153.4735956
P2	End	-27.4816166	153.4733806
P7	Start	-27.47876038	153.4483443
P7	End	-27.47844801	153.4479936
V4	Start	-27.46990202	153.4419944
V4	End	-27.47020999	153.4423792

7.1.2 Species diversity

Species diversity was recorded at each site and presented in Table 7-2.

Table 7-2 Site species diversity

Site Life form	Count of Species
P2 Total	**46**
Ground cover	9
Shrub	32
Tree	5
P7 Total	**45**
Ground cover	8
Shrub	31
Tree	6
V4 Total	**39**
Ground cover	14
Shrub	14
Shrub (weed)	1
Tree	8
Ground cover (non-native)	2

7.1.3 Tree and shrub species stem density

Species stem density was measured within quadrats of varying dimension depending on the density of stems. Results are presented in Table 7-3.

Table 7-3 Site species stem density

Site- form	Quadrat dimensions					
	1 m x 1 m	25 m x 1 m	50 m x 1 m	50 m x 10 m	50 m x 2 m	50 m x 5 m
P2	**482000**	**163200**				**5320**
Ground cover	**62000**	**13200**				
Amperea xiphoclada var. xiphoclada	2000					
Baloskion tetraphyllum subsp. meiostachyum	28000	4800				
Coleocarya gracilis	30000	7600				
Laxmannia gracilis	2000					
Lomandra longifolia		800				
Shrub	**412000**	**146000**				
Austromyrtus dulcis		1600				
Bauera capitata		400				
Boronia rosmarinifolia	4000	800				
Bossiaea heterophylla	6000	800				
Brachyloma scortechinii	2000	1200				
Conospermum taxifolium		800				
Dillwynia retorta	44000	18400				
Hibbertia acicularis		400				
Hibbertia linearis	8000	2400				
Homoranthus virgatus	6000	1600				
Jacksonia stackhousei	6000	4400				
Leucopogon deformis		1200				
Leucopogon ericoides	40000	3600				
Leucopogon leptospermoides		400				
Monotoca scoparia	4000	800				
Ochrosperma lineare	126000	44000				
Olax stricta	2000	800				
Phyllota phylicoides		400				
Pimelea linifolia	10000	4800				
Pseudanthus orientalis	12000	1200				
Ricinocarpos pinifolius	16000	10800				
Strangea linearis		800				
Woollsia pungens	114000	33200				
Xanthorrhoea johnsonii	8000	9600				
Zieria laxiflora	4000	1600				
Tree	**8000**	**4000**				**5320**
Banksia aemula	6000	2400				3000
Corymbia gummifera						640
Eucalyptus planchoniana						1000

Site- form	Quadrat dimensions					
	1 m x 1 m	**25 m x 1 m**	**50 m x 1 m**	**50 m x 10 m**	**50 m x 2 m**	**50 m x 5 m**
Leptospermum trinervium	2000	400				680
Monotoca sp. (Fraser Island P. Baxter 777)		1200				
P7	**184000**	**202800**		**2420**		
Ground cover	**66000**	**75200**				
Amperea xiphoclada var. xiphoclada		400				
Baloskion pallens	46000	61200				
Baloskion tetraphyllum subsp. meiostachyum	8000	2400				
Coleocarya gracilis	4000	7600				
Entolasia marginata		400				
Laxmannia gracilis	4000	800				
Lomandra longifolia	4000	2400				
Shrub	**116000**	**126000**				
Acacia ulicifolia	34000	32400				
Aotus lanigera	2000	3200				
Baeckea frutescens	10000	4000				
Boronia rosmarinifolia	2000	2400				
Bossiaea heterophylla	2000	4400				
Brachyloma scortechinii		800				
Conospermum taxifolium		3200				
Dillwynia retorta	6000	7600				
Hibbertia acicularis		400				
Hibbertia linearis		4400				
Homoranthus virgatus	2000	4400				
Leptospermum polygalifolium		2400				
Leucopogon ericoides		1200				
Leucopogon leptospermoides	6000	2400				
Monotoca scoparia	2000	2400				
Ochrosperma lineare	14000	13600				
Persoonia virgata		800				
Pimelea linifolia	4000	7200				
Platysace ericoides	6000	800				
Ricinocarpos pinifolius	2000	6400				
Strangea linearis		1200				
Woollsia pungens	12000	10800				
Xanthorrhoea johnsonii	12000	7600				
Zieria laxiflora		2000				
Tree	**2000**	**1600**		**2420**		
Banksia aemula	2000	800		1960		
Corymbia gummifera		400		80		
Eucalyptus planchoniana				100		
Eucalyptus racemosa				40		
Leptospermum trinervium				240		

Site- form	Quadrat dimensions					
	1 m x 1 m	**25 m x 1 m**	**50 m x 1 m**	**50 m x 10 m**	**50 m x 2 m**	**50 m x 5 m**
Monotoca sp. (Fraser Island P. Baxter 777)		400				
V4	**30000**		**23400**	**1520**		
Ground cover	**8000**		**9200**			
Aristida jerichoensis	2000		200			
Baloskion tetraphyllum subsp. meiostachyum	2000		1800			
Caustis recurvata	2000		800			
Coleocarya gracilis			1000			
Entolasia marginata			800			
Eragrostis parviflora			600			
Eriachne pallescens	2000		1400			
Hardenbergia violacea			200			
Laxmannia gracilis	2000		800			
Lomandra elongata			400			
Paspalum conjugatum			1000			
Eragrostis parviflora	2000					
Patersonia sericea			200			
Shrub	**18000**		**14200**			
Acacia baueri subsp. baueri			200			
Acacia suaveolens			1800			
Acacia ulicifolia	10000		8800			
Boronia rosmarinifolia			400			
Bossiaea heterophylla	2000		200			
Dillwynia retorta	2000		200			
Gompholobium virgatum			200			
Hibbertia linearis			200			
Homoranthus virgatus			400			
Ochrosperma lineare			600			
Petrophile canescens			200			
Ricinocarpos pinifolius	2000		1000			
Xanthorrhoea johnsonii	2000					
Tree				**1520**		
Allocasuarina littoralis				80		
Angophora leiocarpa				40		
Banksia aemula				200		
Corymbia gummifera				300		
Eucalyptus planchoniana				720		
Eucalyptus racemosa				140		
Lophostemon confertus				40		

7.1.4 Species foliage projected cover

Species FPC was measured along a 50 m measuring tape, laid along the transect centreline at each site. The results of the FPC intercept transect is presented in Table 7-4.

Table 7-4 Site species FPC sorted by dominant cover species

Sum of FPC	**Foliage projective cover per site (%)**		
	V4	**P2**	**P7**
Acacia baueri subsp. *baueri*		0.4	
Acacia suaveolens	8.8		
Acacia ulicifolia	31.6		24
Allocasuarina littoralis			
Allocasuarina torulosa			
Aotus lanigera			1.6
Aristida jerichoensis	1.6		
Austromyrtus dulcis		5.6	
Baeckea frutescens			12
Baloskion pallens			18
Baloskion tetraphyllum subsp. *meiostachyum*	2.2	11.6	3.2
Banksia aemula		15.2	9
Baueri capitata		0.4	
Boronia rosmarinifolia		1.6	2
Bossiaea ensata			
Bossiaea heterophylla		0.8	2.4
Brachyloma daphnoides			
Brachyloma scortechinii			1.2
Caustis blakei subsp. blakei			
Caustis recurvata	4		
Coleocarya gracilis		2	0.8
Conospermum taxifolium			0.2
Corymbia gummifera	2	2	16.6
Dianella caerulea	0.6		
Dianella longifolia	0.2		
Dillwynia retorta			
Dillwynia retorta		20.4	7
Dodonaea triquetra			
Empodisma minus			
Entolasia marginata	1.2	0.8	0.4
Eragrostis parviflora	7.8		
Eriachne pallescens	3.6		
Eucalyptus pilularis			
Eucalyptus planchoniana	6.2	23.6	12
Eucalyptus racemosa subsp. *racemosa*			21.2
Gahnia sieberiana			
Gompholobium virgatum	0.8		

Hardenbergia violacea	0.6		
Hibbertia acicularis		0.4	
Hibbertia linearis		0.4	5.6
Hibbertia salicifolia			
Homoranthus virgatus		2.4	4.2
Hypolaena fastigiata			
Jacksonia stackhousei		1.2	
Laxmannia gracilis	0.2		
Lepidosperma laterale			
Leptospermum liversidgei			
Leptospermum polygalifolium			17.4
Leptospermum semibaccatum			
Leptospermum trinervium		16.6	3.2
Leucopogon deformis			
Leucopogon ericoides			0.8
Leucopogon leptospermoides		0.4	3
Leucopogon margarodes			
Leucopogon virgatus			
Lomandra longifolia			
Monotoca scoparia		4	2.6
Monotoca sp. (Fraser Island P. Baxter 777)		0.8	
Ochrosperma lineare		12.4	1.6
Olax retusa			
Olax stricta		0.8	
Patersonia sericea			
Persoonia virgata			2.4
Petrophile shirleyae			
Phyllota phylicoides			
Pimelea linifolia		0.4	0.2
Platysace ericoides			
Pseudanthus orientalis		0.4	
Pteridium esculentum			
Ricinocarpos pinifolius	0.2	10	7.6
Smilax australis			
Sprengelia sprengelioides			
Strangea linearis		3.2	4
Styphelia viridis			
Woollsia pungens		4	2.8
Xanthorrhoea johnsonii	0.8	39.6	27.6
Xanthosia pilosa			
Zieria laxiflora			

7.1.5 Species List

Table 7-5 Species detections by site code

Site	Species
V4	*Acacia baueri* subsp. *baueri*
	Acacia suaveolens
	Acacia ulicifolia
	Angophora leiocarpa
	Aristida jerichoensis
	Baloskion tetraphyllum subsp. *meiostachyum*
	Banksia aemula
	Boronia rosmarinifolia
	Bossiaea heterophylla
	Caustis recurvata
	Coleocarya gracilis
	Corymbia gummifera
	Dillwynia retorta
	Entolasia marginata
	Eragrostis parviflora
	Eriachne pallescens
	Eucalyptus planchoniana
	Eucalyptus racemosa
	Gompholobium virgatum
	Hardenbergia violacea
	Hibbertia linearis
	Homoranthus virgatus
	Laxmannia gracilis
	Lomandra elongata
	Lophostemon confertus
	Ochrosperma lineare
	Paspalum conjugatum
	Patersonia sericea
	Petrophile canescens
	Ricinocarpos pinifolius
	Xanthorrhoea johnsonii
P2	*Acacia baueri subsp. baueri*
	Acacia suaveolens
	Acacia ulicifolia
	Austromyrtus dulcis
	Banksia aemula
	Boronia rosmarinifolia
	Bossiaea heterophylla
	Brachyloma scortechinii
	Caustis recurvata
	Coleocarya gracilis
	Conospermum taxifolium
	Corymbia gummifera
	Dillwynia floribunda
	Dillwynia retorta
	Entolasia marginata
	Eucalyptus planchoniana
	Hibbertia acicularis
	Hibbertia linearis
	Homoranthus virgatus
	Jacksonia stackhousei
	Laxmannia gracilis
	Leptospermum trinervium
	Leucopogon deformis
	Leucopogon ericoides
	Leucopogon leptospermoides
	Lomandra longifolia
	Monotoca scoparia
	Monotoca sp. (Fraser Island P. Baxter 777)
	Ochrosperma lineare
	Olax stricta
	Persoonia virgate
	Petrophile shirleyae
	Phyllota phylicoides
	Pimelea linifolia
	Pseudanthus orientalis
	Pteridium esculentum
	Ricinocarpos pinifolius
	Strangea linearis
	Styphelia viridis
	Woollsia pungens
	Xanthorrhoea johnsonii
	Zieria laxiflora
P7	*Acacia baueri subsp. baueri*
	Acacia suaveolens

Site	Species
	Acacia ulicifolia
	Amperea xiphoclada var. xiphoclada
	Aotus lanigera
	Austromyrtus dulcis
	Baeckea frutescens
	Baloskion pallens
	Banksia aemula
	Boronia rosmarinifolia
	Bossiaea heterophylla
	Brachyloma scortechinii
	Coleocarya gracilis
	Conospermum taxifolium
	Corymbia gummifera
	Dillwynia retorta
	Dodonaea triquetra
	Entolasia marginata
	Eriachne pallescens
	Eucalyptus planchoniana
	Eucalyptus racemosa subsp. racemosa
	Hibbertia acicularis
	Hibbertia linearis

Site	Species
	Homoranthus virgatus
	Leptospermum polygalifolium
	Leptospermum trinervium
	Leucopogon ericoides
	Leucopogon leptospermoides
	Leucopogon margarodes
	Leucopogon virgatus
	Lomandra longifolia
	Monotoca scoparia
	Monotoca sp. (Fraser Island P. Baxter 777)
	Ochrosperma lineare
	Persoonia virgata
	Pimelea linifolia
	Phyllota phylicoides
	Platysace ericoides
	Ricinocarpos pinifolius
	Strangea linearis
	Woollsia pungens
	Xanthorrhoea johnsonii
	Zieria laxiflora

7.1.6 Strata and structure

Table 7-6 Composition of strata and structural characters at each monitoring site

Site	Strata[1]	Crown cover class[2]	Crown cover class estimated percentage	Mean height	Min height	Max height
V4	T1	V	1	2.1	2	2.2
V4	S1	S	60	0.9	0.1	1.3
V4	G	S	10	0.3	0.1	0.6
P2	T1	S	20	4.3	3	5.9
P2	T1	S	10	2.5	2	2.9
P2	S1	V	10	1.3	1	2.5
P2	G	V	10	0.4	0	0.2
P7	T1	S	30	9.5	7	12
P7	T2	S	10	4.0	2.1	6.7
P7	S1	S	30	2.2	1	3
P7	G	M	60	0.9	0.1	1

[1] as per Eyre et al 2015.

[2] V = very sparse; S = sparse; M = mid-dense; D = dense.

Table 7-7 Strata species composition

Site	Form	Species	Strata	Relative dominance[1]
V4	Tree	*Angophora leiocarpa*	T1	A
V4	Tree	*Eucalyptus racemosa*	T1	A
V4	Tree	*Corymbia gummifera*	T1	C
V4	Tree	*Eucalyptus planchoniana*	T1	C
V4	Tree	*Lophostemon confertus*	T1	A
V4	Shrub	*Acacia suaveolens*	S1	S
V4	Shrub	*Acacia ulicifolia*	S1	D
V4	Ground cover	*Baloskion tetraphyllum* subsp. *meiostachyum*	G	S
V4	Ground cover	*Caustis recurvata*	G	D
V4	Ground cover	*Eragrostis parviflora*	G	S
V4	Ground cover	*Eriachne pallescens*	G	S
P2	Tree	*Banksia aemula*	T1	D
P2	Tree	*Eucalyptus planchoniana*	T1	S
P2	Tree	*Leptospermum trinervium*	T1	A
P2	Tree	*Leptospermum trinervium*	S1	D
P2	Tree	*Eucalyptus planchoniana*	S1	S
P2	Tree	*Banksia aemula*	S1	S
P2	Tree	*Corymbia gummifera*	S1	C
P2	Shrub	*Xanthorrhoea johnsonii*	G	C
P2	Shrub	*Jacksonia stackhousei*	G	C
P2	Shrub	*Ricinocarpos pinifolius*	G	S
P2	Shrub	*Boronia rosmarinifolia*	G	A
P7	Tree	*Eucalyptus racemosa* sub sp. *racemosa*	T1	C
P7	Tree	*Eucalyptus planchoniana*	T1	C
P7	Tree	*Corymbia gummifera*	T1	S
P7	Tree	*Banksia aemula*	T2	D
P7	Tree	*Eucalyptus planchoniana*	T2	S
P7	Tree	*Corymbia gummifera*	T2	A
P7	Tree	*Leptospermum trinervium*	S1	D
P7	Shrub	*Ricinocarpos pinifolius*	S1	S
P7	Shrub	*Leptospermum trinervium*	S2	C
P7	Shrub	*Baeckea frutescens*	S2	C
P7	Tree	*Banksia aemula*	S2	A
P7	Shrub	*Xanthorrhoea johnsonii*	S2	S
P7	Shrub	*Xanthorrhoea johnsonii*	G	S
P7	Ground cover	*Baloskion tetraphyllum* sub sp. *meiostachyum*	G	C
P7	Shrub	*Strangea linearis*	G	A
P7	Shrub	*Acacia ulicifolia*	G	C
P7	Shrub	*Boronia rosmarinifolia*	G	S

[1] D = dominant, C = co-dominant, S = sub-dominant, A = associate

7.1.7 Ground cover type

Table 7-8 Ground cover quadrat data (%)

Site	Average of Native vegetation	Average of Exotic vegetation	Average of Litter	Average of Bare ground	Average of Cryptograms
P2	**78.4**	**0**	**17**	**4.6**	**0**
1	91	0	1	8	0
2	86	0	7	7	0
3	75	0	20	5	0
4	59	0	40	1	0
5	81	0	17	2	0
P7	**62.2**	**0**	**35.8**	**2**	**0**
1	75	0	25	0	0
2	30	0	69	1	0
3	82	0	15	3	0
4	65	0	30	5	0
5	59	0	40	1	0
V4	**30.2**	**0**	**3**	**68.8**	**0**
1	23	0	1	76	0
2	45	0	3	52	0
3	8	0	1	91	0
4	35	0	8	67	0
5	40	0	2	58	0

7.1.8 Foliage Projected Cover

Table 7-9 FPC per species per height class

Site - Species	FPC per height category		
	<1m (%)	>1m (%)	Total (%)
P2	**118**	**63.4**	**181.4**
Acacia baueri subsp. baueri	0.4		0.4
Austromyrtus dulcis	5.6		5.6
Baloskion tetraphyllum subsp. meiostachyum	11.6		11.6
Banksia aemula	1.6	13.6	15.2
Baueri capitata	0.4		0.4
Boronia rosmarinifolia	1.6		1.6
Bossiaea heterophylla	0.8		0.8
Coleocarya gracilis	1.6	0.4	2
Corymbia gummifera		2	2
Dillwynia retorta	18.8	1.6	20.4
Entolasia marginata	0.8		0.8
Eucalyptus planchoniana		23.6	23.6

Site - Species	FPC per height category		
	<1m (%)	>1m (%)	Total (%)
Hibbertia acicularis	0.4		0.4
Hibbertia linearis	0.4		0.4
Homoranthus virgatus	2.4		2.4
Jacksonia stackhousei	1.2		1.2
Leptospermum trinervium	1.6	15	16.6
Leucopogon leptospermoides	0.4		0.4
Monotoca scoparia	4		4
Monotoca sp. (Fraser Island P. Baxter 777)	0.8		0.8
Ochrosperma lineare	12.4		12.4
Olax stricta	0.8		0.8
Pimelea linifolia	0.4		0.4
Pseudanthus orientalis	0.4		0.4
Ricinocarpos pinifolius	3.6	6.4	10
Strangea linearis	3.2		3.2
Woollsia pungens	3.2	0.8	4
Xanthorrhoea johnsonii	39.6		39.6
P7	**114.4**	**100.2**	**214.6**
Acacia ulicifolia	23.2	0.8	24
Aotus lanigera		1.6	1.6
Baeckea frutescens		12	12
Baloskion pallens	18		18
Baloskion tetraphyllum subsp. meiostachyum	3.2		3.2
Banksia aemula	0.8	8.2	9
Boronia rosmarinifolia	2		2
Bossiaea heterophylla	2.4		2.4
Brachyloma scortechinii	1.2		1.2
Coleocarya gracilis	0.8		0.8
Conospermum taxifolium		0.2	0.2
Corymbia gummifera		16.6	16.6
Dillwynia retorta	4.4	2.6	7
Entolasia marginata	0.4		0.4
Eucalyptus planchoniana		12	12
Eucalyptus racemosa subsp. racemosa		21.2	21.2
Hibbertia linearis	5.6		5.6
Homoranthus virgatus	4	0.2	4.2
Leptospermum polygalifolium		17.4	17.4
Leptospermum trinervium		3.2	3.2
Leucopogon ericoides	0.8		0.8
Leucopogon leptospermoides		3	3
Monotoca scoparia	2	0.6	2.6
Ochrosperma lineare	1.6		1.6
Persoonia virgata	2.4		2.4

Site - Species	FPC per height category		
	<1m (%)	>1m (%)	Total (%)
Pimelea linifolia		0.2	0.2
Ricinocarpos pinifolius	7.2	0.4	7.6
Strangea linearis	4		4
Woollsia pungens	2.8		2.8
Xanthorrhoea johnsonii	27.6		27.6
V4	**56**	**16.4**	**72.4**
Acacia suaveolens	3	5.8	8.8
Acacia ulicifolia	28	3.6	31.6
Aristida jerichoensis	1.6		1.6
Baloskion tetraphyllum subsp. meiostachyum	2.2		2.2
Caustis recurvata	4		4
Corymbia gummifera	2		2
Dianella caerulea	0.6		0.6
Dianella longifolia	0.2		0.2
Entolasia marginata	1.2		1.2
Eragrostis parviflora	5.2	2.6	7.8
Eriachne pallescens	3.6		3.6
Eucalyptus planchoniana	1.8	4.4	6.2
Gompholobium virgatum	0.8		0.8
Hardenbergia violacea	0.6		0.6
Laxmannia gracilis	0.2		0.2
Ricinocarpos pinifolius	0.2		0.2
Xanthorrhoea johnsonii	0.8		0.8

8 Appendix 2

8.1 Site Photos

2015	2016	2017	2018	2019
				

Site V4 – Transect Start

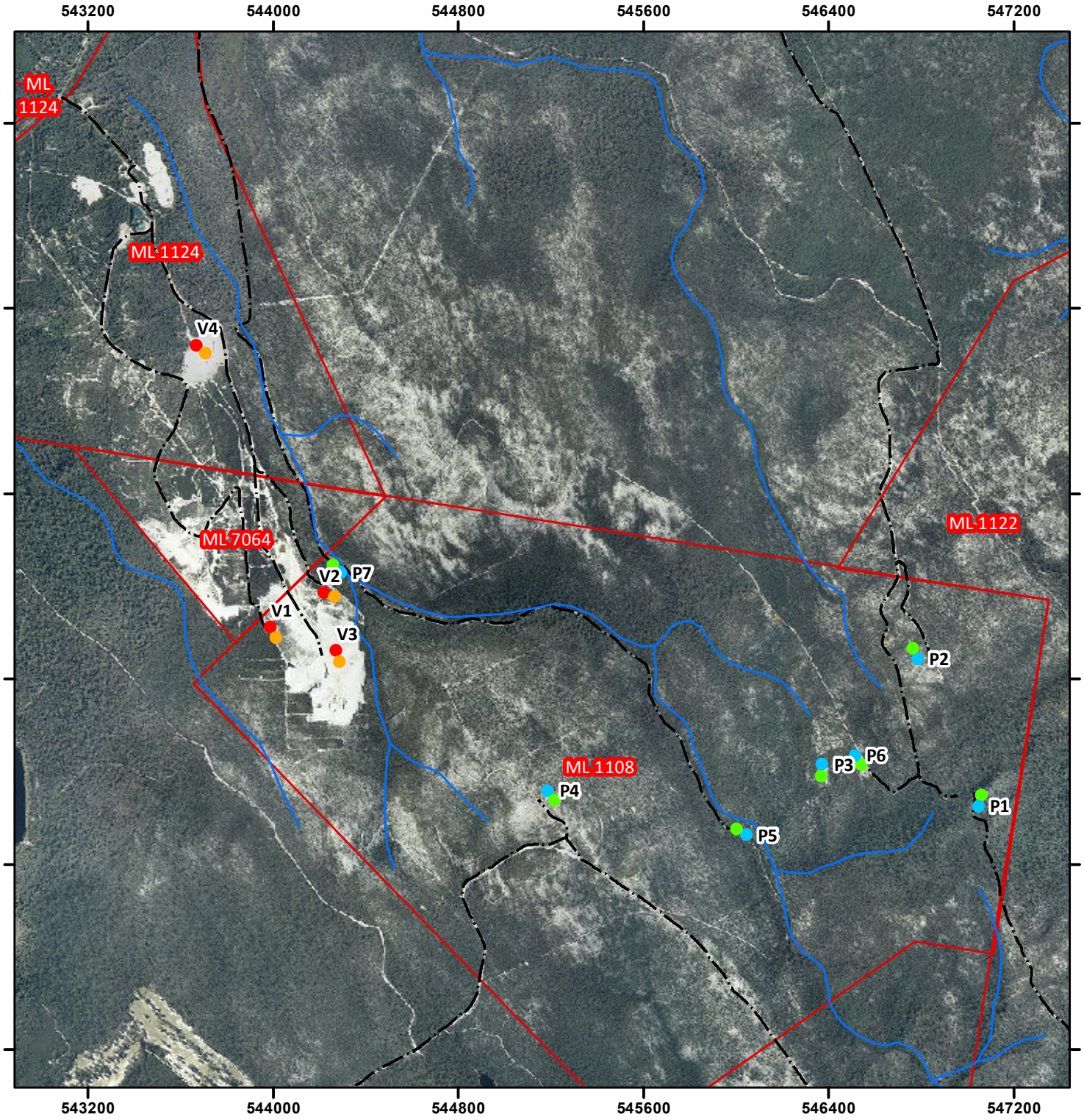
Site V4 – Transect End

Site P2 – Transect Start

2015	2016	2017	2018	2019
				
Site P2 – Transect End				
				
Site P7 – Transect Start				
				
Site P7 – Transect End				

9 Appendix 3

9.1 Map of Monitoring Sites



Ausecology

Sibelco Glass Operations - Vegetation Rehabilitation Annual Monitoring September 2019

Rehabilitation, Primary Reference and Sensitive Area Sites

N

0 0.25 0.5 0.75 1 1.25

Kilometers

Scale: 1:24,000

Page Number: 1 of 1

Coordinate System: GDA 1994 MGA Zone 56

Datum: GDA 1994

Legend

- Mining Leases
- Drainage

Rehabilitation sites

- Start
- End

Primary reference and sensitive area sites

- Start
- End

Data sources:

Mining Lease Boundaries
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Drainage
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