MONJEBUP NORTH

Ecological Restoration Project

2012 - 2013



THRESHOLD environmental

MONJEBUP NORTH ECOLOGICAL RESTORATION PROJECT 2012-2013 Final Report

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THRESHOLD ENVIRONMENTAL

2013

A project commissioned by Bush Heritage Australia

CITATION
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This project was funded by Bush Heritage Australia via Gondwana Link Landscape Manager Simon Smale. Simon initiated the project, had the foresight to commission a Restoration Plan for the site in 2010, and provided strong support for Threshold Environmental to implement the 2012 and 2013 restoration work.

Craig Luscombe was the Seed Manager for Threshold Environmental over both years, identifying and collecting the bulk of the seed for the majority of plant species used in this project. Craig's knowledge of the local flora and vegetation associations is far-reaching and this is reflected in the 148 plant species included in the 2012/2013 project works. Special reference should be made to Craig's extensive knowledge of the Melaleuca genera, of which he identified 23 species, and where he played a large role in getting those species into the seed mixes. Craig also prepared the mulch mixes, collected serotinous species for the burn piles, and worked alongside Threshold staff to spread and burn them respectively.

Lien Imbrechts was the Restoration Officer for Threshold Environmental over both years, providing on-ground support at all phases of the work. This work included seed collection and cleaning, preparation of seed mixes, field support during implementation and post-establishment monitoring, and general project administration. Many long hours of field work in uncomfortable environmental conditions were taken in stride across the two years, showing true commitment to the on-ground work of ecological restoration.

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EXECUTIVE SUMMARY

Following the development of the Monjebup North Ecological Restoration Plan in 2011, Threshold Environmental was contracted to implement the Monjebup North Restoration Project in 2012 and 2013. In that time frame **240 hectares** of best-practice ecological restoration were established across the northern section of the cleared land. A total of **148 plant species** were included in this two-year restoration effort. These species were organised into **13 different vegetation systems** matched to soil type; in an effort to re-establish vegetation communities reflecting the surrounding remnant vegetation as best as possible. In addition to the direct-seeding, **6,809** seedlings were planted in **203 discrete node configurations**. Pure seed was also hand-broadcast in **52 nodes** across the 2012 project area. To further enhance the direct seeding and node plantings, a total of **2,857 *Banksia media* seedlings** were planted across the entire 240 hectares in an approximate 30 x 28 meter grid. In the 2012 project area **824 *Banksia caleyi* seedlings** were also planted in a 30 x 28 meter grid density in all systems except the lower Yate swamp system (VegSys2.2). In the Yate Systems, **1,330 *Eucalyptus occidentalis* seedlings** were planted at a 14 x 16 meter density in the 'Yate Hi'-areas (VegSys2.1), and a 13 x 13 meter density in the 'Yate Low' areas (VegSys2.2). Across the 2012 area, 5.5 kilometres of 5-meter wide graded passes ('seams') were strategically positioned on the contour. On these graded seams, a selection of locally collected vegetation was deposited as **chipped mulch** and **184 small piles of fire-responsive serotinous vegetation were burnt in situ**. In addition, **16 habitat debris piles** were constructed for use by reptiles and small mammals. **Permanent monitoring plots** have been established at 36 locations across the entire 2012/2013 project area to assess the initial recruitment of plants after project implementation. Results indicate a consistent and uniform recruitment in line with the project objectives.

Introduction

This report presents the technical information and initial results of the implementation of two years of on-ground ecological restoration work at Bush Heritage Australia's Monjebup North Reserve. Threshold Environmental Pty Ltd consolidated and improved information developed in the Monjebup North Ecological Restoration Plan (Jonson 2011) and Monjebup North Vegetation Assessment (Jonson 2011) to implement the most sophisticated revegetation program seen within Gondwana Link to date. This report presents the background information underpinning two successive seasons, which include 100 hectares in 2012 and 140 hectares in 2013.

I. 2012 Program

The North-Western paddock (110 hectares) of the Monjebup North property was allocated for restoration in 2012. The Monjebup North Restoration Plan (Jonson 2011) served as a basis for the design of a more detailed restoration map prior to project implementation. Three broadly defined vegetation associations were initially identified in the Restoration Plan, and these were converted into a more detailed layout. With map in hand, modifications were applied to maximise heterogeneity of plant community composition and structure for the benefit of potential future use and habitation by local fauna. This process resulted in the development of eight detail-rich vegetation restoration systems (Fig 1 and 2).

Figure 1. Restoration Map as per the Monjebup North Restoration Plan (Jonson 2011).

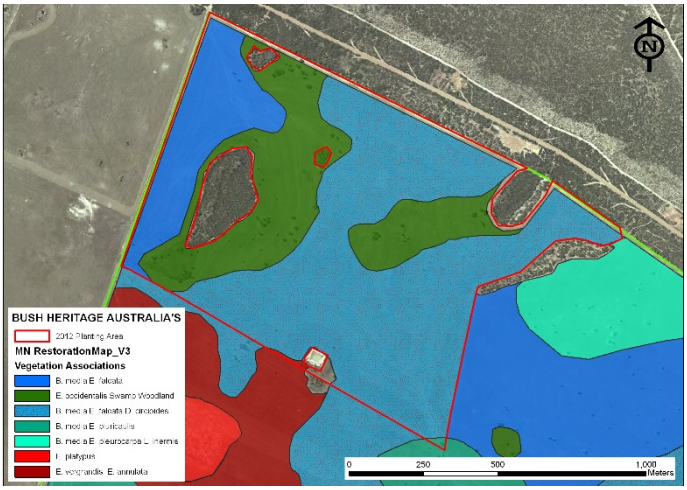
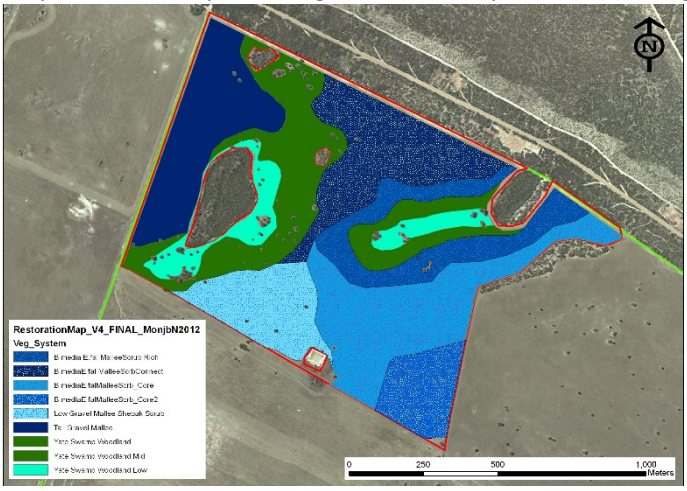


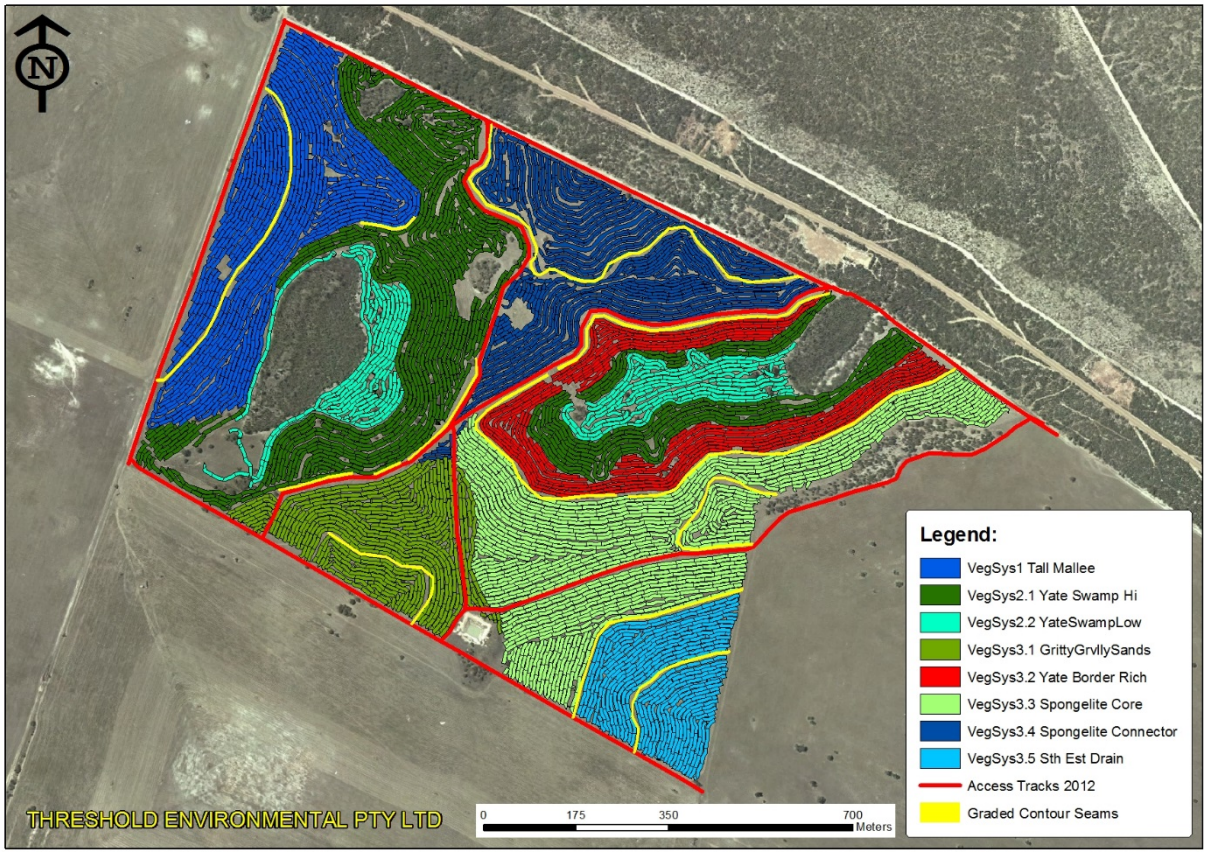
Figure 2. The 2012 operational map showing a modified layout of the revegetation systems.



These eight different vegetation systems are matched to their respective soil types, and were direct-seeded in June 2012 (Fig 3). They are defined as follows:

1. **VegSys 1.0 – Tall Mallee Shrubland** (14.85 Ha)
2. **VegSys 2.1 – Upland Yate Swamp** (20.4 Ha)
3. **VegSys 2.2 – Lowland Yate Swamp** (6.63 Ha)
4. **VegSys 3.1 – Gritty Sand and Gravel Mallee Scrubland** (9.73 Ha)
5. **VegSys 3.2 – Sandy Gravel Duplex Mallee Shrubland Bordering the Yate** (11.3 Ha)
6. **VegSys 3.3 – Sandy Gravel Spongelitic Duplex Mallee Shrubland 'Core'** (19.34 Ha)
7. **VegSys 3.4 – Sandy Gravel Spongelite Duplex Mallee Shrubland 'Connector'** (15.4 Ha)
8. **VegSys 3.5 – Sandy Gravelly Duplex Mallee Shrubland 'Southeast Drain'** (6.58 Ha)

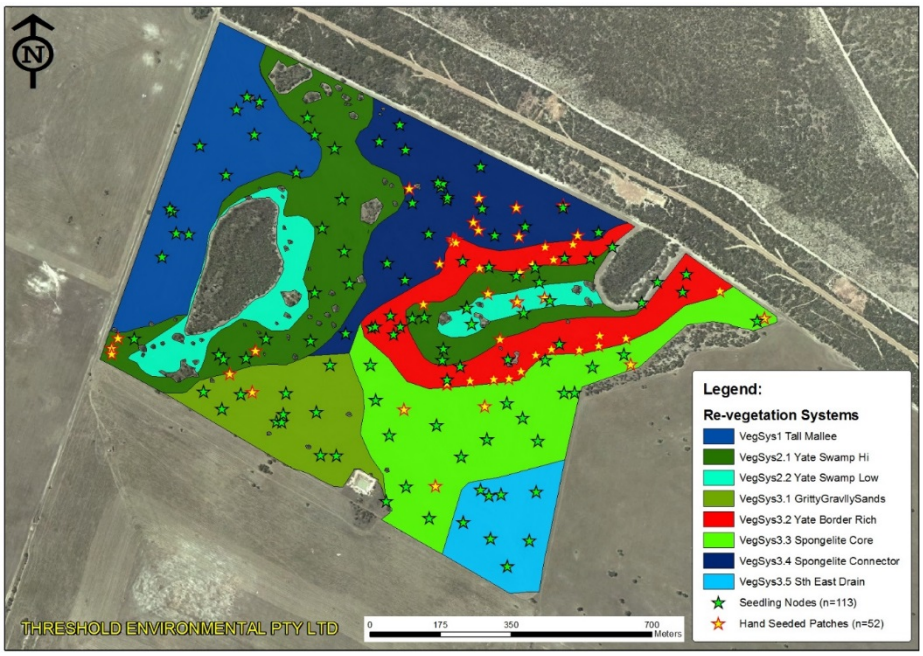
Figure 3. Operational map of 2012 areas showing the tractor workings across the eight systems in situ. Access tracks (red lines) are 15 m wide on the perimeter, while internal access tracks are 10 m. Contour graded 'seams' (yellow lines) were established by two passes of the grader for total width of approximately 6 meters.



A total of 130 plant species were utilised in the 2012 project works. Full species lists for each vegetation association can be found in Appendix A. To initiate establishment of vegetation, a variety of restoration techniques were used, including broad-acre direct-seeding, manual direct-seeding, seedling planting, chipping and mulching, and in situ burn piles. All plant species were allocated to each of the eight revegetation systems to reflect the natural composition of adjacent plant assemblages as much as possible. This allows for the species to be matched to soil types, while also providing the appropriate conditions for a) asynchronistic flowering, b) complex structural diversity of vegetation forms, and c) representative diversity of different plant lifespan capacities (i.e. short versus long lived species). The direct seeding was implemented from the 16th till the 23rd of July.

A total of 2,163 seedlings were used to establish 113 species-specific 'nodes' across the 2012 area. The distribution of these seedling nodes are illustrated in Figure 4 (Green Stars). The number of seedlings planted in any given node ranged from 4 to 60, with an average count of 19 seedlings per node. A summary of the seedling nodes is presented in Table 1a.

Figure 4. Map showing the location and density of seedling 'nodes' and hand-seeded patches across the north-western paddock.



In addition to the seedling nodes, a number of hand-seeded 'patches' were also established across the site in 2012. The location and density of these patches are illustrated in Figure 4 (Yellow Stars). A summary of the species used in the hand-seeded patches is presented in Table 1b.

Tables 1a & 1b. Summary of seedling 'nodes' (a) and hand-seeded Patches (b).

a.

SPECIES	Nodes Count	Total Seedling Count
Acacia assimilis	1	15
Acacia lasiocarpa	2	35
Acacia moirii	1	5
Acacia newbeyi	1	7
Acacia sphacelata	2	30
Acacia spongelitica	7	101
Acacia subcaerulea	1	15
Banksia caleyi	5	110
Banksia nutans	7	85
Chorizema aciculare	2	9
Daviesia benthamii	3	120
Dodonea stenozyga	4	94
Dryandra drummondii	3	53
Gompholobium tomentosum	1	15
Grevillea sp. pallinup	1	15
Hakea commutata	13	200
Hakea corymbosa	3	50
Hakea cygna	4	54
Hakea laurina	3	34
Hakea nitida	15	310
Hakea pandanicarpa	4	115
Hakea strumosa	21	406
Templetonia retusa	9	247
	113	**2125**

b.

SPECIES	Hand Seeded Nodes
Acacia harveyi	2
Acacia lasiocarpa	1
Acacia trulliformis	1
Acacias mixed	1
Allocasuarina humilis	1
Baeckia sp. 1	1
Banksia nutans	1
Banksia sphaerocarpa	4
Beaufortia schaueri	1
Callitris pyramidalis	1
Calothamnus sanguineus	4
Conothamnus aureus	1
Dodonaea ptarmicaefolia	1
Dryandra drummondii	8
Eucalyptus conglobata	1
Eucalyptus pachyloma	2
Eucalyptus perangusta	2
Eucalyptus sporadica	1
Gastrolobium spinosum	2
Hakea strumosa	1
Isopogon trilobus	1
Kunzea preissiana	4
Kunzea recurva	2
Logania buxifolia	2
Melaleuca scabra	2
Melaleuca subfalcata	1
Rhagodia baccata	1
Verticordia plumosa	2
	52

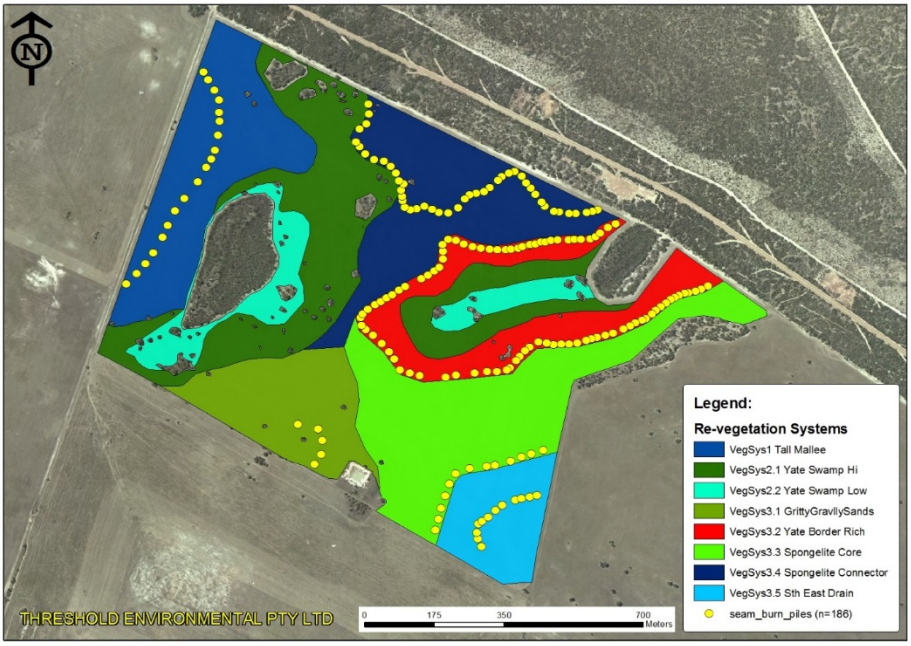
Wide-spaced seedling planting approaches were also employed across the 2012 area. This included the planting of 923 *Banksia media* seedlings planted in a grid across all systems within the 100 hectares at an approximate 30 x 28 meter spacing. In addition, 824 *Banksia caleyi* seedlings were also planted a similar grid-like spacing density. This *B. caleyi* seedling grid was positioned

approximately 15 meters offset from the *B. media* seedling grid. The *B. caleyi* seedlings were also planted in all 2012 systems except for the lower Yate swamp system (VegSys2.1). This approach allows for a very equal distribution of these keystone species across the entire 100 hectares.

For the Yate Systems (27.03 hectares in total), 1,330 *Eucalyptus occidentalis* seedlings were hand-planted to enable better control of stocking densities. For the 'Yate Swamp Hi' (VegSys2.1) areas, seedlings were planted at a 14 x 16 meter spacing, for a target density of approximately 45 stems per hectare. Densities were slightly increased in the 'Yate Swamp Low' (VegSys2.2) areas with seedlings planted at approximately 13 x 13 meters for a resulting planting density of about 64 stems per hectare.

Across the 2012 project area, 5.5 kilometres of 5 meter wide graded and ripped passes were established on the contour in several locations. On these graded 'seams', locally collected vegetation was applied as chipped mulch. In addition, 186 small piles of seed-carrying branches selected from fire-responsive serotinous plant species were spread across the seams and burned in situ to stimulate germination of the included species. The location and distribution of these burn piles is shown in Figure 5.

Figure 5. The 2012 operational map showing the location of the 186 fire-triggered serotinous burn piles distributed along some of the contour graded seams.



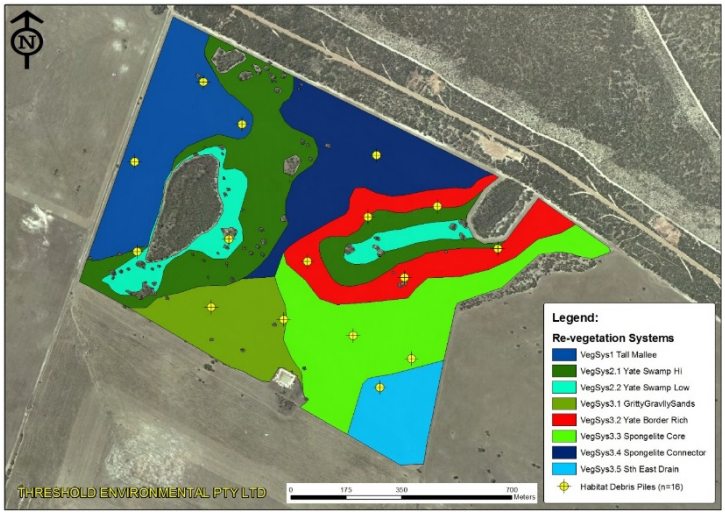
Species used for the fire-responsive serotinous species burn piles were *Dryandra cirsioides*, *Dryandra nervosa*, *Isopogon trilobus*, *Petrophile seminuda*, *Isopogon buxifolius*, *Hakea corymbosa*, *Hakea pandanicarpa*, and *Petrophile phylicoides*. The objective of this approach was to increase the species diversity within the revegetated areas, when no seedlings of these species had been pre-ordered, nor was seed available for inclusion within the direct-seeding mixes. The technique used is depicted in the photos in Figure 6. Although initial establishment from this technique did not seem significantly encouraging, observations in year 2 have identified recruitment of some of the target species including *Dryandra cirsioides*, *Dryandra drummondii, Dryandra nervosa*, *Hakea pandanicarpa*, *Isopogon buxifolius*, and *Hakea corymbosa*.

Figure 6. Photo montage showing several of the steps involved with the fire-responsive serotinous vegetation burn pile approach. (tl) Grader work; (tr) branches piled; (bl) J. Jonson and C. Luscombe light piles; (br) D. Lehmann (in background) tends to some of the burning piles.

Using the practice of re-vegetation as the primary tool for an ecological restoration project is likely to be the most effective means to re-establishing many of the ecological functions supporting faunal populations. However, the absence of course woody debris within revegetated areas over the first 20 years presents substantial time lags in the provision of those critical habitat conditions (Munro et al. 2010). In an effort to establish some form of immediate, yet long-term, structural habitat features, 16 'habitat debris piles' were constructed across the site (Figure 7).

The intended objective of these wood-and-rock built structures is to support reptile and small mammal species known to be potential site occupants over the coming decades. It should be noted these efforts were experimental. While definitive projections regarding their anticipated contribution to faunal use on the site are not possible, we can report their establishment and existence on site as 16 additional built-environment habitat treatments. Photos of the habitat debris piles are shown in Appendix B.

Figure 7. The 2012 operational map showing the location of the 16 habitat debris piles distributed throughout the re-vegetation systems.

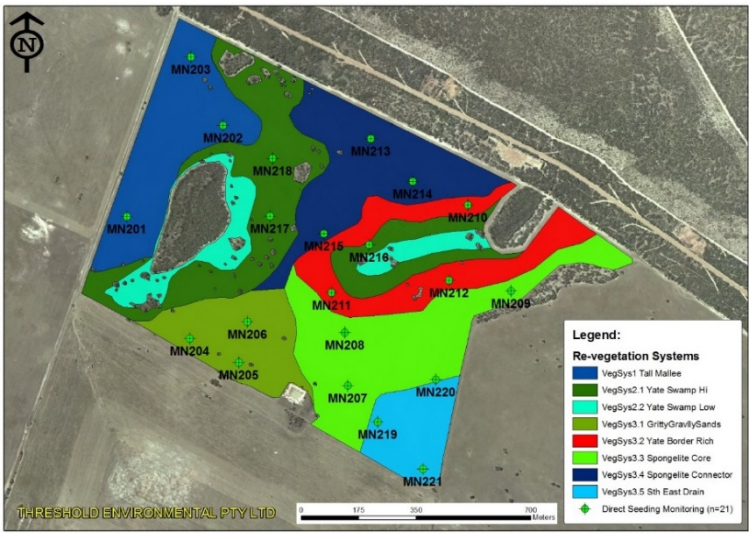


Monitoring 2012

To assess the extent of tree and shrub recruitment achieved through the 2012 direct-seeding program, 21 permanent monitoring plots were established across the revegetation systems (Figure 8). For each of the revegetation mixes except for the Yate Woodland Swamp Low (VegSys2.2), three plots were established in a stratified random position to capture a representative snap-shot of the direct-seeding results.

Monitoring was undertaken in November 2012, four months after direct-seeding. For each location, a 15 meter long and approximately 15 meter wide plot was established. With a seeding machine pass width of 7 meters, seeding five rows at 1.4m spacing, each plot captures two passes of the machine (or 10 seeded rows). For each monitoring plot location, a steel stake and identification tag have been established.

Figure 8. The 2012 operational map showing the location of 21 monitoring plots established to assess the success of the direct seeding works.



Seedling recruits were recorded by genera within each plot. Results of the 2012 initial recruitment are presented in Table 2 and Figure 9. A strong level of recruitment was demonstrated across all

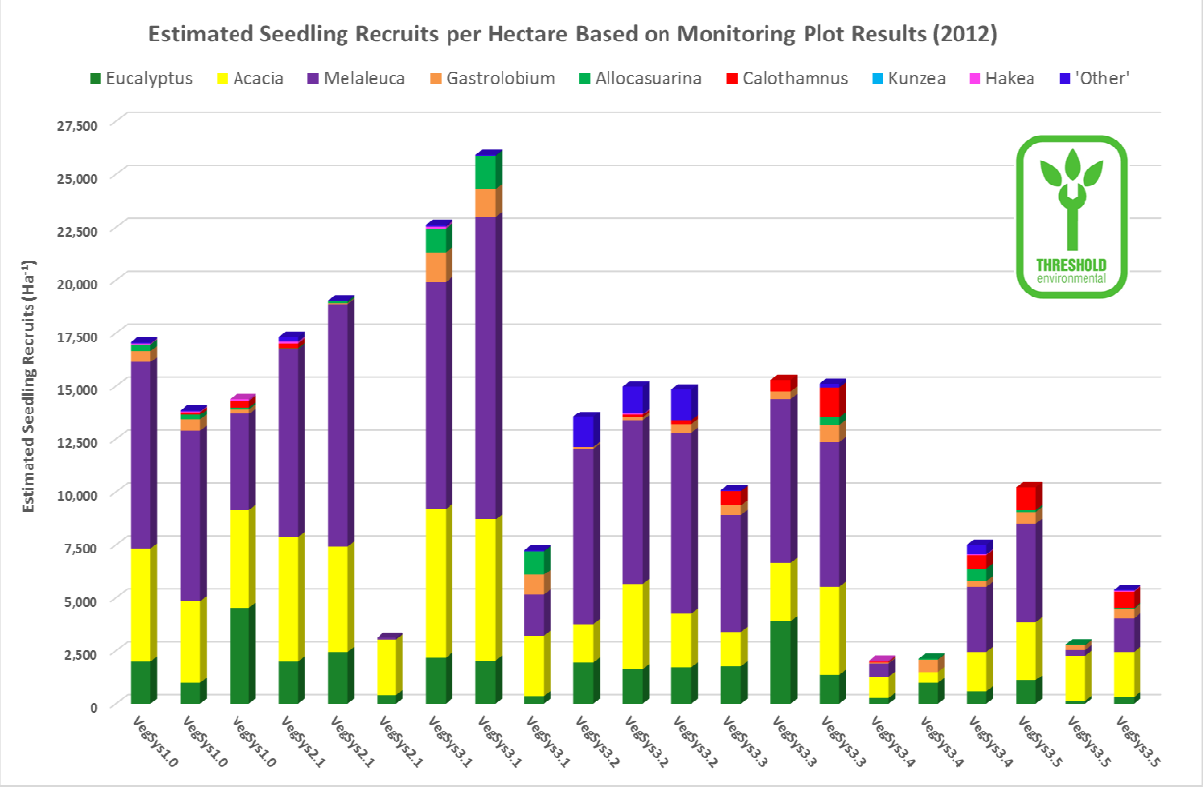
plots, which were positioned widely to capture a representative assessment across the 100 hectare area. Total sampling area represented 0.5% of the total seeded area.

Table 2. Plot monitoring results from 2012 indicating number of recruits per plot following direct seeding.

System	Operational Name	Plot ID	Tag ID	Plot Area m^2	Eucalyptus	Acacia	Melaleuca	Gastrolobium	Allocasuarina	Calothamnus	Kunzea	Hakea	'Other'
VegSys1.0	Tall Mallee	MN201	**02990**	225.0	45	120	198	12	7			1	1
VegSys1.0	Tall Mallee	MN202	**02991**	225.0	22	87	181	12	5	3		1	1
VegSys1.0	Tall Mallee	MN203	**02992**	225.0	102	104	102	5	2	7		2	
VegSys2.1	Yate Swamp High	MN216	**02747**	225.0	45	132	200		1	5		2	5
VegSys2.1	Yate Swamp High	MN217	**02746**	225.0	55	112	258	1	2				1
VegSys2.1	Yate Swamp High	MN218	**02753**	225.0	9	59	2						
VegSys3.1	Gritty Gravelly Sands	MN204	**02993**	225.0	49	158	241	32	25			2	2
VegSys3.1	Gritty Gravelly Sands	MN205	**02994**	225.0	46	150	321	30	35				1
VegSys3.1	Gritty Gravelly Sands	MN206	**02995**	225.0	8	64	44	21	25				1
VegSys3.2	Yate Border Rich	MN210	**02999**	225.0	44	41	186	2					32
VegSys3.2	Yate Border Rich	MN211	**03000**	225.0	37	90	174	3		3		1	29
VegSys3.2	Yate Border Rich	MN212	**02750**	225.0	39	57	192	9		4			33
VegSys3.3	Spongelite Core	MN207	**02996**	225.0	40	36	125	10		15			1
VegSys3.3	Spongelite Core	MN208	**02997**	225.0	88	62	174	8		12			
VegSys3.3	Spongelite Core	MN209	**02998**	225.0	31	93	154	18	8	32			4
VegSys3.4	Spongelite Connector	MN213	**02749**	225.0	6	23	14	1		1		1	
VegSys3.4	Spongelite Connector	MN214	**02748**	225.0	22	12		13	1				
VegSys3.4	Spongelite Connector	MN215	**02745**	225.0	13	42	69	6	14	14		1	10
VegSys3.5	South Easterly Drain	MN219	**02754**	225.0	25	62	104	13	2	24			
VegSys3.5	South Easterly Drain	MN220	**02755**	225.0	3	48	6	5	1				
VegSys3.5	South Easterly Drain	MN221	**02756**	225.0	7	48	36	10	1	17		1	1

Plot recruitment shows variations in stem density and composition both within and between revegetated plant assemblages. This indicates the potential for a wide range of resulting structural plant diversity throughout the project area. Variation in recruitment observed within a given revegetation system is likely to reflect small-scale variations in soil types located within each targeted land unit system, and unavoidable discrepancies in the deposition of seed within bulked seed mixes. The resulting variation in recruitment densities and species composition within the newly establishing plant assemblages will further contribute to improving functional and structural complexity across the site.

Figure 9. Graphical depiction of estimated per hectare seedling recruitment from 2012 monitoring results.



Initial assessment of recruitment density and composition indicate a solid trajectory has been established toward a restored state. *Acacia* recruit density will likely contract within the next decade, as a percentage of the species seeded are short-lived. High *Melaleuca* densities are a first-time accomplishment in Gondwana Link, and given the size of these species, are representative and reflective of surrounding plant assemblages. Initial *Eucalypt* recruitment density across the 2012 project area averaged 1,558 stems per hectare, however a large variation in this stocking occurred from plot to plot. Solid recruitment of the *Gastrolobium* and *Calothamnus* genera further support the functional diversity of the direct-seeded vegetation. Additional recruits unable to be identified by genera were assigned to the 'Other' category. High counts of the 'Other' category in VegSys3.2 are possibly *Taxandria spathulata*.

Operational Notes 2012

Operational delivery was largely without incident for this year. Seasonal precipitation was good and highly supportive to recruitment. Post-seeding weed growth across the site was average, and scalps were able to provide the necessary window of time required for native plant establishment.
In the lead up to planting, a few discrete areas were missed by the spray contractor. Some follow-up spot spraying of those missed areas would have been beneficial in hindsight, however the overall recruitment across the total project area suggest this was not a critical issue of concern.
Seedling quality provided by Blythe Tree Farm was variable in terms of stem thickness and root establishment within seedling plugs, however post planting rainfall was supportive to establishment, and few mortalities were observed.

The 2012 season was a good one for revegetation, and site conditions further supported recruitment.

GIS shapefiles for all treatments are provided with this report, listed in Appendix C.

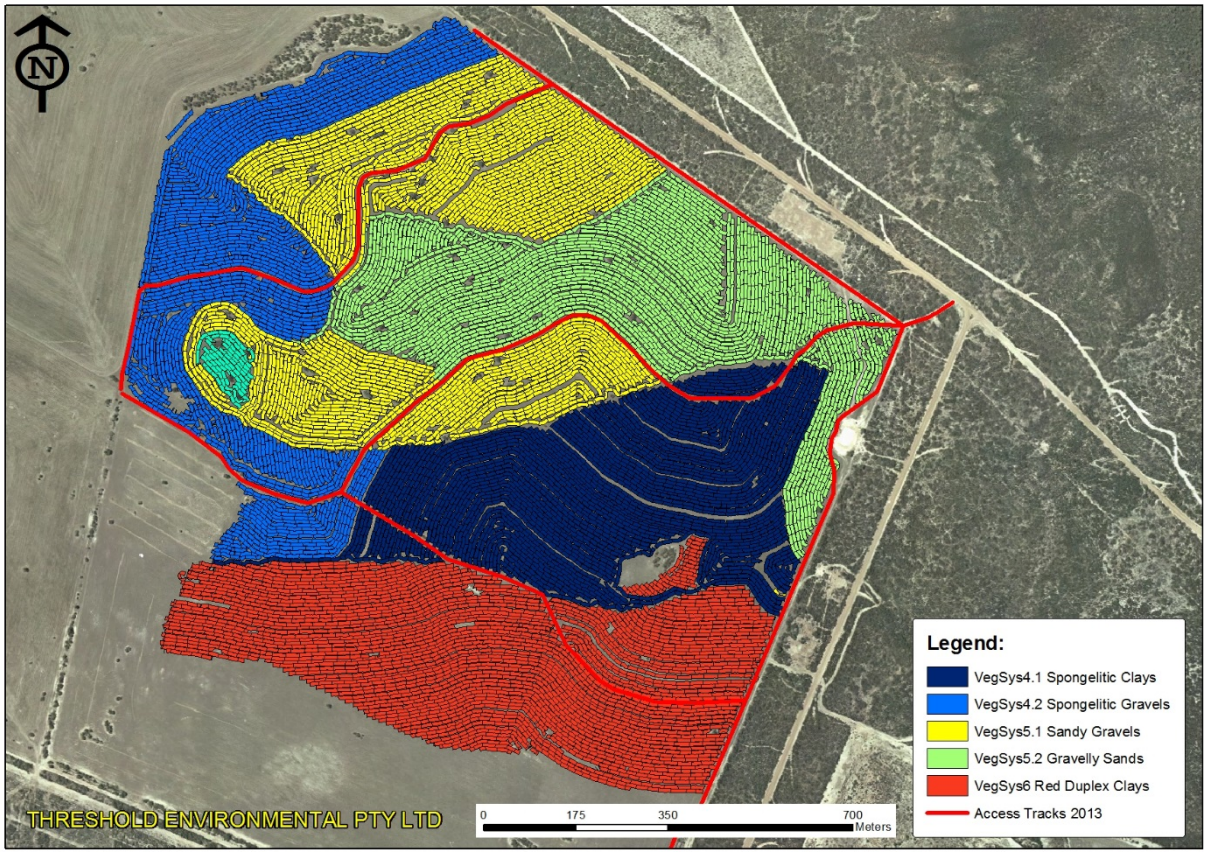
II. 2013 Program

In 2013, a 140 hectare project area was allocated for restoration across the north-eastern part of the Monjebup North property. Once again, the project started by refining the layout of vegetation systems defined in the Monjebup North Restoration Plan (Jonson 2011). To increase the diversity of habitat conditions available to local fauna, plant community composition and structure was diversified to increase heterogeneous ecological features. This process was also informed by the results of the 2012 Program, and was guided by a clear intention to develop a different set of ecosystem properties. The original broad restoration systems defined in the Monjebup North Ecological Restoration Plan were eventually developed into a more appropriately defined selection of five different vegetation restoration systems (Figure 10). *note VegSys2.2 was also recreated on 0.82 Ha in a small sump depression located within VegSys5.1.

These five vegetation systems are matched to their respective soil types and landscape positions, and were direct-seeded in July 2013. The five systems are defined as follows:

1. **VegSys 4.1 – Spongelitic Clay Duplex Mallee Shrubland** (25.75 Ha)
2. **VegSys 4.2 – Sandy Gravelly Spongelitic Mallee Shrubland** (23.19 Ha)
3. **VegSys 5.1 – Sandy Gravel Duplex Mallee Shrubland** (31.86 Ha)
4. **VegSys 5.2 – Gravelly Sandy Duplex Mallee Shrubland** (26.96 Ha)
5. **VegSys 6.0 – Red Duplex Clay Mallee Shrubland** (31.4 Ha)

Figure 10. The 2013 operational map showing the tractor workings across five re-vegetation systems in situ. Access tracks are shown in red lines.



A total of 98 plant species were utilised in the 2013 restoration effort. The full species lists for each of the vegetation associations are provided in Appendix A. In a specific effort to manage the

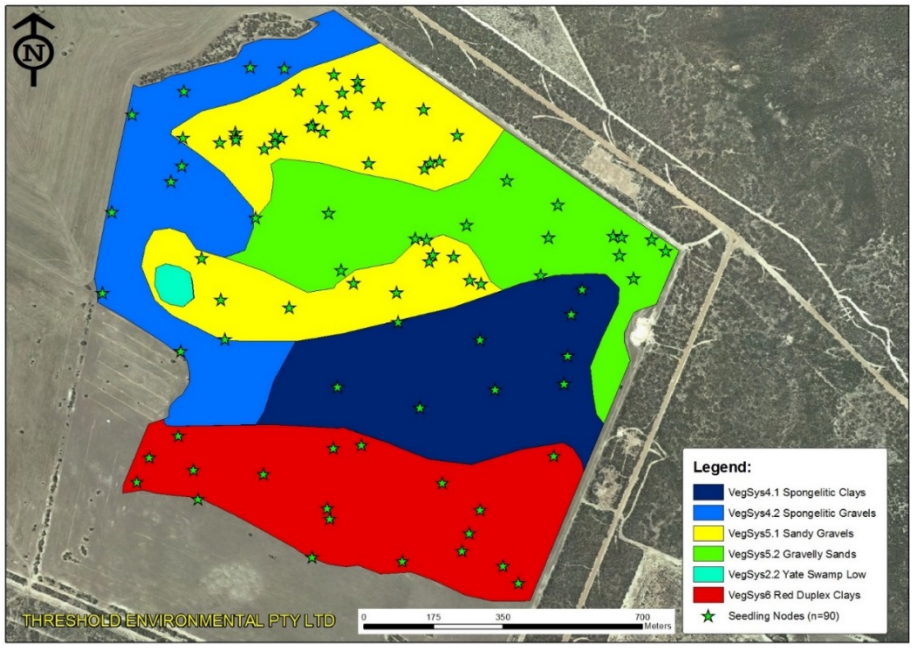
resulting stocking densities and establish a more open plant community structure, direct seeding rates were decreased in the 2013 season. The direct seeding was implemented from the 22nd of July till the 3rd of August.

For the 2013 season, a total of 4,646 seedlings were used to establish 90 seedling 'nodes' across the north-eastern paddock. The approach used in 2013 differed from the 2012 program to provide further variation in potential habitat conditions and resource partitioning across the entire revegetated area. Specifically, the size of each node increased, as did the number of seedlings planted for any given node. The number in each node ranged from 17 to 256, with an average count of 67 seedlings per node across the 2013 area. In comparison, the 2012 Program used 4 to 60 seedlings per node, with an average count of 19 seedlings. The distribution of the 2013 nodes is illustrated in Figure 11 (Green Stars). Information on the seedling nodes is presented in Table 3.

Table 3. Summary of Seedling 'nodes' established in the 2013 program.

SPECIES	Nodes Count	Total Seedling Count
Acacia bidentata	4	256
Acacia declinata	1	256
Acacia newbeyi	1	192
Acacia spongelitica	3	297
Acacia subcaerulea	10	512
Banksia caleyi	2	128
Banksia media	2	128
Banksia nutans	4	355
Calothamnus sanguineus	4	242
Dryandra drummondii	1	150
Hakea commutata	6	320
Hakea laurina	1	64
Hakea lissocarpa	9	73
Hakea marginata	1	88
Hakea nitida	8	447
Hakea pandanicarpa	5	256
Hakea strumosa	5	234
Hakea verrucosa	2	128
Isopogon trilobus	2	129
Kunzea preissiana	6	401
Lambertia inermis	13	54
	90	**4710**

Figure 11. The 2013 operational map showing the location and density of seedling 'nodes'.



In addition to the seedling nodes, 1,670 *Banksia media*-seedlings were planted in a grid-like distribution across all systems within the 140 hectare area, at an approximate 30 x 28 meter spacing.

Approximately 64 *Eucalyptus occidentalis* seedlings were also planted in a small depression within the Sandy Gravel-system, which was defined as a Lowland Yate Swamp (VegSys2.2).

Monitoring 2013

To assess the extent of tree and shrub recruitment achieved through the 2013 direct-seeding, 15 permanent monitoring plots were established across the revegetation systems (Figure 12). For each of the revegetation mixes, except for a small area implemented as a Lowland Yate Swamp System (VegSys2.2), three plots were established in a stratified random position to capture a representative 'snap-shot' of recruitment following seeding. Monitoring was undertaken in December 2013. The methodology from 2012 was again applied for the 2013 monitoring program. Results from the monitoring are presented in Table 4 and Figure 12.

Figure 12. The 2013 operational map showing the location of 15 monitoring plots established to assess the success of the direct-seeding.

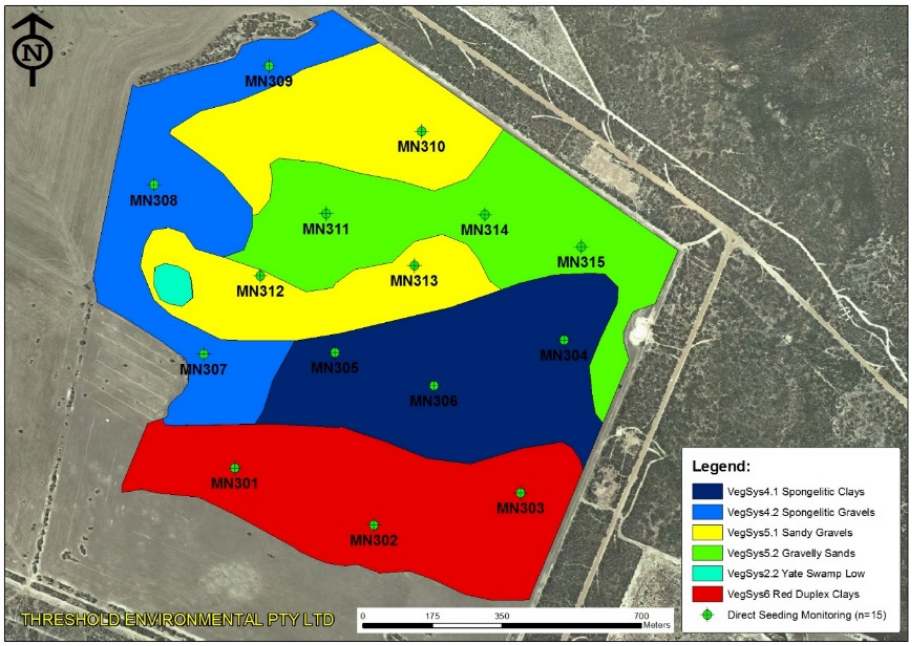
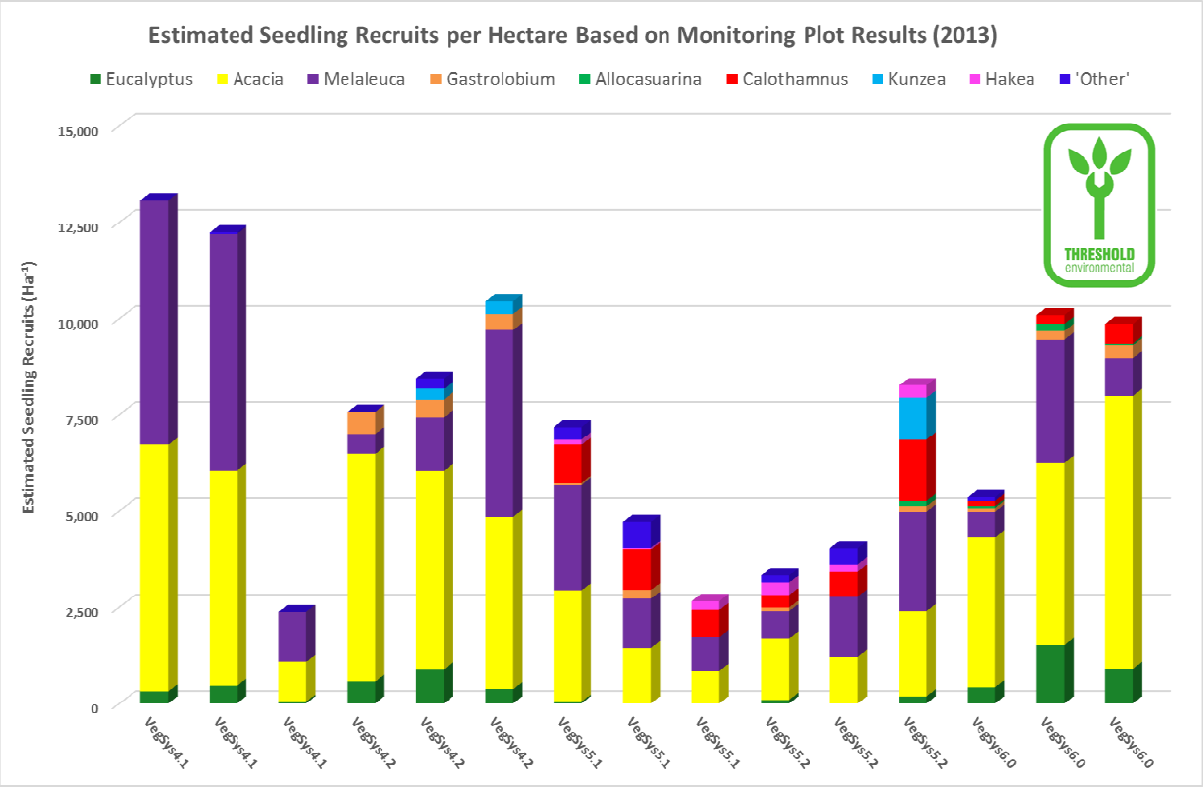


Table 4. Monitoring results from 2013 indicating per hectare recruitment by genera following direct seeding.

System	Operational Name	Plot ID	Tag ID	Plot Area m^2	Eucalyptus	Acacia	Melaleuca	Gastrolobium	Allocasuarina	Calothamnus	Kunzea	Hakea	'Other'
VegSys4.1	Spongelite Clays	MN304	02743	220.5	7	141	140						
VegSys4.1	Spongelite Clays	MN305	02734	218.3	10	122	134						1
VegSys4.1	Spongelite Clays	MN306	02739	214.5	1	22	28						
VegSys4.2	Spongelite Gravels	MN307	02752	211.5	12	125	11	12					
VegSys4.2	Spongelite Gravels	MN308	02736	216.8	19	112	30	10			6		6
VegSys4.2	Spongelite Gravels	MN309	02760	214.5	8	96	104	9			7		
VegSys5.1	Sandy Gravels	MN310	02733	214.5	1	62	59	1		21		3	7
VegSys5.1	Sandy Gravels	MN311	02740	220.5		32	28	5		23		1	15
VegSys5.1	Sandy Gravels	MN312	02738	214.5		18	19			15		5	
VegSys5.2	Gravelly Sands	MN313	02741	213.0	2	34	15	2		7		7	4
VegSys5.2	Gravelly Sands	MN314	02723	216.0		26	34			14		4	9
VegSys5.2	Gravelly Sands	MN315	02757	213.0	4	47	55	3	3	34	23	7	
VegSys6.0	Red Duplex Clays	MN301	02737	213.0	9	83	14	2	1	3			2
VegSys6.0	Red Duplex Clays	MN302	02742	216.0	33	102	69	5	4	5			
VegSys6.0	Red Duplex Clays	MN303	02735	213.0	19	151	21	7	1	11			

Figure 13. Graphical depiction of per hectare seedling recruitment from 2013 monitoring results.



Initial recruitment density and composition indicate a different trajectory has been established compared to the 2012 program, as was intended. Stocking densities are on average roughly one third lower than in 2012. This variation in stocking is likely to provide a suitable contrast within the structural layout of all the revegetated areas, providing a useful framework on which to observe differences in faunal use. Eucalyptus stem densities were reduced by approximately two thirds for a more open ecosystem structure, again providing a highly contrasting vegetation assemblage to the 2012 program area. A specific effort was made to include new species in the 2013 seed mixes, most notably of the Calothamnus and Kunzea genera, which are expected to perform well on the lighter soils.

Operational Notes 2013

Operational delivery in 2013 was largely in line with the 2012 season. Excellent weed management in the lead up to seeding was achieved. In the heavier soils, wire weed (*Polygonum aviculare*) was present in relatively high densities. This was the case even within scalped areas, however the shallowness of the 'A' horizon in these duplex soils conflicted with undertaking deeper scalps. Seedlings provided by Albany Tree Farm were generally an improvement on the 2012 order, however heavier soils and high winds did impact on the number of seedling mortalities observed in some areas of the site. The peak of these winds occurred during the last weekend of August, with winds in excess of 50km per hour. Considerable sand material was mobilised from areas within the operational area, especially within a patch of light soils located on either side of the access track found south of monitoring plot MN309. Some direct seeding recruitment was observed in this area post wind storm, however further infill planting may be required if sufficient densities were not achieved. A large number of seedlings were also planted in this area to target the lighter soils. Initial monitoring indicate that, to date, these issues have not prevented sufficient recruitment, and long term stocking densities of revegetation within this area will provide good contrast to the 2012 operational areas. GIS shapefiles for all treatments are provided with this report (Appendix C).

III. Final Summary 2012-2013

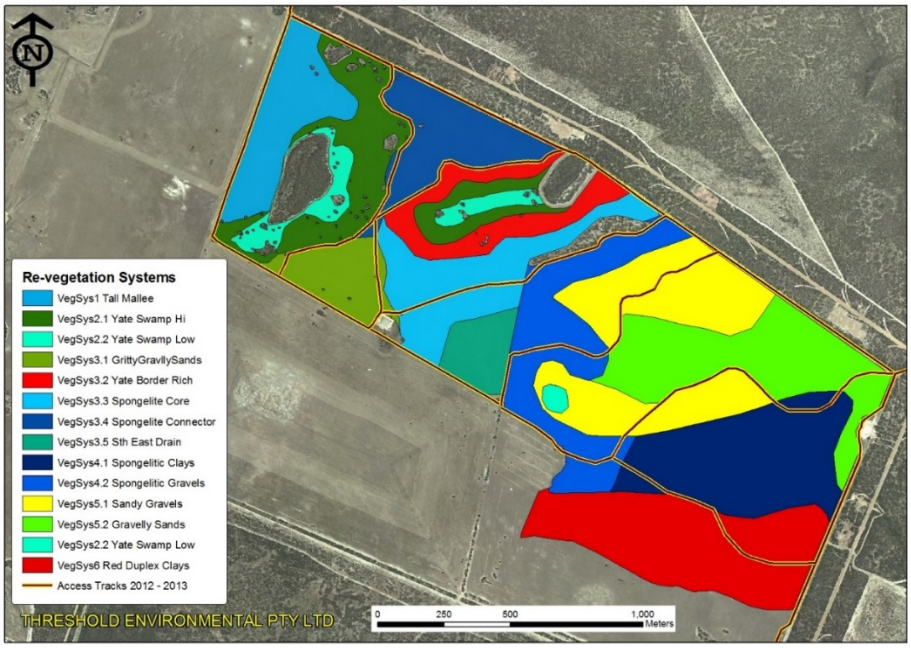
Threshold Environmental greatly appreciated the opportunity to work with Bush Heritage Australia on the Monjebup North Restoration Project from November 2010 until December 2013. In that time frame, Threshold Environmental coordinated the completion of the following project elements:

- Development and design of the first Ecological Restoration Plan in Gondwana Link for the cleared land areas at Monjebup North Reserve (400 hectares);
- Coordination and establishment of the first Five-Star Ecological Restoration in Gondwana Link across 100 hectares in 2012 and 140 hectares in 2013;

Continuity of information built across years, as well as significant time spent working in and around the local ecology of Monjebup North, resulted in a highly detailed and comprehensive demonstration of best-practice revegetation in Gondwana Link. While there is undoubtedly more to be achieved in the practice of revegetation for ecological restoration, the work accomplished over the last three years has set a new benchmark for such projects in Gondwana Link. Some notable achievements include:

- Highly detailed site design, with strong correlations between soil types and revegetation systems, resulting in the establishment of 13 unique vegetation systems;
- Well-designed access tracks, providing excellent site access for management and visitors;
- Inclusion of 148 plant species organised into vegetation associations, allowing for structure and variation within the revegetated areas;
- Establishment of 203 species-specific seedling 'nodes', allowing for the inclusion of keystone species difficult to establish through direct seeding, concentrated and matched to soil type;
- A comprehensive revegetation monitoring effort, with 36 permanent monitoring plots established across the revegetated areas;
- Development of innovative restoration approaches to increase site performance, including:
    - Planting of *Banksia* seedlings across all planted areas (specifically for nectivorous mammals such as the Western Pygmy Possum);
    - In situ burning of serotinous species such as *Dryandra, Isopogon* and *Hakea;*

Figure 14. The 2012 and 2013 operational map showing the layout and extent of the 13 revegetation systems and site access tracks implemented as part of the Monjebup North Ecological Restoration Project.



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APPENDICES

Appendix A. Vegetation-association species-mixes for the revegetation systems.

VegSys1.0 'Tall' Closed Mallee (14.85 ha)

Acacia assimilis	*Acacia pulchella*	*Eucalyptus thamnoides*	*Melaleuca scabra*
Acacia lasiocarpa	*Allocasuarina humilis*	*Eucalyptus uncinata*	*Melaleuca spathulata*
Acacia mimica var. mimica	*Baeckea sp.'Monjebup'*	*Eucalyptus xanthonema*	*Melaleuca subfalcata*
Acacia myrtifolia	*Calothamnus gibbosus*	*Gastrolobium spinosum*	*Patersonia occidentalis*
Acacia cupularis	*Eucalyptus capitiosa*	*Hakea corymbosa*	*Taxandria spathulata*
Acacia consobrina	*Eucalyptus falcata*	*Melaleuca bracteosa*	
Acacia patagiata	*Eucalyptus pleurocarpa*	*Melaleuca hamata*	

VegSys2.1 Yate Swamp Woodland High (20.4 ha)

Acacia acuminata	*Acacia saligna*	*Eucalyptus flocktoniae*	*Melaleuca calysina*
Acacia assimilis	*Acaica lasiocarpa*	*Eucalyptus lehmannii ssp parallela*	*Melaleuca hamata*
Acacia consobrina	*Allocasuarina huegeliana*	*Eucalyptus melanophitra*	*Melaleuca hamulosa*
Acacia cupularis	*Alyogine huegelii*	*Eucalyptus neutra*	*Melaleuca undulata*
Acacia cyclops	*Calistemon phoenicious*	*Eucalyptus vessiculosa*	*Patersonia occidentalis*
Acacia declinata	*Callitris roeii*	*Hakea corymbosa*	*Senna artemisioides*
Acacia myrtifolia	*Calothamnus gracilis*	*Hakea laurina*	
Acacia patagiata	*Dodonaea ptarmicaefolia*	*Hakea nitida*	
Acacia pulchella	*Dodonaea viscosa*	*Melaleuca accuminata*	

VegSys2.2 Yate Swamp Woodland Low (7.5 ha)

Acacia cyclops	*Acacia saligna*	*Eucalyptus vessiculosa*	*Melaleuca hamata*
Acacia dictyoneura	*Alyogine huegelii*	*Hakea laurina*	*Melaleuca hamulosa*
Acacia myrtifolia	*Billardaria sp. (west river)*	*Kennedia eximia*	*Melaleuca undulata*
Acacia patagiata	*Calistemon phoenicious*	*Melaleuca accuminata*	*Melaleuca villosisepala*
Acacia pulchella	*Callitris pyrimidalis*	*Melaleuca carrii*	*Senna artemisioides*

VegSys3.1 'Gritty Gravelly Sands' Mallee Scrub (9.73 ha)

Acacia consobrina	*Allocasuarina huegeliana*	*Eucalyptus uncinata*	*Melaleuca hamata*
Acacia cupularis	*Allocasuarina humilis*	*Gastrolobium parviflorum*	*Melaleuca spathulata*
Acacia mimica v. mimica	*Eucalyptus falcata*	*Hakea laurina*	*Melaleuca subtrigona*
Acacia myrtifolia	*Euc. lehmannii ssp parallela*	*Hakea strumosa*	*Melaleuca tuberculata*
Acacia pulchella	*Eucalyptus phaenophylla*	*Melaleuca bracteosa*	*Melaleuca violacea*
Acacia varia v. parviflora	*Eucalyptus pluricaulis*	*Melaleuca depauperata*	*Sceavola scipigera*

VegSys3.2 'Yate Bordering Rich' Mallee Scrub (11.3 ha)

Acacia cupularis	*Eucalyptus capitiosa*	*Eucalyptus uncinata*	*Melaleuca subtrigona*
Acacia gononphylla	*Eucalyptus falcata*	*Gastrolobium spinosum*	*Melaleuca violacea*
Acacia mimica v. mimica	*Euc. lehmannii ssp parallela*	*Hakea laurina*	*Patersonia occidentalis*
Acacia myrtifolia	*Eucalyptus pachyloma*	*Hakea strumosa*	*Taxandria spathulata*
Acacia newbeyii	*Eucalyptus pleurocarpa*	*Melaleuca bracteosa*	
Acacia pulchella	*Eucalyptus pluricaulis*	*Melaleuca hamata*	
Calothamnus gracilis	*Eucalyptus thamnoides*	*Melaleuca spathulata*	

VegSys3.3 'Spongelite Core' Mallee Scrub (19.34 ha)

Acacia assimilis	*Allocasuarina humilis*	*Eucalyptus thamnoides*	*Melaleuca hamata*
Acacia consobrina	*Beaufortia schaueri*	*Gastrolobium parviflorum*	*Melaleuca pentagona*
Acacia cupularis	*Calothamnus gibbosus*	*Gastrolobium spinosum*	*Melaleuca spathulata*
Acacia mimica v. mimica	*Euc. lehmannii ssp parallela*	*Hakea laurina*	*Melaleuca tuberculata*
Acacia myrtifolia	*Eucalyptus phaenophylla*	*Hakea strumosa*	*Patersonia occidentalis*
Acacia pulchella	*Eucalyptus pleurocarpa*	*Melaleuca apodocephala*	
Acacia spongelitica	*Eucalyptus pluricaulis*	*Melaleuca bracteosa*	

VegSys3.4 'Spongelite Connector' Mallee Scrub (15.42 ha)

Acacia consobrina	*Calothamnus gibbosus*	*Eucalyptus thamnoides*	*Melaleuca hamata*
Acacia cupularis	*Eucalyptus capitiosa*	*Eucalyptus uncinata*	*Melaleuca spathulata*
Acacia mimica v. mimica	*Eucalyptus falcata*	*Gastrolobium parviflorum*	*Melaleuca subfalcata*
Acacia myrtifolia	*Eucalyptus pachyloma*	*Gastrolobium spinosum*	*Melaleuca violacea*
Acacia pulchella	*Eucalyptus phaenophylla*	*Hakea laurina*	*Sceavola scipigera*
Acacia varia v. parviflora	*Eucalyptus pleurocarpa*	*Hakea strumosa*	*Taxandria spathulata*
Allocasuarina humilis	*Eucalyptus pluricaulis*	*Melaleuca bracteosa*	

VegSys3.5 'South Eastern Drain' Mallee Scrub (6.58 ha)

Acacia assimilis	*Allocasuarina lehmanniana*	*Eucalyptus pachyloma*	*Melaleuca bracteosa*
Acacia bidentata	*Allocasuarina thyoides*	*Eucalyptus pleurocarpa*	*Melaleuca spathulata*
Acacia consobrina	*Baeckea sp.'Monjebup'*	*Eucalyptus uncinata*	*Melaleuca turberculata*
Acacia lasiocarpa	*Calothamnus gibbosus*	*Gastrolobium parviflorum*	*Sceavola scipigera*
Acacia myrtifolia	*Eucalyptus falcata*	*Hakea laurina*	*Urodon sp. aff. daysyphyllus*
Acacia pulchella	*Euc. lehmannii ssp parallela*	*Hakea strumosa*	

VegSys4.1 'Spongelitic Clay' Mallee Scrub (25.75 ha)

Acacia assimilis	*Acacia patagiata*	*Eucalyptus phaenophylla*	*Melaleuca hamata*
Acacia consobrina	*Acacia pulchella*	*Eucalyptus pleurocarpa*	*Melaleuca spathulata*
Acacia cupularis	*Acacia saligna*	*Euc. pluricaulis ssp. porphyrea*	*Melaleuca subfalcata*
Acacia cyclops	*Acacia sulcata v. sulcata*	*Eucalyptus thamnoides*	*Melaleuca subtrigona*
Acacia harveyii	*Baeckea sp. 'snowstorm'*	*Eucalyptus uncinata*	
Acacia mimica	*Eucalyptus capitiosa*	*Gastrolobium parviflorum*	
Acacia myrtifolia	*Euc. lehmannii ssp parallela*	*Melaleuca bracteosa*	

VegSys4.2 'Spongelitic Gravels' Mallee Scrub (25.75 ha)

Acacia assimilis	*Acacia lasiocarpa*	*Eucalyptus phaenophylla*	*Melaleuca bracteosa*
Acacia consobrina	*Acacia myrtifolia*	*Eucalyptus pleurocarpa*	*Melaleuca hamata*
Acacia cupularis	*Acacia patagiata*	*Euc. pluricaulis ssp. porphyrea*	*Melaleuca spathulata*
Acacia cyclops	*Acacia pulchella*	*Eucalyptus thamnoides*	*Melaleuca subfalcata*
Acacia gonophylla	*Acacia saligna*	*Eucalyptus uncinata*	*Melaleuca subtrigona*
Acacia harveyii	*Acacia sulcata v. sulcata*	*Kunzea montana*	*Patersonia occidentalis*

VegSys5.1 'Sandy Gravels' Mallee Scrub (29.4 ha)

Acacia assimilis	*Acacia sp. affin. consobrina*	*Eucalyptus pleurocarpa*	*Melaleuca carrii*
Acacia cochlearis	*Acacia sulcata v. planoconvexa*	*Euc. pluricaulis*	*Melaleuca spathulata*
Acacia cyclops	*Acacia sulcata v. sulcata*	*Eucalyptus preissiana*	*Melaleuca tuberculata*
Acacia declinata	*Astartea ambigua*	*Eucalyptus thamnoides*	*Melaleuca violacea*
Acacia dictyoneura	*Baeckea sp. spring fls*	*Gastrolobium spinosum*	*Taxandria spathulata*
Acacia maxwellii	*Beaufortia schaueri*	*Hakea corymbosa*	*Templetonia sulcata*
Acacia myrtifolia	*Calothamnus gracilis*	*Hakea laurina*	*Urodon dasyphyllus*
Acacia patagiata	Eucalyptus captiosa	Hemiandra pungens	
Acacia pulchella	Eucalyptus falcata	Kunzea affinis v. jucunda	
Acacia saligna	Eucalyptus phaenophylla	Kunzea preissiana	

VegSys5.2 'Gravelly Sands' Mallee Scrub (29.4 ha)

Acacia assimilis	*Acacia sulcata var. sulcata*	*Eucalyptus phaenophylla*	*Melaleuca carrii*
Acacia bidentata	*Allocasuarina humilis*	*Eucalyptus pleurocarpa*	*Melaleuca lateriflora*
Acacia cochlearis	*Anigozanthos humilis*	*Euc. pluricaulis ssp. porphyrea*	*Melaleuca ordinifolia*
Acacia cyclops	*Astartea ambigua*	*Eucalyptus thamnoides*	*Melaleuca spathulata*
Acacia lasiocarpa	*Calothamnus gracilis*	*Eucalyptus uncinata*	*Melaleuca subtrigona*
Acacia myrtifolia	*Calothamnus sanguineus*	*Gastrolobium spinosum*	*Taxandria spathulata*
Acacia patagiata	*Conothamnus aureus*	*Hakea laurina*	*Xanthorrhea sp.*
Acacia pulchella	*Eucalyptus captiosa*	*Kunzea micromera*	
Acacia redolens	*Eucalyptus falcata*	*Leptospermum spinescens*	
Acacia saligna	*Eucalyptus pachyloma*	*Melaleuca apodocephala*	

VegSys6.1 'Red Duplex Clays' Mallee Scrub (31.4 ha)

Acacia assimilis	*Acacia saligna*	*Eucalyptus vergrandis*	*Melaleuca pauperiflora*
Acacia consobrina	*Acacia sphacelata v. recurva*	*Eucalyptus xanthonema*	*Melaleuca pentagona*
Acacia cupularis	*Acacia trulliformis*	*Gastrolobium parviflorum*	*Melaleuca scabra*
Acacia cyclops	*Allocasuarina huegeliana*	*Kunzea recurva*	*Melaleuca subtrigona*
Acacia glaucoptera	*Baeckea sp. Cherreninup*	*Melalecua haplantha*	*Melaleuca spathulata*
Acacia gonophylla	*Calothamnus gibbosus*	*Melaleuca bracteosa*	*Melaleuca subfalcata*
Acacia harveyii	*Eucalyptus captiosa*	*Melaleuca cucculata*	*Melaleuca torquata*
Acacia mimica	*Eucalyptus conglobata*	*Melaleuca glaberrima*	*Melaleuca pauperiflora*
Acacia myrtifolia	*Euc. pluricaulis ssp. porphyrea*	*Melaleuca hamata*	
Acacia patagiata	*Eucalyptus thamnoides*	*Melaleuca haplantha*	

Appendix B. Photos of 15 of the habitat debris piles distributed throughout the site.

Appendix C. List of GIS Shapefiles Provided

1. Restoration Operational Map 2012/2013
2. Tractor passes via AgGPS tractor unit 2012/2013
3. Location of Debris Piles 2012
4. Location, Species ID, and treatment info for Hand Seeded Patches 2012
5. Location, Species ID, density, and patch size for Seedling 'Nodes' 2012/2013
6. Location and plot ID for Monitoring Plots 2012/2013