2015 Ecological Monitoring Report

Bulga Coal Complex

Bulga Surface Operations Pty Ltd
& Bulga Underground Operations Pty Ltd

July 2015

Prepared by

DnA Environmental

Disclaimer

This is a report of work carried out by DnA Environmental on behalf of the Bulga Coal Management Pty Ltd and Bulga Underground Operations Pty Ltd, collectively referred to as the Bulga Coal Complex (BCC) and has been prepared according to the brief provided by the client. The information contained herein is complete and correct to the best of my knowledge. The representations, statements, opinions and advice, expressed or implied in this report are produced in good faith but on the basis that DnA Environmental are not liable (whether by reason of negligence, lack of care or otherwise) to any person for any damage or loss whatsoever which has occurred or may occur in relation to that person taking or not taking (as the case may be) action in respect of any or all of the content.

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Executive summary

This is a report of work carried out by DnA Environmental on behalf of Bulga Open Cut (BOC) and Bulga Underground Operations (BUO), collectively referred to as the Bulga Coal Complex (BCC) located near Singleton NSW. The primary objective of the ecological monitoring program is to assess the health and condition of remnant vegetation situated within the BCC.

In 2013, BCC submitted an Environmental Impact Statement (EIS) for the Bulga Optimisation Project (BOP) which is a proposed continuation of open cut coal mining operations at the existing BCC Complex to 2035. A key feature of the BOP is the construction of a noise and visual bund along the western and southern edges of the open cut pit to minimise noise and visual impacts. The BOP was approved in December 2014 with the realignment of the Broke Rd and construction of the western noise and visual bund well under way during June 2015. In 2014, the ecological (and rehabilitation) monitoring program were revised with the submission of the BOP as several sites are situated within the disturbance footprint.

The number of ecological monitoring sites has typically increased since the monitoring was first undertaken by Umwelt in 2003 with eleven sites being monitored annually since 2010. Despite the loss of some sites in 2014 due to the BOP two *Eucalyptus moluccana – E. crebra* (Grey Box – Narrow leaf Ironbark) Woodland sites (BM18, BM19) and one *Casuarina glauca* (Swamp Oak) Forest (BM23) were established. This year however there was a further reduction in the number of sites due to the loss of a *E. moluccana – E. crebra* site (BM6) as a result of the mining expansions. The ten ecological monitoring sites and associated vegetation community assessed in 2015 are listed below.

Site Name	Vegetation community
BM1	Warkworth Sands Woodland CEEC
BM4	Central Hunter Grey Box – Ironbark Woodland EEC
BM5	Central Hunter Ironbark – Spotted Gum – Grey Box Forest EEC
BM7	Central Hunter Paperbark Soaks Woodland
BM8	Warkworth Sands Woodland CEEC
BM10	Central Hunter Grey Box – Ironbark Woodland EEC
BM15	Central Hunter Grey Box – Ironbark Woodland EEC
BM18	Central Hunter Grey Box – Ironbark Woodland EEC
BM19	Central Hunter Grey Box – Ironbark Woodland EEC
BM23	Hunter Valley River Oak Forest

The methodology used has been consistent since 2010 and includes a combination of Landscape Function Analyses (LFA) and an assessment of ecosystem structure and habitat characteristics derived from the CSIRO Grassy woodland Benchmarking project. In 2014 however the size of the monitoring quadrats was reduced to 20 x 20m and the comprehensive soil analyses will be taken on a three year rotation to reduce monitoring effort.

The ecological monitoring report provides a summary of some of the primary ecological indicators and the trends occurring since 2010 and includes a tabulated summary of all ecological indicators that were measured within a "Key Performance Indicator" (KPI) table. The rehabilitation and ecological and monitoring has been undertaken during June – July in all monitoring years since 2010 and this year the field work was undertaken between 9 – 15th June.

Summary of results

The periods of extreme and prolonged dry conditions experienced over the past few years have had a significant impact on the composition and diversity of the vegetation communities. The poorer growing conditions combined with increased disturbance and total grazing pressure has had an adverse effect

on the remnant vegetation as well as on mine rehabilitation areas. Above average rainfall over summer and in autumn this year however has resulted in an increase in plant growth and initiated a flush of annual species with these seasonal conditions being reflected in the monitoring data. While improved seasonal conditions have tended to relax grazing pressure from some areas this year, the expanding mining operations may also be displacing and concentrating animal populations into areas that have previously been less favourable.

The monitoring sites varied in many ecological attributes largely due to their topographic position within the landscape and different vegetation assemblages. Most sites have been subjected to some degree of modification including clearing and grazing, with a range of other associated factors including weed invasion, soil compaction and dieback for example. Therefore in most instances, they were communities undergoing ecological recovery after a long agricultural history, but all sites were stable and generally had a functional patch area, with the exception of BM15, an eroding creek profile caused by historical catchment management.

BM5, the *Corymbia maculata* (Spotted Gum) woodland, continued to be the most ecologically functional site followed the *E. moluccana – E. crebra* grassy woodlands BM10 and BM19. Sites BM1 Warkworth Sands Woodland and BM7 the *Melaleuca decora* (Swamp Paperbark) woodland were less functional than the other ecological communities, apart from BM15. These sites have deteriorated over the past year largely due to macropod disturbance which has tended to result in bare camps and tracks throughout the area and subsequently there has been a decline in litter cover, increased soil surface crusting and hardness and there has been an increase in erosion and deposition. The eroding creek bank site BM15 continued to have the lowest ecological function and there continues to be severe terracette, rilling and pedalstalling on the creek banks. The site also continues to have extensive undercutting, tunnelling and slumping within the incised creek channel.

All sites contained a mature canopy cover but the species and stem densities (>5cm dbh) varied significantly between sites, depending on the level of prior disturbance and regenerative capacity. The lowest density of trees continued to be recorded in the regenerating Warkworth Sands Woodlands (WSW) BM8 (six individuals) while the highest stem density was recorded in BM23, a regrowth *Casuarina glauca* woodland along Nine Mile Creek, which had 122 individuals. In most sites the density of trees have remained relatively constant and in some sites including BM5, BM7, BM15 and BM19 there was a marginal increase in density as existing shrubs and juvenile trees continue to grow.
There appears to be a declining trend occurring in BM1 with another three individuals having died within the monitoring over the past year. In addition large patches of dead acacias and banksia were observed across the larger area of the woodland.

The average diameter at breast height (dbh) recorded in the ecological sites ranged from 10 – 25cm with the minimum being 5cm and the largest being 54cm, a large *Corymbia maculata* in BM5. While the majority of the trees were live individuals, dead trees (stags) were present in low numbers across numerous of the ecological sites. In BM1 34% of the population were dead stags, while there were 18% dead stags recorded in BM10. There were also low numbers recorded in BM4, BM7 and BM15. Of the live tree densities, most individuals in most sites were in moderate health. In most of the ecological sites there were a low number of individuals bearing reproductive structures such as buds, flowers or fruits, except in BM8 and BM19. Mistletoe an important habitat feature was recorded in BM4 and BM7, while a small number of tree hollows were recorded in BM1 and BM10.

While each site was comprised of a different complement and density of species there was a low diversity of tree and/or mature shrub species in BM8, BM10 and BM18 which had only one species, while the highest tree diversity was recorded in BM1 with five different species.

There also continued to be high variability in the densities of shrubs and juvenile trees between sites and this year they ranged from 35 (BM10) to 1221 (BM8). In 2014 the numbers of shrubs and juvenile

trees declined in numerous ecological sites including BM1, BM5, BM7, BM8 and BM15 and was likely to be attributed the prolonged hot and dry conditions combined with increased predation of the more palatable species. This year all sites except BM15 had an increase in the number of shrubs as the seasonal conditions have become more favourable. All sites had a shrub and/or juvenile tree population with individuals in all height categories but the vast majority of individuals were less than 0.5m in height and are likely to be have been initiated by periods of higher rainfall activity received periodically during 2011 – 2013. Most shrubs were prickly or contain unpalatable substances and tend to be avoided by browsers.

The ground cover within the ecological sites are comprised of various combinations of dead leaf litter, perennial vegetation (<0.5m), annual plants, cryptogams and logs. Since monitoring began total ground cover has remained relatively high and all sites except BM1 and BM15 had total ground cover which exceeded 93%, despite some marginal changes over the past year. Total ground cover in BM1 was comparatively lower and continues to be subjected to disturbance from a range of animals including macropods and rabbits (and foxes) and this year there was 86% total ground cover on average. In site BM15 total ground cover was much lower and this has declined to 24% over the past year, largely due to active erosion.

Leaf litter continued to be the dominant form of ground cover in most monitoring sites and provided 37.5 – 89.5% of the total ground cover. Exceptions include BM8, the WSW, where there was a high proportion of low and dense shrub cover and BM15 where overall ground cover was limited. The cover provided by perennial plants (<0.5m) was highly variable across the range of sites with high proportions recorded in BM8 and in the grassy woodlands BM10, BM18 and BM19. There was also high perennial plant cover recorded in BM23 the *Casuarina glauca* forest.

With the exception of the *Corymbia maculata* woodland BM5 which had a very deep litter layer, cryptogams were recorded in all sites. In BM8 (and BM1) the Coral Lichen were particularly important while in BM18 a variety of cryptogams had colonised the otherwise crusted soils. Annual plants and rocks were typically absent and were not an important ground cover component, at least under the study conditions but logs and small branches may have been common in some sites and provided additional site stability as well as increased habitat resources.

Most sites had scattered shrubs and low hanging tree canopies which provided at least some foliage cover in the major vertical height increments, but in BM8 vertical foliage cover >2.0m was particularly low. All sites except BM8 and BM15 had a well developed mature canopy cover (>6.0m).

Over the past year there was no consistent change in species diversity across the range of sites but decreased diversity was recorded in the WSW communities BM1 and BM8 perhaps due to high disturbance from macropods. In BM19 and BM23 floristic diversity was lower probably due the increase in perennial grass cover, which has increased competition and reduced germination niches.

The highest floristic diversity continued to be recorded in BM10, the grassy *E. moluccana – E. crebra* woodland which contained a diversity of 63 species. The WSW communities BM1 and BM8, continued to have the lowest floristic diversity with 31 species. Native species continued to be far more abundant than exotic species and the highest number of native species was recorded in BM10 with 54 species. The lowest number of native species was recorded in BM1 and BM8 with 23 and 24 native species respectively.

The highest diversity of exotic species this year was recorded in the grassy *E. moluccana – E. crebra* woodland BM19 and the Swamp Oak woodland BM23 which each had 14 exotic species, followed by the degraded creek BM15 which had 10 species. These sites are likely to have been subjected to a long history of livestock grazing, and in BM23 and BM15 the sites are subjected to periodic flooding and are therefore more vulnerable to weed invasion. In BM15, the creek channel and banks also provide

additional habitat areas. The lowest number of exotic species was recorded in BM4 and BM7 where there were six exotic species recorded this year.

Native ground cover plants continue to be dominant in all sites but a decline in native plant cover was recorded in numerous sites this year as exotic weeds were recorded in higher abundance. Site BM4 maintained 100% native plant cover, while in BM10, BM15, BM18 and BM19 there was 89 - 96% endemic plant cover. The lowest endemic plant cover was recorded in BM1 with 78%.

The sites were predominantly comprised of herbs (9 – 32) and grasses (6 - 13) with 2 - 4 tree species, 2 – 13 shrubs and 1 - 6 species of sub-shrub. Sites BM10, BM18 and BM19 contained a particularly high diversity of herbs and grasses. Sites BM5 contained a particularly high diversity of shrubs with 14 different species being recorded. Other growth forms such as reeds, vines, ferns and cactus were also present in low numbers (1 – 3 species) within some sites.

Since monitoring began in 2010, the number of species recorded across the range of sites has ranged from 191 – 225 species with 17.8 – 20.6% of these being exotic species. *Cheilanthes sieberi* subsp. *sieberi* (Rock Fern), a native rock fern, continued to be recorded in all ten sites. The native grasses *Cymbopogon refractus (*Barbed-wire Grass) and *Microlaena stipoides* (Weeping Rice-grass) and the exotic weed *Senecio madagascariensis* (Fireweed) were common to nine of the monitoring sites. Most other common species tended to be native species but *Bidens pilosa* (Cobbler's Peg*)* an exotic annual and *Opuntia stricta* (Common Prickly Pear) a noxious cactus was also very common and recorded in eight sites.

The ecological sites were dominated by a variety of different species with *Brachyloma daphnoides* being particularly dominant in BM8, the WSW community. In the other sites other dominant species may have been one or various combinations of the native grasses *Aristida ramosa* (Threeawn Grass)*, Bothriochloa decipiens* (Redgrass), *Entolasia marginata* (Bordered Panic)*, Cymbopogon refractus* (Barbed-wire Grass) and *Microlaena stipoides* (Weeping Rice-grass) as well as native herbs including *Calotis cuneifolia* (Purple Burr Daisy)*, Glycine tabacina* (Variable Glycine)*, Brunoniella australis* (Blue Trumpet)*, Vernonia cinerea var. cinerea* and *Oxalis exilis*. In site BM18, *Allocasuarina luehmannii* (Bulloak) was relatively abundant while *Acacia amblygona* (Fan Wattle) was the most dominant ground cover in BM4. *Cheilanthes sieberi subsp. sieberi* provided the most ground cover in BM1. Site BM5 had a sparse cover of ground cover plants and did not contain any species which were particularly dominant.

No threatened species were recorded but *Grevillea montana,* a 2VC ROTAP (PlantNet 2010) continued to be recorded in the WSW community BM8. *Opuntia stricta* continued to be the most abundant noxious species and was recorded in eight monitoring sites. *Lantana camara* (Lantana) was recorded in five sites while *Opuntia aurantiaca* (Tiger Pear) was recorded three sites and *Lycium ferocissimum* (African Boxthorn) was found in BM19.

Recommendations

Little management intervention is required to maintain or improve most of the ecological sites, apart from noxious weed and animal control with the most common noxious species being *Opuntia stricta* and *Lantana camara*. Environmental weeds including *Hyparrhenia hirta* (Coolatai Grass), *Chloris gayana* (Rhodes grass), *Melinis repens* (Red Natal Grass) and *Pennisetum clandestinum* (Kikuyu) should also be targeted. *Chloris gayana* and *Pennisetum clandestinum* should no longer be used in mine rehabilitation programs.

While the majority of the trees and mature shrubs were in moderate health, dead trees (stags) were increasing in number in the WSW community BM1. While this may be part of the natural successional

process further investigation into the cause of their death may be warranted. Critical habitat could also be improved through the installation of nesting boxes.

The riparian site BM15 continued to suffer from historical catchment management such as clearing and overgrazing and will require significant intervention to improve the function and condition of the riparian ecosystem.

High macropod numbers continue to impact most sites mostly through tracks and camps and there has been a declining trend in numerous ecological attributes especially in sites BM1 and BM7. The actual impact on the native vegetation is however difficult to gauge without a point of reference. The construction of exclusion fences in high utilisation areas may help determine the level of impact and the type of management intervention required, in consultation with relevant experts and authorities.

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1 2015 Ecological Monitoring Program Report

1.1 Introduction

The Bulga Coal Complex is located approximately 15 kilometres southwest of Singleton, 5 kilometres north of the town of Broke and 6 kilometres east of Bulga, in the upper Hunter Valley of New South Wales (Figure 1-1). Bulga Coal Complex comprises two coal mining operations:

- Bulga Surface Operations (BSO)
- Bulga Underground Operations (BUO)

Both the Bulga Surface and Underground Operations are collectively referred to as the Bulga Coal Complex and are managed as separate business units serviced by a common coal handling and preparation plant (CHPP) and rail loading facility located in the northeast corner of BCC (Umwelt 2011).

The Bulga Coal Complex Mining Lease is traversed by Charlton and Broke Roads and includes four kilometres of the Wollombi Brook in its northwest corner. The BCC is made up of land held privately to the west of Charlton Road as far as the margins of the Wollombi Brook floodplain, but not onto it. The lease area also extends southeast into Commonwealth owned land between Broke and Cessnock Roads (Figure 1-2).

In 2013, BCM submitted an Environmental Impact Statement (EIS) for the Bulga Optimisation Project (Umwelt 2013) which is a proposed continuation of open cut coal mining operations at the existing Bulga Coal Complex to 2035 which aims to extract 230 million tonnes of coal. The current open cut operations were approved to operate until 2025, however the approved resources to be extracted will be exhausted by 2018. The underground mining operations which have been approved until 2031 will be largely unaffected by the BOP, except for the relocation of some surface facilities. A key feature of the BOP is the construction of a noise and visual bund along the western and southern edges of the open cut pit to minimise noise and visual impacts (Umwelt 2013).

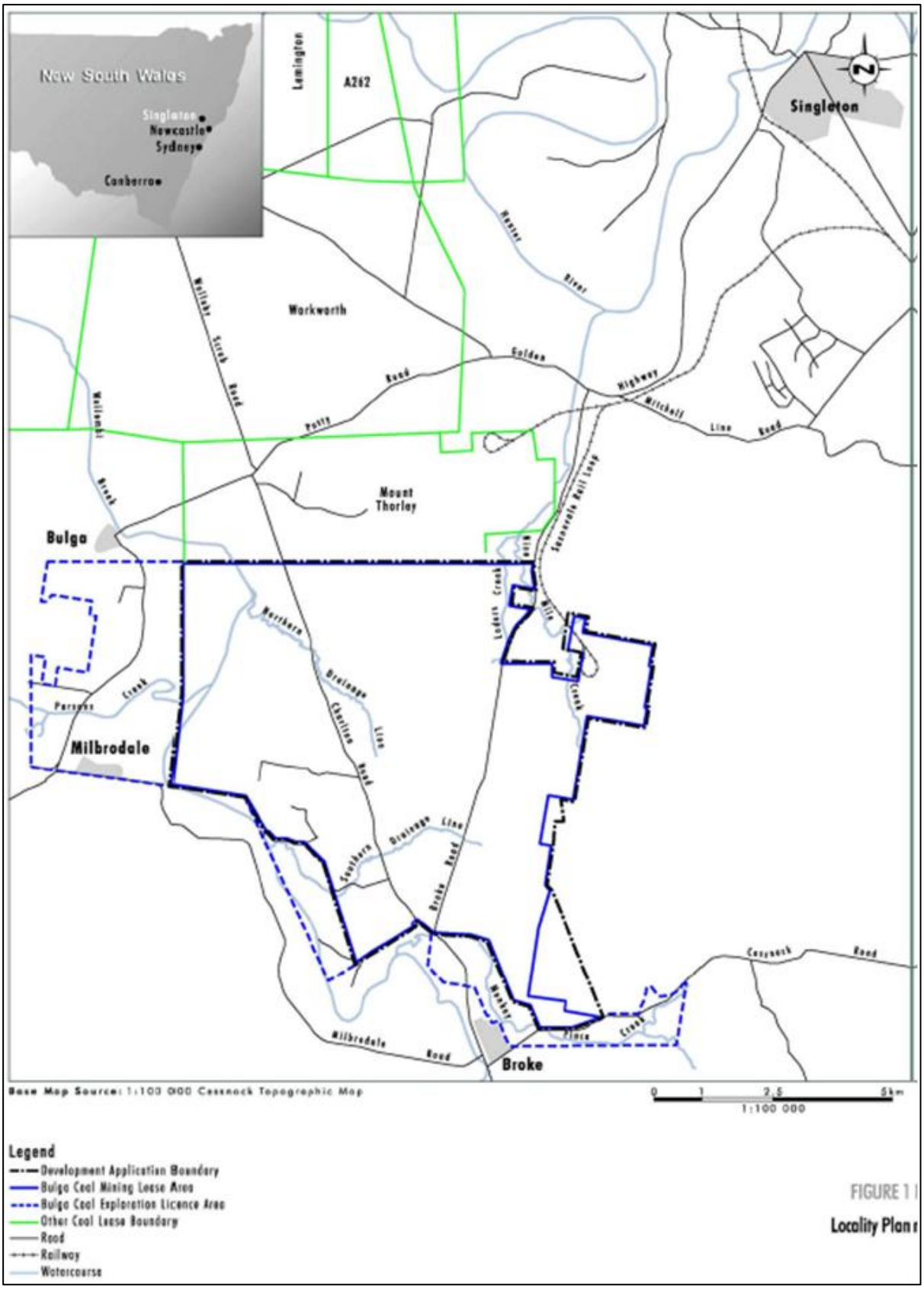


Figure 1-1. Location of the Bulga Coal Complex (Xstrata 2008b).

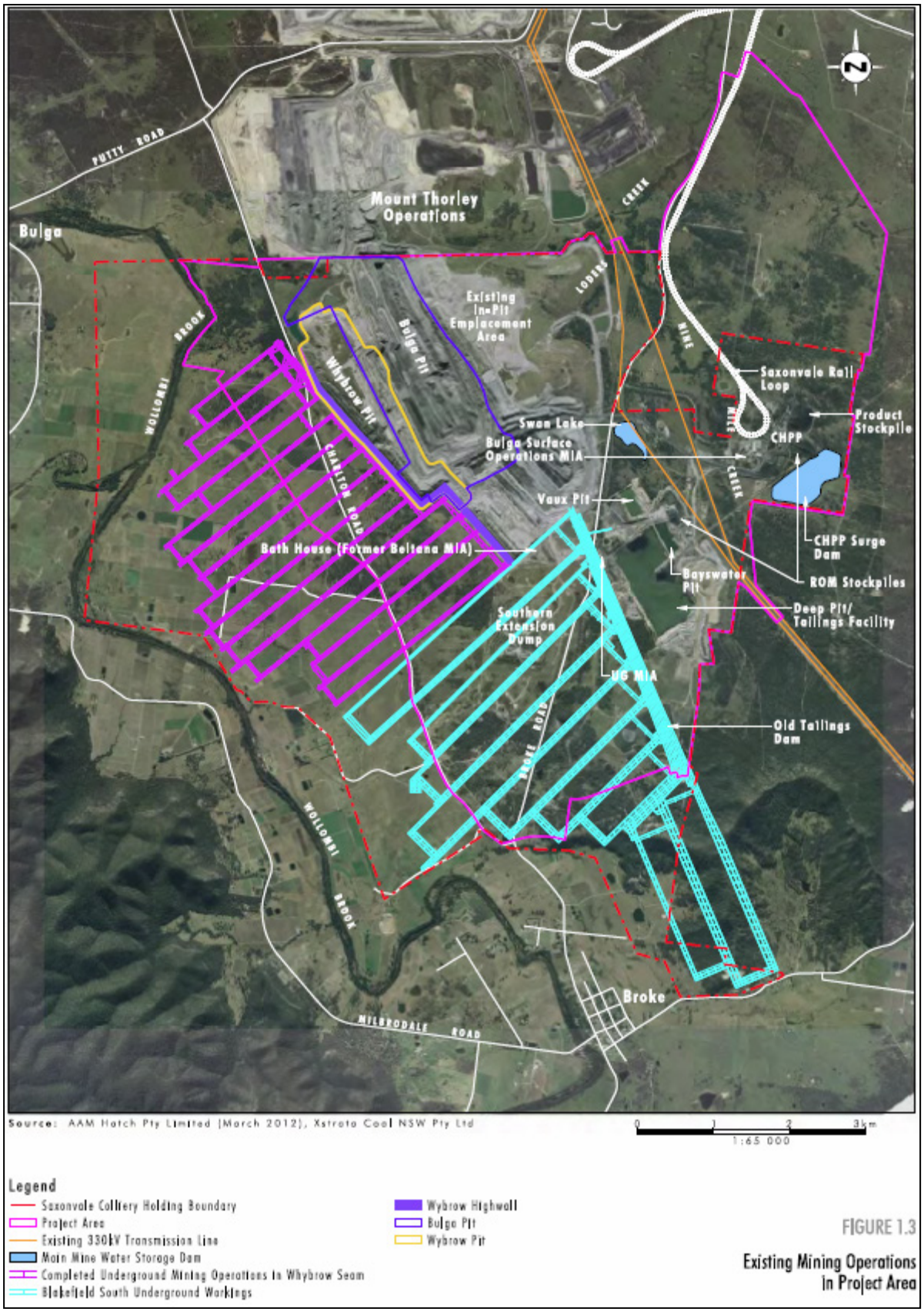


Figure 1-2. Existing mining operations of the Bulga Coal Complex (Umwelt 2013)

2 Bulga Optimisation Project

2.1 Overview

The Bulga Optimisation Project (BOP) aims to maximise the Run-Of-Mine (ROM) coal resource extraction utilising the existing infrastructure where possible whilst minimising environmental and community impacts. A summary of some key features associate with of the BOP (and having some relevance to the rehabilitation monitoring) include:

- A continuation of surface mining operations for an additional 22 years;
- Continued extraction of coal using open cut methods as the current approved rate of 12.2Mtpa;
- The extraction of ~230Mt of ROM coal (an addition 200Mt over existing approvals);
- Conduct mining within three contiguous pit areas (Main, East and South pits). The Bayswater Pit will also be mined, with all areas occurring within the existing mine disturbance footprint;
- Construction of a noise and visual bund along the western and southern edges of the open cut pit to minimise noise and visual impacts;
- The construction of an Eastern Emplacement Area north of the CHPP on the eastern side of Broke Road;
- Realignment of Broke and Charlton Roads;
- Relocation of sections of two 330kV transmission lines and changes to other associated electricity infrastructure;
- Relocation of the Private Irrigation District (PID) water pipeline, Singleton Council – Broke potable water pipelines and other services; and
- Construction of a new water storage dam with approximate capacity of 3000ML (Northern Dam)

Key features of the BOP are provided in the conceptual diagram in Figure 2-1. Full details of the BOP can be found in Umwelt (2013).

The BOP was approved in December 2014 with the realignment of the Broke Rd and construction of the western noise and visual bund well under way during June 2015.

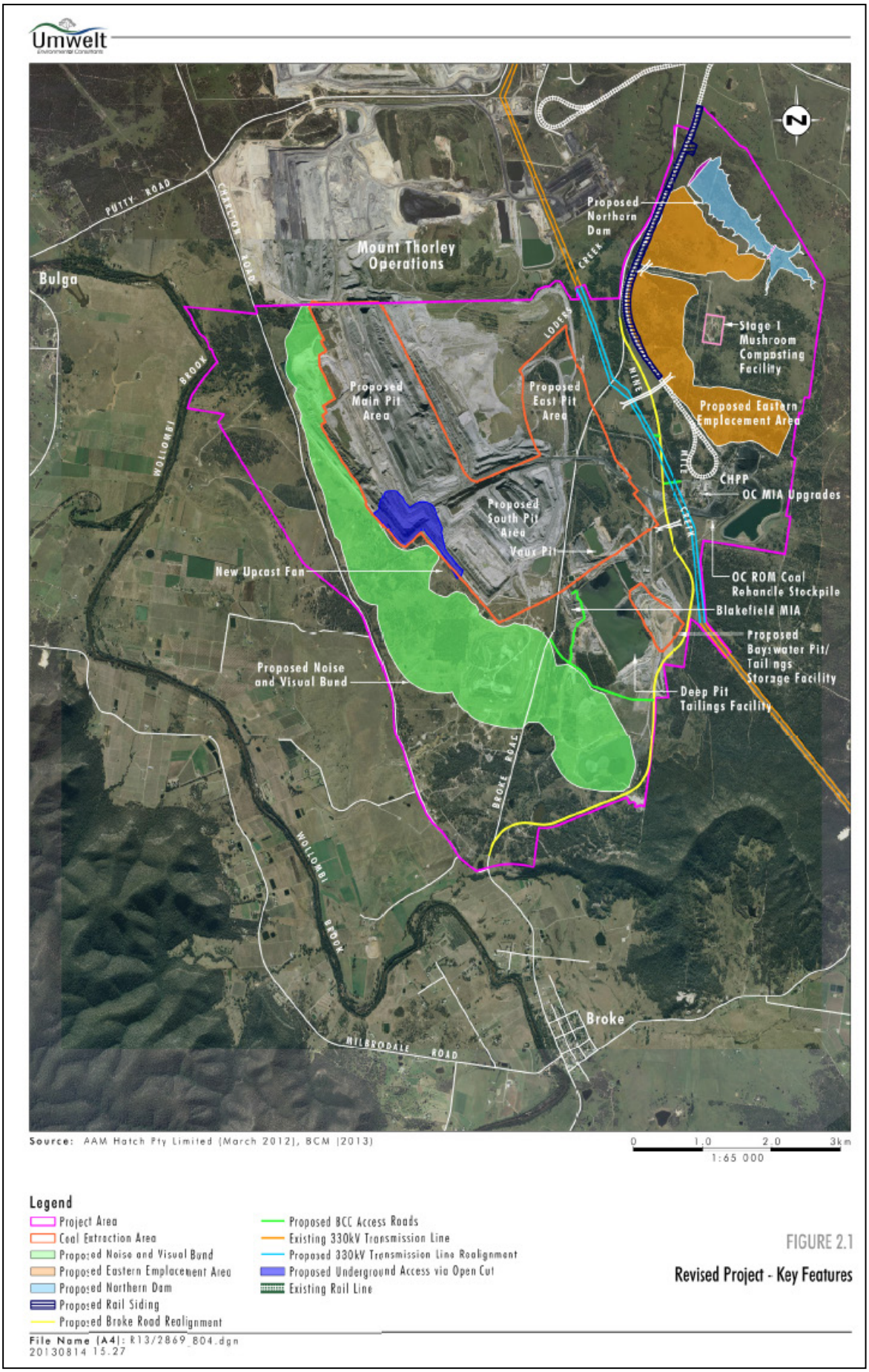


Figure 2-1. Conceptual plan of the BOP (Umwelt 2013).

3 Environmental Context

There are currently a number of residential dwellings private vineyards, an olive farm, cattle grazing properties, public roads and land occupied by the Department of Defence (Singleton Army Training Area) that will be undermined by Bulga Underground Operations (Xstrata 2008a,b). Mount Thorley-Warkworth Mining Complex (MTW) adjoins the northern boundary of the Bulga Open Cut pit. BCM also owns a number of properties surrounding the project and has commercial arrangements with some of the other private landholders which are impacted by BCC (Umwelt 2013).

3.1 Vegetation at the Bulga Complex

Fourteen native vegetation communities and seven types of disturbed or non-vegetated area have been identified by Umwelt (2013). The native vegetation communities include:

- Central Hunter Grey Box – Ironbark Woodland EEC;
- Central Hunter Grey Box – Ironbark Woodland Derived Native Grassland (DNG);
- Central Hunter Bulloak Forest Regeneration;
- Central Hunter Ironbark – Spotted Gum – Grey Box Forest EEC;
- Central Hunter Paperbark Soaks Woodland;
- Central Hunter Swamp Oak Forest;
- Hunter Valley Weeping Myall Woodland EEC;
- Riparian DNG;
- Warkworth Sands Woodland EEC;
- Warkworth Sands DNG;
- Warkworth Sands Disturbed Grassland;
- Hunter Valley River Oak Forest;
- Mixed Shrubland on Alluvial Sand; and
- Grassland on Alluvial Sand.

The most dominant woodlands identified within the project area are Central Hunter Grey Box – Ironbark Woodland EEC and the Central Hunter Grey Box – Ironbark Woodland Derived Native Grassland (DNG) (Umwelt 2013). A small number of planted native corridors also occur and are mostly adjacent to Broke Road, Charlton Road and the access road to the BCC (Umwelt 2013). The distribution of these communities is provided in Figure 3-1.

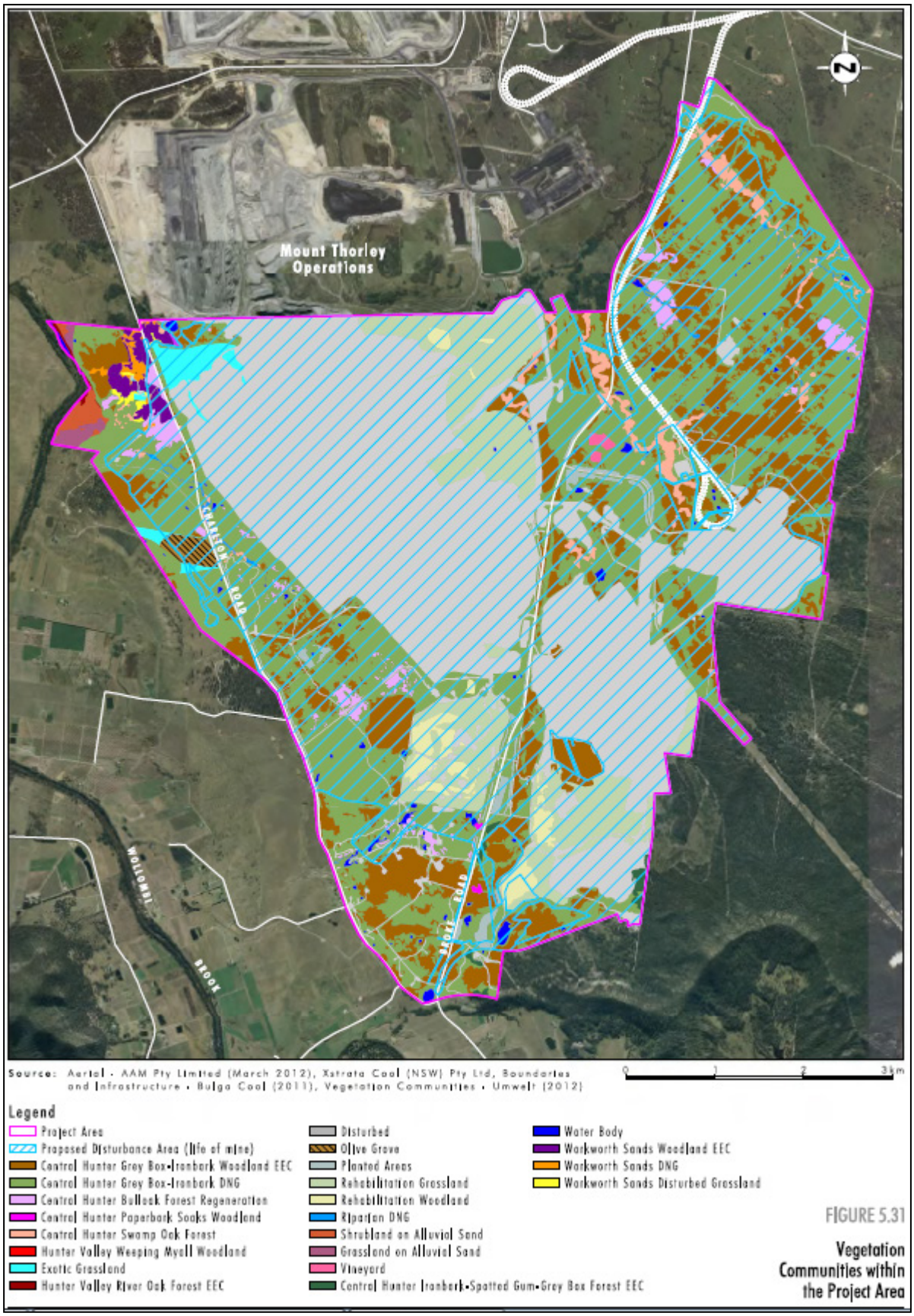


Figure 3-1. Vegetation communities within the Project Area (Umwelt 2013)

3.2 Vegetation condition

Vegetation within the BCC is largely dominated by derived native grasslands with relatively small isolated pockets of regrowth woodland. A large area of less disturbed woodland exists in the south-eastern portion of the project area.

The vegetation has been heavily modified due to a history of clearing and disturbance for agricultural purposes combined with the more recent mining activity, with less than 22% (approximately 1063 ha) comprising woodland or forest regeneration with most being less than 40- years old. Most woodlands have regenerated since 1975 and since the commencement of recent mining activity as a result of the change in land use practices. Due to the widespread clearing of native vegetation within the wider region areas of remnant vegetation provide important refuges for numerous fauna species, many of which are threatened due to habitat loss and fragmentation. Despite the lack of age and condition of the remnant vegetation they may potentially provide important stepping stones which facilitate the movement of wildlife particularly in a north-south direction (Umwelt 2013).

A total of 315 flora species were recorded during field surveys by Umwelt, with 75% of these being native. Six species were declared noxious species (Umwelt 2013). One threatened species Slaty red gum (*Eucalyptus glaucina*) and two endangered flora populations including Weeping Myall (*Acacia pendula*) Woodland and Tiger Orchid (*Cymbidium canaliculatum*) have also been recorded in the project area (Umwelt 2013).

3.3 Fauna

A total of 245 fauna species have been recorded in the BCC (Umwelt 2013) including:

- 13 frogs;
- 18 reptiles;
- 169 birds; and
- 45 mammals.

Twelve (5%) of these were introduced birds and mammals.

3.4 Threatened species

Endangered Ecological Communities (EECs) which will be potentially impacted on by the construction of the out-of-pit waste emplacements and visual bunds (Umwelt 2013) include:

- Warkworth Sands Woodland;
- Central Hunter Grey Box – Ironbark Woodland;
- Central Hunter Ironbark – Spotted Gum – Grey Box Forest; and
- Hunter Valley Weeping Myall Woodland.

A total of 21 threatened fauna have been recorded within or immediately adjacent to the BCC. A list of these species can be found in Umwelt (2013).

4 Ecological monitoring requirements

As part of the regulatory requirements, "Biodiversity monitoring will be conducted over the conservation and buffer land areas, on a schedule considered necessary for progression towards the criteria detailed in the Mine Closure Plan 2007 (BLMP, Xstrata 2008a). The monitoring needs to account for not only the diversity and location of flora and fauna, but also the health and improvement of landscape function systems. All rehabilitation monitoring will be conducted in accordance with Glencore (previously Xstrata) HSEC STD5.13 Closure Criteria Development and Rehabilitation Monitoring in order to maintain an assessment of the long-term stability and functioning of re-established ecosystems on buffer lands (Xstrata 2008a, Bulga Coal 2014). Similar monitoring conditions have been specified in the Flora and Fauna Management Plan (Umwelt 2004, Xstrata 2008b), Land Management Plan (Xstrata 2011) and more recently the draft Biodiversity Management Plan. The Management Plans outline monitoring requirements for various areas including:

- revegetation/rehabilitation areas;
- remnant vegetation; and
- riparian/aquatic habitats.

Part of the monitoring requirements include using methods such as:

- Permanent photo monitoring points;
- Permanent vegetation transects;
- Threatened woodland bird monitoring; and
- Landscape [Ecosystem] Function Analyses.

5 Bulga Coal Complex long-term monitoring program

5.1 Previous monitoring requirements

In 2010 the Bulga Coal Complex commissioned DnA Environmental to review the existing ecological monitoring program first established by Umwelt in 2003 such that it would encompass a variety of regulatory monitoring requirements. The outcome of this review resulted in the separation of the existing monitoring program into the following:

- **Ecological monitoring**: Continue monitoring the condition of the remnant vegetation and riparian ecosystems using a methodology which quantifies the changes occurring within these ecological communities and addresses monitoring requirements of the BUO Environmental Impact Statement (Umwelt 2003) and Flora and Fauna Management Plan (Xstrata 2008b).
- **Rehabilitation Monitoring**: Compare the performance of new revegetation/rehabilitation areas with suitable reference sites using quantified Key Performance Indicators (KPIs) and determine a selection of "Ecological Targets" that comply with and are consistent with Xstrata Coal NSW (2009) HSEC Standards and relevant NSW legislation, Mine closure requirements and best practice guidelines (eg. Nichols 2005, NSW T&I 2013) and Land Management Plan (Xstrata 2011).

In 2014, the rehabilitation monitoring program was further revised such that it would also fulfil the consent conditions and regulatory approvals associated with the submission of the Bulga Optimisation Project (BOP), the disturbance footprint associated with the BOP, Biodiversity Management Plan (Bulga Coal 2014) and the revised ESG3 Mining Operation Plans (MOP) guidelines (NSW T&I 2013). A summary of the long-term monitoring program is provided in Figure 5-1.

Ecological function and sustainability of the rehabilitation sites are directly compared with their relevant reference community according to ESG3 MOP guidelines for completion criteria. "Ecological" monitoring sites are only compared to each other with trends in ecological function and sustainability assessed over time. The range of ecological data recorded in each monitoring site has been tabulated in the "Ecological Performance Indicators" (KPI) table.

The results of the annual Rehabilitation Monitoring Program are provided in DnA Environmental (2010 - 2015).

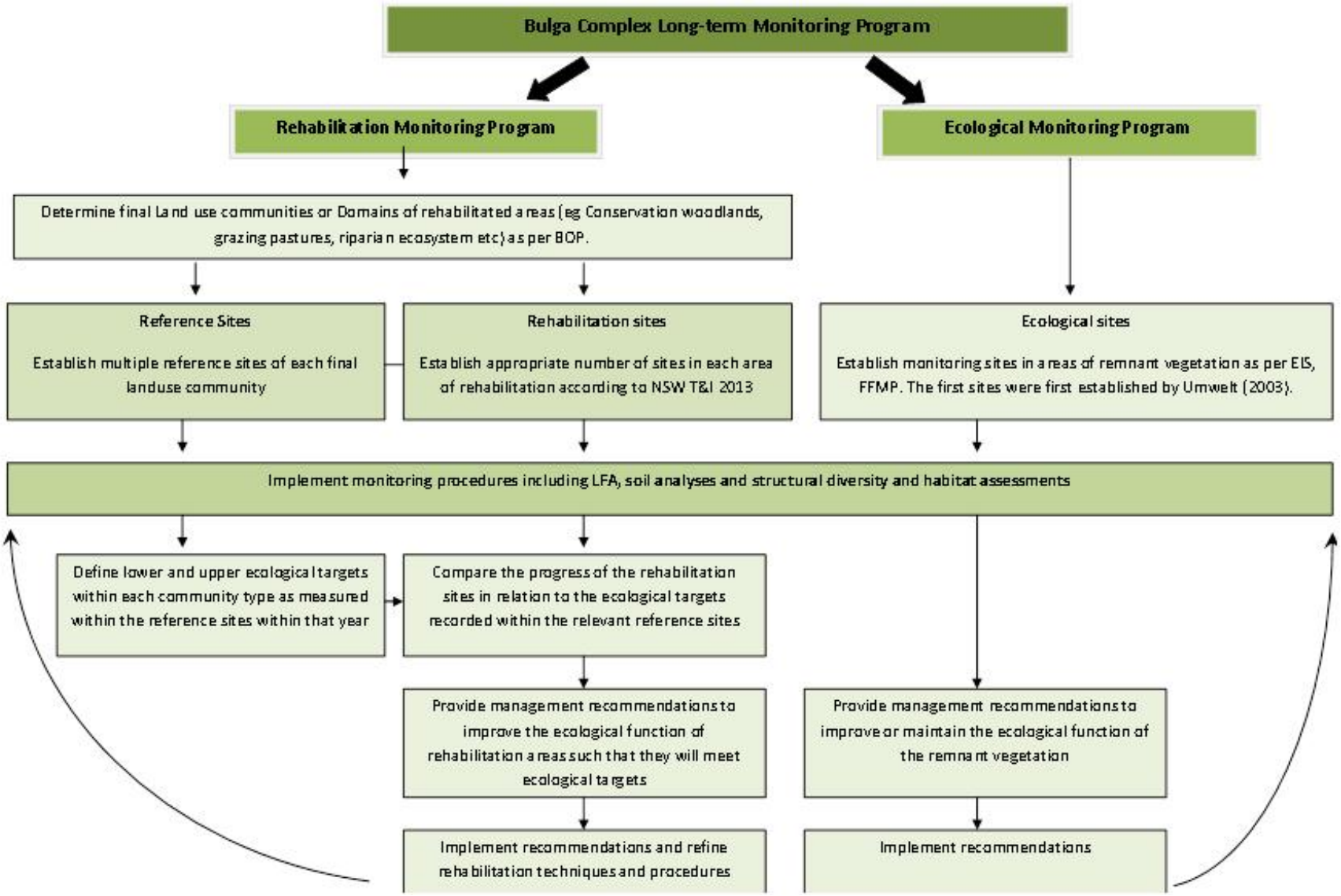


Figure 5-1. Flow diagram of the BCC long-term monitoring program (updated 2014).

5.2 BCC Rehabilitation monitoring program

The rehabilitation sites are largely a combination of mixed native woodland and exotic pasture communities which were rehabilitated under prior rehabilitation approvals and occurred on various waste emplacement dumps including North and South Blakefield and the Southern Extension. Some rehabilitation sites were situated on areas subjected to subsidence repair (BEL5) and one was situated on the old [Beltana] tailings dam (BEL3). Past monitoring also included one riparian restoration projects but this site is situated within the proposed disturbance footprint and was no longer required after 2013.

In 2014 a review of the rehabilitation sites was undertaken and took into consideration the extent of new rehabilitation undertaken during 2013 – 2014, new BOP rehabilitation commitments and sites which will be subjected to disturbance as a result of changes in the BOP. Rehabilitation monitoring sites were considered to be representative of the rehabilitation project as a whole or were similar to and representative of other areas of rehabilitation.

This year there were 14 woodland rehabilitation monitoring sites which included three new rehabilitation sites. One rehabilitation site was established on a newly rehabilitated area on the north western visual bund known as Viking adjacent to Charlton Rd which will be expected to meet completion criteria of a Central Hunter Grey Box - Ironbark Woodland (EEC).

A new site (BUO1) was also established on a very steep slope with remnant Central Hunter Grey Box - Ironbark Woodland (EEC). This area was overlying a long-wall (LW7) where subsidence and subsidence repair is expected to occur (L. Stewart pers. com. 2015). One additional site (BUO2) was also established on a BUO drill site within an area of Central Hunter Grey Box - Ironbark Woodland (EEC) which had recently been rehabilitated.

The single pasture rehabilitation site BEL3 had been significantly compromised by the construction of a waste emplacement on top of this site and was therefore not able to be monitored this year.

5.3 Ecological monitoring program

The number of ecological monitoring sites has typically increased since the monitoring was first undertaken by Umwelt in 2003 with eleven sites being monitored annually since 2010. Despite the loss of some sites in 2014 due to the BOP three replacements sites BM18, BM19 (Woodland) and BM23 (Riparian) were established. This year however there was a further reduction in the number of sites due to the loss of BM6 as a result of the mining expansions. The vegetation community and dominant species of the ecological monitoring sites in provided in Table 5-1.

Three sites BM18, BM19 and BM23 are being used as reference sites in the annual rehabilitation monitoring program. The locations of the ecological monitoring sites are shown in Figure 5-2. GPS co-ordinates and other site specific data are provided in Table 5-2.

Table 5-1. Vegetation community type and dominant species in the ecological monitoring sites.

Site Name	Vegetation community type	Dominant species
BM1	Warkworth Sands Woodland CEEC	*Eucalyptus tereticornis - E. creber* (*Allocasuarina luehmannii*, *Banksia integrifolia*, *A. filicifolia* and *Leptospermum polygalifolium*)
BM4	Central Hunter Grey Box – Ironbark Woodland EEC	*E. crebra and E. moluccana/E. fibrosa*
BM5	Central Hunter Ironbark – Spotted Gum – Grey Box Forest EEC;	*Corymbia maculata - E. crebra* woodland
BM6	Central Hunter Grey Box – Ironbark Woodland EEC	*E. crebra - E. moluccana*
BM7	Central Hunter Paperbark Soaks Woodland;	*E. crebra - Allocasuarina luehmannii - E. moluccana*
BM8	Warkworth Sands Woodland CEEC	*Allocasuarina luehmannii, Brachyloma daphnoides, Grevillea Montana* and *Pimelea linifolia.*
BM10	Central Hunter Grey Box – Ironbark Woodland EEC	*E. moluccana - E. crebra*
BM15	Central Hunter Grey Box – Ironbark Woodland EEC	*E. crebra, E. tereticornis* and *Allocasuarina luehmannii.*
BM18	Central Hunter Grey Box – Ironbark Woodland EEC	*Allocasuarina luehmannii*
BM19	Central Hunter Grey Box – Ironbark Woodland EEC	*E. crebra (E. tereticornis - Angophora floribunda)*
BM23	Hunter Valley River Oak Forest	*Casuarina glauca*

Table 5-2. GPS Co-ordinates for the ecological monitoring sites

Site	LFA Start	LFA Finish	LFA slope°	LFA bearing	Veg transect start	Veg transect finish	Veg transect bearing°
***BM1**	56 317994, 6384923	56 318005, 6384935	5	35 NE	56 318000, 6384929	56 318033, 6384899	120 SE
***BM4**	56 321005, 6378936	56 320988, 6378936	1	250 SW	56 320999, 6378936	56 320989, 6378977	344 NW
***BM5**	56 323034, 6377832	56 323032, 6377855	5	336 NW	56 323034, 6377838	56 323079, 6377859	72 NE
***BM6**: **GONE 2015**	56 320533, 6380478	56 320539, 6380458	2	145 SE	56 320535, 6380472	56 320491, 6380452	233 SW
***BM7**	56 322568, 6380246	56 322549, 6380240	0	240 SW	56 322559, 6380243	56 322547, 6380283	336 NW
***BM8**.	56 317778, 6384761	56 317790, 6384771	3	28 NE	56 317786, 6384768	56 317824, 6384738	118 SE
***BM10**	56 319063, 6381126	56 319081, 6381132	5	45 NE	56 319071, 6381131	56 319103, 6381095	137 SE
BM15	56 325042, 6383312	56 325053, 6383267	15	152 SE	56 325042, 6383312	56 325053, 6383267	152 SE
BM18	56323868, 6381796	56323882, 6381802	4	43 NE	56323875, 6381798	56323888, 6381785	135 SE
BM19	56324812, 6387177	56324795, 6387173	9	214 SW	56324800, 6387177	56324790, 6387192	306 NW
BM23	56323021, 6384500	56323006, 6384490	4	208 SW	LFA = Veg	LFA = Veg	LFA = Veg

* denotes sites established by Umwelt since 2003 (Umwelt 2010).

Figure 5-2. Location of the ecological monitoring sites.

6 Rehabilitation monitoring methodology

A range of ecological data have been collected annually from the various ecological monitoring sites during June – July in all monitoring years and this year the field work was undertaken between 9 – 15th June by Dr Donna Johnston and Andrew Johnston (DnA Environmental). The same ecological data is collected from within the range rehabilitation sites.

Data were obtained using several key monitoring methodologies including a combination Landscape Function Analyses (LFA), accredited soil analyses and an assessment of ecosystem characteristics using an adaptation of methodologies derived by CSIRO Grassy woodland Benchmarking project (Gibbons 2002, Gibbons *et al* 2008a, 2008b). The methodology used has been consistent since 2010 except in 2014 the size of the monitoring quadrats was reduced to 20 x 20m to reduce monitoring effort. A detailed description of the rehabilitation monitoring methodology can be found in the "Rehabilitation monitoring methodology and Quality Control Plan (DnA Environmental 2010a), however a summarised description is provided below.

6.1 Landscape Function Analyses

LFA is a methodology used to assess key indicators of ecosystem function including landscape organisation and soil surface condition as measure of how well the landscape retains and uses vital resources. It was developed by CSIRO scientists Tongway and Hindley (Tongway 1994, Tongway and Hindley 1995, 1996, 2003, 2004). The indicators used quantify the utilisation of the vital landscape resources of water, topsoil, organic matter and perennial vegetation in space and time.

LFA methodology collects data at two "nested" spatial scales.

1. At coarse scale, **landscape organisation** is characterised. Patches and interpatches, indicators of resource regulation, are mapped at the 0.5 to 100 m scale from a gradient-oriented transect (making sense of landscape heterogeneity); and

2. At fine scale, **soil surface assessment** (soil "quality") examines the status of surface processes at about the 1m scale, with rapidly assessed indicators on the patches and interpatches identified at the coarse scale.

At each scale, parameters are calculated that reflect several aspects of landscape function. In the first stage, we identify and record the patches and interpatches along a line oriented directly down slope. Sometimes there are several different types of each patch/interpatch which provides a measure of heterogeneity or "**landscape organisation**".

In the second stage, called "**soil surface condition" (SSC)** assessment, it is possible to assess and monitor soil quality using simple indicators including:

- Rain splash protection;
- Perennial vegetation cover;
- Percent litter cover, origin of the litter and extent of decomposition;
- Cryptogam cover;
- Crust brokenness;
- Soil erosion type and severity;

- Deposited materials;
- Soil surface roughness;
- Surface nature (resistance to disturbance);
- Slake test; and
- Soil surface texture.

These 11 features are compiled and calculated into three indices of soil quality as demonstrated in Figure 6-1:

1. **Stability** (that is, resistance to accelerated erosion);
2. **Infiltration** (the rate soil absorbs water); and
3. **Nutrient Cycling** (the way plant litter and roots decompose and become available for use by other plants).

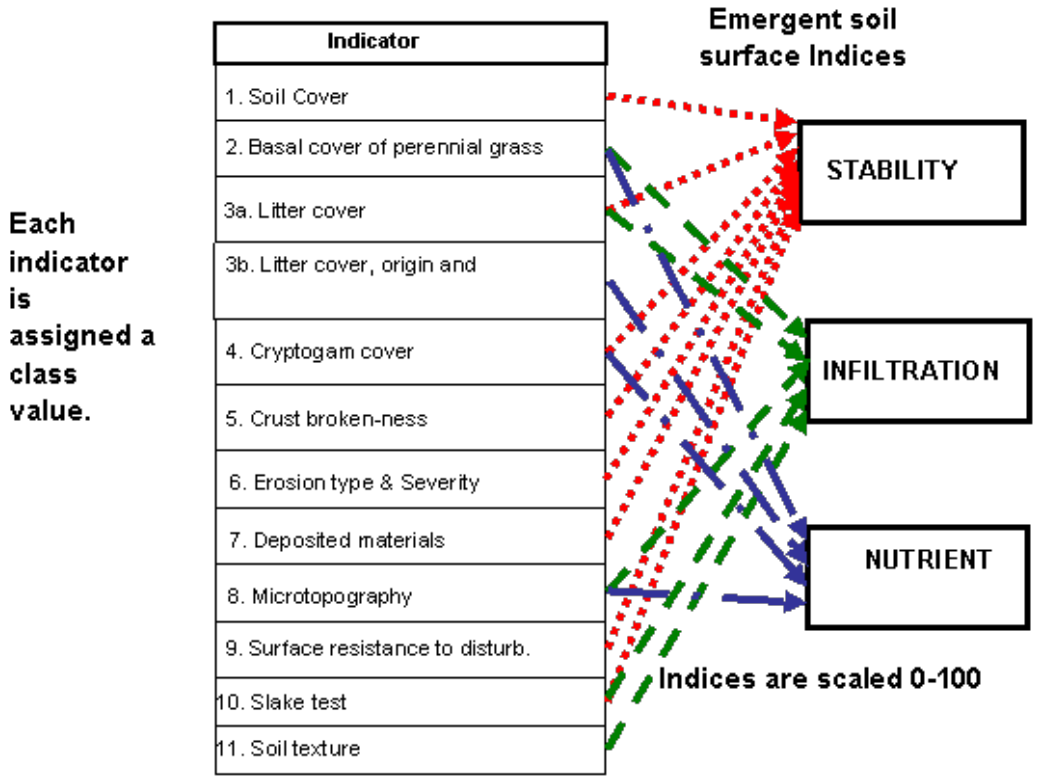


Figure 6-1. How the 11 soil surface indicators are calculated to produce the three indices of soil quality.

6.2 Soil analyses

Soil samples are obtained using standard soil sampling techniques within the monitoring quadrat. At least 12 samples are randomly taken at each site and bulked together. Soil samples are sent to Southern Cross University at their National Association of Testing Authorities (NATA) accredited laboratory for analysis. Soil analysis consists of assessing the following parameters:

- pH;
- Electrical Conductivity (EC);
- Organic Matter (OM);
- Cation Exchange Capacity (CEC;
- Exchangeable Sodium Percentage (ESP);
- Available Calcium (Ca), Magnesium (Mg), Potassium (K), Nitrate Nitrogen (N), Sulphur (S);

- Exchangeable Sodium (Na), Ca, Mg, K, Hydrogen (H);
- Available and extractable Phosphorus (P);
- Micronutrients Zinc (Zn), Manganese (Mn), Iron (Fe), Copper (Cu), Boron (B), Silicon (Si), Aluminium (Al), Molybdenum (Mo), Cobalt (Co) and Selenium (Se) and Total Carbon;
- Heavy metals including Cadmium (Cd), Lead (Pb), Arsenic (As), Chromium (Cr), Nickel (Ni), Mercury (Hg) and Silver (Ag).

A report with analysis and desirable levels recommended in the agricultural industry is provided by the laboratory. Exchangeable Sodium Percentages are calculated as a measure of sodicity or dispersion. From 2014, soil samples for the ecological sites will be taken on a three year rotation (T. Scott pers. com 2014).

6.3 Monitoring structural diversity, floristic and other biodiversity attributes

In addition to LFA, assessments of various biodiversity components must also be made to monitor changes in particular plants and groups of plants through the various successional phases and to document and/or identify critical changes or management actions required.

Some simple and rapid procedures for making these assessments were developed by CSIRO scientists and were developed for assessment habitat quality across a range of vegetation types in the southern NSW Murray-Darling Basin (Gibbons 2002), and Biometric Model used in the Property Planning Process (Gibbons *et al* 2008a,b). Some adaptations have been made to reduce monitoring effort where possible, and to incorporate aspects of newly formed revegetation sites or sites in the early stages of recovery. For example some habitat features such as the detailed measuring and assessment of decomposition of the logs and branches has been omitted, whilst the understorey assessment included planted tubestock, direct seeding as well as natural recruitment and naturally occurring shrubs.

The rapid ecological assessment provides quantitative data that measures changes in:

- Floristic diversity including species area curves and growth forms;
- Ground cover diversity and abundance;
- Vegetation structure and habitat characteristics (including ground cover, cryptogams, logs, rocks, litter, projected foliage cover at various height increments);
- Understorey density and growth (including established shrubs, direct seeding and tubestock plantings and tree regeneration);
- Overstorey characteristics including tree density, health and survival; and
- Other habitat attributes such as the presence of hollows, mistletoe and the production of buds, flowers and fruit.

Permanent transects and photo-points are established to record changes in these attributes over time.

6.4 Amendments

6.4.1 BOP disturbance

With the implementation of the BOP some ecological monitoring sites are likely to be cleared and/or disturbed and subsequently these sites were omitted from the ecological monitoring program in 2014. Three additional sites were however established and these included BM18, BM19 and BM23.

As the final land uses for the rehabilitated waste emplacements include the establishment of EEC woodland and riparian communities, the new ecological sites established were also suitable for use as reference sites within the rehabilitation monitoring program.

6.4.2 Quadrat size

The size of the monitoring quadrats was reduced to 20 x 20m in 2014 to reduce monitoring effort, with little significant change in the way monitoring data is assessed and recorded. One exception however is the "total" floristic diversity which is recorded within the entire monitoring quadrat thus a reduction in floristic diversity (total, native and exotic) can be expected in 2014.

6.4.3 Loss of sites

In 2015 the Central Hunter Grey Box - Ironbark Woodland (EEC) site BM6 had been significantly compromised by the construction of a waste emplacement on top of this site and was therefore not able to be monitored this year.

6.4.4 Species identification

Due to the cold seasonal conditions (including frosts) and heavy grazing pressure, there may have been a lack of reproductive structures that are required for the positive identification of numerous plant genera, and therefore some species were only able to be identified to the genera level and in some cases, the family level of taxonomy. In addition, there were often many small seedlings which had recently germinated and these too were often too small to positively identify or to enable suitable specimen collection.

6.4.5 Soil analyses

Soil analyses will be undertaken on a three year rotation, therefore no soil analyses were undertaken in 2014 or 2015.

7 Rainfall

Prior to 2010 drought conditions were experienced across most of the state which had a deleterious effect on the native vegetation with the prolonged dry conditions also resulting in increased total grazing pressure. In 2010 above average rainfall was received and provided excellent growing conditions into 2011 which initiated plant growth and recruitment for numerous plant species but the remainder of 2011 however remained relatively dry (Figure 7-1), except in September where 140.5mm was recorded.

Generally 2012 was very dry with rainfall well below the annual average and only 500.5mm of rain but there was a period of high summer rainfall which extended into March 2013. The remainder of 2013 however was rather dry and prolonged hot and dry conditions were experienced during December and January 2013/ 2014.

Relief from these conditions came in February 2014 (Figure 7-2) with above average rainfall recorded from February to April, initiating growth and germination of vegetation. During the remainder of the year rainfall was low and typically well below the monthly averages up until November through to January 2015 where above average rainfall was received. In February and March 2015 there was again limited rainfall, but in April 193.8mm was received followed by 51.4mm in May.

The periods of extreme and prolonged dry conditions experienced over the past few years are likely to have had a significant impact on the composition and diversity of the vegetation communities, with the poorer growing conditions combined with increased disturbance and grazing pressures having adverse effects of much of the remnant vegetation and rehabilitation areas. Rainfall received in autumn however has resulted in an increase in plant growth and initiated a flush of annual species with these seasonal conditions being reflected in the monitoring data again this year.

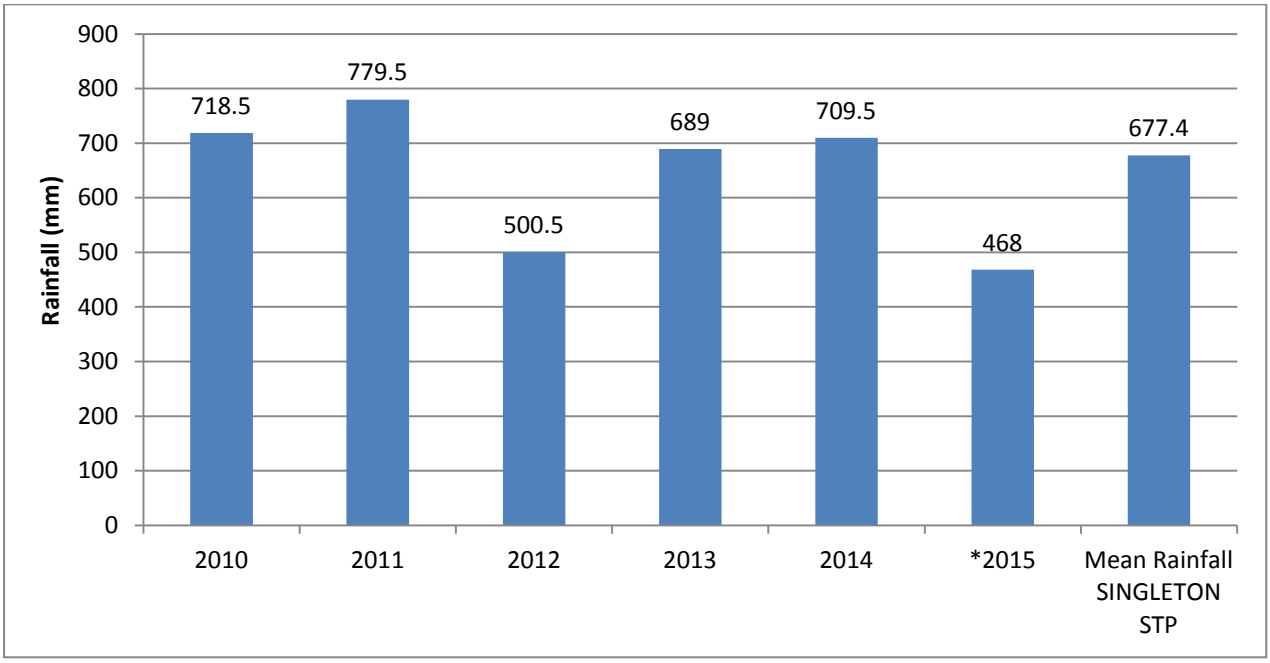


Figure 7-1. Annual rainfall recorded at the Bulga Coal Complex from 2010 to the end of *June* 2015 compared to the long-term monthly averages recorded at Singleton STP (BoM 2015).

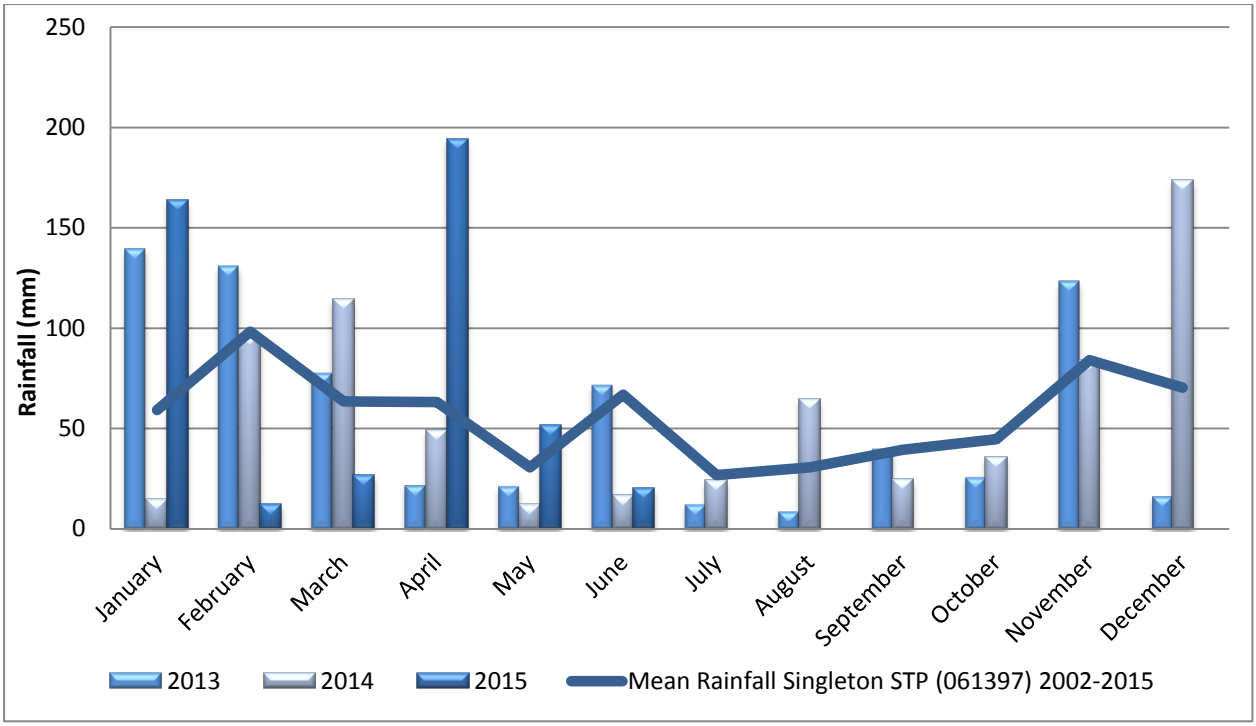


Figure 7-2. Monthly rainfall recorded at the Bulga Coal Complex January 2013 to June 2015 compared to the long-term monthly averages recorded at Singleton STP (BoM 2015).

8 Ecological monitoring site descriptions and permanent photo-points

Table 8-1 provides a brief description of the ecological sites and permanent photo-points taken along the vegetation transect since 2010. In 2014, additional sites included BM18, BM19 and BM23. Please note photos taken 2012 have been omitted for ease of presentation of increasing quantities of data.

Table 8-1. Brief description of the ecological monitoring sites and photo-points taken along the permanent vegetation transect since 2010 (ex 2012).

2010	2011	2013	2014	2015
***BM1:** Warkworth Sands Woodland CEEC dominated by a few large *Eucalyptus tereticornis, E. creber* and regrowth saplings primarily of *Allocasuarina luehmannii*. *Banksia integrifolia*, *A. filicifolia* and *Leptospermum polygalifolium* were common shrubs. Ground cover was dominated by leaf litter and a diversity of scattered native herbs and grasses. A large patch of lichen was also present along LFA transect. There was an extensive network of macropod tracks throughout the site. The area is not subjected to subsidence. Babblers were heard in the area in 2010. In 2011 there was little apparent change but less cover of *Pimelea linifolia*. This site was not monitored in 2012. In 2013 the site appears to have suffered from storm damage with some trees weakened by termites. A large *E. creber* tree had fallen within the site (bottom right). Several other younger Acacia and *E. creber* had also died with some being strewn across the site. Most of the fallen timber had been subjected to termite attack. Macropod camps have created large bare areas within the Leptospermum thickets. There was an active rabbit warren and fox scat. There was a noticeable decline in *Pimelea linifolia*. In 2014, the site appeared to be further degraded with the site becoming more open and had less ground cover, with macropod tracks causing destruction of the lichen layer. Large patches of Banksia had recently died and there were only a few scattered *Pimelea linifolia.* Babblers were heard in the area in 2013 and 2014. In 2015 the site appears further degraded with numerous more trees having fallen down, with increased log cover and a much more open woodland structure. While the LFA transect has tended to remain intact there continues to be high levels of disturbance and an extensive network of animal tracks throughout. There was also extensive sheeting on the perimeter of the WWS woodland area into the WWS woodland area, including the clean diversion water drain which has been eroding at the outlet.				
				
***BM4:** Regrowth *E. crebra and E. moluccana/E. fibrosa* woodland with saplings of *Allocasuarina luehmannii*. The shrubby understorey was patchy and *Dodonaea viscosa subsp cuneata, Acacia amblygona, Bursaria spinosa* and *Lissanthe strigosa* were the most common. The ground cover was largely comprised of leaf litter but *Entolasia* and various other herbs and grasses were sparsely distributed across the site. There were some fallen logs and branches and cryptogams were relatively common. In 2011, there was evidence of a lot of leaf litter moving across the site during heavy rain events. There was some new recruitment of numerous shrub species. In 2012, the new gas pipeline was constructed extremely close to this site (corner peg was demolished) and there were some subsidence cracks but there was no other obvious interference. There was improved level of ground cover and thus in part may be due to increased human activity resulting in a reduction in macropods utilising the area. In 2013, there was little apparent change with the subsidence cracks remaining apparent. There was a lot of shrub regeneration especially *Acacia amblygona*, *Bursaria spinosa* and *Lissanthe strigosa*. The site was very patchy with one end having a well developed litter layer while the other had large hard, bare gravelly patches. There was a high diversity of small woodland birds. Macropods have been having a negative impact over the past year. In 2014, some of the larger shrubs have died however there were numerous seedlings and there continued to be a good leaf litter layer, with cryptogams abundant on the more bare and crusted areas. There was no evidence of the subsidence cracks however Macropods continue to utilise the area. In 2015 there was little apparent change but there was some erosion into the area due to the construction of the adjacent pipeline. The pipeline disturbance areas have become stabilised and have re-established very well in this vicinity. Within the site many shrubs had died especially the larger Dodonaeas which has opened up the structure of the site. There were subsidence cracks evident at 5m along the vegetation transect with several other cracks observed throughout. The construction of macropod exclosures may assist in identifying the levels of macropod impact at this remnant woodland area.				
				

2010	2011	2013	2014	2015

***BM5:** Regrowth *Corymbia maculata - E. crebra* woodland with a moderate stem density situated near the old quarry. There were scattered shrubs including *Dodonaea viscosa subsp cuneata, Acacia parvipinnula,* and *Breynia oblongifolia* with some *Corymbia maculata* juveniles. Many of the shrubs had been heavily browsed or were suffering from dieback. There was a deep litter layer and ground cover species were limited, and fallen tree branches were common. Wombat holes were common. The site is subjected to subsidence. In 2011 there was a decline in the number and health of the shrubs and heavy browsing by macropods defoliating many shrubs. There was some eucalypt and acacia recruitment and increased level of leaf litter. In 2012 the litter layer had further developed and there many small regenerating shrubs, especially those of *Dodonaea* and *Breynia oblongifolia.* There continued to be a high diversity of species but cover abundance was very limited. In 2013 there was little apparent change within the site with extensive regeneration of *Dodonaea viscosa subsp cuneata* and *Breynia oblongifolia*. There had also been extensive disturbance in the general area caused by foraging pigs. In 2013, most of the larger shrubs had died resulting in the site being much more open and there was an apparent decline in ground cover plants, however there continued to be an abundance of shrub seedlings and a very dense leaf litter layer. In 2014 there was little apparent change other than many of the smaller shrubs had grown.

***BM6:** Regrowth *E. crebra* woodland with various densities and ages of *Allocasuarina luehmannii, Callitris glaucophylla, E. moluccana* and *Melaleuca decora. Ozothamnus diosmifolius* and *Lissanthe strigosa* were abundant but *Acacia amblygona, Acacia parvipinnula* and *Daviesia genistifolia* were also present in much fewer numbers. There was moderate recruitment of *Allocasuarina luehmannii.* The ground cover was dominated by leaf litter but there was a relatively high perennial vegetation component in comparison with other sites, but there were also numerous bare patches and an extensive network of macropod tracks. There were also significant patches of cryptogams towards the end of the transect. The site appears to have been previously affected by fire, with evidence of charring and burnt stumps and is currently subjected to subsidence. Babblers were heard in the area. In 2011, water sheeting has left a lot litter accumulating within depressions or plant and log obstructions. In 2012 there appeared to be less disturbance but the more palatable species continue to be heavily browsed. While numerous regenerating shrubs were present there was a conspicuous absence of palatable species. In 2013, there has been a notable decline in the abundance and health of the more palatable shrub species especially those of *Ozothamnus diosmifolius* probably due to heavy browsing by macropods. In 2014, there was a further loss of shrubs and evidence of heavy grazing pressure and a network of macropod tracks throughout the site resulting in the site becoming more open in structure. Babblers continue to be present. The construction of macropod exclosures may assist in identifying the levels of macropod impact at this remnant woodland area. In 2015 this site was not monitored.

2010	2011	2013	2014	2015

***BM7:** Regrowth *Melaleuca decora* Swamp Paperbark) woodland with a few scattered *Allocasuarina luehmannii.* There were few shrubs including *Acacia amblygona, Lissanthe strigosa, Bursaria spinosa, Olearia elliptica and Cassinia sp.* and smaller regenerating *Allocasuarina luehmannii* were also common. While species diversity was relatively high, there was a low cover of abundance. The ground cover was dominated by leaf litter, some cryptogams and fallen tree branches. The site is subjected to subsidence. A Brown Falcon (?) was nesting in large *E. moluccana* south of the plot in 2010. In 2011, water sheeting has left a lot litter accumulating within depressions or plant and log obstructions. There was some recent shrub recruitment and scattered occurrences of *Opuntia stricta.* In 2012 there appeared to be less disturbance but the more palatable species continue to be heavily browsed. While numerous regenerating shrubs were present there was a conspicuous absence of palatable species. In 2013 the site appears to have stabilised and there continued to be high levels of litter cover. There were large patches which had recently been turned over, probably by White-winged Choughs. The *Exocarpus* had died and the Opuntia was sick and dying. In 2014, the site maintains a heavy litter later but has been subjected to high levels of browsing with an apparent reduction in diversity and abundance of ground cover species. The construction of macropod exclosures may assist in identifying the levels of macropod impact at this remnant woodland area. In 2015 there was little apparent change however macropod camps have bared the soils in patches, with these having washed away the deep litter covers leaving them bare and crusted. There continued to be evidence of leaf litter being mobilised across the site.

***BM8:** Regenerating Warkworth Sands Woodland CEEC with several larger individuals of *Allocasuarina luehmannii,* but primarily the site is characterised by a low (<1.5m) but dense shrubby understorey dominated by *Brachyloma daphnoides, Grevillea Montana* and *Pimelea linifolia.* The low shrubs accounted for much of the ground cover but *Cheilanthes sieberi subsp. sieberi* and *Lomandra filiformis* provided most other perennial ground cover. The levels of leaf litter were highly variable and often low, but lichens were extensive across the site. The site is not subjected to subsidence, but there is a significant network of macropod tracks and activity occurring within the area. In 2011 there was little apparent change. In 2012, the weedy *Richardia* and *Melinis repens* continued to be abundant and the crown of the *Brachyloma* were much weaker and less healthy, with many branches being broken probably due to large kangaroos and pigs. (A pig was sighted). Babblers were seen in the area. In 2013 there was little apparent change but there was a decline in the abundance of *Pimelea linifolia.* There was some scattered Angophora regeneration at the end of the vegetation transect. Pigs had been rooting in the area. In 2014, there was a further decline in the abundance and condition of the *Brachyloma* and no Pimelea were recorded. There continued to be a good cover of lichens and the increasing humus contributing to a more stable soil surface, where it had not been disturbed by the network of animal tracks throughout the site. Species diversity was overall low. In 2015 there was little apparent change with a network of animal tracks maintained throughout the site with the lichens being trampled leaving the bare sandy soils exposed. The shrubs however appeared to be healthier this year.

2010	2011	2013	2014	2015

***BM10:** Good quality regrowth *E. moluccana* woodland with a diverse and intact grassy understorey. There were few shrubs but those present included *Acacia amblygona, Myoporum montanum, Canthium oleifolium, Daviesia genistifolia, Indigofera australis, Lissanthe strigosa, Hardenbergia violacea, Cassinia sp.* and a young *Brachychiton populneus.* There was good ground cover dominated by leaf litter and there was a significantly high diversity of native grasses and herbs. The most dominant included *Cymbopogon refractus, Bothriochloa decipiens, Chloris ventricosa, Aristida ramosa* and *Dichondra repens* and the introduced *Senecio madagascariensis.* There was some scattered *Opuntia stricta throughout the woodland remnant* but many individuals were sick and/or dying. *Cryptogams* became more significant towards the end of the transect, where previously soils were bare. There were numerous stumps and fallen branches. Subject to subsidence. In 2011 and 2012, there was little apparent change with the site maintaining very high species diversity. On 2012 a small patch of *E. crebra* trees were highly stressed towards the end of the vegetation transect. In 2013 there was little apparent change. In 2014, it was noted that the large *E. crebra* trees had died, including the epicormic growth and there continued to be some large crack throughout the site. There site was drier and may have been subjected to some light cattle grazing (manure was observed). In 2015 there was no evidence of recent cattle grazing and the site was more green and diverse. Some minor cracks were observed within the soil profile throughout the site.

BM15: Ephemeral creek with a long grazing history and degraded by clearing and overgrazing with the steep sided banks showing active erosion on the northern bank. The southern banks remain in a more functional state with open grassy woodland dominated by a sparse canopy of *E. crebra, E. tereticornis* and *Allocasuarina luehmannii.* There are several shrubs and regenerating eucalypts, including *Acacia falcata, Acacia parvipinnula, Allocasuarina luehmannii, Cassinia quinquefaria* and *Maireana microphylla.* Despite the exceptionally bare northern bank, this site was floristically diverse with *Themeda triandra, Cymbopogon obtectus, Cynodon dactylon* and *Bothriochloa* being the most dominant ground cover plants. The site is not subjected to subsidence and is situated upstream of the CHPP. No water was present at any time of monitoring. In 2011, there has been further erosion on the northern bank and upstream slope. Some shrubs and declined in health or have died. In 2012, the banks have continued to erode with terracetting and perched grass tussocks scattered across the slope. Extensive slumping and tunnelling has also occurred with increased in sediment within the lower creek depressions. The grass tussocks have increased in size. The site remains floristically rich but is weedy within the creek channel. In 2013 the banks continue to erode but the grass tussocks appear to have increased, but they continued to be significantly perched. The saplings continue to grown. There was water within the creek bed after recent rainfall. Downstream the creek banks continue to slump with an *E. creber* having fallen across the creek. In 2014, the stream was dry and there was little apparent change observed within the site. In 2015 the creek banks have further deteriorated with extensive pedalstalling and undercutting. The creek was deeply incised and while it was not running there were occasional shallow ponds. Babblers, Friar Birds and frogs were heard. A tortoise shell was also found.

2010	2011	2013	2014	2015
BM18: In 2015 a new site was established due to the destruction of the original site. It was relatively young regrowth woodland dominated by *Allocasuarina luehmannii* with a grassy understorey situated south of the CHPP and very similar to the original site. There were small patches of *A. parvipinnula* and *Daviesia genistifolia*. The woodland was relatively open with an understorey dominated by *Bothriochloa decipiens* and contained a high diversity of native grasses and herbs, with only sparsely scattered weeds. There were high levels of ground cover and the site was particularly stable. The site is grazed by macropods.				
N/A	**N/A**	**N/A**		
BM19: Low – medium density *E. crebra* regrowth woodland situated on the Hendley's Offset area, mid slope above the shearing shed. There were scattered *E. tereticornis* with a patch of *Angophora floribunda* lower down the slope but these were not necessarily situated within the monitoring quadrat. There were scattered *Bursaria spinosa* and *Lantana camara* but typically shrubs were very sparse. The grassy understorey was dominated by *Cymbopogon refractus, Bothriochloa decipiens and Aristida ramosa* and contained a high diversity of other native grasses and herbs, with scattered weeds. There were high levels of ground cover and the site was particularly stable. The site is grazed by macropods. In 2015 there was little apparent change.				
N/A	**N/A**	**N/A**		
BM23: This riparian woodland reference site was situated on the area of Crown Land along the Nine Mile Creek on the western side of the Broke Road. It was a moderate - high density regrowth forest dominated by *Casuarina glauca* with fringing *Allocasuarina luehmannii* woodland on the upper banks. There were some scattered suckers/regeneration but this area was more open than almost sections along Nine Mile Creek with comparatively fewer weed. The creek sections were typically dominated by highly impenetrable *Casuarina glauca* thickets and/or were dominated by exotic species. The understorey contained high levels of leaf litter and was dominated by *Microlaena stipoides* and scattered native forbs. LFA =Veg transect. Due to the high density of trees and saplings the right 10 x 20m of the plot only was counted. In 2015 there was little apparent change but the grasses were greener and more abundant. The creek had been previously been flooding but presently was still. The water was slightly discoloured orange/brown and frogs were croaking.				
N/A	**N/A**	**N/A**		

9 Ecological trends and primary performance indicators

9.1 Landscape Function Analysis

9.1.1 Landscape Organisation Index

A patch is an area within an ecosystem where resources such as soil and litter tend to accumulate, while areas where resources are mobilised and transported away from are referred to as interpatches. Landscape Organisation Indices (LOI) are calculated by the length of the patches divided by the length of the transect to provide an index or percent of the transect which is occupied by functional patch areas (Tongway and Hindley 2004).

While the range of monitoring sites have typically maintained high patch areas in previous monitoring years there was a minor reduction recorded within BM1, BM7 and BM8 this year (Figure 9-1) and was largely due to macropod disturbance. In these sites there was often an extensive network of animal tracks and in BM7 there were also numerous macropod camps which have reduced the overall functional area of these sites.

In 2014 site BM15 existed as a bare slope with the occasional perched tussock of grass and essentially did not contain any functional patch areas. This year there was a small grass patch developing in the creek bed resulting in an LOI of 9%. The bare and actively eroding banks were probably initiated by past clearing and cattle trampling and grazing, followed by in-stream bank erosion and subsequent incision of the riparian system. Despite the absence of grazing by livestock for a lengthy period of time, the site appears to be slow to recover due to the erosive and unstable substrates combined with limited ground cover and plant propagules required for plant colonisation.

Sites which continued to maintain a Landscape Organisation Index (LOI) of 100% included BM4, BM5, BM10, BM18, BM19 and BM23.

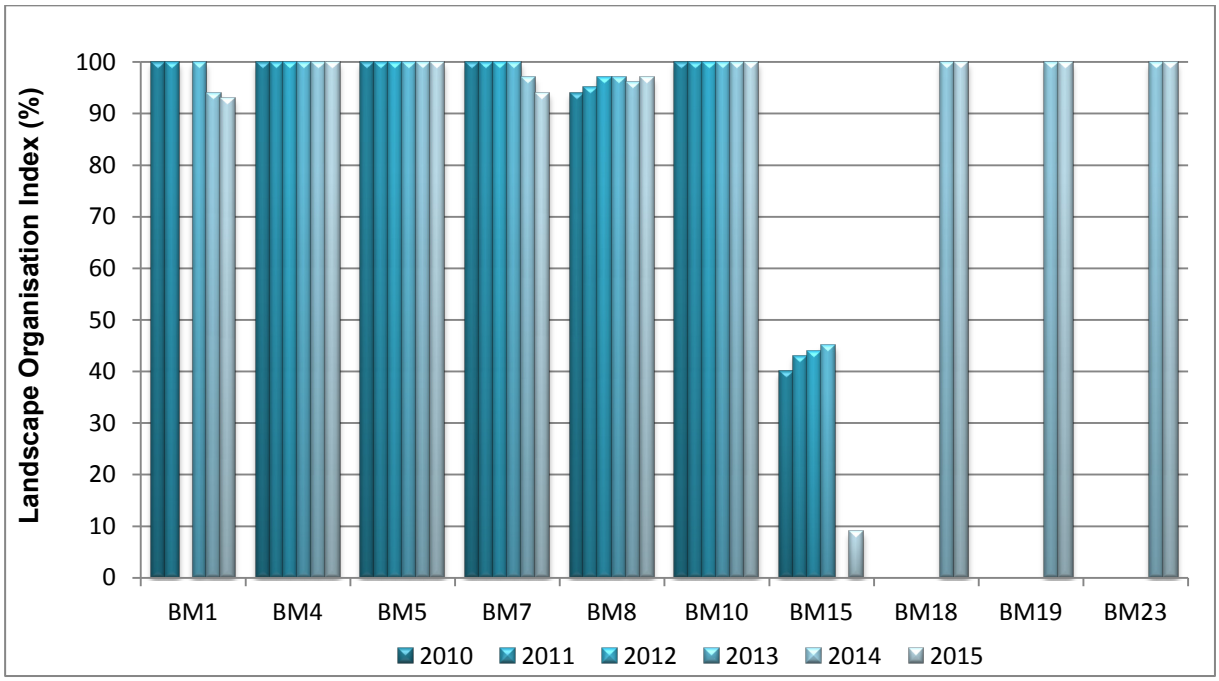


Figure 9-1. Landscape organisation indices recorded in the ecological monitoring sites.

9.1.2 Soil surface assessments

9.1.2.1 Stability

Most sites tended to highly stable communities with the most stable communities including BM4, BM5, BM10, BM18, BM19 and BM23 being comprised of a mature tree canopy and a grassy understorey with moderate to high densities of perennial grasses and herbs. They also had well developed litter layers and humus rich stable soil surface layer. Site BM1 and BM8 were Warkworth Sands communities which were both very different to the other sites as well as each other but both had a high shrub and cryptogam component. Site BM15 was an eroding creek bank with little to no canopy or grass cover and was suffering extensive erosion.

In 2010 LFA stability indices for the ecological sites ranged between 58.9 - 72.1 LFA units but the stability of all ecological sites slightly declined in 2011 largely due to the mobilisation of litter (and some sediments) within the sites after high rainfall events and flooding, with this declining trend also being evident in the woodland reference sites measured as part of the rehabilitation monitoring program (DnA Environmental 2011a).

Since then there has been no consistent trend in the changes in stability but sites which have declined over the past year included BM5, BM7, BM8, BM15 and BM18. This is largely due to increased rates of erosion and/or deposition, with disturbance associated with animal tracks and camps being especially evident in sites BM7 and BM8. In the remaining ecological sites there may have been marginal improvements in the stability of the community and this can usually be attributed to an increase in perennial plant and/or litter cover.

The stability of the sites ranged from a low of 54.4 which was recorded in the eroding creek banks of BM15 to a high of 80.5 in BM19, the regenerating *E. creber* woodland site.

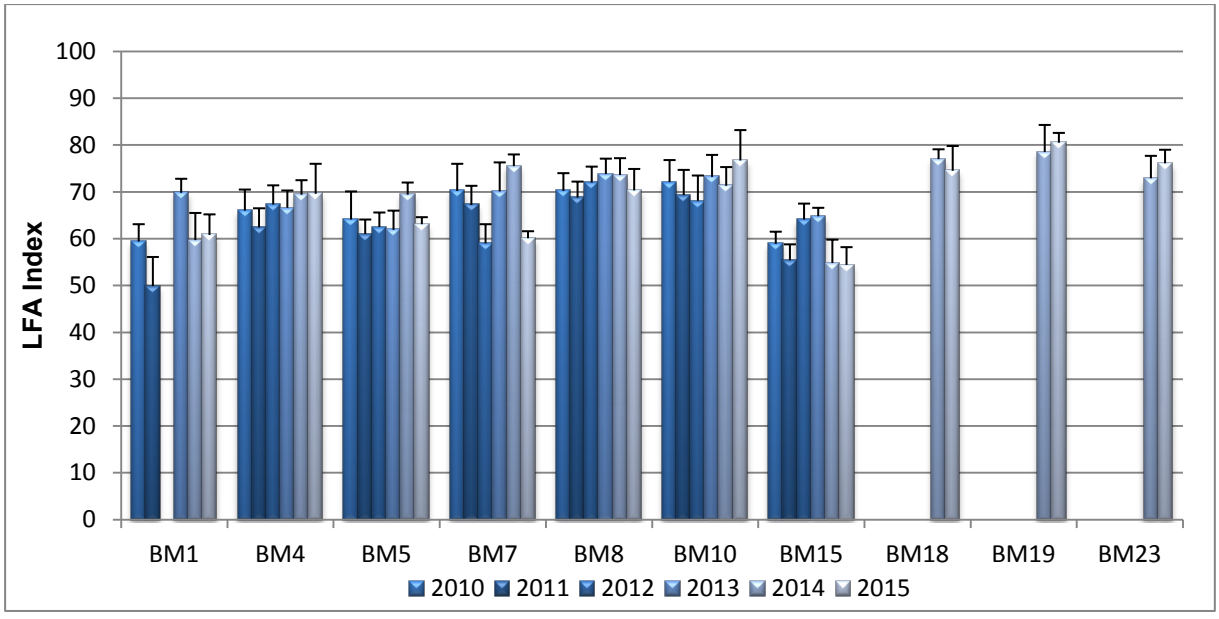


Figure 9-2 LFA stability indices recorded in the ecological monitoring sites.

9.1.2.2 Infiltration

There has been no consistent trend in changes in infiltration capacity across the range of monitoring sites but sites which have deteriorated over the past twelve months include BM4, BM5, BM7 and BM15. In BM4, BM5 and BM7 there tended to be less depth of litter cover as much of the litter had broken

down and condensed and in BM5 and BM7 the litter had become more readily mobilised with high deposition rates recorded in these sites. In BM7 macropod activity had also reduced the functional patch areas as well as increased soil crusting and soil surface hardness. In BM15 the exposure of the heavy clay and hard setting soils after years of active erosion have left the site with little vegetative covers and a very low infiltration capacity. In the remaining sites there was a marginal increase in site infiltration due to the increase in perennial plant and/or litter covers.

The riparian woodland interpatch at site BM15 continued to have the lowest infiltration capacity and scored only 21.8 this year. Despite a reduction in infiltration site BM5, a *Corymbia maculata* woodland, continued to have the highest infiltration with an index of 67.7 (Figure 9-3) due to the very deep layer of leaf litter with extensive rates of litter decomposition, well developed humus layer and limited soil surface crusting. There was also a well developed tree canopy and scattered perennial shrubs.

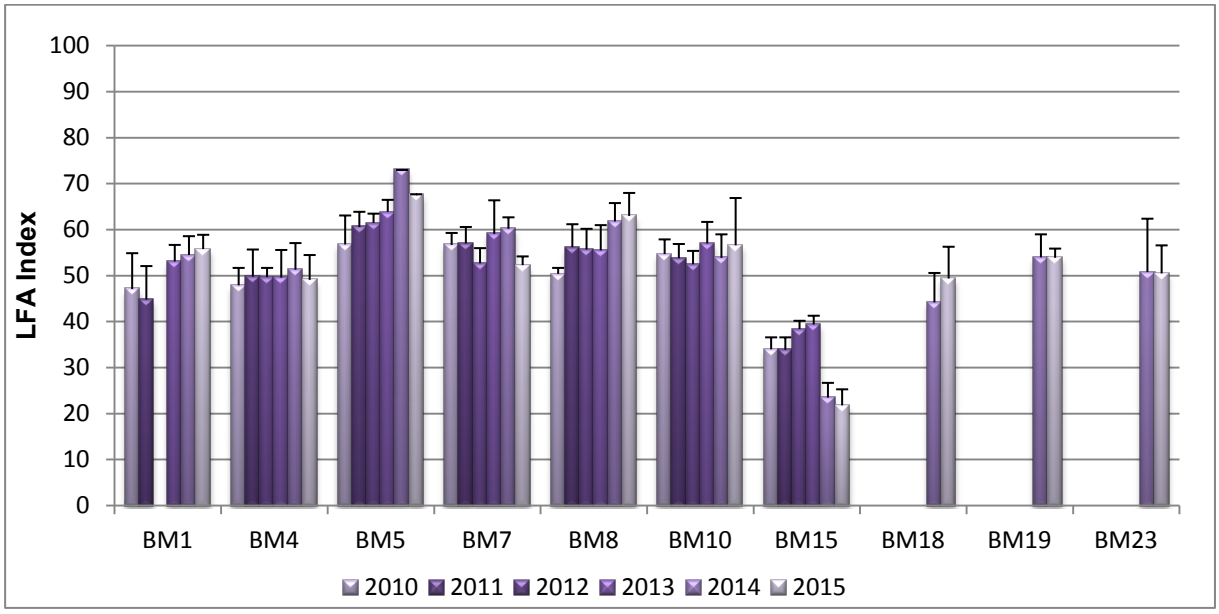


Figure 9-3 LFA infiltration indices recorded in the ecological monitoring sites.

9.1.2.3 **Nutrient recycling**

Similar trends have been reflected with the nutrient recycling capacity of the ecological sites (Figure 9-4). While there have been no consistent change across the range of sites, sites which have shown a reduction in nutrient recycling capacity this year include BM4, BM5 and BM7 with a negligible decline recorded in BM15. This decline can most readily be attributed to the reduction in the depth of litter cover, higher rates of deposition combined with site BM7 also having less functional area and increased crusting and hardness due to high disturbance activity by macropod populations.

Site BM15 continued to have the lowest nutrient recycling capacity of 21.2, while BM5 had the highest index of 64.1 despite a reduction over the past year. The *E. moluccana – E. crebra* grassy woodlands BM10 and BM19 had the next highest nutrient recycling capacities with indices of 55.6 and 55.4 respectively.

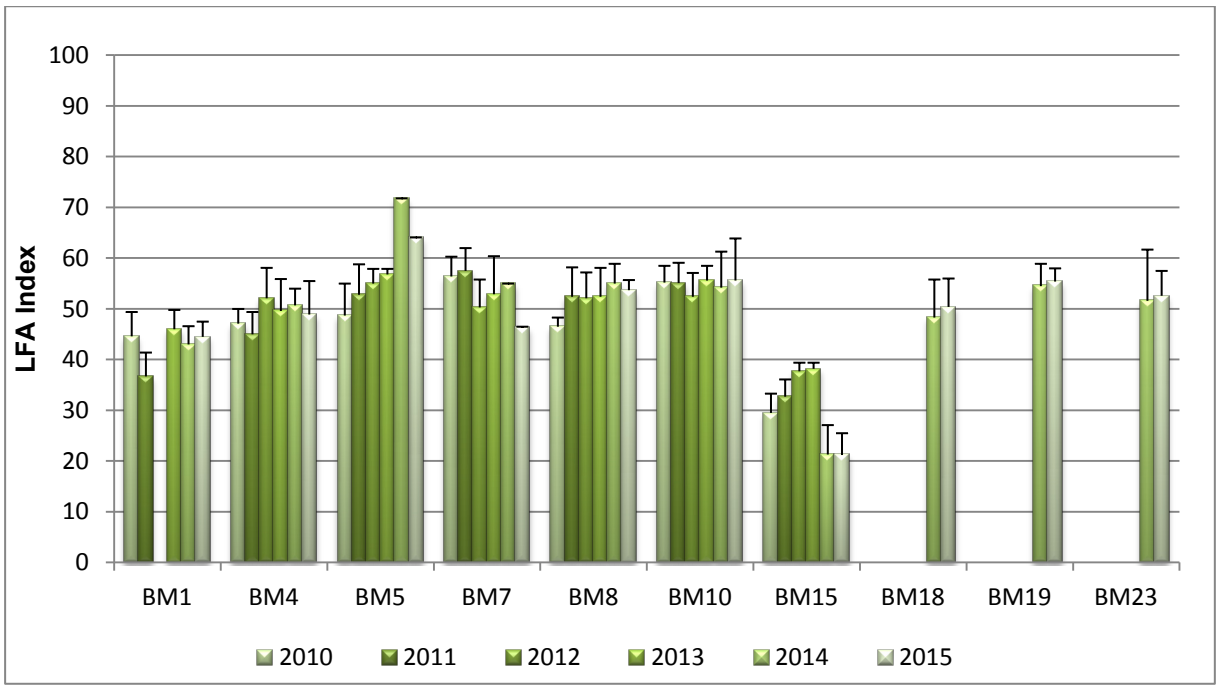


Figure 9-4 LFA nutrient recycling indices recorded in the ecological monitoring sites.

9.1.3 LFA Summary

The sum of the LFA stability, infiltration and nutrient recycling components provide an indication of the most functional to least functional monitoring site recorded in 2015 and is provided in Figure 9-5. The maximum score that can be achieved is 300.

BM5 the *Corymbia maculata* woodland with a deep litter layer, scattered perennial understorey species and shrub regeneration continued to be the most ecologically functional site but this score has declined from 214.2 to 194.9 this year, largely due to the decomposition, mobilisation and reduction in the depth of the litter layers. In this site there was also a mature tree canopy and high rates of litter decomposition which has lead to the reduction soil surface crusting and the development of a spongy soil profile.

The *E. moluccana – E. crebra* grassy woodlands BM10 and BM19 were the next most functional with total scores of 189.8 and 188.9 respectively and these were slightly better than recorded last year. In these sites there tended to be increased perennial plant covers as a result of the improved seasonal conditions. In these sites there was also a mature tree canopy and there have been high rates of litter decomposition which has lead to the reduction soil surface crusting and the development of a spongy soil profile.

BM8 one of the Warkworth Sands Woodlands also performed relatively well with an index of 187, but this was also slightly lower than 190.4 recorded last year. There was a high density of low shrubs which provided high degree of soil surface protection and perennial plant cover. There was also a well developed litter layer and the Coral lichens growing on the sandy soils being a unique and characteristic feature.

Sites BM23, BM18 and BM4 had a sum of indices of 179.2, 174.3 and 167.6 respectively with these communities also contained a mature tree canopy, relatively high shrub/sapling component and varying degrees of perennial plant and litter covers. There was however high variability within these sites with the soils being moderately hard and crusted with cryptogam cover in some patches while in other parts within the site there were deeper litter layers with little to no surface crusting.

Sites BM1 and BM7 were slightly less functional than the other ecological communities. Site BM7 the *Melaleuca decora* woodland has deteriorated over the past year with total LFA scores declining from a total of 190.7 – 158.7. While the site maintained a well developed canopy cover and litter layer, macropod activity has resulted in lower functional patch area, causing the mobilisation of the litter cover and increased surface crusting. BM1 was a Warkworth Sands Community with a mature shrub population of *Acacia filicifolia, Leptospermum polygalifolium* and *Banksia integrifolia*, with occurrences of young *E. tereticornis* and *E. crebra*. The Coral lichens and sandy soils were also a unique and characteristic feature. This year there was a marginal improvement in total LFA scores which have increased from 157.2 – 158.7, largely due to an increase in perennial plant covers, but there has been an increase in erosion and deposition.

The eroding creek bank site BM15 continued to have the lowest ecological function and has shown a marginal reduction in total LFA scores from 99.6 – 97.4 this year and due to the highly unstable soils there continued to be severe terracette, rilling and pedalstalling erosion on the creek banks. The site also continues to have extensive undercutting, tunnelling and slumping within the incised creek channel.

Examples of the substrates and vegetation covers in the woodland monitoring sites have been illustrated in Table 9-1.

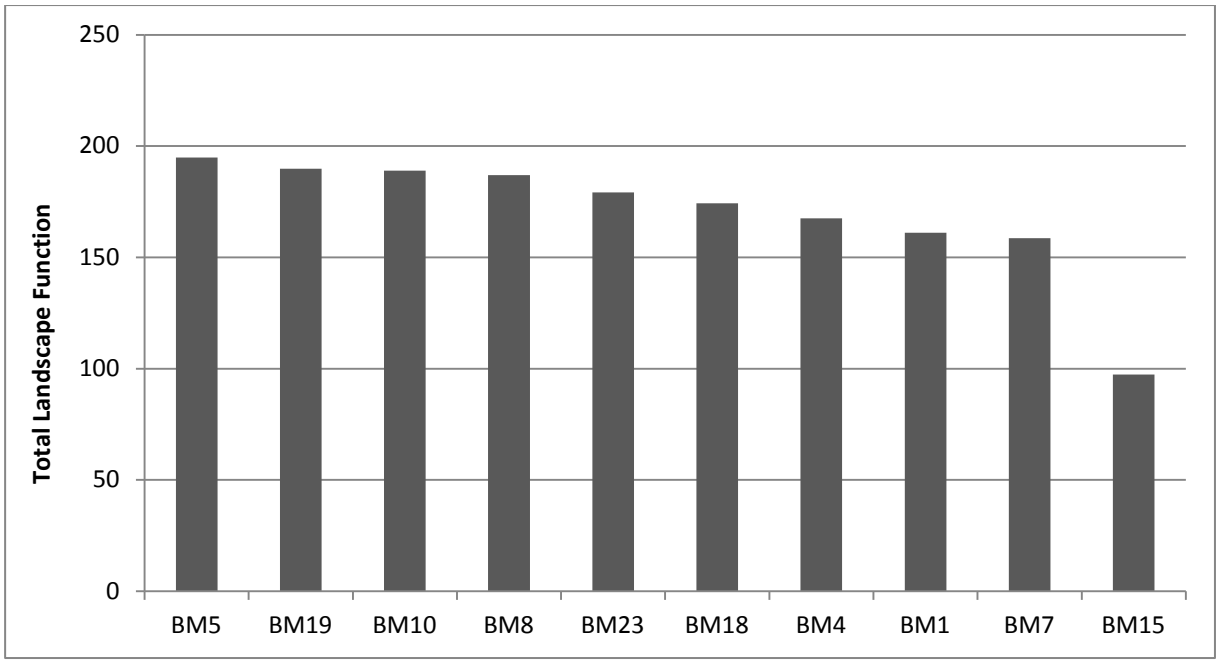


Figure 9-5. Sum of the LFA stability, infiltration and nutrient recycling components indicating the most functional to least functional monitoring site recorded in 2015.

Table 9-1. The various ground covers driving the ecological function within the ecological monitoring sites in 2015.

BM1: Warkworth Sands Woodland with shallow litter layer and sparse ground cover plants	**BM4:** Scattered perennial ground covers and good litter layer in the *E. crebra* - *E. moluccana* woodland
	
BM5: Deep litter layer with sparse plant cover in the *Corymbia maculata* woodland	**BM7**: *Melaleuca decora* woodland with dense litter cover and scattered perennial forbs.
	
BM8: Warkworth Sands Woodland with low shrubby understorey and extensive cryptogams (lichens) and animal tracks.	**BM10**: Combination of leaf litter and perennial plants in the grassy *E. moluccana* woodland.
	

BM15: Perched grass tussocks and eroding creek banks in this *E. crebra - E. tereticornis - Allocasuarina luehmannii* riparian woodland	**BM18:** Good cover of litter and perennial grasses and forbs in *Allocasuarina luehmannii - E. crebra* woodland
	
BM19: Dense litter cover of perennial grasses and forbs in *E. crebra - Allocasuarina luehmannii* woodland	**BM23**: Dense perennial plant and litter cover in regrowth *Casuarina glauca* woodland
	

9.2 Tree and mature shrub populations

9.2.1 Population density

The density of mature shrubs and trees (>5cm diameter at breast height (dbh)) recorded in the 20x20m monitoring quadrats were highly variable across the range of ecological sites. In most sites the density of trees have remained relatively constant and some sites including BM5, BM7, BM15 and BM19 have had a marginal increase in density as existing shrubs and juvenile trees continue to grow (Figure 9-6). There appears to be a declining trend occurring in BM1 with another three individuals having died within the monitoring site over the past year. There were also large patches of dead acacias and banksias observed across the larger area of the woodland, which may be related to the prolonged dry conditions but some were also affected by storm damage in 2013. There was also one less individual recorded in BM15 which had also died. In BM18 there was an additional individual.

The lowest density of trees continued to be recorded in sites BM8 (regenerating WSW) which had six individuals (150 stems/ha). The highest stem density was recorded in BM23, a dense regrowth *Casuarina glauca* forest with 122 individuals (3050 stems/ha) followed by BM19 a regenerating *E. creber* woodland which had 57 individuals (1425 stems/ha).

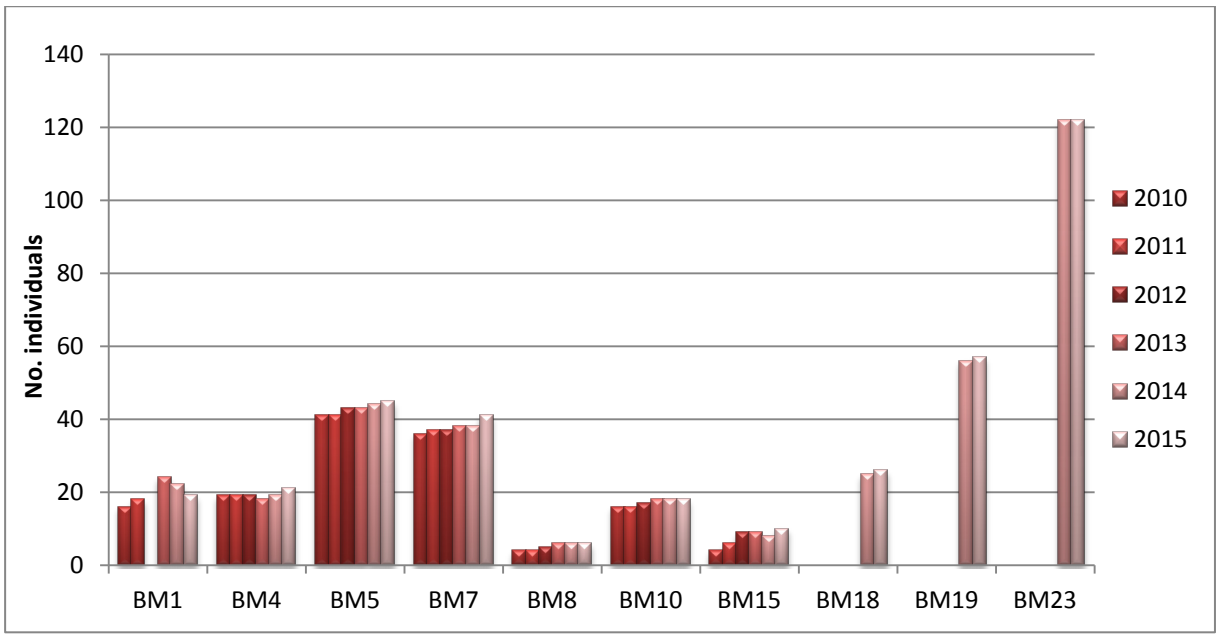


Figure 9-6. Live tree densities (>5cm dbh) in the ecological monitoring sites.

9.2.2 Diameter at breast height

The average dbh recorded in the ecological sites ranged from 10 – 25cm with the minimum being 5cm and the largest being 54cm, a large *Corymbia maculata* in BM5 followed by a 50cm *E. moluccana* in BM10. The relatively low average dbh reflects the relatively young age of the regrowth woodlands.

9.2.3 Condition

While the majority of the trees were live individuals, dead trees (stags) were present in low numbers across numerous of the ecological sites. In BM1 34% of the population were dead stags, while there were 18% stags recorded in BM10. There were also low numbers recorded in BM4, BM7 and BM15 (Table 9-2). Of the live tree densities, most individuals in most sites were in moderate health.

Many of the trees may have died as a result of increased competition levels particularly through the prolonged hot dry conditions in preceding years. In BM1 however storm damage was evident in 2013 with several more Acacias and Banksias individuals having died since then. In sites BM4 and BM10 there were some large cracks evident in the soil profile (pers. obs.) which may be implicated with mine subsidence, but their effect on the health of the tree populations remains unknown.

In most of the ecological sites there were a low number of individuals bearing reproductive structures such as buds, flowers or fruits, except in BM8 and BM19. Mistletoe, an important habitat feature, was recorded in BM4 and BM, while tree hollows were recorded in BM1 and BM10.

9.2.4 Species composition

The ecological moniotring program aimed to assess the health an condition of a range of different vegetation communities occurring across the BCC. Subsequently each site was comprised of a different complement and density of species. There were however a low diversity of tree and/or mature shrub species in BM8, BM10 and BM18 which each had only one species. There was a high diversity of trees and mature shrubs in BM1 which had of five different species. A comprehensive list of species recorded in the individual monitoring sites is provided in Appendix 1.

Table 9-2 Trunk diameters and condition of the trees and mature shrubs in the ecological monitoring sites in 2015.

Site Name	No species	Average dbh (Cm)	Max dbh (cm)	Min dbh (cm)	Total trees	No. with multiple limbs	% Live trees	% Healthy	% Medium Health	% Advanced Dieback	% Dead	% Mistletoe	% Flowers / fruit	%. Trees with hollows
BM1	5	10	23	5	29	4	66	14	45	7	34	0	21	7
BM4	4	14	29	5	21	4	95	29	62	5	5	10	5	0
BM5	3	14	54	5	45	5	100	36	62	2	0	0	9	0
BM7	4	15	43	6	41	9	93	27	59	7	7	2	12	0
BM8	1	15	22	6	6	1	100	17	83	0	0	0	0	0
BM10	1	25	50	9	22	1	82	18	41	23	18	0	5	14
BM15	3	12	38	5	11	0	91	55	36	0	9	0	27	0
BM18	1	12	31	5	26	7	100	35	54	12	0	0	8	0
BM19	2	11	18	5	57	2	100	30	60	11	0	0	0	0
BM23	3	10	27	5	122	24	100	0	84	16	0	0	2	0

9.3 Shrubs and juvenile trees

9.3.1 Population density

There also continued to be high variability in the densities of shrubs and juvenile trees (<5cm dbh) between sites and this year these ranged from 35 (BM10) to 1221 (BM8) indicating there is a large variation in the structure and composition between sites (Figure 9-7). For example BM10, was an open grassy *E. moluccana* woodland with a sparse scattering of shrubs such as *Acacia amblygona* (Fan Wattle), *Lissanthe strigosa* (Peach Heath) and *Daviesia genistifolia* (Broom Bitter Pea). Conversely, BM8 was an open area of Warkworth Sands regrowth woodland with some scattered mature *Allocasuarina luehmannii* but contained a very dense low shrub understorey dominated by *Brachyloma daphnoides* (Daphne Heath) with pockets of *Grevillea Montana* (A Grevillea).

In 2014 the numbers of shrubs and juvenile trees declined in numerous ecological sites including BM1, BM5, BM7, BM8 and BM15 and were likely to be attributed the prolonged hot and dry conditions combined with increased predation of the more palatable species. This year all sites except BM15 had an increase in the number of shrubs as the seasonal conditions have become more favourable.

9.3.2 Height class

All sites had a shrub and/or juvenile tree population with individuals in all height categories but the vast majority of individuals were less than 0.5m in height (Figure 9-8) and are likely to be have been initiated by periods of higher rainfall activity received periodically during 2011 – 2013.

Sites with a relatively high density of seedlings included BM1 (*A. filicifolia* (Fern-leaved Wattle)), BM4 (*Lissanthe strigosa* (*Bursaria spinosa* (Native Blackthorn), *Acacia amblygona* and *Dodonaea viscosa* subsp. *cuneata* (Wedge-leaf Hopbush)), BM5 (*Breynia oblongifolia* (Coffee Bush), *Dodonaea viscosa* subsp. *cuneata*), while BM8 was dominated by the low shrub species *Brachyloma daphnoides*. Sites that were dominated by shrubs and juvenile trees >2.0m in height included BM7, BM15, BM18 and BM23. Most species were prickly or contain unpalatable substances and tend to be avoided by browsers.

9.3.3 Species diversity

The diversity of shrubs and juvenile trees recorded across the range of sites ranged from a low of three in BM18 to a high of 16 in BM5. The most abundant species in any one community tended to be *Acacia amblygona, Acacia filicifolia, Acacia parvipinnula* (Silver-stemmed Wattle), *Allocasuarina luehmannii, Brachyloma daphnoides, Bursaria spinosa, Casuarina glauca, Dodonaea viscosa* subsp. *cuneata, Lissanthe strigosa, Breynia oblongifolia* and *Grevillea montana*.

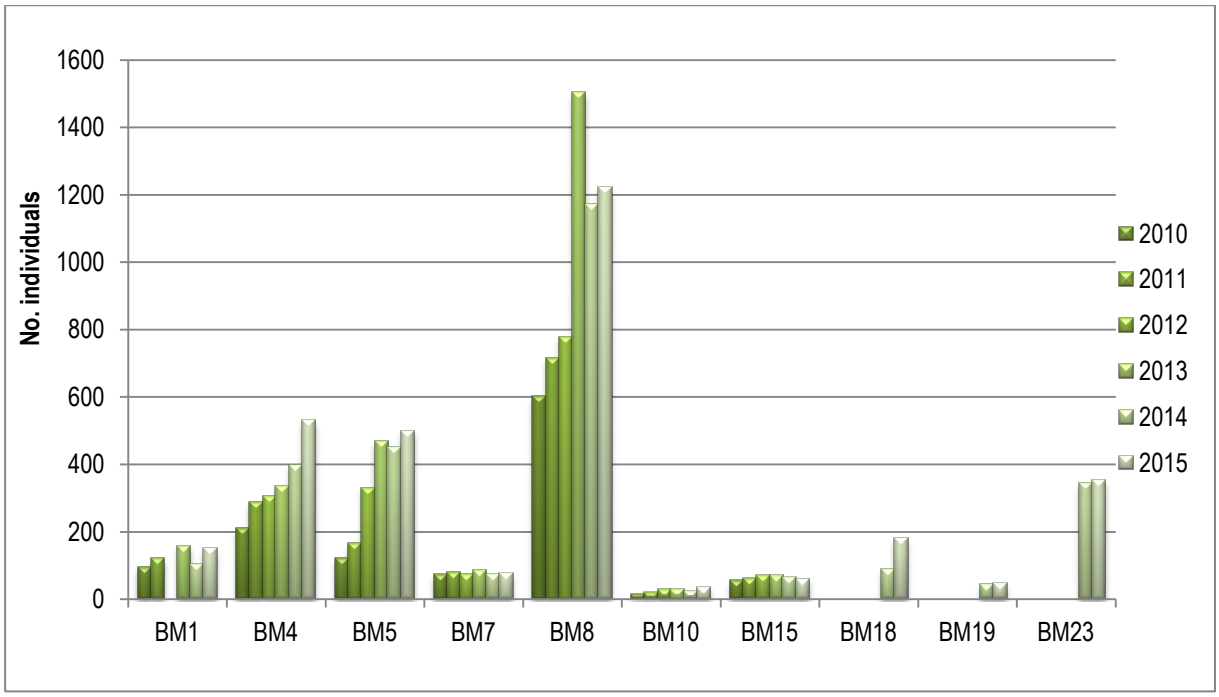


Figure 9-7. Total shrubs recorded in the ecological monitoring sites.

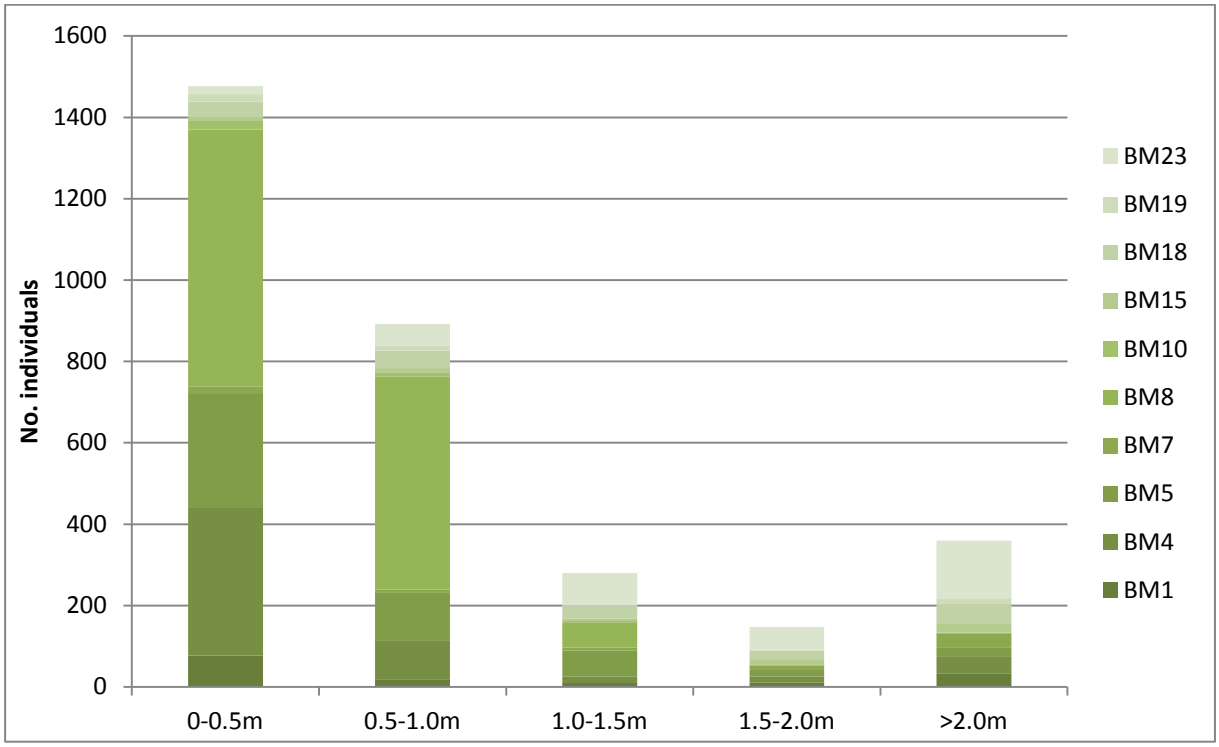


Figure 9-8. Number of individuals represented in each height class across the range of monitoring sites in 2015.

9.3.4 Endemic species

Most shrubs were native species, except for *Lantana camara* (BM5, BM15, BM19 and BM23), *Withania somnifera* (BM5) and *Lycium ferocissimum* (BM19) which were recorded in small occurrences (<11 individuals).

9.4 Total ground cover

The ground cover within the ecological sites is comprised of various combinations of dead leaf litter, perennial vegetation (<0.5m), annual plants, cryptogams and logs. Since monitoring began total ground cover has remained relatively high and all but BM1 and BM15 had total ground cover which exceeded 93%, despite some marginal changes over the past year (Figure 9-9).

Total ground cover in BM1 was comparatively lower and the site continues to be subjected to disturbance from a range of animals including macropods and rabbits (and foxes) and this year there was 86% total ground cover on average. In site BM15 total ground cover was much lower and this has declined from 38.5 - 24% over the past year, largely due to active erosion.

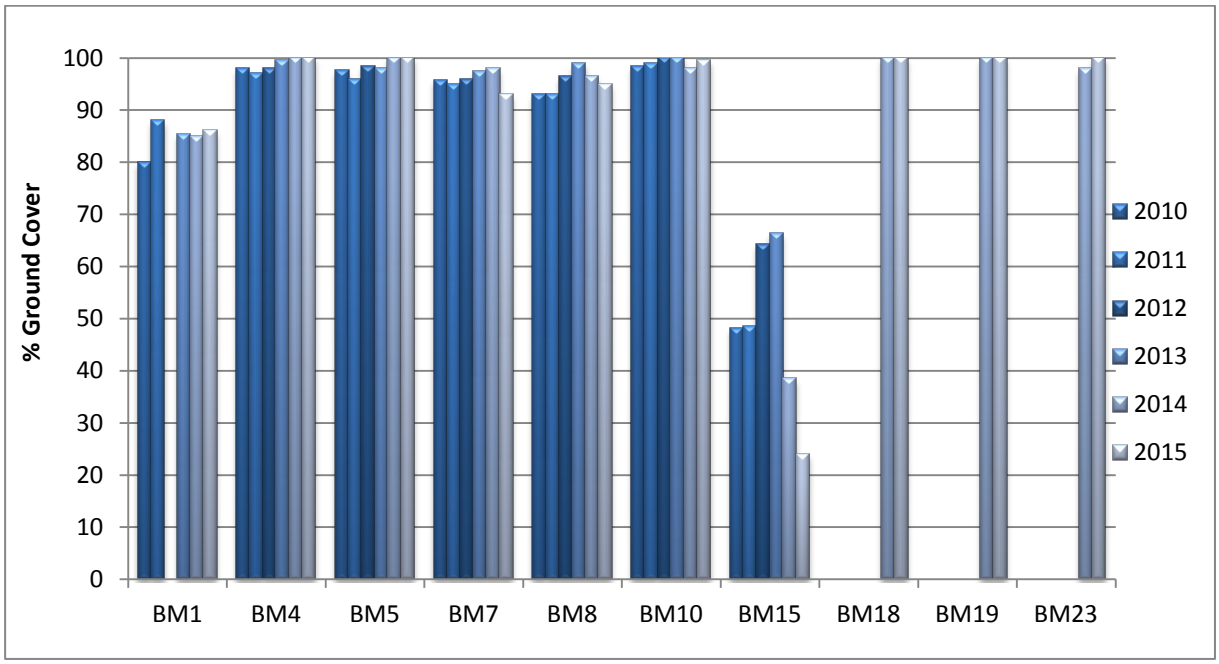


Figure 9-9. Average total ground cover recorded in the ecological monitoring sites.

9.5 Structural composition and habitat complexity

The composition of the ground cover and structural diversity of the ecological sites has been represented by Figure 9-10. Leaf litter continued to be the dominant form of ground cover in most monitoring sites and provided 37.5 – 89.5% of the total ground cover. Exceptions include BM8, the WSW shrub community, where there was a high proportion of low and dense shrub cover and BM15 where overall ground cover was limited. The cover provided by perennial plants (<0.5m) was highly variable across the range of sites with high proportions recorded in BM8 with 41% and in the grassy woodlands BM10 (30.5%), BM18 (42%) and BM19 (44%). There was also 40% perennial plant cover recorded in BM23 the Swamp Oak riparian forest.

With the exception of the *Corymbia maculata* woodland BM5 which had a very deep litter layer, cryptogams were recorded in all sites. In BM8 (and BM1) the Coral Lichen were particularly important

and provided 18.5% while in BM18 a variety of cryptogams had colonised the otherwise crusted soils and provided 16.5% of the total cover. While the Coral Lichen were also present in high abundance within BM1, these were not actually located along the vegetation transect.

Annual plants and rocks were typically absent and were not an important ground cover component, at least under the study conditions but logs and small branches may have been common in some sites and provided additional site stability as well as increased habitat resources.

Most sites had scattered shrubs and low hanging tree canopies which provided at least some foliage cover in the major vertical height increments, but in BM8 vertical foliage cover >2.0m was particularly low (Figure 9-11). All sites except BM8 and BM15 had a well developed mature canopy cover (>6.0m) which provided 16 (BM18) – 64% (BM5) projected foliage cover on average across the sites. The structural compositions of the ecological monitoring sites are illustrated in Table 9-3.

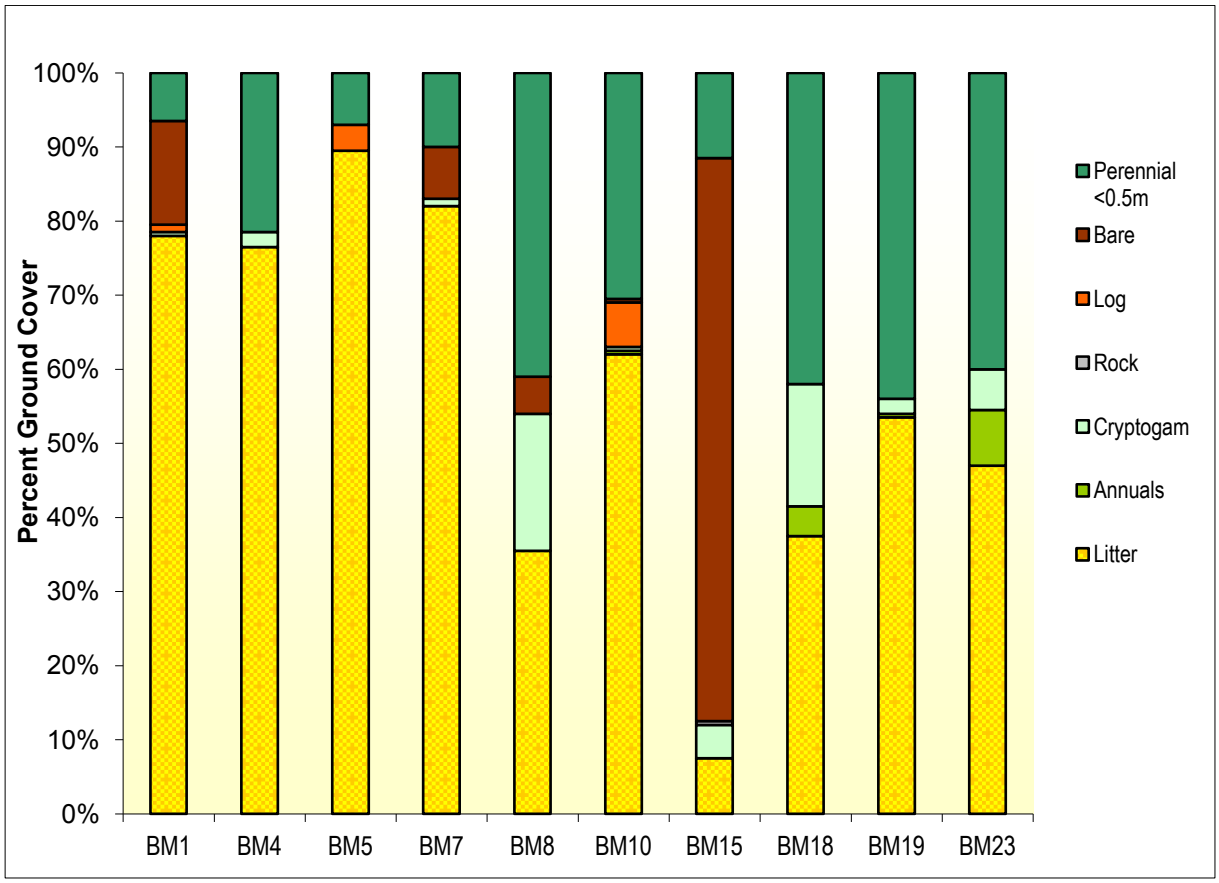


Figure 9-10. Average percent ground cover recorded along the vegetation transect in 2015.

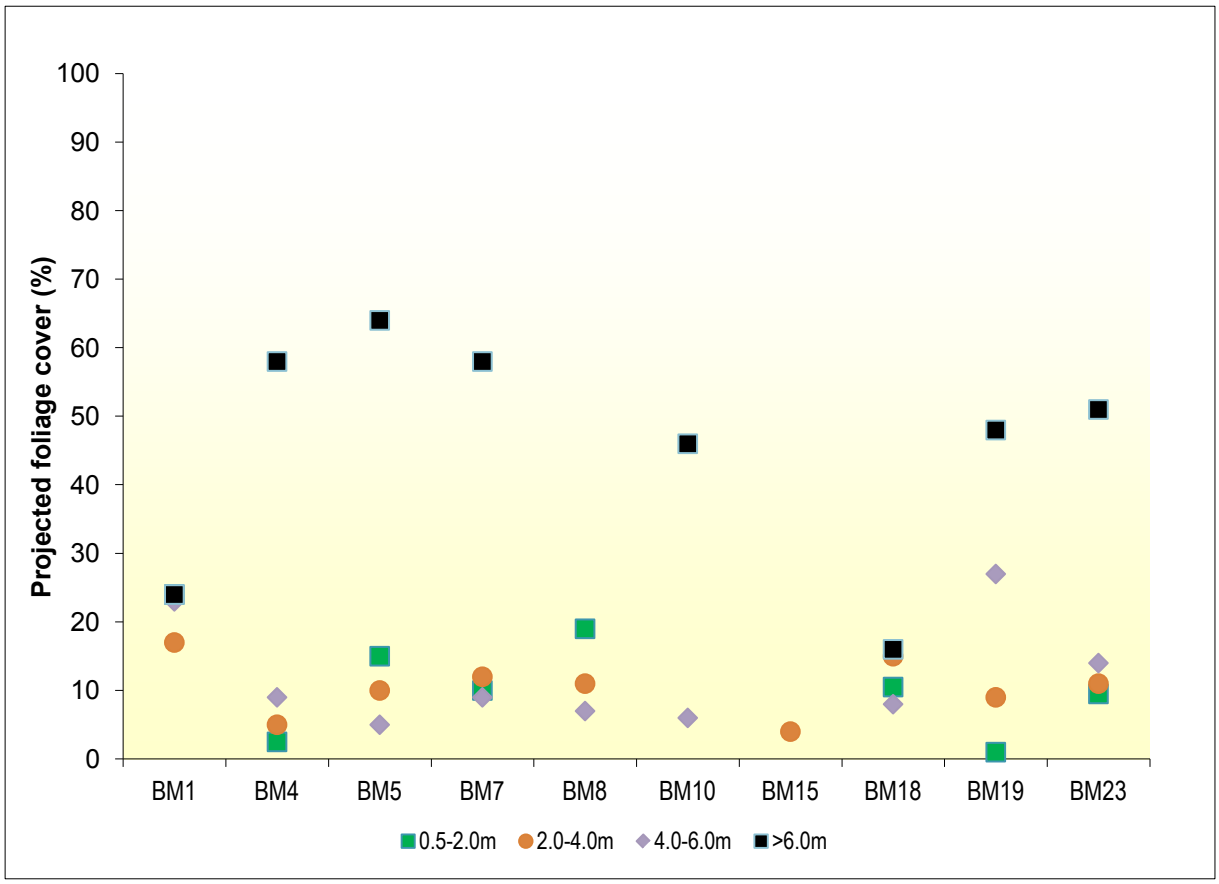
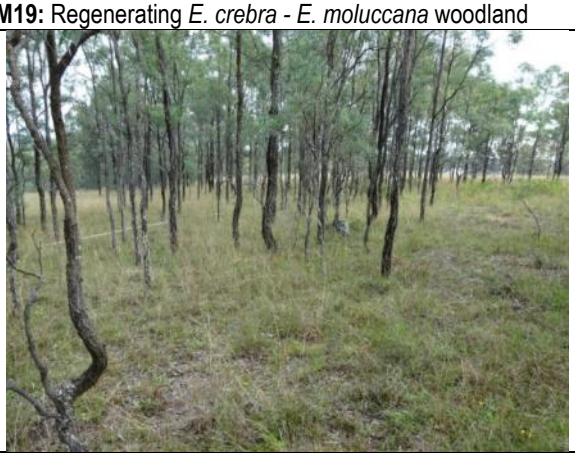


Figure 9-11. Average percent projected foliage cover recorded along the vegetation transect in 2015.

Table 9-3. The structural compositions of the ecological monitoring sites in 2015.

BM1: Warkworth Sands Woodland with scattered shrubs in the foreground having died off over the past few years	**BM4:** regrowth *E. crebra - E. moluccana* woodland with a scattered assortment of shrubs
	
BM5: Spotted Gum woodland with a scattered shrub understorey	**BM7**: *Melaleuca decora* woodland with dense litter covers and sparsely scattered shrubs.
	

BM8: Warkworth Sands Woodland with low shrubby understorey and scattered *A. leuhmannii* regrowth trees.	**BM10**: Grassy *E. moluccana* woodland with sparse scattering of shrubs.
	
BM15:Regrowth *E. crebra - E. tereticornis - Allocasuarina luehmannii* riparian woodland on the upper creek banks	**BM18:** Regenerating *Allocasuarina luehmannii* (*E. crebra - E. tereticornis*) woodland
	
BM19: Regenerating *E. crebra - E. moluccana* woodland	**BM23**: Regenerating *Casuarina glauca* riparian forest
	

9.6 Species Diversity

9.6.1 Total species diversity

There have been no consistent trends in the changes in total species diversity across the range of monitoring sites however in 2014 there was a reduction on the size of the monitoring quadrats which resulted in less species being recorded in most sites. From 2010 – 2013 there was commonly an increasing diversity of species being recorded across all sites except in BM1 and is probably related to the improved seasonal conditions.

Over the past year there was no consistent change in species diversity across the range of sites but decreased diversity was recorded in the WSW communities BM1 and BM8 perhaps due to high

disturbance from macropods. In BM19 and BM23 there was also a reduction in species diversity as there was an increase in perennial grass cover, which may have increased competition and reduced germination niches.

The highest floristic diversity was recorded in BM5, in BM10 a grassy *E. moluccana* woodland which contained a diversity of 63 species within the 20x20m plot (Figure 9-12). Species diversity was also relatively high in BM4, BM5, BM15, BM18, BM19 and BM23 which each had 50 - 58 species. Sites BM1 and BM8, within the WSW communities continued to have the lowest floristic diversity with 31 species.

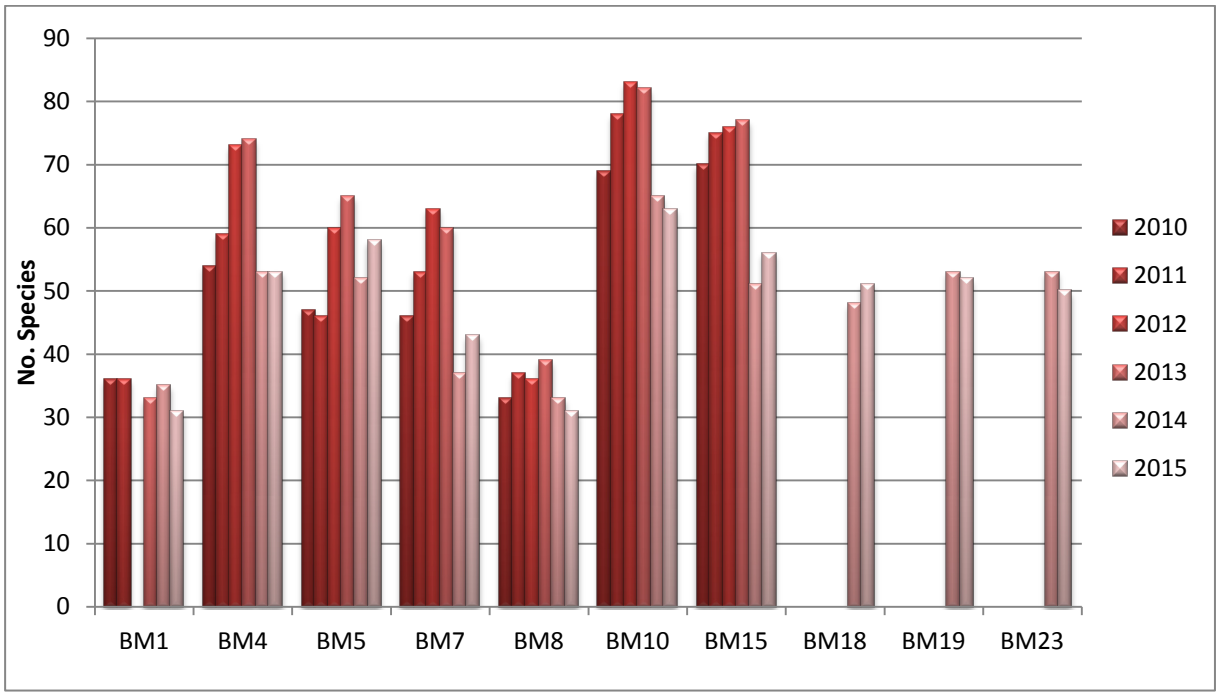


Figure 9-12. Total species diversity recorded in the ecological monitoring sites. *NB: There was a reduction on the size of the monitoring quadrats in 2014.*

9.6.2 Native species diversity

Native species continued to be far more abundant than exotic species and while there have been no consistent changes across the range of sites most sites there tended to be an increase in native species richness between 2010 - 2013. In 2014 all sites except BM1 had a significant reduction in native species diversity due to the reduction in monitoring area (Figure 9-13). This year declining native diversity was recorded in BM1, BM4, BM8, BM10, BM19 and BM23 and is likely to be implicated with animal disturbance and/or increasing competition.

The highest number of native species was recorded in BM10 with 54 native species, followed by BM4 which had 48 native species. The lowest number of native species was recorded in BM1 and BM8 with 23 and 24 native species respectively.

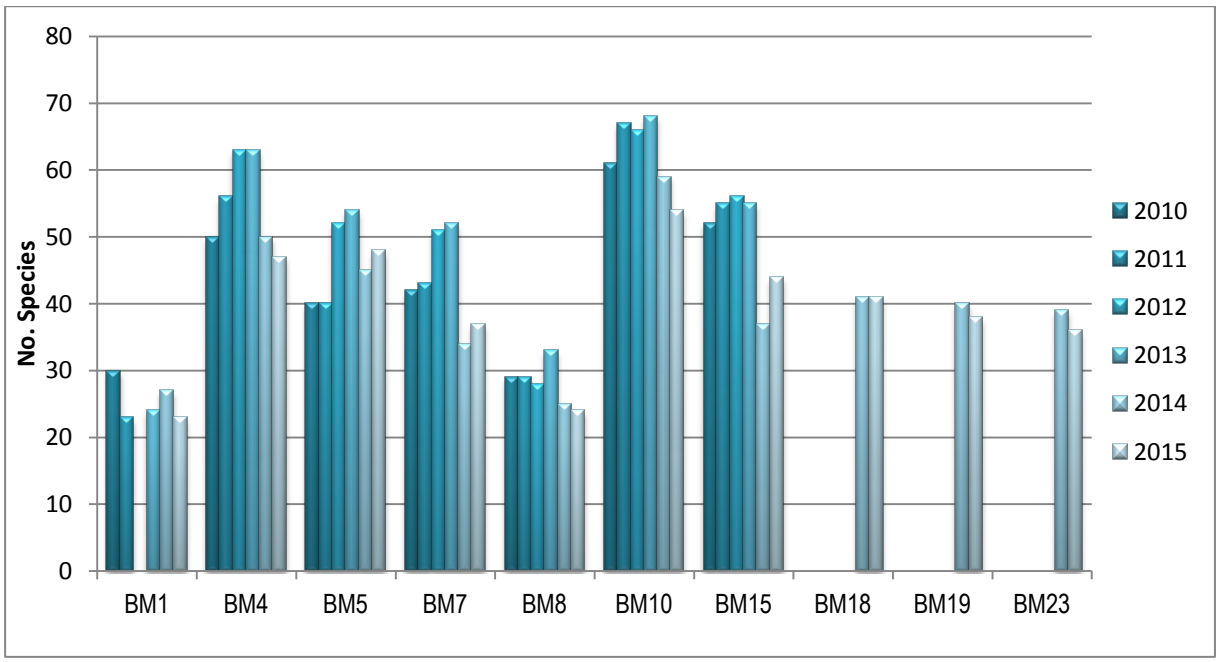


Figure 9-13. Total native species diversity recorded in the ecological monitoring sites. *NB: There was a reduction on the size of the monitoring quadrats in 2014.*

9.6.3 Exotic species diversity

There were no consistent trends in the exotic species diversity across the monitoring sites but most sites had increasing numbers of exotic species between 2010 – 2013 due to improved seasonal conditions (Figure 9-14). In 2014 all sites except BM8 had a reduction in exotic species diversity due to the reduction in monitoring area.

The highest diversity of exotic species this year was recorded in the grassy woodland BM19 and the Swamp Oak forest BM23 which each had 14 exotic species, followed by the degraded creek BM15 which had 10 species. These sites are likely to have been subjected to a long history of livestock grazing, and in BM23 and BM15 the sites are subjected to periodic flooding and are more vulnerable to weed invasion. In BM15, the creek channel and banks also provide additional habitat areas.

The lowest number of exotic species was recorded in BM4 and BM7 where there were six exotic species recorded this year.

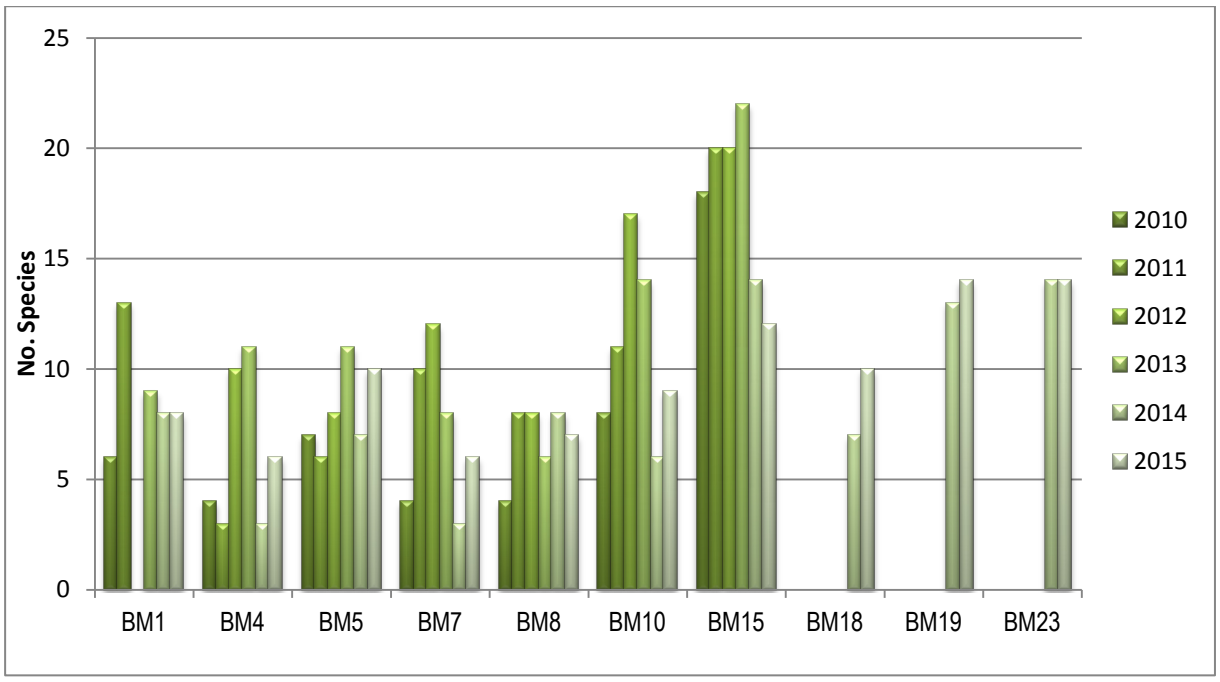


Figure 9-14. Total exotic species diversity recorded in the ecological monitoring sites. *NB: There was a reduction on the size of the monitoring quadrats in 2014.*

9.7 Percent endemic ground cover

The percent endemic ground cover is an ecological indicator used to provide some measure of the cover abundance of the live native vegetation along the vegetation transect and therefore indicates the level of weediness at the monitoring sites. While it is only estimation the percent cover of endemic ground cover species has been derived by the following equation.

Percent cover endemic species = sum of the five Braun- blanquet scores for native species / (sum of the five Braun-blanquet scores of exotic species + native species) x 100

Native plants continue to be dominant in all sites but decreased native plant cover was recorded in numerous sites this year as exotic weeds were recorded in higher abundance (Figure 9-15). Site BM4 maintained 100% native plant cover, while in BM10, BM15, BM18 and BM19 there was 89 - 96% endemic plant cover. The lowest endemic plant cover was recorded in BM1 with 78%, while there were 84.5%, 86% and 87% recorded in sites BM23, BM8 and BM5 respectively.

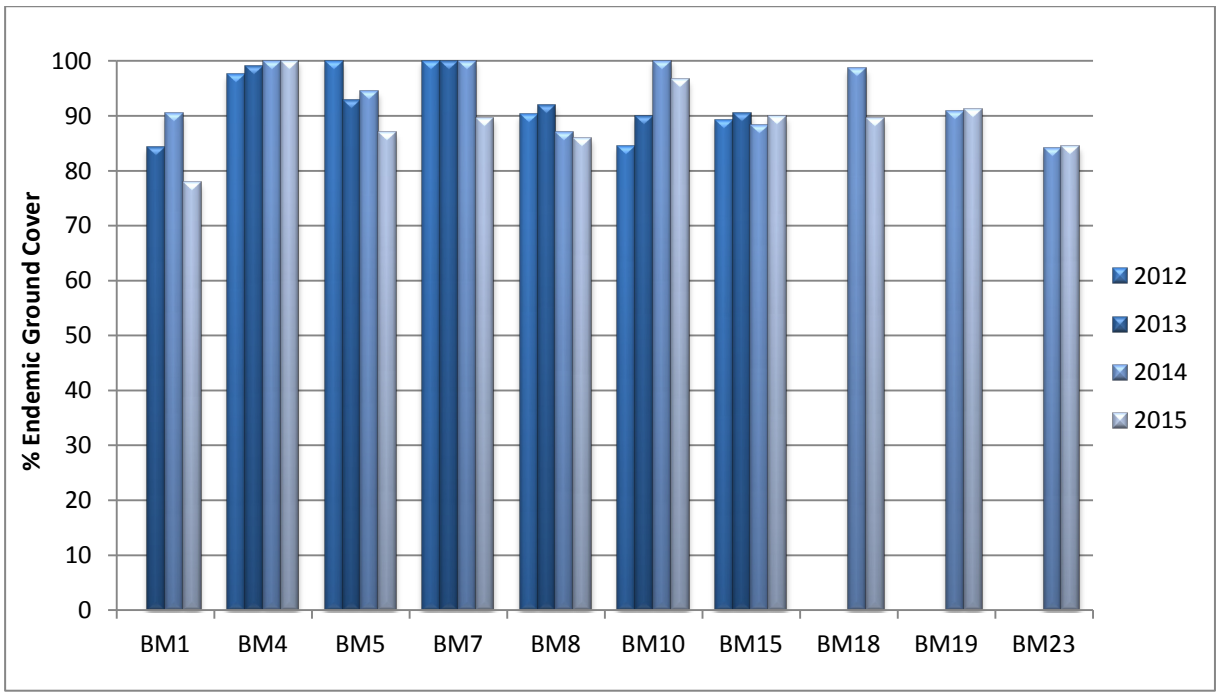


Figure 9-15. Percent endemic ground cover recorded in the ecological monitoring sites.

9.8 Vegetation composition

The composition of the vegetation as categorised by nine different growth forms recorded in 2015 is given in Figure 9-16.

The sites were predominantly comprised of herbs (9 – 32) and grasses (6 - 13) with 2 - 4 tree species, 2 – 13 shrubs and 1 - 6 species of sub-shrub. Sites BM10, BM18 and BM19 contained a particularly high diversity of herbs and grasses. Sites BM5 contained a particularly high diversity of shrubs with 14 different species being recorded. Other growth forms such as reeds, vines, ferns and cactus were also present in low numbers (1 – 3 species) within some sites. Sites BM1 and BM8 were the least diverse of the ecological monitoring sites.

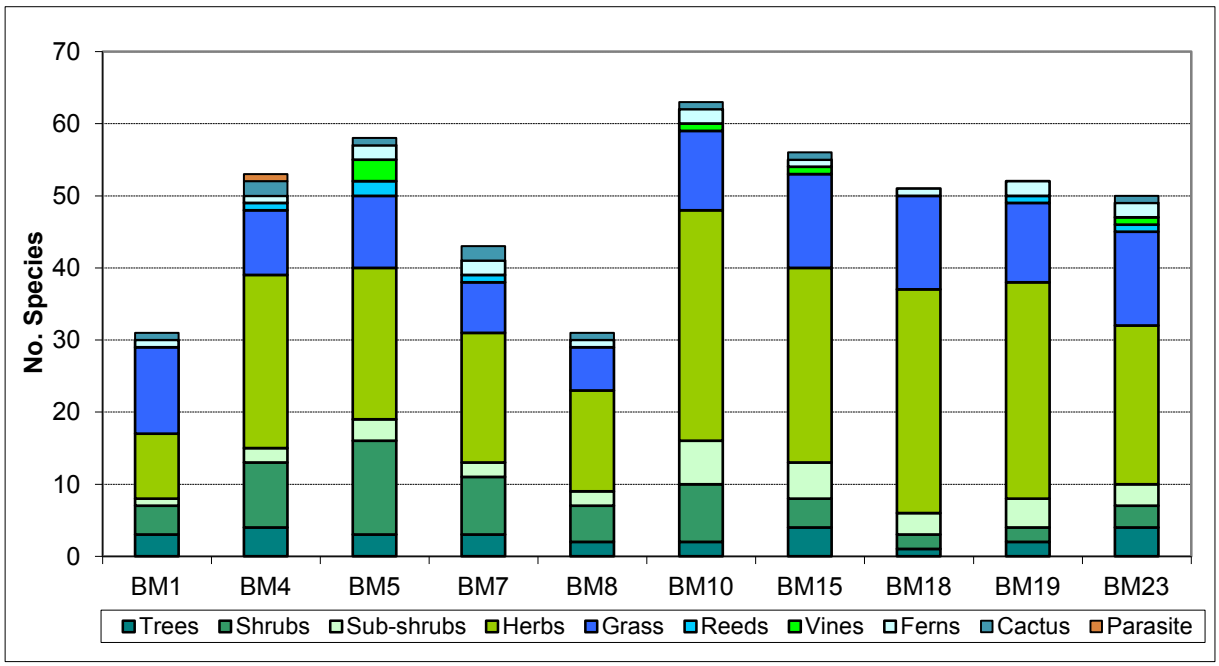


Figure 9-16. The composition of the ecological monitoring sites in 2015.

9.9 Most common species

The lowest diversity of vascular plants recorded across the range of ecological sites was recorded in 2014 however this was due to the reduction in the size of the monitoring quadrats. Since monitoring began in 2010, the number of species has ranged from 191 – 225 species with 17.8 – 20.6% of these being exotic species (Table 9-4).

The most common species (those that were recorded in at least six of the ten monitoring plots) in 2015 is given in Table 9-5 and there were 19 of these. *Cheilanthes sieberi* subsp. *sieberi* (Rock Fern), a native rock fern, continued to be recorded in all ten sites. The native grasses *Cymbopogon refractus (*Barbed-wire Grass) and *Microlaena stipoides* (Weeping Rice-grass) and the exotic weed *Senecio madagascariensis* (Fireweed) were common to nine of the monitoring sites. Most other common species tended to be native species but *Bidens pilosa* (Cobbler's Peg*)* an exotic annual and *Opuntia stricta* (Common Prickly Pear) a noxious cactus was also very common and recorded in eight sites.

A comprehensive list of species recorded in all ecological monitoring sites in 2015 has been included in Appendix 1.

Table 9-4. Summary of the number of species recorded in the rehabilitation monitoring sites since 2010.

Year	No. sites	Total species	No. Exotic species	% Exotic species
2010	11	214	44	20.5
2011	11	219	42	19.2
2012	10	223	46	20.6
2013	11	225	46	20.4
2014*	11 (3 new)	191	34	17.8
2015	10 (ex BM6)	193	35	18.1

***** *NB: There was a reduction on the size of the monitoring quadrats in 2014.*

Table 9-5. Species that were recorded in at least six of the ten ecological monitoring sites in 2015.

Family	exotic	Scientific Name	Common Name	Habit	BM1	BM4	BM5	BM7	BM8	BM10	BM15	BM18	BM19	BM23	Total
Adiantaceae		*Cheilanthes sieberi subsp. sieberi*	Rock Fern	f	1	1	1	1	1	1	1	1	1	1	10
Poaceae		*Cymbopogon refractus*	Barbed-wire Grass	g	1	1	1	1		1	1	1	1	1	9
Poaceae		*Microlaena stipoides*	Weeping Rice-grass	g	1	1	1	1		1	1	1	1	1	9
Asteraceae	*	*Senecio madagascariensis*	Fireweed	h	1	1	1		1	1	1	1	1	1	9
Casuarinaceae		*Allocasuarina luehmannii*	Bulloak	t	1	1		1	1		1	1	1	1	8
Asteraceae	*	*Bidens pilosa*	Cobbler's Peg	h		1	1	1	1	1		1	1	1	8
Convolvulaceae		*Dichondra repens*	Kidney Weed	h		1	1	1		1	1	1	1	1	8
Cactaceae	*	*Opuntia stricta*	Common Prickly Pear	c	1	1	1	1	1	1	1			1	8
Poaceae		*Aristida ramosa*	Threeawn Grass	g	1	1	1			1		1	1	1	7
Poaceae		*Bothriochloa decipiens*	Redgrass	g		1		1		1	1	1	1	1	7
Schrophulariaceae		*Brunoniella australis*	Blue Trumpet	h		1	1	1		1	1	1	1		7
Asteraceae		*Chrysocephalum apiculatum*	Common Everlasting	h		1			1	1	1	1	1	1	7
Myoporaceae		*Eremophila debilis*	Amulla	ss		1		1		1	1	1	1	1	7
Myrtaceae		*Eucalyptus crebra*	Narrow-leaf Ironbark	t	1	1	1	1			1		1	1	7
Fabaceae (Faboideae)		*Glycine clandestina*	Climbing Glycine	h	1	1	1	1		1			1	1	7
Lomandraceae		*Lomandra filiformis*	Wattle Mat-rush	h		1	1	1	1	1	1	1			7
Poaceae		*Aristida vagans*	Wire Grass	g		1	1	1		1	1	1			6
Phormiaceae		*Dianella revoluta*	Native Flax Lily	h		1	1			1	1	1	1		6
Lomandraceae		*Lomandra multiflora*	Many-flowered Mat-rush	h		1	1			1		1	1	1	6

Note: Number "1" denotes the presence of a species within the monitoring quadrat and is not a measure of cover abundance.

9.10 Most abundant species

The most abundant species recorded in each of the woodland monitoring sites this year are provided in Table 9-6. The most abundant species were those that collectively summed to a Braun-blanquet total of 7 or more from the five replicated sub-plots along the vegetation transect. The maximum score that can be obtained by an individual species is 30.

The ecological sites were dominated by a variety of different species with *Brachyloma daphnoides* being particularly dominant at BM8, in the WSW community. In the other sites other dominant species may have been one or various combinations of the native grasses *Aristida ramosa* (Threeawn Grass), *Bothriochloa decipiens* (Redgrass), *Entolasia marginata* (Bordered Panic), *Cymbopogon refractus* (Barbed-wire Grass) and *Microlaena stipoides* (Weeping Rice-grass) as well as native herbs including *Calotis cuneifolia* (Purple Burr Daisy), *Glycine tabacina* (Variable Glycine), *Brunoniella australis* (Blue Trumpet), *Vernonia cinerea var. cinerea* and *Oxalis exilis*. In site BM18, *Allocasuarina luehmannii* (Bulloak) was relatively abundant while *Acacia amblygona* (Fan Wattle) was the most dominant ground cover in BM4. *Cheilanthes sieberi subsp. sieberi* provided the most ground cover in BM1. Site BM5 had a sparse cover of ground cover plants and did not contain any species which were particularly dominant.

Table 9-6. The most abundant species recorded in the ecological monitoring sites in 2015.

Scientific Name	Common Name	BM1	BM4	BM5	BM7	BM8	BM10	BM15	BM18	BM19	BM23
Cheilanthes sieberi subsp. sieberi	Rock Fern	7									
Acacia amblygona	Fan Wattle		9								
Entolasia marginata	Bordered Panic		8		8					11	
Lissanthe strigosa	Peach Heath		7								
**Melinis repens*	Red Natal Grass					7					
Brachyloma daphnoides	Daphne Heath					22					
Grevillea montana						11					
Cymbopogon refractus	Barbed-wire Grass						17		14	9	
Oxalis exilis							8				
Themeda australis	Kangaroo Grass							10			
Allocasuarina luehmannii	Bulloak								11		
Bothriochloa decipiens	Redgrass								17	15	
Glycine tabacina	Variable Glycine								9		
Vernonia cinerea var. cinerea									8		
Aristida ramosa	Threeawn Grass									9	
Brunoniella australis	Blue Trumpet									8	
Microlaena stipoides	Weeping Rice-grass									12	13
Calotis cuneifolia	Purple Burr Daisy										12

9.11 Threatened flora

No threatened species were recorded but *Grevillea montana,* a 2VC ROTAP (PlantNet 2010) continued to be recorded in the Warkworth Sands communities (site BM8). The ROTAP coding system devised by Leigh, Briggs and Hartley is still commonly seen in numerous scientific and general publications.

Although having no legal standing, the system provides a relatively simple means of categorising the 'at risk' status of Australian plants, including many that are not currently listed in the EPBC schedule. For this reason, an understanding of the ROTAP coding system is worthwhile. *Grevillea montana* has been recognised as a Rare or Threatened Australian Plants (ROTAP) which has a restricted distribution (2) with a range extending less than 100km, is Vulnerable (V) and is at risk over a longer period (20-50 years) but is known to occur within a proclaimed reserve (C) (http://anpsa.org.au/coding.html).

9.12 Noxious and invasive species

Opuntia stricta continued to be the most abundant noxious species and was recorded in eight monitoring sites (Table 9-7). *Lantana camara* was recorded in five sites while *Opuntia aurantiaca* (Tiger Pear) was recorded three sites and *Lycium ferocissimum* (African Boxthorn) was found in BM19.

Hyparrhenia hirta (Coolatai Grass) is an invasive grass species which can readily displace native plants and can contribute to changed fire regimes that affect native vegetation structure and biodiversity. Other invasive grasses include needle grasses (*Nassella* spp.), feather-grasses (*Pennisetum* spp.), veldt grasses (*Ehrharta* spp.), Buffel grass (*Cenchrus ciliaris*), wheat-grasses (*Thinopyrum* spp.), Rhodes grass (*Chloris gayana*) and African lovegrass (*Eragrostis curvula*). *Melinis repens* also fits within this category and continued to be recorded in both Warkworth Sands communities (BM1, BM8). Invasion of native plant communities by exotic perennial grasses has been listed as a key threatening process under the NSW *Threatened Species Conservation Act 1995*. In some local government areas in NSW, *Hyparrhenia hirta* is declared a Class 3 weed and the plant must be fully and continuously suppressed and destroyed (CRC 2008). *Hyparrhenia hirta* was recorded in BM15, *Ehrharta erecta* (Panic Veldtgrass) was recorded in BM23, while *Chloris gayana* was recorded in BM15 and BM23.

Table 9-7. Noxious and environmental weeds recorded in the ecological monitoring sites in 2015.

exotic	Scientific Name	Common Name	Habit	BM1	BM4	BM5	BM7	BM8	BM10	BM15	BM18	BM19	BM20	BM23	Total
*	*Chloris gayana*	Rhodes Grass	g							1				1	**2**
*	*Ehrharta erecta*	Panic Veldtgrass	g											1	**1**
*	*Hyparrhenia hirta*	Coolatai Grass	g							1					**1**
*	*Lantana camara*	Lantana	s			1				1		1	1	1	**5**
*	*Lycium ferocissimum*	African Boxthorn	s									1			**1**
*	*Melinis repens*	Red Natal Grass	g	1				1							**2**
*	*Opuntia aurantiaca*	Tiger Pear	c		1		1						1		**3**
*	*Opuntia stricta*	Common Prickly Pear	c	1	1	1	1	1	1	1				1	**8**

10 Ecological Performance Indicator table - 2015

Rehabilitation Phase	Aspect or ecosystem component	Ecological Targets	Performance Indicators	Description of performance indicators	Unit of measurement (desirable)	BM1	BM4	BM5	BM7	BM8	BM10	BM15	BM18	BM19	BM23
Landform establishment and stability	Landform slope, gradient	Landform suitable for final landuse and generally compatible with surrounding topography	Slope	Landform is generally compatible within the context of the local topography.	Degrees (<14°)	5	1	5	0	3	5	15	4	9	4
	Landform function	Landform is functional and performing as it was designed to do	LFA Stability	Based on key physical, biological and chemical characteristics the LFA stability index provides an indication of the sites stability	%	60.8	65.6	63.1	60.1	70.3	76.7	54.4	74.5	80.5	76.1
			LFA Infiltration	Based on key physical, biological and chemical characteristics the LFA infiltration index provides an indication of the sites infiltration capacity	%	55.8	46.3	67.7	52.3	63.0	56.6	21.8	49.4	53.9	50.5
			LFA Nutrient recycling	Based on key physical, biological and chemical characteristics the LFA nutrient recycling index provides an indication of the sites ability to recycle nutrient	%	44.5	48.9	64.1	46.3	53.7	55.6	21.2	50.4	55.4	52.6
			LFA Landscape organisation	The Landscape Organisation Index provides a measure of the ability of the site to retain resources	%	93	100	100	94	97	100	9	100	100	100
	Active erosion	Areas of active erosion are limited	No. Rills/Gullies	Provides an assessment of the number of gullies or rills occurring in a 50m transect and that these are limited and stabilising	No.	0	0	0	0	0	0	0	0	0	0
			Cross-sectional area of rills	Provides an assessment of the extent of soil loss due to gully and rill erosion and that it is limited and/or is stabilising	m2	0	0	0	0	0	0	0	0	0	0
Growth medium development	Soil chemical, physical properties and amelioration	Soil properties are suitable for the establishment and maintenance of selected vegetation species	pH	pH is typical of that of the surrounding landscape or falls within desirable ranges provided by the agricultural industry	pH (5.6-7.3)	NA	NA	NA	NA	NA	NA	NA	6.9	5.5	6.4
			EC	Electrical Conductivity is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	< dS/cm (<0.150)	NA	NA	NA	NA	NA	NA	NA	0.050	0.054	0.113
			Organic Matter	Organic Carbon levels are typical of that of the surrounding landscape, increasing or fall within desirable ranges provided by the agricultural industry	% (>4.5)	NA	NA	NA	NA	NA	NA	NA	3.8	2.6	5.6

Rehabilitation Phase	Aspect or ecosystem component	Ecological Targets	Performance Indicators	Description of performance indicators	Unit of measurement (desirable)	BM1	BM4	BM5	BM7	BM8	BM10	BM15	BM18	BM19	BM23
			Phosphorous	Available Phosphorus is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	mg/kg (50)	NA	NA	NA	NA	NA	NA	NA	12.5	10.5	27.6
			Nitrate	Nitrate levels are typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	mg/kg (>12.5)	NA	NA	NA	NA	NA	NA	NA	1.1	0.8	6.8
			CEC	Cation Exchange Capacity is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	Cmol+/kg (>14)	NA	NA	NA	NA	NA	NA	NA	15.0	6.6	13.3
			ESP	Exchangeable Sodium Percentage (a measure of sodicity) is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	% (<5)	NA	NA	NA	NA	NA	NA	NA	4.4	4.9	5.5
Ecosystem & Land use Establishment	Vegetation diversity	Vegetation contains a diversity of species comparable to that of the local remnant vegetation	Diversity of shrubs and juvenile trees	The diversity of shrubs and juvenile trees with a stem diameter < 5cm	species/area	6	12	16	7	7	10	7	3	4	6
				The percentage of shrubs and juvenile trees with a stem diameter <5cm dbh which are local endemic species	% population	100	100	98	100	100	100	97	100	74	98
			Total species richness	The total number of live plant species provides an indication of the floristic diversity of the site	No./area	31	53	58	43	31	63	56	51	52	50
			Native species richness	The total number of live native plant species provides an indication of the native plant diversity of the site	>No./area	23	47	48	37	24	54	44	41	38	36
			Exotic species richness	The total number of live exotic plant species provides an indication of the exotic plant diversity of the site	<No./area	8	6	10	6	7	9	12	10	14	14
	Vegetation density	Vegetation contains a density of species comparable to that of the local remnant vegetation	Density of shrubs and juvenile trees	The density of shrubs or juvenile trees with a stem diameter < 5cm	No./area	151	531	500	77	1221	35	61	181	47	352
	Ecosystem composition	The vegetation is comprised by a range of growth forms comparable to that of the local remnant vegetation	Trees	The number of tree species regardless of age comprising the vegetation community	No./area	3	4	3	3	2	2	4	1	2	4
			Shrubs	The number of shrub species regardless of age comprising the vegetation community	No./area	4	9	13	8	5	8	4	2	2	3
			Sub-shrubs	The number of sub-shrub species comprising the vegetation community	No./area	1	2	3	2	2	6	5	3	4	3

Rehabilitation Phase	Aspect or ecosystem component	Ecological Targets	Performance Indicators	Description of performance indicators	Unit of measurement (desirable)	BM1	BM4	BM5	BM7	BM8	BM10	BM15	BM18	BM19	BM23
			Herbs	The number of herbs or forb species comprising the vegetation community	No./area	9	24	21	18	14	32	27	31	30	22
			Grass	The number of grass species comprising the vegetation community	No./area	12	9	10	7	6	11	13	13	11	13
			Reeds	The number of reed, sedge or rush species comprising the vegetation community	No./area	0	1	2	1	0	0	0	0	1	1
			Vines	The number of vines or climbing species comprising the vegetation community	No./area	0	0	3	0	0	1	1	0	0	1
			Ferns	The number of ferns comprising the vegetation community	No./area	1	1	2	2	1	2	1	1	2	2
			Cactus	The number of cactus comprising the vegetation community	No./area	1	2	1	2	1	1	1	0	0	1
			Parasite	The number of parasitic plants comprising the vegetation community	No./area	0	1	0	0	0	0	0	0	0	0
			Aquatic	The number of aquatic species comprising the vegetation community	No./area	0	0	0	0	0	0	0	0	0	0
Ecosystem & Landuse development	**Protective ground cover**	Ground layer contains protective ground cover and habitat structure comparable with the local remnant vegetation	Litter cover	Percent ground cover provided by dead plant material	%	78	76.5	89.5	82	35.5	62	7.5	37.5	53.5	47
			Annual plants	Percent ground cover provided by live annual plants	<%	0	0	0	0	0	0.5	0	4	0.5	7.5
			Cryptogam cover	Percent ground cover provided by cryptogams (eg mosses, lichens)	%	0.5	2	0	1	18.5	0.5	4.5	16.5	2	5.5
			Rock	Percent ground cover provided by stones or rocks (> 5cm diameter)	%	0	0	0	0	0	0	0.5	0	0	0
			Log	Percent ground cover provided by fallen branches and logs (>5cm)	%	1	0	3.5	0	0	6	0	0	0	0
			Bare ground	Percentage of bare ground	< %	14	0	0	7	5	0.5	76	0	0	0
			Water	Percent ground cover provided by water (eg creek)	%	0	0	0	0	0	0	0	0	0	0
			Perennial plant cover (< 0.5m)	Percent ground cover provided by live perennial vegetation (<0.5m in height)	%	6.5	21.5	7	10	41	30.5	11.5	42	44	40
			Total Ground Cover	Total groundcover is the sum of protective ground cover components (as described above)	%	86	100	100	93	95	99.5	24	100	100	100

Rehabilitation Phase	Aspect or ecosystem component	Ecological Targets	Performance Indicators	Description of performance indicators	Unit of measurement (desirable)	BM1	BM4	BM5	BM7	BM8	BM10	BM15	BM18	BM19	BM23
	Ground cover diversity	Vegetation contains a diversity of species per square meter comparable to that of the local remnant vegetation	Native understorey abundance	The abundance of native species per square metre averaged across the site provides an indication of the heterogeneity of the site	> species/m^2	**3.4**	**9**	**2.8**	**5.8**	**4.4**	**11**	**4**	**12.2**	**11.4**	**6.2**
			Exotic understorey abundance	The abundance of exotic species per square metre averaged across the site provides an indication of the heterogeneity of the site	< species/m^2	**1.2**	**0**	**0.6**	**1**	**1**	**0.6**	**0.6**	**2**	**1.8**	**1.2**
	Native ground cover abundance	Native ground cover abundance is comparable to that of the local remnant vegetation	Percent ground cover provided by native vegetation <0.5m tall	The percent ground cover abundance of native species (<0.5m) compared to exotic species	%	**77.8**	**100.0**	**87.0**	**89.6**	**86.0**	**96.6**	**90.0**	**89.6**	**91.1**	**84.5**
	Ecosystem growth and natural recruitment	The vegetation is maturing and/or natural recruitment is occurring at rates similar to those of the local remnant vegetation	shrubs and juvenile trees 0 - 0.5m in height	The number of shrubs or juvenile trees <0.5m in height provides an indication of establishment success and/or natural ecosystem recruitment	No./area	**77**	**363**	**282**	**17**	**631**	**21**	**10**	**38**	**18**	**20**
			shrubs and juvenile trees 0.5 - 1m in height	The number of shrubs or juvenile trees 0.5-1m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment	No./area	**19**	**96**	**118**	**6**	**524**	**9**	**12**	**43**	**11**	**54**
			shrubs and juvenile trees 1 - 1.5m in height	The number of shrubs or juvenile trees 1-1.5m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment	No./area	**12**	**14**	**63**	**8**	**62**	**3**	**6**	**30**	**2**	**80**
			shrubs and juvenile trees 1.5 - 2m in height	The number of shrubs or juvenile trees 1.5-2m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment	No./area	**11**	**14**	**17**	**11**	**2**	**1**	**10**	**23**	**2**	**56**
			shrubs and juvenile trees >2m in height	The number of shrubs or juvenile trees >2m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment	No./area	**32**	**44**	**20**	**35**	**2**	**1**	**23**	**47**	**14**	**142**
	Ecosystem structure	The vegetation is developing vertical structure and complexity comparable to that of the local remnant vegetation	Foliage cover 0.5 - 2 m	Projected foliage cover provided by perennial plants in the 0.5 - 2m vertical height stratum indicates the community structure	% cover	**24**	**2.5**	**15**	**10**	**19**	**0**	**0**	**10.5**	**1**	**9.5**

Rehabilitation Phase	Aspect or ecosystem component	Ecological Targets	Performance Indicators	Description of performance indicators	Unit of measurement (desirable)	BM1	BM4	BM5	BM7	BM8	BM10	BM15	BM18	BM19	BM23
			Foliage cover 2 - 4m	Projected foliage cover provided by perennial plants in the 2 - 4m vertical height stratum indicates the community structure	% cover	17	5	10	12	11	0	4	15	9	11
			Foliage cover 4 - 6m	Projected foliage cover provided by perennial plants in the 4 -6m vertical height stratum indicates the community structure	% cover	23	9	5	9	7	6	0	8	27	14
			Foliage cover >6m	Projected foliage cover provided by perennial plants > 6m vertical height stratum indicates the community structure	% cover	24	58	64	58	0	46	0	16	48	51
	Tree diversity	Vegetation contains a diversity of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree diversity	The diversity of trees or shrubs with a stem diameter >5cm. Species used in rehabilitation will be endemic to the local area	species/area	5	4	3	4	1	1	3	1	2	2
				The percentage of maturing trees and shrubs with a stem diameter >5cm dbh which are local endemic species	%	100	100	100	100	100	100	100	100	100	100
	Tree density	Vegetation contains a density of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree density	The density of shrubs or trees with a stem diameter > 5cm	No./area	29	21	45	41	6	22	11	26	57	122
			Average dbh	Average tree diameter of the tree population provides a measure of age, (height) and growth rate	cm	10	14	14	15	15	25	12	12	11	10
	Ecosystem health	The vegetation is in a condition comparable to that of the local remnant vegetation.	Live trees	The percentage of the tree population which are live individuals	% population	66	95	100	93	100	82	91	100	100	100
			Healthy trees	The percentage of the tree population which are in healthy condition	% population	14	29	36	27	17	18	55	35	30	0
			Medium health	The percentage of the tree population which are in a medium health condition	% population	45	62	62	59	83	41	36	54	60	84
			Advanced dieback	The percentage of the tree population which are in a state of advanced dieback and that the percentage	<% population	7	5	2	7	0	23	0	12	11	16
			Dead Trees	The percentage of the tree population which are dead (stags)	<% population	34	5	0	7	0	18	9	0	0	0
			Mistletoe	The percentage of the tree population which have mistletoe provides an indication of community health and habitat value	% population	0	10	0	2	0	0	0	0	0	0

Rehabilitation Phase	Aspect or ecosystem component	Ecological Targets	Performance Indicators	Description of performance indicators	Unit of measurement (desirable)	BM1	BM4	BM5	BM7	BM8	BM10	BM15	BM18	BM19	BM23
			Flowers/fruit: Trees	The presence of reproductive structures such as buds, flowers or fruit provides evidence that the ecosystem is maturing, capable of recruitment	% population	21	5	9	12	0	5	27	8	0	2
			Hollows	The percentage of the tree population which have hollows provides an indication of community health and habitat value	% population	7	0	0	0	0	14	0	0	0	0

11 Management recommendations

11.1 Tree health

While the majority of the trees and mature shrubs were in moderate health, dead trees (stags) were present in low numbers across numerous of the ecological sites with up to 34% of the tree population being dead stags in BM1 and there appears to be a declining trend occurring over the past few years. There were also low numbers recorded in BM4, BM7, BM10 and BM15. Many of the trees may have died as a result of increased competition levels particularly through the prolonged hot dry conditions in preceding years. In BM1 however storm damage was evident in 2013 with several more mature acacias and banksias having died since then and large patches of dead banksia also observed across the larger area of the woodland. While this may be part of the natural successional process further investigation into the cause of their death may be warranted.

Within sites BM4 and BM10 there were some large cracks evident in the soil profile (pers. obs.) which may be implicated with mine subsidence, but their effect on the health of the tree populations remains unknown.

11.2 Weeds and weed control

Noxious weeds and invasive species should continue to be monitored and controlled on a regular basis. All restoration works, including those on rehabilitation areas should use local native species or local soils, hay and other materials to limit the spread and potential invasion of weeds, or restrict the use of introduced pasture species to those that are non invasive. The use of *Chloris gayana* is one example of a species that is used widely in mine rehabilitation, with potentially significant adverse environmental impacts, and is now found within several of the ecological sites around the Bulga Coal Complex. This species has been recommended for listing as a noxious weed (Peake 2006) and is presently acknowledged as an invasive species with this species now included in the BCC weed control programs. The rehabilitation pasture species mixes as provided in preceding Management Plans have been amended to exclude invasive species such as *Chloris gayana* and *Pennisetum clandestinum* to avoid their potential invasion into areas of remnant vegetation (Bulga Coal 2014).

11.3 Pests and pest control

Feral and pest animals and noxious weeds also require monitoring and targeted control programs need to be implemented. High numbers of macropods continue to be observed across the Bulga Complex. While improved seasonal conditions have tended to relax grazing pressure from some areas this year, many areas have been degraded in the past as a result of increased disturbance and grazing pressure during prolonged dry periods. In addition, the new areas being subjected to mine disturbance as part of the expanding mining operations may be displacing and concentrating animal populations into areas that have previously been less favourable. Small exclusion areas (no smaller than 50 x 20m) to exclude grazing animals especially macropods in high concentration areas will assist in quantifying the impact and extent of browsing on the vegetation and provide information on the need for and level of management intervention required in consultation with advice from relevant experts and authorities. Other exclusion methods such as electric fencing or sonar or chemical deterrents in sensitive high impact areas could also be considered.

11.4 Lack of critical habitat

All ecological sites are regrowth woodland areas and only two sites BM1 and BM10 contained a small number of trees mature enough to bare hollows, reflecting the lack of suitable habitat required to sustain hollow dependant wildlife populations. As recommended by Umwelt (2010), installation of nesting boxes can be one active management strategy to improve the wildlife habitat throughout the Bulga Coal Complex, targeting threatened and declining wildlife species. Installing purpose built nesting boxes has also been specified as a management action in the Flora and Fauna Management Plan (Xstrata 2008b) and the new Biodiversity Management Plan (Xstrata 2014).

11.5 Increase riparian function and habitat quality

Of all of the sites, BM15, a riparian site, was the site with the least ecological stability and could benefit from works that aim to increase ground cover and limit further erosion of the creek banks. Applying local native pasture hay on the denuded areas may be one simple and effective way to increase some functional attributes of this site. Significant sections of these riparian systems associated with BM15 would also benefit from amelioration works that reverse the stream bed and bank incision with the aim to reinstate the creek with its floodplains. This may be achieved through the construction of leaky weirs that form a series of chains-of-ponds, characteristics of those observed along Nine Mile Creek. Functional drainage systems improve the quality, productivity and diversity of the local landscape as well as improve the health of the local catchment areas.

12 Conclusion

Little management intervention is required to maintain or improve most of the ecological sites, apart from noxious weed and animal control (particularly *Opuntia stricta* (Prickly Pear) and *Lantana camara* (Lantana).

While the majority of the trees and mature shrubs were in moderate health, dead trees (stags) were increasing in number in the Warkworth Sands Woodlands BM1. While this may be part of the natural successional process further investigation into the cause of their death may be warranted. Critical habitat could also be improved through the installation of nesting boxes.

The riparian site BM15 continued to suffer from historical catchment management such as clearing and overgrazing and will require significant intervention to improve the function and condition of the riparian ecosystem.

High macropod numbers continue to impact most sites mostly through tracks and camps and there has been a declining trend in numerous ecological attributes especially in sites BM1 and BM7. The actual impact on the native vegetation is however difficult to gauge without a point of reference. The construction of exclusion fences in high utilisation areas may help determine the level of impact and the type of management intervention required, in consultation with relevant experts and authorities.

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Appendix 1. 2015 Comprehensive Flora Species List

Group	Family	exotic	Scientific Name	Common Name	Habit	BM1	BM4	BM5	BM7	BM8	BM10	BM15	BM18	BM19	BM23
Dicotyledon	Apiaceae		*Centella asiatica*	Pennywort	h								1		
Dicotyledon	Apiaceae		*Hydrocotyle laxiflora*	Stinking Pennywort	h									1	
Dicotyledon	Asteraceae	*	*Bidens pilosa*	Cobbler's Peg	h		1	1	1	1	1		1	1	1
Dicotyledon	Asteraceae		*Brachyscome formosa*	Pilliga Daisy	h						1				
Dicotyledon	Asteraceae		*Brachyscome multifida*	Rock Daisy, Cut-leaved Daisy	h		1								
Dicotyledon	Asteraceae		*Calocephalus citreus*	Lemon Beautyheads	h								1		
Dicotyledon	Asteraceae		*Calotis cuneifolia*	Purple Burr Daisy	h	1									1
Dicotyledon	Asteraceae		*Calotis lappulacea*	Yellow Burr Daisy	h						1			1	
Dicotyledon	Asteraceae		*Cassinia spp.*		s						1				
Dicotyledon	Asteraceae		*Chrysocephalum apiculatum*	Common Everlasting	h		1			1	1	1	1	1	1
Dicotyledon	Asteraceae	*	*Cirsium vulgare*	Spear Thistle	h				1			1	1	1	
Dicotyledon	Asteraceae	*	*Conyza spp.*	Fleabane	h			1		1				1	
Dicotyledon	Asteraceae		*Cymbonotus lawsonianus*	Bear's Ear	h								1		
Dicotyledon	Asteraceae		*Euchiton gymnocephalus*		h						1				
Dicotyledon	Asteraceae	*	*Gamochaeta americana*	Cudweed	h									1	
Dicotyledon	Asteraceae		*Glossocardia bidens*	Cobbler's Tack	h		1						1		
Dicotyledon	Asteraceae	*	*Gomphocarpus fruticosus*	Swan Plant	ss			1			1		1		
Dicotyledon	Asteraceae	*	*Hypochaeris glabra*	Smooth Catsear	h	1			1	1					
Dicotyledon	Asteraceae	*	*Hypochaeris microcephala*	White Flatweed	h							1	1	1	1
Dicotyledon	Asteraceae	*	*Hypochaeris radicata*	Flatweed	h			1				1	1	1	
Dicotyledon	Asteraceae		*Lagenophora gracilis*	Slender Lagenophora	h						1				
Dicotyledon	Asteraceae		*Minuria leptophylla*	Minnie Daisy	h							1			
Dicotyledon	Asteraceae		*Olearia elliptica*	Sticky Daisy Bush	s			1							
Dicotyledon	Asteraceae		*Ozothamnus diosmifolius*	Pill Flower	s				1						
Dicotyledon	Asteraceae		*Podolepis jaceoides*	Showy Copper-wire Daisy	h	1				1					
Dicotyledon	Asteraceae	*	*Richardia humistrata*		h	1				1					1
Dicotyledon	Asteraceae	*	*Richardia stellaris*		h								1	1	
Dicotyledon	Asteraceae	*	*Senecio madagascariensis*	Fireweed	h	1	1	1		1	1	1	1	1	1
Dicotyledon	Asteraceae		*Sigesbeckia orientalis*	Indian Weed	h			1							
Dicotyledon	Asteraceae		*Solenogyne bellioides*		h		1								
Dicotyledon	Asteraceae		*Solenogyne dominii*	Smooth Solenogyne	h								1	1	
Dicotyledon	Asteraceae	*	*Sonchus asper*	Prickly Sowthistle	h		1								
Dicotyledon	Asteraceae	*	*Sonchus oleraceus*	Milk Thistle	h				1			1		1	1

Group	Family	exotic	Scientific Name	Common Name	Habit	BM1	BM4	BM5	BM7	BM8	BM10	BM15	BM18	BM19	BM23
Dicotyledon	Asteraceae	*	*Tagetes minuta*	Stinking Roger	h						1				
Dicotyledon	Asteraceae		*Vernonia cinerea var. cinerea*		h		1		1		1		1		
Dicotyledon	Asteraceae		*Vittadinia cuneata*	Fuzzweed	h							1			
Dicotyledon	Asteraceae		*Vittadinia spp.*	Fuzzweed	h			1					1	1	
Dicotyledon	Asteraceae		*Vittadinia sulcata*	A Fuzzweed	h						1				
Dicotyledon	Boraginaceae		*Cynoglossum australe*	Forget-me-not	h			1							
Dicotyledon	Boraginaceae		*Cynoglossum spp.*		h										1
Dicotyledon	Brassicaceae	*	*Lepidium africanum*	Peppercress	h						1				
Dicotyledon	Cactaceae	*	*Opuntia aurantiaca*	Tiger Pear	c		1		1						
Dicotyledon	Cactaceae	*	*Opuntia stricta*	Common Prickly Pear	c	1	1	1	1	1	1	1			1
Dicotyledon	Campanulaceae		*Wahlenbergia communis*	Tufted Bluebell	h								1		
Dicotyledon	Campanulaceae		*Wahlenbergia gracilis*	Sprawling Bluebell	h	1				1				1	1
Dicotyledon	Campanulaceae		*Wahlenbergia luteola*	Australian Bluebell	h							1		1	
Dicotyledon	Campanulaceae		*Wahlenbergia spp.*	Bluebell	h		1								
Dicotyledon	Casuarinaceae		*Allocasuarina luehmannii*	Bulloak	t	1	1		1	1		1	1	1	1
Dicotyledon	Casuarinaceae		*Allocasuarina torulosa*	Forest Oak	t					1					
Dicotyledon	Casuarinaceae		*Casuarina glauca*	Swamp Oak	t										1
Dicotyledon	Chenopodiaceae		*Atriplex semibaccata*	Creeping Saltbush	ss							1			
Dicotyledon	Chenopodiaceae		*Einadia hastata*	Berry Saltbush	h		1	1	1						
Dicotyledon	Chenopodiaceae		*Einadia nutans subsp. linifolia*	Climbing Saltbush	h							1			
Dicotyledon	Chenopodiaceae		*Einadia nutans subsp. nutans*	Climbing Saltbush	h			1	1		1				1
Dicotyledon	Chenopodiaceae		*Einadia trigonos*	Fishweed	h										1
Dicotyledon	Chenopodiaceae		*Enchylaena tomentosa*	Ruby Saltbush	ss							1			
Dicotyledon	Chenopodiaceae		*Maireana enchylaenoides*	Wingless Fissure Weed	h							1			
Dicotyledon	Chenopodiaceae		*Maireana microphylla*	Eastern Cottonbush	ss			1				1			
Dicotyledon	Cloanthaceae		*Spartothamnella juncea*	Bead Bush	s			1							
Dicotyledon	Clusiaceae		*Hypericum gramineum*	Small St. John's Wort	h							1	1		
Dicotyledon	Convolvulaceae		*Convolvulus erubescens*	Australian Bindweed	h							1			
Dicotyledon	Convolvulaceae		*Dichondra repens*	Kidney Weed	h		1	1	1		1	1	1	1	1
Dicotyledon	Dilleniaceae		*Hibbertia diffusa*		ss					1					
Dicotyledon	Droseraceae		*Drosera peltata*	Pale Sundew	h					1					
Dicotyledon	Epacridaceae		*Astroloma humifusum*	Native Cranberry	ss	1				1				1	
Dicotyledon	Epacridaceae		*Brachyloma daphnoides*	Daphne Heath	s					1					
Dicotyledon	Epacridaceae		*Lissanthe strigosa*	Peach Heath	s		1		1		1				
Dicotyledon	Euphorbiaceae		*Breynia oblongifolia*	Coffee Bush	s			1							
Dicotyledon	Euphorbiaceae		*Chamaesyce drummondii*	Caustic Weed	h				1		1	1	1		

Group	Family	exotic	Scientific Name	Common Name	Habit	BM1	BM4	BM5	BM7	BM8	BM10	BM15	BM18	BM19	BM23
Dicotyledon	Euphorbiaceae		*Phyllanthus virgatus*	A Spurge	ss				1		1			1	
Dicotyledon	Fabaceae (Faboideae)		*Daviesia genistifolia*	Broom Bitter Pea	s		1				1		1		
Dicotyledon	Fabaceae (Faboideae)		*Desmodium brachypodum*	Large Tick trefoil	ss		1				1				1
Dicotyledon	Fabaceae (Faboideae)		*Desmodium varians*	Slender Tick-trefoil	h				1		1	1	1	1	
Dicotyledon	Fabaceae (Faboideae)		*Dillwynia retorta*	Heathy Parrot-pea	s		1								
Dicotyledon	Fabaceae (Faboideae)		*Glycine clandestina*	Climbing Glycine	h	1	1	1	1		1			1	1
Dicotyledon	Fabaceae (Faboideae)		*Glycine spp.*	Glycine	h					1					
Dicotyledon	Fabaceae (Faboideae)		*Glycine tabacina*	Variable Glycine	h							1	1		
Dicotyledon	Fabaceae (Faboideae)		*Hardenbergia violacea*	False Sarsparilla	v			1			1	1			
Dicotyledon	Fabaceae (Faboideae)		*Indigofera australis*	Hill Indigo	s		1		1		1				
Dicotyledon	Fabaceae (Faboideae)	*	*Trifolium spp.*	A Clover	h						1				
Dicotyledon	Fabaceae (Mimosoideae		*Acacia filicifolia*	Fern-leaved Wattle	s	1				1					
Dicotyledon	Fabaceae (Mimosoideae)		*Acacia amblygona*	Fan Wattle	s		1		1		1				
Dicotyledon	Fabaceae (Mimosoideae)		*Acacia falcata*	A Wattle	s		1					1			
Dicotyledon	Fabaceae (Mimosoideae)		*Acacia implexa*	Hickory	s		1	1							
Dicotyledon	Fabaceae (Mimosoideae)		*Acacia parvipinnula*	Silver-stemmed Wattle	s			1				1	1		
Dicotyledon	Fabaceae (Mimosoideae)		*Acacia spp.*	A Wattle	s				1						
Dicotyledon	Goodeniaceae		*Goodenia rotundifolia*		h		1		1		1				
Dicotyledon	Goodeniaceae		*Velleia paradoxa*	Spur Velleia	h							1		1	
Dicotyledon	Lamiaceae		*Ajuga australis*	Australian Bugle	h										1
Dicotyledon	Lamiaceae		*Mentha satureioides*	Native Pennyroyal	h									1	
Dicotyledon	Lauraceae (Cassythaceae)		*Cassytha spp.*		p		1								
Dicotyledon	Linaceae		*Linum marginale*	Native Flax	h							1			
Dicotyledon	Linaceae	*	*Linum trigynum*	French Flax	h								1		
Dicotyledon	Lobeliaceae		*Pratia purpurascens*	Whiteroot	h			1							1
Dicotyledon	Malvaceae		*Abutilon oxycarpum*	Flannel Weed	ss			1							
Dicotyledon	Malvaceae		*Sida corrugata*	Corrugated Sida	h						1	1	1		1
Dicotyledon	Malvaceae	*	*Sida rhombifolia*	Paddy's Lucerne	ss						1	1			1
Dicotyledon	Malvaceae		*Sida subspicata*	Spiked Sida	ss						1				
Dicotyledon	Myoporaceae		*Eremophila debilis*	Amulla	ss		1		1		1	1	1	1	1
Dicotyledon	Myoporaceae		*Myoporum montanum*	Western Boobialla	s						1				
Dicotyledon	Myrtaceae		*Corymbia maculata*	Spotted Gum	t			1							
Dicotyledon	Myrtaceae		*Eucalyptus albens*	White Box	t							1			
Dicotyledon	Myrtaceae		*Eucalyptus crebra*	Narrow-leaf Ironbark	t	1	1	1	1			1		1	1
Dicotyledon	Myrtaceae		*Eucalyptus fibrosa*	Broad-leaved Red Ironbark	t		1								
Dicotyledon	Myrtaceae		*Eucalyptus moluccana*	Grey Box	t		1		1		1				

Group	Family	exotic	Scientific Name	Common Name	Habit	BM1	BM4	BM5	BM7	BM8	BM10	BM15	BM18	BM19	BM23
Dicotyledon	Myrtaceae		*Eucalyptus tereticornis*	Forest Red Gum	t	1						1			1
Dicotyledon	Myrtaceae		*Leptospermum polygalifolium*		s	1				1					
Dicotyledon	Myrtaceae		*Melaleuca decora*		s				1						
Dicotyledon	Oleaceae		*Notelaea longifolia*	Mock Olive	s			1							
Dicotyledon	Oleaceae		*Notelaea spp.*	Native Olive	s			1				1			
Dicotyledon	Oxalidaceae		*Oxalis exilis*		h					1	1				
Dicotyledon	Oxalidaceae		*Oxalis perennans*	Yellow Wood-sorrel	h		1					1			1
Dicotyledon	Pittosporaceae		*Bursaria spinosa*	Native Blackthorn	s		1	1	1		1				
Dicotyledon	Plantaginaceae		*Plantago debilis*	Plantain	h		1		1		1				
Dicotyledon	Plantaginaceae	*	*Plantago lanceolata*	Ribwort	h	1	1					1	1	1	
Dicotyledon	Plantaginaceae		*Plantago varia*	Variable Plantain	h		1				1		1		
Dicotyledon	Plantaginaceae		*Veronica plebeia*	Trailing Speedwell	h			1							1
Dicotyledon	Primulaceae	*	*Anagallis arvensis*	Scarlet Pimpernel	h								1		
Dicotyledon	Proteaceae		*Banksia integrifolia*	Coastal Banksia	s	1									
Dicotyledon	Proteaceae		*Grevillea montana*	A Grevillea	s					1					
Dicotyledon	Ranunculaceae		*Clematis aristata*	Old Man's Beard	v			1							1
Dicotyledon	Rhamnaceae		*Cryptandra amara var. Amara*	Bitter Cryptandra	ss								1		
Dicotyledon	Rubiaceae		*Asperula conferta*	Common Woodruff	h		1				1	1	1	1	
Dicotyledon	Rubiaceae		*Opercularia diphylla*	Stinkweed	h						1				
Dicotyledon	Rubiaceae		*Psydrax oleifolia*	Wild Lemon	s						1				
Dicotyledon	Santalaceae		*Exocarpos strictus*	Dwarf Cherry	s			1	1						
Dicotyledon	Sapindaceae		*Dodonaea viscosa*	Sticky Hop-bush	s										1
Dicotyledon	Sapindaceae		*Dodonaea viscosa subsp. cuneata*	Wedge-leaf Hopbush	s		1	1							
Dicotyledon	Schrophulariaceae		*Brunoniella australis*	Blue Trumpet	h		1	1	1		1	1	1	1	
Dicotyledon	Solanaceae	*	*Lycium ferocissimum*	African Boxthorn	s									1	
Dicotyledon	Solanaceae		*Solanum brownii*	Violet Nightshade	h			1							
Dicotyledon	Solanaceae		*Solanum cinereum*	Narrawa Burr	h		1				1				1
Dicotyledon	Solanaceae	*	*Solanum nigrum*	Blackberry Nightshade	h			1			1				1
Dicotyledon	Solanaceae		*Solanum opacum*	Green berry nightshade	h			1							
Dicotyledon	Solanaceae	*	*Withania somnifera*	Winter Cherry	s			1							1
Dicotyledon	Stackhousiaceae		*Stackhousia viminea*	Slender Stackhousia	h				1				1		
Dicotyledon	Sterculiaceae		*Brachychiton populneus*	Kurrajong	t			1			1				
Dicotyledon	Thymelaeaceae		*Pimelea curviflora*	Curved Rice Flower	ss									1	
Dicotyledon	Thymelaeaceae		*Pimelea linifolia*	Rice Flower	s	1				1					
Dicotyledon	Ulmaceae		*Trema tomentosa*	Native Peach	s			1							
Dicotyledon	Verbenaceae	*	*Lantana camara*	Lantana	s			1				1		1	1

Group	Family	exotic	Scientific Name	Common Name	Habit	BM1	BM4	BM5	BM7	BM8	BM10	BM15	BM18	BM19	BM23
Dicotyledon	Verbenaceae	*	*Verbena rigida*	Veined Verbena	h							1		1	
Dicotyledon	Vitaceae		*Cayratia clematidea*	Slender Grape	v			1							
Monocotyledon	Anthericaceae		*Arthropodium milleflorum*	Vanilla-lily	h		1		1		1			1	
Monocotyledon	Anthericaceae		*Laxmannia gracilis*	Slender Wire Lily	h	1			1						1
Monocotyledon	Cyperaceae		*Carex inversa*	Knob Sedge	r			1							
Monocotyledon	Cyperaceae		*Fimbristylis dichotoma*	Common Fringe Rush	r		1		1					1	1
Monocotyledon	Cyperaceae		*Gahnia aspera*	Rough Saw-sedge	r			1							
Monocotyledon	Iridaceae	*	*Romulea rosea*	Onion Grass	h									1	
Monocotyledon	Lomandraceae		*Lomandra filiformis*	Wattle Mat-rush	h		1	1	1	1	1	1	1		
Monocotyledon	Lomandraceae		*Lomandra glauca*	Pale Mat-rush	h					1					
Monocotyledon	Lomandraceae		*Lomandra leucocephala subsp. leucocephala*	Irongrass	h					1					
Monocotyledon	Lomandraceae		*Lomandra multiflora*	Many-flowered Mat-rush	h		1	1			1		1	1	1
Monocotyledon	Phormiaceae		*Dianella caerulea*		h			1			1			1	
Monocotyledon	Phormiaceae		*Dianella revoluta*	Native Flax Lily	h		1	1			1	1	1	1	
Monocotyledon	Poaceae		*Aristida calycina*	Number Nine	g	1		1		1	1				
Monocotyledon	Poaceae		*Aristida ramosa*	Threeawn Grass	g	1	1	1			1		1	1	1
Monocotyledon	Poaceae		*Aristida vagans*	Wire Grass	g		1	1	1		1	1	1		
Monocotyledon	Poaceae		*Aristida warburgii*		g	1				1					
Monocotyledon	Poaceae		*Austrostipa scabra subsp. falcata*	Speargrass	g			1			1			1	
Monocotyledon	Poaceae		*Austrostipa verticillata*	Slender Bamboo Grass	g						1				1
Monocotyledon	Poaceae	*	*Axonopus fissifolius*	Narrow-leaf Carpet Grass	g			1							
Monocotyledon	Poaceae		*Bothriochloa decipiens*	Redgrass	g		1		1		1	1	1	1	1
Monocotyledon	Poaceae		*Chloris divaricata*	Slender Windmill Grass	g							1			
Monocotyledon	Poaceae	*	*Chloris gayana*	Rhodes Grass	g							1			1
Monocotyledon	Poaceae		*Chloris truncata*	Windmill Grass	g								1		
Monocotyledon	Poaceae		*Chloris ventricosa*	Tall Windmill Grass	g						1	1	1	1	
Monocotyledon	Poaceae		*Cymbopogon obtectus*	Silky Heads	g					1					
Monocotyledon	Poaceae		*Cymbopogon refractus*	Barbed-wire Grass	g	1	1	1	1		1	1	1	1	1
Monocotyledon	Poaceae		*Cynodon dactylon*	Couch	g	1						1			1
Monocotyledon	Poaceae		*Dichanthium sericeum*	Queensland Bluegrass	g								1		
Monocotyledon	Poaceae	*	*Ehrharta erecta*	Panic Veldtgrass	g										1
Monocotyledon	Poaceae		*Entolasia marginata*	Bordered Panic	g		1	1	1					1	1
Monocotyledon	Poaceae		*Entolasia stricta*	Wiry Panic	g			1							
Monocotyledon	Poaceae		*Eragrostis brownii*	Brown's Lovegrass	g								1		
Monocotyledon	Poaceae		*Eragrostis lacunaria*	Purple Lovegrass	g	1									
Monocotyledon	Poaceae		*Eragrostis leptostachya*	Paddock Lovegrass	g				1					1	1

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Monocotyledon	Poaceae		*Eragrostis spartinoides*		g	1				1					
Monocotyledon	Poaceae	*	*Hyparrhenia hirta*	Coolatai Grass	g							1			
Monocotyledon	Poaceae		*Leptochloa divaricatissima*	Canegrass	g						1				
Monocotyledon	Poaceae	*	*Melinis repens*	Red Natal Grass	g	1				1					
Monocotyledon	Poaceae		*Microlaena stipoides*	Weeping Rice-grass	g	1	1	1	1		1	1	1	1	1
Monocotyledon	Poaceae	*	*Panicum maximum*	Guinea Grass	g	1									1
Monocotyledon	Poaceae		*Panicum queenslandicum*	Coolibah Grass	g					1					
Monocotyledon	Poaceae		*Panicum simile*		g	1						1	1	1	1
Monocotyledon	Poaceae		*Rytidosperma bipartitum*	Wallaby Grass	g		1					1		1	
Monocotyledon	Poaceae		*Rytidosperma racemosum*	Wallaby Grass	g						1				
Monocotyledon	Poaceae		*Rytidosperma sp.*	Wallaby Grass	g		1		1				1		
Monocotyledon	Poaceae	*	*Setaria gracilis*	Slender Pigeon Grass	g	1									1
Monocotyledon	Poaceae		*Sporobolus creber*	Western Rat's-tail Grass	g		1					1	1	1	
Monocotyledon	Poaceae		*Themeda triandra*	Kangaroo Grass	g			1				1	1		
Pteridophyta	Adiantaceae		*Cheilanthes distans*	Bristly Cloak fern	f			1	1		1			1	1
Pteridophyta	Adiantaceae		*Cheilanthes sieberi subsp. sieberi*	Rock Fern	f	1	1	1	1	1	1	1	1	1	1