Appendix K
Revegetation Plan

Supplementary Biological Report

McArthur River Mine

Open Cut Project

November 2005

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1. Introduction

Establishment of vegetative cover is one of the important elements of a rehabilitation plan for a mine site (Bell, 1999). It is proposed the revegetation for the McArthur River Diversion Project be carried out over two years using two methods: a) the planting of seedlings and b) direct seeding.

The aim of this report is to provide the:

- criteria for species selection
- basis for species mix
- estimated duration and time for harvesting and seeding
- methods of seeding and planting

2. Criteria for species selection

Provenance: Only species that grow in the area have been selected and all will be collected as close as possible to the area to be rehabilitated. This is based on the concept that local populations have evolved and adapted to local conditions and better adapted to long-term survival (Coates & van Leeuwen, 1996). The Tree and Shrub species will be collected from within the boundaries of the McArthur river catchment while the Grass species will be collected from within the mining lease itself.

Species diversity: The ideal situation is to include as many species as possible that grow in the adjoining section of the river. All species from the mid and upper stratum of Vegetation Communities 7 and 8 (Appendix H.4) have been included, as have all the *Poacea* species from the lower stratum. Some mid and upper stratum species from Vegetation Communities 5 and 6 have been added (*Acacia* species and *Atalaya hemiglauca*) as they are important colonisers of disturbed ground. A number of Poacea species from Vegetation Communities 5 and 6 have also been added to aid initial bank stabilisation. Suitable herb, sedge and forb species from Vegetation Communities 5, 6, 7 and 8 will also be targeted opportunistically as part of the grass harvesting process and will be added to the final mix.

A total of 40 species have been included:

Mid and Upper Stratum	**Lower Stratum: Grasses, sedges & Rushes**
Acacia drepranocarpa	*Aristrida latifolia*
Acacia hemsleyi	*Astrebla sp.*
Acacia holosericea	*Brothriochloa ewartiana*
Acacia platycarpa	*Brachyachne convergens*
Atalaya hemiglauca	*Chrysopogan elongatus*
Barringtonia acutangula	*Chrysopogon fallux*
Casuarina cunninghamii	*Cyperus sp.*
Corymbia bella	*Cyanachne cyathapoda*
Eucalyptus camaldulensis	*Dicanthium sericeum*
Eucalyptus microtheca	*Digitaria brownii*
Ficus coronulata	*Ectrosia leporina*
Ficus racemosa	*Erogrostis sp.*
Ficus sp.	*Eulalia aurea*
Hibiscus panduriformis	*Fimbrostylis sp.*
Lophostemon grandiflorus	*Iseilema sp.*
Melaleuca argentea	*Panicum decompositum*
Melaleuca leucadendra	*Paspalidium jubiflorum*
Nauclea orientalis	*Paspaladium scrobiculatum*
Terminalia platyphylla	*Sorgum timorense*
Terminalia volucris	*Urochloa sp.*

Succession: Plant succession models indicate that there may be long term impacts if a representative range of species do not initially establish on the rehabilitation areas. Also studies have shown that recruitment of species into rehabilitated areas is slow or minimal and therefore, all desired species should be included in the original seed mix to ensure species diversity and establish a self-sustaining ecosystem (Roche et al., 1997, Walker & del Moral, 2003). It is also important to include coloniser species that will establish quickly. These species will help to create the right environment for other slower establishing species to flourish.

Nitrogen Fixing: It may be noted *Acacia* species are not common along the riverine corridor but will be included as part of the seed mix. Adequate amounts of nitrogen must be available in soils if plants are to grow properly and *Acacia species* are a nitrogen fixing species, which provide steady levels of nitrogen for the life of the plant. The long-term nitrogen requirements come from the return of organic matter to the soil (Wong et al., 1999).

Erosion control: The area to be rehabilitated consists mainly of alluvial soil, which is readily eroded and therefore the establishment of vegetation will assist in controlling erosion. Grasses, and *Acacia* species, which can establish very quickly, will be used to stabilise the surface in the short-term. Many smaller species have a relatively, shallow root system, therefore the inclusion of large species which have deeper root systems will be important in the event of flooding.

Seed availability: This is an important factor for collection, as direct seeding requires large volumes of seed (application rates of 2.5 to 5 kg/hectare are standard) therefore it is necessary to target species that produce seed which can be collected in the quantities required for the project. Seeds required for propagation in the nursery require comparatively minute quantities.

3. Basis for species mix

Ideally the proportion of seed for each species should replicate the proportions in which they naturally occur. The final seed mix will be dependant on what species can be collected in adequate quantities. Also the final landform will have an influence on the specific amounts of each species to be used on different areas. For example, if the ground in a particular area is rocky and freer draining, less *Melaleuca* species and more *Eucalyptus/Corymbia* species will be used.

A total of 35 hectares is to be rehabilitated in the wet season of 2006-07, with another 25 hectares in the wet season of 2007-08. As the site is subject to water inundation and is likely to be prone to erosion it is suggested that a fairly high seeding rate be used.

The tree and shrub seed will be applied at a rate of 4 kg per hectare. A total of 140.kg will be required for the 2006-07 wet-season and a further 100.kg for 2007-08.

The Grass (including herb and forb) seed will be applied at a rate of 10 kg per hectare, with a total of 350 kg required for the 2006-07 wet season and 250 kg for 2007-08.

Anticipated Quantities of Seed collection for 2006/07 and 2007/08

Species	**Amount for 06/07**	**Amount for 07/08**
Acacia drepanocarpa	0.5 kg	0.5 kg
Acacia hemsleyi	6 kg	4 kg
Acacia holosericea	2 kg	1.5 kg
Acacia platycarpa	6 kg	4 kg
Atalaya hemiglauca	3 kg	2 kg
Casuarina cunninghamii	30kg	20 kg
Corymbia bella	15 kg	11 kg
Eucalyptus camaldulensis	23 kg	17 kg
Eucalyptus microtheca	8 kg	6 kg
Hibiscus panduriformis	2 kg	2 kg
Lophostemon grandiflorus	1 kg	1 kg
Melaleuca argentea	23 kg	16 kg
Melaleuca leucadendra	15.5 kg	10 kg
Terminalia platyphylla	2.5 kg	2.5 kg
Terminalia volucris	2.5 kg	2.5 kg

The grass (including herb and forb) species will be harvested from mixed stands on the mining lease. The quantities of each species will be estimated at the time of harvest.

Also small quantities of seed of the following species will be collected for growing in the nursery.

Nauclea orientalis
Barringtonia acutangula
Ficus coronulata
Ficus racemosa
Ficus sp.
Pandanus aquaticus

4. Harvesting and seeding times

Harvesting and seeding times are based on previous season's collections. These estimates are based on the assumption it will be a poor season and therefore necessary to cover large distances to collect the required seed (Setterfield, 2002). In a "good year" these times would be reduced significantly.

Approximate Time and Method for Grass Seed Collection

Species	**Season**	**Method**
Aristida latifolia	January	Machine
Chrysopogan elongatus	January – March	Hand
Cyperus sp.	January	Hand
Ectrosia leporina	January	Machine
Eragrostis sp	January – May	Hand
Fimbrostylis sp	January	Hand
Paspalidium jubiflorum	January – May	Hand
Paspalum scrobiculatum	January – May	Hand
Astrebla sp	March – May	Machine
Bothrinochloa ewartiana	March – May	Machine
Brachyachne sp	March – May	Machine
Dicanthium sp	March – May	Machine
Eulalia aurea	March – May	Machine
Iseilema sp,	March – May	Machine
Panicum decompositum	March – May	Machine
Sorghum timorense	March – May	Machine
Herb and Forb species	March – May	Machine

During January it is estimated the harvesting of grass seed will take 7 days for 5 people, most of which will be hand collection.

The species ripening in the March– May period will take 7 days for 3 people, all of which will be collected by machine.

Approximate Time and Method for Collection of Woody Species:

Species	**Season**	**Method**	**Time 05/06** (days)	**Time 06/07** (days)
Corymbia bella	Dec - Feb	Hand held cutters	14	10
Eucalyptus camaldulensis	Dec - Feb	Hand held cutters	12	9
Lophostemon grandiflorus	Dec - Feb	Hand held cutters	1	1
Melaleuca argentea	Dec - Feb	Hand held cutters	12	9
Casuarina cunninghamii	Apr - Jun	Hand held cutters	15	10
Melaleuca leucadendra	Sep - Nov	Hand held cutters	12	8
Acacia drepanocarpa	Apr - Jun	Hand	1	1
Hibiscus panduriformis	Apr - Sep	Hand	1	1
Terminalia platyphylla	May - Sep	Hand	0.5	0.5
Acacia hemsleyii	Sep - Nov	Hand	1	0.5
Acacia holosericea	Sep - Nov	Hand	0.5	0.5
Acacia platycarpa	Sep - Nov	Hand	0.5	0.5
Atalaya hemiglauca	Sep - Nov	Hand	0.5	0.5
Eucalyptus microtheca	Sep - Nov	Hand held cutters	3	2.5
Terminalia volucris	Oct - Jan	Hand	0.5	0.5
Barringtonia acutangula	Dec - Feb	Hand	0.25	0.25
Nauclea orientalis	Apr - Jun	Hand	0.25	0.25
Ficus racemosa	Sep - Nov	Hand	0.25	0.25
Ficus coronulata	Oct - Nov	Hand	0.25	0.25
Pandanus aquaticus	Sep - Oct	Hand	0.25	0.25

For the volumes identified in the table above, first 6 species (which make up the bulk of the seed mix), it is estimated it will require 6 people to collect and clean the seed ready for seeding. The next 9 species will require up to 10 people to collect and clean, and the remaining 4 species will not require much time at all to harvest.

5. Methods for seeding and planting

Direct Seeding: This is a cost effective means of establishing vegetation for those species that have seed that can be collected and stored for a period of time before distribution. Direct seeding has the advantage that rainfall is not so critical as the native species have adapted to the climatic conditions of the area and, also is suitable to rocky areas where planting seedlings is impossible.

The strong seasonal influence of the climate dictates that direct seeding should occur as early in the “wet season” as possible. This allows the larger plants to become established so they can survive the long dry period that follows (Ashwarth et. al., 1994). The ground needs to be wet enough to maintain sufficient moisture for seedlings to survive a period of several days between rain. Rainfall patterns of previous years indicate that the optimum time is from mid December to mid January.

Some species have a dormancy factor and will require pre-treatment if rapid germination is to occur (Gunn & Solomon, 2001). For example, the *Acacia* species will require mechanical scarification or hot water treatment prior to mixing with sawdust. The sawdust is used to add bulk and aid distribution, which will be carried out by hand. Mechanical application of seed is not considered as an option given the variety of seed sizes and shapes. It will be necessary to broadcast grass seed separately to the trees and shrub seed due to the different seed consistencies.

It is anticipated one person can seed 0.25 hectare/hour for the direct seeding process. This includes pre-treatment and mixing back at base as well as organization once out on site.

6. Propagation in Nursery

A number of species are best established by propagation in the nursery. Some riverine species need to be grown from fresh seed (*Barringtonia acutangula, Nauclea orientalis, Ficus sp's*), as it ripens during the wet season. Some species for which the seed is hard to obtain will be grown in the nursery to make the best use of the limited seed available (*Lophostemon grandiflorus, Chrysopogon elongatus*). One species is grown by digging up the plant and dividing it (*Chyanachne cyathopoda*). Small amounts of other key species will also be grown in the nursery to ensure they are well represented in the final rehabilitation.

Where ever possible seedlings will be only three to four months old, as small seedlings have a greater chance of survival than large plants, which have higher water requirements.

Species	**Amounts**	**Method of Propagation**	**Time of planting**
Corymbia bella	200	Seed	Sept 06
Eucalyptus camaldulensis	200	Seed	Sept 06
Melaleuca leucadendra	200	Seed	Sept 06
Melaleuca argentea	200	Seed	Sept 06
Casuarina cunninghamii	200	Seed	Sept 06
Barringtonia acutangula	1000	Fresh seed	Wet Season 05-06
Nauclea orientalis	1000	Fresh seed	Wet Season 05-06
Chrysopogon elongatus	1000	Seed	Sept 06
Chionachne cyathopoda	600	Division	Sept 06
Lophostemon grandiflorus	600	Seed	Sept 06
Pandanus aquaticus	200	Seed	Sept 06
Ficus sp's	200	Fresh Seed or Cutting	Sept 06

The planting of seedlings will be carried out using hand tree planting tools. It is estimated that the planting will take place some time in December, depending on the season. At least 10 (but up to 20) people will be used for the planting and will be able to plant 100-200 plants per person per day. The planting will take approximately 3 days in total, depending on the number of people available.

7. Conclusion

It is anticipated by combining both direct seeding and plant propagation methods maximum vegetative coverage of the area will be achieved. The long-term success of the vegetative rehabilitation will depend on initial engineering work done to provide some stability to the readily erodible alluvial soils. Also fire will need to be excluded form the site for at least 10 years to ensure the vegetation establishes and matures enough to withstand fires in the long term.

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