Wirralie Gold Mine

TSF Rehabilitation Strategy

March 2014

prepared for Solomons Gold

by Northern Resource Consultants

Northern Resource Consultants Pty Ltd
ABN 55 126 894 693
www.northres.com.au
contact: Marty Costello
phone: 07 4772 6500
email: marty@northres.com.au

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Table of Contents

List of Figures

List of Tables

Introduction

1. Scope of the Rehabilitation Strategy

The Wirralie Tailings Storage Facility (TSF) rehabilitation strategy has been developed as an addendum to the Wirralie Gold Project Plan of Operations 2014 – 2019 (the PoO) to address the rehabilitation of the Wirralie TSF. The TSF is approximately 72ha and therefore represents the greatest potential closure liability for the site. This rehabilitation strategy aids in quantifying this potential liability, as well as addressing the following aspects:

– Detail proposed rehabilitation activities for the TSF
– Describe monitoring methods for the TSF rehabilitation
– Propose acceptance criteria for the TSF rehabilitation
– Describe water management aspects for the TSF

2. Description of the TSF Operation

The current tailings dam has a surface area of 72ha and this is expected to remain constant throughout the new operation. The facility was formed by the construction of an earth and rock fill embankment across a broad, shallow valley on Sugarbag Creek. The downstream embankment is approximately 900m, with the Wirralie waste dumps constructed adjacent to the embankment to create an integrated landform. The waste dump has been previously rehabilitated, though it is anticipated that some minor remedial works are required to the dump. These are described in detail in the Plan of Operations.

The profile of the tailings surface is gently sloping across the entire surface, with water shedding across the surface to a permanent water dam forming over approximately 25ha at the eastern end of the dam. A further 5ha surrounding the permanent storage is inundated on a semi-permanent basis. A heap leach circuit will be established on the north-western end of the TSF and is projected to cover an area of 5ha. A 3.5ha rehabilitation trial area will be established within the southern end of the tailings dam to inform the rehabilitation strategy described below. Figure 1 shows the location of the semi-permanent wetland and rehabilitation trial area.

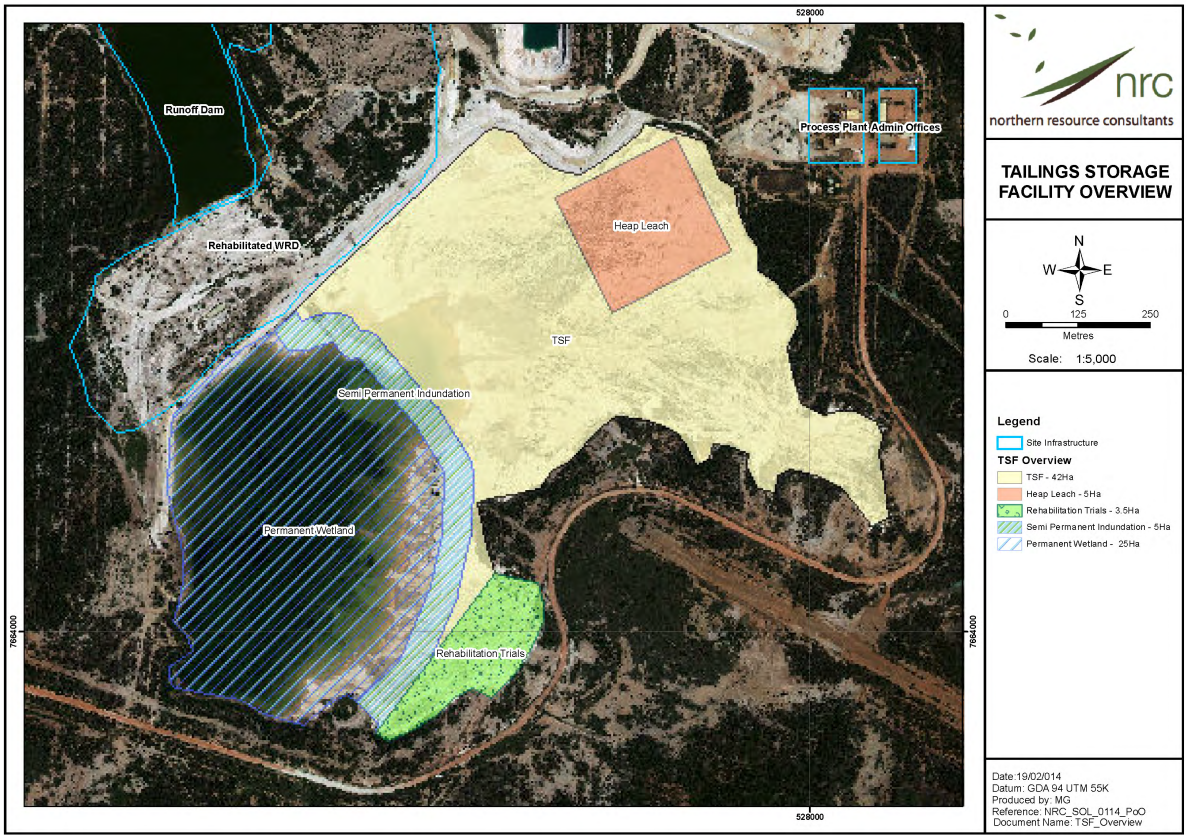

Figure 1: Tailings Storage Facility Overview including Wetland and Rehabilitation Trial Area

3. Closure Objectives

The mine closure objectives of the Wirralie Gold Mine are to:

- Protect the environment and public health through the use of responsible rehabilitation practices.
- Ensure any landforms constructed as part of site rehabilitation will be geochemically stable – resistant to weathering and oxidation and not generating seepage or leaching contaminants to surface water or groundwater.
- Reduce or eliminate potential impacts to the surrounding environment.
- Establish conditions that are consistent with the pre-determined end land use where practicable.
- Reduce the need for long-term monitoring and maintenance by establishing effective physical and chemical stability of disturbed areas.
- Facilitate lease relinquishment.

Performance of rehabilitation activities undertaken will be gauged against specific closure criteria, which will include:

- Quality of water leaving the rehabilitated landforms will meet acceptable standards and pose no adverse impact to off-lease water resources. Water will demonstrate stable or improving water quality over a number of wet and dry cycles.
- Achieving agreed post-mining and use objectives nominated in the Environmental Authority that are compatible with the climate, soils and topography of the final landforms.
- Final rehabilitated landforms that show trends toward long-term stability.

The specific post mine land use description for the TSF is contained in the Environmental Authority for the site. The TSF post mine land use is **Class VII – land not suitable for cultivation and only careful pastoral use** (DME 1995).

TSF Rehabilitation Strategy

1. Proposed Landforms

The final landform type for the TSF is proposed as a mixed landform made up of an ephemeral wetland and native habitat containing some pasture species. This design is based on maintaining water storage within a portion of the facility. Approximately one third of the tailings surface area is inundated following an average wet season. This water is confined to the western corner of the dam adjacent to the spillway. A further 5ha is inundated on a semi permanent basis and is also suitable as a wetland. The remainder, approximately 42ha, will require active rehabilitation through the development of a suitable capping. The cover method will be determined through rehabilitation trials that are proposed to start in the first year of the recommencement of operations (detailed below). Stock will be excluded from the area through the construction of a perimeter fence to limit access to water and enable native vegetation to establish.

2. Water Management

2.1 Water Quality

The water storage within the Wirralie TSF is approximately 25ha, and anecdotal evidence from local landholders indicates that the storage is permanent, having not dried out since the site was put on care and maintenance ten years ago. Water quality within the storage was assessed in January 2014 and meets the ANZECC Livestock Drinking Water Guideline for most analytes assessed. A summary of the current water quality assessment for the TSF is included in Table 1, showing that sulfate and TDS exceed the guideline values. However, the concentration of arsenic and all metals assessed are within the ANZECC guideline. The elevated TDS and sulfate levels at this stage do not represent a risk to the environment, livestock will be excluded from the permanent water storage through the installation of an exclusion fence around the perimeter. Elevated TDS and sulfate can cause health problems in livestock following long term or chronic exposure. Cattle and other livestock will be excluded from the mine site by a perimeter fence, which is to remain post closure, so it is not anticipated that the opportunity for chronic exposure will eventuate (ANZECC, 2000)

Table 1: Water Quality Wirralie TSF Spillway January 2014

Parameter	Unit	TSF Spillway	Livestock Drinking Water Guideline (ANZECC)
pH	pH Units	7.1	-
Total Dissolved Solids Dried at 175-185°C	mg/L	**9100**	5000
Zinc, Zn	mg/L	<0.01	20
Sulfur as Sulfate, SO_4	mg/L	**4300**	1000

Parameter	Unit	TSF Spillway	Livestock Drinking Water Guideline (ANZECC)
Sulfur, S	mg/L	1400	-
Molybdenum, Mo	mg/L	0.014	0.15
Arsenic, As	mg/L	0.80	0.5-5
Copper, Cu	mg/L	<0.003	1 (Cattle)
Cadmium, Cd	mg/L	0.0065	0.01
Lead, Pb	mg/L	<0.003	0.1
Selenium, Se	mg/L	0.014	0.02
Total Zinc	mg/L	<0.01	-
Total Molybdenum	mg/L	0.014	-
Total Arsenic, As	mg/L	0.81	-
Total Cadmium, Cd	mg/L	0.0069	-
Total Copper, Cu	mg/L	<0.003	-
Total Lead, Pb	mg/L	<0.003	-
Total Selenium, Se	mg/L	0.014	-
Mercury	mg/L	<0.00005	0.002
Total Mercury	mg/L	<0.00005	-
Weak Acid Dissociable Cyanide	mg/L	<0.004	-

3. Geochemical Nature of Tails

The deposited tailings are consolidated and considered suitable for earthworks, including the heap leach and rehabilitation works. Characterisation of the tailings for rehabilitation purposes was completed by EGI (2004) and determined that the acid potential risk of the tailings was low. The geochemical investigation was undertaken on the tailings to:

– Assess the acid-forming potential of the tailings.
– Identify any elements that are enriched and/or soluble in the tailings that may present an environmental concern for water quality, soil contamination or dusting.
– Provide recommendations for rehabilitation.

The results of the test work indicated that the tailings are relatively barren in terms of acid generation, and the acid rock drainage risk from the tailings storage is considered to be low. However, the material is saline and contains relatively soluble arsenic at concentrations that may be of concern for closure and rehabilitation.

Arsenic is present in both the surface and at depth in the profile samples of the tailings, with a recommendation in the EGI report that a surface layer be installed over the tailings to isolate this risk. However, arsenic seems contained within the tailings, as recent water quality results from the TSF indicate that arsenic is within the ANZECC Livestock Drinking Water Guideline (Table 1).

4. Water Storage Landform

Construction of the permanent wetland will commence during the closure phase once the heap leach and active tailings deposition have ceased. Surrounding the permanent water storage, there is an area of semi-permanent inundation. Some minor earthworks may be required in order to return the batter on the dam to a natural slope, as well as some minor stabilisation works. A number of water plant species (*Cyprus* sp., *Enchylaena tomentosa*, and *Typha* sp.) have already begun to colonise the perimeter of the dam. These will continue to be monitored during the next phase of the operation and if necessary these will be propagated for either seeding or direct planting as part of the rehabilitation of the wetland. Figure 2 below shows the existing water storage at the Wirralie TSF and some of the vegetation that has colonised around the permitter of the storage. Figure 2: Wirralie TSF Semi-Permanent Water Storage (Photo taken February 2014).Water quality monitoring of the TSF will continue during the operational phase of mining and processing at Wirralie as required in the EA. Water quality objectives for the semi-permanent wetland will be developed prior to rehabilitation commencing. It is anticipated that ongoing monitoring of the water quality will continue during post closure until it can be demonstrated that these water quality objectives have been met and will continue to be met into the future.

Figure 2: Wirralie TSF Semi-Permanent Water Storage (Photo taken February 2014).

5. Native Habitat and Grazing Pasture Landform

5.1 Summary of Previous Trials

Detailed experiments and trials have been conducted previously using the tailings from the Wirralie TSF. The outcomes of these experiments have been used to inform this rehabilitation strategy and are summarised below.

Freak (1993) conducted several experiments using tailings in pot trials to determine seed germination ability and seedling growth under various treatments of topsoil and fertiliser. From this study, it was determined that tailings from the Wirralie TSF inhibited seed germination and initial seedling establishment of most species examined. High germination percentages were however recorded for *Cenchrus ciliaris, Chloris gayana, Acacia holosericea, Lysiphyllum hookeri* and species of *Atriplex, Dysphania, Enchylaena* and *Eucalyptus* when germinated in tailings with added topsoil. Additionally, seedling survival of these species was enhanced with additions of fertiliser (Freak, 1993).

Freak (1993) also reported that *Acacia harpophylla* exhibited moderate growth rates in treatments with and without topsoil (direct sewing in dried tails). The growth of *A. shirleyi* in tailings could not be accurately determined as external factors, such as sensitivity to shading and transplanting, interfered with the effect of tailings on growth. It was suggested that *A. shirleyi*, may be a potentially useful species for revegetating the tailings dam, as field trials indicated that this species grows well with added topsoil and fertiliser. *Eucalyptus camaldulensis* and *E. trachyphloia* exhibited rapid growth rates and high tolerance to both tailing types, but only under treatments with added topsoil (Freak, 1993).

Freak (1993) also examined the species used in tailings pot trials under field conditions within the Wirralie TSF. On a small-scale tailings dam plot, seed germination and vegetation cover were monitored over one year. Greater vegetation cover was recorded in areas with added topsoil and fertiliser compared to areas with added topsoil but no fertiliser, which supported the results from the pot trials. Additionally, there was evidence that compaction of the placed soil by heavy earthmoving machinery occurred at the plot, and that this appeared to severely restrict seed germination over most of the plot (Freak, 1993).

5.2 Proposed Trials

A cover trial for the existing TSF is proposed, with a focus on examining different rehabilitation methods through scientific trials, demonstrating their effectiveness and determining the most suitable methodology for rehabilitation of the TSF. The rehabilitation trials proposed will build on the previous work conducted by Freak (1993). The proposed trials are considered to be commensurate with current best practice and regulatory requirements for equivalent sites and climatic conditions.

5.3 Existing Material Available

As noted previously, the tailings are relatively benign with studies to date determining that they represent a low acid forming risk, and whilst arsenic concentrations are above desired levels this is relatively immobile and is below ANZECC guidelines in the water storage area.

An area of approximately 3.5ha is immediately available within the existing TSF to commence rehabilitation trials and monitoring upon the recommencement of operations. This area is representative of the whole tailings storage facility and will therefore provide a suitable rehabilitation trial area. Figure 3 to Figure 5 below are recent photographs of the proposed tailings trial area and are indicative of the whole tailings storage facility.

A topsoil balance of approximate 60,000m^3 remains in stockpiles around the tailings dam and process areas. This topsoil will be used for revegetation of the tailings dam.

Figure 3: Wirralie TSF Rehabilitation Trial Area (Photo taken February 2014).

Figure 4: Wirralie TSF Rehabilitation Trial Area (Photo taken February 2014).

Figure 5: Wirralie TSF Rehabilitation Trial Area (Photo taken February 2014).

5.4 Site Preparation and Revegetation Method

The deposited tailings materials within the trial area are consolidated and considered suitable for earthworks, having been undisturbed for approximately 10 years. Further compaction of the tailings surface is not recommended for the trial area.

The surface of the whole trial area will be graded if necessary to ensure that water drains to the water pond area. A small fence or other suitable marker will delineate the trial areas. In

addition, a small nib wall will be constructed on the lower end of the trial area to minimise the potential for water inundation. This will be slotted to allow drainage, and formed so that it has no impact on the DSA of the TSF.

The following is an overview of the proposed trial methods:

Option 1 Trial – Capillary Break

- A capillary break layer (0.5m deep) made up of screened coarse material from the proposed heap leach pad will be constructed over the area. This material will be readily available following the heap leach process and represents a potential beneficial reuse of the material. The layer will be track rolled with a dozer for the trial prior to placement of topsoil.
- Topsoil from the existing topsoil stockpiles surrounding the TSF will be spread directly over the trial area to a depth of approximately 0.2m. Topsoil will be placed in alternate strips nominally 5m in width to enable the full area to be covered and maximise the available topsoil resource. This will be shallow ripped using a grader to minimise potential compaction from machinery, prior to seeding.
- Topsoiled sections will be seeded using acacia tree species, a mix of groundcover/pasture species and a single dose of fertiliser. Given the relatively benign nature of the tailings, it is not considered necessary to limit species selection for rehabilitation to shallow rooting species.

Option 2 Trial - Moonscape

- Oxide mine waste transported from the pit will be paddock dumped on the tailings to form islands. These shall be pushed over to form mounds approximately 0.8m high.
- Topsoil from the adjacent stockpiles will be selectively spread on each of the islands to a depth of approximately 0.2m.
- Topsoiled sections will be seeded using acacia tree species, a mix of groundcover/pasture species and a single dose of fertiliser. Given the relatively benign nature of the tailings, it is not considered necessary to limit species selection for rehabilitation to shallow rooting species.
- An engineered low permeability drainage system shall be installed to collect surface runoff and direct surface flows directly to the wetland area.

Option 3 Trial – Topsoil Strips Direct on Tails

- Topsoil will be directly spread over the trial area to a depth of approximately 0.2m in alternate strips approximately 5m wide. Spread topsoil with then be shallow ripped to incorporate the topsoil tailings media and minimise the impact from compaction of the surface by earthmoving equipment.
- Topsoiled sections will be seeded using acacia tree species, a mix of groundcover/pasture species and a single dose of fertiliser.

Option 4 Trial – Direct Seeding

- The surface of the trial area will be shallow ripped along the contour to promote infiltration and limit erosion potential.
- A seed mix will be directly sown into the TSF using acacia tree species, a mix of groundcover/pasture species and a single dose of fertiliser.
- Trial 4 option is a control and will be used to benchmark the overall rehabilitation performance of each trial.

All four options will be trialled over the 3.5ha area. It is anticipated that options 3 and 4 will be able to commence in year one of the operation. Options 1 and 2 require the generation of suitable by product through mining and processing activities and so will not be able to commence until at least year two of the operation.

The following sections describe common elements within the trial, including:

- Topsoil treatment
- Timing
- Species selection
- Seed and fertiliser application rates

These proposed trials build on previous trials conducted on the TSF at both Wirralie and the nearby Yandan operations between 1990 and 1992 (Freak, 1993).

5.5 Topsoil Treatment

An existing topsoil stockpile from the previous operations will be accessed to provide topsoil for the trial. Each of the trials will have topsoil from the same stockpile area. Following placement, the topsoil will be lightly ripped to an approximate depth of 5 - 10mm. This is to minimize the potential effects of compaction during transport and placement. In addition, this will aid in the rainfall infiltration and seed germination. Ripping will occur across the surface contour to minimize the erosion potential.

5.6 Timing

Rehabilitation of the full tailings will not be able to commence until processing ceases on the site. Opportunities for the progressive rehabilitation of the TSF are limited. The rehabilitation trial area is likely to be the only area available within the TSF for rehabilitation prior to mine closure.

The rehabilitation trial is proposed to commence within the first year of operation under the current Plan of Operations. This will enable the trial to run over the full term of the Plan of Operations and allow a decision on the preferred cover strategy to occur prior to the next Plan.

Site preparation is proposed to occur in June/ July with the site fully prepared, including topsoiled ahead of the wet season.

Previous studies carried out during the operation of the TSF have recommended that the site be prepared and revegetation postponed for a full 12 months to enable surface salts to leach away (Freak, 1993). As the facility has been inactive for over a decade, at this stage there is no recognised benefit in postponing revegetation for the trials.

5.7 Plant Species Selection

Topsoil used on the tailings dam will likely have a degraded natural seed bank. This, coupled with the nature of the tailings necessitates extra seeding to ensure successful revegetation. In order to ensure high diversity, a wide range of pasture grasses, native shrub and tree species will be necessary. This diverse species mix will also improve the the chance of successful establishment of at least some species.

The following species are recommended for the tailings dam rehabilitation based on seeding trials conducted by Freak (1993): *Cenchrus ciliaris, Chloris gayana, Triodia pungens, Acacia holosericea, A. shirleyi, Lysiphyllum hookeri, Eucalyptus camaldulensis, E. melanophloia, Atriplex nummularia, Dysphania glomulifera* and *Enchylaena tomentosa*. These species have shown high potential for growth in tailings in field trials and glasshouse experiments carried out by Freak (1993). These species are also locally occurring and suited to the climatic conditions at Wirralie. Although many other chenopod species are available for revegetation purposes, the family is not predominant in the Wirralie region and the family is likely better suited to arid climates (Freak, 1993).

5.8 Seed and Fertiliser Application Rates

Seeding rates will need to be moderate to high due to the nature of the tailings and the uncertain viability of the seed bank in the topsoil stockpiles. A recommend seeding rate of 4 kg ha^{-1} for most low-toxic tailings dams will be utilised across topsoil areas within the TSF (Ward and Warren 1989, taken from Freak 1993 thesis).

Seed can be used economically by sowing the areas of grass, herb, and saltbush species together, and alternating these areas with rows of tree and shrub species. This method of sowing will reduce competition between ground cover species and trees, and the rows of trees will provide a series of windbreaks across the dam. Freak (1993) recommended a design of 5 m wide strips of tree species, alternating with 10 m wide strips of grass and herb species. These rows of vegetation should be established across the contours of the dam to minimise soil erosion. This approach is considered appropriate for the trial plots proposed in this strategy. Minor amendments to the methodology may be required once the dimensions of the trial plots are taken into account.

Nutrient analyses of the tailings completed by Freak indicated extremely low levels of plant-available nitrogen, phosphorus and potassium. Therefore applications of N.P.K. compound fertiliser are recommended for the trial. A rate of 300 kg of fertiliser per hectare is considered adequate to successfully establish vegetation. A second application of fertiliser at the same rate will be applied prior to the second wet season to further assist vegetation establishment and further balance the nutrient deficit (Freak, 1993).

For the trial one option, the strips between the windrows without topsoil will be planted with a selection of tree seedlings to trial whether they can be directly planted into the tailings media. In addition, if successful this will form a windbreak across the tailings dam surface and reduce the risk of wind blown tailings. A range of tree species will be trialled at different densities.

6. Proposed Monitoring Methods

A regular monitoring program will be established to determine the success rate of the rehabilitation methods as well as act as an early warning system should rehabilitation fail. Monitoring will typically occur quarterly for the first 2 years, and then bi-annually during the remaining trial period. Quarterly monitoring provides a quantifiable measure of progression of rehabilitation (or lack thereof) and will provide an indication of whether the system is successful following the two year period. Future bi-annual monitoring will measure the stability of the system as well as aim to detect potential changes occurring at the rehabilitated sites.

A rehabilitation monitoring program has previously been undertaken on the site, although this was suspended under the previous operators during the care-and-maintenance period. Wirralie will look at actively re-establishing this program to improve the available understanding of the success of previous rehabilitation programs and to inform future programs.

The rehabilitation assessment will utilise contemporary monitoring techniques, including monitoring of suitable analogue sites to develop site-specific rehabilitation success criteria. Wirralie will use the principles of Landscape Function Analysis to obtain information on the success of rehabilitation by drawing comparisons to control/analogue sites for a variety of target values.

Landscape Function Analysis

The primary goal of rehabilitation is to restore or replace missing or ineffective processes in the landscape in order to improve the soil habitat quality for desired biota. To gauge the progression of rehabilitation at Wirralie, annual monitoring using landscape functional analysis (LFA) methodology is recommended. LFA is a cost-effective monitoring procedure that uses simple indicators to provide a broad scale assessment relating to how well the rehabilitated ecosystem works as a biogeochemical system. This type of analysis allows a landscape to be categorised into a highly functional or highly dysfunctional system.

LFA is often used on rehabilitated mine sites to assess the biophysical functioning of the ecosystem in terms of soil habitat present. These assessments determine how sustainable the landscape is when presented with possible disturbance, high rainfall events or various climatic conditions. The LFA process provides a snapshot of how rehabilitation is performing and whether vegetation will be sustainable over a long period of time.

Tongway and Hindley's (2004) *Landscape Function Analysis: Procedures for monitoring and assessing landscapes* with special reference to mine sites and rangelands is considered a

best practice guide for LFA that will be consulted for future monitoring events. Monitoring will entail seven fundamental processes, the details of which are provided below:

1. Establishing a series of analogue (reference) and test (rehabilitated) sites where 50m vegetation transects can be established to monitor the progress of rehabilitation over time. Sites are to be established within the initial monitoring event.
2. Identifying features of the landscape such as length and width of patches and interpatches while walking along the transect. Patches accumulate resources by trapping litter, nutrients and water. These patches create an environment that is ideal for the establishment and germination of plant species, positively contributing to the rehabilitation process. Interpatches are the spaces between patches where nutrients are quickly transported over an area (e.g. areas of bare soil). Generally, a healthier landscape could be considered one with a high patch to interpatch ratio as little organic material and topsoils are lost to the system.
3. Measuring patch and interpatch distances to gauge the potential energy that could be caused during a high rainfall event. The larger the distance between the patches and inter-patches the more risk of erosion (hill-slope assessment).
4. Characterising the soil surface properties (soil surface assessment of the patches and interpatches). Characteristics include: rain-splash protection (vegetative or other protection of the bare soil), perennial vegetation cover, litter cover, cryptogram cover, crust brokenness, erosion type and severity, amount of deposited materials, surface roughness, surface resistance to disturbance, stability following rapid wetting and soil texture.
5. Using quadrats within transects to quantify vegetation cover.
6. Scoring habitat complexity for faunal habitat potential by assessing the habitat features of a given area to identify the development of environmental niches provided for vertebrate fauna. Habitat as well as vegetation descriptions and condition notes are to be recorded These assessments determine how sustainable the landscape is when presented with possible disturbance, high rainfall events or various climatic conditions.
7. Repeat LFA processes annually and compare the aforementioned characteristics over time.

Annual monitoring of the analogue sites will determine the response of native grasses, herbs, shrubs and tree species to the natural fluctuations in the environment, and after a sufficient amount of data has been obtained, final rehabilitation success criteria will be determined for the rehabilitation sites.

7. Proposed Rehabilitation Acceptance Criteria

Measuring revegetated sites against control/analogue sites provides a comparative basis for assessing the success of rehabilitated areas. The success of rehabilitation is determined by the continued progression, stability and self-sustainability of the revegetated system. It is expected that rehabilitated sites eventually reach the same level of landscape functionality as a given control/analogue site.

Monitoring using LFA methodology assists in determining whether resources are being lost or gained at the rehabilitated site. Loss of landscape function indicates that the site is losing

resources (such as nutrients due to lack of groundcover) and an increase in function gain indicates that the site is maintaining resources, which is a step toward self-sustainability and therefore successful rehabilitation (Tongway and Hindley 2005).

Conclusion and Recommendations

The Wirralie TSF covers an area of 72ha, with 3.5ha available to trial a number of rehabilitation options. By initiating a large scale trial within the early operational and processing phase of the project, sufficient timescale should be available to examine a number of rehabilitation techniques. By trialling a number of different rehabilitation methodologies and through quantitative analysis of these methods, an appropriate large scale cover method should be indicated within the two year period. Additionally, rehabilitation acceptance criteria will then be developed for application to the TSF.

References

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Appendices