2012 Workshop on Environmental Management

GOLDFIELDS ENVIRONMENTAL MANAGEMENT GROUP

PROCEEDINGS

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FOREWORD

AngloGold Ashanti is one of the leading global gold mining companies with 20 operations spanning 10 countries on four continents as well as an extensive portfolio of exploration tenements in both established and new gold regions across the globe. AngloGold Ashanti is committed to fulfilling its obligations and duties as a responsible corporate citizen, ensuring that its behaviour reflects its values and concerns for its stakeholders, including shareholders, employees, their families and the communities and environments in which we live and work.

For AngloGold Ashanti, sustainability is important because we believe that the wellbeing of society and the natural world is critical for businesses to thrive and create value. Our vision is to be the leading mining company, and we will only achieve this vision if we can prove our ability to operate sensitively to and with our host communities, demonstrating that we will partner with them to create enduring value.

Sustainability focus areas for the business include safety, health, community relationships, human rights and environmental and natural resource stewardship. We need to be mindful of these issues during the full lifecycle of our operations, to ensure orderly closure of our operations and that we leave communities better off for our presence.

With these principles in mind, AngloGold Ashanti Australia is proud to be the major sponsor of the 2012 GEMG Workshop, and is committed to supporting leading environmental practices across the industry.

In conducting this environmental management workshop, the Goldfield Environmental Management Group aims to facilitate the transfer of knowledge between environmental practitioners to achieve environmental excellence in the WA mining industry.

As one of the few truly “environmental practitioner” focused workshops, this forum is critical to the success of mining industry in achieving a sustainable outcome. This workshop provides an invaluable forum for sharing knowledge and experiences in environmental management initiatives within the mining industry throughout Western Australia.

AngloGold Ashanti wishes you all the best for the workshop, and we hope that the knowledge and contacts you gain at the workshop will continue to move our industry forward on the journey to providing leading environmental practices.

Mike LeRoy
Vice President: Sustainability

INTRODUCTION TO THE GEMG

The Goldfields Environmental Management Group (GEMG) is a technical and professional body of people working to achieve environmental excellence. Most of our members are located in the city of Kalgoorlie-Boulder situated in the Eastern Goldfields region of Western Australia.

The GEMG provides a source of expertise and information on environmental management practices with a focus on arid and semi arid environments exploring such issues as protection of biodiversity, mine closure and rehabilitation, environmental management systems, environmental culture and management of water issues.

The GEMG achieves this by providing information and education to the public and industry with a key component being the sharing of knowledge and information between members. The GEMG conducts biennial workshops which are an important component in achieving the above, and are highly regarded for their low cost, high standard and productivity.

The GEMG was formed in 1988 by a small number of individuals involved in land rehabilitation in the Eastern Goldfields region of Western Australia. Today we have approximately 200 members from a broad range of backgrounds such as government organisations, consultants, rehabilitation contractors and mine-site environmental personnel.

"Cover image of *Eremophila punicea* provided by Andrew Brown and Bevan Buirchell,
authors of A Field Guide to the Eremophilas of Western Australia (2011)"

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A Fish Called Telfer -
When Wastewater Demands Out of the Box Thinking...

Renee Berry, Newcrest Mining Pty Ltd

Abstract

The O'Callaghan's deposit is located approximately 10 km south of Newcrest's Telfer Gold Mine within the Great Sandy Desert of Western Australia. The potential O'Callaghan's project is currently in the pre-feasibility stage, and one of the key aspects for consideration is water management. The deposit is likely to yield a significant amount of water of variable quality. The primary use of the water will be in the Telfer process plant, however there is a need to manage the excess as discharge to the receiving environment is not possible due to environmental considerations. . The nearest defined river system is 50 km away and is intermittent. Evaporation ponds, if used as a management strategy for excess water, would need to be significant in size thus requiring the clearing of vast areas of land. While several options, including pit storage and reinjection, are being considered at present, the option of an algaculture and aquaculture plant has several key benefits which may make it an attractive opportunity for inclusion in the project scope.

In theory both algaculture and aquaculture can make use of mine dewater and wastewaters, adding profitability from by-products. Newcrest is currently investigating the option for a self sustaining, stand alone, algaculture system to produce algal biomass for biofuel processing, with the option of an additional aquaculture component to produce fish fit for human consumption.

The O'Callaghan's Project may require a system designed for an indicative waste water input of 10ML/day, with outputs being:

- algal biomass to produce biofuel on site;
- potential in the future to use micro-algae to bio-sequestrate carbon from mine waste water and industrial exhaust carbon sources (such as vent rises from the underground mine),
- use of post process algae as organic medium for rehabilitation programs; and
- potential production of fish as a food source for human consumption.

The system being considered as a potential option for the O'Callaghan's Project may incorporate an aquaculture (fish farm) system once the algaculture has been proven to work effectively at Telfer for managing water. An addition of aquaculture to an already functioning algaculture system is a cost effective way of supplying nutrients, a more sustainable natural system and offers greater opportunity for regional employment.

The use of algae in a mining environment presents a number of opportunities for efficiencies and management of excess water and waste products. For a non-discharge site, water has traditionally been stored in either dams or disused open pits, and either evaporated, or utilized in the process plant where possible. More recently, reinjection has been used as a means for returning water to the aquifer. However, when challenges to reinjection occur (such as troglofauna habitat, or interconnected aquifers such that reinjection would cause significant recharge to the mine), algae farming may be considered as an effective way to manage excess water at the O'Callaghan's Project.

Introduction

Water management in an arid environment is often a balancing act between finding enough water to allow mining and processing to take place, and managing an excess of water with stringent discharge requirements.
Water can be introduced to the mine footprint via:

- groundwater ingress to surface or underground operations;
- surface water runoff from disturbed or utilized areas;
- open pits, acting as catchments for runoff; and
- recharge (particularly when discharging to a salt lake, or reinjecting back into the aquifer.

Once water has been introduced to the mining system, it must be managed in accordance with license conditions. These vary from site to site, but usually include conditions related to the amount of water that can be discharged, water quality requirements for discharge, and management of potential impacts associated with discharge.

Methods of water disposal from mining operations may include (depending on regulatory conditions):

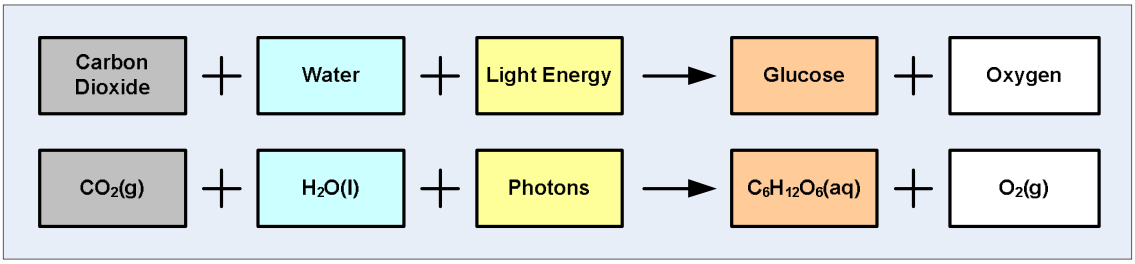
- Use in processing facilities on site;
- Storage/evaporation;
- Discharge to a water body (including streams, rivers, salt lakes, marine environments, etc.);
- Sale or gifting of water to other users (including towns, pastoral stations, etc.); or
- Reinjection to an existing groundwater aquifer.

In addition to the above disposal options for managing excess water, the use of algae as a method of sequestering carbon and extracting biofuel makes algae farming a potentially attractive use for excess wastewater in a no-discharge environment.

Microalgae and the Production of Biofuel

Microalgae are free floating, photosynthetic organisms that produce lipids, which can then be processed into oil. The chemical equation for this process is as follows:

Figure 1: Microalgae Oil Production Equation



Using this process, algae biofuel can be produced at a rate of approximately 55,000 litres per hectare of ponds (of depth 1.5m), per annum in an unmanaged environment, or up to 100,000 litres per hectare per annum with various management techniques (outlined further below). This yield consumes approximately 1.6 million tonnes of atmospheric carbon dioxide per hectare, per annum (Algorythm Pty Ltd 2012).

A number of studies (e.g. CSIRO 2009) have examined the possibility of using algae to sequester carbon and to generate end products such as human food supplements, animal feed, biodiesel and cosmetic oils.

Some of the perceived advantages of microalgae are as follows:

- Fast growing;
- Significantly higher biofuel yield per hectare than oil plants;
- Can sequester excess carbon dioxide as hydrocarbons;
- Produce a fuel that contains no sulphur, low toxicity, and is highly biodegradable;
- Does not compete with food crops as many biofuels do; and
- Can be produced with saline water, in non-arable climate/land areas, (CSIRO 2009).

In addition to the above benefits, the introduction of aquaculture (fish farming) to the process presents an opportunity for further return on investment and waste product utilization.

Microalgae Farming – The Process

There are a number of ways to establish a microalgae farming process (CSIRO 2009, Algorythm 2012). The pilot plant established by Algorythm Pty Limited in South Australia utilizes the following infrastructure on a small (1 hectare) scale:

- 5 ponds lined with bentonite to prevent seepage;
    - Pond 1: water balancing pond, designed to maintain optimum salinity and water levels between remaining ponds and for storage of groundwater introduced to ponds system;
    - Pond 2: fish pond, where fingerlings are raised to adulthood, feeding off algae waste product. During initial startup when algae waste product is not available, other waste products such as grain waste can be used for fish food;

- Pond 3: initial algae growth pond (algae is introduced through either direct propagation, or is propagated with airborne copepods), using **Oloids** to generate a uniform distribution of algae growth throughout the water column;
  - Pond 4: concentration of algae using an **Algae Photobioreactor**;
  - Pond 5: **Greenhouse** harvesting of oil product and algae biomass, and recycling of waste water to Pond 1;
- Gravity or solar pump system to feed water between the ponds;
- Maintenance chambers for flow isolation, removal of detritus (e.g. branches) from ponds, and isolation of predators if necessary;
- Pond depth of 0.5 – 1.5m for maximum algae growth.

There are numerous algae species that lend themselves to biofuel production and carbon sequestration. Table 1 below outlines two species, and their growth rates and tolerances.

Table 1: Optimum Algae Farming Species

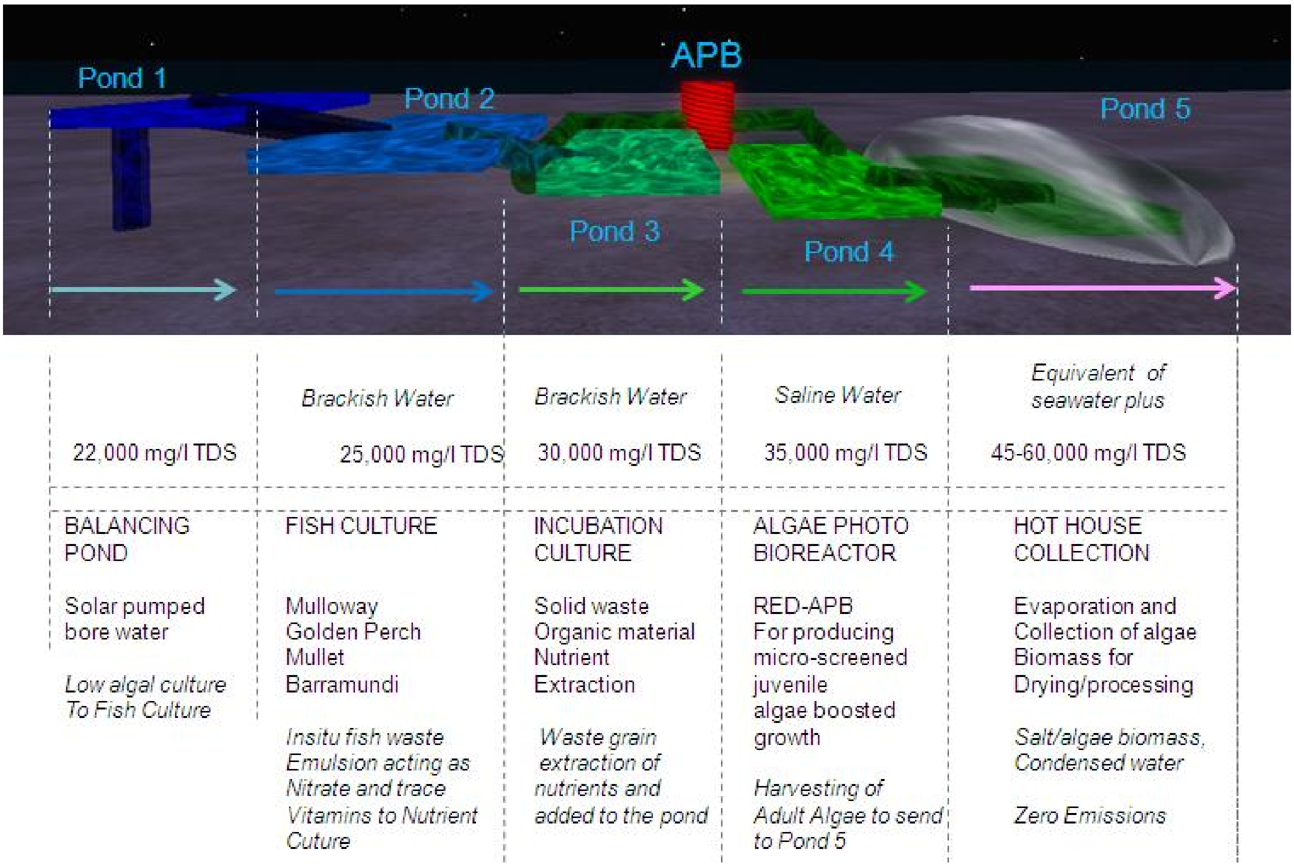
	Chorella sp.	***Dunaliella sp.***
Growth Rate	1.6 x per day	2.1 x per day
Temperature Tolerance	Up to 40°C	10°C - 45°C
Salinity Tolerance	Up to 25,000 mg/l TDS	>25,000 mg/l TDS (limit of 60,000 mg/l TDS)

(Algorythm 2012).

Algae from the above system can be harvested every 10-15 days. The three features highlighted in bold (Oloids, Algae Photobioreactor, and Harvesting Greenhouse) represent management techniques that have the potential to increase yield to approximately 100,000 litres per hectare per annum (Algorythm 2012).

This process is currently being trialed at Darke Peak in South Australia and is summarized by the diagram below.

Figure 2: Darke Peak Microalgae Production Layout



(Algorythm 2012).

Enhancing the Process

As outlined above, there are a number of ways to enhance the algae production process to obtain maximum yields. These are outlined in brief below.

Oloids

An oloid is a convex shape made by intersecting two congruent discs at right angles to each other, so that the distance between their centres is equal to their radius (Dirnböck, H. & Stachel 1997). The oloid was discovered by Paul Schatz in 1929, and is used to create an even flow, as the object rolls smoothly on itself due to the distance between the two congruent discs.

An oloid, when used to agitate the pond surface in this setting, achieves an even mixing of algae culture within the water column, increasing algal biomass to all depths of the pond. As a result, oloids are able to achieve a number of efficiencies and improvements to the standard microalgae pond production, including:

- Boosting growth;
- Concentration of algae within the ponds;

- Reducing oxygen available for airborne predators; and
- Eliminating mosquito production.

Algae Photobioreactor

A photobioreactor is a closed system which provides controlled access to light. Photobioreactors consist of transparent tubes, cylinders or plates that receive a high density culture of algae under daylight conditions, and are exposed to infrared lighting to extend the photoperiod of the culture. A regulatory 'dark' phase is retained; however this is shorter in time than the natural dark period during a day. The longer 'daylight' period enhances the growth rate of the algae culture.

Algae photobioreactors can be used at various stages in the production process. At the Darke Peak trial, the culture enters the photobioreactor at Pond 4, and is continuously pumped through the light/dark circuit, adding water borne nutrients (preferably wastewater) to improve growth. This continues until a uniform, high density culture is formed (with a toothpaste-like consistency), at which point the adult cells (culture) are harvested.

Harvesting Greenhouse

There are a number of ways and steps in which algae culture may be harvested. Typically, the oil is skimmed off the surface, and algae biomass is extracted via centrifuge, evaporation or a press mechanism. At the Darke Peak trial, a harvesting 'greenhouse' is utilised to harvest algae, as follows:

- Adult algae cells are transferred to Pond 5, which is covered in a plastic film to create a greenhouse environment;
- The water in this pond, through evaporation and concentration, reaches salinity levels of over 60,000 mg/l TDS, causing the algae cells to stress. This in turn causes the cells to produce more oil, as a defence mechanism to the saline water, and increases oil production.
- Oil is skimmed off the culture and transferred to storage tanks;
- The remaining algae culture is dried using thermal heating and hydrocyclone technology, creating a 'cake' of residue product which is extremely high in protein;
- The freshwater from condensation is captured and recycled through Pond 1; and
- Salt is captured for sale as a gourmet product.

Aquaculture in the Algae Process

Utilising fish in the algae production process allows for the insertion of a high revenue stream to assist with cost management, and provides a closed loop option for managing the algae waste product (the 'cake' material outlined above has a number of uses, including the production of fish food pellets).

A traditional hatchery is required on site to produce fish to a fingerling size for insertion into the process at Pond 2. Species typically used due to their ability to feed on the algae waste product, and relatively fast growth rate (12 months from fingerling to sale weight), include the Golden Perch (*Macquaria ambigua*) and the Mulloway (*Argyrosomus hololepidotus*). These species are also able to be fed waste from a grain product, or traditional fish food pellets, at the commencement of the process if the algae by-product is not available.

The aquaculture aspect of the algae production chain is not an essential step in the process, however does increase the potential revenue from the system, and also creates the opportunity for additional employment, being particularly suited to indigenous employment in remote areas, or when traditional food supplies have been affected by other activities such as mining.

Limiting Factors

There are a number of factors that limit or prevent the production of algae in the system outlined above. These include:

- Space – the availability of land for development of ponds may limit the amount of algae able to be produced. To effectively operate an algae farm as outlined above, 6 ponds are required (comprising of the 5 outlined above, and an additional containment pond for emergency discharge, if required);
- Salinity tolerance of algae species;
- Water temperature tolerance of algae species;
- Product desired (for example, using *Dunaliella sp.* will allow for the production of beta-carotene oil, and has the advantage of growing at a faster rate than other species);
- Outbreak of disease, mosquitoes and airborne predators (all these occurrences can be treated by dosing ponds with chlorine, however this will also kill the algae, requiring the process of algae production to begin again);
- Control of external algae species that may be introduced via airborne copepods and may out survive the propagated species;
- High levels of copper sulphate in water (which inhibit algae growth); and
- High levels of chlorine in water (which inhibit algae growth).

(Note: the availability of water is also a limiting factor in algae production, however given this paper discusses the use of algae as a means for utilising excess water, the requirement for water is not listed as a limiting factor above).

Summary of Outputs

The outputs available from the algae production are characteristic of an extremely efficient process, with saleable or recyclable products available at each step of the process. A summary of potential outputs from the algae production cycle, include, but are not limited to:

- Biofuel/Oil;

- High grade food and cosmetic oils, including beta-carotene and Omega 3 (approximately 10% of oil from the *Dunaliella sp* is available for this oil production);
- High protein algae cake which can then be utilized for a number of products, including:
    - Cattle salt licks
    - Beer
    - Fish feed
- Food grade salt; and
- Fresh water.

Opportunities

The use of algae in a mining environment presents a number of opportunities for efficiencies and management of excess water and waste products. For a non-discharge site, water has traditionally been stored in either dams or disused open pits, and either evaporated, or utilized in the process plant where possible. More recently, reinjection has been used as a means for returning water to the aquifer. However, when challenges to reinjection occur (such as troglofauna habitat, or interconnected aquifers such that reinjection would cause significant recharge to the mine), algae farming may be considered as an alternative to disposal.

While the startup costs (particularly for elements such as the algae photobioreactor) are significant, the benefits of such a system as opposed to standard evaporation methods for water management include:

- Sequestration of atmospheric and non-atmospheric carbon;
- Production of biofuels or biodiesel for use in the mine;
- Indigenous employment opportunities (which may, if groundwater resources are available post mining, continue after mine closure); and
- Return on investment through the sale of revenue products, including high value beta-carotene oil, and food grade fish.

Bottom Line

The cost of algae production can be as variable as the elements of the process described above. The management of production using algae photobioreactors, oloids and a harvesting greenhouse all involve significant capital costs, which will vary based on the size of the system installed. In addition, return on investment will depend on the algae species used, and the growth rates available due to climate and water quality.

An estimation of some potential returns are listed below:

- 100,000 litres of algae biofuel (the maximum amount so far produced per hectare per annum in a managed environment) is currently returning approximately $5 AUD per litre, indicating a return of $275,000 per hectare per annum (Algorythm 2012);

- 1 million tonnes of algae biomass consumes 1.6 million tonnes of carbon dioxide and emits 1.2 million tonnes of oxygen. This rate of sequestration is ten times more efficient than that of sequestration in a standard forest environment (Algorythm 2012);
- 10% of algae biofuel (or approximately 10,000 litres per hectare per annum) from *Dunaliella sp.* can be converted to beta-carotene oil, which retails at approximately $300/kg.

Conclusion

There is little doubt that to include an algae production farm in a mining process could be considered as innovative, and would involve significant capital expenditure up front, particularly if alternatives such as pit storage or reinjection are available. However, where these options are not available, algae farming may represent an opportunity to obtain greater efficiencies from a waste product, while generating return on investment, or a sustainable food product for indigenous populations that may have been adversely affected by mining.

In a world where a carbon price is a reality and efficiencies with water and energy are considered leading practice, the use of algae may represent a rare opportunity for an aspect of the mining process to become truly sustainable throughout the mining life cycle.

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Ecological Risk Assessment – What Is It And Why Should I Think About Using It?

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Abstract

Environmental risk assessment has been used within the mining industry for a number of years, primarily as a tool to assess the potential impacts of a project or a specific task and to prioritise work programs. It is effective in investigating how a project or activity interacts with the broader environment and generally involves assessment of impacts on flora, fauna, water and air. The management recommendations that come from this assessment process are not usually based upon a detailed understanding of geochemical processes, contaminant transport or ecological toxicity. This may result in recommendations that do not address key contaminant issues at the mine or that are overly conservative, resulting in unnecessary capital expenditure.

Ecological Risk Assessment (ERA) is a more specialised and targeted means of assessment that is now being used in the mining approval process. It provides a set of formal, scientific methods used for defining and estimating the probabilities and magnitudes of adverse impacts on plants, animals and/or whole ecosystems posed by a particular contaminant or stressor. The ERA process identifies ecological receptors of concern, estimates the contaminant concentration that they may be exposed to and based on the magnitude of this concentration, determines whether they are at risk.
Mine sites typically have complex environments, with a range of factors including:

- Soil, rock, waste rock and tailings geochemistry.
- Hydrology and hydrogeology.
- Design requirements for waste rock dumps and tailings storage facilities.
- Presence of pit lakes.
- Processing plants and other infrastructure.
- Sensitive receptors such as flora, fauna, human health and livestock.

Conventional environmental risk assessment methodologies were not established to deal with this level of complexity. In contrast, the ERA process is based upon a comprehensive appraisal of contaminant exposure pathways and toxicity in the receiving environment. Recommendations from this risk assessment process can be tailored to more effectively suit the specific geochemical and ecological environments surrounding a project.

MBS Environmental has been undertaking ERAs for a range of mining projects in Western Australia and Queensland. It has been an invaluable tool in the assessment of issues such as:

- Potential locations for a new tailings storage facility.
- Alternative tailings disposal forms including paste or slurry.
- Final product/concentrate transport route and associated port storage and ship loading options.
- Disposal of tailings to a historical pit lake.

This paper focuses on the latter as a case study. The proposed project involves disposal of both nickel concentrator and gold carbon-in-leach (CIL) tailings into a historic pit lake in the northern Goldfields. The discussion will address why an ERA approach was recommended to the client,

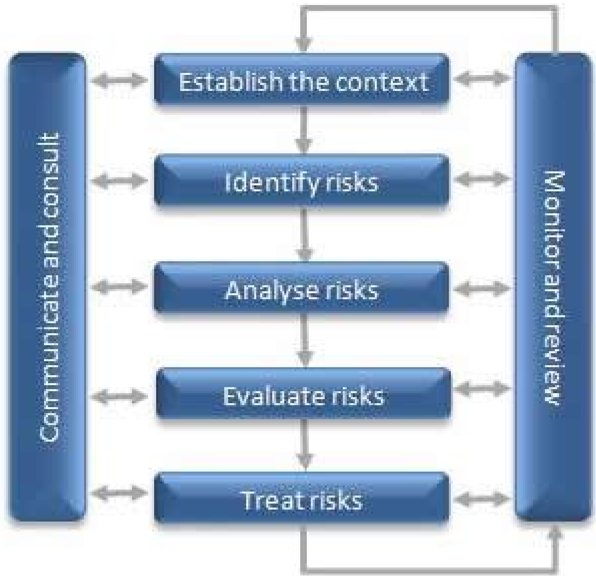
results of the ERA and practical outcomes of the ERA including how it supported project planning and the environmental impact assessment process.

Introduction

Risk Assessment in the Mining Industry

In the mining industry, the management of environmental risks associated with a project or specific activity has been based primarily upon the risk management process depicted in Figure 1.

Figure 1: Risk Assessment Process (Australian Standards 2009)



This approach is acceptable for activities commonly associated with mining projects (including land clearing, mine development, construction and processing) for which there is a large volume of scientific information and past experience. Risks can be identified, analysed and evaluated with a fair degree of certainty. Many potential environmental impacts associated with these activities also have a very prescriptive set of legislative requirements such as specific parts of the *Environment Protection Act 1986* (EP Act) in relation to the clearance of vegetation and licensing conditions specified by the Department of Environment and Conservation (DEC) such as emissions and discharges to the environment.

The EP Act and *Contaminated Sites Act 2003* have been legislated to prevent ‘potential or actual harm to the environment’. The *Mining Act 1978* requires the achievement of a ‘safe and stable landform’ upon mine closure. If an organisation is using a risk management approach to demonstrate best practice or compliance with these legislative requirements, it requires a risk analysis tool that not only demonstrates sound understanding of environmental processes, contaminant transport and ecological toxicity, but is also presented in a form recognised and accepted by the regulators.

Ecological Risk Assessment (Value and History)

Ecological Risk Assessment (ERA) emerged in Australia during the 1990s as a more targeted tool to assess risks posed by particular stressor/s to flora, fauna or an ecosystem. The value of an ERA is that the risk assessment process is based upon a comprehensive appraisal of the local environment, including contaminant exposure pathways and toxicity in the receiving environment.

The ERA has its origins in the assessment of existing contaminated sites using methodologies developed by the United State Environmental Protection Authority (USEPA) in the 1980s. In Australia, the framework for an ERA was first presented in the Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites (ANZECC and NHMRC 1992). At the time it was based upon the USEPA model and comprised four main phases: data collection and evaluation; toxicity assessment, exposure assessment and risk characterisation. A *Guideline on Ecological Risk Assessment* (NEPC 1999 and NEPC 2011) was developed in the late 1990s and recently revised, by the National Environmental Protection (Assessment of Site Contamination) Measure (NEPM). Development of ERA methodologies in Australia was also further enhanced by the risk-based hierarchical assessment process adopted in the National Water Quality Management Strategy – Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ 2000).

MBS Environmental has adapted the ERA tool in two ways to facilitate the decision making process for a project:

- The assessment process now considers a broader range of receiving environments which commonly need to be addressed for a project including geochemistry, surface water, groundwater, flora, fauna, heritage and human populations.
- Similar to its former use in contaminated site assessments, the adapted assessment process can focus on existing contamination issues, but can now also be used to predict and characterise ecological impacts from potential future issues.

The Role of ERA in Decision Making

ERA can assist decision making by providing the following:

- Evaluation and comparison of design options or process scenarios.
- Guidance for controls required at the design, commissioning, production or closure stages of a project to assist meeting environmental goals.
- Technical supporting documentation for project approval documents.
- Design of monitoring programs.

Given that the application of ERA to the mining industry is fairly new, this list is not considered to be exhaustive. Often when there are uncertainties associated with a project due to limited available technical data, ERA can identify key risks that need to be addressed to enable a project to move forward.

Level of Detail Required for an ERA

As with many forms of assessment, the level of detail required for an ERA will depend on a combination of factors including the availability of data and other relevant studies and the nature of potential consequences and perceived risks. The three levels of detail that an ERA can be conducted are shown in Table 1.

Table 1: Levels of ERA (NEPC 1999 and NEPC 2011)

Level	Description
1	A desktop assessment involving screening contaminant concentrations against generic ecological screening levels (such as DEC 2010 or ANZECC & AMRCANZ 2000). Limited consideration of site specific aspects of project environmental setting, contaminant transport behaviour, fate and/or ecological toxicity.
2	A comprehensive desktop assessment, with some field studies. This level applies more specific ecological screening levels. It often involves predictive modelling, transport behaviour, fate and/or ecological toxicity of contaminants supported by geochemical modelling and detailed receptor toxicological review.
3	A comprehensive desktop assessment, with more sophisticated field studies. This level applies specific ecological screening levels determined via detailed ecotoxicology survey and laboratory test work. Predictive modelling, transport behaviour, fate and/or ecological toxicity effects of contaminants are usually more detailed and may also be supported by longer term geochemical or remedial test results (such as column leachate tests or remediation field trials).

For the majority of projects to date at MBS Environmental, a Level 2 assessment has provided an effective outcome, balancing the need to adequately address perceived risks, with the constraints of available scientific data. In several cases, where the toxicity of potential contaminants to particular species was not well understood and perceived risks to the receiving environment were high, a Level 3 assessment has been more suitable.

Key Elements of ERA Methodology

The core structure of an ERA comprises the following key elements (NEPC 2011):

- Problem identification.
- Receptor identification.
- Exposure assessment, including development of a conceptual site model.
- Toxicity assessment.

- Risk Characterisation.

These elements are discussed in the following sections.

Problem Identification

The problem identification phase is similar for all levels of assessment. It identifies the problems and issues on which to focus the ERA process. Problems typically involve a release or potential release of contaminants to the receiving environment.

Contaminants of concern are identified as part of the problem identification and are established via a review of potentially contaminating activities that may be associated with a project or activity. Typical examples of contaminants of concern associated with common mining activities are shown in Table 2.

Table 2: Typical Contaminants of Concern for Mining Activities

Activity	Typical Contaminants of Concern
Tailings Storage	Various metals and metalloids, cyanide, acidity, sulphate, salinity, neutral to alkaline drainage waters with elevated toxicants such as selenium.
Waste Rock Storage	Various metals and metalloids, salinity and natural asbestiform minerals.
Sewerage Treatment	Nutrients and biological pathogens.
Mineral concentrate storage, handling and transportation	Metals and metalloids associated with dominant minerals.
Diesel fuel facilities and mechanical workshops	Petroleum hydrocarbons and polycyclic aromatic hydrocarbons.

Receptor Identification

Receptor identification involves the assessment of ecological values associated with a site, followed by the identification of sensitive organisms or ecological communities associated with these values. Typical examples of ecological values and specific receptors that require protection are shown in Table 3.

Table 3: Receptor Identification Based on Ecological Values

Ecological Value	Sensitive Receptor Examples
Health and biodiversity of playa lake ecosystems.	Fringing woodland and halophyte communities, salt lake micro and macro invertebrates.
Health and biodiversity of ephemeral creek ecosystems.	Vegetation communities and livestock, rare and endangered flora and fauna, aquatic communities.

Ecological Value	Sensitive Receptor Examples
Health and biodiversity of groundwater dependent ecosystems.	Woodland, birds, amphibians, tall mulga, stygofauna and troglofauna.
Health and biodiversity of marine and estuarine ecosystems in the vicinity of export shipping facilities.	Fish, birds, reptiles, molluscs, crustaceans, flora and fauna in the water column and underlying marine sediments, and humans.
Agricultural land use.	Crop plants and livestock.
Potable water resources.	Pastoral station residents, town water supply.
Human health.	Employees and contractors at the mine, rural residential and urban residential.

Exposure Assessment

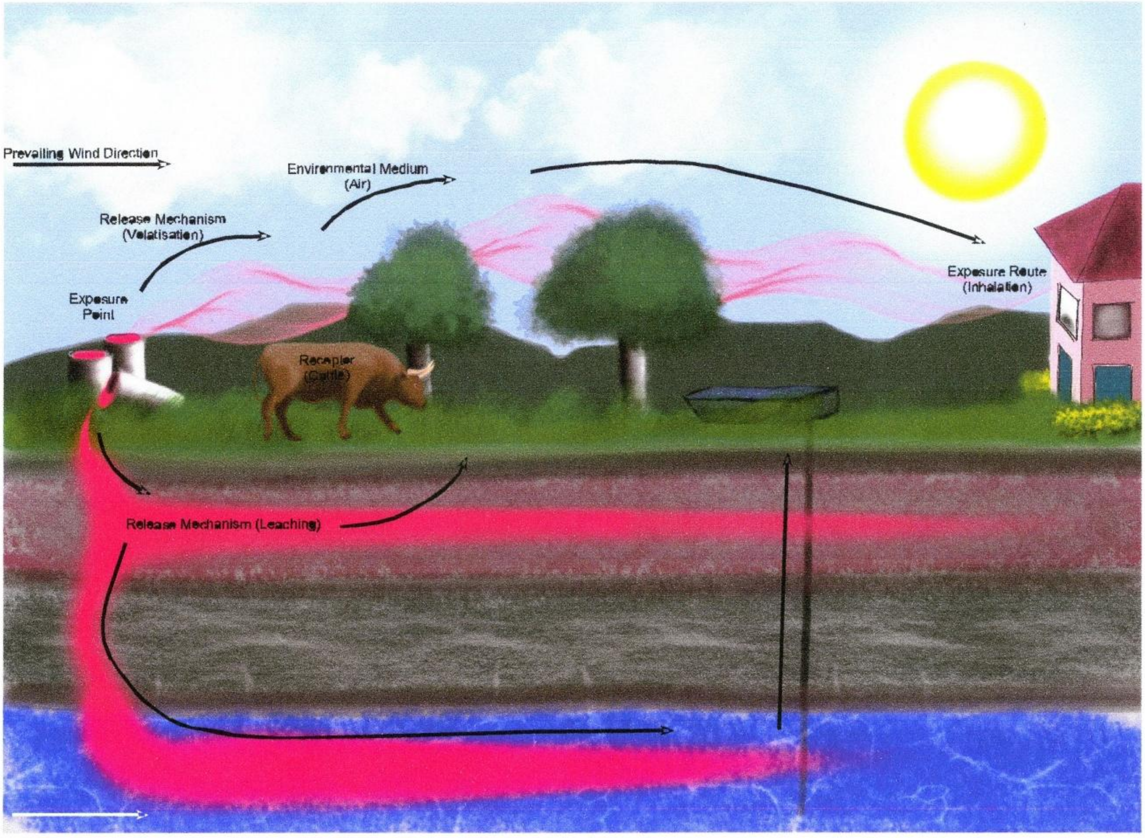
Exposure assessment identifies the mechanisms in which contaminants of concern are exposed to ecological values and receptors. This typically comprises the characterisation of contaminant release mechanisms, exposure pathway media, fate and transport mechanisms and reception mechanisms. Examples of these exposure assessment parameters are shown in Table 4.

Table 4: Examples of Exposure Assessment Parameters

Exposure Assessment Parameter	Examples
Release Mechanism	Chemical spillage, leakage, tailings or waste rock dump seepage, dust generation, transportation collision or container failure.
Exposure Pathway Media	Surface water, groundwater, air, sediment, soil, food.
Fate and Transport Mechanisms	Processes such as mixing, dispersion, mineral dissolution and chemical environments that control solubility such as pH and materials that may adsorb contaminants such as clays and iron oxide minerals.
Reception Mechanisms	Inhalation, ingestion and dermal absorption by humans and fauna, root uptake of bioavailable contaminants, leaf tissue absorption, uptake of bioavailable contaminants by flora and fauna in sediments or within the water column.

The objective of exposure assessment is to identify critical pathways from contaminant release to reception in the surrounding environment. These critical pathways are best presented schematically as a conceptual site model (CSM), such as the example shown in Figure 2. Conceptual site models provide a means in which to visualise the exposure assessment, summarising the release mechanisms, exposure pathways, environmental fate and transport aspects, as well as the reception mechanisms.

Figure 2: Example of a Conceptual Site Model (CSM) (MBS 2012)



Toxicity Assessment

Toxicity assessment determines the likely dose - response relationship for sensitive receptors in terms of the contaminant concentration and form that they may receive.

A Level 1 ERA toxicity assessment involves the screening of contaminant concentrations against either generic ecological screening levels (such as DEC 2010 or ANZECC & ARMCANZ 2000) or pre-determined site-specific ecological screening levels.

Level 2 and 3 assessments necessitate more targeted dose - response data which may be obtained by characterisation of the following:

- Relative toxicity of dominant chemical forms of the contaminant. In some cases, particularly in relation to heavy metals, toxicity can be significantly reduced in environments that have elevated salinity, alkalinity or are rich in organic materials. This can be established by geochemical speciation modelling and literature review.

- Bioavailability of dominant chemical forms of the contaminant. In many cases bioavailability is limited by processes such as solubility and adsorption. This can be established by geochemical speciation modelling and literature review.
- Bioaccumulation of the contaminant by an organism. This is largely determined by how the organism metabolises the contaminant and can be established via literature review or through chemical analysis of plant/animal tissue.
- Biomagnification of a contaminant in a food chain. This is largely dependent upon the type of organisms that are vulnerable to bioaccumulation of a contaminant and their respective position in the food chain. This can be established via literature review or through chemical analysis of plant/animal tissue.

Risk Characterisation

Using findings from the exposure and toxicity assessments, the risk characterisation phase evaluates the likelihood of contaminants of concern impacting on ecological values and receptors and predicts the level of impact that they will be subject to. Risk is calculated using a risk matrix developed via the principals of AS/NZS ISO 31000:2009 (Risk Management – Principles and Guidelines) (Australian Standards 2009).

Case Study - Windarra Nickel Project

Project Description

The Windarra Nickel Project (WNP), owned by Poseidon Nickel Limited (Poseidon), is located 260 kilometres north-north-east of Kalgoorlie and 20 kilometres north-west of Laverton. The WNP involves recommissioning and expansion of historic nickel and gold mining operations that commenced in 1969 and were last operated in 1994 (MBS 2012a).

Proposed processing infrastructure at the WNP consists of a nickel concentrator and a carbon-in-leach (CIL) plant. Tailings from each of these facilities will be combined to produce a single waste stream for disposal to an existing pit lake, located 16 kilometres to the south-west (Coffey Mining 2011 and Coffey Mining 2012). This method of tailings disposal equates to a form of subaqueous deposition, with all material remaining below water for the duration of the project and post-closure (MBS 2011a and MBS 2011b).

This approach would provide a number of environmental benefits, but also raised concerns regarding the fate of residual cyanide in gold tailings and interactions with sulphide minerals in nickel tailings (MBS 2011a). To address this issue, the option of sophisticated numerical modelling was considered. However, it was concluded that the complexity surrounding the fate and transformation rates of cyanide from the gold tailings would be subject to a large margin of error and would result in unreliable conclusions. As an alternative, a Level 2 ERA was undertaken to provide a more pragmatic, risk-based approach to inform decision-making processes.

Problem Identification

The objective of the study was to evaluate the magnitude of risk posed to sensitive receptors in the immediate vicinity of the pit lake as a result of co-disposal of gold and nickel tailings (MBS 2012b). The study identified key contaminants of concern via several information sources which included process design documents, waste characterisation reports (GCA 1993; MBS 2011a; and MBS 2011b), contaminant accumulation modelling and experimental laboratory trials (MBS 2012b). The key contaminants of concern that became the subject of the study were (MBS 2012b):

- All forms of cyanide including free cyanide (HCN and CN-), thiocyanate (SCN-), cyanate (OCN-) and various Weak Acid Dissociable (WAD) cyanide-metal complexes (which include copper and nickel cyanide complexes).
- Soluble metals and metalloids: arsenic, boron, cobalt, cadmium, copper, manganese, nickel, selenium and zinc.
- Inorganic anions: nitrate and sulphate.

This paper focuses on three of these contaminants of concern, notably cyanide, nickel and sulphate.

Receptor Identification

Ecological values identified in the study were based upon flora and fauna surveys in the vicinity of the project, geological studies of the pit and a review of beneficial water uses in the area. The following ecological values were identified (MBS 2012b):

- Human health of WNP personnel and other contractors.
- Groundwater quality for the purpose of stock drinking water.
- Health and biodiversity of native fauna that may use the pit lake as a drinking water source or habitat.
- Health and biodiversity of groundwater dependent ecosystems (particularly flora that may depend upon alluvial aquifer water resources).

A set of sensitive receptors associated with these ecological values was then identified. Sensitive receptors included (MBS 2012b):

- WNP personnel and site visitors in the immediate vicinity of the tailings outlet into the pit lake and return water process flows.
- Livestock using two stock bores located approximately two kilometres hydraulically down gradient of the pit lake.
- Significant fauna with a reasonable potential to occur in the vicinity of the pit lake; birds such the Australian Bustard, Peregrine Falcon or Rainbow Bee Eater and marsupials such as the Long-tailed Dunnart.
- Tall mulga vegetated areas within the ephemeral creek lines located approximately 1.4 kilometres west of the pit lake.

Exposure Assessment

Contaminant Transport Media

To enable examination of contaminant flow paths, the following contaminant transport media were identified in the ERA (MBS 2012b):

- The pit lake water body.
- Process return water flows from the pit lake.
- Groundwater transport in the surrounding upper alluvial and lower fractured rock aquifers.
- Air immediately above the pit lake and process return water flows.

Contaminant Fate and Transport

One of the central elements of the ERA was to understand the fate and transport of cyanide species in the pit lake. The fate and transport conceptual model is presented in Figure 3. It assumes that a significant amount of total cyanide is removed from the lake and return water streams via the following processes (MBS 2012b):

- Formation of thiocyanate due to an abundance of sulphide in the process tailings stream that will eventually biodegrade within the pit lake and surrounding aquifers.
- Formation of metal-cyanide complexes, particularly nickel-cyanide, that will eventually biodegrade within the lake and surrounding aquifers. No formation of iron-cyanide complexes due to an absence of iron in process water streams or the pit lake.
- Formation of cyanate that rapidly hydrolyses and oxidises into more biodegradable forms.

The remaining free cyanide was assumed to be subject to volatilisation and oxidation by sunlight. However the rate of volatilisation was significantly slower than normally occurs upon a tailings storage facility, due to the depth of the pit lake.

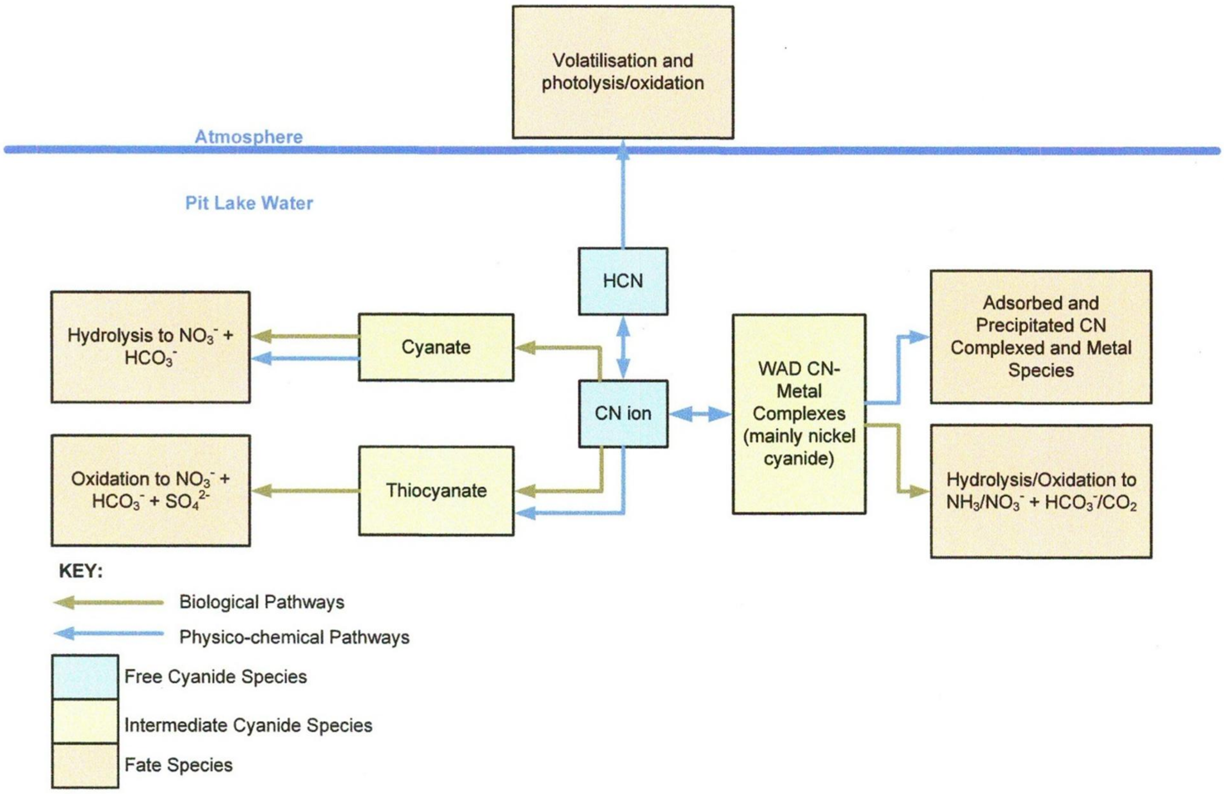
All other contaminants such as nickel and sulphate were assumed to be progressively removed from the water column by surface adsorption to tailings, sediments and pit wall regolith.

Contaminant Reception Mechanisms

To qualify the manner in which contaminants are most likely to be received by sensitive receptors, the following reception mechanisms were identified via the ERA process (MBS 2012b):

- Inhalation and dermal exposure in the immediate vicinity of the tailings discharge point and return process water by WNP personnel and contractors.
- Incidental inhalation, ingestion and dermal contact of impacted pit lake water by significant fauna.
- Ingestion of impacted groundwater by stock using the two stock bores down gradient of the pit lake.
- Root uptake of bioavailable contaminants in groundwater by mulga vegetation.

Figure 3: CSM for Cyanide Species (MBS 2012b)



Toxicity Assessment

The ERA process requires an assessment of how toxic contaminants will be when they are received by sensitive receptors. The toxicity assessment was undertaken as a detailed literature review, as this was appropriate for a Level 2 ERA. The intention of the literature review was to qualify the relative toxicity attributes of the contaminants such as toxicity, bioavailability, bioaccumulation and biomagnification.

In summary cyanide is considered the most toxic in the form of free cyanide rather than thiocyanate, metal-cyanide complexes or cyanate. Cyanide in the form of free cyanide is readily absorbed into the body through inhalation, ingestion and dermal contact. Most organisms rapidly detoxify cyanide via the formation of less toxic compounds such as thiocyanate. These less toxic by-products can be readily expelled from the organism.

Metals such as nickel are micro-nutrients in low concentrations, but display various forms of metabolic toxicity at elevated concentration. These contaminants have relatively low volatility and solubility in the membranes of most organisms and thus the main bioavailable pathway is digestion or root uptake. These contaminants are not often subject to bioaccumulation and biomagnification.

Inorganic compounds such as sulphate are recognised as environmental stressors due to the associated salinity and accompanying osmotic stress in exposed organisms. These contaminants are also not subject to bioaccumulation and biomagnification (MBS 2012b).

Risk Characterisation

The study examined a total of 92 contaminant reception scenarios, focussing on the likelihood of various contaminant releases and exposure pathways and anticipated impacts on the receiving receptors (MBS 2012b). The risk characterisation was undertaken using an evaluation of probability and consequence, based upon the principles of AS/NZS ISO 31000:2009 (*Risk Management – Principles and Guidelines*) (Australian Standards 2009).

As an example, the risk posed by the reception of free cyanide by livestock using water sourced from two bores two kilometres down gradient of the pit lake was considered to be very low due to the following key aspects effecting likelihood and consequence:

- Free cyanide is not likely to migrate two kilometres through fractured rock or alluvial aquifers at significant concentrations.
- Rates of cyanide volatilisation are likely to restrict measurable free cyanide concentrations to the pit lake.
- Toxicity effects at the stock bores are not possible as free cyanide will not be present at any measurable concentration (based upon contaminant transport timeframes and rates of cyanide volatilisation).

Results of the risk assessment indicated all contaminant reception scenarios represented either a very low or low risk to ecological receptors both during tailings deposition and in subsequent decades.

All risks to humans in the vicinity of the pit lake and livestock in the surrounding pastoral leases were determined to be very low. All risks posed to significant fauna in the immediate vicinity of the pit lake and vegetation areas within ephemeral creek lines located west of the pit lake were also determined to be low.

ERA Recommendations

MBS Environmental provided the following recommendations, based upon results of the ERA (MBS 2012b):

- To undertake monitoring at the pit lake and in groundwater monitoring bores for the following analytes:
    - Free, WAD and thiocyanate forms of cyanide.
    - Arsenic, copper, manganese, nickel, cadmium, nitrate, selenium, sulphate and zinc.

- To use maximum contaminant concentrations calculated in the report as trigger values for monitoring pit lake water quality and the use of appropriate livestock drinking water guidelines (ANZECC & ARMCANZ 2000) for monitoring bores in the vicinity of the lake.
- Where monitoring indicates that free cyanide concentrations exceed trigger values for the pit lake monitoring locations, hydrogen peroxide or ferric sulphate could be used to reduce free cyanide concentrations. Dosing may be applied prior to tailings transfer at the CIL plant or at the discharge outlet to the pit lake.

How the Poseidon ERA Informed Decision Making

The results of the ERA assisted decision-making processes for the client in the following ways:

- It provided a set of monitoring requirements for the project, aimed at identifying contamination issues before they have the potential to impact on sensitive receptors. Importantly, it also eliminated unnecessary monitoring requirements by highlighting the very low risks associated with particular scenarios.
- It increased confidence in the viability of utilising a pit lake for tailings disposal, which is not a common approach in the Goldfields.
- At the project approvals stage, the ERA document provided evidence of the rigor applied to identifying key risks associated with the project.
- At the operational stage, it will provide a set of practical measures to address elevated levels of free cyanide in the lake and return process water streams.
- It provided a conceptual framework for any further modelling of contaminant accumulation and assessment of key risks for future studies associated with further development of the project.

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Mineral Development Infrastructure
– A Green Community Legacy?

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Abstract

Traditionally, mining infrastructure – including the void created by ore and waste extraction, after any mine closes has been seen as an environmental and financial liability. Historical closure requirements (if any) or minimal community expectations have left a legacy of global mining and smelting sites that feed the often negative perception of the industry.

Legislation is now requiring the industry to submit mine closure plans at an early stage of any approval process, together with financial “bonds” held against any failure to comply with regulated closure requirements. While these requirements relate to expected environmental standards (restoration through “regreening”) to be achieved at the end-of-life, there is significant merit is progressing restoration during mining activities. While restoration can generate regional jobs, significant employment is unlikely to be sustained.

Increasingly the mining industry has to secure and maintain the “social license to operate” – placing an emphasis on corporate social responsibility projects – such as education and healthcare in the developing world. However, the disruptive community impact of the arrival and departure of the modern mining industry is a major management and governmental challenge. An interesting and logical trend is emerging where the mine infrastructure is being considered as an asset at the end of the mine life – rather than a liability. Such thinking – often focussed around the installation of renewable energy technologies – might retain significant employment in the region, provide on-going site management and allow mining companies to transfer ownership of sites with productive capacity, rather than incur costs of management in perpetuity.

This paper will explore some global examples of innovative solutions that are emerging and further synergies that are worthy of investigation.

Introduction

Until recently, and still in the minds of many in industry and regulators, mine closure has been viewed as a costly element of the post-mining activity in a linear sequence of exploration, mining (including waste rock disposal), processing (including tailings disposal), and eventually mine closure. However, there have been few examples of mining companies being able to hand back legal responsibility of sites even after extensive remediation efforts and associated expenditure. Such expenditure often comes as an unpleasant surprise to shareholders and should be regarded along with many other factors as an element of project and company risk management. The economic indicators of net present value (NPV) and internal rate of return (IRR) do not acknowledge the significant financial impact of mine closure costs, especially of a long life operation during which regulatory requirements and community expectations will change. However, recent regulations are requiring the development of a detailed closure plan early in the mining sequence and the lodging of financial bonds to ensure completion of such plans. Increasingly, such closure plans are incorporating progressive remediation with the costs (hopefully) built into financial projections and the possible staged return of the financial bond. Clearly, this is a more sophisticated process that should involve the closure professionals early in the planning process, as well as when mining and processing proceeds.

Current environmental legislation often requires that the site be returned to as near a condition as possible to that existing prior to the commencement of mining; often ignoring or relegating to a lower category of preferred outcome an alternate use for the site. Given the millions, possibly billions, of dollars that have been invested in the mine site, it could (the author argues should) be regarded as an asset, requiring the overused expression “paradigm” shift in many mining professionals.

This paper explores this concept from the position of developing continuing (hopefully sustainable) employment at the mine site. The requirement for sustainable employment in the area impacted by mining is becoming an important issue in corporate social responsibility (CSR) expectations, particularly for the Canadian mining industry. However, this can result in funds being directed at the immediate (i.e. impacted) community rather than paid nationally or regionally for broader priorities in education, healthcare and/or infrastructure. This can create tensions (and possibly confusion) in project development in developing countries.

This paper attempts to look at some of the emerging opportunities that might arise from the paradigm shift in regarding the mine infrastructure as an asset supporting future community employment.

Infrastructure

A mine site offers significant infrastructure advantage to any possible future activity. These advantages include security, transport, communication, power and water supply, skilled staff within a supportive community. Environmental liability, in particular with regard to acid mine drainage and other fugitive emissions, and physical health and safety issues are possibly the major disadvantages to be addressed. Mine waste sites clearly have low value or negative value (i.e. it is accepted money must be spent on the site). This substantial alters the economics of any future project. Tourism is one opportunity; however for remote locations (particularly in the developing world) projects beyond the preservation and retention of mining heritage may not be viable.

One of the most successful projects that has redeveloped a former mining activity to a tourism attraction is the Eden Project in Cornwall, England. Less well appreciated is the extensive work that was done of the "manufacture" of soil – a continual site specific challenge in mine site vegetation. However, again a transfer of process engineering skills available in mining regions can offer an innovative R&D workforce.

Recent developments within the renewable energy sector have looked at connecting opportunities with mining operations in a number of parts of the world, including in many instances legislation changes and economic incentives (such as R & D investment). A multi-stakeholder project in Nevada as one of six demonstration projects within the US "Mine-Scarred Lands Revitalization" is a good example (reference). On a former Barrick Gold site, solar and wind energy potential is being investigated. Elsewhere in Nevada, Barrick Gold has developed a $10 million 7,404 solar panel facility, generating about 1 MW – required under State law to meet a portion of generating needs from renewable energy when users move to become generators. This is part of a change introduced in 2005 allowing large power users to develop their own sources of power. The solar project compliments a 115 MW gas-fired station, constructed by the company to make it independent of the grid, reducing production costs by a reported US$9 an ounce (Seelmeyer, 2008).

Innovative thinking can provide further ideas that might link mine sites and renewable energy. The "thermal tower" concept can to the mining person look at first glance like a shaft headgear (Figure 1). However, when you appreciate that the mirror array required suffers from operational problems in high winds and have a mining background – placing the mirrors on the benches of an open pit and locating the collector within the pit could remove the need for a tower.

Figure 1

The use of open pit mines and quarries for waste disposal (i.e. landfill) has long been practiced in many countries with the decay of organic materials generating methane gas. The methane can be captured and combusted for power generation (reference) with employment continuing long after mining ceases.

"Regreening"

Efforts by mining companies to present a more pleasing visual amenity and control airborne and water borne emissions (dust and sediment) are well-documented. The expectation or requirement to recreate the environment temporarily destroyed by mining activity has driven internationally-recognised research and development in Australia (Alcoa, 2012) – such that this is one more area where we are seen to be world-leading. The term "regreening" when applied to waste rock and tailings storage facilities that have never been green is possibly a misnomer; however the landscape redesign undoubtedly has a significant impact on the community and its general perception of the mining company or companies. These efforts might have to address generations of mining and processing activities and will provide temporary employment. These employment opportunities might be timed to support the mining-impacted community at times of recession (prevent layoffs from the industry itself or providing broader community employment) (Ross, 2001).

Productive "Regreening" – The Biofuel Revolution

The growth of fast-growing biofuel crops (willow via short rotation coppicing) on coal mine waste sites has been proposed in the UK. Since the biofuel is produced near to coal-burning power generators, co-combustion is an economic option; however the prime economic driver is the disposal of sewage sludge. Here land spreading of sludge does not involve the crop entering the food chain, the heavy metals contained in sludge being of concern. A revenue stream can be derived from the disposal of sewage sludge (possibly following composting). However, there might be community opposition to becoming a waste disposal site.

Recent work from Sudbury, Canada, has shown that biofuel crops (canola, soy and switchgrass) can be grown in layers of waste materials from the paper industry on highly sulphidic tailings dams. The concerns are again of metal transfer to the food chain via the biomass; however initial research is showing little transfer of metals to the biomass (Hargreaves, et al, 2012; Abedin, J., Beckett. P. and Spiers, G. A., 2012). Only those locations with significant area of mine waste and tailings might be able to generate sufficient biomass to command a dedicated biofuel production plant (with associated employment) – but the mining activity might trigger such a regional development or provide a guaranteed user of quantity of product. There are many examples of mining companies developing biofuel crop projects across many parts of the world.

Research into phytoremediation (uptake of metals by plants) has been conducted as a means of removing metals from otherwise potentially productive agricultural land (following the spreading of sewage sludge) (Maxted, et al, 2007) or from mine wastes or sub-economic materials (Abedin, Beckett and Spiers, 2012). Again in isolation such projects, including possible metal recovery from biomass, might not be economically viable – but as part of a more holistic view of mine closure should be considered.

Water and Other Products

In arid regions of the world, quality water availability is a major issue. Mining operations are familiar with handling large volumes of often saline ground water. Treatment of such water, including the recovery of contained salts, should be considered as a supportive activity. New technologies, often involving solar energy, are rapidly being developed (Randell, Nathoo and Lewis, 2009) that can selectively produce salts from highly saline waters. The market for such salts needs to be considered in the context of "industrial ecology" (Anon, 2012). The supply of water to communities, including for agricultural uses (supporting food security), and/or for sustaining productive "regreening" should be considered as part of holistic closure planning.

Conclusions

A holistic view of mine closure regarding any mine site as a community and/or economic asset with a focus of sustainable job creation is proposed. Many stakeholders will need to be engaged in the planning, research and development of such concepts that incorporate ideas from the field of industrial ecology.

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Goldfields Hydrogeology in Relation to Mining

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Department of **Water**

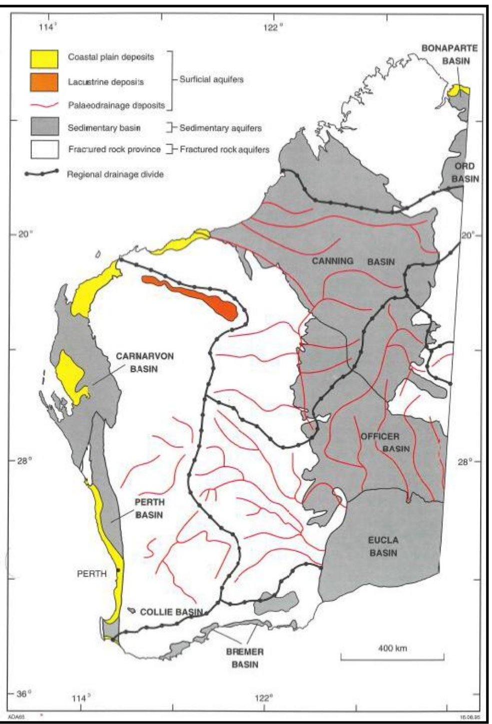
GOLDFIELDS HYDROGEOLOGY

Chris O'Boy
Department of Water
Swan Avon Region

Government of **Western Australia**
Department of **Water**

Aquifers Locations

- surficial
- sedimentary
- fractured rock



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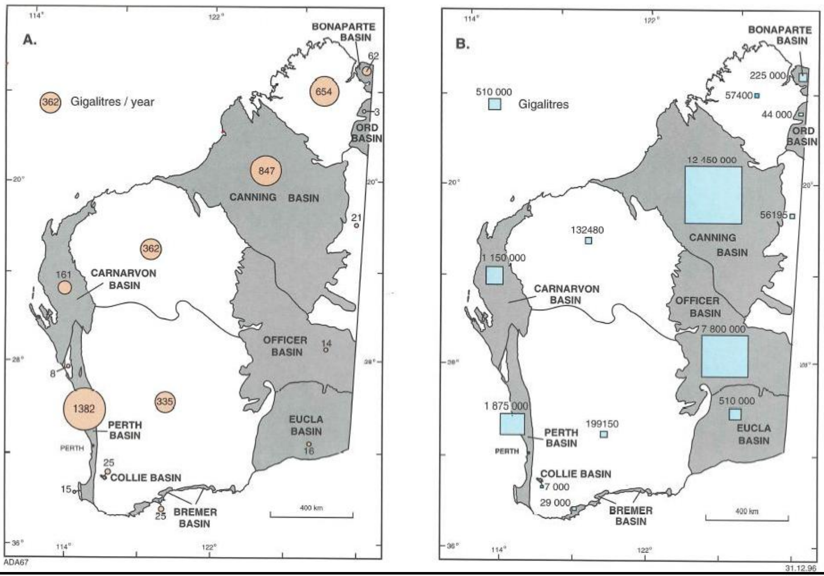
RENEWABLE AND STORED GROUNDWATER RESOURCES



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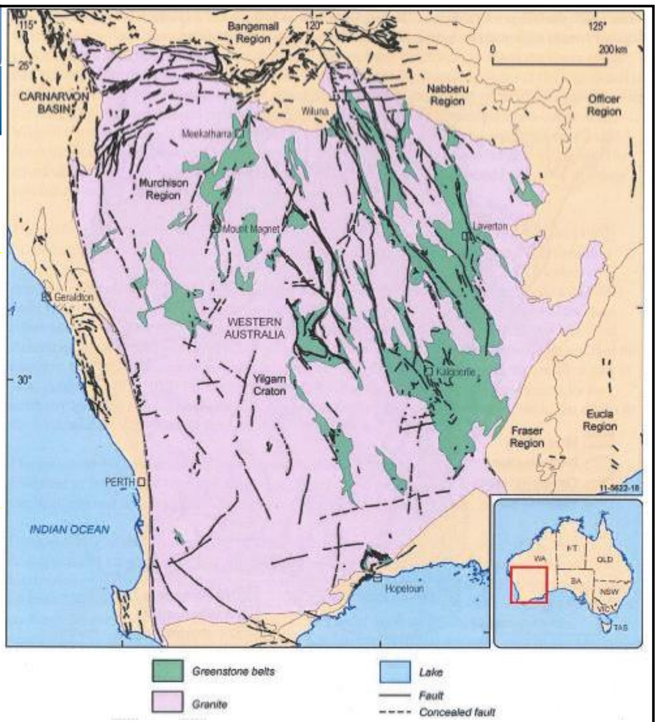
Geology of the Yilgarn Craton

2.6 to 3.0 Ga



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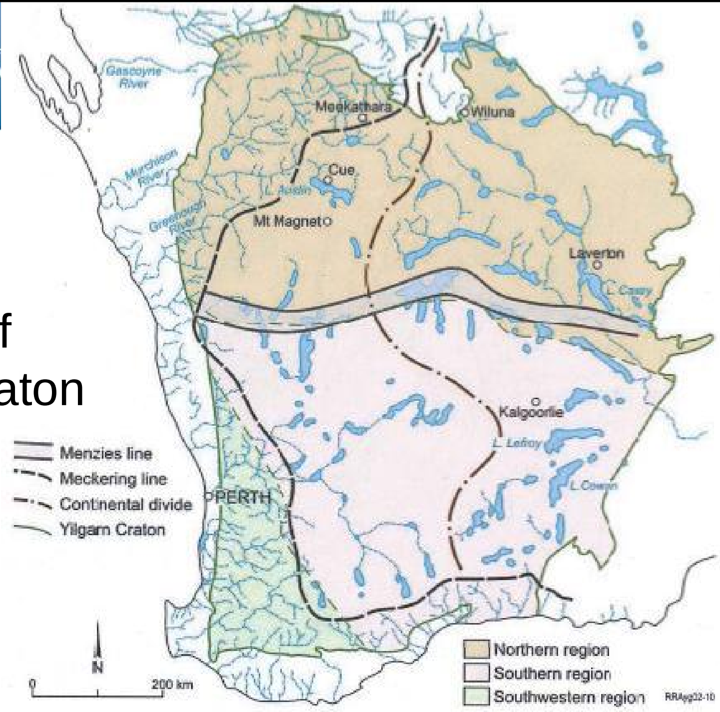
Drainage Patterns of Yilgarn Craton



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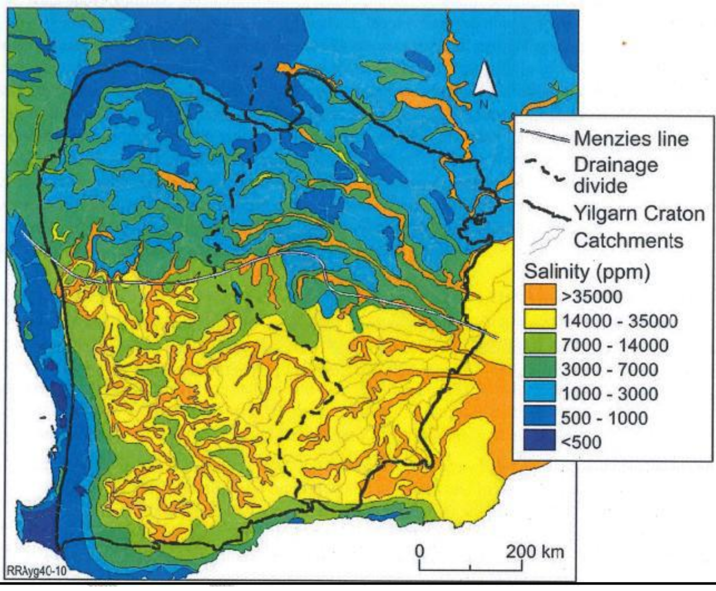
GROUNDWATER SALINITY AT THE WATERTABLE



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GOLDFIELDS AQUIFERS

- Surficial
  - Calcrete, alluvium, colluvium, aeolian and lacustrine
- Palaeochannel sand
- Fractured and weathered basement rocks
  - Fractures, joints, shears and faults primary porosity in saprock and fresh rock
  - Secondary porosity from chemical alteration in the weathering profile of these features
  - Dykes and sills

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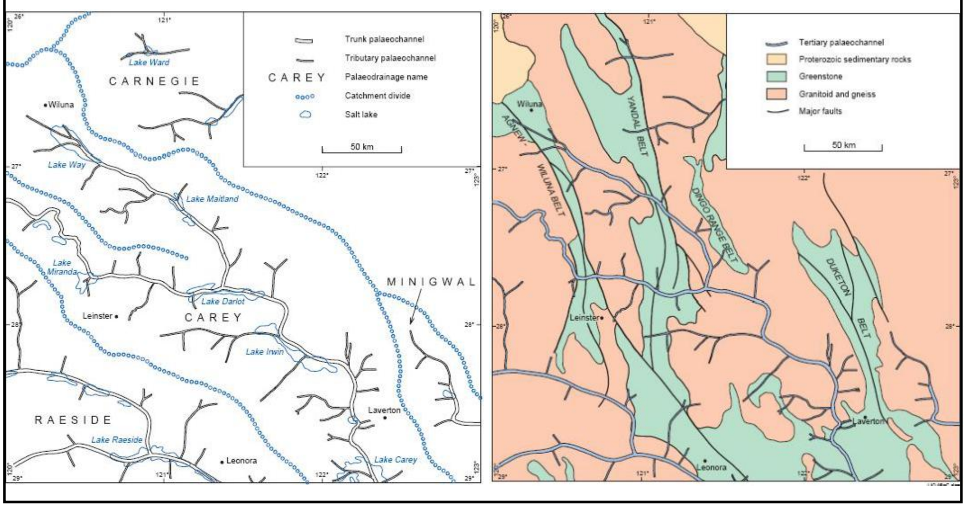
NORTHERN GOLDFIELDS



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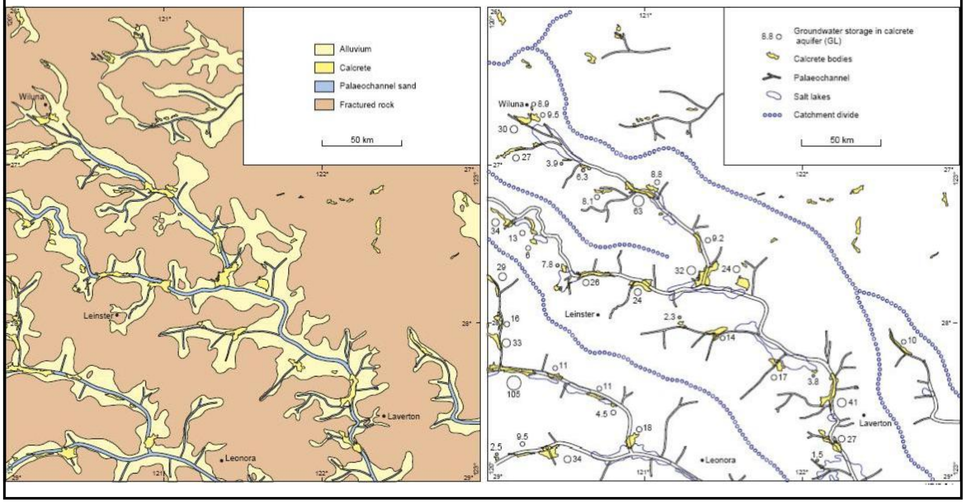
AQUIFERS AND CALCRETE STORAGE



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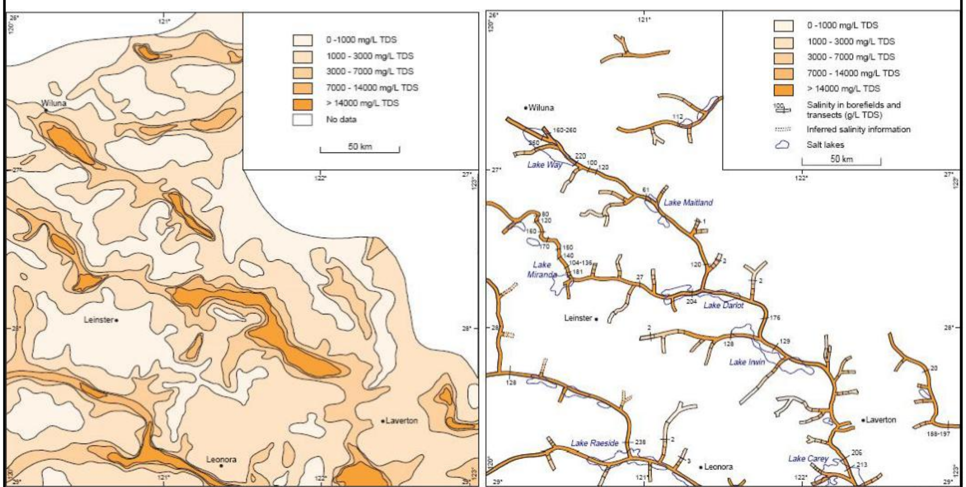
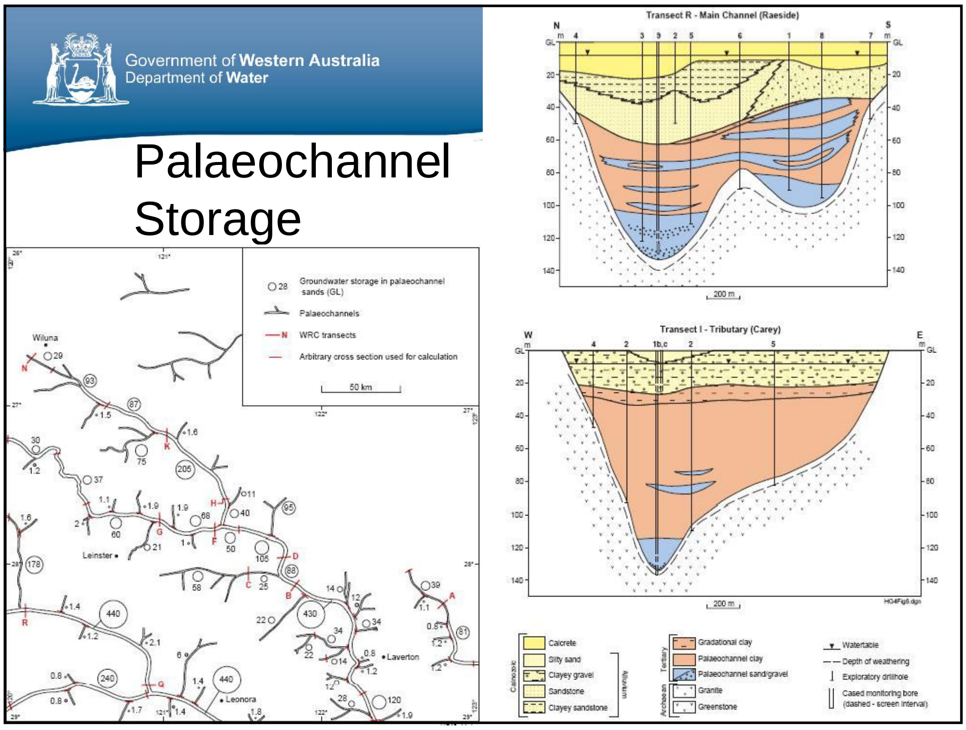
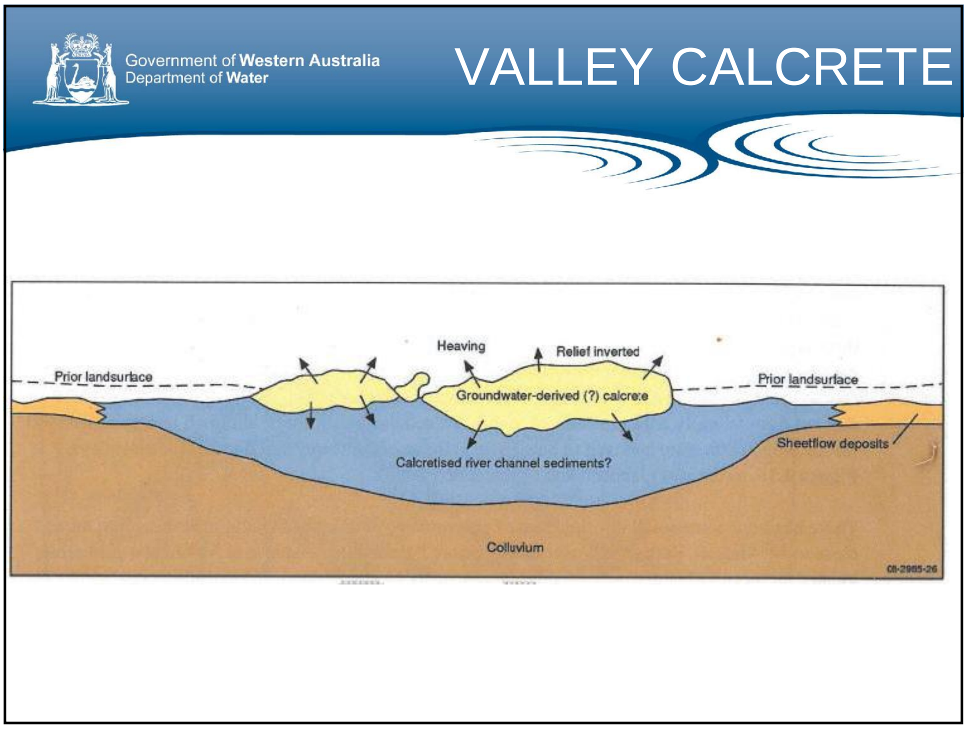
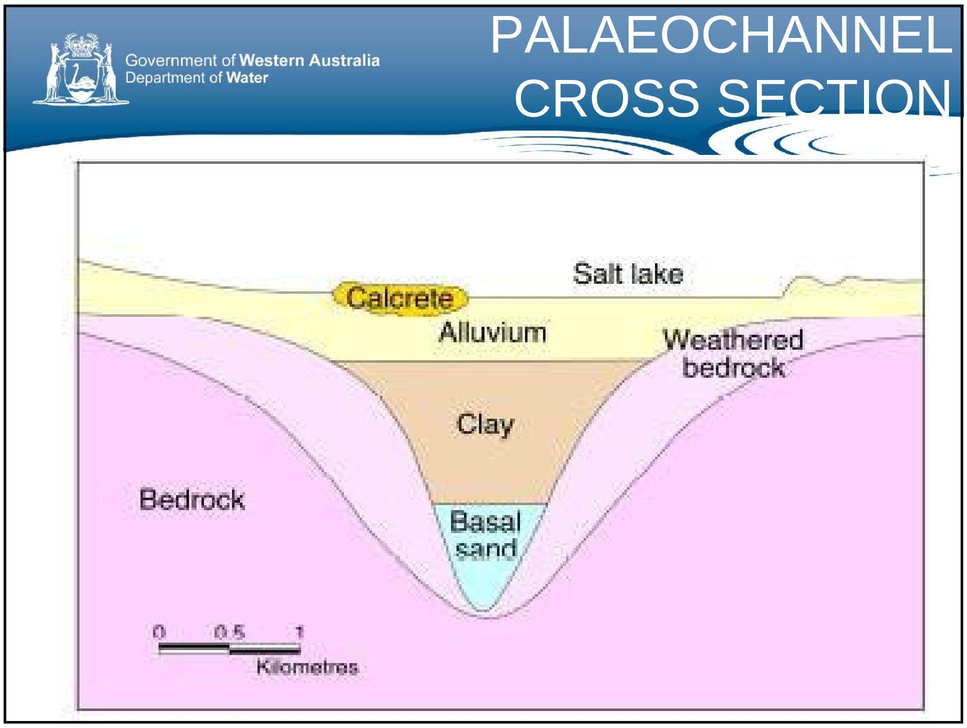
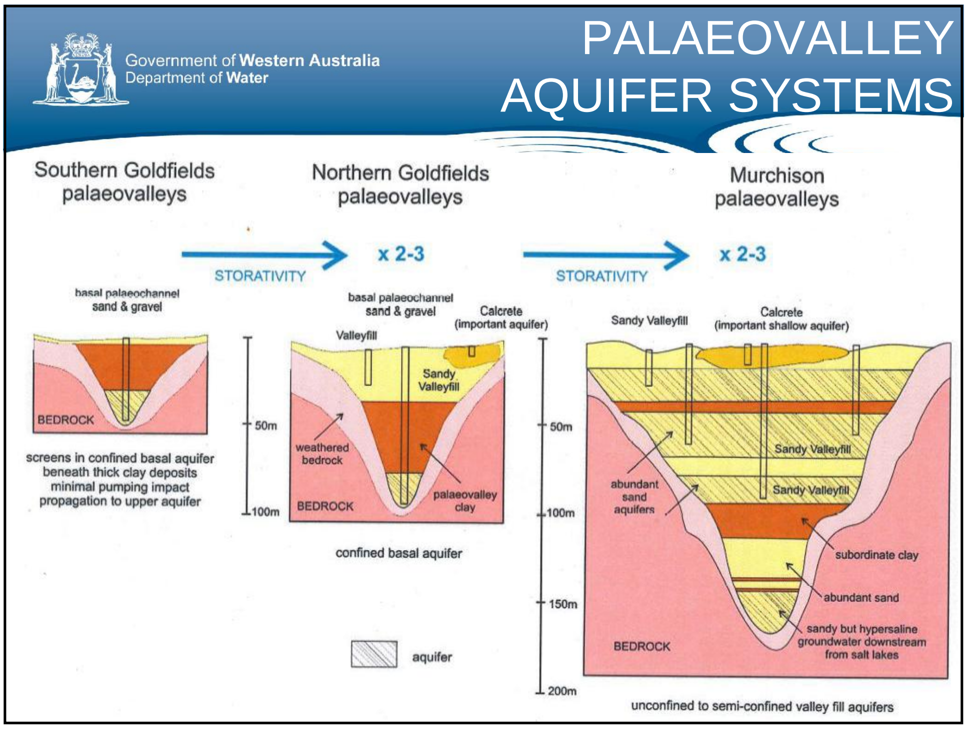
SALINITY




Government of Western Australia
Department of Water
Palaeochannel Storage
Groundwater storage in palaeochannel sands (GL)
Palaeochannels
WRC transects
Arbitrary cross section used for calculation
50 km
Wiluna
Leinster
Leonora
Laverton
Transect R - Main Channel (Raeside)
Transect I - Tributary (Carey)
200 m
Calcrete
Silty sand
Clayey gravel
Sandstone
Clayey sandstone
Gradational clay
Palaeochannel clay
Palaeochannel sand/gravel
Granite
Greenstone
Watertable
Depth of weathering
Exploratory drillhole
Cased monitoring bore (dashed - screen interval)

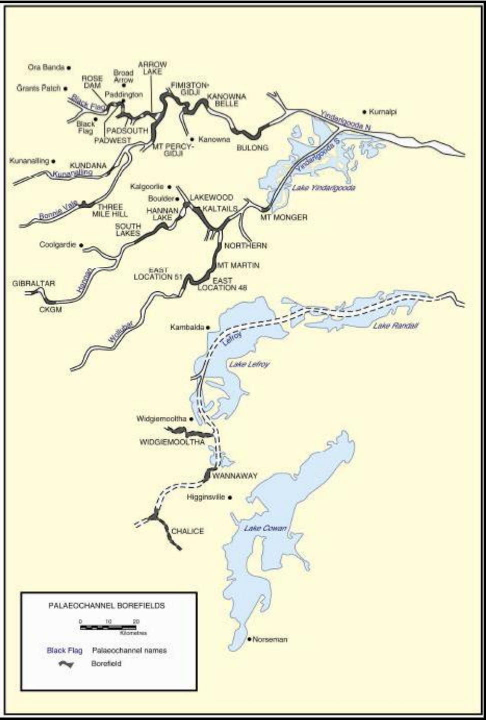

Government of Western Australia
Department of Water
VALLEY CALCRETE
Heaving
Relief inverted
Prior landsurface
Groundwater-derived (?) calcrete
Prior landsurface
Sheetflow deposits
Calcretised river channel sediments?
Colluvium
08-2985-26


Government of Western Australia
Department of Water
PALAEOCHANNEL CROSS SECTION
Salt lake
Calcrete
Alluvium
Weathered bedrock
Clay
Bedrock
Basal sand
0 0.5 1
Kilometres


Government of Western Australia
Department of Water
PALAEOVALLEY AQUIFER SYSTEMS
Southern Goldfields palaeovalleys
Northern Goldfields palaeovalleys
Murchison palaeovalleys
STORATIVITY
x 2-3
STORATIVITY
x 2-3
basal palaeochannel sand & gravel
BEDROCK
screens in confined basal aquifer beneath thick clay deposits minimal pumping impact propagation to upper aquifer
50m
100m
basal palaeochannel sand & gravel
Calcrete (important aquifer)
Valleyfill
Sandy Valleyfill
weathered bedrock
BEDROCK
palaeovalley clay
confined basal aquifer
aquifer
50m
100m
150m
200m
Sandy Valleyfill
Calcrete (important shallow aquifer)
abundant sand aquifers
Sandy Valleyfill
Sandy Valleyfill
subordinate clay
abundant sand
sandy but hypersaline groundwater downstream from salt lakes
BEDROCK
unconfined to semi-confined valley fill aquifers

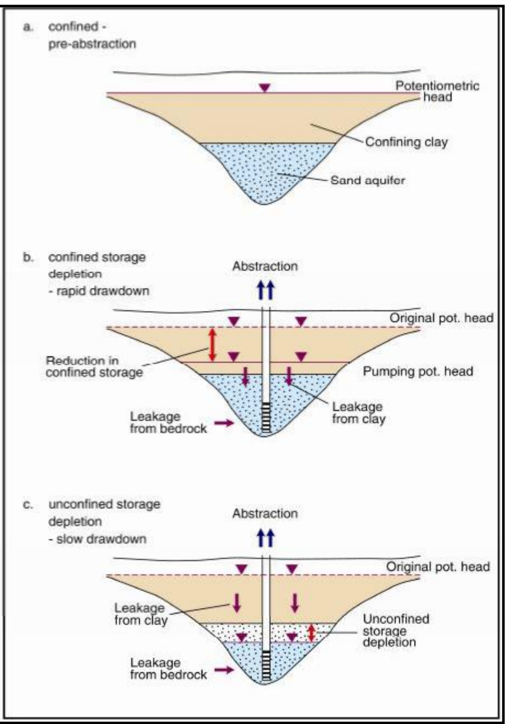
Government of **Western Australia**
Department of **Water**

Eastern Goldfields Palaeochannel Borefields



Government of **Western Australia**
Department of **Water**

Palaeochannel Aquifer Transition from Confined to Unconfined State



Government of Western Australia
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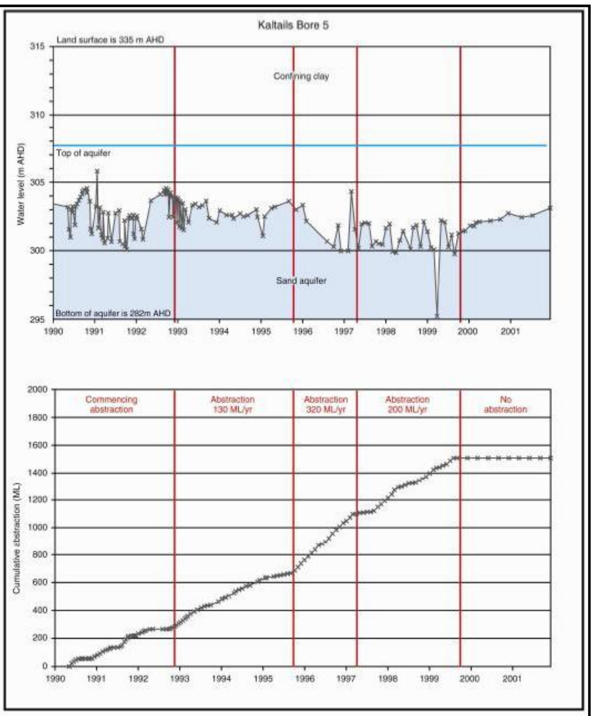
Water level change and cumulative abstraction

- Commandable Storage



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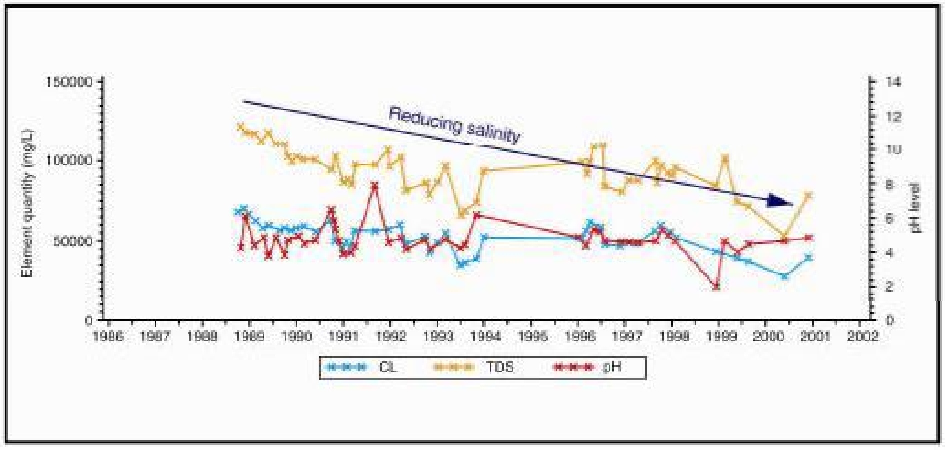
SALINITY

Mostly no significant change



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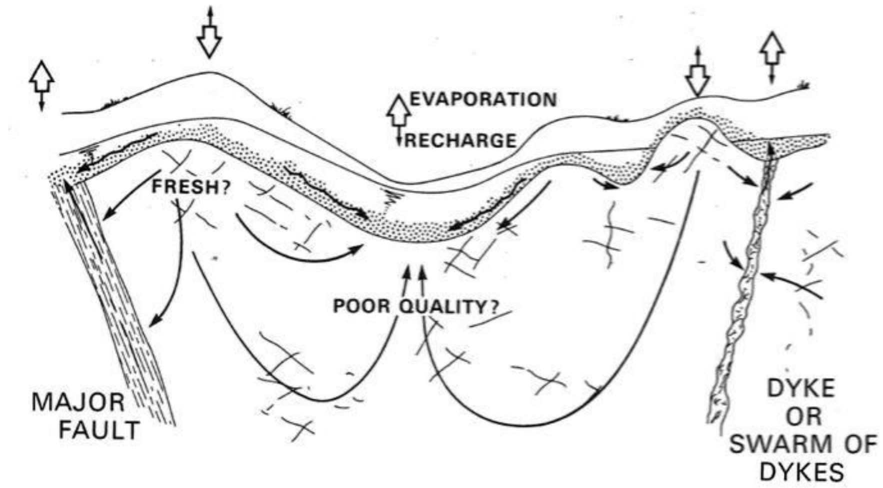
FRACTURED ROCK REGIONAL GROUNDWATER MOVEMENT



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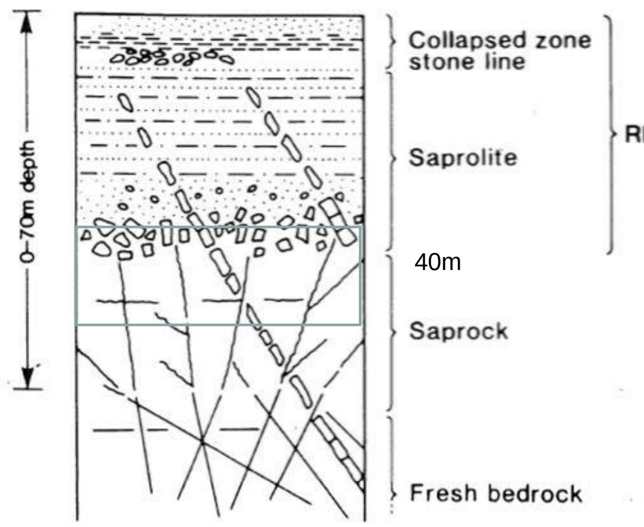
FRACTURED ROCK WEATHERING PROFILE



Sandy / stony on watershed clayey in valley bottoms

K and effective porosity increase with depth as kaolinite / smectites decrease with depth

Cohesive weathered bedrock

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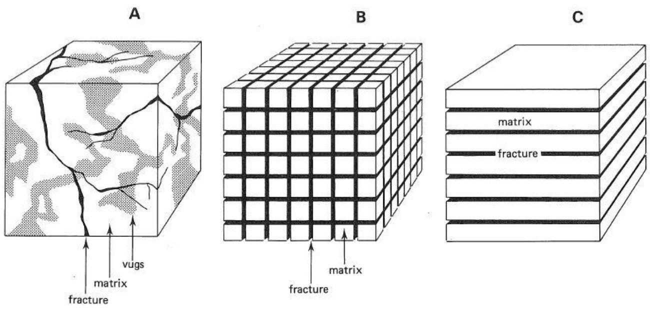
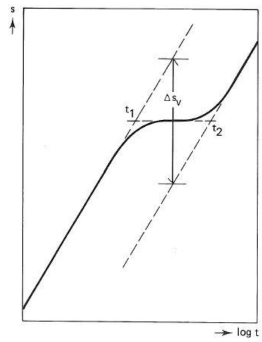
UNIFORMLY-FRACTURED DOUBLE PORIOSITY





A: Naturally fractured rock
B: Orthogonal fracture system
C: Idealized horizontal fracture system

Semi-log time drawdown plot

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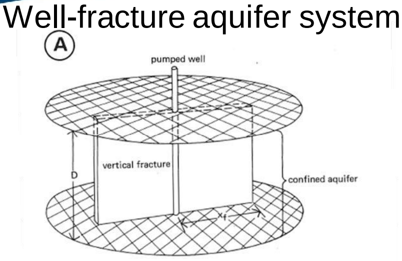
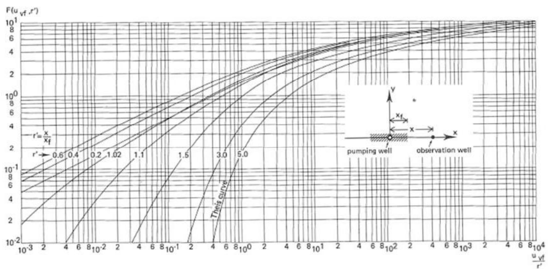
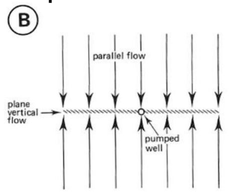
SINGLE VERTICAL FRACTURES

Well-fracture aquifer system

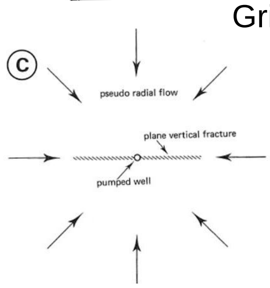




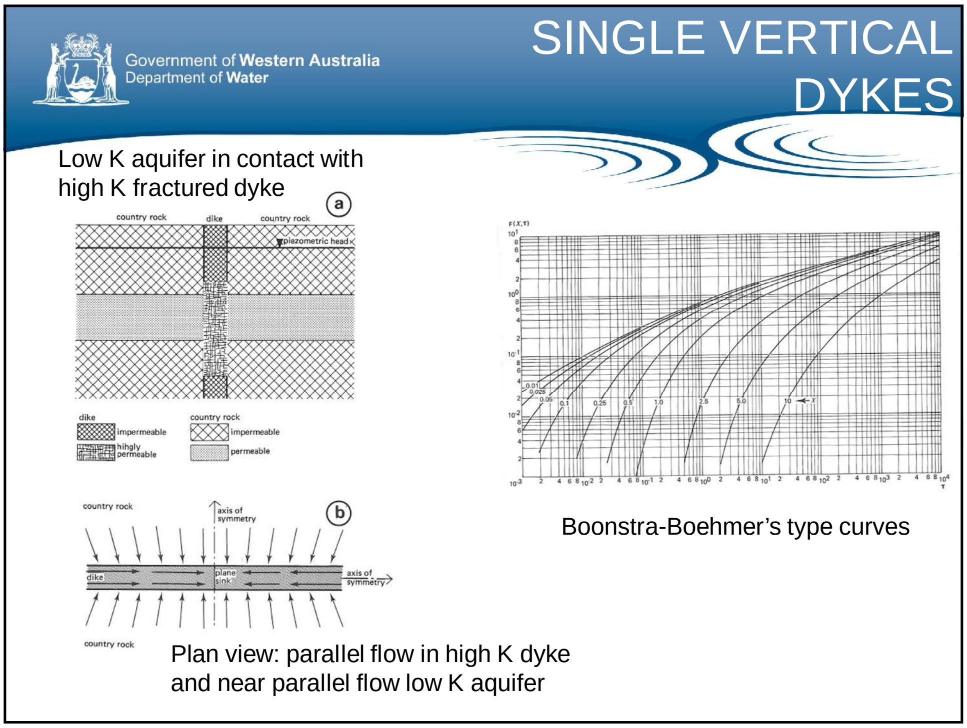
Parallel flow at early pump times

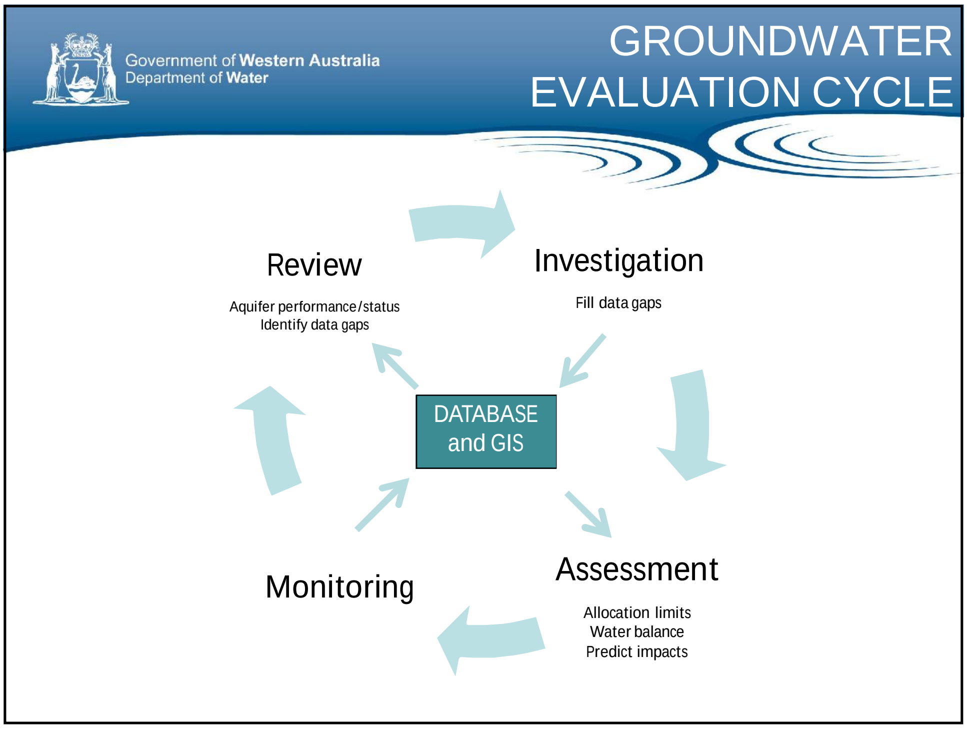


Gringarten-Witherspoon type curves



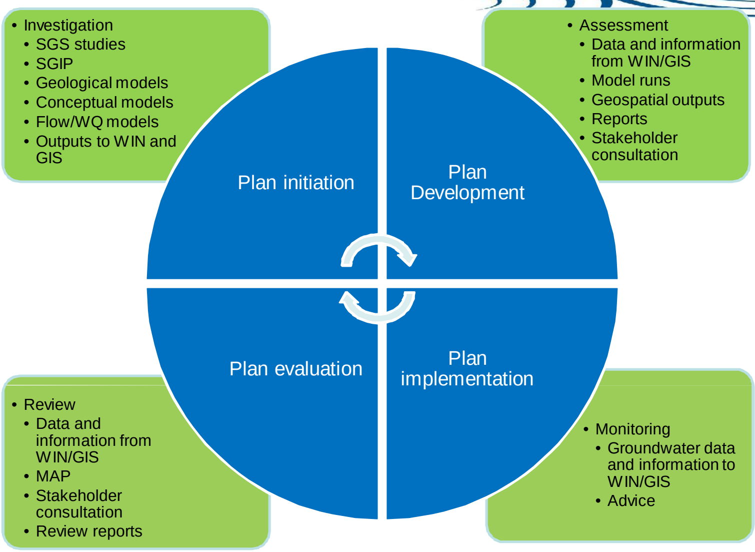
Pseudo-radial flow at late pumping times


Government of Western Australia
Department of Water
SINGLE VERTICAL DYKES
Low K aquifer in contact with high K fractured dyke
a
country rock
dike
country rock
piezometric head
dike
impermeable
highly permeable
country rock
impermeable
permeable
b
country rock
axis of symmetry
dike
plane sink
axis of symmetry
country rock
Plan view: parallel flow in high K dyke and near parallel flow low K aquifer
Boonstra-Boehmer's type curves


Government of Western Australia
Department of Water
GROUNDWATER EVALUATION CYCLE
Review
Aquifer performance/status
Identify data gaps
Investigation
Fill data gaps
DATABASE and GIS
Assessment
Allocation limits
Water balance
Predict impacts
Monitoring

Government of Western Australia
Department of Water

WATER PLANNING PROCESS



Government of Western Australia
Department of Water

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Environmental Approvals, Speed Dating and Achieving Happily Ever After

Kristy Sell and Freea Itzstein-Davey, MBS Environmental

Claire Tolley, Sandfire Resources NL

Abstract

Speed dating has become popular in recent years as a novel way for singles to meet each other. Arguably it increases chances of finding a romantically compatible mate as first impressions are often permanent. Some may find lifelong love after five short minutes.

The environmental approvals process can be analogous with speed dating in the sense that you need to put yourself out there to meet and greet your regulators and get the most for your buck. If it goes well, the reportedly elusive “happily ever after” can be achieved. Legislation and approval procedures rapidly change and to keep abreast of current knowledge, you need to remain attentive and receptive. It pays to find out early in the assessment process who you need to engage with and which officers will have involvement or will be responsible for assessment of your project. The Department of Mines and Petroleum (DMP) have designated Environmental Officers for Minerals Fields and the Department of Environment and Conservation (DEC) has multiple regional and Perth based divisions that may be involved with individual mining projects. If you are complacent, your date book may not include all the people you need to engage with, you may be at the wrong place wondering what you have done to deserve a no show, or you may miss the bell ringing to tell you that you are moving onto a brand new officer. Life happens and things change.

This presentation will explore the current environmental assessment process in WA for mining projects with lessons learnt in particular from the Sandfire Resources NL DeGrussa Copper Project. Gaining approvals in a timely manner should not be thought of as akin to finding a pot of gold at the end of a rainbow. You just need a good treasure map to get you started, a team of committed and flexible people to go looking with, set realistic goals and then hold on tight and enjoy the ride to get to happy ever after.

Introduction

This paper focuses on the environmental assessment process in Western Australia for mining projects that are assessed under the *Mining Act 1978* and Part V of the *Environmental Protection Act 1986* by the Department of Mines and Petroleum (DMP) and the Department of Environment and Conservation (DEC). Lessons learnt from one of the fastest developing mining projects in Australia, Sandfire Resources NL (Sandfire) DeGrussa Copper Project, are highlighted. The staged approach utilised by Sandfire is discussed with focus on regulator consultation during the environmental approvals process and its similarity to speed dating. Speed dating and timely approvals can be successful, but it needs repeated effort, effective communication and perseverance. If it goes well, the reportedly elusive “happily ever after” can be achieved.

Sandfire Resources NL

Sandfire is an Australian resource company with ownership of the DeGrussa Copper Project in Western Australia. In April 2009, Sandfire discovered the high grade DeGrussa volcanogenic massive sulphide (VMS) copper gold deposit in the north-eastern part of their Doolgunna tenement package. Initial drilling returned some of the best intersections seen in the Western Australia mining industry in recent times. Since this time, Sandfire has completed more than 200,000 metres of diamond drilling resulting in delineation of the DeGrussa deposit, the underlying Conductor 1 deposit, the adjacent Conductor 4 and Conductor 5 deposits.

The DeGrussa Project is located in the Doolgunna area approximately 900 kilometres north-east of Perth and 150 kilometres north of the regional mining hub of Meekatharra. The project is being developed as an open pit and underground mine and is set to become Western Australia’s biggest copper mine with total resources of 652,000t of contained copper and 742,000oz of gold. Mine life is estimated to be seven years based on the four high grade VMS lenses discovered to date with potential to extend this life through ongoing exploration.

Sandfire became Australia’s newest copper-gold producer with first ore mined at their DeGrussa Copper Project in February 2012. The DeGrussa Project is one of Australia’s fastest moving mine developments – less than three years after drilling the first discovery hole in April 2009, Sandfire completed definitive feasibility studies, obtained the required environmental approvals and mined its first Direct Shipping Ore (DSO) from their open pit in February 2012.

Development of the DeGrussa Project involved construction of an open pit mine, underground mine, copper flotation plant, Integrated Waste Landform (IWL) including a fully lined Tailings Storage Facility (TSF) and ancillary infrastructure including a borefield, power station, mining camp and airstrip. Construction of the DeGrussa operations including the open pit and underground mine, commenced just two years after the orebody discovery, on 15 April 2011. Construction is on track to be completed by Q3, 2012.

The success of the DeGrussa development can be linked to the close involvement of the Sandfire construction and mining teams to the environmental approvals process. Commitments made through this process were placed within tenders, schedules, policies and procedures and personnel at all levels of the organisation were aware of their environmental obligations.

Staged Approvals

Why was This Approach Taken?

The DeGrussa Project was aimed to be a fast tracked project from exploration to first development and production of saleable product. In the early stages of project development, the environmental team sat down with the Sandfire management team to identify the various components of the project. The timeframes required for construction and operation of each component was understood and a timeline was established for interlinking development. The likely regulatory approval needs for each component, information requirements (scientific and engineering), potential constraints and resources were considered. This led to the decision to use a staged approach to obtain necessary approvals.

Some of the issues that led to the decision to use a staged approach included:

- Requirement to construct a camp early in the project to allow future works to be undertaken in a timely manner. The DeGrussa site is remote and the small exploration camp was insufficient to allow construction of the open cut mine, underground mine and ore processing facilities in the timeframes Sandfire required. Camp construction needed to commence before design for other components of the project were likely to be finalised.
- Granting of tenure had not been completed for all aspects of the project and the timing was not always well aligned with development of environmental assessment applications. Some aspects of the project were split from the more encompassing Mining Proposals because of tenure related issues. Separation of the borefield aspects into separate Mining Proposals allowed later submission of those aspects without delaying assessment of other key aspects.
- Parts of the project were located on previous pastoral leases recently converted to Unallocated Crown Land (UCL) as part of the DEC led pastoral lease buyback. Other parts of the project were on an active pastoral lease. Considerable confusion was encountered regarding the conservation status of the area of UCL given it is currently managed by DEC, but has not had its land use formally changed to any conservation related purpose. This affected the need for Clearing Permits and assessment of Mining Proposals by the Environmental Management Branch (EMB) of DEC as well as by DMP.
- Timeframes to obtain scientific and engineering information necessary to support various applications. Tailings characterisation studies identified potentially acid forming tailings would be produced. This information led to a requirement for detailed engineering for a fully lined TSF. Few facilities of this type had been designed and operated successfully in Australia. The TSF required considerable co-operation between the design engineers, Sandfire project management team, Sandfire operations team and MBS Environmental to ensure a design

was developed that would satisfy the full range of requirements during construction, operation and post closure. The time required to complete this work was identified to be a significant hold point for the project. This led to the decision to separate the TSF construction and operation from other project components for both the Mining Proposal and Works Approval processes.
- Differing information needs of various regulatory agencies. Whilst sufficient details were available for preparation of a Mining Proposal for the copper processing plant, insufficient information was available at the same time for preparation of a Works Approval document. This led to differing subject matter in the Stage 1 and 2 Mining Proposals compared to the Stage 1 and 2 Work Approvals.

Pros

Benefits of the staged development approach were:

- Construction could commence rapidly. This was very important to Sandfire.
- Assessment could occur concurrently to project development on longer lead time items.
- More efficient deployment of resources for the project. The environmental team focused on aspects where work was complete whilst other aspects were still under development.
- It allowed Sandfire access to project funds once key approvals were received.
- Increased project flexibility. As changes were made to some aspects of the project, the outcomes were able to be fed through to the other aspects still under development.

Cons

Difficulties associated with using a staged approach were:

- Defining logical and practical boundaries for each stage and maintaining these across the various applications and regulatory authorities. There needed to be a good reason for separation and this needed to be able to be justified to the project management team and to other stakeholders.
- Regulator apprehension. The large number of assessment documents presented and the status of each was a concern to some, particularly where new people entered the assessment process once it was underway.
- Regulator exhaustion. The staged approach resulted in six separate Mining Proposals, three Works Approval applications and three Clearing Permit applications.
- Staging required preparation of a large number of environmental documents in a relatively short period of time. This placed pressure on both the MBS and Sandfire project teams to ensure all documents were technically correct, addressed various stakeholder concerns and were of a consistently high standard.
- Maintaining consistency across all project documentation. A large number of environmental commitments were made in the various documents. Care was required to ensure these were not contradictory, were applicable to the actual assessment document being prepared, were

achievable and compliance could be tracked by the Operations Environmental Manager during project construction and operation.

- The rapid pace of document development resulted in rework of some documents as documents were being prepared in advance of completion of all technical studies. The large amount of experience in both the MBS and Sandfire teams allowed anticipation of likely engineering and environmental requirements, however this needed to be backed up by results of scientific and engineering studies. Changes to other aspects of the project design occasionally had ramifications resulting in the need to rework some documents.
- Ability to be highly flexible, responsive and accommodating to project change.

This detailed planning could be compared to defining what you want in a potential mate. Speed dating, internet dating or a blind date may be more successful if you know what you want. Some people may start the process with no idea; it may fizzle out quickly due to different ideas and wants. Some people may not know the boundaries. Often it is just good to get out there and talk to people so you can work out what you want. Well prepared ideas can be engineered into strategic plans that can be implemented into successful relationships and projects!

Outcome

Table 1 summarises the approvals documentation prepared, dates submitted and when approvals were received. To date there have been six Mining Proposals, three Clearing Permits (and one addendum) and three Works Approvals approved.

Table 1: Sandfire Resources NL DMP and DEC Approvals

Approval Type	Date Submitted	Date Approved
Mining Proposals		
Accommodation Camp and Borrow Pit	8/12/2010	21/03/2011
Stage 1: Open pit, underground mine, boxcut, waste rock dump, power plant, fuel farm, workshops, processing plant, minor rock dump, administrative buildings, concrete batch plant, crusher, water storage facilities, dewatering infrastructure, explosives magazine, landfill and access/haul roads.	21/12/2010	14/04/2011
Stage 2: Tailings Storage Facility (TSF) within an Integrated Waste Landform (IWL) and associated tailings pipeline, paste plant, ROM Pad, process water pond.	3/05/2011	3/08/2011
Airstrip	13/05/2011	26/08/2011
Borefield	10/08/2011	26/08/2011
Borefield Addendum	30/09/2011	29/11/2011
Clearing Permits		
DeGrussa Project Development (242 ha)	10/10/2010	17/02/2011

Amendment to DeGrussa Project Development (302 ha – an increase of 60 ha)	11/05/2011	14/07/2011
Airstrip (70 ha)	13/05/2011	14/07/2011
Borefield (18 ha)	25/07/2011	22/09/2011
Work Approvals		
Exploration Landfill	4/12/2010	11/11/2010
Stage 1: DeGrussa landfill, crusher, sewerage, dewatering, batch plant.	8/12/2010	7/07/2011
Stage 2: Processing plant, tailings pipeline and TSF, paste plant.	6/05/2011	27/01/2011

The net result of the staged approach was that Sandfire achieved its stated objective of rapid development of the DeGrussa Project. Obtaining necessary environmental approvals did not cause delay to project schedules and allowed the project development team to commence construction on time and with clear and effective environmental requirements.

Regulator Interaction

Is it Needed in the World of Online Submissions?

We often under estimate the importance of meeting people in person as our world is increasingly moving towards online social interaction. Many are keen to put a profile up on internet dating websites, but not so keen on speed dating. Putting yourself out there to meet people requires taking a risk on personal interaction. It can be exciting and daunting at the same time. Meeting people face to face often provides greater benefits in the long term, allows us to interpret tone and body language, and minimises the risk of misunderstanding between both parties. This is just as important for regulatory interaction as for dating.

Regulator interaction is paramount to obtaining any environmental approval and it is important to meet regulators well before the submission point. DEC only accepts online applications for Works Approvals, however you can submit Mining Proposals to DMP either electronically through the Environmental Assessment and Regulatory System (EARS) or in hard copies.

DEC requires the submission of an Application Enquiry Form with a brief summary of the proposed works. Once endorsed, a Scoping Meeting is required with the DEC licensing officer, preferably face to face in their region, to discuss the main issues and the content of the application to be submitted.

DMP does not require any formalised form prior to submission of a Clearing Permit or Mining Proposal, but it is invaluable to meet (or at the very least, phone) to discuss the proposal with the Environmental Officer responsible for the region. This enables the Environmental Officer to provide input into the content of the proposal and importantly develops a relationship early in the process.

Greenfields Versus Existing Operations

Regulatory interaction is particularly important for emerging companies such as Sandfire which developed from an exploration to a mining company and for greenfields projects where introduction of the project to DMP and DEC is valuable to enable them to understand the project they may assess. This may not be as important with existing operations where an existing relationship with regulatory officers is in place. With the constant change in personnel in both regulatory agencies and mining companies, it is valuable to discuss and document any proposed amendments or expansion with Environmental Officers to understand future plans.

Who Do I Consult With?

Once the likely approval needs were identified for Sandfire, a list of stakeholders was developed. These included regulatory agencies (both regional and Perth based officers), local government, pastoral lease holders, adjoining tenement holders, indigenous stakeholders, Main Roads, Port Authorities and local communities potentially affected by road transport of product. Individuals within each stakeholder group were contacted to confirm likely interest in the project and to establish a way for ongoing contact. Correct identification of stakeholder's interest in the project is important, just as selecting a potential mate and making sure they are interested, is important too.

One of the challenges for Sandfire was communication between different groups within regulatory agencies. Regulatory agencies, particularly DEC, are large, with individual branches or divisions having different responsibilities, perspectives and located in geographically different locations. Differing advice was sometimes received during the consultation process and changes in requirements over time did occur. Understanding and managing engagement between and within regulatory agencies can be a challenge for proponents.

Who Does the Consultation and How?

It can often be complex determining who conducts the primary stakeholder consultation with regulators: project owners, consultants or both. There is no right or wrong answer. A designated person was chosen to streamline regulator contact to create consistent dialogue for the Sandfire project. It is important to be open and honest with regulators at all times, and be consistent and transparent. Senior managers within Sandfire remained active in the consultation process and worked closely with MBS and regulators to ensure information needs were satisfied and the assessment process progressed smoothly.

The distance and time required to meet regional regulators face to face can be difficult for people based in Perth. There are short-cuts around this in today's technological world with email, tele-conferencing and video-conferencing very real options. Whilst these methods of communication can be employed, the added benefits of making the effort to visit regulators cannot be underestimated.

Sandfire used a range of consultation methods during the environmental assessment process including face to face meetings, formal presentations, written correspondence, one to one phone calls and tele-conferences. Less formal consultation and communication methods were able to be employed once relationships had been established and individual regulatory officers became more involved with project details.

Ensuring you are understood in speed dating and in the work place is vital. First impressions often do count, so aim to connect.

Regulators can be involved with many significant projects at one time. They can, and do, get overwhelmed with the volume of documents to assess, particularly when a staged approach is used and a large number of documents are received. It is unreasonable to expect regulators to know and understand intricate details of each specific project instantaneously. Like getting to know someone on a date, be keen, but ensure you provide space for information absorption.

The Person I Deal with Keeps Changing

Significant time can be spent liaising with regulators to develop very effective working relationships with individual officers. However, the bell keeps ringing during speed dating and it can also during project development and assessment of applications. Sometimes different officers get assigned to a project mid-way through an assessment, due to change in jobs, fieldwork requirements, leave and simply workloads. Communication and flexibility are the best way to get through these periods. You must be prepared to take the time to brief the new person as best you can regarding the project and its current status, and work towards developing another working relationship. Like dating, speed or otherwise, you may make a lot of new friends and improve your skills along the way. Developing effective working relationships with individual officers that may or may not be present for the duration of a project assessment is never a waste of time or effort.

Benefits of Regulatory Interaction

When a staged approach to environmental assessment was discussed with Sandfire, the need for effective and regular stakeholder interaction was paramount. Benefits of regular regulator consultation were:

- Regulators were given the opportunity to understand the scope of the full DeGrussa Project prior to any impact assessment documents or approval applications being submitted. Given the large number of assessment documents and applications this was important.
- The proposed staging and reasons behind this were able to be clearly explained. This included discussion of the likely timing of submission of the various documents and applications. This assisted regulators with resource management (people and time) for the project and modifications to the proposed staging were able to be made prior to submission.

- Sandfire was able to better understand regulator requirements and likely issues from all the regulatory agencies prior to document submission. This minimised the need for rework of documents after initial submission and minimised the need to formally submit additional information to clarify regulator concerns.
- Assessment timeframes were better understood early on in the project development process and were able to be factored in to the project development schedule by Sandfire.
- Consistent consultation with regulators minimised duplication between departments as the communication process aimed to inform discussion and assessment outcomes.
- Sandfire and their consultants were able to develop effective working relationships with the large number of regulators. Given the number of assessment documents, applications and the complexity of some project components, this was essential to achieve the rapid project development Sandfire aimed for. The open and honest communication allowed development of trust between the proponent and regulators. Sandfire aimed to maintain this relationship during project construction and operations to ensure environmental compliance.

Lessons learnt from Sandfire Resources

Changes in Application of Legislation

Changes in the interpretation and implementation of legislation by regulators are not always well documented or publicised. Prior to mid 2010, Mining Proposals could be approved whilst Clearing Permit applications were still under assessment. This has since changed and the initial Mining Proposal for development of the accommodation camp was not able to be approved until the Clearing Permit was assessed and approved. The significant difference in assessment timeframes between Clearing Permit applications (60 to 90 days) and Mining Proposal submissions (30 days) meant that the project schedule needed to be revised to ensure Clearing Permit Applications were submitted well in advance of Mining Proposals to minimise the risk of delays.

The level of project definition needed to develop a project footprint for a Clearing Permit application is much lower than what is needed for a Mining Proposal. For this reason, Clearing Permit applications should be submitted well in advance of Mining Proposals to minimise the risk of project delays.

Differing Assessment Timeframes

DEC work towards a 60 day assessment period for Works Approvals upon online receipt of applications. This does not include the initial application enquiry form or the scoping meeting which ideally should be held in the regional DEC office. There are differences in regions – for example the Midwest office has an internal target of 45 days to assess applications, whilst experience has shown that the Karratha office which handles about 75% of the state's Works Approvals finds it very difficult reaching the 60 day timeframe. There are several "stop the clock" scenarios, including request for more information and invoicing. Invoices can be emailed directly rather than posted, saving valuable time, especially if funds are available to pay application fees by credit card over the phone.

DMP work towards a 30 day assessment period for Mining Proposals, however, it is common to receive feedback that the submission requires further information, or on more complex issues, submission of a revised document. EARS does not allow you to submit revised Mining Proposals online - all revisions must be submitted as two hard and electronic copies with a cover letter proforma. Complex Mining Proposals, such as the Stage 1 and 2 Mining Proposals for Sandfire, required several revisions, partially due to further requests for more information from DMP once initial information was supplied.

Involvement of DEC (EMB) in Mining Proposals and Clearing Permits When on Ex Pastoral Leases

The DeGrussa Project was largely situated on the previous Doolgunna Pastoral Station. The pastoral lease was purchased by the State in 2000 with assistance from the Federal Government with the intent of using the land for conservation purposes. Since purchase of the lease, the land zoning had been changed from Pastoral to Unallocated Crown Land. DEC was managing the land for conservation in practice and the area had been identified as the proposed Doolgunna Conservation Park, but no legal designation of the land for conservation use had been made. No information was publically available to identify why the Doolgunna Conservation Park was proposed by DEC and what the environmental values of significance were in the area Sandfire was proposing to mine.

Discussions between DMP Land Titles and DEC Environmental Management Branch identified conflicting political desires for the land in question. This resulted in confusion in the Mining Proposal assessment process as the role of the Environmental Management Branch of DEC and the applicability of conservation requirements to a mining project were unresolved. A significant complicating factor was the land clearing exemptions applicable to approved mining projects in Regulation 5, Item 20 (Low impact or other mineral or petroleum activities 10 hectare per tenement per financial year) exemption of the *Environmental Protection (Clearing of Native Vegetation) Regulations 2004* are not able to be used for a conservation area. Schedule 5, Clause 2 of the *Environmental Protection Act 1986* defines a conservation area as *"land or waters reserved, protected or managed for the purpose of, or purposes including, nature conservation"*. This resulted in additional Clearing Permit applications being required for the borefield tenements. Whilst preparation of the additional Clearing Permit applications was not technically difficult, the 60 to 90 day assessment process had not been factored into the project development schedule and prevented the Mining Proposal being approved until the Clearing Permit was assessed and granted.

If a project is located on an ex-pastoral lease purchased by DEC, the land tenure should be understood. Knowing the level of involvement of DEC in actual land management and consultation with EMB to determine the application of exemptions to Clearing Permit requirements is essential.

Formal Referral by the Environmental Protection Authority (EPA)

The Office of the Environmental Protection Authority (OEPA) and DMP have a Memorandum of Understanding (MOU) on a number of criteria used to determine if a Mining Proposal requires referral to the EPA for assessment under Part IV of the *Environmental Protection Act 1986*. However, there are some other issues that are not clear whether referral is required. It is therefore up to the proponent whether to self-refer or hedge that no Decision Making Authority (DMA) will refer the project if assessed under the *Mining Act 1978*. Sandfire encountered this issue as the location of their project on what DEC considered land managed for conservation. The legal tenure of the land is Unallocated Crown Land and Land Titles within DMP considered DEC to have no legal tenure over the land. Early consultation with the OEPA had indicated the EPA had no interest in formally assessing the DeGrussa project under Part IV of the *Environmental Protection Act 1986*. As this was verbal feedback from a meeting with the Chairman of the EPA, and Sandfire had no formal written advice from the EPA, considerable discussion resulted between DEC and DMP about the need to make a formal referral to the EPA and if so, who this would be done by. Subsequent to DEC (EMB) raising the proposed conservation park issue, the need for involvement of the EPA was revisited at a further meeting between Sandfire and the EPA. Further liaison with OEPA, DMP and DEC resulted in a decision that the project could be assessed under the *Mining Act 1978* and Part V of the *Environmental Protection Act 1986*. The lack of written documentation from the EPA confirming their view that formal assessment was not required contributed to delays and conflict between other regulatory agencies. Careful considerations should be given to the need to submit a Referral Document to the EPA when potential issues may arise that the current MOU is not clear.

Role of DEC (EMB) in Assessment of Mining Projects

Some sensitive issues arose during the Mining Proposal and Clearing Permit assessment for Sandfire as DMP requested DEC comment on the application. DEC stated that Sandfire had not sufficiently liaised with their department. This was not intentional – Sandfire had liaised extensively with the Midwest Office of DEC regarding their larger Doolgunna Project (exploration) and had met with them to identify their intention to develop the DeGrussa Project (mining). This included development of a Conservation Management Plan reviewed by DEC for their exploration activities on the former Doolgunna Pastoral Lease area.

Sandfire had not identified DEC (EMB) as a stakeholder for development of their DeGrussa Project. DEC environmental impact assessment officers in the Midwest Office had not notified Sandfire that consultation with EMB would also be required. Sandfire subsequently found out during the Mining Proposal assessment process that in the case of DEC managed land or where there are sensitive ecological issues, it is important to liaise with the region for exploration activities, but once the decision is made to develop the project into a mining project, it is important to liaise with both EMB and the region. Proponents should not assume information presented to one part of a regulatory agency is shared with other branches or officers. If in doubt, include DEC (EMB) in regulatory consultation unless they notify you otherwise that they do not wish to participate.

Involvement of Environmental Professionals Early in Project Planning and Scheduling

Sandfire achieved its aggressive project development objectives because they recognised the need to involve environmental professionals and engage regulators early in the project development process. Just like dating, sometimes you need to seek the help of friends, put your profile on the net or do something “outside the square” like speed dating. Environmental professionals are often unique in that they have a broad understanding of an entire project rather than just individual components like the mine or processing plant. For the DeGrussa Project, involvement of environmental professionals extended beyond just having input into project development and environmental assessment schedules.

Sandfire actively engaged external environmental professionals with extensive mining, specifically copper mining experience. This allowed focused baseline and engineering studies to be commissioned concurrent with resource definition. Results of these were used as part of the project planning.

Sandfire actively involved environmental personnel in development of environmental requirements at the design stage for the processing plant and IWL including the TSF. Many companies engage environmental professionals too late in the process, when designs are largely complete rather than contributing to a list of specifications for the design engineers. Sandfire ensured environmental personnel were also involved in review of Plant and TSF designs to ensure the required environmental outcomes had been achieved and the manner of achievement was practical, effective and infrastructure was likely to be immediately operated after construction was complete.

Recruitment of an Operations Environmental Manager as the project progressed continued the close involvement of environmental professionals in all facets of project. The broad knowledge of the project allowed the Environmental Manager to identify competing or conflicting resource needs and potential failures to meet regulatory requirements of voluntary commitments made during the environmental assessment process. The close working relationship between the Operations Environmental Manager and MBS personnel concurrently developing assessment documents and applications ensured all applications were relevant, practical and commitments could be achieved.

Conclusion

A key component of successful work and relationships revolves around communication - talking and listening. Personal interactions between the project team, key stakeholders and regulators are critical to ensure sound project development. The most logical way to obtain a solution may not always be the best way. The final scenario is usually one that takes into account stakeholder views through early engagement to determine and anticipate their needs.

Consistent engagement with follow up and accurate documentation of events will ensure one can keep abreast of changes – because they will happen. Be flexible with changes whilst staying as close as possible to original timeframes. Be adaptable, because sometimes things happen that blow out timeframes and always allow a “buffer” in case blow-outs do happen.

Sandfire was successful in its environmental assessment experience. Necessary approvals were obtained in a timely manner and just as importantly, commitments made to obtain the approvals are being successfully implemented during construction and early stages of the operation. The environmental outcomes Sandfire wants to achieve are being achieved. Success doesn’t just happen – there was hard work and commitment from Sandfire, its consultants and regulators. Whilst the similarity to speed dating may seem flippant, when the timeframe from first development to first product exported from site is considered, it can be seen that for this project it *was* speed dating, and it worked!

Gaining approvals in a timely manner should not be thought of as akin to finding a pot of gold at the end of a rainbow. You just need a good treasure map to get you started, a team of committed and flexible people to go looking with, set realistic goals and then hold on tight and enjoy the ride to get to happy ever after.

AVOIDING THE LONG GREEN ARM OF THE LAW

Andrew Mack, General Manager – Syrinx Environmental PL

Abstract

The regulatory process has become increasingly complex. As our natural and cultural resources are subjected to increasing pressures, there are inherent increased levels of scrutiny and protection.

Any development, project or proposal has the potential to impact on the environment. The size and nature of these impacts will determine exactly where a proponent sits within the landscape of enforcement. Just as importantly, the approach taken by a proponent will also dictate the ultimate outcome in terms of enforcement.

So what are you doing right now to avoid enforcement action?

If the answer is something along the lines of 'not much at all' then chances are you will be unprepared when something does go wrong.

Planning to avoid enforcement action starts now, no matter where you are in your project's life-cycle and there are a number of facets to your approach that will dictate an ultimate enforcement outcome. Planning to avoid enforcement action should be a proactive part of your business, rather than a reactive measure that relies heavily on something not going wrong in the first place.

This paper will present some of the issues associated with enforcement and prosecution and also provide some ideas and thoughts as to how best avoid the long green arm of the law, both from a State and Federal perspective.

Introduction

The Long Green Arm of the Law can refer to a range of different aspects. Be it land tenure, impact assessment, licensing, emissions accounting or restoration, rehabilitation and closure – all of these are covered by some level of environmental legislation.

Of course a key concern for any operator is the issue of enforcement or prosecution. How can you avoid being the subject of enforcement action? Whether this results in a 'guilty' finding or not, such actions can be extremely damaging to a company's reputation and its market position.

Someone once said that the best form of defence is a good offence. This may be a truism in certain circumstances, but when faced with threat of prosecution, the best form of defence is to have not done anything wrong in the first place.

If you have done something wrong, might have done something wrong or might do something wrong at some stage in the future, what can you do about it?

The Boy Scout's famous motto is "Be Prepared". This applies to a great many aspects of life, including environmental management. Planning to avoid environmental prosecution should be a part of the way you do business. It should be a proactive part of your business, rather than a reactive measure that relies heavily on something not going wrong in the first place. In his famous text, "Scouting for Boys", Robert Baden-Powell, the founder of the scouting movement, explained his views on this phrase. "Be Prepared in Mind by having…thought out beforehand any accident or situation that might occur, so that you know the right thing to do at the right moment, and are willing to do it" (Baden-Powell, 1909).

It is precisely this forethought that will form the crux of avoiding any enforcement action.

Discussion

Avoiding enforcement action for any offence relies on a number of critical factors.

Firstly, and most importantly, it would be extremely helpful if you haven't actually committed an offence. The obvious consideration here is really whether you know what constitutes an offence and whether you are at risk of such an offence, either now or in the future. Similarly, having the information available in a form that stands up to scrutiny can also save a costly enforcement process.

Knowing your operations, its people and its statutory requirements are absolutely critical unless you're relying on a 'hindsight' defence.

The assumed knowledge here is that you actually know your operations, what you're doing or what you're getting into. In terms of preventing a leap of faith into the unknown, the best value for money for you is probably a thorough due-diligence before even becoming involved with the operations. Spending this sort of money is a smart decision and can save much heartache and money down the track (and perhaps a stint in jail). It allows you to have a thorough knowledge of what you might be getting into before you actually do…and that's all it's about at the end of the day. Really getting to grips with what's going on. What are your approvals telling you? Do you have suitable management measures or a management system in place? Are you complying with your approvals?

The American businessman Alan Lakein once said "Planning is bringing the future into the present so that you can do something about it now" and planning in this context can be likened to an insurance policy. Yes, it costs money up front, it's generally not cheap and the insurance may never be used. But ultimately it forms a basis from which to defend a prosecution at the very least and, more importantly, a regime that minimises the risk of any threat of prosecution in the first place. You will find that any industry advocates that best practice at ensuring compliance and avoiding prosecution should part of your forward-planning process.

Surprisingly, the fundamental building blocks of environmental compliance, the approvals (licences, permits and the like), are often overlooked in the whole scheme of things. Knowing what you actually need to do to comply with your environmental obligations is obvious and yet it is surprising how often this gets overlooked. Ensuring that the requirements for environmental compliance are reasonable is also critical. Never assume that you can actually meet what's on your licence and don't be afraid of questioning those requirements (or using the appeal provisions of the relevant legislation if needed).

Equally as important is having a team of trusted staff and personnel around you.

Do you know who you've employed? Do they have the same ideals and ethos as you and will they align themselves with you and the company if an iceberg does some serious damage to the ship? Who are your contractors? Who are your consultants and lawyers? Do they know you? Are they working in your best interests? It's not uncommon to find companies being committed to a suite of un-needed requirements by their consultants if their work isn't being verified and understood? Ensuring you know what is required means that you're able to instruct and guide the people who are working for you and ensure that what you need and what they are going to provide are one and the same.

On top of all of this, letting your team do its job is a fundamental part of any operation. You pay good money for professional consultants and lawyers to do a job. As long as you know them and they know you, let them do their job and allow them in to your operation. The more they know, the more they can help you (and help you minimize your exposure to prosecution and additional expense down the track). Ultimately, these people are going to be talking about you and your operations…perhaps within a legal framework. You really need therefore, people who aren't going to be flavouring their work, interviews, witness statements and evidence with discontent, suspicion, malice or any other negativity.

One aspect of compliance and enforcement that frequently gets noted is the systems that are set up within an organisation and the way it handles and manages data. Aside from the ease of being able to put a finger on particular data as it is required, the very fact that there is a logical approach to data management will also suggest, if not demonstrate, that there is a system in place that deals with all things environmental. An Environmental Management System (EMS) can be a critical component of your operations and refers to the management of an organisation's environmental programs in a comprehensive, systematic, planned and documented manner. It includes the organisational structure, planning and resources for developing, implementing and maintaining policy for environmental protection.

An EMS is a way of avoiding the need for a defence in the first place (if implemented properly) and can actually form part of a defence in itself.

An Environmental Management System (EMS):

- Serves as a tool to improve environmental performance
- Provides a systematic way of managing an organization’s environmental affairs
- Is the aspect of the organization’s overall management structure that addresses immediate and long-term impacts of its products, services and processes on the environment
- Gives order and consistency for organizations to address environmental concerns through the allocation of resources, assignment of responsibility and ongoing evaluation of practices, procedures and processes
- Focuses on continual improvement of the system

(QSE Solutions 2012)

As a tool, an EMS also provides a range of associated benefits. Whilst not perhaps being the most reliable source of scientific information, Wikipedia offers a useful summary in relation to the benefits of an EMS:

- Financial
    - Cost savings through the reduction of waste and more efficient use of natural resources
    - Avoiding fines and penalties from not meeting environmental legislation by identifying environmental risks and addressing weaknesses.
    - Reduction in insurance costs by demonstrating better risk management.
- Operational and Internal
    - Improved overall performance and efficiency.
    - Able to monitor and reflect (audit) your business and see which areas need Intervention
- External
    - Better public perception of the organization, leading to improved sales

- Reduction of the impact of your activities on the environment, leading to more community support and a better company profile
- Feel-good factor

(Wikipedia 2012)

These all relate directly and/or indirectly to a defence and are covered within the DEC's Enforcement and Prosecution Policy (2008) whereby a range of factors are considered when looking at any enforcement action, including Compliance (and history thereof), the nature of the alleged offence, where enforcement would be in the public interest and finally the attitude of the company involved.

Such commentary is obviously drawn from the statutory requirements of the *Environmental Protection Act 1986*, in this case Sections 74-75 which describe 'Defences to Certain Proceedings'. Preparation is something that is strongly emphasised and one of the best means of preparation is having an EMS in place.

Perhaps more importantly is the imperative of knowing who you're dealing with outside your pricing structure. The community for example can be your best friend or worst enemy depending on how you interact with them. It's absolutely critical that they don't get the wool pulled over their eyes and consider when you want to give them information and how.

Equally as important as your staff and community are your Government officers. In this regard, honesty is often the best policy and getting them involved in what you're doing, how and why as early as possible means that they will understand your operations that little bit better and can provide advice and assistance provided you treat them as a stakeholder in your operations. If you can do this, and allow them to do their jobs, the whole process becomes that much easier.

Having said all of this about setting up relationships with Government, it is also important not to be afraid to challenge them particularly if you are confident with the work undertaken and you have planned ahead. In fact, undertaking the planning and ensuring you're fully aware of your systems, your EMS and your external factors will often derive a level of confidence which would not otherwise be present to you and your team.

A judgment recently handed down in the Federal Court has forced a reconsideration of a proposed 'Controlled Action' under the *Environment Protection and Biodiversity Conservation Act 1999*. This outcome came on the basis that the Applicant (Landcorp) had done their planning and was of the opinion that the Federal Department of Sustainability, Environment, Water, Population and Communities (SEWPAC) had not considered fully the weight of evidence being put forward in relation to the matter. Furthermore, the Guidelines being utilized by SEWPAC in relation to this matter were only in draft format, had been circulated internally within SEWPAC, had not been produced for public consideration or deliberation in a transparent fashion at the time and are, to date, yet to be adopted (Lavan Legal 2012).

Obviously, the challenge centered on a distinct lack of clarity and certainty within the process, leading to a question of what constitutes a significant impact.

The Federal Court agreed and found error with SEWPAC's approach, including that Landcorp had been denied natural justice. The findings of the court included the following:

- That Government decision-makers must provide all documents on which they are basing their views and give the proponent the opportunity to comment.
- That Guideline documents cannot outweigh the need for project and site specific assessment.

As a result of this finding in the Federal Court, SEWPAC's original decision has been quashed the matter has now been forced back to SEWPAC for a decision free of error (Freehills 2012).

The lawyers acting on behalf of Landcorp on this matter, Lavan Legal, had this to say in relation to the benefits to industry from these findings:

- The internal processes of SEWPAC have been exposed to judicial scrutiny.
- Secret policies cannot be formulated and applied, otherwise decisions upon which they are based can be successfully challenged in the Federal Court.
- The practices and procedures of SEWPAC will need to be modified to ensure that policies are applied in a fair and transparent manner, with key aspects of the policies being made known to proponents, with an opportunity to respond, prior to decisions being made.
- The basis for making decisions about potential projects must take into account appropriately prepared scientific reports, not simply a rigid application of policies, absent lucid and careful consideration being given to the site's specific circumstances.

(Lavan Legal 2012)

Lavan also had this to say "In the meantime, the doors to the asylum have been unlocked and some sense of sanity has been restored."

This outcome emphasises the need for proper planning, a clear understanding of your legal obligations and requirements and a demonstrable attention to detail with respect to so-called 'lines of evidence'. Your operations need to be water-tight in relation to environmental risk. If you are even unsure or debating the level of risk that it might be appropriate to take, it's worth keeping in mind another case recently heard within the WA State Administrative Tribunal (SAT) which brought findings against a land developer on the basis of the Precautionary Principle.

In "Wattleup Road Development Company Pty Ltd and Western Australian Planning Commission [2011] WASAT 160", the Tribunal found that, despite a substantial weight of evidence suggesting otherwise, there was enough scientific uncertainty regarding an environmental risk for residents of the proposed subdivision in relation to dust from a nearby residue disposal area and sand quarry. In this regard, the Tribunal brought into play the precautionary principle and found that "the precautionary principle warranted refusal of the proposed subdivision, unless and until adequate air quality monitoring is undertaken and reviewed in relation to the site demonstrating that the proposed subdivision would be acceptable in relation to the health and amenity impacts of dust."

Whilst this may seem a little self-explanatory and obvious, it is worth pointing out that up until fairly recently, air quality monitoring had shown little offsite impact and suggested the risk was acceptable, certainly to the extent of zoning the site as "Urban Deferred" and hence suggesting that future development could take place in a normal and orderly fashion. It is also worth pointing out that the DEC's own air quality monitoring suggested exactly this and it was the subsequent uncertainty about future risks from the reside facility that brought the matter to a head. Whilst the Applicant in this matter had seemingly assured themselves that there was an adequate weight of scientific data to support their contentions, the Tribunal disagreed. For the land-owners waiting to develop this land after a substantial investment, it presents itself as something of an expensive white elephant if the issues cannot be resolved.

Drawing the attention back to the "Be Prepared" mantra, all eventualities must be catered for as far as practicable. A corollary to Murphy's Law says that if you perceive that there are four possible ways in which something can go wrong, and circumvent these, then a fifth way, unprepared for, will promptly develop. Being prepared for unforeseen circumstances is what it's all about and this involves an inherent understanding of your operation and your team.

One approach to understanding your operations and your liability is to undertake a risk assessment. This allows you to determine areas of concern (future prosecution), rank them and determine where money should be spent – the biggest bang for your buck. Which risks should you be spending money on now? Where do your risks lie? Are they significant? Can they become significant? What areas of your operations could be subject to prosecution?

It really comes down to a matter of knowing what's going on. If you don't know what's going on, either with your emissions, your operations, your staff, your consultants, your stakeholders or your regulators, your chances of a prosecution are likely to rapidly increase. Having this understanding also allows for a more successful challenge to a purported enforcement action or defence against one that is brought against you.

Conclusion

Taking all of the above into account, can you realistically expect to avoid the long green arm of the law? The answer, perhaps unfortunately, is a firm no. Any operation is always going to be subjected to a range of statutory requirements in terms of permits and approvals and there is the ever present vigilance from regulators and the wider suite of stakeholders including the community (the old adage of a 'social licence to operate').

Notwithstanding this, avoiding the unpleasant side of this legal framework can be achieved if you take control of your operations, understand them and the people who form part of your team, plan ahead and perhaps have a little bit of luck on our side.

Unfortunately, there also needs to be recognition that even the best laid plans can often be laid to waste by something out of left field. The former US president Dwight D Eisenhower made this observation “In preparing for battle I have always found that plans are useless, but planning is indispensable”.

In the heat of battle, having planned all you can, sometimes the plans that you have put in place fall by the wayside and you become reliant on your knowledge and the people, stakeholders and systems associated with your operation.

If you know them and trust them, then your defence against an enforcement action and the tightening grip of the long green arm of the law stands a very good chance.

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Environment in Design – Getting the Balance Right

Vanja Sekizovic, Operations Manager Environment – Calibre Global

Abstract

Getting the balance right between applying for environmental approvals early to meet project schedule versus having sufficient design information has always been a challenge. Where approvals are sought too early in the design stage, required information is generally unavailable or inadequate and changes to the project scope and approvals are likely down the track. This can also result in the inability to influence design to achieve better environmental outcomes. However, applying for environmental approvals once sufficient design information is known, usually leads to tight schedules and unnecessary pressures placed on regulatory bodies to approve applications to meet construction dates.

Calibre's Business Management (BMS) and Environmental Management Systems (EMS) have recently been updated to reflect the requirements of early consultation with the Environmental Team to ensure environmental concerns are addressed during preliminary stages of project planning. Methodologies employed include provision of various templates to identify legal and other requirements, design review criteria checklists, implementation of 'gates' in design phase and environmental education of engineering and design teams.

Whilst these processes are in their early implementation stage, anecdotal evidence shows positive results. These results include timely planning and scheduling of adaptable approvals, positive contributions to design reviews and subsequent integration of environmental requirements into construction activities leading to improved compliance and better environmental outcomes.

Introduction

As environmental professionals we are largely aware of what we should be doing in order to ensure best practice environmental management within our organisations. This includes ensuring environmental concerns and aspects are considered early in the design and planning phase of projects, to ensure best possible (sustainable) environmental outcomes in the longer term. The problem is not usually the why, it is the how. How do we, as environmental professionals, ensure all stakeholders (internal and external) are aware of environmental constraints and their impacts on scheduling of environmental approvals? How do we ensure these stakeholders are adequately informed and what information is required to ensure approvals are obtained in a timely manner to achieve project milestones?

Getting this balance right between applying for environmental approvals early in the project planning stage, versus applying for environmental approvals later in the project definition stage has always been a challenge. If approvals are sought too early in the design stage, required information is generally unavailable or insufficient, and changes to the project scope and approvals are likely down the track. However, applying for environmental approvals later on in the project stage, once the project scope is more certain and sufficient design information is known, usually leads to tight schedules and unnecessary pressures placed on regulatory bodies to approve applications to meet construction and operation dates. The cost of getting the balance wrong can potentially run into many millions of dollars in opportunity cost, in correction of design errors and/or in additional resources to meet original schedules.

Calibre Global Pty Ltd (Calibre) is certified to AS/NZS ISO 14001, and as such our EMS provides a framework for managing environmental obligations so they are effectively integrated into overall business operations. This paper identifies the techniques which Calibre employs to ensure environmental aspects are addressed appropriately, and to clarify for its stakeholders how we can 'Get the Balance Right'.

Planning

The difficulty for anyone in a similar situation is communicating with the engineering teams, to inform them of their roles and responsibilities. At Calibre, the Environmental Team took a leaf out of Safety's book, specifically the 'Safety in Design' requirements. The Occupational Health and Safety (OHS) law is governed by a framework of Acts and Regulations along with supporting material, such as guidance notes. Under these Acts and Regulations a designer/engineer is required to know and understand their OHS statutory responsibilities and duties. Designers have a duty of care to consider the health and safety of their designs over the entire lifecycle. This duty of care extends to all persons who will, or may be involved in the construction, commissioning, operation, maintenance and decommissioning of that project. The designers were made aware of their 'Safety in Design' duties through an extensive training and competency campaign within Calibre. While there are no such specific requirements written into the environmental legislation, the duty of care with regards to environmental harm still exists. The Environmental Team decided to undertake a similar approach with 'Environment in Design'.

The initial stage of planning for 'Environment in Design' involved reviewing the existing Environmental Management System (EMS). The EMS at that point in time included 19 finalised procedures and approximately 10 other supporting documents in draft form. Additional tools were available, but not readily accessible or equally applied across all projects. The review of the documentation and subsequent risk assessment identified numerous improvements. Currently the EMS includes approximately 92 documents, and is continually growing as new document requirements are identified. These documents (procedures, work instructions, forms, guides and registers) are available, but not necessarily utilised on all projects. These documents are mapped via Microsoft Visio to identify their inter-relationships including hierarchy. An example of the relationships of the documents is shown in Figure 1.

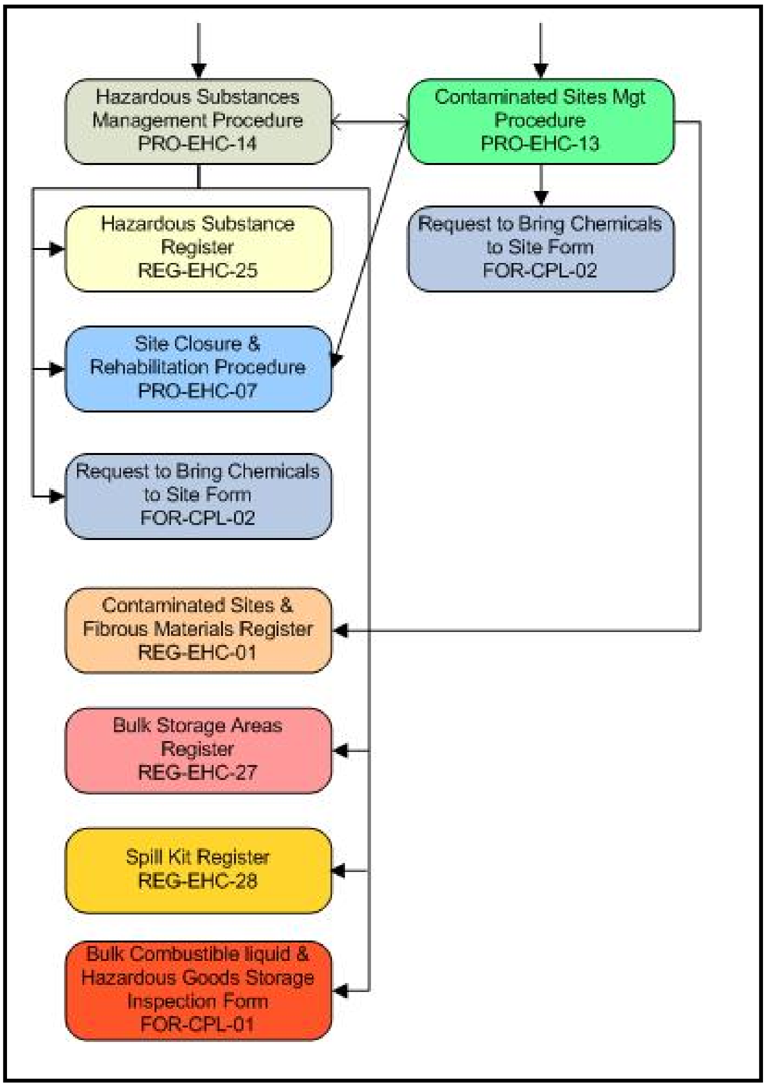

Figure 1: Example EMS Document Map

These tools (plans, procedures, work instructions, guidelines, forms and registers) were seen as an integral part of the Business Management System (BMS) and the EMS. The aim is to ensure all environmental obligations are met and to assist in the successful delivery of current and future Calibre projects. They can also be used to control risk and capitalise on opportunities within the wider BMS and business operations. The documents were considered to form a part of the Environmental Design Life Cycle, as depicted in Figure 2, below.

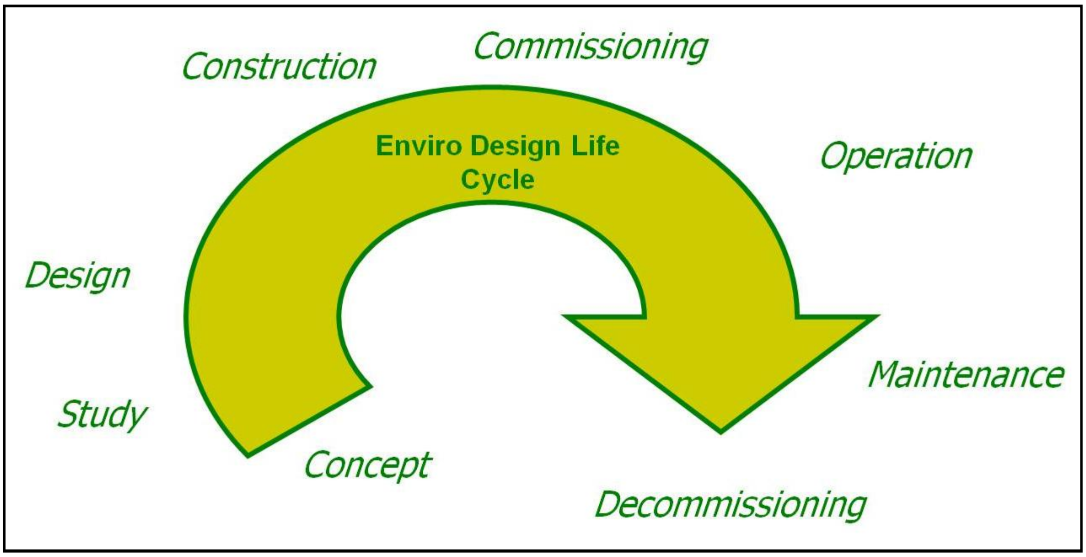

Figure 2: Environmental Design Life Cycle

Understanding the Environmental Design Life Cycle and where the Environmental Team should leverage the 'Environment in Design' framework was found to be integral to the success of the EMS. Integration into the project delivery system was seen to be the key, as was the requirement to meet ISO14001 standards.

Legal Obligations

Identification of applicable environmental Acts and Regulations to Calibre's project activities commenced with thorough analysis of all potentially applicable legislation. The research identified approximately 13 Commonwealth Acts, nine Commonwealth Regulations, 47 State Acts (WA) and 58 State Regulations applicable to Calibre's Projects. In addition, the research identified 26 Australian/New Zealand Standards which applied based on our Health, Safety, Environment and Quality Policy. State Government Agency guidance notes and policies were not documented during this review, but may form a part of future revisions of this Legal and Other Requirements Register (LORR).

The LORR includes:

- Act and/or relevant regulation;
- Jurisdiction (State/Commonwealth);

- The objectives of the Act (commonly known as the Objects Clause);
- Section(s) of the Act relevant to Calibre's activities;
- Key environmental obligations (such as permits required, minimum standards etc.);
- Relevant internal documents (such as a procedures, plans, or work instruction which address the key environmental obligations);
- If the Act/Regulation is relevant to that Project scope;
- If relevant, what actions are to be taken (such as an approval to be applied for, implementation of waste management plan etc.);
- Record of the actions being completed; and
- Reference number for the actions/approval document.

An additional spreadsheet exists within the LORR work book which identifies and tracks revisions of the legislation and if any actions are required following amendments (such as updating Calibre internal documents and Company wide communication requirements). This ensures sufficient record keeping is completed by the projects to ensure we fulfil our statutory obligations and subsequently meet our ISO14001 requirements.

The LORR is directly linked to the Commitments Register and Audit (CRA). The CRA is specific to any commitments made by a project (such as commitments contained within approval documents), and any subsequent government approval conditions (such as tenement conditions). The document includes:

- Unique commitment/obligation reference number;
- Client/government reference number;
- Document title;
- Site location;
- Approval type;
- Approval date;
- Expiry date (which is conditionally formatted to alert us to upcoming required renewals);
- Status of the document (approved, expired etc.);
- Regulatory department;
- Commitment/obligation requirements;
- Aspect;
- Phase the commitment/obligation relates to (design, construction, operation, rehabilitation);
- Responsible organisation/person/position;
- Status (open, closed, ongoing);
- Compliance document/evidence and its storage location;
- Recurrence (usually for reporting requirements);
- Close out date (for audit purposes);
- Current compliance status (yes, no or ongoing); and
- Comments relating to the commitment/obligation.

These documents provide a basis to achieve the requisite definition of what, how, who and when to ensure adequate fulfilment of legal and other requirements. Through integration with the BMS, Calibre's EMS allows for linking between these spreadsheets and the environmental resourcing guide.

The resourcing guide links compliance activities with indicative timings for each activity providing a scientific basis to determine the required number of environmental professionals for each project, both in the Home office and on site. The guide is based on the geographical spread, risk/environmental sensitivity and number of environmental approvals required (or the number of contractors for site based staff). The Project/Construction Managers are able to access the specification/guide and based on the information above identify effort required by the environmental professionals for the duration of the project, which is then utilised in scheduling and budget allocation. This is an example of how through the implementation of a robust BMS, the EMS has been able to influence early project tendering, planning and resourcing.

Calibre has successfully commenced implementing the LORR and CRA, and the feedback to date has been that the package is easy to use and clarifies everyone's roles and responsibilities with regards to legal and other obligations, especially during the Concept and Study stages, where many aspects can be managed by implementing adequate environmental controls during design.

Concept Design Reviews

The concept design stage (typically 15% design review), is conducted early on in a project's life. At this stage it is important to ask the right scope of questions to ensure commencement of applications in respect of long term approvals (such as Part IV scoping documents under the Environmental Protection Act 1986 (WA). An example of the Concept checklist is found in Figure 3 below. At Calibre, we encourage engineers to think outside the box, and consider future proofing their designs to allow for sufficient buffers for the inevitable scope creeps/changes that are the reality of working in this industry.

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15% Environmental Design Review Checklist

FOR-EHC-13

Ref	Description	Checked	Action Register Ref #
1.0	**Scope**		
1.1	Is sufficient information known about the scope? (i.e. what are we actually going to construct)		
1.2	Has all ancillary infrastructure been considered?		
1.2.1	Signalling (signalling pads, solar panel locations, battery boxes, asset protection sites)		
1.2.2	Communication (FOC, Telstra, Repeater stations, temporary construction communication)		
1.2.3	Power (installation, relocation, modification and decommissioning, interaction with existing services, energy efficiency)		
1.2.4	Access Roads (sufficient buffers available for haul roads, expansion of existing roads or construction of new, SME & LV interaction, future expansion work proofing, transport for equipment from port/Perth to site)		
1.2.5	Borrow/Ballast (borrow sourcing strategy, quantities required, utilisation of mine waste, borrow pit search area identification, commercial supplier options, transport to site)		
1.2.6	Camps (construction of new camps to cater for scope changes, expansion of existing camps, utilisation of existing camps, energy efficiency)		
1.2.7	Hydrological impacts (e.g. are culverts being extended, any major drainage lines / creeks which will require diversion, bridges, is modelling required etc)		

Figure 3: Example 15% Environmental Design Review Checklist

The form is to be used by the engineering and design teams as a prompt, or the Environmental Specialist while attending the design reviews. A part of the BMS is a Project Controls 'gate' which does not allow the project to move on with further design until the completed form is signed off by the Area Manager and the Environmental Specialist.

Study Design Reviews

The study design stage (~50% design reviews) involves a very similar design checklist, in which the project scope is questioned and further refined. This 'gate' includes defining the environmental deliverables required for the client or project, as shown in Figure 4. These can be adjusted to include site specific management plans, approval commitments or obligations (such as Significant Species Management Plans).

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50% Environmental Design Review Checklist

FOR-EHC-14

Ref	Description	Checked	Action Register Ref #
3.0	**Environmental Risks / Aspects**		
3.1	Has a preliminary, high level Project Risk register been completed (refer to Environmental Risk Management Guide)?		
3.2	Have the environmental risks been addressed adequately?		
3.3	Have the risks been communicated through to the client (e.g. potential schedule delays, drop dead dates etc)		
4.0	**Legal and Other Obligations**		
4.1	Has the Legal and Other Requirements register been completed for the Project?		
4.2	Have the approvals been planned/implemented?		
4.3	Has the Obligations/Commitments register been compiled?		
5.0	**Environmental Objectives and Targets**		
5.1	Are there any specific Objectives and Targets (O&Ts) that apply to the Project (Calibre or Client requirements to be addressed)		
5.2	Are any of the O&Ts relevant to the Study Stage (e.g. Commitments to minimising clearing, greenhouse gas emissions, strategies to reduce waste etc)		
5.3	Will Environmental Improvement Plans be required for O&Ts?		
6.0	**Resourcing**		
6.1	Does the environmental resource strategies identified during Concept stage still apply? (i.e. are additional resources required?)		

Figure 4: Example 50% Environmental Design Review Checklist

At this stage Calibre has decided to lock in the scope and freeze the project boundary. This ensures a solid understanding of the project scope/boundary and approval schedule expectations, and avoids the inevitable schedule delays as out of scope items are introduced. The process for scope changes at this point is managed through the Project Controls team and controlled via the 'Scope Change' procedure. This procedure ensures a robust review of all impacts including risks and delays prior to sign off by the client. At this stage the Environmental team requires confidence on the definition of water sources for the project, borrow strategy, secondary infrastructure (such as batching plants, water treatment plants, crushing and screening locations) and other general items (such as fibre optic cables, general laydown areas, manning levels etc.). A number of approvals are encouraged following this step, including the Native Vegetation Clearing Permits, scoping documents for Works approvals, State Agreement Act Project Proposals etc.

Constructability Reviews

Constructability reviews should be conducted as early as possible on the project. Calibre Environmental team originally suggested completing these at either 50% or 85% design reviews, but upon further discussions with the Engineering teams it was suggested that constructability reviews should be conducted even earlier (as early as 30% design reviews). Discussions with the engineering leads indicated that they felt comfortable being asked specific questions even at this early stage, as in their experience any scope changes following the 30% Design reviews were would have too great an impact (with regards to schedule and cost). This is subject to further discussion and trial implementation.

The constructability reviews must be undertaken in order to prevent cost and schedule blowouts and numerous site instructions once construction or operation commences. The suggested approach should include a number of disciplines. These include the construction management, signalling, communications, earthworks, civil, mechanical, contracts, environmental, safety and other teams. The process can be completed as a part of the risk assessment or mitigation strategies to ensure everyone is aware of the controls to be implemented. The focus of the constructability review would be the ability to construct the project based on proponent commitments, likely/actual regulatory conditions and site requirements. Example questions to be asked during this stage are shown below on Figure 5.

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Constructability Environmental Design Review

FOR-EHC-15

Ref	Description	Checked	Action Register Ref #
1.0	**Constructability**		
1.1	Access (is there sufficient access for the types of machinery to be used – cranes, scrapers, dozers, semis)		
1.2	Vehicle turn around/parking areas (is the size sufficient for planned fleet size? Consider if multiple contractors are being utilised and how they will be segregated)		
1.3	SME/LV separation (consider safety first, ensure sufficient buffers/areas are identified for passing/parking, ingress/egress)		
1.4	Signalling pads (consideration of pad size and how it impacts on access roads)		
1.5	Stockpiles – vegetation, topsoil, subsoil, spoil, borrow, ballast etc (are they planned in areas for easy access, away from drainage lines, erosion controls planned, weed management strategies)		
1.6	Washdown requirements considered (utilisation of existing, creation of new – temporary vs permanent)		
1.7	Batching plant design (flood risk identified, water recycling encouraged, dust suppression controls planned, waste management planned)		
1.8	Culvert extensions/new flows considered (inflow/outflow heights, stream training upstream and downstream, rock protection, erosion controls etc)		

Figure 5: Example Constructability Environmental Design Review

Following the 85% design review, Mining Proposals, Bed and Banks and Planning/Shire approvals can be progressed.

Construction, Implementation and Commissioning

During the on site construction, implementation and commissioning, the focus should be on legal compliance. This can be achieved through implementation of management plans, auditing, daily/weekly inspections, corrective and preventative action management, emergency management and management reviews.

Operation, Maintenance and Decommissioning

During operation, maintenance and decommissioning, regular legal obligations audits/reviews are to be conducted to ensure legal compliance. Where early planning is undertaken, rehabilitation can take place progressively. This may include direct placement of topsoil, suitable access to surplus spoil for rehabilitation of legacy sites etc. Good planning and progressive rehabilitation will reduce the associated cost of rehabilitation and contribute to improved rehabilitation outcomes.

Environmental Education, Training and Awareness

Calibre has implemented a number of techniques to ensure environmental education, training and awareness is conducted for all staff. New starters are required to undertake a Calibre induction, which contains specific environmental requirements, such as our obligations under ISO14001, risk management and introduction to the EMS. Project and/or site specific inductions are also held, and outline any client specific requirements, project risks, legal obligations etc.

In addition, Calibre has developed an environmental toolbox schedule covering the next two years. Projects are required to undertake one mandatory environmental toolbox per month, with topics based on the Calibre EMS and ISO14001 requirements. The toolbox presentations, posters and other materials are completed a few months before the schedule date by the Corporate Environmental Team, and provided to project Environmental Teams to allow for any project specific adjustments required.

Supplementary training has also been put into place via 'Lunch and Learn' sessions. These sessions caters for employees who wish to expand their knowledge in specialist areas. They usually run for an hour at lunchtime (with lunch provided by Calibre). For example, a recent lunch session was run to introduce the 'Environment in Design' checklists. The session was well received and a request for further similar sessions to be run in the future.

Ad-hoc awareness sessions are undertaken by the environmental teams being present during design reviews, project meetings and associated project discussions. These forms of awareness training, while not documented, have proven successful in ensuring the project teams are aware of their environmental requirements throughout the project planning and implementation stages.

Lessons Learnt

Corporate knowledge within Calibre has been identified as a significant asset. Until recently there has been no formal way of capturing this knowledge, through a lessons learnt process. Calibre Project Management and Environmental teams are currently working together on ensuring that a manageable 'Lessons Learned' process is implemented and maintained. This includes reflecting on lessons learnt at each stage of the project, rather than just at the completion of the project, when limited resources are available. The lessons learnt will be captured in a database available to all staff via the Calibre Intranet, and include leading questions such as what has worked well, what requires improvement and what aspects could have been show stoppers. Specific ‘gates’ within the design reviews and Project Control systems will be implemented to ensure that future project allocate sufficient resources at each stage of the project to review previous lessons learnt and ensure they are considered.

Problems Encountered

While the majority of the Calibre BMS/EMS implementation has been smooth, there have been a number of bumps in the road.

Current approach to Project schedules do not enable sufficient time between the design reviews. This can diminish the team’s ability to implement environmental control actions prior to moving onto the next stage of the Project. Calibre is continuing to work on this issue and is implementing further training and guides for the Project teams to improve scheduling of environmental approvals and associated matters.

There may be significant benefits where large project boundaries are permitted. This will contribute towards earlier submission of approval applications and more time for processing by the regulatory agencies. This would provide for more buffered approvals schedules and reduce the pressure placed on the regulators to issue approvals within tight timeframes. The reduction in approval amendments and changes would enable more time spent assessing approvals once, rather than re-assessing them each time there is a minor scope change. The benefits where large polygons (if sufficiently surveyed and risk assessed) can be utilised to future proof project where sufficient controls and mitigation strategies are implemented. Through the implementation of design review checklists, Calibre hopes to be able to provide better environmental outcomes through early engagement with regulators through the clients.

Further environmental training and awareness may be required to ensure site constructability issues are understood by environmental professionals (including ecologists, regulators, approvals specialists etc). This includes awareness of typical environmental controls (and which are practicable and reasonable or otherwise), clarity of environmental legislation (inclusion of duties along the lines OHS Safety in Design requirements) and continued competency training within the industry.

Conclusion

The successful implementation of Calibre’s EMS has relied on a number of factors. These include having a number of ‘closet’ environmentalists in the engineering teams who have taken on the role of champion for the environmental cause with little encouragement. Effective communication has been the key. The Environmental team has changed the way we do business, focusing on communicating in a way they comprehend, rather than writing wordy procedures which the engineers find tiresome.

The team has also commenced writing procedures with outcome based objectives in mind where possible, or specifications in-line with engineering specs where required.

The design review process has enabled better co-ordination between the different teams, and applying the approach taken for the 'Safety in Design' to 'Environment in Design' framework on the has provided a commonality that has received a warm reception by all.

Whilst these processes are in their early implementation stage, anecdotal evidence shows positive results. These results include timely planning and scheduling of adaptable approvals, positive contributions to design reviews and subsequent integration of environmental requirements into construction activities leading to improved compliance.

Calibre is always striving to continually improve our EMS through peer discussions and reviews to ensure that we 'Get the Balance Right'.

Adapting to Climate Change in Southwest Western Australia:

Managing Groundwater Decline and Restoration of Groundwater Dependent Ecosystems has Implications for Environmental Management on Mine Sites.

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Southwest Western Australia has experienced an unparalleled climate shift since the mid 1970's, characterised by reduced rainfall which has contributed to declining groundwater levels. Climate modelling attributes part of this change to atmospheric greenhouse gases, and predicts the drying trend will increase over coming decades.

The drying climate combined with other stressors including groundwater extraction threatens the survival of Groundwater Dependent Ecosystems (GDEs) including communities of stygofauna which are listed as Threatened Ecological Communities (TECs) (status Endangered) under the Federal Environmental Protection and Biodiversity Conservation Act. Recovery Plans prepared by the Department of Environment & Conservation (DEC) have failed to conserve these TECs and most occurrences have already been lost.

Recently the Augusta-Margaret River Tourism Association (AMRTA) and other collaborators have instigated measures to control and manage groundwater decline and restore habitat for stygofauna in Lake Cave. The recovery trial involves harvesting rainfall to supplement groundwater recharge combined with surveillance monitoring of water physico-chemistry to ensure that natural background ranges are maintained. In tandem with this a study is underway to model the eco-hydrogeology with the goal of developing management strategies for adapting to a drying climate future.

This case study has implications for environmental management of groundwater resources and subterranean GDEs throughout Western Australia including mine sites where groundwater extraction and dewatering are undertaken.

Further Information / References:

<http://www.subterraneanecology.com.au>

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The Measurement of Weeds to Meet Government Compliance for Resource Projects

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Abstract

Resource managers increase the risks of non-compliance of government conditions for weed management unless careful consideration of the quantitative, spatial and temporal data requirements are considered. Furthermore, these data need to be incorporated in management actions such that the effectiveness of weed management can be measured. This paper presents a summary of some Western Australian environmental approval conditions relating to weeds and shows how they became explicit in the late 2000s. We then discuss pragmatic approaches to measure compliance with these conditions when doing weed survey, monitoring and management.

Introduction

Increasingly regulators are applying approval conditions to projects that aim to restore native vegetation communities with weed levels comparable to either pre disturbance reference or regional reference levels (EPA 2012). In order to ensure compliance resource project managers require survey, monitoring and management protocols that assist both in planning, evaluation and compliance reporting. The objective of this paper is to show that Western Australian environmental approval conditions relating to weeds have become more demanding and that a more pragmatic approach is required to comply with them. We discuss a quantitative approach to survey and monitoring that can be used to inform the status of weeds on projects, and evaluate management actions, such that proponents can comply with government conditions.

Change in Conditions

Environmental approval conditions explicitly relating to weeds in Western Australia became common additions to project environmental approvals in the late 2000s (Table 1). Prior to this weed management was included implicitly, as part of obligations to develop rehabilitation and closure plans with details determined in consultation with the EPA or DEC (EPA 2012). The only explicit requirements for weed management were obliged through the more general declared weed legislation e.g. Agriculture and Related Resources Protection Act 1976. For example, in the case of the Cawse Nickel Project from 1996 no specific mention is made to weed management, though some management is implicit within requirements for rehabilitation planning. This implicit requirement has expanded with time (e.g. 3rd stage of the Fimiston project in 2007) however there is still no direct mention of weeds. By 2009 the conditions for the Cundaline and Callawa project made a quantitative leap. They refer specifically to which weeds (declared and environmental), the desired level of cover (not greater than pre-mining state or reference site) and that there should be no new species. The conditions for the Wheatstone gas project are more explicit, adding the type of survey required (baseline and repeated measures), periodicity (every 2 years), spatial extent of monitored area (within 50 m facilities footprint) and location of reference sites (further than 200m from facilities footprint).

Hence, many mining companies have not adapted to the more stringent realities of recent conditions regarding quantitative weed distribution and management. We use the rest of this paper to discuss a pragmatic approach on how this might be better done with respect to survey (species distribution and abundance at one point in time), monitoring (changes distribution and abundance over time compared to a reference) and evaluating management success (actions to reduce distribution and abundance).

Table 1: Examples of environmental approval conditions for resource projects relating to weed management (EPA 2012).

Project Name **Report #** **Dated assessed**	**Summary of weed related conditions**
Cawse Nickel Project, 50km north-west of Kalgoorlie EPA Bulletin 825 July 1996	Contains no direct mention of weeds. Condition 4.9 Decommissioning and rehabilitation/Technical information states *"In the long term, to establish a community of plants as stable, diverse and resilient as the pre-mining vegetation and which is compatible with the surrounding environment and land uses"*
Fimiston Gold Mine Operations Extension (Stage 3) and Mine Closure Planning Bulletin 1273 December 2007	Contains no direct mention of weeds. Condition 11.1.8 states "*the proponent shall prepare a Rehabilitation and Closure Management Plan to the requirements of the Minister for the Environment on advice of the Environmental Protection Authority and shall submit the Plan to the Department of Environment and Conservation. The Plan shall include:* *8. a detailed Rehabilitation and Revegetation program which includes local vegetation, performance criteria and a timetable to be met;"*
Cundaline and Callawa Mining Operations EPA Report 1338 September 2009	Directly mentions weeds. Condition 6.1 states *"within 1 year following the cessation of productive ore mining, the proponent shall commence rehabilitation of waste dumps and areas disturbed through implementation of the proposal".* Condition 6.2 requires rehabilitation must achieve the following: *4. The percentage cover of living native vegetation and species diversity .... targets shall be identified....., using the average values of suitable reference sites chosen in consultation with the Department of Environment and Conservation.* *5. The percentage of area covered by weeds (including both declared weeds and environmental weeds) shall not exceed that identified in baseline monitoring undertaken prior to commencement of operations, or exceed that existent on comparable, nearby land which has not been disturbed during implementation of the proposal, whichever is less.* 6. *No new species of weeds (including both declared weeds and environmental weeds) shall be introduced into the area as a result of the implementation of the proposal.*
Wheatstone Development - Gas Processing, Export Facilities and Infrastructure EPA Report 1404 June 2011	Directly mentions weeds. In condition 16 Weeds the report states the Proponent shall ensure that: *i. No new species of declared weeds and environmental weeds are introduced into the proposed extension to the Cane River conservation park that can be attributed to the Proposal.* *ii. Prior to ground disturbing activities the Proponent shall undertake a baseline weed survey to determine the species and extent of declared weeds and environmental weeds present at weed monitoring sites within 50 metres of the onshore facilities including the pipeline disturbance corridor and at least three reference sites on nearby undisturbed land beyond 200 metres from the Onshore Facilities disturbance footprint in consultation with DEC.* *iii. Baseline and reference weed monitoring sites .....monitored every 2 years for the life of the proposal ....* iv. *If the results of monitoring under condition adverse changes in weed cover and type within 50 metres of the onshore facilities footprint are Proposal attributable, the Proponent shall report the monitoring findings to DEC within 3 months of completion of the monitoring and shall immediately undertake weed control and rehabilitation in the affected areas, where Proposal attributable weed cover has adversely changed, using native flora species of local provenance.*

Setting Management Objectives

As with all environmental management, the most important step in developing any survey, monitoring or project evaluation project is determining management objectives. Defining clear, realistic objectives of what you want to measure and how it responds to the government conditions lays the foundation for the sampling design, directing the management questions, target species, data requirements and the extent of the survey area. Appropriate management evaluation frameworks should guide the development of the management and monitoring program. Environmental Management Systems following ISO 14001 or nationally recognised management frameworks by the IUCN provide management structure and direction for key environmental issues. In Australia, biodiversity management has adopted the IUCN Monitoring and Evaluation Framework (Hockings *et al*. 2006). Rio Tinto Iron Ore now use the IUCN framework to guide all biodiversity management decisions in their Pilbara operations (IUCN 2012, Rio Tinto 2010). The focus in IUCN frameworks is guidance in the development of monitoring programs that evaluate management effectiveness by combining monitoring <u>output reporting</u> with monitoring of management <u>outcomes</u> based on specified targets for biodiversity; for example, no decline in condition of a Threatened Ecological Community.

Surveys

A weed survey aims to capture sufficient data to provide an accurate representation of weed species within a defined survey area at a single time. It forms a baseline against which to determine future change which is detected by a monitoring program. Information collected may include inventories of presence, spatial location and variation in attributes such as cover, abundance and reproductive status.

Systematic, purposeful or opportunistic?

A weed survey can be described in four broad categories, namely random, systematic, purposeful or opportunistic (Thompson 2002). A simple random survey, is a method of sampling where survey locations are selected at random times or locations throughout the survey period or study area. A systematic weed survey is undertaken using a design based sampling approach. This requires field personnel to traverse a survey area in a methodical pattern, based on arbitrary spatial divisions and record the presence or absence of target weed species. A purposeful, or stratified, survey incorporates model based sampling design and may focus on particular strata such as for example categories of locations or specific weed species. Opportunistic surveys essentially include any unplanned, incidental or casual recording of weed data. Weed survey designs may also incorporate combinations sampling approaches, for example a model assisted sampling design might incorporate habitat strata sampled using a systematic method (a useful review can be found at http://www.epa.gov/quality/qs-docs/g5s-final.pdf).

Partial vs. comprehensive surveys

The degree to which a survey area was inspected, and the consistency with which data was collected, have important ramifications for the utility of the data. If collected data is representative of all target weed species across the entire surveyed area a survey may be labelled comprehensive or absolute. Where the data collected provides an incomplete representation of target weed species within a survey area a partial survey is achieved. Partial surveys have less utility when used to compare spatial and temporal differences of populations; however they may provide sufficient data to test for changes in species presence or species richness. To fulfil the requirement of a baseline survey a comprehensive survey must commonly be undertaken.

Monitoring

Monitoring programs that determine changes in weed species, distribution and abundance with time are essential to meet more recent weed explicit conditions required by the EPA. For some conditions monitoring approaches are suggested, such as for the Wheatstone project. However in most instances a proponent must determine the monitoring approach required, albeit in consultation with regulatory authorities. In this section a brief summary of monitoring approaches and tools that are applicable to the monitoring of weeds within mining projects are introduced.

BACI

'Before' – 'After' -'Control' – 'Impact' monitoring or BACI is a classic method for monitoring aimed at identifying environmental impacts (Green 1979). BACI monitoring involves measuring change before and after an event or pre disturbance and post disturbance; as well as measuring comparative situations separate from an event, or disturbed and non-disturbed situations. BACI monitoring provides a framework for determining whether observed impacts are the result of project activities or due to broader factors. The undisturbed reference site monitoring conditions, included in latter governance examples are intended to be monitored using a BACI approach. Potential applications include distinguishing between multiple impacts such as overlapping mining and pastoral tenure or weed introduction via nearby public transport routes. A limitation of the BACI approach is that it requires adequate 'before' data to work effectively and so cannot be retrofitted to existing operations. **Where adequate before data is unavailable an asymmetric analysis may be appropriate (**Thompson 2002).

Design-based vs. model-dependant sampling

Sampling can also be distinguished based on whether a design-based or model-dependant approach is adopted (Thompson 2002, Royle and Dorazio 2008). Model-dependant approaches are used when there is no clear definition of the target area or population. In this approach, data are collected without using a standard sampling design, and the data are analysed using a model such as ANOVA or hierarchical model. An example of model-dependent approach is the commonly applied method of sampling within vegetation or habitat stratifications. In contrast, the design-based approach can be used when the target area or population is clearly defined, and the data are collected using a standard sampling design, such as the systematic design: e.g., selecting transects every 50 m or sampling every third grid cell. Using a design-based approach requires some prior knowledge of population size (which is finite) but unlike the model-dependant approach, does not assume an underlying distribution of the target population. Design-based approaches will provide unbiased estimates of population means, totals and variance, whereas the model-dependent approach provides unbiased estimates of the mean of the underlying distribution of parameters of the chosen model. The design-based approach is preferable where reducing bias is a priority; or when there is no interest in making inferences about areas outside of the target area or about populations other than the target population.

In our spoken presentation, we provide two case studies of design-based and model dependent weed survey sampling from the central and western Pilbara.

Sample Size

The desired sample size for a given level of confidence of the estimates can be estimated when variability of the weed population (such as density or frequency of occurrence) in the target area is known. When the main interest is to examine differences in weed levels, such as over time or as a result of management, a power analysis may be carried out to determine the optimal sample size. However, variance and effect size (a measure of the effect of weed management) must be known to carry out the power analysis. Typically, a range of sample sizes is estimated from a range of hypothesised variance and effect size or a range of target confidence and hypothesised variance (Cochran 1977, Quinn and Keough 2002). The initial sample size can be selected from the range according to constraints, such as budget. Once some data have been collected, variance and effect size from the data can then be used to update the sample size for subsequent sampling.

Timing

Seasonality is an important consideration when designing ecological monitoring programs (Lindenmayer, 2010). Weed surveys are best conducted during the growing season of target weed species, when detectability is increased. Surveys undertaken outside of this period may fail to capture a complete inventory of weed presence. This is particularly important when monitoring is required to inform weed control programs, so as to identify weed germination prior seed set.

Data Collection

The type of data collected is ultimately determined by management objectives, the monitoring methods applied, reflecting the purpose for collecting monitoring data. With repeat sampling, temporal analysis of these data must allow an evaluation of the weed management outcomes. At a minimum weed data should provide a record of the location monitored, an inventory of weed species observed and the date of observation. As monitoring becomes more comprehensive the identification of the spatial location of weed occurrences and measurement of a range attributes may be included. These include: Species (scientific name); Common name; Area (for polygons); Abundance (stem count); Cover (percentage foliar cover); Maturity (seedling, immature, mature); and Reproductive status (sterile, flowering, seeding, seeded)

In our spoken presentation, we provide one case study from the coastal Pilbara describing the weed measurement variables that allow management evaluation to be made.

Data analysis is not addressed within this current paper. However, careful consideration of the analysis is required to avoid bias in repeat-measures data that is used to demonstrate effective management; that is, spatial and temporal autocorrelation.

Sampling Method

Fixed point monitoring sites can be surveyed as a one off snap shot or routinely providing a repeated measure. Commonly applied fixed point monitoring site designs include line intercept transects, transect strips and quadrats. Fixed point monitoring sites can provide a fine scale detailed level of weed data. However, such fine scale data may not always be representative of broader landscape conditions or provide information that is useful for informing management. As fixed points are static it is possible that the dynamic expression of weeds is not adequately captured. Hence increasing the scale, while reducing intensity, can improve the utility of fixed point monitoring. Three methodologies are commonly used in monitoring projects, point data, line intercepts and quadrats,

Point Data

Point data is most often used to locate individual weed occurrences and small patches. For example a point may be used to locate a single athel pine or 100 Mexican poppy plants at a creek crossing. The application of point data to locate populations of weeds can be less accurate, particularly if estimates are made for large areas. Points that record estimates of weed occurrence over large areas may as a result be less useful for making spatial or temporal comparisons.

Line Intercept

Line intercept transects can produce continuous data representing fine scale assessment of weed and vegetation status. Line intercept sampling involves extending a tape between two points the cover and attributes of weed species that intersect the tape are then recorded. Whilst line transects are excellent for detecting change, they have very limited spatial cover and hence a limited ability realistically detect all species and their distribution. Alternatively quadrats have a greater spatial coverage but can be labour intensive.

Weed Record Points (Astron)

Astron has developed a practical data standard for mapping and monitoring weeds such that spatial or temporal changes can be detected called the Weed Record point (WRP). A WRP a geospatial data point recording the presence or absence of weed species over a discrete 5 m x 5 m. Attribute information is also recorded, as categorical classes, for foliar cover, abundance, life form, life stage and control methods. The inspected area is limited to 25 m^2 so that field personnel can validly estimate measured attributes. The WRPs are then collected at intervals to provide a spatial representation of weed populations. The extent and weed attribute information can be displayed using a graduated colour scale, such as in the example presented in Figure 2. In this example WRP data has been scaled up using a 50 x 50m raster grid displaying a foliar cover classes.

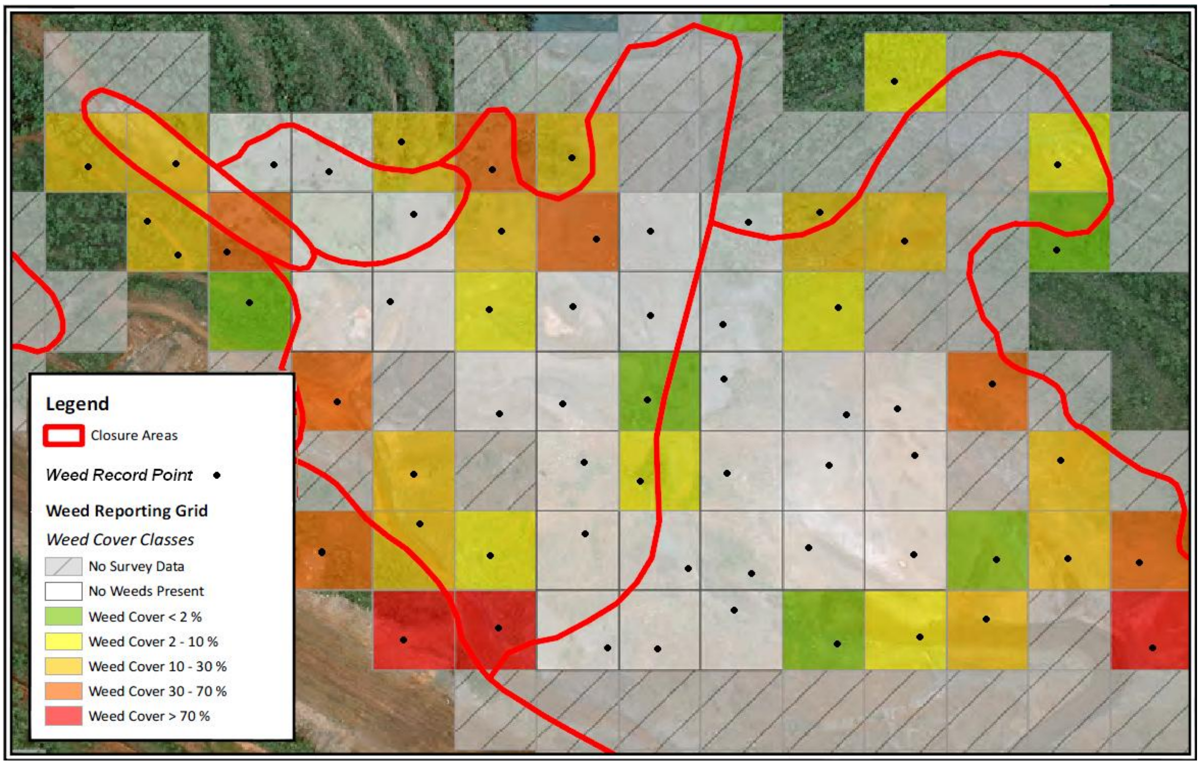

Figure 2: Example of Astron Weed record Point weed survey map display, showing weed presence by cover class. Each WRP represents a 5 x 5 m area. In this example WRP cover class attributes are scaled up by informing a 50 x 50 m grid to create a weed survey map.

Polygons

Polygon data can be used to capture information on weeds present within a bounded area. Typically polygons are drawn to encompass areas where weed density (cover, abundance) or other attributes are similar. Collecting polygons can provide a more efficient method for capturing data over large areas however, as for point data, polygon attributes estimated for large areas can lack accuracy. Polygon data is suited to creation from a desktop using aerial or remote sensing imagery. However, in sensitive, high value vegetation communities, polygons measuring baseline and post management distribution and densities of weeds have been collected using differential Global Positioning System; for example, the Brixton Street Wetlands within the Perth urban environment.

Remote Sensing

Weed data can be garnered directly from assessment of aerial and remote sensing imagery (Walsh et al. 2008). Whilst tools for remotely sensed weed management are improving, appropriate detail is not yet available for all but the most obvious species such as trees. On the ground verification of weed presence, distribution and abundance is required to calibrate remote tools but it is likely that these methodologies will improve in the near future.

Conclusion

Applying an adaptive and integrated approach to weed management is needed to ensure resource projects remain compliant with environmental approval conditions relating to weeds. Recently the implicit and explicit requirements for weed monitoring and management included in environmental approvals have changed. To better evaluate the effectiveness of weed management, frameworks that structure the design and reporting of weed monitoring projects are essential. Weed sampling methods require careful consideration of spatial and temporal distributions of weeds species, and the analysis needs to address some of the bias that are inherent in repeat-measures data. A quantitative monitoring program is essential to both trigger management actions and to allow evaluation of the effectiveness management.

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Closure Cost Estimating Methodologies: A Review of Mine Closure Cost Estimating Methodologies and for Different Reporting Purposes

R. Haymont, Director. – Trajectory

Abstract

Mine closure liability cost estimation methodology is not always supported by clearly defined or mandated guidance tools. There are a range of different liability estimation requirements and approaches depending on the reporting objective or purpose of the liability assessment. These often include bankable feasibility studies, due diligence assessments, fulfilment of international, national or internal accounting standards or estimates for the calculation or performance bonds or assurances which vary for the different regulatory jurisdictions in Australia. The Western Australian government recently finalised a “Guideline for the Preparation of Mine Closure Plans” which includes a requirement for the preparation estimates of mine closure liabilities. Although these estimates are reportable only upon request by the Department of Minerals and Petroleum, the methodologies through which they are derived must be provided within Mine Closure Plans. This paper discusses the various applications of mine closure liability estimation and expands upon several of the standard methodologies applied to derive such estimates and the sensitivity which exists with respect to various methodology options.

Introduction

There is no right answer and there is no correct number with respect to mine closure liability estimating to the extent that different methodologies may be applied for different reporting purposes. This is entirely appropriate as a closure liability estimate should be conducted within a specified context such that it meets the needs of the target user or audience. Within different methodological settings however, liability estimates can be reasonably accurate if appropriately resourced and conducted. Liability estimates are models, and as with all models they are sensitive to the assumptions used to construct the model and the input data provided. Determination of the scope, limitations, inclusion, exclusions, physical measurements, accounting treatments and degree to which probability, uncertainty and contingency are applied to estimates are all an essential part of the development of estimating processes. Ultimately however the factor which can have most influence on an estimate is the "sentiment" of the entity controlling or requiring the estimate. All of this suggests that a very clear determination of the intended methodologies, inputs, exclusions and contingencies is essential to getting a result which corresponds to the reporting purpose

Why Estimate Mine Closure

The most recent development in mine closure estimating is the finalisation of the WA guidelines for the preparation of Closure Plans which requires that a methodology through which closure provisions are calculated is provided.

"The process and methodology for calculating the cost estimates must be transparent and verifiable. Refining closure cost estimates will be a key component of the review of the Mine Closure Plan required under the Mining Act 1978 or as defined by the EPA.

Estimated costs must take into account all aspects of closure costs. The estimate should include:

- *Earthmoving and land forming*
- *Management of problematic materials where relevant*
- *Research and trials*
- *Decommissioning and removal of infrastructure*
- *Remediation of contamination*
- *Survey program*
- *Remediation program*
- *Maintenance and monitoring*
- *Progressive and final rehabilitation*
- *Maintenance and monitoring programs (including post closure phase)*
- *Ongoing stakeholder consultation process*
- *Closure project management costs*
- *Administration*
- *Specialist Consulting Fees*
- *Legal requirements*

- *Provision for unplanned closure / care and maintenance*
- *Need to allow for earthmoving machinery to be available on site after*

Closure for remedial earthworks (or else provide funding for remobilisation of equipment if required)

The Mine Closure Plan is required to contain a summary of mine closure costing methodology, assumptions and financial processes to demonstrate to DMP and/or the EPA that The corporate entity has properly considered and fully understood the costs of meeting closure outcomes identified in the plan, and made adequate provisions in corporate accounts for these costs.

Reference to the detailed closure costing report is to be provided in the Closure Plan. DMP and/or the EPA may require a full/detailed closure costing report to be submitted for review, and/or an independent audit to be conducted on the report to certify that the company has adequate provision to finance closure"

This follows the development of estimating tools for bond calculations from the NSW and NT mine regulators and a guidance document from the Qld mine regulator for the calculation of Financial Assurances. Importantly there are a number of other circumstances when an understanding of liability is required for internal or external reporting purposes. Set forth below are five different occasions for which liability estimates might be generated. What's worth noting is that for each of these types of estimates there may be a number of different assumptions, criteria or methodologies which can be applied.

Due Diligence

This activity should be one of the most important, rigorous and carefully scrutinised kinds of estimates. It is the estimate which is undertaken when an entity is considering taking over accountability, usually via asset purchase, of a mining liability. It should involve careful scrutiny of existing estimates or reproduction of new estimates if existing estimates are not sufficiently robust. Frequently there is insufficient time or resources allocated to realise a true picture or extent of the liabilities involved.

Bankable Feasibility

During feasibility or Bankable Feasibility studies where external investment entities are involved, estimates of residual liability after mine operation are often calculated. These estimates are generally intended to be prepared to the same level of accuracy, + or – 10% for example, as the construction, commissioning and operational phase estimates. This is often a challenge as closure designs are sometimes only conceptual in nature whereas the level of estimating detail is expected to reflect more robustly designed operational phases. There are Australian Accounting Standards Board 137 guidelines, *Provisions, Contingent Liabilities and Contingent Assets,* which can be referred to for this purpose or other estimating purposes within Australia

Reporting for foreign Stock Exchanges

North American companies listed on the US or Canadian Stock exchange must report in compliance with the *Financial Accounting Standards Board* Standard (FAS 5 and FAS 143) for the US and for Canada the Canadian Institute of Chartered Accountants *Asset Retirement Obligation* Standards. The international Financial Reporting Standards, IAS 37, *Measurement of Liabilities*, is broadly similar to this. All of these standards have the same general principles which are:

- Reports estimate the amount of liability actually incurred up to a specific reporting date
- Off sets for sale of assets cannot be included
- Obligations can include legally binding obligations or public commitments
- Estimates need to be completed assuming “fair value” which is what an informed entity would charge to take accountability for and mitigate the liability. This is usually interpreted as “third party costs” i.e. what a third party would charge to retire the liability.

Government Bonds, Sureties, Assurances

As mentioned above there are a number of methodologies and models to calculate government bonds, sureties or assurances. The WA government is still in the process of determining a revised approach in WA. Some models which have been considered include the NT and NSW model each which use a calculation tool, the Qld Model which provides textual guidance and the Nevada model, the RCE, Reclamation Cost Estimator, which has been further developed by Barrick into BRCE.

LOM Operational and Rehabilitation Budget

An important internal requirement of estimating is the whole of life cycle or LOM cost estimate. This estimate may or may not be reportable externally, but it is an important process of development of budgets such that costs for progressive rehabilitation and closure phases are estimated and scheduled such that appropriate budgetary provisions can be made.

Methodologies

The various inputs, once established need to be combined through prescribed methodologies. These are set out below in the following broad areas:

- Assumptions, Criteria and Limitations
- Cost Structure and Model
- Physicals
- Direct Cost Estimates - Equipment, Unit and Activity Costs
- Indirect Cost Estimates – Owners Costs, Post Closure Costs and Mob and De Mob
- Contingency

Assumptions

The following general assumptions from the closure plan and regulatory conditions and commitments are often applied and used to calculate the rehabilitation and closure costs where no specific guidance is provided in via specific assumptions or criteria.

- Demolition – demolition and/or removal of infrastructure and services no longer needed during, and at the end of mine life.
- Cleanup and Remediation – clean-up of contaminated areas of soil and water during, and at the end of mine life.
- Rehabilitation and Revegetation – development of a stable non-polluting and self-sustaining landform that has been disturbed by mining operations. Rehabilitation and revegetation is conducted progressively during operations and at the end of mine life.

The mine site closure cost estimate are usually based on the scope of closure works that the corporate entity has committed to in various approvals and project documents, and can rely on the internal unit and activity cost estimates. There are opportunities to refine the scope of closure works for each domain, based on the outcomes of closure planning tasks undertaken prior to cessation of operations.

The following parameters are frequently applied to the cost estimate:

- The closure cost estimate includes costs for all physical works that the corporate entity will be responsible for undertaking in implementing the mine site Closure Plan.
- It is assumed that all required closure works will be undertaken after cessation of operations including landform profiling, construction of abandonment bunds etc. The corporate entity may however schedule for closure works to be undertaken during operations.
- Owner's management costs or those costs that will be incurred by the corporate entity in supporting the closure program (accommodation, messing, management etc) have been estimated.
- The closure cost estimate has been delivered in current AUD figures.
- A contingency allowance nominated by the corporate entity has been applied to the closure cost estimate. This was applied at different rates to different aspects according to confidence levels.
- It is sometimes assumed that the mining and earthworks contractors will be available to undertake all closure earthworks as required by the mine site mine closure plan. As such specialist earthworks contractors may or may not be mobilised to site.
- Post closure costs (including environmental monitoring and reporting, rehabilitation maintenance and lease payment costs) are often estimated to continue for 10 years beyond the cessation commercial production. Costs can be scaled down appropriately during over this period. It is often assumed that lease relinquishment will be achievable after 10 years but this may not be the case.

- Costs may be estimated for both the current footprint liability as of a specific date and for the full footprint of the project as indicated in approvals documentation using the full life of mine costs and then estimating the percentage of footprint disturbed as a surrogate of liability incurred. Costs can be included / excluded from the full footprint closure cost estimate progressively as the project expands or as otherwise required.

The following limitations in relation to the cost estimates are sometimes applied:

- The estimate excludes all costs associated with redundancies, repatriation, retraining and outplacement of the corporate entity workforce and of any contractors' workforce.
- The estimate excludes all costs associated with sudden or unplanned closure
- The estimate excludes all costs associated with care and maintenance or preservation activities
- The estimate excludes all costs associated with disposal of stores inventory.
- The estimate excludes all costs associated with removal of the corporate entities non-fixed assets (as described in), redundant equipment and scrap; it is assumed that this will be removed prior to closure.
- No cost offset has been assumed for the resale of any assets or scrap.
- The estimate excludes all costs associated with closure planning, design, reporting and related professional costs prior to cessation of operations.
- The estimate excludes all costs associated with any change in closure obligations which may arise during the life of the operation or after closure.
- The estimate makes no allowance for inflation to closure, calculation of net present value, or amortising etc. Such mechanisms may be applied according to the accounting standards used but are not usually built into the basic estimate

Cost Structure and Model

The cost model is best developed to align with the closure plan whereby the project is divided into the domains which deal with the various spatial and post closure aspects of the project.

Each Domain is further divided into Areas or Features, which are generally defined by spatial or specific management area boundaries.

Each Area is divided into Activities which are the specific actions for which units of measure and costs can be combined to form an estimate.

From an accounting and cashflow perspective the mine site closure cost estimate has been assembled into a series of worksheets which separate costs into various tiers of detail:

1. Summary
2. Cashflow
3. Details per domain

4. Unit and activity cost register

The summary table represents high level summary costs for each domain. The cashflow table provides scheduled expenditures for closure costs incurred through time, both before and after cessation of operations, until obligations associated with the mine site tenements cease.

The detailed domains worksheets are often divide each domain into relevant disturbed sites. Details of the closure tasks associated with each disturbed site are outlined, the cost assumptions and calculation inputs are detailed, and the closure cost is itemised for each closure task.

Physicals

Getting the right physical measurements in crucial to estimating and a failure to do so is often a source of poor estimating outcomes .It is essential that the physical measures derived correspond with the conditions and commitments so that they are an accurate reflection of legal obligations. Such measures can include:

- Depths of cover to be placed (sometimes multiple covers at different depths or different coverers over different spatial locations
- Spatial area of disturbance
- Length of corridors, roads, pipelines, powerlines, bunds etc
- Footprint area of different types of infrastructure
- Specific Gravity of various materials to be moved
- Angles of slopes and batters
- Widths of berms and bunds
- Depths of ponds and dams

These measures should be captures within the estimates spreadsheet and ideally reference the source/activity through which they were derived

Equipment, Unit and Activity Costs

The methodologies adopted to estimate closure costs for each category of closure tasks, follow customary mining and demolition industry standard practices. Estimates have been derived from a number of cost areas including:

Equipment costs;

Unit costs; and

Activity costs.

These costs may be applied to:

Earthworks Costs;

Revegetation Costs;

Demolition Costs; and

Indirect Costs.

Equipment Costs

Equipment costs form the basis of many unit and activity costs. Equipment costs can be derived via a number of methodologies or combinations of methodologies. In the case that there is only limited equipment costs available from existing contracts for equipment, which is intended to be used for both operational and closure activities.

Consequently most unit and activity costs associated with equipment have been derived from ‘hourly hire costs’ or ‘price per volume managed’ costs already derived and aligned within the cost estimates. Where these are not available costs are derived through the utilisation of relevant benchmark or analogue third party costs derived from recent earthworks activities in the region. These are generally a reliable guide to cost estimating. Hence, where planned closure activities have no contractual precedents on site, costs have been derived from one of the following sources:

Costs derived from similar projects in Western Australia or the Northern Territory where contract or actual costs are available and services are delivered by a third party.

Costs from published estimating tools such as those produced by the NSW Department of Primary Industries and Northern Territory Department of Resources which have been benchmarked and researched extensively.

Costs derived from first principles using standard cost development methodologies (rental, labour, fuel, wear, preventative maintenance, tyres, supervision, overheads and profit).

Equipment costs generally need to be calibrated based on productivity and correction factors which consider haul distance, elevation, material nature, competency of operator, slope and visibility. The impact of push length on dozer productivity is demonstrated in the figures below. The level of this specification is general as design parameters which would dictate several of these inputs are still not specified to a high level of accuracy in some cases.

Unit Costs

Unit costs are the basic units of the cost estimating process including:

- Hour of machine time;
- Cubic meters moved;
- Kilogram of seed;
- Hour of labour;
- Suite of water analysis; and
- Plugging of a drill hole.

Unit costs for a mine site are often derived by site contract rates or relevant cost experience in the region. The following is a list of some typical unit costs:

- Dozer push to reprofile slopes ($/m3);

- Load, haul and spread over various distance increments ($m3/km);
- Demolition Labour ($/hr);
- Seed Mix ($/kg); and
- Accommodation costs ($/night).

Figure 1 and 2 provides examples of how some unit costs can be calibrated using dozer efficiency tables.

Figure 1: Dozer Productivity versus Push Length

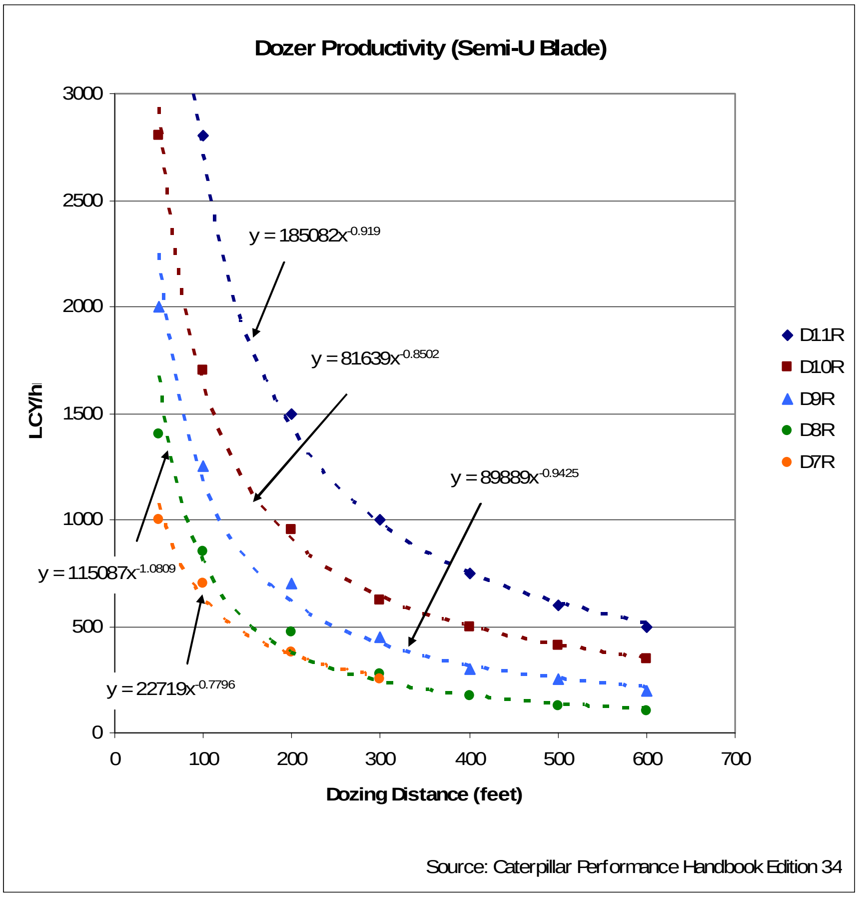

Table 2: Dozer Productivity versus Push Length

Dozer Productivity vs. Grading Distance					
Average Dozing Distance (feet)	Production (LCY/hr)				
	D11R	D10R	D9R	D8R	D7R
50	4800	2800	2000	1400	1000
100	2800	1700	1250	850	700
200	1500	950	700	475	375
300	1000	625	450	275	250
400	750	500	300	175	
500	600	410	250	125	
600	500	350	200	100	

Source: Caterpillar Performance Handbook Edition 34

Activity Rates

Activity Rates are usually a combination of units of cost and are measured in lengths and areas or unit of service:

- Hectares of topsoiling;
- Hectares seeding;
- Kilometres of road rehabilitation;
- Area of drain lining (m2);
- Volume of contaminated material managed (m3)and
- Report preparation.

Activity rates have been developed for the mine sites using local or relevant analogue costs.

Deconstruction

Deconstruction includes all activities associated with dismantling aboveground fixed assets and infrastructure to concrete level or ground level, removing saleable items, and disposing of other items as required. Deconstruction includes removal or burial of concrete, removal of potentially contaminated soils and reprofiling ground levels.

Deconstruction activities are estimated primarily through a combination of the following:

- Unit rates per m2 of different infrastructure categories derived through benchmarks or from various government bodies.
- Specialised equipment hourly hire rates (cranes, forklifts and excavators with shears or rock breakers as required).
- Skilled labour (supervision, oxy cutting, dogman and machine operators).
- Overheads (project management, mobilisation and demobilisation, consumable and profit).

Generally an assessment is made of the volume of material involved, its footprint or the number of similar units and, based on experience and industry guidelines, an estimate of the number of hours a skilled demolition team would take to complete the task.

Revegetation

The revegetation program for mine sites are frequently developed through the following processes:

- The site flora species list was reviewed and placed within a spreadsheet.
- Seed purchase costs were identified from three suppliers where the species specified were identified on seed supply lists (Nindethana Seeds, Kimseeds and Mulka Seeds as an example).
- Where no costs were available some indicative costs were used for similar species.
- Average costs per kilogram were established through the averaging of the entire available price per kilogram data.

- Rates of seeding per hectare were roughly assigned for each species.
- A rate of seed to be provided per hectare was determined based on average regional seeding rates.
- Rates for fertilizer, mechanical or hand seed spreading, contour ripping and supervision were each established.

Through this total rates per hectare established.

Indirect Costs

Technical Studies and Investigations

Financial provisioning estimates need to include include for the following studies and investigations which should be undertaken throughout operations:

- closure related technical studies;
- social studies; and
- rehabilitation trials.

The closure related which may be undertaken and require estimates to be provided include:

- hydrogeological/ ground water modelling;
- pit-lake recharge/water quality studies;
- landform erosion modelling;
- final landform design;
- development of landform decommissioning plans;
- tailings geochemistry studies;
- waste characterisation and rehabilitation material balance studies; and
- surface water drainage assessment studies.

Social and stakeholder studies to be undertaken for estimating may include:

- social impact assessments; and
- post closure land management plan.

Owner's management

Owner's management costs include the following cost items:

- Project management
- Engineering and technical support
- Supervision and professional
- Operators, deconstruction, trades and general labour
- Flights, travel, messing and accommodation

All of the above costs have can generally be from actual owner's costs, contractor rates or relevant regional analogues from recent projects. Duration estimates can be derived from the volumetric estimates and machine productivity rates, or from the work rates of demolition, earthworks and/or technical teams as required.

Post operations management and maintenance

Post operations management, in addition to owner's management costs, include:

- Reporting costs which are derived from current actual report preparation costs based on third party consultants providing this service.
- Specialist consultant reports with respect to groundwater, engineering design, designs of surface water control measures, contaminated sites assessments or liability estimating. These are also derived from recent industry experience using third party consultants.
- Lease holding costs were derived using the current mining lease rental costs.
- Vehicle, utility and incidentals were derived using operational costs as a benchmark.

Post operations monitoring

The mine site should have a limited and well defined post closure monitoring strategy. Post closure monitoring is primarily focussed on rehabilitation and revegetation performance will include routine assessments of land stability, floristic diversity and abundance, and ecosystem sustainability. Water, sediment and in some circumstances dust monitoring may also be important features of the monitoring estimate. Estimates for post closure monitoring have been derived from experience within the Western Australian mining industry.

Contingency

Contingency settings are made in response to uncertainty in estimating, where the level of accuracy or the probability of liability adjustments which cannot be currently forecast, requires recognition. In many of the mine site contingency settings have been determined based on generally accepted standards in the mining industry; the contingency setting for each area of the liability has been calibrated based on confidence levels. As a general rule contingency can be set at 10 to 15% which is consistent with the upper bound of what some of regulatory authorities nominate within Australia.

Contractor demobilisation

Demobilisation costs for contractor plant and equipment should be included in the mine site estimate. Costs for mob and demob are sometimes derived by calculating 1% of the total project costs

Conclusions

Mine Closure and Rehabilitation Liability Assessments are essential to understanding the complete picture of the business in the long term and fulfilling a number of reporting requirements. Accurate estimates can ensure that mine closure and rehabilitation is given adequate management focus and can influence decision making appropriately and avoid unforeseen costs and impediments to the business as the project matures. There are many influences on mine closure estimating processes. It is sometimes a challenge to secure enough resources and expertise to conduct rigorous estimates, particularly when the results of such activities generally lead to increases is business liabilities, many of which must be reported externally. This can lead to subtle (and sometimes not so subtle) pressures to either avoid too much rigour or to continually delay the acknowledgement of liabilities through a continual resort to "further studies". Although this may fulfill the short term interests of some within the business leadership, it damages the long term interest of the business through a lack of understanding and preparedness for liabilities and a lack of focus on what optimisation, mitigation and operational phase opportunities exist to reduce these liabilities in the near term.

Developing and Maintaining Systematic and Robust Mine Closure Plans

Ian Mitchell, Outback Ecology Services

Abstract

The '*Guidelines for Preparing Mine Closure Plans',* introduced in July 2011 and jointly prepared by the Department of Mines and Petroleum (DMP) and the Environmental Protection Authority (EPA), require a mine closure plan to be submitted to the DMP as part of Mining Proposal applications. Furthermore, existing mining operations that have a Mining Proposal and/or Notice of Intent (NOI) approved under the *Mining Act 1978*, will require rehabilitation and closure plans and rehabilitation plans to be submitted by June 30 2014, in accordance with the new guidelines.

In the event that the EPA assesses mine closure plans as part of the Environmental Impact Assessment (EIA) process, the EPA's primary objective is to ensure that the mine is capable of being closed in an ecologically sustainable manner. As part of this more-rigorous regulatory environment, companies are required to undertake a review of their mine closure plan and re-submit to the DMP no more than three years after its initial approval. This review process will require the ongoing collection and analysis of significant data to assess rehabilitation progress towards the agreed post mining land use. In order to effectively manage and facilitate this ongoing review process, it will be critical for mining operations to better manage their rehabilitation and closure data.

This paper provides an insight into the development of systematic and robust mine closure plans, and the maintenance and refinement of closure plans through operations and beyond. The paper will also discuss the use of electronic tools that assist and streamline the data management and review process to save valuable time and resources for mining companies.

Introduction

The mining landscape changed considerably in Western Australia in July 2011 when the Western Australian (WA) Department of Mines and Petroleum (DMP) and the Environmental Protection Authority (EPA) jointly released the *Guidelines for Preparing Mine Closure Plans (guidelines)*. The guidelines were developed to provide assistance for the preparation of Mine Closure Plans (MCP) to meet new Western Australian regulatory requirements brought into effect in 2010 through amendments to the *Mining Act 1978.*

The guidelines were designed to assist operations to create robust and systematic MCPs with a focus on the need to commence mine closure rehabilitation and closure planning early. This requires operations to start collecting, storing and managing data and information throughout the life of mine to assist with the rehabilitation, closure and relinquishment process. These requirements now make it imperative on operations to have in place systems that can assist in the management of this data as well as its manipulation into reports for the updates to the mining plans that are now required.

This paper will discuss the development of systematic and robust mine closure plans, and their maintenance and refinement through operations and beyond. The paper will also discuss the use of electronic tools that assist and streamline the data management and review process to save valuable time and resources for mining companies and potentially government reviewers and other associated stakeholders, thus reducing the burden for all stakeholders of the new legislative controls.

Mine Closure Plan Guidelines Overview

The purpose of the guidelines are to provide guidance on the preparation of MCPs to meet new Western Australian regulatory requirements brought into effect in 2010 through amendments to the *Mining Act 1978.* The amendments stipulated that a MCP (prepared in accordance with these guidelines) be submitted to DMP for approval as part of Mining Proposal applications received after 30 June 2011. Furthermore, it requires retrospective actions for mining operations that had a Mining Proposal and/or a Notice of Intent (NOI) approved under the *Mining Act 1978* prior to 1 July 2011.

The ultimate aim of the guidelines is to improve the performance of mine closure in Western Australia via a detailed planning process to ensure mines can be closed, decommissioned and rehabilitated in an ecologically sustainable manner, consistent with agreed post mining outcomes and land uses, and without unacceptable liability to the WA government.

Through the integration of closure planning from the outset the guidelines benefit mining companies by minimising costs by following a systematic, integrated and adequately costed approach. It has been recognised that a detailed MCP is an essential management tool to ensure mines are adequately rehabilitated upon closure and relinquished in a cost effective manner. The guidelines assist mining companies to identify early risks associated with mine closure. This ensures that the cost of closure is adequately represented in company accounts, while also allowing for monitoring of plans to achieve sustainable rehabilitation outcomes.

Furthermore, the guidelines are designed to ensure the development of MCPs through the early phases of a mines life followed by its continued management and refinement through construction, operations and closure (**Figure 1**).

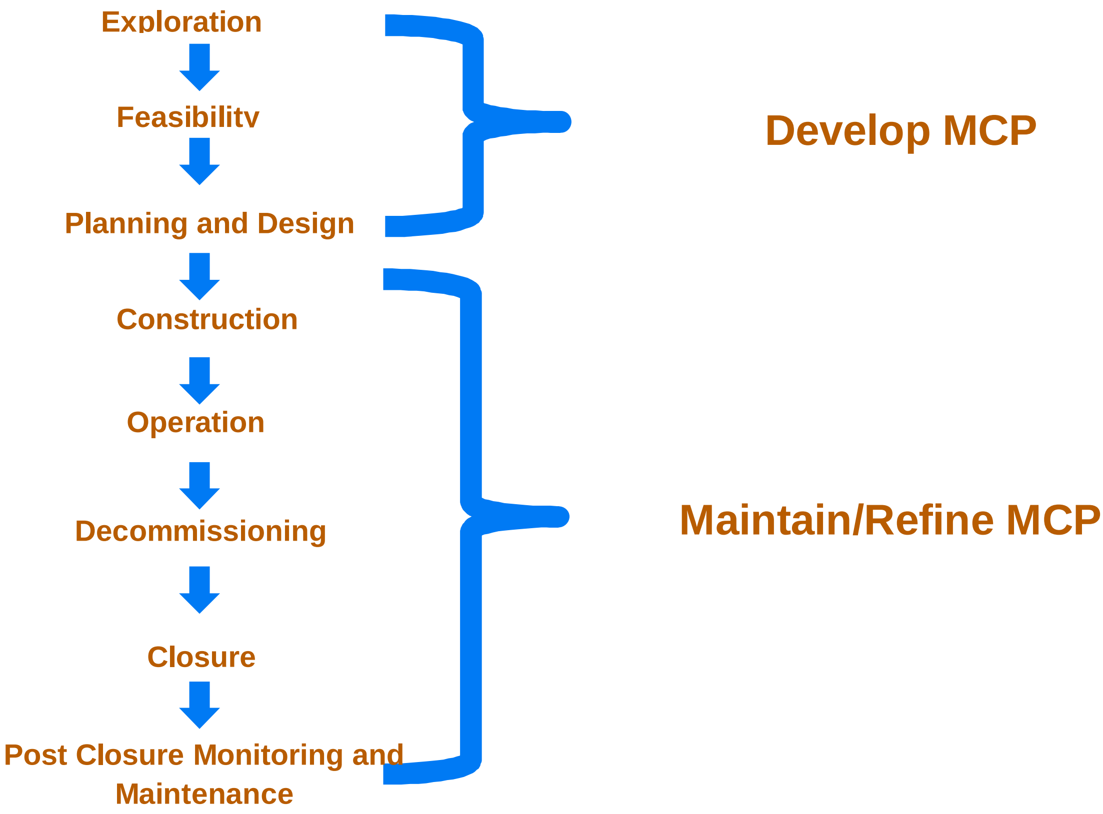

Figure 1: Mine life cycle in relation to the development and refinement of Mine Closure Plans

Mine Closure Plan Development

The development of a robust MCP is now required to be integrated into the initial phases of the mine life (exploration, feasibility and planning and design) which is seen as critical to achieve successful closure outcomes (Bentel 2009). Core planning activities which are required to take place for the successful development of a MCP include:

- stakeholder consultation;
- baseline studies;
- material characterisation;
- post-mining land use and closure objectives;

- completion criteria;
- risk assessment;
- domain breakdown; and
- financial provisioning.

Stakeholder Consultation

Stakeholder consultation is a central component of successful mine closure planning. Stakeholders can be differentiated into two categories, primary and secondary. Primary stakeholders are those with a vested interest in the closure planning of a project, while secondary stakeholders include those who have an association with a project, though not as directly as the primary stakeholders.

Effective stakeholder consultation is an inclusive process and is critical to ensure that all stakeholders are able to contribute to the closure planning process. The degree of dialogue and influence (and the level of engagement) this process has will vary within and between projects. Consultation approaches cover a spectrum from low levels of engagement (providing information to stakeholders) through to empowering stakeholders in the decision-making process (Department of State Development 2009). The benefits of successful consultation range from improved planning decisions and more motivated staff to good relations with regulators and the community (ANZMEC/MCA 2000). Components that require consultant from a rehabilitation and mine closure perspective include post-mining land use, the development of closure objectives and completion criteria and rehabilitation and monitoring programs.

Baseline Studies

Having sufficient environmental baseline information to support feasibility phase closure planning is essential. Mining proposals are most likely to be challenged because of an insufficient understanding of the baseline environmental information, ranging from water quality, hydrology, and geochemical data to flora and fauna data. This data can be used to understand the pre-mining environment as well establish both a local and regional context to the potential impacts of the operation.

A pre-mining database of environmental information can be used to set completion criteria and help ensure the criteria can be met at the end of a mining operation. The establishment of baseline information during the early phases of the mining life that can then be monitored during the operational phases is essential. Monitoring baseline data allows for determination of impact of the environment from the mining activities and the rate of recovery once rehabilitation commences.

Post-Mining land use and closure objectives

An important aspect of closure planning is defining the post-mining end land use and related closure objectives. MCPs must identify post-mining land use(s) and set out site specific closure objectives consistent with those land use(s) (DMP 2011).

The post-mining land use(s) must be:

- relevant to the environment in which the mine will operate or is operating;
- achievable in the context of post-mining land capability;
- acceptable to the key stakeholders; and
- ecologically sustainable in the context of local and regional environment.

The closure objectives should reflect the agreed post-mining land use and also the commitments and policies of the mining company, together with those of regulators, and other stakeholders. Closure objectives are designed to be reviewed over the life of the mine to reflect the expectations of the stakeholders. It is anticipated that the closure objectives will cover a range of aspects including safety, pollution, landform stability and rehabilitation.

Completion Criteria

Completion criteria are necessary to provide the basis on which successful rehabilitation and mine closure, and achievements of closure objectives are determined. The agreed land use(s) and closure objectives establish the basis for developing completion criteria and performance indicators. Completion criteria are defined as agreed standards or levels of performance, which demonstrate successful closure of a site (DITR 2006b). Once achieved, they demonstrate to the mining company, regulators and other stakeholders that bond and/or lease relinquishment can occur (Friedel *et al* 2012).

Completion criteria must be site specific to the mine being closed, and reflect the unique set of environmental, social and economic circumstances of the site. They should also be quantitative and capable of objective verification (ANZMEC/MCA 2000). This criteria can be defined by the S.M.A.R.T acronym, in that they are should be specific, measurable, achievable, relevant, and timely. When developing criteria based on the S.M.A.R.T philosophy some simple questions can be asked to determine if the criteria being developed is acceptable.

Specific:

Is the criteria directly related to the intent of the objective? For example if a completion criteria is to restore a flora species density, the criteria should be linked to what is required for monitoring, in this case flora species density against quantifiable parameter.

Measurable:

Is the monitoring routine to measure the criteria practicable, readily repeatable and allow for external verification?

Achievable:

Is on-going monitoring cost-effective, physically achievable and is the data analysis able to be conducted by suitably qualified personnel?

Relevant:

Is the criteria relevant to the site and is the data being collected relevant to the criteria?

Timely:

Can the monitoring, analysis and reporting be done in an appropriate timeframe and are expectations of the time it may take for rehabilitation establishment to take place realistic?

Material Characterisation

One of the major components associated with successful mine closure involves the successful rehabilitation of waste landforms. Issues may arise from surface instability, inadequate vegetative establishment and growth, and/or the release of chemically-hostile materials. Characterising waste materials before constructing the landform, is a key step to maximising the likelihood that the final landform satisfies stakeholder expectations (Jasper & Braimbridge 2008).

In detailing the importance of waste charcterisation in the long-term performance of rehabilitation on waste landforms, the guidelines state that:

"Comprehensive characterisation of materials (including soils and wastes) is critical to successful progressive rehabilitation and should start during the exploration phase and continue throughout all stages of the mine (DMP 2012)."

During the development of the MCP therefore, comprehensive characterisation therefore should be conducted on the following materials as a minimum:

- soils to identify the soil types and horizons which are capable of supporting a self-sustaining vegetative cover and determine the potential plant growth limitations.
- overburden and waste rock to identify material capable of supporting plant growth and could be used in the root zone as well as material to construct landforms that may not be suitable for rehabilitation purposes.

Risk Assessment

A structured risk assessment framework and a meaningful stakeholder consultation process enable identification early in the planning process of mine closure risks and opportunities associated with rehabilitation and closure (DITR 2007). Risk assessment enables the scale of risks to be identified in the mine closure process, their potential environmental impacts, likelihood and consequence, mitigation measures and management of residual risk.. The outcomes of the process can then be used to prioritise closure planning, rehabilitation works and monitoring throughout the life of the mine.

The main elements of risk management are described below (DITR 2008):

- communicate and consult;
- establish the context;
- identify risks;
- analyse risks;
- evaluate risks;
- treat risks; and
- monitor and review.

Domain Breakdown

A recommended approach to developing a mine closure plan is to segregate the mine into specific areas or domains. A domain is classified as a group of landform(s) or infrastructure that has similar rehabilitation and closure requirements and objectives (DMP 2011). Each domain should be treated as a separate entity for detailed work plans, but within an overall plan which addresses the integration of the domains (DTIR 2006).

Financial Provisioning

A summary of the mine closure financial provisioning is required to be included in all new MCPs. The summary must clearly show the costing methodology used, assumptions and financial processes to demonstrate that costs of meeting closure outcomes identified in the plan has been understood, and adequate financial provisions have been made. The closure cost estimates must be regularly reviewed to reflect changing circumstances and to ensure that the accuracy of closure costs will be refined.

Maintenance of a Robust/Systematic Closure Plan

As per the guidelines, the MCP developed through the initial phases of the mine life cycle is now required to be updated at least every three years. Management and continued collection of the data acquired during the development phase of the MCP is critical in maintaining the robustness of the closure plan.

The acquisition of baseline data through the early phases of the mines life is the starting point for successful rehabilitation and mine closure planning. The management and refinement of the MCP then occurs from construction through to closure (**Figure 1**). The data acquired is built on and used during these phases to refine the MCP. This process may include but not be limited to undertaking progressive rehabilitation or completing investigative tasks and research trials.

Having appropriate baseline data is critical to making the best technical and social decisions during the review phase of the MCP (DITR 2006a). Tasks required to be undertaken to ensure the information obtained in the development phase is managed and enhanced during this phase of the mine life include:

- continued stakeholder consultation;
- continued data collection/monitoring;
- research/investigative tasks;
- financial provisioning; and
- technical documentation.

Continued Stakeholder Consultation

Consultation should be conducted on a regular basis to ensure communication channels remain open and that any changes to mine plans or changes to identified stakeholders are communicated effectively. A summary of the consultation process should be documented within a Stakeholder Consultation Register.

Data Collection/Monitoring

Data established during the MCP development needs to be updated and maintained throughout the operation of the mine and beyond in order to update the MCPs to ensure adherence to regulations. The collection of environmental data should be continued and expanded throughout the project life and include as an example:

- continuation from baseline surveys;
- rehabilitation monitoring;
- tailings monitoring; and
- ground and surface water monitoring.

The collection of this data will assist in the refinement of closure objectives and completion criteria.

Research/Investigative Tasks

The collection of environmental data should also include data from research, field trials and investigations, and to identify the spatial and temporal variations in the surrounding environments (DITR 2006b). Investigative/research tasks that can be conducted include:

- landform rehabilitation trials;
- soils/waste investigations;
- sampling/monitoring during operations (e.g. tailings); and
- surface and ground water hydrology.

Updated Financial Provisioning

The closure cost estimates are required to be regularly reviewed to reflect changing circumstances and to ensure that the accuracy of closure costs will be refined and improved with time. The process and methodology for calculating the cost estimates must be transparent and verifiable (DMP 2011).

Technical Documentation

Technical documentation and reports created during the construction and operations phases should be saved and stored with the other rehabilitation and closure related documentation created during the development of the MCP. These documents may include but are not limited to Tailings Storage Facility as-built documents and Annual Environmental Reports.

Tools to Facilitate the Information Management Process

The development and maintenance of a MCP leads to a vast "database" of information that details all the information related to rehabilitation and closure planning collected through all the mining phases. This information starts with the baseline information gathered at the early phases of the mine life to ongoing maintenance and refinement of the closure plan during operations.

The collected information needs to be able to be used and disseminated to stakeholders on a regular basis and this needs to be done in the most practical and timely manner possible.

Electronic systems which can be used to manage, maintain and update this information will become more important as the amount of data increases and the information that is required by regulators grows during the life of the mine. Further benefits of electronic management systems include the ability to store all data in a centralised location. These systems can also hold data in perpetuity, and provide online or static output (information and data) as required (DMP 2011).

Electronic systems that enable companies to manage this information include:

- consolidated databases of information;
- making use of Geographical Information Systems (GIS) tools to capture information on a domain basis;
- electronic task registers; and
- tools that allow us to populate our updated plan with the above information.

Consolidated Databases

The mining industry is well known for its reliance on storing large amounts of critical data in rigid and potentially ineffective tools such as spreadsheets. The alternative option of storing information in databases enables greater flexibility for storage, sorting and reporting. Rehabilitation and closure related data that can be stored within a database include:

- baseline studies;
- exploration database;
- topsoil management;
- weed management;
- material characterisation;

- rehabilitation monitoring;
- stakeholder consultation;
- monitoring information;
- updated closure costs; and
- background technical information and reports.

Domain Information

GIS based tools are a good way to store and retrieve domain specific data. GIS tools allow users to view Domains and their corresponding sub-domains or features. **Figure 2** shows the Tailings Storage Facility 'feature' from within the 'Landform' domain of the Challenger minesite as displayed within the PRAC™ (Progressive Rehabilitation and Closure) System developed by Outback Ecology.

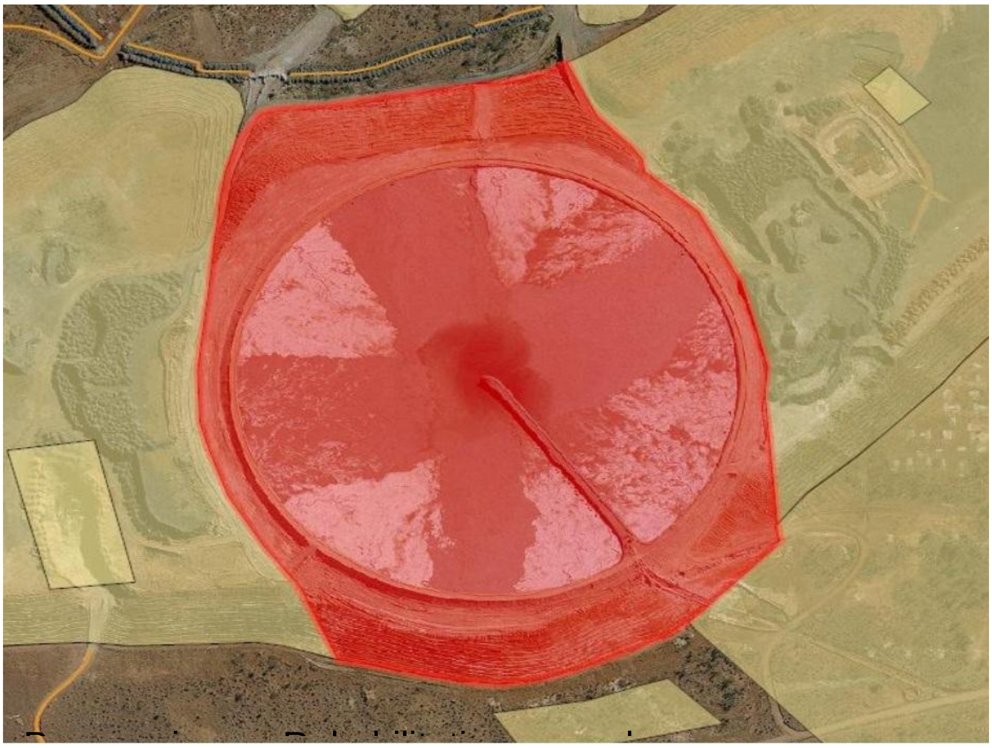

Figure 2: Tailings Storage Facility highlighted within the PRAC™

(Progressive Rehabilitation and Closure) System at Challenger mine site.

By clicking on the highlighted feature the user can then see information and documentation relating to it, making information access straightforward and efficient (**Figure 3**).

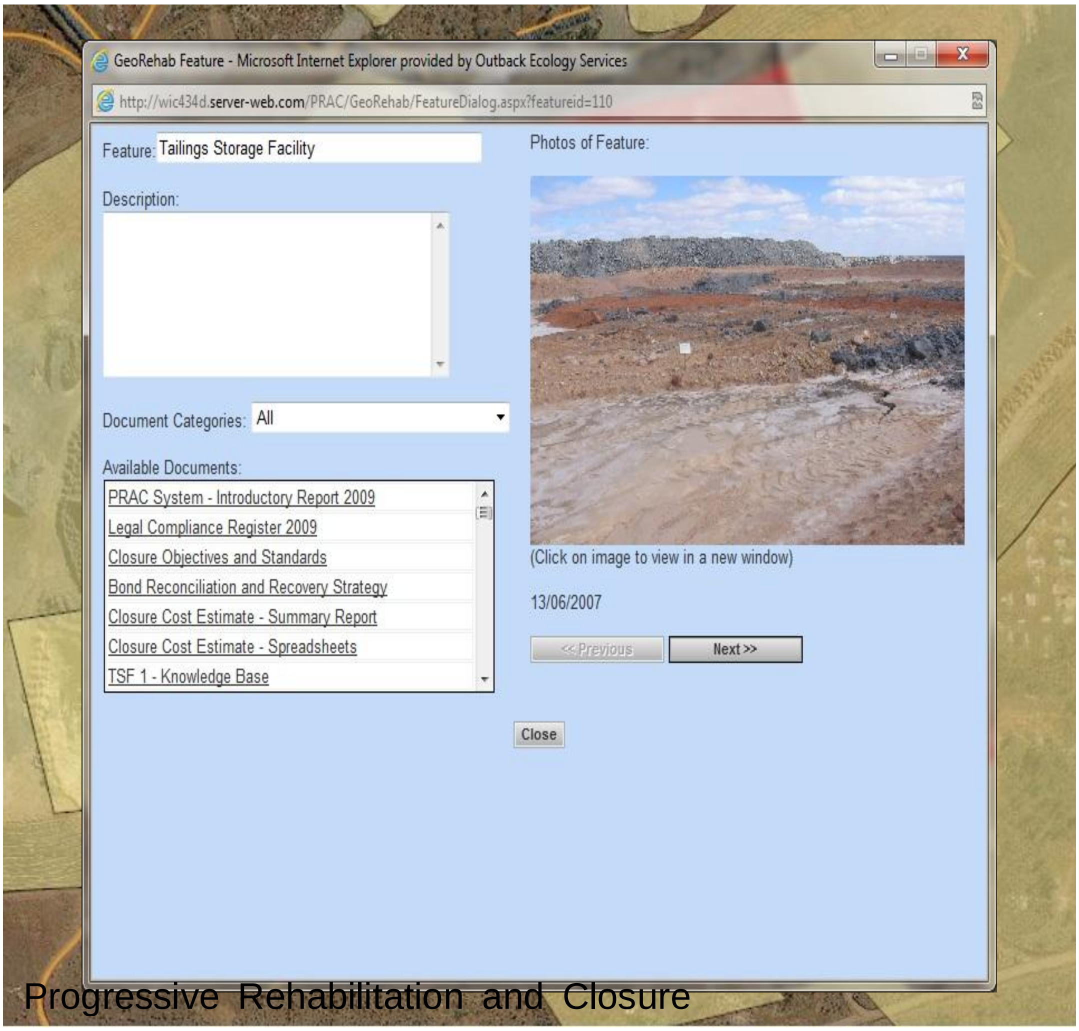

Figure 3: Tailings Storage Facility information within the PRAC™ (Progressive Rehabilitation and Closure) System at Challenger mine site.

Task Register

Electronic task registers can also be used as they have many advantages over hardcopy style task registers. Electronic task registers are by definition more dynamic than 'static' document based registers as they can be updated quickly and efficiently and need never become out of date due to changing priorities of an operating mine site. Furthermore, dynamic task registers offer more flexibility and control over prioritising tasks during the life of the mine. And when combined with software for managing rehabilitation and closure budgets, electronic task registers enable personnel to have greater control in managing rehabilitation and closure costs.

Conclusion

With the new mine closure legislation now in effect, mine closure planning is now more of a priority for organisations. The successful development of a MCP is reliant on a systematic and integrated planning process during the initial phases of a mines life. The guidelines for preparing mine closure plans developed by the DMP/EPA provide guidance in achieving this outcome. The maintenance and refinement of a MCP during the operations and closure phases of the life cycle is just as important.

Reliable data management is a key component in being able to take a well developed MCP, and refine it during operations and ultimately relinquish the mine site to the satisfaction of the regulators. A large amount of data is now required to be collected through the whole life cycle to validate rehabilitation and performance against agreed criteria in line with the guidelines. Electronic tools exist and are becoming increasingly common to assist with the management of this data and the reporting processes associated with the mine closure process. Tools include consolidated databases to ensure all closure related information is centralised, GIS technologies to define and store domain specific information and electronic task registers that enable rehabilitation and closure implementation to be conducted more efficiently. These tools mean the new legislative requirement need not be an operational burden.

Acknowledgements

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Geophysics for Total Mine Site and Tailings Leakage Characterisation

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Abstract

The challenge for planning for mine closure and in implementing rehabilitation works on large mine sites that may have legacy workings, leaking tailings dams, waste areas and former waste or processing areas, is to rapidly and reliably characterise the total site and particular “hotspot” areas. This is especially a challenge when site history records are less than complete.

For new mine sites, baseline site characterisation for mine closure and operational impact planning, using rapid methods to characterise the site early in the site history, enables informed ongoing environmental management planning and decisions for future site usage over the life of mine period.
Landform and eco-system functional analysis of a mine site includes mapping of soils and geomorphology for such diverse applications as potential for contamination and contaminant retention, catchment protection, botanical mapping, planning for new large tailings facilities and for identifying suitable soil borrow areas for remediation soil supplies or tailings dam lining material.
Airborne geophysics data, notably airborne radiometrics data, both regional and detailed, together with a terrain model, is generally available at most mine sites and surrounding environs. This data can help rapidly characterise the soils, based on radiometric chemistry, for identification of in-situ, disturbed (by mining operations) and transported soils on mine lease areas. With suitable ground-truthing and establishment of soil associations, the airborne geophysics soil mapping is a core soil / terrain classification method supporting many aspects of the landform and eco-system functional analysis approach.

Electrical resistivity techniques using the “mise-a-la-masse” method whereby current source electrodes are placed in and energise either a water filled leaking mine pit or a current or disused leaky tailings dam. This enables mapping of preferred leakage paths in fractured rock and alluvium around the pit or dam. The highly saline waters and tailings of the WA pits and tailings dams lend themselves to the innovative application of “mise-a-la-masse” for investigating leakage paths around facilities having unplanned leakage to the groundwater.

Multi-frequency electromagnetic mapping on a detailed scale, as in urban contaminated site work, can map the industrial archaeology and legacy of former mine infrastructure sites such as former processing plants or workshops requiring clean-up and rehabilitation. It can also map proposed tailings facilities sites and shallow saline seepage from existing mine water / tailing facilities.
This paper presents three case examples to illustrate the application and utility of these three geophysical methods for Goldfields mine environments.

Introduction

The challenge for environmental managers for planning for ongoing site works / mitigation, soil management, mine closure and in implementing rehabilitation works on large mine sites that may have legacy workings, leaking tailings dams, waste areas and former waste or processing areas, is to rapidly and reliably characterise the total site and particular "hotspot" areas. This is especially a challenge when site history records are less than complete and soil maps are nonexistent.

For new mine sites, baseline site characterisation for mine closure and operational impact planning, using rapid methods to characterise the site early in the site history, enables informed ongoing environmental management planning and decisions for future site usage over the life of mine period.

This paper presents three geophysical methods with case examples of how geophysics can be used to assist mine site environmental managers with site environmental management and planning.

For commercial considerations, the case study locations are not disclosed but are real examples either directly applicable to or taken from WA Goldfield's and broader general mine environments.

The three case example topics covered are: -

- Soil / terrain classification of a mine site for soil management and classification and landform analysis (LFA) using airborne radiometric data
- Mise-a-la- masse methods for leaking tailings tams / pits
- Multifrequency electromagnetics for shallow site characterization for rehabilitation of former mine infrastructure and waste spoil areas

Mine Site Soil / Terrain Classification Using Airborne Radiometrics

Mine site / lease environmental managers would be advantaged if they had even a coarse or better still, a semi-detailed soils map of the mine site / lease, preferably prepared early in the mine life of before start-up (baseline mapping). This would provide documented soil / site terrain classification to plan soil and vegetation management during the mine life and for mine closure planning. This would assist in achieving better outcomes for such activities as soil stockpile planning, botanical mapping (with soil associations), avoidance of sterilisation of more valuable soils or parts of the site, environmental impact definition for mine management and the regulators, site run-off and general catchment characterization plus definition of valuable borrow pit area for tailings dam lining material or rehabilitation soils.

Some mine sites are applying land form analysis (LFA) methods to characterize the site for the above outcomes, and these methods use airphoto, digital terrain model and limited and partly systematic soil sample analysis / interpretation to characterize the terrain and soils.

Airborne radiometric data analysis can provide more comprehensive site coverage and up front soil mapping and classification for LFA or simple soil mapping, with the radiometric mapping ground truthed and calibrated with targeted (on the radiometrics) soil sampling.

Overview of the radiometric survey method

Almost all of Australia is covered systematically by Government airborne geophysical surveys which include radiometrics surveying. These surveys are flown typically at best at 400 metres fight line spacing and 150 metres terrain clearance. At these survey specifications the survey aircraft collect average gamma radiation from a circular area typically of the order of one to 1.5 times the aircraft height in diameter (say ~150 – 220 metres). This coarsely maps the average gamma ray characteristics of the soil over this ~150 – 220 metres. In practice a gamma ray spectrometer measures different energy gamma rays in energy bands diagnostic of all elements (so-called Tocal Count (TC) gamma count) and specific radiometrics isotopes of potassium (K - a key component of clays in soils with clay content approximately linearly related to K and therefore K isotope energy and gamma count), plus trace concentrations of thorium (Th) and uranium (U) adhering to clays or organics. The gamma radiation emanates from the top ~0.5 metres of soil

Many mine sites in early exploration stages are covered by higher resolution, more detailed radiometric surveys, flown at 50 to 100 metre line spacings and 60 -100 metre terrain clearance. The WA DMP website MAGIX index[1] shows the extent of the large number of airborne surveys covering WA.

The mine site radiometrics may have been used to help make a detailed geological map of the mine-site, or use may have only been made of the magnetics data acquired on the survey. The detailed radiometric surveys gives slightly better definition of the terrain / soils radiometric characteristics and enable targeted soil sampling.

In either case the previous airborne surveys will have radar altimeter survey and therefore probable generated digital terrain model, which in the absence of better data (e.g. LIDAR can be very useful

All this data can be put to use to map the mine site for use during the mining life of the property.

Airborne radiometrics classification of soils

Using the available K, Th, U data, this data can be processed to separate the terrain into radiometric classes (initially an unsupervised classification method is used) or the site can be classified on K count alone indicative of % clay variations across the site. Essentially radiometric chemistry classification that can be ground truthed and calibrated using targeted (on the radiometric classes) soil sampling and then the classification can be further refined (supervised classification).

Figure 1 shows 25km (east-west) x 30 km (north-south) portion of a typical WA mine site K count image which is essentially a relative soil %clay image, that needs to be calibrated to ground truthing from soil sampling of high, medium and low K count areas (high clay % soils are red, low % clay soils are blue). The left hand image is potassium count only on a linear scale. The right hand image is the same potassium count "draped" over the topography derived from the survey aircraft altimeter. There are two surveys shown in the image. The coarse background image is from a regional survey flown

[1] (*http://mapserver.doir.wa.gov.au/GeoVIEW2/viewer.htm?Title=GeoVIEW.WA&startTheme=Geophysics*)

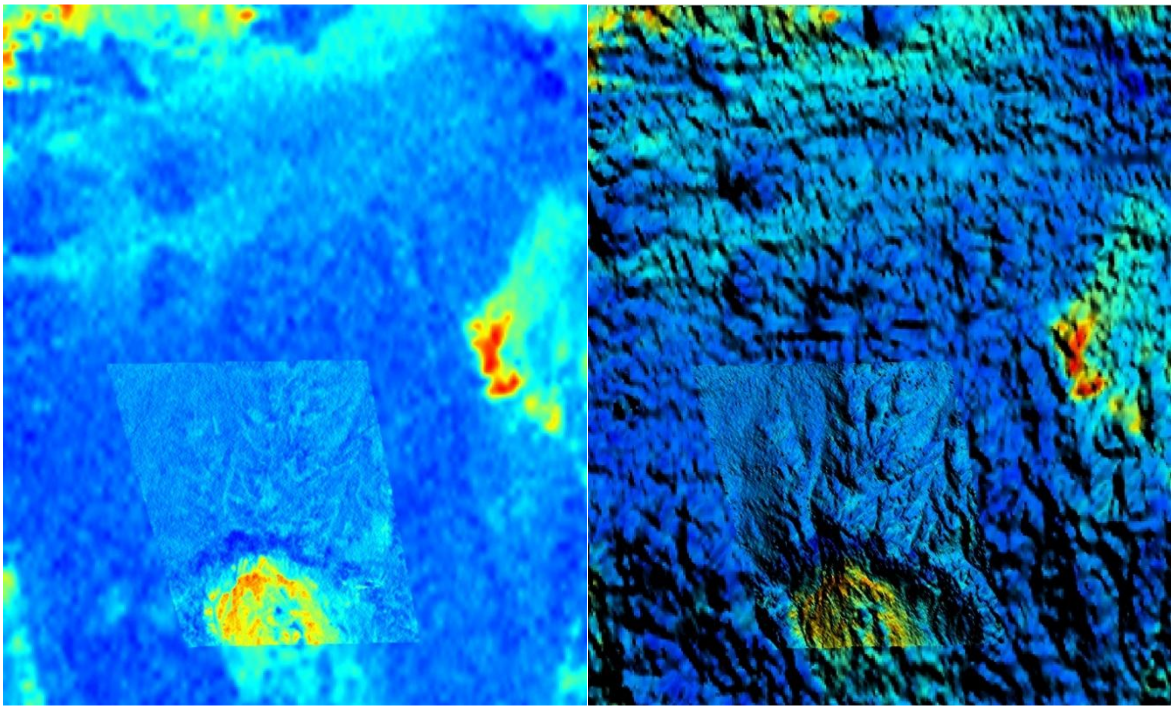


Figure 1. Mine site K image alone and draped over the digital terrain model

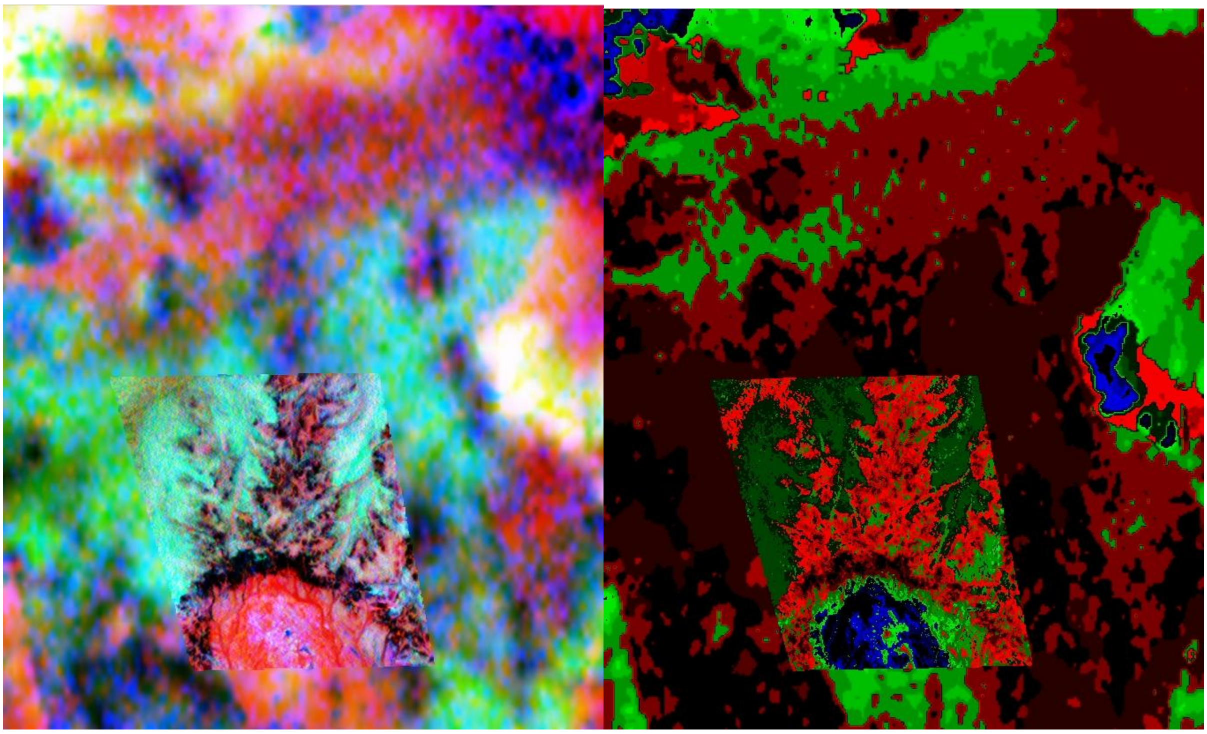


Figure 2. Mine site K-Th-U airborne radiometrics false colour RGB and classification images

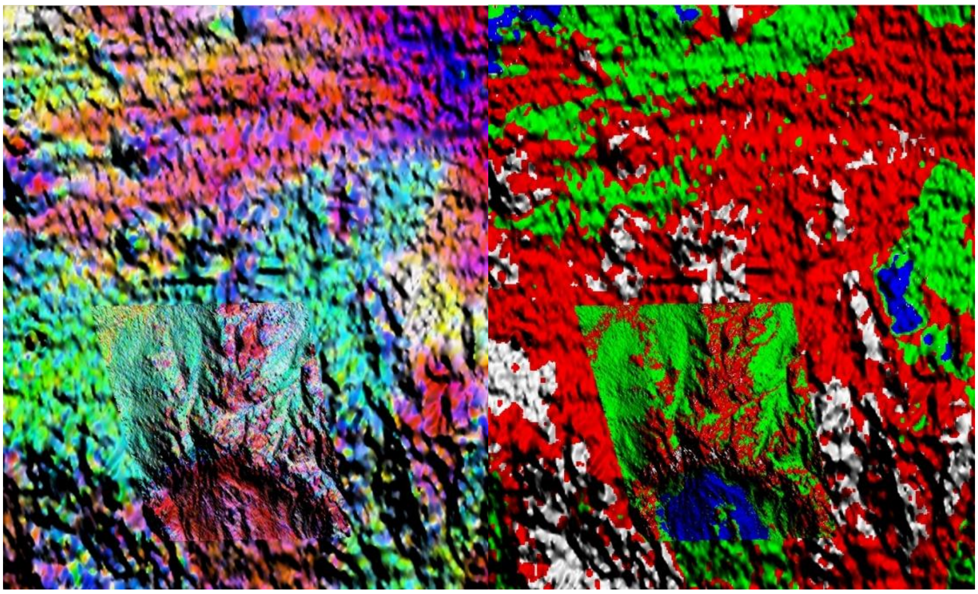


Figure 3. Mine site K-Th-U airborne radiometrics false colour RGB and classification images draped over the digital terrain model

for regional geological mapping purposes at 400 metre line spacing and 100 metres terrain clearance. The detailed parallelogram survey is from a mine-site survey flown at 50 metres line spacing and 20 metres terrain clearance. The difference in detail and resolution of soil variations as reflected in the potassium signature of the clay fraction of the soil types across the site. is marked and due to the survey parameters. Both surveys however yield useful data but the detailed survey more so.

Because of the importance of clays in soil acidification, soil moisture retention and therefore vegetation habitat, contaminant retention, permeability for infiltration (groundwater recharge) and run-off, with suitable ground-truthing and calibration of any soil associations (with botanical, physical or chemical parameters etc), the K maps can help in many soil related mapping applications with K as the surrogate (calibrated) parameter. Also with terrain slope data the K maps can identify where the soil is in-situ or transported.

Figure 2 shows a false colour image (similar to satellite or hyperspectral false colour imagery) showing K-Th-U in a RGB three colour presentation, alongside the 1st pass unsupervised classification (each colour representing a different class of soil – radio-chemistry wise).

Figure 3 shows the same data in Figure 2 but draped over the terrain model from the aircraft altimeter.

The combination of the interpretation of the classified radiometrics and terrain and slope, plus detailed hydrology and the airphoto can form the basis of the quasi-geomorphological classification of a site and as input to the LFA process. The process of refinement of the site / terrain classification can be taken further with suitable ground truthing, refined processing and interpretation of all available data as part of general site overview mapping or a more rigorous LFA process. Soil association (surrogate parameter) mapping is another possible use of the data either now or in the future.

Although the resolution of the radiometric classification is poor compared to other imagery and models of the site, it is vastly more representative soil-wise than limited soil sampling and it is directly reflecting the complexity, the variability and subtlety of average soil condition variations across a site (compared to what can be gleaned from colour photography and digital terrain models alone).

The end result with use of the objective radiometric data that is suitably processed and interpreted could, is that it provides information which is a helpful guide/tool for the site environmental manager and a permanent record for the mine site corporate memory bank.

Ultimately a better mine closure outcome may be achieved, because life of mine site use has been carried out on a known site soil condition mapping basis, not ignorance of baseline conditions.

High resolution, ground-based collection of radiometric data is an established technology and has a very small (~2 metres) foot-print and can greatly enhance the high-level overview of an airborne radiometric classification and take use of this method even further.

Defining Potential Leakage Paths from Pits and Dams

Electrical resistivity techniques using the "mise-a-la-masse" method whereby current source electrodes are placed in and energise either a water filled leaking mine pit or a current or disused leaky tailings dam enables mapping of preferred leakage paths in fractured rock and alluvium around the pit or dam.

Disused pit potential leakage example

Figure 4 shows geophysical survey results from a quarry site used to quarry volcanic rock from a cylindrical volcanic pipe in a granitic host rock. The quarry is in a major river catchment and close to the main river. The water table was well down in the base of the quarry and potentially there could be discharge from the quarry to the river. With the end of pit life and contemplation of alternative uses of the site (e.g. as a regional landfill), the regulator agreed to a proposed fractured rock aquifer geophysical study of the site as a scientific way of targeting monitoring bores and taking forward any project for either further use of the site or for responsible closure of the pit. Placing the electrode in the water (mise-a-la-masse – in the body) maximised the possibility of electrical imaging of the shears (compared to ground electromagnetic or resistivity surveys or airborne EM surveys).

The survey was carried out with a positive current electrode placed in the water at the base of the pit and the negative return current electrode placed at a long way from the site. The relative voltage potential (relative to a reference electrode again placed at a distance from the pit) was mapped at the site, around the pit on a regular grid. Subtle distortions in the millivoltage measurements, visible in sun-angle imaging of the contoured millivoltage surface (in x-y-voltage imaging space), were mapped that represented electric current channeling from the base of the pit along conductive shears in the granitic rocks around the pit, that were in electrical and hydraulic contact with the groundwater table (left hand figure in Figure 4).. The monitoring bore network was targeted for the interpreted shears (right hand figure in Figure 4).

A variant of this mise-a-la-masse technique, measuring with highly sensitive magnetometers, the minute variation in the magnetic field associated with current channeling along saline leakage paths can be utilized also.

The highly saline waters and tailings of many of the WA pits and tailings dams lend themselves to the innovative application of “mise-a-la-masse” for investigating leakage paths around excavations and dams having unplanned leakage to the groundwater, because of the expected greater conductivity of the shears (and especially saline saturated shears / fractures) with respect to the host rock beneath pits and tailings dams in the goldfields, compared to the Figure 4 case example.

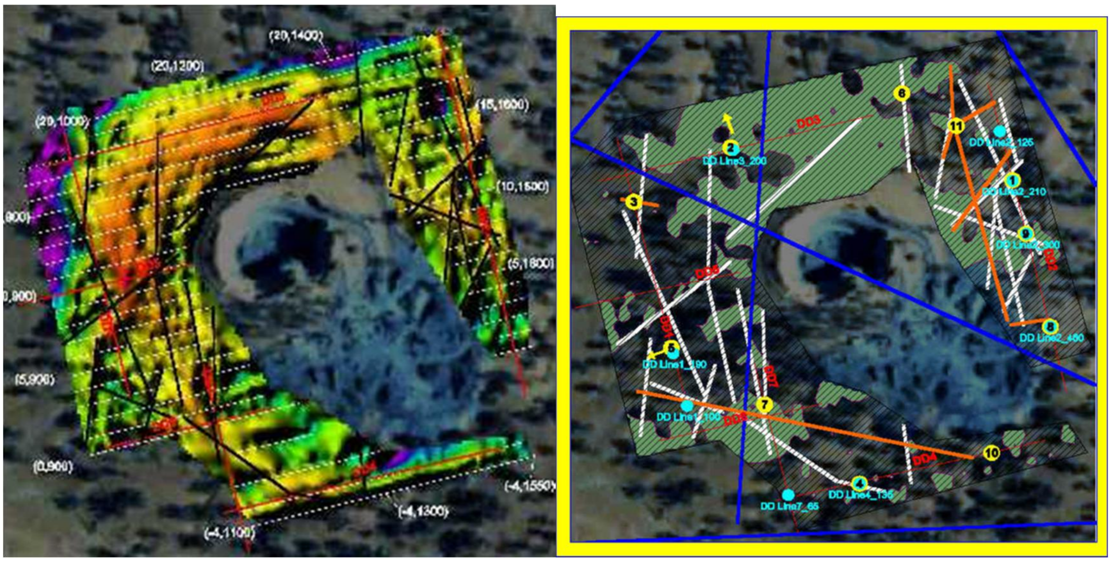


Figure 4. Mise-a-la-masse survey of a pit at end-of-life, for location of monitoring bores

Multi-frequency EM for Site Characterisation of Legacy Infrastructure and Waste Material Site.

Multi-frequency electromagnetic (EM) mapping on a detailed scale, as regularly used in urban contaminated site work and in archaeological geophysics, can map the industrial archaeology and legacy of former mine infrastructure sites such as former processing plants or workshops requiring clean-up and rehabilitation. It can also map proposed tailings facilities sites and shallow saline seepage from existing mine water / tailing facilities. In favourable cases it can map chemical alteration of soils due to former waste dumps or spills.

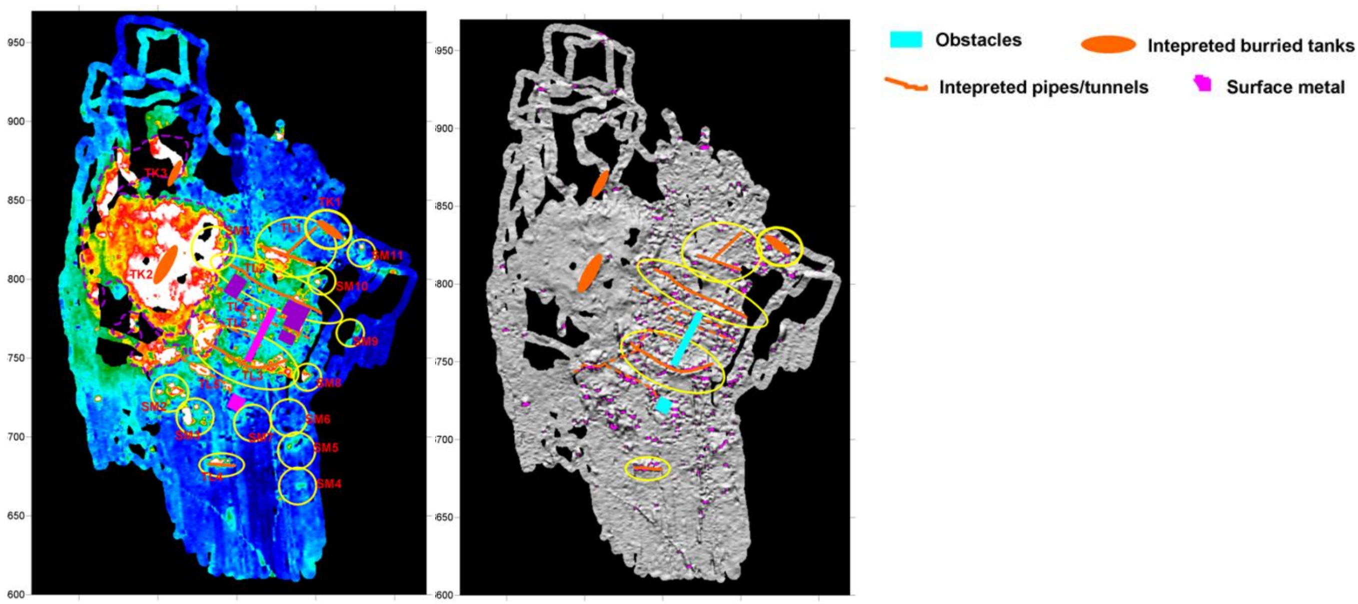
Figure 5 shows an example of a GEM2 survey from a former mineral processing plant, where pipes, tunnels and buried tanks were known to exist but the site history was lost Figure 5 shows the apparent conductivity image coloured image and a sun-angle image interpreted for infrastructure.

The multi-frequency GEM2 instrument allows many more images for interpretation of the site to be generated such as in-phase (metal detection), quadrature and/or conductivity (for soils), apparent magnetic susceptibility and a 50 Hertz monitor to detect live underground cables or earthed pipes.

Conclusions

Geophysics provides several tools for the mine environmental manager, three of which are: -

- Radiometrics to manage soils and plan activities that are using and impacting soils throughout the mine operational life and to plan for mine closure,
- Resistivity mise-a-la-masse to investigate and locate likely leakage paths from pits and tailing dams that may be impacting groundwater and
- Multifrequency EM to investigate and plan clean-up of former infrastructure where the site history and plant layout has been lost or is uncertain.



Selecting Appropriate Vegetation-Based Completion Criteria for Mine Site Rehabilitation

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Abstract

Establishing a vegetation community to satisfy rehabilitation objectives and meet completion criteria requirements is often regarded as an essential aspect of mine rehabilitation programmes. Vegetation establishment on rehabilitated mine sites can have diverse benefits such as providing erosion resistance, dust reduction and increasing landform stability, advancing ecosystem function, promoting nutrient cycling and infiltration processes, contributing to local and regional biodiversity and improving visual amenity.

The importance placed on developing vegetation-based completion criteria, can however, be overstated, resulting in a suite of unrealistic or unachievable quantitative standards or criteria targets. Successful vegetation establishment for rehabilitation purposes is directly linked to landform design and the capacity of the waste-soil profile to support plant growth. If the essential physical and chemical attributes to support plant life are present, achieving early standards relating to soil characteristics are often an essential compliment to vegetation criteria and in some cases can substitute for actual vegetation-criteria as indicators of a landform's capacity to support vegetation.

There are several questions to consider when designing vegetation-based rehabilitation completion criteria, including:

- What is the objective for the vegetation community and desired end land use?
- What are the main site specific and regional factors that will impact on criteria design?
- What vegetation parameters are crucial to rehabilitation success?
- Are the criteria specific, measurable, achievable, relevant and timely?
- What cost effective monitoring approaches can be used to track rehabilitation progress against criteria?
- How do we know when to stop monitoring?

Rehabilitation completion criteria are more appropriate if site-specific and designed as part of a suite of broader objectives. Outback Ecology has engaged with mines in different environments around Australia, from the tropics to the arid interior, to design vegetation-based rehabilitation completion criteria that best match each unique environment, and the expectations of local stakeholders. This paper explores the process of developing appropriate vegetation based completion criteria, the corresponding monitoring methods that allow measurement of specific vegetation parameters, and some of the challenges which are faced in the criteria design process.

Our only caveat in presenting this paper is that it is based on our experience, permission to present all the information specific to individual mines, although potentially forthcoming, would be a vastly time consuming and difficult task that has to be foregone in this instance, and therefore at times only generic references to mine areas and regions are made throughout the paper.

Introduction

How do you keep everyone happy? It's one of the perpetual challenges of taking mine-site rehabilitation and turning it into an acceptable outcome for the return of liabilities and overall closure. How can the objectives of the mine, the regulatory standards of governing bodies and the expectations of all varied stakeholders be aligned to achieve this? Many mine sites will experience a continuous attempt to strike a balance between what is achievable from the point of view of available rehabilitation materials and what is acceptable from the stakeholders' and regulators' point of view. Tongway and Ludwig (2011) describe this as an adaptive learning loop, in which lessons are learnt and solutions continuously implemented until such point as the rehabilitation objectives can be considered 'achieved', or at least 'on track' toward the target ecosystem values.

Outback Ecology provides completion criteria and closure services to mines across Australia, from the tropics to the arid interior. In our experience, most sites have the same problems: what to do with waste material, how to develop this into a stable functional and self-sustaining landform, and most importantly, how to prove rehabilitation success to regulators and stakeholders. We believe this involves establishing a monitoring strategy that doesn't just 'monitor just for the sake of monitoring'; and provides a strategy that collects the data needed to be able to show progression to an ultimate state, usually based on the qualities and characteristics of a target ecosystem. The development of a completion criteria framework assists by taking broad objectives and individually deciding what standards need to be achieved for them to be met.

The establishment of vegetation to some degree usually forms part of the broad suite of objectives usually applied to mine site rehabilitation, but should not be considered in isolation from the other objectives, which might also include resistance to erosion and stable soil surface properties. Too much emphasis is usually put on establishing species rather than preparing fundamental landscape processes. The soils (mine waste/ growth medium) must be "right" before the vegetation can be "right", and once achieved, this forms part of the fundamental positive feedback loop of rehabilitated systems; soils and vegetation each enhancing and improving the function and quality of the other through time. While this paper describes a number of approaches in designing completion criteria for vegetation, we acknowledge holistically the close relationship between abiotic and biotic factors, and that they must be considered in unison for a restored landscape to be considered ultimately complete. In summary we discuss the process of developing site-specific, realistic or achievable quantitative vegetation-based completion criteria.

Completion Criteria

The Function and Use of Completion Criteria

The development of acceptable and achievable completion criteria is a necessary part of mine closure planning. Completion criteria are defined as agreed standards or levels of performance, which demonstrate successful closure of a site (DITR 2006). Once achieved, they demonstrate to the mining company, regulators and other stakeholders that financial assurances and liabilities can be removed and/or lease relinquishment can ultimately occur.

Although completion criteria are tailored to the specific requirements of each mine site, a range of vegetation parameters, including measures of cover, density and diversity, are almost always included. For mine site rehabilitation, vegetation parameters are logical and valid assessment criteria and are generally a major focus for completion. Vegetation data can be easily and efficiently recorded, and information can be accurately related back to the rehabilitation plan for immediate implementation of any appropriate modifications (Osborne and Brearley 2000).

The first stage of the development of competition criteria is the setting of rehabilitation objectives. In Australia, post mining objectives are generally related to creating safe, stable and non-polluting landforms, capable of sustaining an agreed post-mining land use (DMP and EPA 2011). A common desired post mining outcome is the achievement of a self sustaining ecosystem that exhibits comparable characteristics to the local natural environment (e.g. Osborne and Brearley 2000, Jasper et al. 2003). From these broad objectives, more specific criteria can be identified, which are complimented by appropriate monitoring tools and quantitative standards. Criteria can cover aspects ranging from physical elements, such as drainage and erosion, to biological aspects, such as vegetation and fauna habitat (Outback Ecology 2011).

Monitoring in relation to a criteria framework

Mining operations typically operate on a shorter time frame than that of ecosystem development and this creates a need for an agreed framework in which all stakeholders can assess the acceptability of rehabilitation, at an early stage. Completion criteria which focus on the essential foundations of the ecosystem can provide this framework. In general, the first priority should be to establish an appropriate physical foundation, followed by appropriate biological components, then finally post-closure management. The proposed criteria can be defined by the SMART acronym, in that they are intended to be specific, measurable, achievable, relevant, and timely.

Generally a framework is proposed in which broad rehabilitation objectives are supported by more-specific criteria. Each criteria in turn is supported by an appropriate monitoring tool and where possible a quantitative standard. Overall objectives for rehabilitation, as well as specific targets and standards, should only represent what can be achieved (Nichols et al. 2005) and should be related to ecosystem functionality and processes, not simply composition. So, where very little or no vegetation is sustained in the surrounding natural environment, alternative closure targets are required. A number of criteria other than vegetation parameters are available, for example, measures of soil organic matter or soil loss through erosion. However, criteria to assess rehabilitation success need to be simple, objective, and easy to measure if they are to be regularly used for management of the rehabilitation areas, even if the ecosystem processes involved are complex (Bellairs 1998).

Once developed, the criteria will provide a focus for rehabilitation monitoring, and may lead to refinements to the current monitoring approach. A monitoring program should be designed and implemented that feeds the "adaptive learning loop" (Tongway and Ludwig 2011) and feedback is implemented until rehabilitation can be seen on track toward the rehabilitation objectives. A monitoring program must be designed to tell us what we want to know, should be suited to the host environment and must take into account the scale and variability of an area, and should monitor parameters that are directly linked to the criteria (i.e. not monitoring just for the sake of monitoring). In general, the cessation of the monitoring can occur when the rehabilitation area demonstrates that it has become self sustaining and is resilient in the face of stochastic events. The area should also have met and/or exceeded the defined criteria for a number of successive monitoring events and have achieved a set threshold level.

Selecting Appropriate Analogues

Assessing natural sites unaffected by mining (analogue sites) is an integral part of monitoring rehabilitation and can generate values to support completion criteria, depending on both seasonal and stochastic events such as storms, droughts and fire. Given the importance of the physical characteristics of the landscape and soil in determining vegetation communities, a suitable analogue site is one that has many of the very broad physical attributes of the planned final landscape. Key physical attributes may include similar slope, the more essential edaphic factors, and capacity for regulation of resources such as rainfall and vegetation litter. Data collected from regional analogue sites is a vital part of the monitoring process; varying seasonal conditions are captured providing a "band" of values to act as reference values for rehabilitation (Tongway and Hindley 2005).

Criteria are often designed to be comparable to a target ecosystem or to posses various qualities that match it to a target ecosystem. Target ecosystems are variously referred to as control sites, reference sites, or analogues. It is important to note that a target ecosystem does not have to be a natural ecosystem or in an undisturbed environment. Analogues, however, usually represent a natural ecosystem because there may be a lack of suitable successful rehabilitation for comparison, and a natural undisturbed environment usually has the desirable qualities as a 'benchmark' for rehabilitated landforms.

It should be noted that even 'pristine' sites have often been subject to years of historic disturbance, pastoral grazing regimes or weed encroachment. For example, we find in the immediate Kalgoorlie area many potential analogue slopes have been used for recreational purposes such as four-wheel driving and dirt biking, not to mention the fact that it is basically it is all recent re-growth and subject to extensive fossicking and prospecting. Finding undisturbed target ecosystems suitable for analogue data can be challenging, particularly in many historic mining areas.

Natural analogue ecosystems, however, have developed over many millennia and one of the first concessions that must be made is to accept the fact that in most cases replicating exact "function" over mine landforms – a highly disturbed environment is not going to be achievable. As Tongway and Ludwig (2011) indicate, it "*is not about returning damaged lands to some notional pristine state; it is about repairing landscapes to an acceptable level of functionality*".

For example, many naturally occurring slopes in the Pilbara consist of rocky skeletal soils covered with *Triodia* and many analogues replicate these areas. *Triodia* itself is not always present or easy to establish on the rehabilitation, so this automatically creates challenges. The sorts of tussock grasses and shrubs that develop on the rehabilitated surface don't always have the same capacity of *Triodia* to trap and retain resources. Where *Triodia* establishment has been successful it is often when inordinate amounts of topsoil (a precious resource) or a suitable growth medium have been used – and often a different species, such as *Triodia pungens* instead of *Triodia wiseana*. In this case, the function of *Triodia* is more important than an exact matching of the species and the criteria should reflect this.

The analogue site must be regional to the mine where possible, as rainfall is variable over the arid regions. When using an analogue to compare against a rehabilitated area, the analogue must be subject to comparable preceding rainfall conditions. In many environments finding a sloping analogue that closely represents the final desired attributes of the mine can be difficult, given the flat nature of the surrounding environment. For one mine in South Australia the altitude varies by as little as several metres over a vast area, and if a sloping vegetation community exists, it is unlikely to match a large waste landform; the rehabilitation objectives may be quite dissimilar.

Analogue sites used in several mines in the Goldfields and Northern Goldfields region were chosen by Outback Ecology to represent similar physical features to those of the rehabilitated sites. The sites are generally located on moderately sloping area, though with few approaching the steepness of most rehabilitated waste landforms due to the limited availability of such areas in the surrounding environment. In this case the key task must be the collection of appropriate scientific data from the best sites available.

Once the appropriate analogue is selected, a number of approaches may be taken in accumulating an analogue data set. Where numerous years of data exist for the same set of analogue sites, the data can be pooled on the assumption that it includes a band of both above and below average rainfall events, and that the results in any given year for the analogues should fall somewhere within the band. This could be more beneficial in environments experiencing regular rainfall. A more comparable result (particularly when there are only limited years of data or fluctuating rainfall), would be using only the analogues from the current year of assessment to compare with the rehabilitation in any given year. This means that the rehabilitation has been subject to the same rainfall conditions as the analogues preceding the assessment. For example, a mine in South Australia's arid interior experiences fluctuating climatic conditions, so the actual quantitative value for completion criteria targets are not fixed, being based only on analogue monitoring values gathered during the same year as rehabilitation data.

Landscape Function Analysis

While vegetation based completion criteria are commonly centred on plant cover and density indices, environmental factors (i.e. a lack of permanent vegetation cover) may make these indices ineffectual. Landscape Function Analysis (LFA) is a method which may be used in place of traditional vegetation assessments in some circumstances. LFA is a cost-effective, rapid-assessment method which is now commonly used throughout Australia, as well as internationally, to monitor disturbed environments, usually as part of a broader monitoring system called Ecosystem Function Analysis (EFA) which incorporates additional measures of vegetation, erosion and habitat complexity (Figure 1Figure). Using the LFA, it is possible to define and rapidly record the influence of vegetation along with non-vegetation based indices toward completion criteria (for stability, infiltration and nutrient cycling), and therefore, assess rehabilitation success or help to identify areas performing below expectation, without recourse to the standard vegetation data collection.

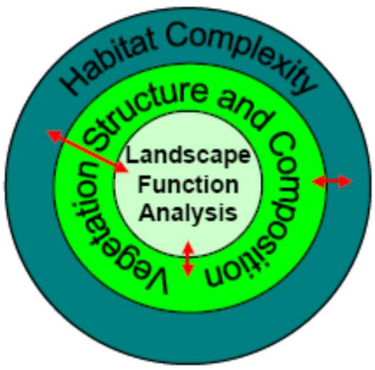

Figure 1: Schematic showing the inter-relationship of the three primary components that are integrated to form EFA (Tongway and Hindley 2005)

LFA was developed by the CSIRO approximately 25 years ago for application by Australian rangeland managers and scientists to monitor changes in the distribution and frequency of different landscape zones along a transect, and to provide measures for each of their soil surface characteristics. The LFA tool uses 11 indicators (surface soil assessment indicators) to produce indices for stability, infiltration and nutrient cycling. The tool was drawn from a wide range of scientific disciplines and applied research conducted over a number of decades (Lacy et al. 2010) and has undergone verification in several studies (Tongway et al. 1997, Tongway and Hindley 2005).

The LFA procedure divides the landscape into zones of resource accumulation (‘patches’), and ‘interpatches’, from which resources tend to be mobilised and transported. ‘Patches’ tend to be richer in resources and have enhanced soil properties such as better infiltration, nutrient availability and soil surface stability (Tongway and Hindley 2005). ’Patch’ zones can include grass and litter zones, each of which can score slightly different soil surface characteristics. The characteristics are measured for each zone using surface soil indicators (Figure 2Figure 2), which each correspond to three soil surface indices (stability, infiltration and nutrient cycling). In this way, the soil surface indices can provide information about the nature of the rehabilitation area before vegetation has established. For example, trough structures present in a landform with ripping can provide the patches in the absence of vegetation. In ideal conditions, as the landform loses its bank/trough integrity over time, vegetation should (or organic patch zones) develop to take its place. These zones usually develop in what were the troughs due to their initial function in trapping seed, water and sediment. Therefore in some instances, troughs can be looked at as showing a potential to facilitate vegetation establishment.

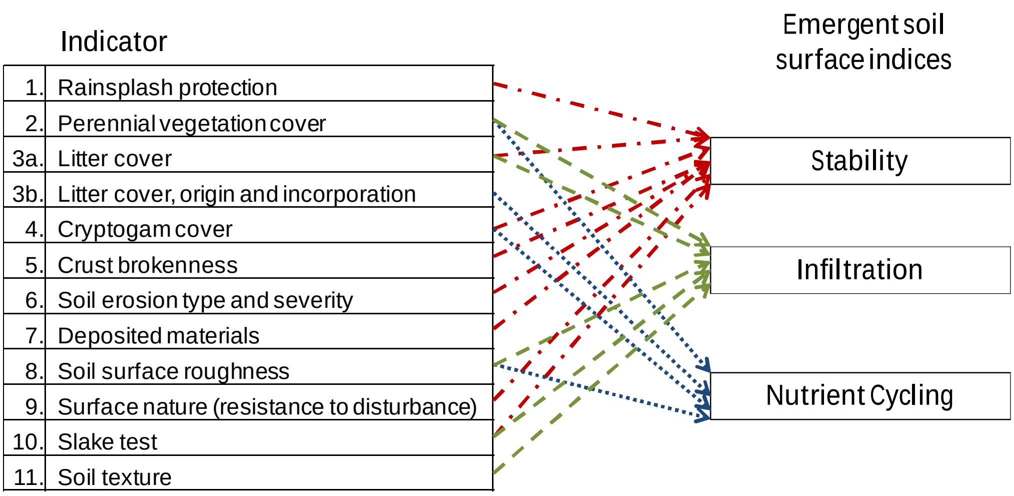

Figure 2: LFA emergent soil surface indices and indicators (adapted from Tongway and Hindley, 2005)

For arid environments which have highly variable rainfall totals, perennial plant cover can be absent or unreliable, therefore rendering traditional vegetation monitoring ineffective. Ephemeral plant cover may be common in these areas; however, as it fluctuates with sporadic rainfall events, it is not a very reliable indicator of rehabilitation success. Given the limited range of completion targets able to be applied due to the absence of vegetation, another vegetation based completion criterion would need to be assigned. LFA may be used to provide surrogates or indicators for vegetative productivity. Organic ‘patch’ proportion (cover of ‘patches’) relates to the presence of, and distinguishes between, different vegetative components, with factors such as litter cover being used as an indication of past productivity. The proportion of ‘patch’ or resource accumulation zones (including litter and plants) can be a useful index to build into the completion criteria.

Lower Storey Vegetation

Perennial vegetation assessments can be conducted through the application of highly repeatable rapid assessment methods along a defined transect. Lower storey vegetation is a fundamental component for many types of successful rehabilitation, providing functions such as landform stability, promoting nutrient cycling and infiltration processes, contributing to local and regional biodiversity and improving visual amenity.

When assigning criteria for lower storey vegetation, a height limit should be defined, this depends on the vegetation type of the area and can be modified to suit the vegetation monitored. For areas with limited species richness, a single criterion for ground cover (e.g. *Triodia* hummock grassland) may suffice whereas for areas with high species richness, separate criteria for various layers of lower storey vegetation at different class heights (e.g. grasses, shrubs and trees < 1 m) may be required.

Plant species are also divided into perennial and annual species. Perennial plants are classified as plants that live for more than two years compared to shorter lived annual and bi-annual species that are seasonal and only live for a brief life cycle. Lower storey perennial plants are essential for providing soil stability, and resource capture zones for nutrients and water on rehabilitation areas (Tongway and Hindley 2005). Annual plant species also provide nutrients and litter to a landform, particularly on desiccation, however unlike the functions of perennial plants this function is ephemeral and effects are thought to be transitory.

The use of lower storey vegetation in determining completion criteria for a landform is an effective way of analysing assessing the performance of rehabilitation. Quantitative parameters such as plant cover, density and species richness are commonly recorded, in addition to some qualitative parameters such as plant maturity and health. Two common ways of recording some of this data is through the use of the plotless method Point Centre Quarter (PCQ) and the Quadrat Method, typically used as part of the Ecosystem Function Analysis method (Tongway and Hindley, 2005). Both are preferably recorded along permanent transects in order to record the progression of the rehabilitation over time. Selecting the appropriate vegetation monitoring method is essential in order to assess the rehabilitation and the progress towards the developed criteria.

The choice of monitoring methods depends on both effectiveness and efficiency. PCQ is most commonly used in low rainfall areas where the vegetation is naturally sparse such as in a mulga or chenopod shrubland in arid and semi-arid areas such as the Goldfields. PCQ was determined to be the most effective monitoring program in some areas as the PCQ method allows for efficient monitoring in these sparse conditions and provides accurate data for plant cover, density and species richness (Mitchell 2007). The method is also flexible and can be tailored to suit different vegetation requirements, for example criteria for multiple layers of vegetation in the dry tropics of Northern Queensland and specific species information for invasive perennials in the Northern tropics. PCQ also uses actual measurements rather than estimations by eye and plants can be any distance from the transect within the monitoring area (Moiler et. al. 2011). Disadvantages to this method include the exclusion of the quantitative analysis of annual plant species. The PCQ method, however, is commonly used in climatic regions where perennial plant species provide permanent functions in the landscape, while annual plants are only temporary and are not seen as providing a strong, lasting effect on the landscape, with the exception of providing nutrients, particularly in desiccation.

Alternatively, the quadrat method assesses both perennial and annual plant cover and density and is commonly used in a variety of environments such as the dry tropics of the Pilbara and tropical and sub-tropical climates of the Kimberley. The quadrat method can be applied to areas with various plant cover and density; however the main disadvantages of this method include its reliance on visual assessments for cover and propensity to human error (Floyd and Anderson, 1987).

Numerous other methods exist and are being used to monitor vegetation cover, such as the ground cover determination using the point-intercept methodology (Viert et al. 2010) used for reclamation monitoring at a Goldfields site. Regardless of the method, it is critical to recognise the benefits and flaws of each particular method and to select a method that best balances the type and quality of information collected against cost, efficiency and timeliness, and that the monitoring method provides the relevant information required to measure rehabilitation progress against the defined criteria.

Upper Storey Vegetation

Upper storey vegetation typically consists of shrubs and trees of a designated minimum height, for the purposes of monitoring, or any tree/shrub species with the potential to reach or exceed that height in future. This height category varies in relation to the environment and species monitored.

Monitoring methods such as the plotless Wandering Quarter (WQ) are used to monitor plants exceeding a set height limit (e.g. 1.5 or 3 m). For some mine sites, it can take many years for an individual plant to achieve this height; it has been proposed that a designated density of species with the potential to reach this height be included as the quantitative standard. Immature individuals would therefore be monitored under the assumption that they will, in the future, achieve the desired height. Plotless methods can be useful as they may be more time efficient than plot-based counting procedures (Tongway and Ludwig, 2011). Some sites monitored by Outback Ecology use plot-based quadrat techniques whereby the density and cover of individual perennial species are recorded in a 1 x 1 m or 2 x 2 m quadrat along set spacing on a permanent transect. Whilst this can be an effective technique for capturing lower storey vegetation, observations from frequent use of this method have indicated that the quadrat technique does not realistically capture the upper storey present in a rehabilitation area, particularly in environments such as the Pilbara where upper storey may be sparsely distributed.

Criteria selected for upper storey vegetation may include cover, density (stems/hectare) and species richness. Depending on the environment and end land use requirements, criteria may need to incorporate only one or several of these parameters.

There are several considerations to take into account when designing upper storey criteria. The potential for the establishment of an upper storey is dependent on the variety of species included in the original seed mix used for rehabilitation. Some landforms are intentionally not-seeded with upper storey species due to the presence of potentially hostile material in the underlying surface profiles, or because some landforms will not be designed to support trees as some roots may damage the integrity of the surface profile. In some cases, upper storey species may not be a significant component of the surrounding undisturbed environment and thus this is reflected in the seed mix used. Some trees have remained relatively shallow-rooted due to the hard setting nature of the waste material below the topsoil. Recent monitoring by Outback Ecology in 2012 in cyclone prone areas has seen the effects where trees have been felled by the wind (Plate 1Plate 1), at times exposing shallow and proportionally insignificant root structures.

Plate 1: *Acacia ancistrocarpa* trees felled by cyclone effects

Caution should be taken when designating upper storey criteria, as there may be cases where the criteria for cover and density are satisfied but to the detriment of other species such as essential ground cover or other upper storey species. In the dry tropics of North Queensland, rehabilitated landforms have been observed with a high density of *Acacia holosericea*. In the process of natural succession the *Eucalyptus* upper storey usually replaces the *Acacia*, with a natural 'thinning out' of this short lived species, yet on 20 year old rehabilitation, *Acacia holosericea* persists and in some cases exceeds the density of the analogue sites, to the detriment of other species (Plate 2Plate 2**)**.

Plate 2: *Acacia holosericea* dominating a landform in Northern Queensland

In some cases, trees in analogue areas used for comparison with rehabilitated areas may be decades old and it is obvious that the rehabilitated area will not be able to satisfy this criteria for many years. In other environments, upper storey vegetation may be critical to a rehabilitated area's success due to the habitat values that trees can provide, significance to Traditional Owners and provision of visual amenity in areas with tourism and recreation as an end land use. The selection of upper storey criteria should therefore be considered on a regional, local and landform by landform basis.

Species Matching

We belive the re-building of fundamental landscape processes should be the focus of rehabilitation efforts, rather than on purely trying to replicate the type and proportions of species found on the natural target ecosystem. For this reason, a simple count of species richness (the number of species present) is often a component of vegetation completion criteria, and the types and proportions of species present are often not considered. This is because some species are more successful in establishing on mine waste and disturbed areas than others. For example, in the Murchison region of Western Australia, the natural vegetation is dominated by *Acacia* and *Eucalyptus* species, whereas rehabilitation sites in the same region are overwhelmingly dominated by saltbush (*Atriplex* spp.) and bluebush (*Maireana* spp.), a function of the edaphic factors of mine waste (and sometimes seed mixes selected). In this respect, a criterion based on replicating the natural plant composition would be unachievable.

In some instances, however, the return of particular plant species or a group of species is a key objective of mine site rehabilitation. In these cases, a more tailored approach is necessary. Examples of completion criteria relating to specific plant groups can be drawn from recent work in the Kimberley of W.A where a framework for a site included criteria based on:

- Percent of native perennial grasses;
- Traditional Owner species of interest; and
- Re-sprouter (fire tolerant) plants.

Perennial grasses are a dominant component of the Kimberly region and an objective used by the mine in this region was to 'ensure that rehabilitated areas blend visually with the surrounding environment'. For this reason, a criterion was introduced that related to the percentage cover of native perennial grasses. A number of exotic grass species, such as Buffel grass, are prevalent in the Kimberley region and this criterion has a dual purpose of ensuring that the perennial grass cover is native. It was suggested that native perennial grass cover should be at least equivalent to a set percentage of the median for the target ecosystem for rehabilitation at this site.

Traditional owner plant species of interest are those which play an important role in local Aboriginal culture, such as providing food or materials for shelter and hunting and can be considered when setting completion criteria. A criterion was assigned indicating that 'the richness of agreed 'species of interest' resembles that in natural areas'; requiring a list of the desired species has been compiled in consultation with Traditional Owners.

In the wet-dry tropical savannah region of northern Australia, landscape-scale fires can occur annually, usually during the dry season months of May to November (Myers e*t al.* 2004). It is therefore important that rehabilitation areas in this region are sustainable under such a regular fire regime, and that some form of measurement of the potential fire tolerance of rehabilitation could be included in completion criteria. To reach reproductive maturity in fire-prone savannas, juvenile trees must survive fire (Lawes *et al.* 2011). Seeder species, such as most *Acacia* species, tend to be killed by fire and rely on seed stores in the soil to recolonise an area. These plants have less chance of surviving regular fires given the time required for plants to reach reproductive maturity. Mature individuals of re-sprouter species tend to survive most fire events and this includes species such as *Eucalyptus* and *Corymbia.* It is these plants that can be considered fire tolerant in a criteria framework. This approach can lead to objectives such as 'ensure rehabilitated vegetation structure is sustainable under a regular fire regime'. In order to measure such a criterion, the proportion of upper storey re-sprouter species vs. re-seeder upper storey species was examined on the target ecosystem and rehabilitation. The criterion was that 'sufficient upper storey re-sprouter (fire tolerant) species are present to maintain vegetation structure'. The target ecosystem with the lowest proportion of the desired plants was used to determine the level of 'sufficient' upper storey re-sprouter plants.

It is possible to develop a suite of criteria relating to the presence of specific species or the proportions of specific species on rehabilitation, as has been applied in the above situations. The example criteria were implemented according to the objectives of the mine and in relation to the mines climatic location and position within the local community. However, in many other instances, particularly in drier climates, such specific criteria are generally unachievable. Instead, one criterion relating to perennial species richness could be used. Comparing perennial species richness on target ecosystems with that of rehabilitation would be simple and achievable, while ensuring that if a high number of plants are present in the target ecosystem, a high number must also be present on rehabilitation for it to be considered successful.

Weeds

Selecting appropriate criteria for weeds first requires a definition of a weed species, and the appropriate consideration of the local area. Depending on the specific site context and environmental setting, a weed can be an introduced species declared under the *Agriculture and Related Resources Protection Act 1976* (e.g. Mexican Poppy *Argemone ochroleuca*); non-declared introduced species (Ruby Dock, *Acetosa vesicaria*); commercially valuable, non-declared introduced species such as Buffel Grass (*Cenchrus ciliaris*) and even naturalised native colonisers such as Roly Poly (*Salsola tragus*).

Disturbed environments such as mine sites and associated areas such as transport corridors, discharge areas, waste landforms and mesic habitats such as creeklines and floodplains are particularly susceptible to weed invasion. What unites these weed species is their typically aggressive, colonising properties and tendency to outcompete native vegetation, particularly during the initial establishment phase in mine rehabilitation. Conversely, some weed species may have beneficial properties such as providing stability to waste landforms by binding soil through root structure and providing habitat or food sources for fauna. It is crucial for mining operations to consider all of these impacts when selecting weed criteria and to have an integrated approach to weed management by involving relevant stakeholders and community, and consider weed management at all phases of mine operation (weed hygiene measures) and rehabilitation i.e. selecting appropriate native local provenance seed mixes, topsoil handling and storage techniques, and targeted weed control.

For instance, for alluvial rehabilitation at a mine in the wet tropics of W.A., completion criteria for weeds have been suggested. In such areas, non-declared, introduced species such as *Aerva javanica*, *Calotropis procera*, *Cenchrus ciliaris* have been identified. Some of these species are tolerated in the region and as such do not require active control at all times despite their ability to have deleterious effect on native ecosystems over time, and also where waterways may have downstream impacts on other systems through transport of weed propagules. Given the high cover of those plants on some areas of alluvial rehabilitation, a suggested criterion was introduced, '*the cover of introduced plant species does not exceed that of native species*.'

Regarded by many as one of Australia's serious environmental weeds (Franks 2002; McIvor 2003; Jackson 2005, Grice 2006), Buffel grass is an aggressive coloniser. It is also now one of Australia's most widely sown perennial pastoral grasses throughout agricultural Australia (Dixon et al. 2002). Buffel grass has the potential to outcompete native species, resulting in altered habitat complexity and fire regimes. However in areas where Buffel grass has died out, we have found that a suite of native species will re-develop. In north Queensland, Buffel grass has featured prominently in mine rehabilitation works where it is valuable pastoral fodder and is also considered to assist with erosion control. However, Buffel grass is considered by some as an environmental weed in WA, with Buffel grass colonising various disturbance and discharge areas throughout the Pilbara.

On the other hand, we have noted benefits to the presence of introduced, dense perennial grasses such as Buffel grass as they can provide stability to the landform as well as habitat for fauna such as snakes and roosting birds. Although introduced grasses should be managed due to their status as an environmental weed and aggressive colonising tendencies, there may be instances where the weed's stabilising properties and provision of habitat may be crucial to a particular area of rehabilitation and this may need to be taken into consideration when preparing completion criteria.

In environmentally sensitive areas, such as in a mining operation located in sclerophyllous shrubland heath north of Perth, characterised by a high level of endemism, the focus of criteria for restored vegetation is that species present should be of local provenance. However, it is recognised that a complete absence of weed species would not be a feasible option given that some weeds have been found in control sites, and initial criteria values have been suggested as a maximum of five plants of weed species per quadrat (1m2) given that data over time has indicated a reduction in number of weed species over time, and after approximately 5 years after initial rehabilitation works.

Various approaches for developing weed related criteria may exist based on presence/absence, declared introduced species vs. non-declared introduced species and presence to an acceptable limit, such as no greater than that found in a target ecosystem. The criteria examples presented here were selected according to the end land use of the mining operation, other proposed standards and objectives and in relation to the general environmental context. We have observed that selecting a criteria of 0% weed presence may be overly ambitious, given that due to the disturbed nature of most mining operations and subsequent rehabilitation, it is unlikely that this criterion would be achievable. Instead, focus should be given to correct planning throughout the mine life such as seed mix planning using native local provenance species, correct topsoil handling and management techniques, weed management throughout the mine life and then developing criteria to ensure that introduced and declared weed species do not exceed an acceptable limit as determined by target ecosystems.

Conclusions

Vegetation establishment on rehabilitated mine sites can have diverse benefits such as providing erosion resistance, dust reduction and increasing landform stability, is essential for advancing ecosystem function, promoting nutrient cycling and infiltration processes, contributing to local and regional biodiversity and improving visual amenity.

Achieving early criteria related to soil characteristics such as surface stability and infiltration is an important primary step before the establishment of vegetation can occur. Successful vegetation establishment is directly linked to soil and growth medium's capacity to support plant growth and landform design affects this greatly to. Selecting and assessing natural sites unaffected by mining (analogue sites) is an integral part of monitoring rehabilitation and can generate values to develop completion criteria and gains and understanding of the functional values in the surrounding ecosystem.

Numerous parameters can be monitored to track rehabilitation progress towards achieving vegetation based completion criteria and these can include: soil surface condition indices (Landscape Function Analysis), and measures of lower storey and upper storey vegetation cover, density and species richness and weeds. Various monitoring methods may be used to monitor progression towards satisfaction of designated criteria, including Landscape Function Analysis for landscape parameters and plot and plot-less techniques for vegetation parameters. Whichever method is used in the end, it is essential to consider that any method will have benefits and flaws. What is important is to select the method most appropriate to the site which balances the type and quality of information obtained against cost, efficiency and timeliness and to establish a relevant monitoring programme that effectively captures the progress of rehabilitation towards achieving the designated criteria.

We have seen various examples of vegetation specific completion criteria used throughout various environments. For example, a complex rehabilitated landform in the Kimberley region may have specific Traditional Owner requirements and biodiversity values that need to be satisfied, in which case a suite of criteria encompassing species composition, cover and density in various height classes would be needed, whereas a site in the arid interior of South Australia may lack vegetation entirely and instead have criteria for landscape function and patch/interpatch proportion. What works for one site and environmental setting may not work for another. Essentially - whatever the final criteria framework may be, it should be specific, measurable, achievable, relevant and timely and be tailored to take into account regional, local and site specific factors (biotic and abiotic) and satisfy stakeholder and regulatory requirements.

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Closure Modelling: Reaping the Benefits of Forward Planning

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Abstract

Traditionally mining companies have based the provision for closure and rehabilitation on unconditional performance bonds lodged with the Department of Mines and Petroleum (DMP). This can lead companies to be unprepared for the cost of closing a mine site, as bonds only provide a proportion of the cost of rehabilitation. In July 2011, the *Guidelines for Preparing Mine Closure Plans* were jointly issued by the DMP and the Office of the Environmental Protection Authority (OEPA). These guidelines describe the new standards required for closure of mine sites that will apply to both existing and new mining operations in the future. Among the key changes is a requirement to include estimates of mine closure costs as part of the Mine Closure and Rehabilitation Plan to be submitted to Government as part of the project approvals process. The closure cost estimations must be supported by information on the costing method and assumptions on the financial processes used to estimate costs. The Standardised Reclamation Cost Estimation (SRCE) model has become an invaluable tool in respect to this, and can be used to estimate costs associated with closure.

Karara Mining Limited (KML) engaged SRK Consulting to develop a preliminary cost estimate for the establishment and management of rehabilitation and mine closure for the Greater Karara Project. Conceptual reclamation and closure methods were used to evaluate the various components of the mining operations and Version 1.4 of the SRCE was used to prepare a closure cost estimate. Karara mine personnel provided user input data describing the physical layout, geometry, dimensions of project components obtained from the Closure Plan, AutoCAD and GIS information. Along with this data, the model used first principle methods to estimate quantities, productivities, and work hours required for various closure tasks and cost data based on 2011 standardized industry unit costs for labor, equipment and materials. The model is reviewed and updated on a 6 monthly basis. By using this methodology KML have developed an increasingly accurate closure cost estimate that will reflect changes over the life of the project and will also assist KML with fulfilling the requirements of the new Closure guidelines.

Introduction

Karara Mining Limited

Karara Mining Ltd (KML) was established in 2007 through the 50-50 joint venture between Gindalbie Metals Limited and Anshan iron and Steel Group Corporation. Karara, located 200km east of Geraldton, is the first major magnetite operation in the Mid West and will underpin a substantial, long-life iron ore business with robust economics. The operation includes construction and operation of a large open pit mine, a processing plant to produce magnetite concentrate and all associated infrastructure.

Karara is a world-class ore body in terms of its size, quality, consistency and extremely low waste-to-ore stripping ratio with the potential to produce +30 mtpa for more than 30 years. The company currently employs 140 personnel and has approximately 1,700 contactors onsite for the construction phase of the project.

Karara also incorporates numerous Direct Shipping Ore (DSO) hematite deposits. The first shipment of DSO was made at the end of March 2011, with production expected to ramp up to 2 Mtpa during 2012. The first production of 8 Mtpa magnetite is expected to commence in September 2012.

Karara Vision

Karara pride ourselves on recognising the values, qualities and biodiversity present within the Mid-West region in which we operate. This recognition has been a key driver in securing environmental approval for the Karara Project under State and Commonwealth legislation, and has been the basis of the development of innovative management strategies and processes to minimise environmental disturbance areas and protect the environment. KML strives to be an industry leader in regards to environmental best practice and recognizes the benefits that can be achieved from preparing for closure during the planning stages of the project. This can be demonstrated by KML developing a robust Closure Cost Estimate that will account for changes over the life of the project.

Mine Closure Legislation

Closure plans are not optional – the *Mining Act* 1978 was amended on 28 June 2010 to specifically require the inclusion of a closure plan as an essential component of a mining proposal [Section 70O(1)(c)]. The amendments to the Act require regular review and updating of mine closure plans [Section 84AA (3) *Mining Act* 1978]. Minimum bonding rates are determined in accordance with the DMP Bond Policy (2009). Higher bonds may be applied at the discretion of the Department of Mines and Petroleum. Other pieces of WA legislation (for example the EP Act 1986 and many State Agreement Acts) have provisions which allow imposition of financial assurances or other conditions relating to planned or unplanned closure.

In July 2011 the Guidelines for Preparing Mine Closure Plans were jointly issued by the DMP and the OEPA. These guidelines describe the standards required for closure of mine sites that will apply to both existing and new mining operations. Among the key changes is a requirement to include estimates of mine closure costs in the Mine Closure and Rehabilitation Plan to be submitted to Government as part of the project approvals process.

Karara Closure Model Strategy

In early 2011, Karara identified the need for a Closure Cost Estimate Model as financial provision for rehabilitation had previously been based on unconditional performance bonds. Performance bonds only provide a fraction (industry estimate of 40% of total rehabilitation cost based on the 2013 DMP Bond Policy) of the total cost of rehabilitation, leaving the company with the risk of being unprepared for closure. In additional to this, the Draft *Guidelines for Preparing Mine Closure Plans* outlined the new standards required for closure of mine site. Among the key changes is a requirement to include estimates of mine closure costs in the Mine Closure and Rehabilitation Plan (MCP). The guidelines require the closure cost estimations to be supported by information on the costing method and assumptions used in the financial processes to estimate costs. As Karara were in the process of developing the Mining Proposal for the Mungada Iron Ore Project, it became evident that a MCP and Reclamation Cost Estimate would be required to submit with the Mining Proposal. In March 2011, Karara engaged SRK consulting to develop a Standardised Reclamation Cost Estimate (SRCE) Model for the KML Project.

Conceptual reclamation and closure methods were used to evaluate the various components of the mining operations and Version 1.4 of the SRCE was used to prepare a closure cost estimate. Karara mine personnel provided user input data describing the physical layout, geometry, dimensions of project components were derived from the Closure Plan and spatial data (AutoCAD and ARCGIS). Along with these data, the model uses first principle methods to estimate quantities, productivities, and work hours required for various closure tasks cost data based on 2011 standardized industry unit costs for labor, equipment and materials.

Materials and Methods

History of the SRCE model

In 2002 a group of professionals representing the mining industry, and state and federal regulatory agencies in the State of Nevada (USA) met to discuss the concept of developing a standardised cost estimating approach to improve the consistency of mine closure cost estimates. The SRCE model was originally developed primarily for use in the State of Nevada. This model was seen as a useful and flexible tool for other applications and started being used around the world, including:

- Mine closure cost planning;
- Feasibility studies;
- Due diligence assessments;
- Budget tracking; and
- Financial reporting.

The original version of the model was released for a six-month trial period in March 2006 after approximately 3 years of development and beta testing. During the six-month trial period additional modifications were implemented, as well as comparisons made with actual field data from ongoing reclamation. A second version was subsequently released in 2007 following feedback received on the trial period. Since that time the SRCE model has been updated and is continually being improved to represent evolving mine operations. The most recently available SRCE model (Version 1.4) was used in the Karara cost estimation.

Overview of SRCE

The purpose of the SRCE model is to provide a flexible tool to assist mining professionals in improving the consistency and accuracy of reclamation and closure cost estimations. Although the model was developed to provide standardised approaches to reclamation and closure cost calculations, the need to account for diverse approaches to mine closure, and differences between mining operations and regulatory requirements required that the model also provide a reasonable amount of flexibility. To that end, the model requires only limited user inputs to perform the calculations, yet allows the user to combine or subdivide the input data in a flexible manner to account for site specific conditions and differing reclamation methods.

The method of calculation used in the model is based on first principle approaches for volume and distance calculations and productivity estimation. Where possible, the model uses the simplest methods for volumetric estimation. For example, pond volumes are calculated based on the formula for the frustum of a regular pyramid to determine pond volumes for backfilling and surface areas for liner installation/removal. Where simple calculations are not sufficient, the model uses combinations of first principles to estimate volumes.

All calculations used in the model to determine the quantity of seeded area and volumes of cover material are based on true surface areas rather than footprint areas. Only where the model assumes facilities to be flat, e.g. yards, landfill surfaces and building foundations, does the surface area equal that of the footprint area.

Equipment productivities are derived from several different sources with the primary source being the Caterpillar Performance Handbook; other sources include the Means Heavy Construction Cost Data, equipment and material suppliers and localised contractors. In some instances, where applicable, productivity data was collated from actual work performed in the field. Productivity curves were developed for each task required to complete a reclamation or closure activity, e.g. where a dozer is required to push X amount of material from point Y to point Z. Uphill/downhill and loaded/unloaded retarding curves and correction factors such as job efficiency, slope grading, rolling resistance, operator efficiency and material density types were also included. Whilst the user can specify minutes worked per hour and average dozer drive skill level, to further represent the conditions/activities on site.

The model combines the information input by the user for each facility with the productivity formulae, tables and correction factors created from published data and industry data to calculate the individual productivity for a given task. For example, if the user adds a 25 m high waste rock dump (WRD) facility that will require grading from angle of repose to a 3H:1V slope, the model will follow the below steps:

- Calculate the volume of cut material to push;
- Calculate the push distance;
- Apply the dozing distance vs. productivity curve formulae to estimate uncorrected productivity;
- Apply correction factors based on user input and standard values to calculation corrected dozer productivity;
- Divide dozing volume by corrected productivity to calculate work hours; and
- Multiply equipment and labour rates to work hours to calculate total cost.

The model is presented in a workbook which is divided into different worksheets; each contains information related to a particular type of facility or activity. Generally the first two tables on each sheet are for user inputs, while the others display the results of the model calculations. Entering data into each of the worksheets has been standardised in the model to highest degree possible. However, the model requires slightly different user inputs for each of the different facility types to calculate closure costs, and also allows for a great deal of flexibility in how the cost estimate for each facility is approached.

Setting up an SRCE model for Karara

The development of the Karara's SRCE model involved collecting information from the following sources:

1. Karara's GIS database;
2. Ground Disturbance Permits;
3. Approval documentation (i.e. Public Environmental Reviews, OEPA Reports, Ministerial Conditions and Mining Proposals);
4. Preliminary Closure Plans; and
5. Assumptions based on discussions with Site Personnel.

1. GIS Data

The KML GIS Specialist played a vital role in providing a majority of the spatial information required for the model. The KML Database contains designs and footprints approved in Mining Proposals and PER Reports, data from environmental studies such as flora, fauna, vegetation communities, groundwater and heritage surveys and information on Ground Disturbance Permits (GD). Spatial data is used to characterise the location, physical layout, geometry and dimensions of project components. This information was used to obtain the required model inputs for aspects such as roads, yards, turkey's nests, ROM Pads, stockpiles etc.

The GIS Specialist also developed a Closure Model layer within the GIS Database which connects to the information in the model and provides a visual summary of the domains.

2. Ground Disturbance Permits

Karara's Approvals Request and Ground Disturbance Permit System (ARGD System) was used as a source for obtaining spatial and design information. The ARGD system is a detailed process designed to ensure all ground disturbing work is conducted with full adherence to the applicable conditions. The permitting system is initiated when a need to conduct ground disturbing work is identified. A request for approval is submitted and rigorously reviewed by various specialists including environmental, heritage, tenure, approvals and land access personnel. Following approval, a Ground disturbance permit is issued for the work. A standard condition included in all GD permits is that construction personnel provide GIS coordinates of the actual area cleared upon completion of the clearing works, as well as areas rehabilitated. The remaining footprint (being the operational footprint)is then recorded as a shape file in the GIS Database. A log is maintained by the KML Environmental Department that lists all GD Permits issued, their current status and final disturbance areas. The GIS Database and log were used to obtain an up to date information on areas disturbed and rehabilitated during the project.

3. Approvals Documentation

Specific details, such as information on the construction of the waste dump, ROM pads, the Processing Plant and tailings dam, were obtained from the Public Environmental Reviews, OEPA Reports, Ministerial Conditions, and Mining Proposals.

4. Preliminary Closure Plan

The MIOP and KIOP Preliminary Closure Plans were a useful source for obtaining information on post mining closure land uses/ agreements and monitoring. The closure monitoring outlined in these plans had been built on information collected during baseline environmental surveys and routine operational monitoring.

5. Interviews with Site Personnel

After obtaining a majority of the information from the various sources (electronic and discussions) a site visit was held to ground truth information and interview personnel from the Mining, Construction, Maintenance and Site Environmental Departments.

These Departments were able to provide the following information:

- **Mining:** Expected Equipment Fleets that will be available to utilise during closure.
- **Construction**: Quantities of concrete and steel installed both currently, and, at the completion of the construction phase for the processing plant, information on building types and footings.
- **Hydrogeologists:** Water requirements during closure, for example surface water drainage requirements, availability of groundwater bores and ground water monitoring requirements.

- **Site Environmental**: Seed mixes, growth media application depths, fertiliser rates, contaminated sites, proposed research and trials; haul routes and mulching and grading requirements. As well as plans for the post closure land use and identifying the plans for site personnel and care takers that will be onsite during the closure period.

A summary of the information gathered from all sources is shown in Table 1.

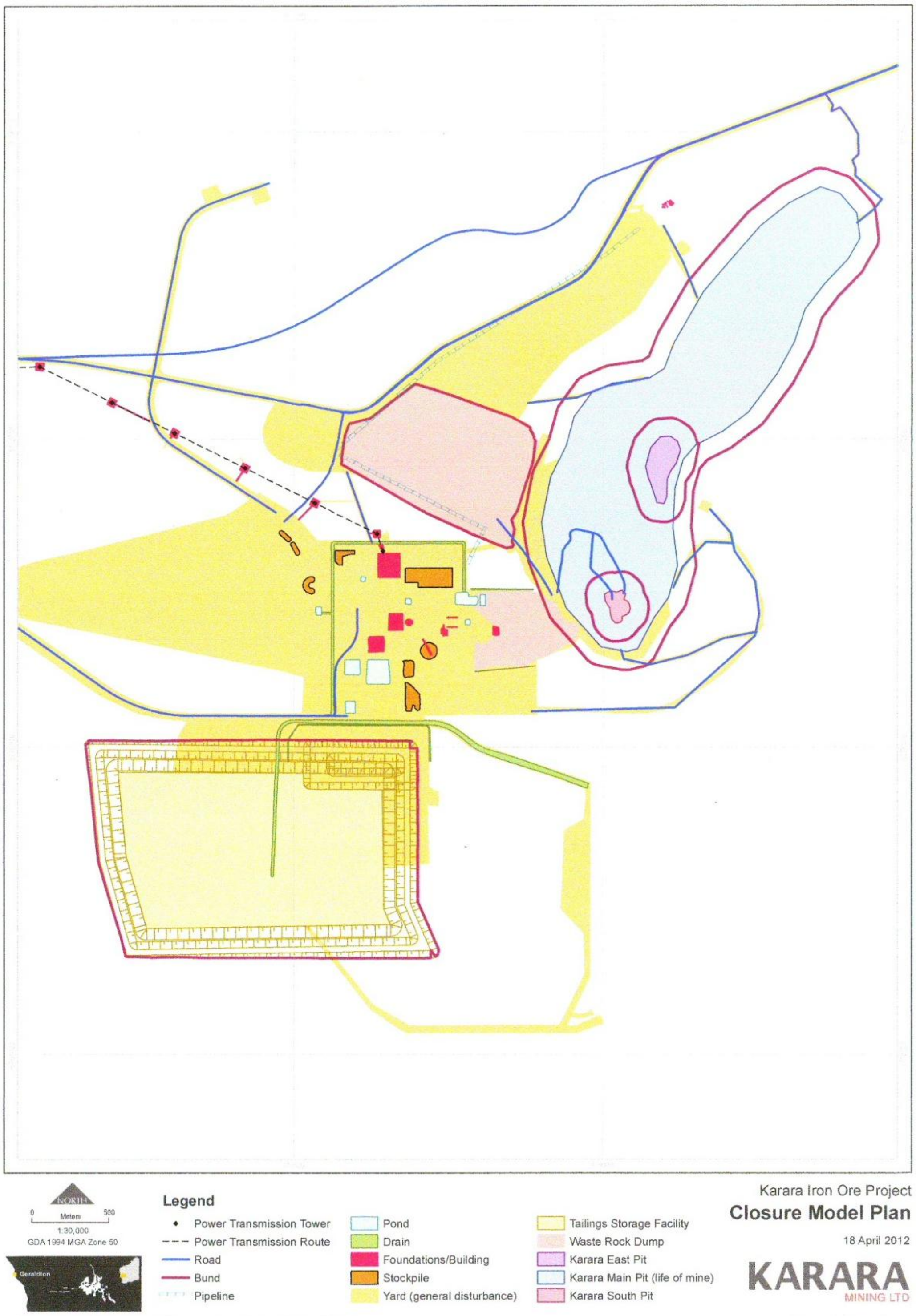
Table 1: Closure cost estimate assumptions

Project Aspect	Domains	Assumptions for Closure Cost Estimate
General		• Closure works will commence at the Karara Iron Ore Project in 2042 • Closure earthworks undertaken over a 3 year closure period • Sufficient rehabilitation materials including rock cover, growth media and seed, are located and available on site • The final land use will not be returned to pastoral land
Landforms	Waste rock dumps (WRD) & Run of mine pads (ROM), Pits, Stockpiles	
	WRDs & ROM pads	• Stockpiles of cover and growth media in close proximity to WRDs (500 m haul distance) • cover material applied to slopes and flats • topsoil applied to slopes and flats • heights of ROM pads
	Pits	• Pit abandonment bund lengths calculated based on a 120 m setback • Average haul distance of 1 km • Berm material type is likely to be broken rock
	Stockpiles	• Ore stockpiles, including low grade ore, will not be present at closure • Topsoil and cover media stockpiles to be used in rehabilitation works- therefore not require earthworks
Water Storage Facilities	Process ponds and Turkeys nests	
	Process Ponds & Turkeys Nests	• Turkeys nests dimensions based on % of total area of disturbance • 100 % backfill • <50 m from backfill source • growth media applied to surface area • Ponds are lined
Yards	Ground disturbance areas (yards, laydown areas, car parks, cleared areas etc.)	
	Ground Disturbance Areas	• Rehabilitation works involve ripping, application of growth media and seeding • topsoil applied • 500-750 m haul distance • Material to be reworked most likely resembles un-consolidated rock/broken rock • No regrading will be required • No contaminated sites present • Yards and laydown areas are contractors responsibility
Roads	Access roads and Haul roads	
	Access Roads	• Only Blue Hills access road to require closure, remaining roads to be retained • 5 m width – project road • No road gradient – flat terrain • Rehabilitation works involve ripping, application of growth media and seeding • Material to be reworked most likely resembles un-consolidated rock/broken rock
	Haul Roads	• Two 7m haul roads that will require closure • No road gradient – flat terrain • Rehabilitation works involve ripping, application of growth media and seeding • Material to be reworked most likely resembles un-consolidated rock/broken rock

Project Aspect	Domains	Assumptions for Closure Cost Estimate
Demolition	Buildings & Foundations	
	Buildings & Foundations	• Concrete footings on accommodation 100 mm thick • Slabs under workshop facility • Break and bury demolition method • Majority of the infrastructure is comprised of demountable buildings- offices and contractors ablutions • One power sub-station to be decommissioned • Ore crushing facilities are mobile and will be removed from site at closure
Miscellaneous Costs		
	Equipment and Labor	• Fleets & crew rates based on 2011 standardised industry cost data • Fleet selections provided by KML accurately reflect the fleets on site • One way equipment mobilisation distance - 215 km
	Material Hauling	• Haul routes & roads are current, based on latest available aerial imagery
	Contingency/ Maintenance	• Based on 20 % of revegetated areas and reworked landforms failing to become self-sustaining
	Weeds	• Weed eradication and maintenance assumed to be undertaken during the closure and post closure monitoring period and based on industry experience
	Tenement Costs	• Costs associated with keeping in good standing across all regulator and shire mineral lease rents. Actual rent rates supplied by Karara
Monitoring	Water Sampling	
	Water Analysis	• Environmental Technicians will be retained onsite during the closure period • Water sampling and analysis to be conducted for 10 years • Monitoring to be undertaken in accordance with mine closure and performance monitoring plans
	Rehabilitation Monitoring	• Environmental Technicians will be retained onsite during the closure period • Rehabilitation Monitoring to be conducted for 10 years • Monitoring to be undertaken in accordance with mine closure and performance monitoring plans

Closure Model Layer

Once all assumptions were finalised and input data added to the SRCE model, the GIS Specialist developed a Closure Model layer within the GIS Database. These layers relate to the model and provides a visual summary of the domains (Figure 1).



Results

Financial Provisioning

Once the Closure Model had been finalised, Asset Retirement Obligation (ARO) and Life of Mine (LOM) costs and schedules for financial breakdown were provided to Karara Accountants. The ARO calculates the cost to close the mine site if unfeasible circumstances lead to the closure of the mine at the end of the last closure model reporting period, while the LOM calculates the cost to close the mine site at the expected year of closure.

Karara has established a rehabilitation provision liability in accordance with the requirements of Australian Accounting Standards Board 137 - Provisions, Contingent Liabilities and Contingent Assets. The provision comprises a fixed amount per tonne of product for the rehabilitation and closure of the mine site. The amount per tonne is based on the estimated cost rehabilitation and decommissioning derived from the SRCE model and the expected rate of production over the life of the operation.

Auditing

Karara is audited on a six monthly basis. As a result of the rehabilitation being a material amount in the financial statement, the auditors will review this balance each audit. This will include a review of the entire SRCE model taking into account any changes from the prior period and reviewing the reasonableness of the model.

Discussion

Moving Forward

As per reporting period requirements, Karara intend to update the mine closure cost model in January and July each year. Unit costs for labor, equipment and materials will be updated annually and are included in the July update of the Model. Going forward, Karara intend to update the model in-house and utilise SRK to conduct a third party review for each update and to provide unit costs on an annual basis.

Lessons Learnt

Accurate record keeping is the key to updating the Model successfully. Karara have developed a Closure Cost Model Update spreadsheet which tracks each change made to the model, when the change was entered into GIS, the GD number, the domain, when the change was made in the LOM and ARO and the cost of the change. An example for the Roads Domain is outlined in Table 2. The example in Table 2 captures changes for July to December 2011 therefore there is no cost for updating the Unit Data, which is updated in June of each year. The LOM and ARO also differ as the road was planned during the reporting period but not yet constructed; therefore an LOM cost is included as the road is expected to be rehabilitated when the mine site is closed in 30 years time, while an ARO cost is not required as the road has not yet been constructed.

Table 2: Closure Cost Model Update Spread Sheet Road (Example)

Description of update	GD No.	Date of Ground Disturbance	Domain	Date entered into GIS	Date entered into LOM	Cost	Date entered into ARO	Cost
Unit costs	N/A	N/A	Road	N/A	Not update in January	N/A	Not update in January	N/A
Additional Pit to Waste Dump	GD1765	September 2011	Road	15/1/12	25/1/2012	$9,127	25/1/2012	$9,127
Additional road from Waste Dump to ROM	GD1780	Scheduled for May 2012	Roads	15/1/12	25/1/2012	$1,888	Not cleared yet	
Total for Roads					**LOM Total $11,015**			**ARO Total $9,127**

Rehabilitation

The model will be utilised by Karara as an auditable tracking tool recording vital information on how rehabilitation was completed for each domain. For example, once the rehabilitation of a waste dump is completed, instead of deleting the area, the section of the model that applies is marked as complete, so that records of batter angles, topsoil depths, seed mix and equipment utilised can be viewed at a later date.

Continuous Improvement

DMP Closure Plan Guidelines state that the closure cost estimates must be regularly reviewed to reflect changing circumstances and to ensure that the accuracy of closure costs will be refined and improved with time. During the operational phase of the Project it is realistic to expect that designs will change and additional information will become available that will improve the rehabilitation during the closure phase. The Model is easily modified during each update to incorporate changes throughout the mine life. For example, Karara has recently developed a list of key flora species required for successful rehabilitation of the different land systems, such as the upper slopes and crests of the ridges, and flats plains. Karara will be able to incorporate the information into the seed mixes of the next version of the Model. This will be particularly useful for rehabilitating waste dumps and tailings dams, as they both have various slopes requiring different seed mixes.

Future Models and Planning

The Closure Plan Guidelines emphasise that mine closure planning should be an integral part of mine development and operations planning, and as such, the level of information required will correspond to the life span of the mine and reflect the various stages of the life cycle of the project. The SRCE model can also be used to assist with future planning decisions, such as determining the cost of altering batter angles of waste dumps, developing additional drainage channels/ponds or widening roads. There are several new prospects Karara are currently in the process of obtaining approval under the *EP Act*. An SRCE Model will be developed at the early stages of planning, as the model will provide a central location for storing data and will assist the engineering department with making decisions on the final design.

Conclusions

Planning for mine closure is an essential aspect of environmental management in the mining industry. Historically, provisions for Mine Closure have been based on unconditional performance bonds only, and earthworks have not been considered to the end of the mining life. This leads to sites being unprepared for the cost of closure and often unaware of the actual amount of resources required for remediation.

Forward planning enabled the proactive development of a SRCE Model in collaboration with the sites MCP. As a result, the Greater Karara Project has made provision for costs and resources required for closure. In undertaking this work early, Karara can reap the benefits of planning during the initial stages of development.

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Stygofauna of the Lake Way Associated Calcretes: A Case Study of the Toro Energy Wiluna Uranium Project.

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Stygofauna are obligate groundwater inhabitants that are restricted to their subterranean environments and as such, can have restricted geographical distributions. Many species are considered short range endemics, which are defined as having limited distribution ranges of less than 10,000 km^2. Diverse stygofauna assemblages associated with calcrete systems in the northern Yilgarn region of Western Australia have been documented, with molecular and morphological investigations indicating that each calcrete can host many endemic species, thereby, acting largely as subterranean calcrete islands. The potentially restricted distributions of stygofauna species to a single calcrete means species are more vulnerable to extinction, particularly through anthropogenic perturbations, such as lowering the water table as a result of groundwater extraction to meet mining, pastoral and urban demands.

Toro Energy's (Toro) proposed Wiluna Uranium Project includes the development of two mines associated with uranium deposits that have formed as shallow mineralised zones within the Hinkler Well and Uramurdah calcrete delta areas that flow into Lake Way. The project also involves the development of a borefield associated with the Lake Violet calcrete. This presentation will present the species diversity, abundance, distributions and habitat preferences found in the Level 2 stygofauna survey undertaken by Outback Ecology for Toro as part of the environmental impact assessment of the proposed development on the obligate groundwater species assemblages associated with the Hinkler Well, Lake Violet and Uramurdah calcretes.

Since 2007, over 200 stygofauna net haul samples were collected from more than 100 bores as part of the survey. The quality of the groundwater within sampled bores was also analysed to provide information on the groundwater habitats present, including the nature of the haloclines present, particularly as a function of distance from the lake playa where groundwater was hypersaline. The groundwater data was also used to assess stygofauna species tolerance to varying levels of salinity.

In total, 38 species and morphospecies were identified using DNA sequence data as well as taxonomic specialists. Copepoda was the most abundant and speciose group with 1,416 specimens collected representing 19 species, 12 of which were found to be relatively widespread, occurring across multiple calcretes in the area.

DNA sequence data showed gene flow to occur amongst multiple neighbouring calcrete bodies for the amphipod Chiltoniidae sp. SAM1 and diving beetles *Limbodessus wilunaensis* and *Limbodessus millbillilliensis*. For example, the distribution range of Chiltoniidae sp. SAM1 was demonstrated to extend from Uramurdah calcrete across the northern Lake Way calcrete systems, including the Lake Violet calcrete to Millbillillie Bubble Well calcrete 38 km to the north-west.

The analysis of groundwater parameters indicated some syncarid and copepod species to occur in hypersaline groundwater environments in excess of 100 mS/cm. Further, numerous species were found to be tolerant of relatively wide ranges in salinity with *Limbodessus hinkleri* and *Dussartcyclops* *uniarticulatus* present in groundwater ranging from 2.02 to 41.2 mS/cm and *Schizopera austindownsi* from 26,700 to 112,800 mS/cm.

The study provided a comprehensive assessment of the diversity and distribution patterns for numerous taxonomic groups at a local spatial scale. The findings gave new insights into the distribution ranges and habitat preferences of a number of stygofauna groups. It was found that hypersaline groundwaters are not incompatible with the presence of stygofauna and that similar to other invertebrates inhabiting saline environments in Western Australia, stygofauna taxa exhibit a natural tolerance to elevated salinities. The results indicated that although many species of a stygofauna assemblage can be confined to a single subterranean calcrete island, numerous other species within the assemblage were more widespread and occurred in close neighbouring calcretes within associated drainage systems.

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A Multi-disciplinary Approach to Lead Dust Emissions

Scott Young

Abstract

Product Stewardship

Safety, Health, Environment and Community Manager

Product stewardship is a concept that is increasingly being taken up by the mining industry. Part of product stewardship relates to managing impacts and minimising associated risks with a product.

Over the late 2010 and 2011 period MMG Golden Grove Pty Ltd faced some significant product stewardship challenges.

Lead forms a key part of the High Precious Metals (HPM) concentrate which has for decades been exported from the Golden Grove mine through the Geraldton Port. However, stewardship issues surrounding the shipment of non-MMG lead products through other Western Australian ports and the accompanying heightened community and environmental concern resulted in a tightening of lead limits under the Geraldton Port Authority licence. This included the introduction of a tighter lead dust emission limit at the Geraldton Port of 0.5g/m^3 for lead as TSP (a 24 hour ambient air quality) in late 2009.

Following this change, in October 2010 during the loading of a shipment of MMG HPM, this limit was exceeded and MMG subsequently voluntarily suspended shipping of HPM concentrate through the Geraldton Port until such time as it was satisfied that shipments could be undertaken without risk of further exceedances.

MMG's desire to continue to load and ship its HPM concentrate through the Geraldton Port in a safe mann undertake an extensive number of initiatives from late 2010 and throughout 2011. These activities were risk based and multifaceted and often required the technical input from external experts and consultants. These measures included infrastructure upgrades and engineering improvements, procedural and administrative controls, environmental and health studies as well as extensive community and stakeholder engagement activities.

Through the implementation of these initiatives and the positive cooperation between MMG and the Geraldton Port Authority throughout, MMG obtained approval to resume the loading and shipping of its HPM concentrate through the Geraldton Port in October 2011. This paper will present an overview of the path MMG travelled from the initial voluntary suspension of HPM shipping to the authorised resumption of HPM shipping through Geraldton Port.

For a copy of the presentation please email scott on: scott.young@mmg.com

Importance of Surface Water Flow Concentration and its Impact on Erosion Potential of Constructed Mine Landforms

Evan Howard, Landloch Pty Ltd

Dr Brendan Roddy, Landloch Pty Ltd

Abstract

There is a prevailing orthodoxy in the WA mining industry (including consultants and regulators) on the most appropriate approach to designing mine waste landforms to provide an erosionally stable final surface. This approach continues to include use of berms and cross slope ripping.

It is assumed that berms act to quarantine slope segments, and reduce erosion potential, enabling higher waste dumps to be built. However, it has been Landloch's experience that rather than limiting erosion, this configuration in fact exacerbates erosion through berms failing and overtopping; either due to insufficient initial capacity or through reductions in capacity as they fill with sediment over time. Where dispersive materials exist, berms also exacerbate tunnel potential.

For the last 13 years, Landloch has recommended the use of site and material specific landform designs that discourage flow concentration and avoid reliance on engineered features for erosion control. This paper provides results from landform evolution simulations to compare the relative erosion potential of landforms built to the prevailing batter design configuration (flow concentrating) with those of that do not concentrate flows. In both these cases, erosion potential has not been minimised. The paper also provides landform evolution simulations output for a batter design that does reduce erosion potential.

Introduction

During the life of a mine, considerable focus is typically given to production and its requirements during the operational phase of mining. Dumps are typically constructed in lifts, with final heights that are known to greatly exceed the height at which rehabilitated batters are erosionally stable. Instead of reducing dump height and gradient, mining proponents have sought to manage erosion of post mining landforms by limiting effective slope length in other ways.

As a consequence, final landform designs have relied on the use of berms as a way of segregating long slopes into shorter ones, and to limit the accumulation of flow and hence erosion as slope length increases. However, the risks associated with berms are well known (Loch and Willgoose 2000; Vacher *et al.* 2004; Loch and Vacher 2006; Stevens 2006; Howard *et al.* 2010).

Berms incorporated into final waste landform designs are typically 5-10m in width, are back-sloped (though in many cases this is not consistently achieved), and separate the total outer batter length of a dump into individual lifts 10-20m high. One characteristic of berms that promotes failure is their ability to concentrate surface water flows. Once flows cease moving in shallow disorganised flow patterns and begin moving as deeper flows within an organised flow network, the capacity for sediment to be transported increases and larger erosion features such as gullies usually develop on the relatively homogenous unconsolidated material. Although not discussed in this paper, berms also act to pond water, which can cause tunnelling and significant gully development. This also increases the potential for gully networks to form and further limits the actual functionality of berms.

To examine the issue of flow concentration by berms, this paper will firstly introduce some fundamental concepts of soil erosion by water on steep constructed batter slopes to highlight the importance of flow converging features. Flow convergence will be further examined using modelling to compare the effects of berms on long term erosion rates.

Basic Concepts

Soil material on a constructed batter will begin to be transported when the rainfall rate exceeds the soil's infiltration capacity. When this water flow is shallow, broad, and evenly spread across a slope, its ability to erode soil is low. But when water moves within concentrated flow lines (as occurs in rills and gullies), erosion rates increase as the more erosive water detaches material from the unarmoured and often unconsolidated walls and base of the rill or gully. As slope length increases (increasing flow accumulation) and slope gradients steepen (creating higher flow velocities) erosion rates significantly increase. Designs that seek to minimise erosion potential and discourage the development of flow concentration in the long term will be more stable than designs that do not consider these factors.

Berms on Waste Landforms

A common method to combat rill erosion on long steep waste landform slopes has been to break the slope by means of a berm. The idea of a berm is to decrease flow velocity by intercepting the flow with a level section of the slope to remove kinetic energy and potentially reduce flow accumulation by providing an area of infiltration. As a consequence the use of berms in waste landform designs has been widespread.

Although these expectations may be true at the time of construction and in the early stages of rehabilitation, conditions will change so that rather than acting to inhibit erosion, the berm becomes a design feature that increases rates of erosion. There are three main ways in which berms on waste landforms have been observed to fail:

1. Berms are designed to reduce flow velocity on a slope, and this also means that the sediment transport capacity of the flow is reduced so that the berm becomes an area of deposition (Figure 1). The capacity of the berm is progressively reduced so that it overtops with increasing frequency at a few discrete points and discharges concentrated flows onto the batter below.
2. Unless berms have sufficiently large capacity and are constructed with a high degree of precision to ensure they are level, they will concentrate water flows from the slope above, overtop in extreme events, and discharge the water in a concentrated form onto the slope below (Figure 2).
3. When constructed of dispersive materials, berms exacerbate ponding and actively drive the tunnelling process. If a tunnel outlet is formed on the outer batter slope, erosion of the tunnel rapidly increases and an 'instant gully' is often created (Figure 3).

Assessment of Berm Functionality

The instability caused by flow convergence on berms of non-dispersive materials (points 1 and 2 above) can best be demonstrated by comparing the erosion potential of different batter slope designs created from the same waste materials. An assessment of the performance of berms in the long-term is most readily performed using long-term landform evolution models. To this end, three landform batter scenarios were considered. The three waste landform batter configurations (100m width of batter) used in the simulations are:

1. 20m high waste dump slope with a 5m wide back sloping berm (5%) constructed at 10m lift height with an average batter angle of 20°.
2. 20m high waste dump with a single slope with an average batter angle of 18°. The footprint of this slope is the same as the one above.
3. 20m high waste dump slope with a designed concave profile of batter angles ranging from 6° to 17°. The footprint of this batter is larger than either of the configurations outlined above.

The SIBERIA model was used to simulate waste landform evolution over a 100 year period for these

Figure 1. A 5m wide berm that has become filled with sediment one season after construction.

Figure 2. A sloping section of berm that is concentrating flow laterally to a point where it has overtopped and created a large gully feature on the batter below.

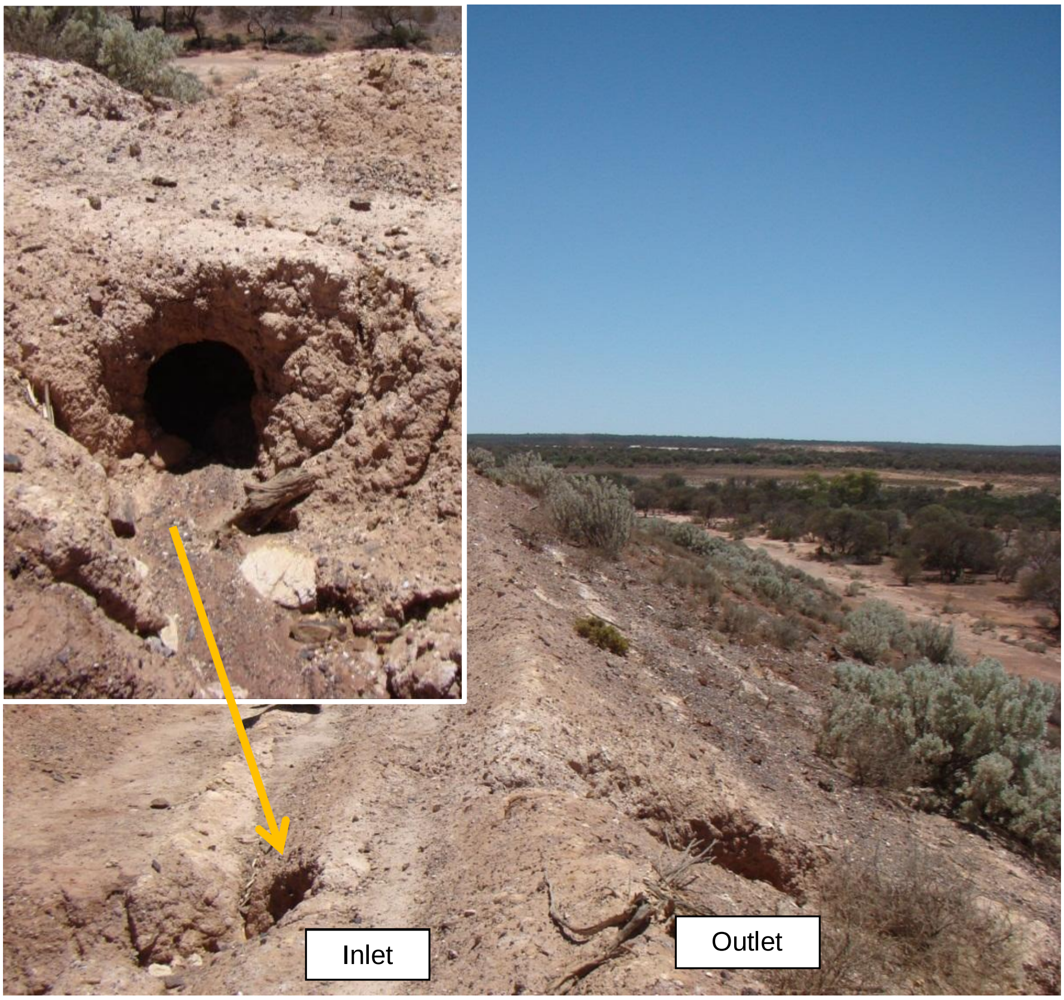

Figure 3. Tunnel formed where water has ponded in a berm on a waste dump containing dispersive materials. Tunnel inlet shown in inset.

Methods

Long-term simulations of the impacts of erosion on a constructed landform shape, and the influence of its changing shape on the development of flow networks were carried out using the SIBERIA landform evolution model. The SIBERIA model (Willgoose *et al.* 1989, Willgoose *et al.* 1991) is the most developed and accepted landform evolution model available.

The SIBERIA model simulates runoff and erosion from a landform shape that changes in response to predicted erosion and deposition. It is a 3-dimensional topographic evolution model, which predicts the long-term development of land surfaces on the basis of erosion and deposition, and can consider the development of concentrated flow networks. This model has been successfully applied to explain aspects of geomorphology of natural landforms (Willgoose 1994). Given that it can model both erosion and deposition, and then modifies the land surfaces in response to the predicted erosion or deposition, SIBERIA is especially suited to the assessment of the development of gully networks. The erosion input parameters are related to both runoff and soil erodibility (Willgoose *et al.* 1989) and must be derived for each particular material at each particular site.

The erosion parameters used were derived from information on infiltration, shear stress and detachment rates collected in a study using simulated rainfall and overland flow for a topsoil near Kalgoorlie.

A batter section 100m wide was established for each scenario, and a 3-dimensional gridded digital elevation file (1m spacing) was developed using the batter profiles shown in Figure 4. A random roughness of ±0.1m on the 1m grid spacing of the elevation model was applied to the initial elevation models of each scenario. The two scenarios that contain linear batters (scenarios 1 and 2) both have the same footprint (61.5m). The concave batter (scenario 3) has a footprint of 122.5m.

The SIBERIA model was run using these erodibility parameters and the three digital elevation models. Output was given by SIBERIA for every second year until year 20, and then every 20 years until year 100 in the simulation time.

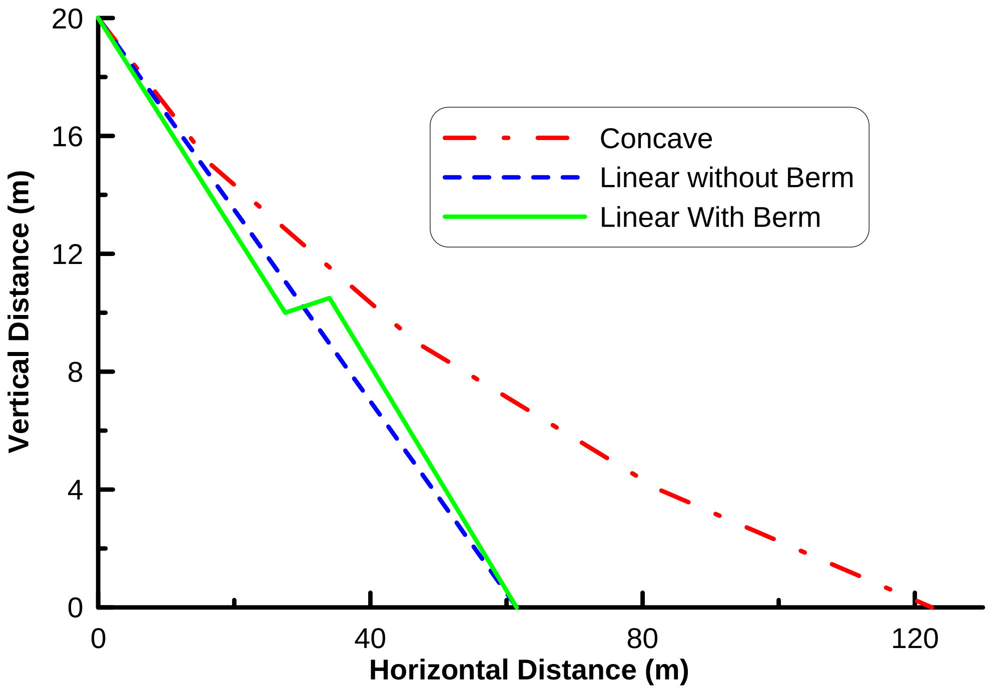

Figure 4. Batter profiles are the scenarios assessed. Vertical height is exaggerated.

Results

Average soil loss values predicted by SIBERIA are given in Figure 5. For the batter containing a berm (scenario 1), the displayed erosion refers to erosion of the bottom lift, as this is the lift that is most significantly affected by any berm failure. SIBERIA output for periods of 6, 10, 20, and 100 years from the commencement of simulated runoff, erosion, and deposition, is given for each scenario in Figures 6 to 8.

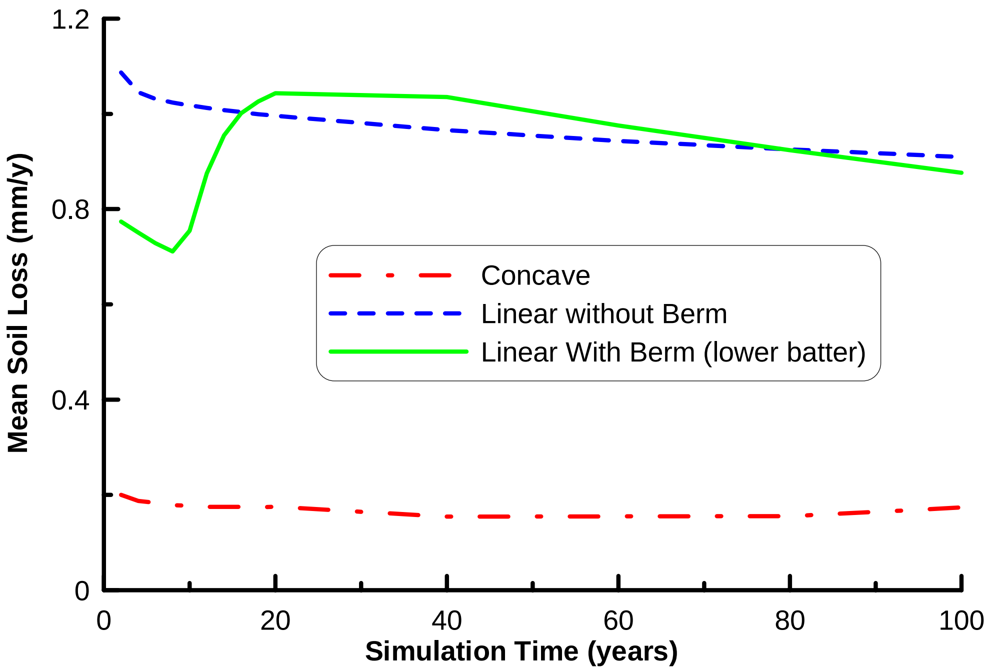

Figure 5. Changes through time in erosion rates for three profiles simulated using SIBERIA

Scenario 1 – Batter with berm

The lower batter of scenario 1 (below the berm) is predicted to be relatively stable in the short term (<10 years). No significant erosion is observed, nor is a strongly connected flow network predicted to form (Figure 6). At this point in time, Figure 6 shows that erosion rates are actually trending lower.

However, between year 10 and year 20, erosion is predicted to rapidly increase to a rate similar to that predicted for the continuous slope without a berm (scenario 2). This increase is in response to the breaching of the berm by the formation of concentrated flow lines as the berm overtops. Sediment deposition can clearly be seen within the berm (shown in blue in Figure 6). Gully initiation is occurring at the berm at 10 years (shown in red in Figure 6), and there is clear development of a strongly connected flow network on the bottom batter after 20 years. These gullies are predicted to be actively incising and delivering large quantities of sediment to the toe of the slope.

Between 10 and 20 years, gullies are predicted to form on the top batter, indicating that the predicted erosion rates, even for a 10m high batter at a gradient of 20°, are sufficiently high to initiate gullying in the medium term.

After 100 years, the berm is predicted to be heavily eroded, and both batter slopes are also heavily eroded.

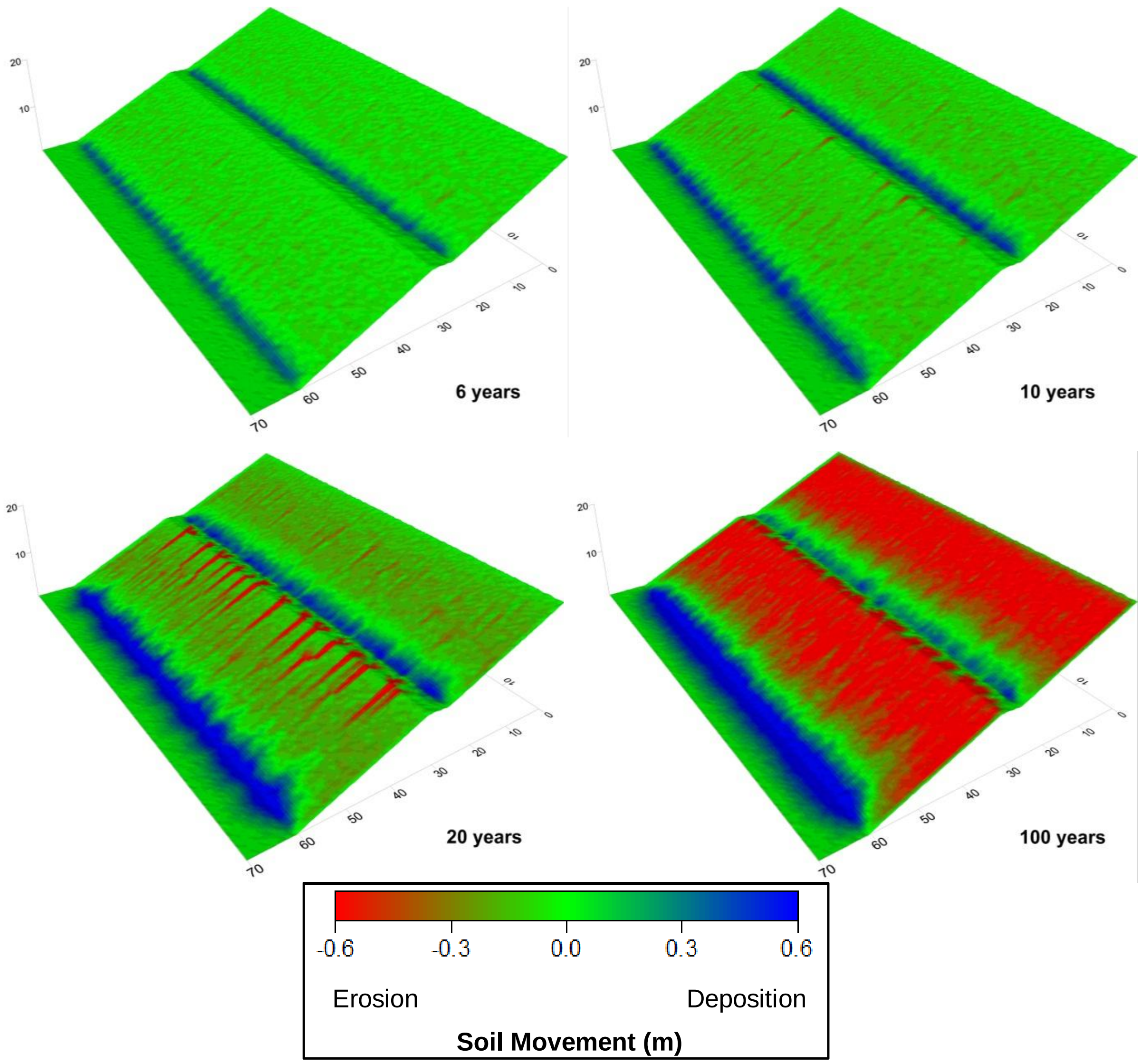

Figure 6. SIBERIA output for a two 10m high topsoiled batters with gradient of 20°, separated by a 5m back-sloping berm. Top left, 6 years; top right, 10 years; bottom left, 20 years; bottom right, 100 years.

Scenario 2 – Batter Without Berm

Erosion patterns after 10 years on the batter without a berm show development of a more extensive rill network than was predicted for scenario 1 (Figure 7). The rill network continues to develop across the slope, and at 100 years, the entire slope is eroded. Importantly, after approximately 20 years, the predicted mean soil loss for scenario 2 is comparable to that of scenario 1; the berm had little effect on long term erosion rates.

The predicted trend in erosion rates of the batter without a berm shows no acute changes in the long term erosion. This is in contrast to scenario 1, where erosion rates started by trending lower, rapidly increased as the berm failed, and then trended lower again.

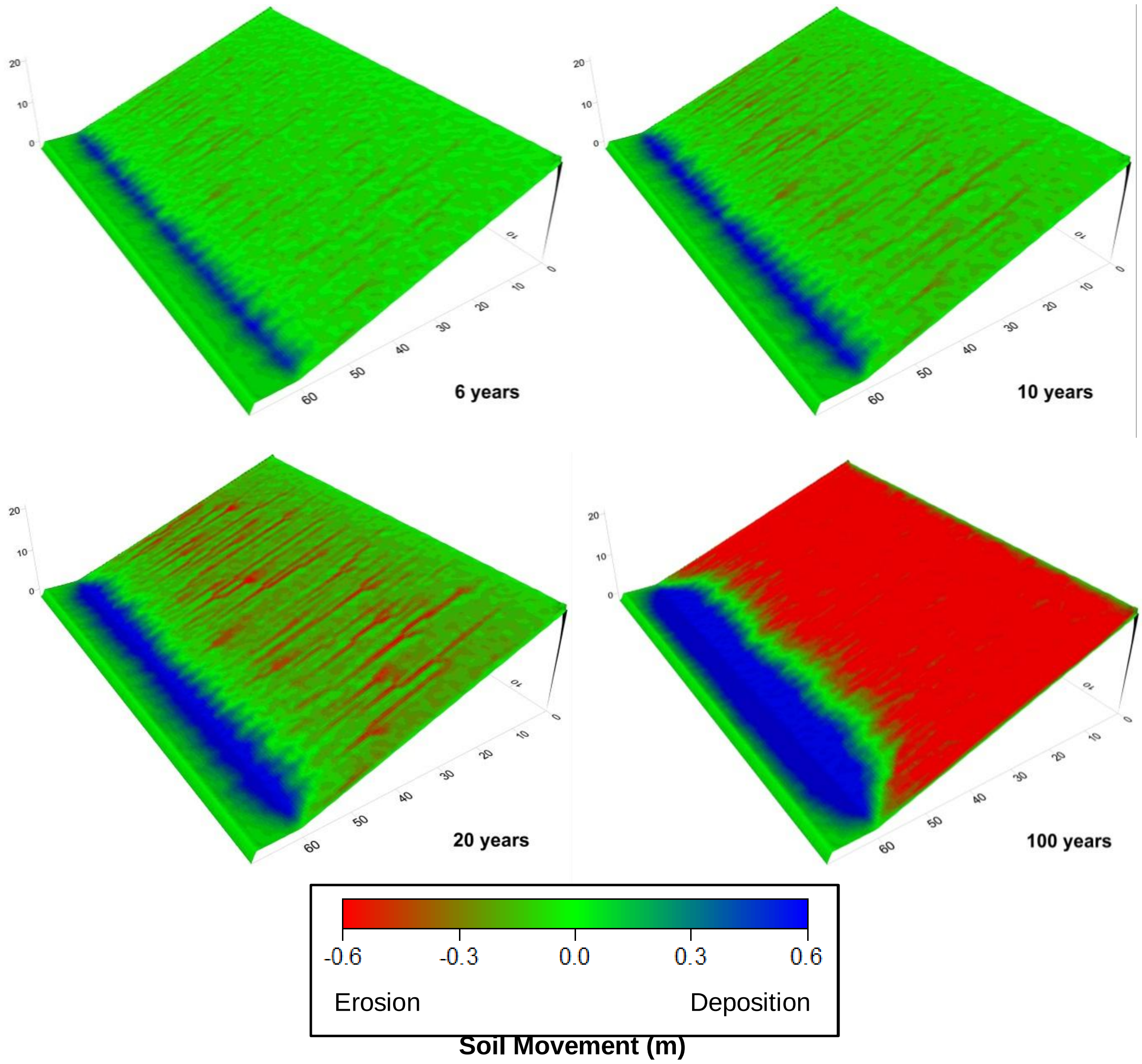

Figure 7. SIEBRIA output for a single topsoiled 20 m high batter slope with a gradient of 18°. Top left, 6 years; top right, 10 years; bottom left, 20 years; bottom right, 100 years.

Scenario 3 – Concave Slope with Lower Erosion Potential

The predicted erosion rate for the concave profile remains relatively constant over the entire simulation period (Figure 5). As was seen for scenario 2, the lack of a berm created a situation where there was not potential for erosion rates to change significantly.

Strongly developed surface water networks were not predicted to form. After 100 years, some rilling of the upper concave section was predicted (Figure 8). However, this flow network dissipates as the slope gradient decreases downslope. As such, soil loss from the slope is low.

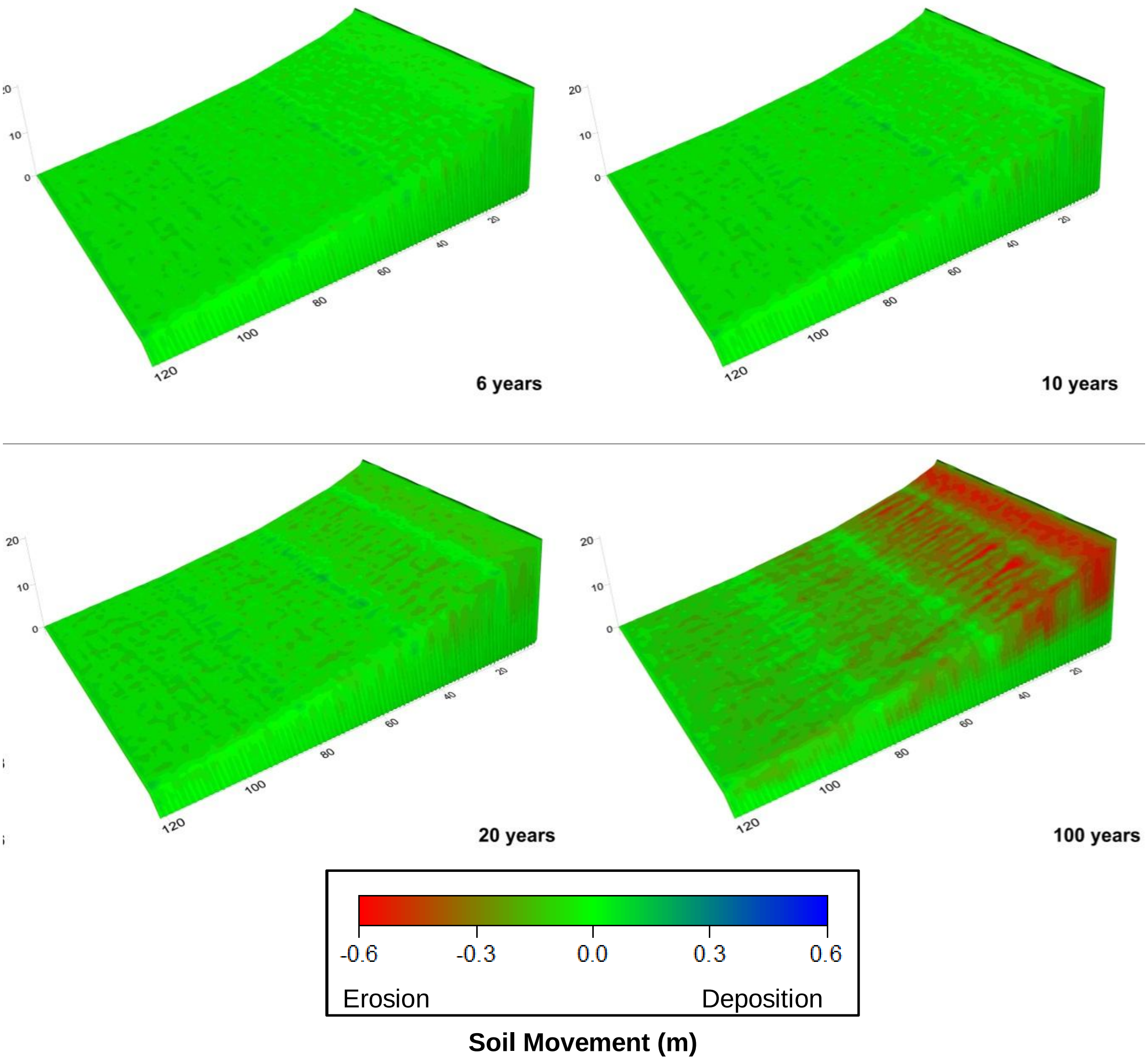

Figure 8. SIEBRIA output for a topsoiled concave profile with reduced erosion potential. Top left, 6 years; top right, 10 years; bottom left, 20 years; bottom right, 100 years.

Comparison of the Three Scenarios

The predicted erosion rate for the concave profile is significantly lower than that predicted for either of the other two linear batter configurations (Figure 5). The concave profile was developed to reduce rilling potential, whereas the other two batter configurations were chosen arbitrarily, although consistent with common landform designs being implemented.

The predicted erosion on the lower batter below the berm (scenario 1) is predicted to be initially lower than the erosion predicted from the batter without a berm (Figure 5), but erosion rates in the long-term show no significant benefit from installation of a berm.

Discussion

In the short term, the presence of the berm significantly and rapidly reduces the erosion potential of the waste dump slope considered. Important implications of this include:

- In the field, the waste dump slope with a berm would appear to have low erosion potential and the berm would initially be a stabilising design feature.
- Assuming typical rainfall conditions in the early phases of rehabilitation, early monitoring of surface stability of the dump slope with a berm (i.e. in the first 10 years) would likely show this slope as increasing in stability.
- The failure of the berm irreversibly changes the erosion potential of the lower batter. The berm could be described as being "primed" for failure once a sufficiently large event causes overtopping. The volume of runoff required to cause overtopping will decrease over time as the berm fills with sediment.
- The slope that includes a berm is not resilient in the long term to changes in the capacity of the berm, and can be considered brittle.

Construction of the batter slope without including a berm is predicted to increase erosion potential of the batter due to a doubling in slope length and the resultant increase in flow accumulation. However, the erosion potential of this batter, as distinct from the slope that contains a berm, does not increase significantly and irreversibly over time in response to failure of the engineered structure. Importantly, for both the batter profiles defined arbitrarily on the basis of commonly used configurations, erosion rates are significantly higher than those predicted for the concave profile. This demonstrates:

- Use of an arbitrary design that does not consider material properties and climate cannot achieve surface stability with any degree of reliability or certainty.
- Landform shapes designed on the basis of material properties and climate can significantly reduce the landform's tendency to develop gully networks.

Rill and gully erosion typically account for 75-85% of total erosion from a slope (Govers and Poesen 1988). Landform designs that minimise the potential for rill and gully formation will be considerably more resilient.

The period over which a berm remains 'functional' is dependent on its ability to store runoff, taking into consideration the gradual reduction in storage capacity due to deposition of eroded sediment. To illustrate this, Table 1 shows the predicted time periods for various berm storage capacities to fill with sediment (Landloch, unpublished data). Periods were estimated on the basis of predictions of runoff and sediment deposition for a range of soils for which Landloch has measured the erosion parameters required by the Water Erosion Prediction Program (WEPP) (Flanagan and Livingston 1995). The soil and climate used to derive the Goldfields data listed in Table 1 are different to those used previously in this paper for the assessment of berm functionality using SIBERIA.

Table1: Length of time before berms have filled with sediment for various soils in a range of locations across Western Australia. The berm is assumed to receive runoff and sediment from a 20m high batter with gradient of 18 degrees.

Berm Width (m) (5% backslope)	Goldfields	Southwest WA	Kimberley
5	2	6	1
10	17	23	1
15	31	45	3
20	46	78	6

Conclusion

Use of ‘off the shelf designs’ that have been perceived to work elsewhere, without consideration of material properties and the prevailing climate, cannot provide any certainty that landforms will be stable in the long-term.

It has been shown in this paper (and observed many times), that while berms may provide stability for waste landforms in the short term, conditions will alter in the long term and berms will eventually increase the likelihood of flow concentration, resulting in gully development and eventual slope failure.

It should be remembered that sediment filling of a berm is not the only mode of slope failure. For the Goldfields, the presence of tunnel-prone wastes provides further reason not to use berms within final landform shapes. The water that ponds within the berm can act to disperse materials, causing tunnelling, and the eventual formation of ‘instant gullies’ as the ceiling of the tunnel collapses.

Consideration must be given to designing waste landform features (particularly slope angle, materials, and elevation) that suit the local climatic conditions, not just for closure but for the long term. Runoff/erosion and landform evolution modelling provides a method of using site specific information on material characteristics to test the long term stability of a design. The ability to assess many different designs using the same material parameters allows other site limitations (e.g. footprint, bulk material moving costs, rehabilitation costs) to be assessed as part of selecting the most appropriate designs.

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Beyond Compliance: The benefits of Proactive Environmental Management

A Case Study from the Birla Nifty Copper Operation

Michael Robinson, Environmental Manager – Birla Nifty

John Read, Ecological Horizons, University of Adelaide

Introduction

The Nifty Copper Mine was originally developed by Western Mining Corporation in 1992 to produce copper cathode from oxide ore via a heap leach facility and solvent extraction and electro winning plants. Nifty was purchased by Straights Resources in 1998. Aditya Birla Minerals Ltd (ABML) purchased Nifty in 2003 and subsequently developed the underground mine and copper concentrator in order to produce copper concentrate from sulphide ore which is primarily exported to a smelter in India.

The Birla Nifty Copper Operation (BNCO) is located in the East Pilbara, a six hour drive east of Port Hedland, and employs approximately 500 people managed on a fly in/fly out basis out of Perth. Nearby mines include Consolidated Mineral's Woodie Woodie mine which is located 30 km west of Nifty, and Newcrest's Telfer mine, which is located 60 km east of Nifty.

BNCO is situated amongst the sand dunes of the Great Sandy Desert. The regional landscape consists of undulating sand dunes 10-20 metres high, generally oriented south-east to north-west. The principal vegetation in the swales is *Triodia basedowii* which is replaced by *Triodia schinzii* on dunes. Several Eucalyptus, Acacia and Grevillea species form a sparse overstory in some areas. No water courses are present in the BNCO tenement. The BNCO region supports one of the world's most diverse reptile assemblages (Pianka 1986), along with a diverse assemblage of mammals and birds which include several Environment Protection and Biodiversity Conservation Act (EPBC) listed critical weight range (CWR) mammals e.g. bilby and mulgara (McKenzie and Youngson 1983, Read 1998).

ABML recognizes the environmental responsibilities of mining in such an environmentally significant area and therefore is conducting regional wildlife surveys in order to better understand the status of CWR mammals in the region with the intention of developing management programs for key threatening processes. BNCO recognises that these are region wide issues that must be looked at beyond its site borders and therefore is initiating partnerships with other regional mines, community groups, researchers and regulators. Through this work, BNCO strives to legacy net environmental benefits in our region.

In this talk we plan to outline our initial findings and our current plan to further this work.

Materials and Methods

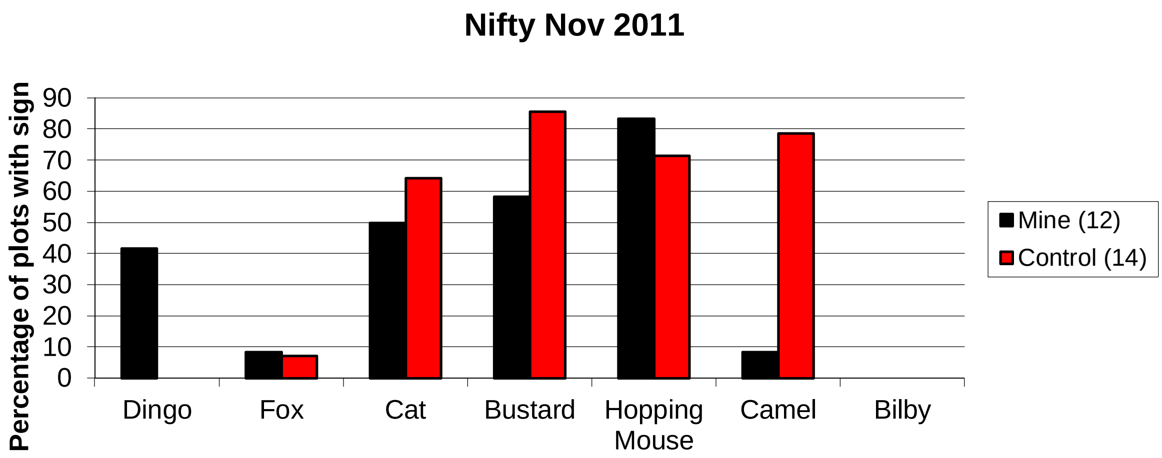
Track based monitoring involves collecting information on the presence or absence of animals in an area based on their tracks, burrows, scats, diggings and other signs. Track based plots have been demonstrated to be the most useful and repeatable technique for assessing the distribution and change in abundance of many threatened species and feral animals (Moseby et al. 2011). BNCO has been utilizing a standardised method of monitoring 2-hectare track plots which has been accepted by a wide range of stakeholders as the national standard for track-based monitoring in arid zones. This method involves spending approximately twenty minutes walking over a two hectare (100 m x 200 m) plot of land, zig-zagging up one side and back down the other. Track imprints and other signs of threatened and feral animals, as well as other information including vegetation and time since fire are recorded on the standardised data sheet.

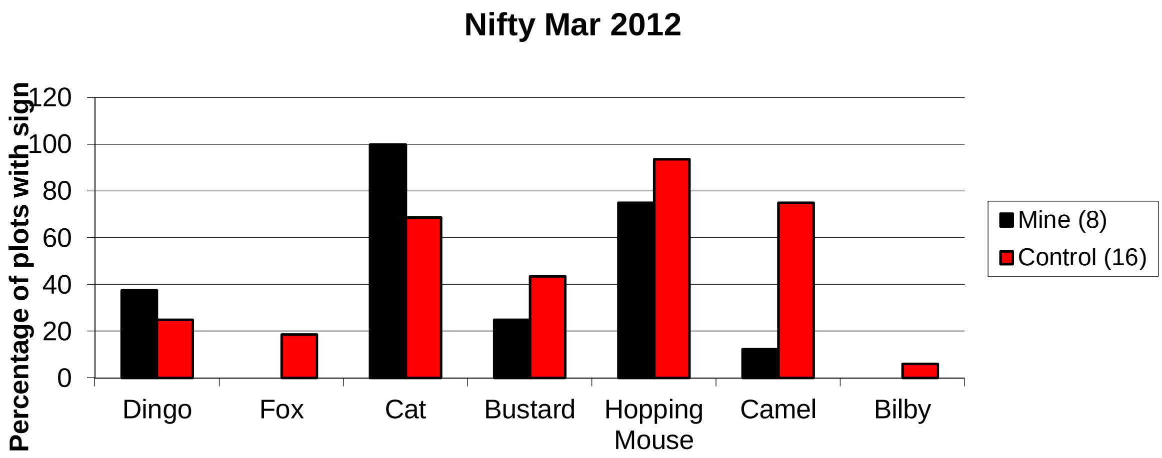
We initiated replicated two hectare plots, both within ten km of the Nifty mine and up to 50 km from the Nifty mine in order to detect whether the mine has had any impact on the distribution of threatened and/or feral animals, and to increase the likelihood of detecting core populations of threatened species that would benefit from applied management. These plots have been surveyed in November 2011 and March 2012 with the intention of repeating and expanding on this program.

Results and Interpretations

Eight 2ha sandplots were monitored within 5km of the Nifty mine and 16 ‘control’ sand plots were monitored at least 9km from the mine. Although one of the plots coincided with an area that Mulgara were recorded in the mid 2000’s and three plots were in areas where Greater Bilbies were recorded, no sign of these EPBC-listed mammals were recorded in the vicinity of Nifty in either November 2011 or March 2012. Since bilbies, in particular, leave diggings, burrows and scats that may persist for over a year, it is likely that they are no longer found in at least parts of their previously-occupied range in the Nifty region. The only sign of bilby recorded was from a site 55km south of Nifty, which incidentally was one of the few sites where neither hopping mice nor cats or foxes were recorded.

Hopping mice and cats were all recorded from at least half of the monitoring plots in both the mining and control treatments in both November 2011 and March 2012 (Fig. 1). This very high recording rate suggests that hopping mice and cats in particular were virtually ubiquitous throughout the region given that tracking conditions were suboptimal for detecting their tracks at several sites. The reduced reporting rates for Bustard sign from November 2011 to March 2012 , despite recording several individuals at sites in the latter survey, likely reflects the erasing of older tracks due to the heavy rain a few days before the March survey. Foxes, one of the most significant predators of predators of bilbies, mulgaras and bustards were recorded from three control transects and hence a reasonably widespread in the region. Dog (presumably dingo) tracks were recorded from approximately 40% of the mine sampling areas but also from roads adjacent to several control plots in March 2012, particularly on the Telfer pipeline road (Fig. 1). Camels were recorded from most control sites but only one mine site in both surveys, but obvious impacts to vegetation were limited.





Livestock (cattle) were only recorded from one monitoring plot on the periphery of the study area, although this cattle occupied site was in the vicinity of historic bilby records. These regional surveys highlighted two other environmental issues. Firstly, none of the randomly selected plots had been burnt within five years. Fire is an important ecosystem driver in Triodia deserts and different succession stages following fire favour different plant and animal communities. Secondly, buffel grass was recorded along roadsides at several sites. Buffel grass can be a habitat transforming invasive weed, which is considered a Key Threatening Process for many arid zone fauna and flora species.

Discussion

Our surveys have demonstrated a decline in bilby and mulgara activity and an increase in feral cat activity in the BNCO region since baseline activities were conducted fifteen years ago. These trends were consistent both adjacent to the mine and at distance from the mine suggesting that factors other than mining are responsible for these declines.

Recent declines in CWR mammals in Northern Australia have been partially attributed to an increase in cat predation (Woinarski 2011). In addition to increasing cats, it is possible that rainfall, changing fire regimes and other factors might be implicated in these declines. Other threatening processes identified through the survey include the invasion of buffel grass into the region. Due to its propensity to displace native grasses and shrubs, its growth form that eliminates bare grounds and its flammability that kills fire-sensitive plants and increases fire frequency, buffel is a transformer species in arid environments. A recent national survey has identified dozens of threatened plants and animals that are directly or indirectly threatened by buffel grass. Unfortunately once established and spread beyond immediate disturbed areas, buffel has proven to be virtually uncontrollable. Urgent and proactive control of invading buffel grass populations is a priority. Cattle, spreading from their leases into the margins of the Great Sandy Desert also potentially reduce habitat quality for bilbies, particularly since both species prefer similar run-on areas.

As a result of these initial findings BNCO plans to increase the geographic scale of our wildlife surveys by engaging with other mines in our region, coordinating with the DEC, working with community groups, and conducting research in order to identify core refuge habitats for CWR species. Once a better understanding of the threatening processes is gained we plan on conducting adaptive management of these threats to maximize the likelihood that these iconic species persist and are benefited by mining. Mining companies are often located in environmentally significant areas and are well positioned to be able to have a net environmental benefit towards land management in their regions should they take the time and effort to do so; they typically occupy a mine for 20+ years, have communications, transport and staff in remote areas, are relatively well resourced financially, and a network of mines in a region are able to work together to solve regional issues.

Environmental departments have a core responsibility of ensuring that their operations meet environmental compliance against a complex network of Australian guidelines and regulations. However, BNCO questions that the responsibilities of environmental management stops at simply meeting compliance at the boundary of the mine; only so much can be gained by spending all available environmental resources on waste rock dump rehabilitation, contaminated sites assessments, hydrocarbon management issues, etc. BNCO argues that achieving a net environmental benefit in the regions in which they operate is an integral responsibility of working in the mining industry and can only be achieved through collaboratively working with regional partners including other mines, community groups, and regulators. Accepting this responsibility as an industry will help to ensure that these iconic Australian species will not go extinct, and has additional flow on effects for mining companies which are likely to include a more positive view of our operations by the communities in which we operate as well as the by the government regulators, which can help to smooth out future approvals processes (eg Read 2003). In addition, because of the general interest in wildlife by staff, these programs are very good at encouraging staff engagement with their environmental departments, which improves environmental awareness and encourages employees to better follow environmental management systems.

Conclusion

BNCO has been conducting track-plot monitoring in the region to quantify the presence of threatened species and feral animals. These surveys have demonstrated a decline in bilby and mulgara activity and an increase in feral cat activity in the BNCO region since baseline activities were conducted fifteen years ago. These trends were consistent both adjacent to the mine and at distance from the mine suggesting that factors other than mining are responsible for these declines. With the expansion of our surveys, bilby have been located 50 km away from BNCO, and we are consulting with other regional mines, regulators, and community groups in order to identify core refuge habitats for CWR species so that we can ultimately assist with developing regional management programs for key threatening species. We argue that while meeting compliance at our mine sites is the main requirement for mining companies, companies also have the responsibility of promoting a net environmental benefit in their regions. ABML accepts this responsibility and notes that environmental management at BNCO has already improved since this program began through the improved engagement with staff who are interested in better understanding the wildlife around the mine; this engagement with the environmental department has encouraged employees to better adhere to environmental procedures on site. ABML encourages other mines to think beyond their tenements and beyond compliance in order to bring a net environmental benefit to the regions in which the mining industry operates.

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Plant Communities of Calcrete Palaeodrainage Channels in Northern Goldfields

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Abstract

Palaeodrainage channels are extensive in WA in the arid zone and are all that remains of a network of ancient rivers systems formed during the early Cenozoic (65-23 mya). Approximately 23 mya the Australian climate began to dry which led to the formation of calcrete in the channels and the deposition of uranium within the calcrete. The latest survey focused upon the flora and vegetation calcrete units within these palaeodrainage channels in the Northern Goldfields. The calcrete vegetation was species poor with few endemic or rare taxa recorded. Similarities in community composition were most similar between neighbouring calcrete paleochannels and not within these systems, consistent with colonisation of the calcrete by species from the surrounding landscape. Low beta diversity and endemism indicate that conflicts between resource development and flora conservation values are unlikely to be as significant those found on other geologies.

Final paper will be available from the Conservation Science WA website:
http://www.dec.wa.gov.au/content/view/2321/310/

Resource Not Landfill – Closing the Loop on Food Waste in a Remote Village

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Rio Tinto Alcan, Gove Village, N.T.

Abstract

"They claim this mother of ours, the Earth, for their own use, and fence their neighbours away from her, and deface her with their buildings and their refuse" - Sitting Bull

We live in the age of mega-packaging and general excess and the impacts of this reality are most evident when viewed in isolation. Harsh environments and isolation are an intrinsic feature of remote mine site villages which now are dotted all around Australia and the world. The word village is somewhat misleading as often they are best considered as mini-municipalities or towns. As the dots on the map increase in size, number and proximity there is an emerging opportunity to implement large scale technology solutions to manage the growing town-scale waste issues. As organic waste is a key component of the waste stream now in the foreground, we need specific solutions to separate, recover, process and reuse this resource.

The most common approaches to treating food waste include in-vessel composting, anaerobic digestion, vermiculture, maceration and enzyme digestion. Each treatment method has an optimum scale of operation and specific parameters and conditions that need to be met for the system to work successfully. If we reverse analyse the system requirements for a remote mining village what would be the best solution from this list of options? Experience has demonstrated that there is still no easy or well managed solution for a remote mining village. We can expect about 0.5 kg of food waste per person from a remote village and with these populations often exceeding 500 residents we start to see an enormous pile of putrescent waste and all the crows circling above.

This paper details a method of food waste dehydration which meets a host of remote village specific parameters and conditions. It is relatively new to Australia, but widely implemented overseas. The technology is a system which breaks down, ferments and sterilizes food waste over an 8-10 hour cycle. The process drives off moisture which is condensed back into a grey water output equating to about 70% original input at 40^0C and 15% heated water vapour (exhaust) at 60^0C. The remaining biomass is sterilized at high temperature and when cooled it has a final dried biomass content of 10-15% original input (<5% moisture content). The carbon and nitrogen content is preserved and the potential applications range from use as soil amendment, stock-feed supplement or pelletized fuel source. In summary, the outputs of the system include water, reusable solids and heat energy. The major input of energy can be balanced against the offsets of diverted landfill greenhouse gas and transport inputs. Positive offsets can be achieved by using biodiesel fuel or renewable sourced energy, harnessing heat transfer energy exchange and/or reuse of the solid outputs as a source of fuel for other applications. This paper will detail several case studies in Australia including a 1200kg per day system at Olympic Dam Village and a 100kg per day system at Melbourne Town Hall. It will also provide an insight into an organic waste closed loop utopian vision whereby the nutrients and water return to the Earth and living landscapes are created, much to the delight of Sitting Bull.

Introduction

This paper presents a discussion on the treatment, recovery and reuse of organic wastes generated as a result of food production and catering services in Australian remote mining villages. In this discussion, organic wastes are defined as the food waste fraction of the organic waste stream, which includes raw and cooked vegetable, fruit, meat, pastry, farinaceous and other food related items usually disposed to landfill. The objective is to examine background investigations undertaken at mining village sites operated by one particular company and to present the justification and subsequent selection of the preferred food waste technology solution. Changes in Australian legislation coupled with the potential community and environmental benefits will continue to shift the economic viability of all food waste reduction programs. Therefore, selection of appropriate solutions must consider the combined economic, social and environmental aspects for a holistic sustainable outcome.

This paper is written from the perspective of Sodexo - a company which provides services at over 70 remote mining accommodation sites across Australia. These services include the provision of hot and cold eat-in and take-away meals for mining village residents. Globally, the Sodexo group operates in 80 countries at 33,400 sites with 413,000 employees worldwide servicing 50 million consumers every day. As such, food waste is a significant environmental aspect of the business and reducing this operational footprint requires an innovative and effective management strategy. Recognising this need Sodexo has made the commitment to reduce the organic waste in all the countries where it operates and at clients' sites by 2015 and to support initiatives to recover organic waste. The core discussion is based on the commitment strategy of tracking waste reduction initiatives and recovery volumes based on three sets of measures: improved measurement (data gathering) processes; awareness and behaviour changes with consumers and employees; and processes and equipment for volume reduction, treatment and recovery of wastes.

Remote mining villages, in a broad sense, have inherent waste management aspects and impacts that form the basis of any business case proposal for a food waste reduction program. Villages are often in environmentally sensitive areas that have a suite of environmental, heritage, legal, economic and community considerations. These may restrict access or availability to: local markets for food products; land; water; labour availability; raw materials (i.e. woodchips, landscaping materials); efficient transport networks; off-site waste management services; clean and efficient power sources; and the economics of on-site waste management and land filling operations. Contamination of the food waste stream with non-organic post consumer wastes, for example from the plate-scrape, is a key consideration. In addition, quarantine, storage availability, duration, space, manual handling, odour and vermin control, disease weed seed and pathogen sterilization are equally important.

In summary, the following discussion will address these measures and considerations with an emphasis on a specific food waste dehydration process called GAIA™ technology (GaiaRecycle) and why it is the preferred solution to the food waste problem for Sodexo in Australia at this time.

Discussion

The following discussion will address the aforementioned set of three measures for an organic waste reduction and recovery strategy: improved measurement (data gathering) processes; awareness and behavior changes with consumers and employees; process and technology for volume reduction, treatment and recovery of wastes. The latter section will be discussed in detail with a particular emphasis on the selected food waste dehydration technology solution.

It is important to consider, before applying any of these measures, the relevant regulatory, legal and economic factors that will impact on the appropriate solution to the food waste problem. For example, the majority of remote mining villages operate under legal requirements similar to those required by the Environmental Protection (Rural Landfill) Regulations 2002 for WA which stipulate the responsibilities and penalties for non compliance with best practice landfill management. Some key issues that need to be addressed include:

- windblown litter;
- feral cats, crows and other vermin;
- putrescibles and potential leaching of contaminants into groundwater;
- production of methane;
- reducing the amount of topdressing required while maintaining coverage; and
- control of access and the reclamation of potentially recyclable materials.

In addition to these requirements, operating a landfill on a mining lease or in a rural town demands certain approval and closure planning commitments plus the ongoing management and site selection costs which may include blasting, fencing and earth moving equipment. Further to local and state legal requirements, Australia is moving towards a low emissions economy through the implementation of the Clean Energy Act (CEA) 2011 on July 1, 2012. This will directly impact on landfill operators and liable entities through an initial carbon cost of \$23t/CO_2^{-e} (2012-2015). The calculation of the landfill carbon factor has increased in the most recent revision of the National Greenhouse Accounts Factors (DoCCEE, 2011) from 0.9 to 1.6 t CO_2^{-e} per tonne of food waste. Therefore, when estimating the Scope 3 Green House Gas Emissions (GHGE) of food waste disposal to landfill the following formula is used:

GHGE (t CO_2^{-e}) = $Q_j \times EF_j$

Where: Q_j is the quantity of food waste; and, EF_j is the emission factor of waste type (p70).

For example, where 1 t of food waste is generated daily, the GHG emission will be 1.6 t CO_2^{-e}/day and when buried in landfill the degradable organic carbon fraction is converted at the ratio of 1:21 to methane gas (CH_4). It is inevitable that these changes to landfill carbon emission calculation factors and subsequent costs to operators and municipal councils will be passed onto users. The CEA is structured to provide economic incentives (including compensation) for taxpayers, public and private entities. In addition the Carbon Farming Initiative (CFI) is a program that targets assistance for liable companies as they move into a carbon-restrained economy, particularly as future phases of the CEA open up international trading of Australian Carbon Credit Units (ACCU's) post 2015. The CFI focuses on improving unproductive farmland and may lead to biodiversity offsets from improvement programs that sequester carbon and should be investigated in further detail when building the business case for an organic waste treatment and recovery solution.

Measurement

The first step in any project is to establish the baseline data and risk profile of the activity area. Sodexo have used a standardised audit methodology and conducted supervised food waste audits of three sites in October 2010 which covered a 24 hour/7 day period. These audits captured raw and cooked food waste from the production area of kitchens of varying capacities ranging from medium (800 resident) to large (1800 resident) mining villages. These audits were of kitchens preparing food for breakfast, dinner and crib (take-away lunch). The average weight of both raw and cooked food waste from these audits over 7 days was 0.34 kg/person/day.

Cosmos Kitchen Waste Audit

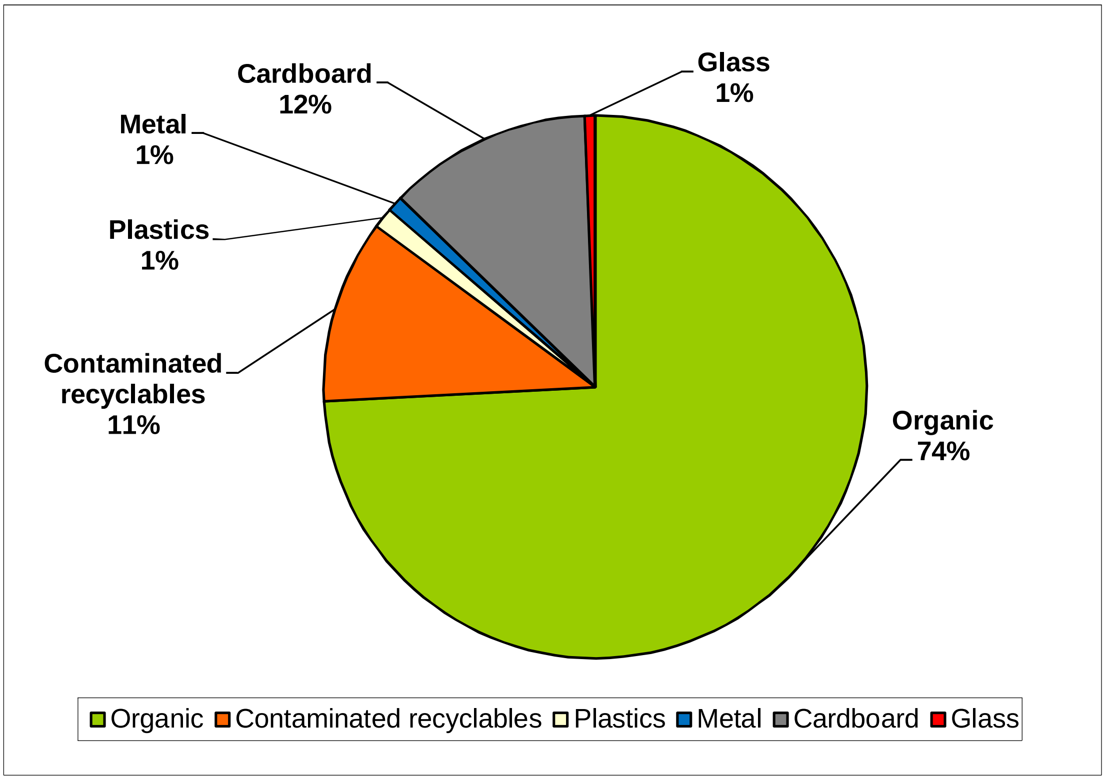

Figure 1: Cosmos kitchen waste audit: percentage composition (Talbot, 2008)

A contrasting example of a mining village kitchen waste audit (Talbot, 2008) was conducted at Cosmos Village in WA, an Xstrata Nickel Australasia operation with a smaller site population of 269 residents at the time; this audit was delivered over a period of 24 hours. This audit captured all waste derived from the kitchen facility during that period. The kitchen provided full meal provision for breakfast, lunch and dinner plus a take-away crib service. The waste was collected in bulk form and hand sorted into various streams (Figure 1). The total average weight of the organic fraction from this 24 hour audit was 0.85 kg/person/day; with the direct food waste portion equivalent to the aforementioned Sodexo results equating to 0.70 kg/person/day. The results indicate that the smaller site generated twice the average food waste volume of the aforementioned larger sites, but there are factors such as number of meal services, duration and methodology of audit which may skew this simple comparison. Figure 2 illustrates the practical sorting and weighing of the various waste streams encountered during the audit.

Figure 2: Cosmos kitchen waste audit: physical sorting of waste (Talbot, 2008)

Olympic Dam Village

Following a pre-selection audit it is important to conduct secondary field measurement prior to implementation of a chosen solution. The next example is a project in progress at the BHPB Olympic Dam Village (a Sodexo managed village) in South Australia. The site is currently in preparation for the implementation of a 1200kg per day GaiaRecycle food waste dryer due for completion later in 2012. The field measurement methodology is relatively simple and is based on recording the daily tally of filled food waste bins with major types of wastes (e.g. fruit, vegetable, cooked) recorded to provide a basis for predicting the volume and moisture content of the source materials. Food waste is being collected from the production kitchen using a designated colour coded organics bin system and does not include plate scrape to limit contamination of the materials. The ongoing daily average indicates that 14 x 120L bins (80% filled capacity) are providing source materials with about 60% fruit /vegetable trimmings and 40% cooked, wet and other food waste including meats. Given the average volume to weight ratio of food waste is 2:1 and village occupation rates range from 900 to 1200 the comparative rate is approximately 0.70 kg/person/day. It is also worth noting that this is one of the 3 sites selected in the 2010 audit which recorded a 0.38 kg/person/day rate at that time. This supports the practicality of conducting a second round of data gathering to verify the pre-selection audit data prior to implementation. This is because situations change and ultimately system requirements can only be set accurately with real time information. Figure 3 illustrates the delivery of the unit which has been contained in a custom made housing, designed to provide secure and flexible mobility options for the unit in the future.

Figure 3: GaiaRecycle G-1200H being delivered in customised Sodexo modular housing to Olympic Dam Village rear kitchen dock.

In summary, the methodology used for assessing the food waste fraction that can be captured through a treatment and recovery program is important as results can vary as demonstrated by the aforementioned examples. Formal waste audit methodologies, such as the data collection specifications of the National Australian Built Environment Reporting Scheme (NABERS, 2009) can be useful guidance tools for improved consistency and validity of results. These methods can be adapted to specific food waste audit applications, and should include the following considerations:

- data collection measures total materials generated in a pre-defined area;
- recommended audit period over 10 consecutive working days;
- must have greater than 75% of full time equivalent occupiers or users of the facility; and
- audit cannot occur in certain periods (e.g. last two weeks of December, during shutdown) which may alter the "normal" activity that could be expected.

As discussed, there are multiple ways to conduct a food waste audit which can be effective depending on the objective or requirement. However, when comparing audit results between sites the methodology should be identical. Sodexo uses the general "rule of thumb" estimated average of 0.5 kg/person/day of food waste production when referring to mining villages; however it is important to conduct a suitable site specific waste audit before sizing the system requirements for a specific site and to follow up with some field measurement prior to implementation.

Awareness and Behaviour

Accountability for the wastes that we generate as individuals and businesses alike is central to the cultural shift that is needed to promote food waste as a resource not landfill. Most people are familiar with recovering high value items, such as aluminium and copper, and it is widely accepted that we should collect waste office paper, cardboard, most plastics and glass where possible. The contamination of these core recycling streams with organic waste is a key issue restricting the net resource recovery potential. This leads to a large component of items gathered by municipalities and other contractors to eventually end up in landfill despite the efforts of the consumer. Underlying this problem is the general lack of awareness, behavioural mechanisms and cultural norms needed to drive successful resource recovery from the bottom up. Organic waste is arguably the only waste stream that can be treated effectively and simply at the source with the benefits directly reapplied *in situ*. Therefore, in the remote mining village context it is essential that the management system developed to treat and recover organic waste has been sanctioned by the company executive(s) and accountability for the program delivery is assigned to the highest level of senior management who can directly control and deliver the objectives and targets.

Raising employee awareness, by communicating the importance of reducing and recovering organic waste can be achieved using a number of methods. Promoting discussion at frequent team meetings and using visual media and prompts is as important as providing clearly designated resource recovery equipment. Processes and equipment should be accompanied by appropriate work aids/instructions, safe work procedures, competency assessments, tool-box talks, on-the-job training and other relevant procedures. It is important to reward success and openly communicate issues and solutions as they arise so everyone is involved in reaching the program objectives.

Raising consumer awareness, including the village residents and visitors, can be achieved through the use of effective visual media which provides information explaining the program objectives and why it is important with tangible examples. The location and number of prompts is important and they should be frequently updated and reinforced with activities, newsletters, awards and events that increase the engagement of this key group and provide them with a sense of linked-ownership to the program objectives.

Process and Technology

The most common approaches to treating organic waste include in-vessel composting, anaerobic digestion, vermiculture, maceration and enzyme digestion. Each treatment method has an optimum scale of operation and specific parameters and conditions that need to be met for the system to work successfully. Sodexo has had experience with these techniques and in general found that there are some significant issues that prevent ongoing investment of time, labour, energy and money in these solutions unless a particular situation justifies the approach. For example, at this time, most off-shore facilities macerate their solid food waste and disperse the particles directly into the ocean. The general issues that have been experienced with some common technology solutions for treating food waste are as follows:

- Requirement for additional carbon (e.g. woodchips) source;
- Constant monitoring and control of carbon-nitrogen and moisture balance;
- Manual handling of inputs and outputs;
- Unpleasant odours;
- Attraction of vermin;
- Biodiversity impacts via food chain disruption;
- Sanitation and health risks to personnel;
- High level of personnel training and management to ensure successful operation;
- Large space and infrastructure requirement;
- End product requires further treatment or disposal;
- Limited opportunities for *in situ* water or solids reuse; and
- Unsafe systems of work.

Composting

Composting of organic waste refers to the biological decomposition of organic material which can occur on an aerobic and anaerobic level. Combinations of aerobic and anaerobic biological activity encourage the consumption of methanogens and a lowering of pH also results. The key aims of composting include achieving a reduction in volume of waste; destruction of pathogens; termination of weed seeds and production of a nutrient rich, moisture retaining soil medium useful for landscaping and rehabilitation purposes. Composting in nature generally takes 3 months to aerobically decompose organic waste by microbial action and bioturbation by worms and other organisms. During this time, the material is exposed to fluctuating temperatures and uncontrolled moisture levels. Nutrients such as nitrogen and potassium may be diluted and leached by rain and the original composition of the waste will determine the duration of composting and the final quality.

Fully composted organic material will normally have the following characteristics:

- 60-80% moisture content;
- 0.2% to 10.5% nitrogen;
- 0.2% to 0.5% phosphorus; and
- 0.4% to 1.5% potassium.

In good compost there are expected to be high levels of nitrogen and particles consisting of organic phosphorus, and as these slowly decompose in the soil they are good for plants as fertilizer. The organic matter in the compost decomposes due to microorganisms in the soil. Compost as a result of decomposition increases the soil moisture content and provides many other effects, including improvement of the physical characteristics of the soil such as tillage. In addition, it increases the soil's ability to absorb fertilizers, blocks acidification of the soil, and improves the soil chemical properties. There is recognized value in artificially controlling the natural composting cycle for rapid improvement of soils and crop productivity and quality. Compost is a valuable fertilizing and moisture retaining organic medium which can be used to increase the quality and quantity of production in commercial and domestic horticulture. Composting has been practiced on an industrial scale in the horticultural and agricultural sectors for many years. The recent step change is that now local councils, state authorities and other industries are finding value in recovering and treating the organic fraction of the municipal and industrial waste stream. The benefits include recovery of a product which has commercial value by reducing the contamination of the non-organic waste stream and also as a stand-alone saleable product. Waste handling and disposal costs can be reduced while increasing the financial returns from the sale of resources recovered for reuse and recycling.

GaiaRecycle Solution

It is the search for an appropriate solution that addresses the common problems with food waste treatment that has led Sodexo to selecting and promoting the following technology. GaiaRecycle was first seen in practice by Sodexo representatives at Heathrow Airport, U.K. where food waste is still being managed using a series of two G-1200H units capable of processing (as the name suggests) 1200kg per day of food waste each (Figure 4). The technology was founded in South Korea and has been the local solution to wastes from piggeries, fish, seaweed and food factories with units capable of processing up to 3000kg per unit per day now in operation. Gaia Corporation has also applied the same principles of operation on a truly industrial scale with plants treating up to 60 tonne per day of organic waste. The process does not traditionally compost material as described earlier; rather it gently and rapidly dehydrates, sterilizes and homogenizes the organic mass resulting in a concentrated organic product suitable for reuse in a number of applications. Laboratory analysis of this product by Gaia Corporation confirms that it can be described as a high nitrogen slow nutrient release soil amendment. Appendix A illustrates the process sequence of the system.

GaiaRecycle, has already been widely implemented in Europe, Japan, the USA and Canada and is now being deployed in Australia, with an installation at Melbourne Town Hall (G-100H) already in operation, and a Sodexo implementation at Olympic Dam Village (G-1200H) nearing completion. The Melbourne Town Hall installation is the forerunner of a future strategy by the Melbourne City Council in partnership with the Australian distributor of the technology, EcoGuardians, to install more units to clean up food waste resulting from the numerous restaurants in the laneways of the city (Wells, 2012). EcoGuardians have indicated that there is growing interest in the technology from a number of different entities including airlines, offshore gas, land based mining, hospitals, universities and municipal councils looking for a solution to reduce their cost profile and environmental impact (Pers. Comm.,March,2012).

Returning to the Olympic Dam example, Sodexo conducted scoping for selection of the GaiaRecycle solution which included a calculation estimate of the carbon footprint of the overall installation based on 50% utilization (which is equivalent to one cycle of processing per day). Using the aforementioned National Greenhouse Account Factors the carbon footprint equation predicted a 256 t CO_2^{-e} or 65% reduction in GHGE per annum. The calculation includes transport of waste (scope 1), landfill (scope 3) and purchased electricity to operate the unit (scope 2). The technology comes with the option of gas/electric or electric only power source with a third option to run the unit using biodiesel. The Olympic Dam system is an electrical installation which has the highest carbon footprint of the available options. Overall, based on 50% utilization only, the additional estimated benefits of the system expected each year include:

- 456m^3 landfill volume avoided (2010 local landfill levy rates @ ~$25/$m^3$);
- 11,315 heavy duty plastic bin liners not required;
- 170kL grey water recovered for reuse potential; and
- 34t of biomass output recovered for next use opportunities.

At 100% utilization a positive carbon return without any other offsets could be realised. To increase this positive offset profile there are other applications that can be considered in further detail, including the pelletizing of the output into a biomass briquette suitable for use in a fuel boiler or similar for heat and/or energy production. A further application to be investigated is the harnessing of the exhaust vapour in a heat exchange process for supplementing an air or water cooling and heating system. The use or purchase of renewable energy for supplying electrical power to the system would also lead to positive offsets.

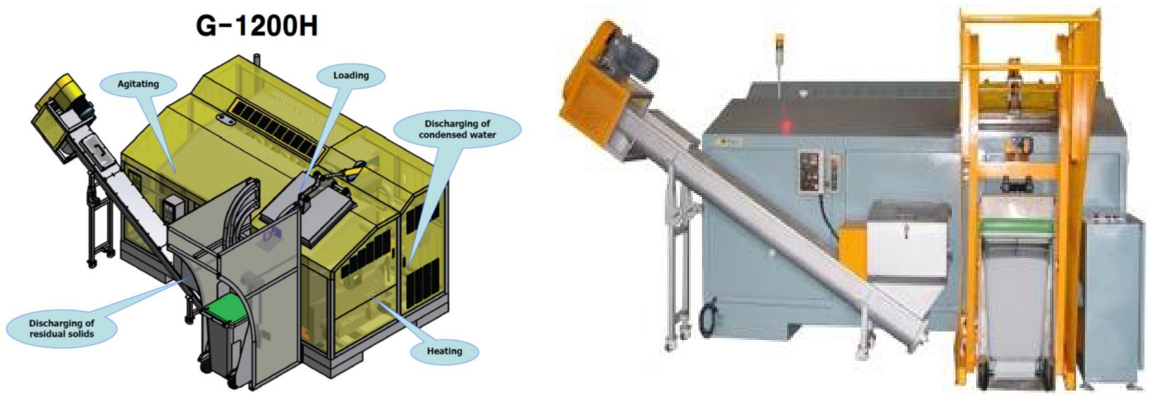

Figure 4: GaiaRecycle G-1200H: base unit

The basic process involves automatically heating, shredding, dehydrating and deodorising organic waste in a closed chamber on the premises where the waste is generated. The equipment is located under cover, as close as possible to the main area of waste generation. The batch-process requires only the input of electrical power and heat energy (electricity or gas), while the outputs comprise condensed water, deodorised air and a dry biomass.

Unlike many other processes, the GaiaRecycle system requires no additives whatsoever:

- NO water;
- NO sawdust;
- NO woodchips;
- NO enzymes; and
- NO microbes.

Untreated organic waste is added to the GaiaRecycle chamber (either gradually or in batches from storage bins / buckets) until the chamber is two-thirds full (Figure 4). A rotating agitator inside the chamber is used during the loading process to shred waste such as vegetable trimmings, thus maximizing the utilization of the available chamber volume. Once the chamber is full, the lid is closed and latched securely before the “Start” button is pressed. The process thereafter is automatic and takes approximately 8 to 10 hours to complete (Table 1).

		1 hr	2 hr	3 hr	4 hr	5 hr	6 hr	7 hr	8 hr	9 hr	10hr	
Load												
Heat **												
Agitate												
Deodorise air												
Condense water vapour												
Cool												
Unload												

Table 1: GaiaRecycle generic processing cycle

The waste is kept in constant motion by the rotating agitator while thermostatically controlled hot air is circulated through it. In this way, the physical structure of the waste is broken down while the temperature is elevated – akin to the cooking process in a stirring kettle – creating an "organic stew" inside the machine. Bacteria that cause rotting are killed as the temperature rises above 40°C while thermophyllic bacteria are activated at 70°C and above. These latter bacteria cause rapid fermentation of the waste, breaking down the cellular structure while also promoting the production of yeast which is a highly desirable component of soil amendments.

The water content of the waste evaporates during this process and is passed over an ambient-temperature condenser where it returns to liquid form and passes out of the machine at a temperature of approximately 40°C. This condensate is virtually pure but may have a slightly elevated mineral content. It may be drained to sewer without any environmental concerns or liquid trade-waste issues or, if appropriate, it may be captured for use in grey-water applications such as cleaning, toilet flushing or irrigation.

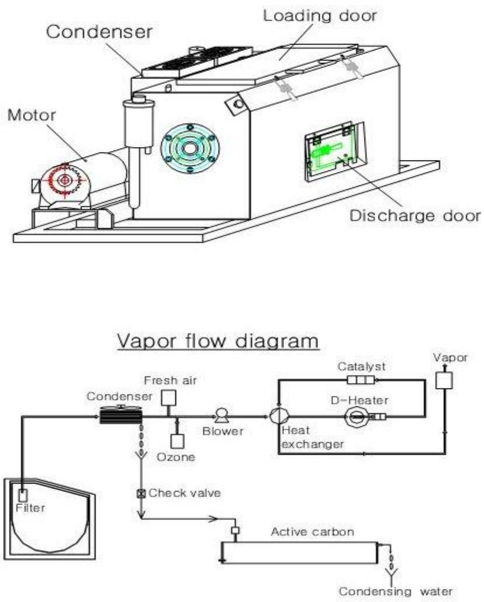

Figure 5: GaiaRecycle heated air treatment process diagram

While the moisture is evaporating and being condensed, a controlled amount of external air is drawn into the GaiaRecycle unit and a corresponding volume of heated air is vented from the unit after being subjected to cleansing by a physical filter, by a catalytic deodoriser and by ozone treatment. This expelled air is at a temperature of approximately 60°C and it may either be ducted to atmosphere or, if appropriate, it can be directed through a heat exchanger, utilizing its energy to pre-heat incoming air or water for other purposes in the establishment (Figure 5).

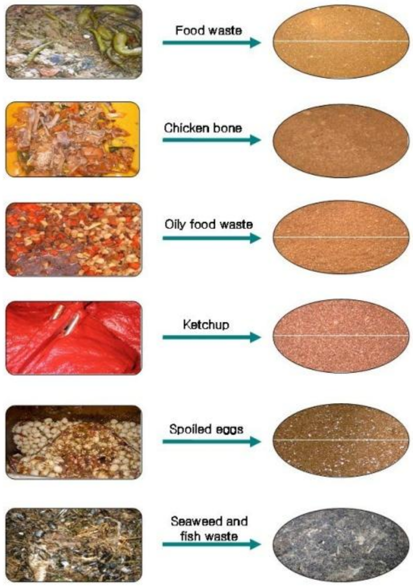

Figure 6: GaiaRecycle: Various before and after (treated biomass output)

Once the dehydrating phase is completed, the heat source is switched off while the agitator and circulating fan continue to run, allowing the contents of the chamber to cool. At the end of this phase, the unit shuts down pending the intervention of an operator to initiate the unloading process.

Remaining in the chamber at this point is a dried nutrient-rich bio-mass that has between 10% and 15% of the original volume of the untreated waste, it is inert in that all bacteria, pathogens and seeds have been neutralized in the processing and it is so dry that it may be stored on site, if necessary, for many days. It is unloaded automatically from the GaiaRecycle unit through a hatch on the front face of the machine.

The bio-mass is virtually odourless (Figure 6). Options for disposing of the bio-mass include:

- use directly as a soil amendment;
- use as brown waste in a composting process;
- use as a supplement for animal feed (subject to local regulations);
- conversion to heat briquettes; and
- dumping to landfill, in the knowledge that the volume, cost and “rotting factor” have been greatly reduced.

The modular treatment units range from 30 kg to 3000 kg capacity per day. The larger capacity units incorporate conveyors and other materials-handling solutions according to site needs. “Capacity per day” is defined on the basis that in a single, 8 – 10 hour shift one process will be completed and a second one will be started which will run unattended for unloading at the commencement of the following day’s shift.

The sustainable benefits of the GaiaRecycle process include:

- the reduction of organic waste in landfill saving landfill space for other purposes and eliminating the anaerobic rotting of the waste which generates methane and leachate;
- the reduction of carbon emissions that would otherwise result from transporting the waste to disposal sites;
- the utilisation of the condensed water effluent as grey water for reuse *in situ*;
- the potential secondary usage of recovered heat energy to pre-heat other media within the establishment;
- requires no additives such as water for the processing of the waste;
- it is not a pulping system and therefore does not discharge water with high Total Suspended Solids and /or generating a high Biological Oxygen Demand; and
- it is not an enzymic system and does not discharge water from which solids may precipitate downstream.

The economic payback from the process arises from the long term reduction or elimination of fees for hiring skips or bins and paying landfill tip fees or other costs such as sewer discharge fees.

Yirrkala Banana Farm

Sodexo manage the accommodation villages associated with the Rio Tinto Alcan Gove operations in the Northern Territory. This example is of a low technology system of composting which presented some tangible benefits through the diversion of over 280t of organic waste destined for landfill. Organic waste and cardboard was provided by the kitchen operations to the local banana farmer who combined the materials in a converted “cement truck” composter (Figure 7). This aerobic process produced a partially composted material which was then used as inter-row mulch within the orchard of bananas, paw paws and lemons. However, demand for a carbon source to balance the mix exceeded supply which challenged the project and recently the supply of organic material has been stopped while improvements to the system are being investigated. Sodexo is considering the GaiaRecycle solution for this situation in anticipation that this activity can be relaunched with a product which will significantly advance the effectiveness of the process.

Figure 7: “Cement Truck” composter (left) and Yirrakala Banana Farm, Gove (right)

Super Vegetable Gardens

Sodexo has a global community working group initiative called Super Vegetable Gardens which has the objective of providing local communities in the vicinity of our operations with a business model for the establishment of productive food gardens. These gardens will firstly support the food requirements of the local community which will the hopefully evolve into a sustainable business model with targeted support and infrastructure. Ultimately, the nearby remote site or extended community can benefit from the purchase and consumption of the fresh seasonal produce that can be grown by the local community. The initiative has been implemented in many third world countries, such as Peru, and is transforming the local communities in which the company operates. Sodexo are investigating opportunities in Australia to introduce this program.

Conclusion

As Sodexo develop and implement improved solutions for organic waste treatment and recovery in Australia it is anticipated that the outputs of a food waste treatment and recovery process such as GaiaRecycle can provide significant benefits. The Yirrakala Banana Farm is a working example of how these activities can be integrated for multiple benefits; however there are also many other untapped opportunities that could be explored.

The problem of food waste is magnified as the world and Australia in particular move towards a carbon restrained economy. With increasing mouths to feed the world not only needs to limit the energy inputs and waste associated with food production but also the wastes and harmful emissions that are generated from its’ disposal. The GaiaRecycle solution or any other proven system that provides similar benefits is a great leap forward in the management of food waste that will generate local community and environmental benefits at the source. This paper has presented a holistic system which returns water and nutrients to the Earth by turning a waste into a resource. We hope that will provide living landscapes and opportunities for local communities which in turn will also win the support of the company accountant.

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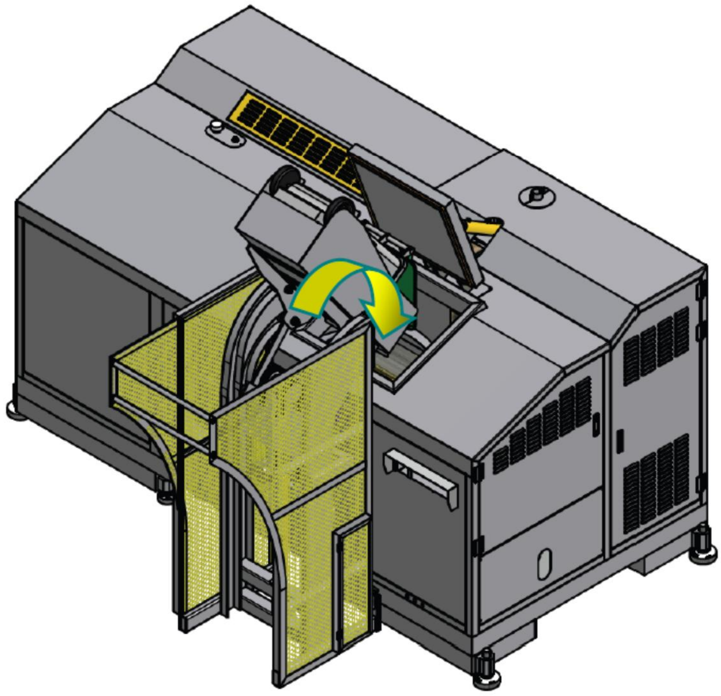
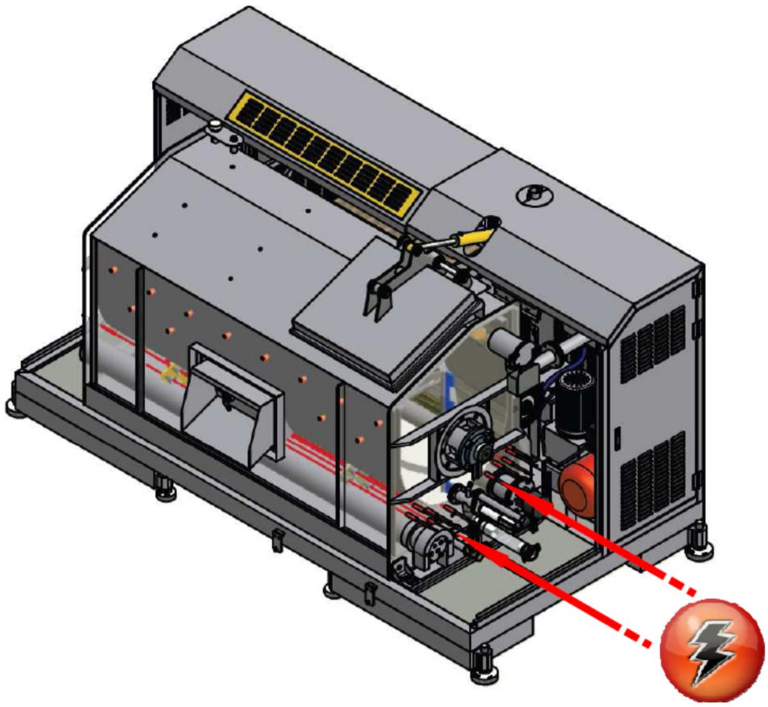
Appendices

G-1200H drying process sequence

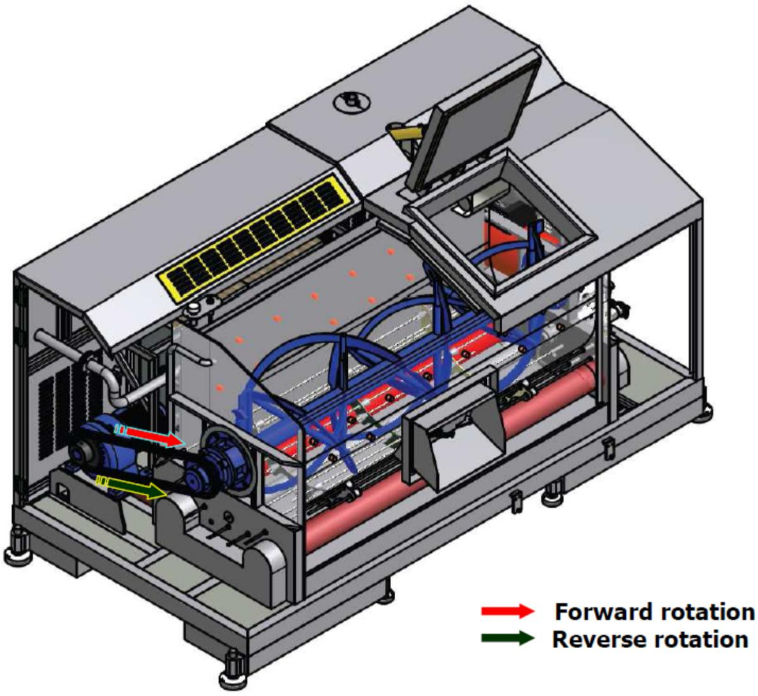
Phase 1 : Foodwaste loading process



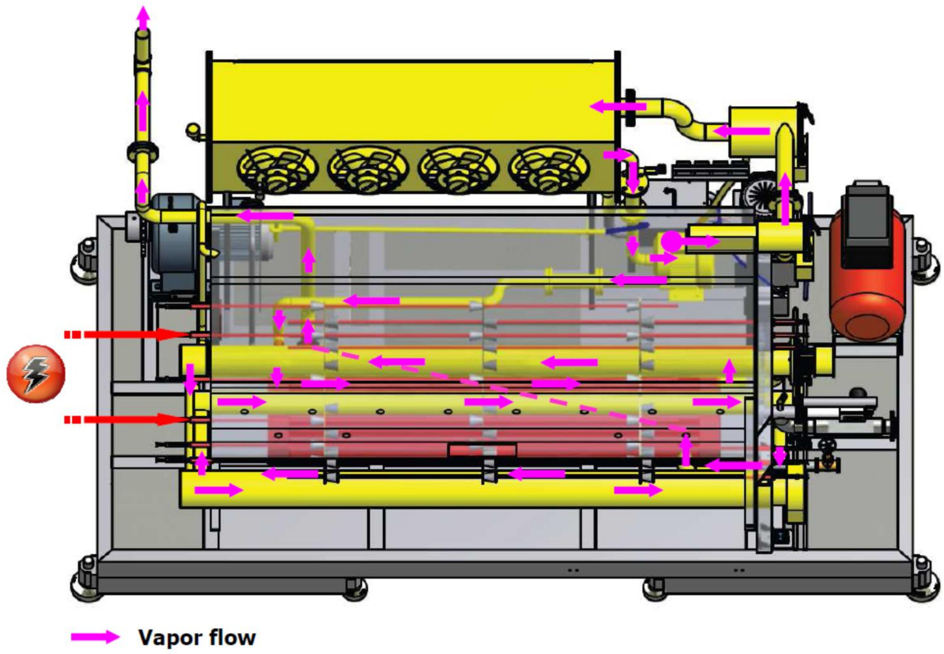
Phase 2 : Heating process



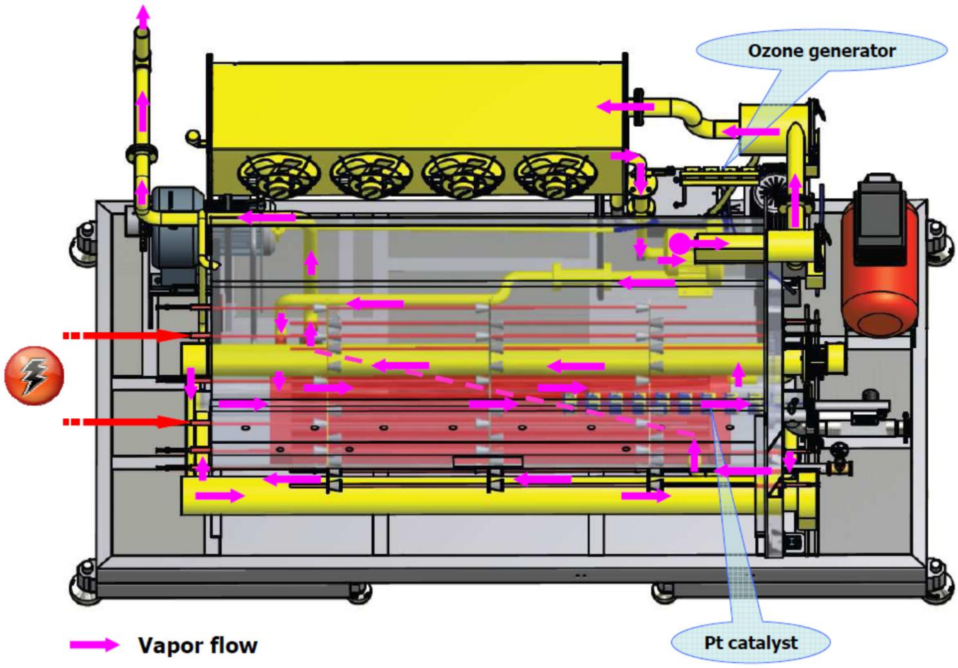
Phase 3 : Agitating process



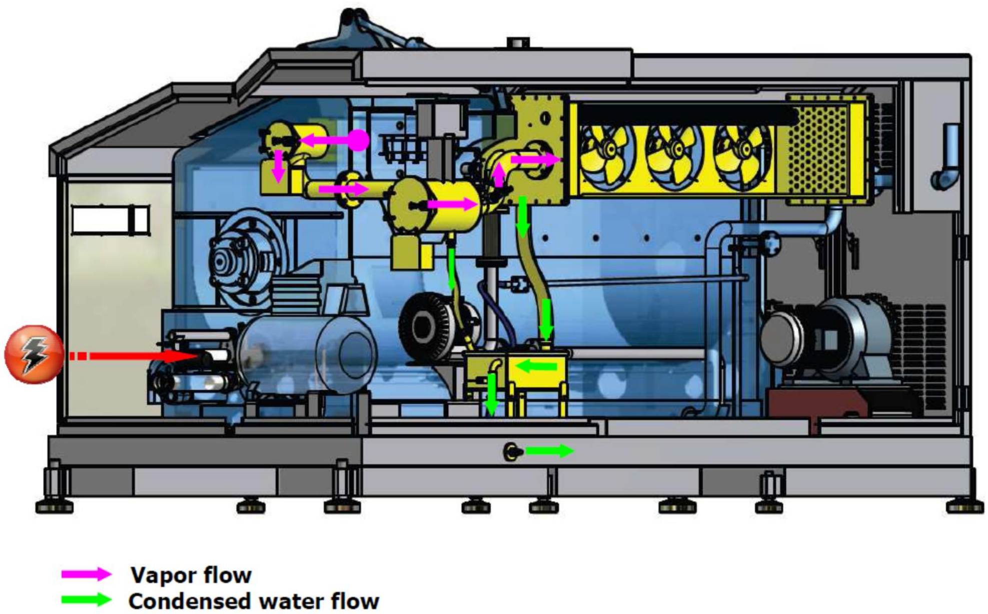
Phase 4 : Dehydration process



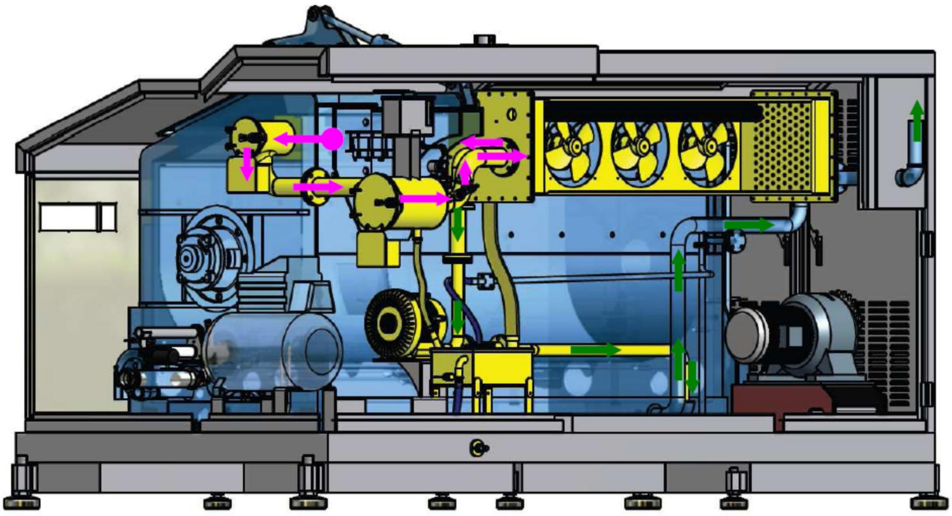
Phase 5 : Deodorisation process



Phase 6 : Discharging process of condensed water

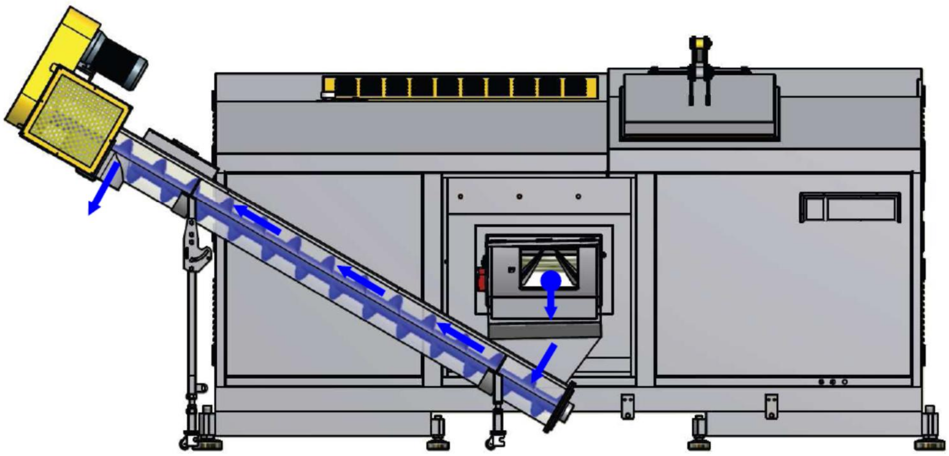


Phase 7 : Cooling process with ambient air



Vapor flow (high temperature)
Vapor flow (low temperature)

Phase 8 : Discharging process of residual solids



Solids flow

Hedging Against the Carbon Pricing Mechanism – Using the Goldfields to Create Carbon Offset Credits

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Abstract

The introduction of the Carbon Pricing Mechanism (CPM) in Australia in July this year will mean that Australia's 80 largest resource companies will pay over $1.8 billion per annum for the greenhouse gas (GHG) emissions they produce. The CPM represents an immediate increase in the cost of production for all Australian resource companies regardless of whether they are directly liable because of a reduction in the fuel tax credits companies can claim. A certified carbon offset portfolio is one way to reduce the financial costs imposed by the Federal Government's CPM.

Companies that have direct liabilities under the CPM can mitigate the annual cost by using compliance Australian Carbon Credit Units (ACCUs) that are verified under the Carbon Farming Initiative (CFI). Based on estimates from CSIRO, Australian rangelands offer carbon offset opportunities in excess of $2.4 billion per annum. More than a decade of comprehensive carbon research at Sturt Meadows near Leonora provides scientifically robust evidence that the Goldfields region has the potential to create substantial volumes of compliance ACCUs.

While the CPM is a direct cost to the mining industry, carbon finance can be used as a catalyst to drive substantial environmental rehabilitation across thousands of hectares of degraded land in the Goldfields.

Outback Ecology has been working with companies who own pastoral leases in the Western Australian Goldfields and other regions of the State to explore ways to create compliance ACCUs on these properties. The benefits of an offset project are:

- the company creates compliance ACCUs at a cost lower than the CPM price, this becomes increasingly important as the CPM price is predicted to reach $29 per tonne carbon dioxide equivalents (CO_2e) by 2020;
- degraded areas on pastoral leases are rehabilitated which in turn enhances biodiversity and other ecosystem services in the region; and
- offset projects can provide training and employment programs for local people, contractors, Indigenous people and communities.

This paper discusses how resource companies can benefit from creating compliance and voluntary ACCUs. It provides an overview of the legislative environment that underpins the commercialisation of compliance and voluntary ACCUs. Finally, this paper briefly outlines the key mechanics of an offset project in the Goldfields region.

How big is the bucket? - The volume and value of the Australian Carbon Market

In 2010 the global carbon market was worth more than $US120 billion and this is expected to increase with the introduction of the Carbon Pricing Mechanism (CPM) in Australia in July 2012, and the adoption of Emissions Trading Systems (ETS) elsewhere, including some provinces in China.

The Federal Government has committed to reduce Australia's carbon emissions by 160 million tonnes by 2020. While a substantial proportion of this reduction in emissions will occur from driving energy efficiency, there will be a strong demand for carbon offsets once the 'easy fruit' or the least cost abatement actions have been fully utilised.

The implementation of the Carbon Farming Initiative (CFI) under the Federal Government's Clean Energy Future Act is a mechanism that has the potential to provide new economic opportunities for pastoral leases in the Western Australian Goldfields while also reducing legacy greenhouse gas emissions. Demand for carbon credits created under the CFI is expected to outstrip the supply in this decade (Point Carbon 2012).

In the short term, there will be a potential demand of 16 million tonnes compliance ACCUs, this equates to potential gross revenue of $3.6 billion in 2012 / 13 financial year. At present, the existing projects already generating compliance ACCUs can only supply less than one million tonnes per year. Despite this market opportunity, a potential risk is a change in the Federal Government's policies regarding the CPM and the CFI. Substantial changes or 'watering' down of the policy settings could result in a reduction in the expected market price.

It will be very difficult (but not impossible) for the Federal Coalition, should they be successful in the 2013 election to rescind the CPM because they are unlikely to have the number of seats required to control both Houses of Parliament. It is probable that changes to the existing carbon pricing policy will be made, hence like any new investment, offset projects will need to be designed with flexibility to be able to adjust to any future policy changes and trading conditions.

The Rules of Engagement

The CFI is a government offset scheme that issues compliance and voluntary ACCUs to project developers when they sequester or abate a tonne of carbon dioxide equivalent (CO2e). The compliance and voluntary ACCUs can be sold to companies who are financially liable under the CPM and / or other companies who want to simply demonstrate their commitment to sustainability / climate change to their employees, shareholders, customers or clients.

There are broadly two categories of offset projects that may be implemented under the CFI:

1. Emissions avoidance / abatement projects – a project that prevents the release of carbon dioxide (CO2), methane (CH4) or nitrous oxide (N20) into the atmosphere.

2. Carbon sequestration projects – a project that removes CO_2 from the atmosphere and stores it in living biomass such as forests or in the soil (Carbon Market Institute 2011a).

Each tonne of carbon dioxide equivalent (t CO_2e) emissions that is reduced or stored by a CFI project is issued with one ACCU. ACCUs are defined as “personal property” under the CFI Act and will be treated as such for the majority of existing legislative regimes. International emissions accounting guidelines (namely Kyoto Protocol) determine whether credits created by a CFI project can be traded in the compliance or voluntary market (Figure 4).

Compliance ACCUs will be used by companies liable under the CPM from 1 July 2012. A company may use compliance ACCUs to cover up to 5% of its liability during the fixed price period (2012/15) and for up to 100% of compliance from 1 July 2015 (when the flexible price period commences) (Carbon Market Institute 2011b). Compliance ACCUs may also be eligible to be traded in other international compliance markets such as the New Zealand Emissions Trading Scheme (ETS) and European Union (EU) ETS.

Voluntary ACCUs will be able to be traded in Australia’s voluntary scheme (the National Carbon Offset Standard [NCOS]) and the voluntary international markets (Carbon Market Institute 2011b). The value of both types of ACCUs will be demand-driven and it is expected that the value of compliance ACCUs will be higher because they can be sold into a range of different markets. The Federal Government intends to spend $250 million over six years starting in 2012/13 to purchase voluntary ACCUs to provide some short-term certainty in price in the voluntary market (Clean Energy Future 2011).

Figure 4: Eligibility of different CFI projects for the compliance and voluntary markets (reproduced from Carbon Market Institute 2011a)

Resource companies liable under the CPM will have to choose the composition of their carbon credit portfolio. The type of units held in a company's portfolio will be largely driven by supply / demand of credits and the company's appetite for risk. For example, if a gold miner had the confidence that its Life-Of-Mine (LOM) was 20 years, then it could negotiate a contract with an offset provider to supply compliance ACCUs at a competitive price for the emissions that will occur over that period. The benefit of this hedging strategy is that it could buffer the company from the annual increase in the carbon price in Australia.

The CFI Scheme is administered by a number of specialised government regulators. To qualify as a certified carbon offset it must meet a number of certain criteria. These criteria are important to maintain a high standard of integrity and provide confidence to investors in the product that they are purchasing. The criteria for a certified offset CFI project are:

- Additionality - requirement that emissions abatement or sequestration is additional to 'business as usual';
- Permanence - emissions that are taken out of the atmosphere and stored must not be re-released back into the atmosphere for at least 100 years;
- Leakage - CFI projects must avoid emissions rising outside of their boundary that may be caused by the emissions reduction activity;
- Measurable and verifiable - measurement and monitoring systems must be able to quantify and verify emissions reductions and be auditable;
- Conservative - conservative assumptions in estimations / procedures should be used; and
- Internationally consistent - accounting methods must be consistent with the National Greenhouse Accounts and Australia's National Inventory Report (Carbon Farming Initiative 2011a).

How do you create compliance-grade offset credits in the WA Goldfields?

A rangeland restoration offset project creates a carbon credit by increasing the baseline amount of carbon that is stored in the soil and the vegetation. To create a carbon credit through rangeland restoration one or a combination of the following management practices needs to be implemented:

- partial destocking and implementation of improved land management practices;
- full destocking, removal of feral animal species and reforestation of native species;
- continuance of current land use practices (livestock farming/mining), with the identification of suitable areas for carbon sequestration to be de-lineated and excluded (fenced off) from existing land use practices; or
- improved land management and stocking rates, while implementing a sustainable fire program to assist the ability of the selected areas to sequester carbon.

Rangeland restoration offset projects can technically occur on any area of land in the Australian rangelands that has a sufficiently low baseline level of carbon. There is considerable scope for carbon offset progams in the Western Australian Goldfields due to the large amount of land in poor condition. Approximately 30% of the land area on most pastoral leases in the Goldfields is in poor condition due to historical overgrazing. This provides a substantial opportunity for carbon sequestration because the baseline level of carbon stored in the soil and vegetation is presently very low. The capacity for sequestration in the Goldfields was demonstrated by the comprehensive carbon accounting research undertaken at Sturt Meadows Pastoral Lease near Leonora (Yamada et al. 1999).

While a rangeland restoration offset project can be verified under the CFI, one of the major development costs of a project is the preparation of a 'methodology'. A CFI project methodology outlines:

- how the proposed activity can reduce emissions or sequester carbon;
- the assumptions and formulas used in the estimations; and
- the procedures used for monitoring, reporting and verification.

At present, an approved CFI methodology does not exist for rangeland restoration based projects. However, Outback Ecology has been commissioned to develop this rangeland restoration methodology by a consortium of public and private interests (Australian Rangeland Carbon Enterprises). The methodology should be approved by the Federal regulator by the end of 2012 and will allow projects in the Goldfields to create compliance ACCUs from the rehabilitation of degraded areas on pastoral leases.

The key components required to implement a carbon offset based project in the Goldfields are:

- suitable land that has a low carbon baseline (i.e. high proportion of the pastoral lease is in poor soil and vegetation condition);
- land that can support trees greater than two metres in height and greater than 20% canopy cover;
- the legal rights to the carbon within the offset project area (or the financial capacity to fund the legal costs of securing these from the State Government);
- adequate tenure to allow carbon sequestration activities within the offset project area (or the financial capacity to fund the legal costs of securing these from the State Government);
- a Carbon Farming Initiative Methodology to be approved by the Federal Regulator;
- baseline assessment and verification of the project estimates; and
- capital to finance and maintain the project over the 100 year commitment period.

Conclusion

Resource companies that own pastoral leases in the Western Australian Goldfields have the potential to hedge against their liability under the CPM by creating their own compliance ACCUs. This hedging strategy may convert the pastoral lease from a liability to an asset on the company's balance sheet. While, changes to the existing carbon pricing policy settings are inevitable, it is likely that there will be a price on carbon in Australia going forward. A limited number of proactive resource companies are moving beyond the 'wait-see' approach and exploring carbon offset opportunities that both sustain shareholder returns and rehabilitate degraded pastoral leases.

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Short-Range Endemic (SRE) Terrestrial Invertebrates: an Overview of Current Knowledge, Survey Methods, and Considerations for Environmental Impact Assessment.

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We review current knowledge regarding terrestrial Short-Range Endemic (SRE) invertebrates in WA, including definitions, typical SRE taxa, habitats and microhabitats, survey methods, and environmental impact assessment (EIA) under relevant legislation and EPA guidance. Terrestrial SRE invertebrates are those species that are only known to occur in small or confined areas (< 10,000 km^2 as per EPA Guidance Statement 20). These range-restricted species may be vulnerable to a variety of impacts arising from human activity. Over the last decade, a high diversity of mostly un-described species have been recognised as having potential to be short-range endemic. Many of these species have been discovered in the Pilbara and Yilgarn regions during environmental surveys for mining approvals. However, survey coverage is far from complete, and much remains to be known about the taxonomy and distribution of putative SRE species. EIA of mining projects in regards to SRE fauna is guided by EPA (2009) Guidance Statement 20; although, the science of SRE fauna is developing rapidly as the number of surveys increases and ecological knowledge is refined. We present recent case studies to demonstrate various approaches towards assessment of SRE invertebrates, and to highlight some strategies for dealing with uncertainty and reducing potential risks to projects.

Threshold Analyses Regarding Factors Influencing Soil Erosion on Gold Mine Rehabilitation in Western Australia

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Abstract

Forty-two landforms at gold mines in the Goldfield's region of Western Australia were evaluated for factors influencing soil movement and the thresholds at which those factors become important. Data utilized for the evaluation of erosional slope stability included those pertinent to the erosional model "Revised Universal Soil Loss Equation" (RUSLE). Variables analyzed include physical components of subject landforms such as slope angle, slope length, and aspect along with surface cover and both physical and chemical properties of growth media. Evaluated growth media properties include, but are not limited to: texture, percent organic matter, exchangeable sodium percentage (ESP), and electrical conductivity (EC). Ground cover data include percent cover of plants, rock, litter, and bare ground exposure. Analyses compared soil loss values from rehabilitated areas to a related value for soil loss developed from ten native analogue sites that are ecologically and topographically similar to reclaimed landforms. Methods of statistical evaluation included: 1) regression analysis and 2) analysis of variance to discern data patterns, thresholds, and relationships between variables of interest. Following analyses, several variables that demonstrated a relationship to soil loss were further evaluated in an attempt to determine "threshold" values. The primary and seemingly dominant variable affecting soil loss is slope angle. In addition, the variables of slope length, percent rock cover, and percent bare ground exposure demonstrated considerable influence over soil loss both individually and collectively. Preliminary thresholds seem to be evident whereby these variables become important to soil loss and this knowledge will eventually lead to guidelines for future landform construction, or the mitigation of problematic areas on existing rehabilitation. Future data collection and refinement of analyses techniques will improve confidence in forthcoming iterations of this evaluation.

Introduction

In 2010, rehabilitation on several Barrick Gold Australia (Barrick) properties in Western Australia were evaluated using the newly established Reclamation Monitoring & Final Relinquishment protocol. Results were summarized into annual reports for each property and also compiled to form a large empirical data set for analysis. This paper is split into two logical sections; the first provides a brief description of the methodologies used to evaluate each rehabilitated landform or mine facility, the second section provides detailed information, including methodologies and results, in regards to the empirical data set. Analysis of currently available data is encouraging and demonstrates that there are some engineering design criteria or remediation guidelines that can be developed and refined that, in turn, could help alleviate soil erosion.

Rehabilitation Monitoring Programme

The following protocol briefly describes the soil surface and rehabilitation evaluation procedures to be used for monitoring and analysis of rehabilitation performance (Viert 2010). This protocol is based on step-wise procedures that concentrate on: information control; evaluation of soils; evaluation of soil stability; performance of revegetation; consistent and meaningful reporting; and development of, and compliance with, release criteria to facilitate relinquishment of any regulatory mandated financial assurances and/or liability. Two important side-benefits are: 1) the timely detection of latent rehabilitation issues along with corrective action guidance, and 2) a standardized means of recording information that precludes loss due to staffing changes / turnover.

Step 1 <u>Organization of Existing Information</u>

The first step in the overall monitoring process is to collect and organize any and all existing information regarding each unit of currently reclaimed land and then complete an as-built sheet for those units. The as-built sheet is designed as a check sheet to facilitate recording of the most pertinent data from a unit of reclaimed land that may be necessary to facilitate a determination of problematic conditions, or simply to document the rehabilitation metrics that occurred.

Step 2 <u>Site-Specific Procedures for Evaluating Growth Media on a Managerial Unit of Reclaimed Land and Selection of Reference Areas</u>

Growth Media

It is <u>strongly</u> recommended that in-situ growth media be sampled and evaluated for quality prior to recovery in advance of operations. This <u>one-time evaluation</u> (unless problematic pockets are found) ideally would occur prior to development of rehabilitation plans, but lacking such activity must occur immediately following lay-down of the material and prior to any seedbed preparation for a given unit of land. The sampling plan would utilize a systematic grid overlaying the area, with the number of sample points determined by the overall size of the unit. In general, the larger the area, the more samples collected. In addition to this systematic distribution of sample points, any notable areas of aberrant growth media should be identified and sampled as well. At the very least, samples should be analyzed for soil structure, pH, EC, SAR or CEC/ESP, texture, and basic fertility components (N, P, K, and % Organic Matter).

Analogue Sites

The selection of analogue sites must necessarily occur very early in the rehabilitation process and certainly before stability and / or vegetation evaluations are implemented. The selection of analogues sites must occur with great care and should be performed by a well-experienced rehabilitation specialist. Analogue sites should be selected from undisturbed (by mining operations) and representative examples of local vegetation communities and physical topography that support the land use that is the target of post-mining rehabilitation.

Step 3 <u>Site-Specific Procedures for Evaluating Soil Stability</u>

Evaluations of soil stability should occur to document this parameter and collect data necessary for remediation or relinquishment. There are three procedures utilized to determine soil stability; two analyze observational and measured data trends over time at specific points on the unit and one analyzes different biotic and abiotic parameters across the entire unit to determine potential soil erosion. Trend monitoring for erosional stability will be comprised of two observational procedures, one that is co-located with each vegetation sampling transect (Step 4) and one that is based on established erosional gullies and monitored independently from the cover procedure. Gully monitoring will consist of annual measurements and observations to determine if the gullies are active or stabilizing.

The Revised Universal Soil Loss Equation (RUSLE) will be utilized to provide defensible numeric values to display soil stability on the units using potential erosion rates as the means of comparison. The RUSLE model is based on six parameters utilized to estimate or quantify the factors that affect the potential for soil erosion. The RUSLE model is as follows and will allow a comparison of the reclaimed units against the reference / analog areas:

$$A = R \bullet K \bullet L \bullet S \bullet C \bullet P$$

Where:

A = Soil loss in tons / acre / year

R = Rainfall/runoff erosivity factor
K = Soil erodibility factor
LS = Hillslope length and steepness factors (combined as one)
C = Cover-management factor
P = Support practice factor

Step 4 <u>Evaluate Establishing Vegetation Using Vegetation Measurement Protocols</u>

There are three stages of vegetation monitoring implemented with this protocol. Stage I of vegetation monitoring will occur concurrently with the implementation of soil sampling protocols and will consist of two components: 1) a brief qualitative evaluation of the reclaimed surface and manifested physical and biotic attributes, and 2) a brief evaluation of emergent plant density. Stage II vegetation monitoring protocols will be implemented for all rehabilitation units that have achieved sufficient vegetation growth and development to warrant the effort.

The procedure for vegetation monitoring in Stage II is same as that utilized for bond release sampling (Step 6), but not as statistically rigorous. Stage III is essentially a holding period where rehabilitation has achieved adequate parameters to be relinquished, but the area is not operationally ready to be released from the permit. In these instances, compliance monitoring would be initiated requiring an evaluation once every 3 years to insure that the reclaimed area has not regressed or otherwise developed problems.

Step 5 <u>Prepare Monitoring Report</u>

Monitoring reports should consist of three levels of communication: 1) immediate, 2) short-term, and 3) standard longer-term documentation. Immediate reporting should be used for observations of conditions (or lack thereof) that need immediate attention from environmental or rehabilitation department staff. Short-term reporting should be used for observations of conditions that need attention during the current field season, but do not warrant immediate attention. The final level of reporting involves the standard longer-term documentation of field activities and findings that will be prepared during the non-field season. This last report will present the results of monitoring data analyses and any management recommendations in a user-friendly format.

Step 6 <u>Development of Site-Specific Standards for Determination of Successful Rehabilitation and Subsequent Financial Guarantee or Assurance Relinquishment for Mined Areas</u>

Consistent with the requirements of Rehabilitation Permitting, final rehabilitation success will be evaluated through three broad concepts:

- Documentation that erosional stability has been achieved as detailed in Step 3.
- Comparison to an adequate analog or reference area(s) representative of the pre-existing vegetation community(s) and/or desirable baseline/ecological conditions which will act as surrogate for the post-mining land use;
- Evaluation of plant species present in, and/or resulting from, the proposed (and planted) seed mixes.

Monitoring and eventual evaluation will typically involve sampling of ground cover within each reclaimed unit under consideration for financial guarantee or assurance relinquishment and the appropriate analogue site. Sampling for ground cover will be accomplished using a systematic grid for determining sample sites and data will be collected utilizing the point-intercept procedure along transects of 100 intercepts each using modern instrumentation (e.g. lasers or optics).

Data collection will continue within each discrete sampling unit (reclaimed unit or analog/reference area) for ground cover until a statistically adequate sample has been obtained (if Bond Relinquishment is being sought). Adequacy of sampling will be achieved when, for each discrete unit, the number of samples actually collected (n) provides a level of precision within 10% of the true mean with 90% confidence.

After an adequate sample has been collected for both the reclaimed units and analogue sites, the reclaimed areas will be compared to the developed bond relinquishment standards. If the reclaimed units pass all relinquishment standards, a report and bond relinquishment request will be submitted to the appropriate regulatory agencies.

Step 7 Incorporate Rehabilitation Monitoring Results into Mine Closure Plan and Costing

Rehabilitation monitoring results must be used to create a feedback loop for identifying issues, selecting remediation, and evaluating the success of applied interventions.

This overall procedure meets the intent to establish a reasonable, effective, and statistically defensible program to track the progress of soil stabilization and rehabilitation on areas generally closed to active mine operations. When implemented, this program will provide a scientifically defensible means to determine when units of reclaimed land will meet rehabilitation success criteria and can be identified as "ready for surety and liability release". These procedures will also identify those areas, or substantive portions of areas, that are not responding sufficiently to be releasable. This latter point is one of the critical components of the monitoring program. Properly designed monitoring procedures will shed light on potentially problematic areas saving both time and financial costs as well as provide a forum for the determination of corrective measures and subsequent release of all reclaimed units.

Evaluation of Slope Stability Factors

Background

Data utilized for the evaluation of erosional slope stability included information collected for, and produced by, the erosional model RUSLE from several Barrick mines in the Goldfields. Examples of data used include slope angle, slope length, soil texture, and estimated soil loss among others. Data analyses attempted to discern patterns and variables correlated to significant effects on soil erosion and included simple means, ranges, regressions, and ANOVA's. A high level of variability was observed within the data set, but a few strong indications of "controlling factors" were identified. These controlling factors may be manipulated to help limit erosion. Additional iterations of data and analysis are still needed to improve confidence in the results from this preliminary investigation. Additional years of monitoring are encouraged for verification of preliminary interpretations and recommendations and "fine-tuning" of analyses.

Methodology

As part of continuing efforts to evaluate rehabilitation and slope stability of landforms, statistical analyses were performed using 18 independent variables that relate to the dependent variable of soil loss. Data for these variables were collected during 2010 rehabilitation monitoring at five Barrick properties in Western Australia. Variables analyzed include physical components of target landforms, such as slope angle, slope length, and aspect along with physical and chemical properties of soils collected from each landform. Evaluated soil properties include, but are not limited to, texture, percent organic matter, exchangeable sodium percentage (ESP), and electrical conductivity (EC). Ground cover data collected by Cedar Creek were also utilized in this analysis and include percent cover of plants, rock, litter, and bare ground exposure. The total data set, including analogue areas, contained over 5,700 individual data points.

Analyses were performed using the statistical software package JMP 9.0 (SAS Institute, 2010). Data were initially evaluated by assessing the mean, range, maximum value, and minimum value for each variable. The distribution of response variables was then displayed and transformations were attempted where normalization of non-normal distributions appeared appropriate. As commonly observed with biological data, no transformations were successful so adjustments were made to the appropriate models to accommodate for the non-normal distributions. Regression analyses were then performed to discern data patterns related to soil loss and to determine any significant effects due to the variables of interest. If a single variable or mix of variables were determined to be statistically significant, then a generalized linear model was used to further investigate the relationship.

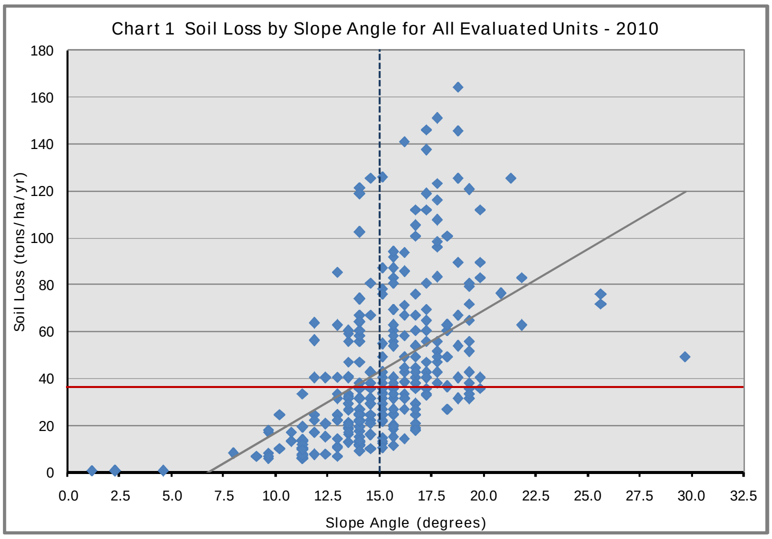
To determine those variables contributing most to excessive erosion, a threshold value for soil loss was created by averaging the natural soil loss from all analogue areas and multiplying that value by 110%. In this manner, a benchmark value was created for the purposes of this evaluation. This resulted in a value of 38 metric tons per hectare per year of soil loss as a benchmark of acceptable erosion from a landform. Although an apparent threshold can be developed in this manner, it must be noted that this data set displays a high level of variability. Though relationships were identified, there are no certainties that can be accepted with a high level of confidence. However, these data and findings suggest additional modeling opportunities, analyses, and future data collection needs that may be used to refine and elevate the confidence of interpretation.

Preliminary Findings

Following the aforementioned analyses, several variables demonstrated promising relationships that impact soil loss. The primary and seemingly dominant variable affecting soil loss is **slope angle**. In addition, the variables of **slope length**, **percent rock cover**, and **percent bare ground exposure** also demonstrated considerable influence over soil loss both individually and collectively. These relationships will be discussed as they relate to the entire data set.

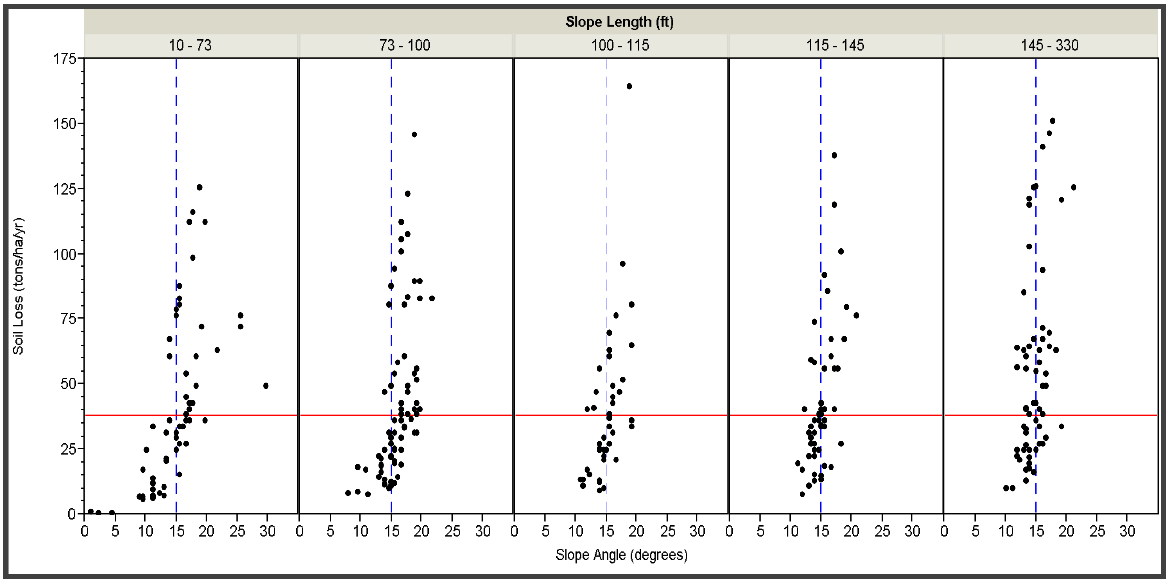
The central observation of this preliminary evaluation is that slope angle appears to dominate soil loss from mining landforms. Although consistent with common sense, this analysis has identified an apparent threshold for maximizing slope stability and demonstrates that slope angle can influence additional factors that affect landform stability such as plant establishment and the effectiveness of rock cover. Chart 1 displays the relationship of slope angle and soil loss. The solid red line is the 38 tons/ha/yr benchmark described earlier and the vertical, dashed blue line marks an apparent maximum slope angle where exceedances of the soil loss threshold become more common.

Across all sites, slopes of 15^{o} or less had a failure rate of 21% (27 of 125 slopes), with a maximum failure percentage of 29% for any singular angle. However, a slope angle of even 15.5^{o} increases the failure rate to 35% (9 of 26 slopes), and all slopes over 15.5^{o} exhibit a 61% failure rate (111 of 181 slopes). Although there is no clear slope angle that guarantees stability, probabilities for passage are significantly higher for those slopes flatter than 15°, and conversely lower for those above 15°. However, it is anticipated that future data collection refinements and analyses may facilitate more refined guidance.



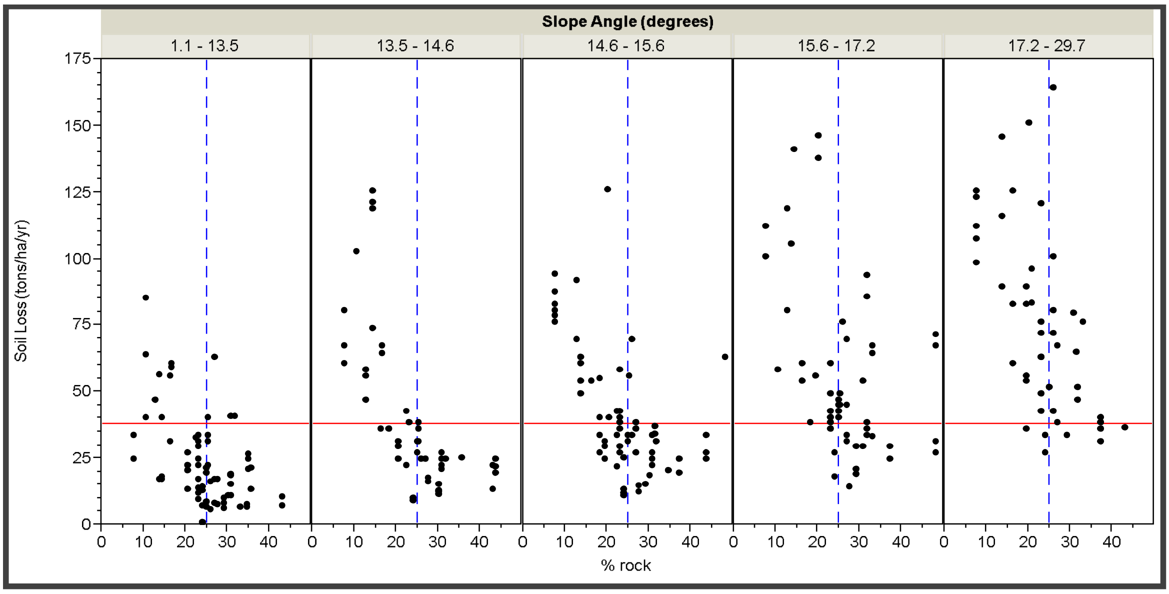
Other factors that have shown a significant effect on soil loss include slope length, percent rock cover and percent bare ground exposure. Additional variables showing at least some relationship with soil loss include ESP, EC and texture (percent silt and clay). Although soil chemistry factors have some level of influence over soil loss, control or management is far more difficult than with a physical variable such as slope angle. To the contrary, slope length is a physical factor that is subject to managerial control. In this regard, there is a weak relationship to soil loss when considering slope length by itself, but when paired with slope angle its influence can readily exacerbate the amount of erosion. As seen on Chart 2 soil loss is still largely controlled by slope angle, but as slope lengths increase past 44 m (145 ft) there is an increase in benchmark exceedances (adverse soil loss), especially for slope angles less than 15°.

Chart 2 – Comparison of Soil Loss given Slope Angle and Slope Length on All Evaluated Units



Rock cover (rock mulch) was observed to be another important component for slope stability and in many cases this feature can be readily engineered to help mitigate erosion. Across all evaluated slopes it appears that 25% or greater rock cover tends to control soil loss to below the 38 tons/ha/yr benchmark on slopes up to 15.6^{o} (Chart 3). Above 15.6^{o} 25% rock cover is less effective, but there are still fewer slopes that fail than slopes with less than 25% rock cover. It is a reasonable hypothesis that more rock cover (to a point) would help even further, and this management method warrants additional experimentation and evaluation.

Chart 3 – Comparison of Soil Loss given Slope Angle and Percent Rock Cover on All Evaluated Units



The amount of bare ground exposure can certainly impact soil loss, but it appears that slope angle and length are still more dominant factors in determining potential erosion. Based on this initial data set, ground covers (plants, litter, and rock) resulting in less than 50% bare ground exposure demonstrate more stability over a larger range of slope angles and lengths than slopes exhibiting greater than 50% bare ground exposure. In other words, the greater the cover by plants, litter, and rock, the more likely a slope is to pass a slope stability evaluation. In this latter case plant, litter, and rock cover combined need to exceed 50% total cover to have a more profound impact on soil erosion and slope stability.

Conclusion

This initial analysis based on currently available data is encouraging and demonstrates that there are some engineering design criteria or remediation guidelines that can be developed and refined that, in turn, could help alleviate soil erosion. At this time across all evaluated slopes, it was demonstrated that slopes less than 15^o and 44 m (145 ft) in length more consistently pass a slope stability evaluation. Rock cover of 25% or greater also consistently demonstrates more stable slopes even where slopes were greater than 15^o and 44 m in length. A final significant finding cannot be easily controlled by engineering or construction metrics, but may be controlled to some extent by revegetation procedures – restriction of bare ground exposure to less than 50%. Certainly the majority of these design criteria are more easily implemented during the construction phase of landforms as opposed to remediation once rehabilitation has been completed. However, in some cases, certain criteria may be used as guidelines to facilitate increased stability where interventions are required.

Using the remediation guidelines, mitigation scenarios can be modeled in the RUSLE program to determine efficacy. Then, cost implications can be considered and a preferred alternative selected. Once a remediation scenario is selected, updating the closure plan and costing is vital. Rehabilitation monitoring results must be used to create a feedback loop for identifying issues, selecting remediation, and evaluating the success of applied interventions. Pertinent information should be included in the mine closure plan and costing in order to ensure that lessons learned from previous rehabilitation efforts can be applied to future rehabilitation efforts.

Bibliography

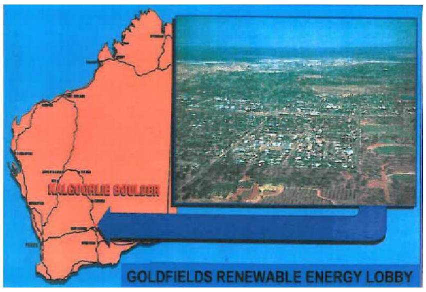
Viert, S. R. (2010). Barrick Gold Corporation's standardized protocols for reclamation monitoring and final relinquishment in Proceedings of the Fifth International Conference on Mine Closure. Australian Centre for Geomechanics.

Carbon Free Energy Supply From Large Scale Renewables – Using Remediated Land to Deliver Clean Energy.

Rod Botica & Jim

Rod Botica and Jim Thomson, Goldfields Renewable Energy Lobby

Goldfields Renewable Energy Lobby (GREL)



The Goldfields Renewable Energy Kalgoorlie-Boulder based was formed in 2010.

The primary purpose of the group is to positively lobby and promote the establishment of a large scale Solar Power Precinct near Kalgoorlie/Boulder within the next 5 years.

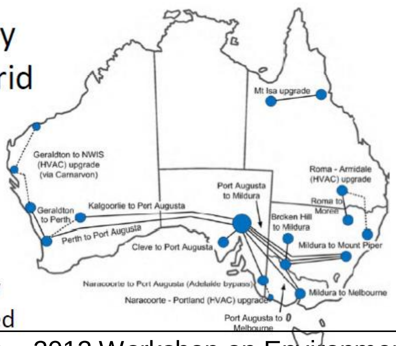
Long term aim is to foster a positive environment for renewable energy sources, cultivating conditions for large scale renewable energy generation and support the vision for Australia of the Beyond Zero Emissions – Zero Carbon Australia 2020 Stationery Energy Report.

GOLDFIELDS RENEWABLE ENERGY LOBBY
(GREL)

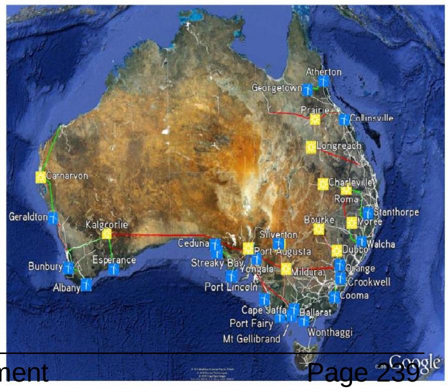
Federal Govt Commitment to the National Plan

- Lobby Federal Politicians to support the BZE Plan.
- Request Infrastructure Australia in partnership with State Development Authorities to support funding upgrades of the NEM and the WA SWIS HV Bulk Transmission Lines in accordance with the BZE Plan to facilitate private renewable energy generation.
- Seek out proponents to access Clean Energy Council Funding
- Support Renewable Energy Feed-in Tariff for base load suppliers and other suppliers.

21st Century Electricity Grid

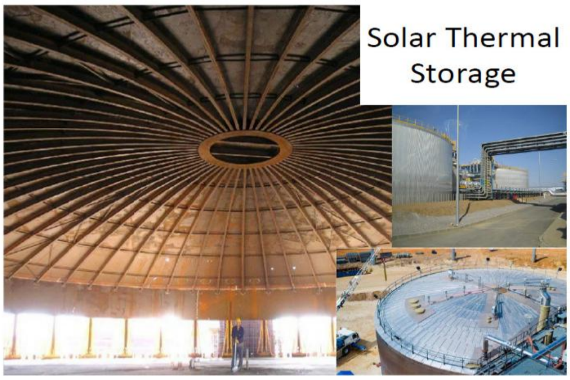


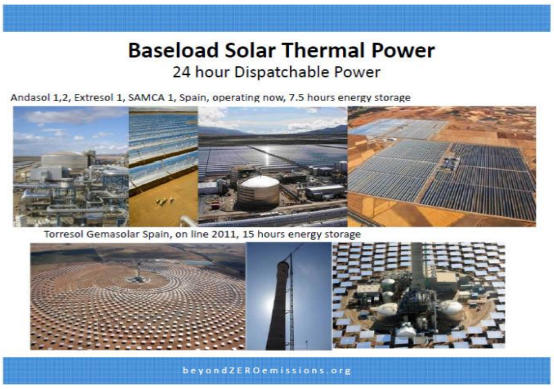
Every connection and upgrade fully modelled & costed

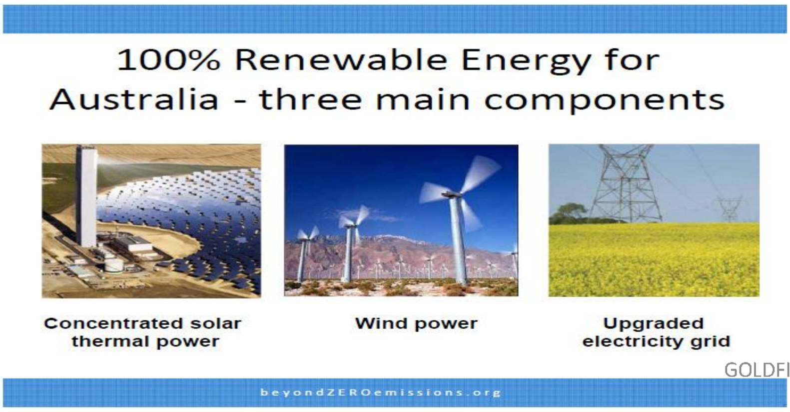


GOLDFIELDS RENEWABLE ENERGY LOBBY
(GREL)

Solar Thermal Options



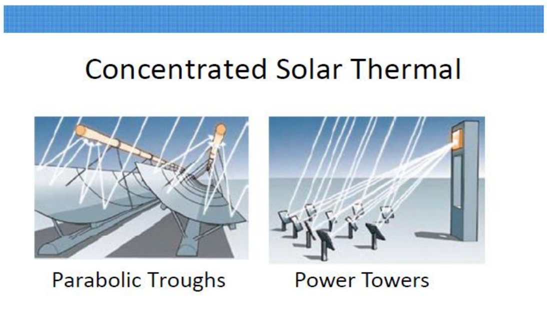


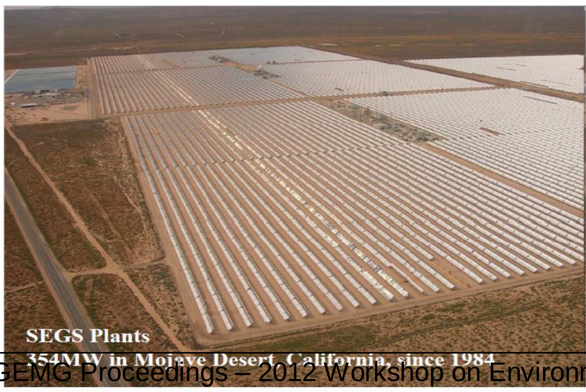


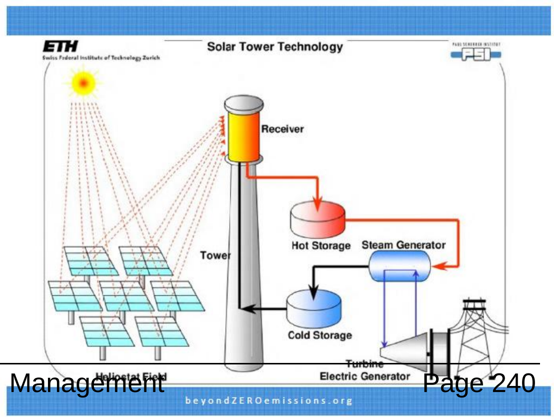
GOLDFIELDS RENEWABLE ENERGY LOBBY (GREL)

Solar Thermal Options

Linear Fresnel Solar Thermal Boost – Kogan Creek Qld 2012







GOLDFIELDS RENEWABLE ENERGY LOBBY (GREL)

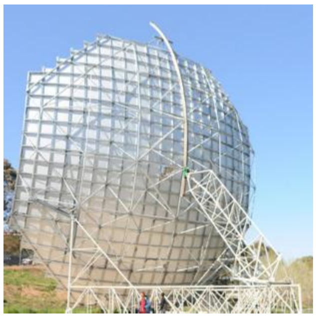
Kogan Creek Solar Boost Linear Fresnel Technology

An aerial impression of where the solar boost project will be constructed at Kogan Creek Power Station.

Kogan Creek QLD - Solar Boost
April 2011, the Kogan Creek Solar Boost project was officially launched. The project will cost $98.8 million and be constructed by Areva using superheated solar steam technology. Kogan Creek Solar Boost will be the largest integration of solar technology with a coal-fired power station in the world. Construction started in 2011 and be complete in 2012.
The project involves the installation of a CLFR solar thermal system capable of generating 44 MW electrical at peak solar conditions, by supplying extra steam to the power stations existing turbine, thereby displacing coal. The project will reduce carbon emissions by about 35,000 tonnes per year, which is 0.8% of emissions, at a cost of only A$3 per tonne of carbon for the first year's emissions .

GOLDFIELDS RENEWABLE ENERGY LOBBY
(GREL)

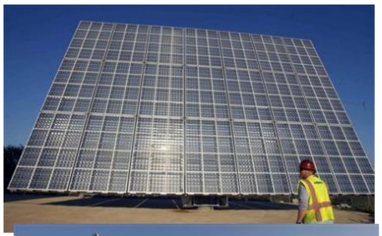
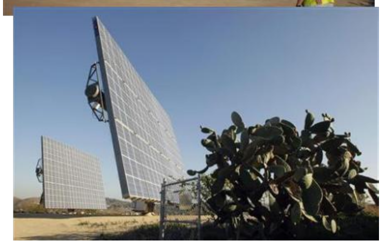
Solar Thermal Options – Big Dish Technology



Power Generation
Each Big Dish is capable of generating temperatures to 1,700ºC.
These temperatures are tailored for specific purposes:
500ºC to 650ºC for steam-based power generation
700ºC to 1700ºC for thermochemical applications and materials processing
900ºC to 1400ºC for gas turbines
This ability to deliver heat at a range of high-temperatures enables a number of options for power generation including:
Direct steam – the Big Dish delivers steam conditions that match most turbines – subcritical and supercritical
Integrate with gas power generation – the Big Dish's ability to match appropriate temperatures with gas fired plant equipment allows management of power generation during solar transients and after sunset. This offers utilities and grid operators a solution to the solar power issue of intermittency and power demand after sundown, providing a reliable yet flexible power generation solution.
Energy Storage – high-temperatures allow for a range of energy efficient storage options.
High Temperature Heat
Many industrial processes require high temperatures. Currently these are generally produced through burning fossil fuels, however Big Dish solar fields could provide the required heat. Examples of applications which require temperatures above 500ºC and that could utilise the heat from Big Dishes include:
Closed loop systems coupled with methanation for solar energy storage
Open loop systems to make: syngas; hydrogen; reduction of metallic oxides to make metals; detoxification and recycling of waste

GOLDFIELDS RENEWABLE ENERGY LOBBY
(GREL)

Concentrating Solar PV Generation

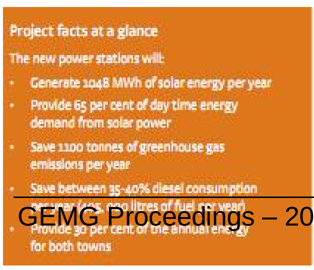




- Concentrating photovoltaic solar, or CPV is a fledgling but fast-growing solar technology that multiplies the sun's power up to many hundreds of times. Currently achieves >40% conversion efficiency compared to 20% for high efficiency Solar PV panels.
- CPV promises to deliver cheaper electricity than traditional panels and has received the backing of some major industry players.
- CPV, the technology is best suited for very sunny, desert-like locations.
- CPV is competitive even with the sharp drop in the price mainstream solar panels.
- Because the sun's power is literally multiplied, fewer solar cells, which are made from costly semiconductor materials are needed. That's a major advantage, CPV manufacturers say, as renewable energy is still racing to reduce its cost to compete without government subsidies with nuclear, coal and natural-gas-fired power.
- The cost of a high-efficiency CPV system is roughly equivalent to other PV projects today but is poised come down faster than other solar technologies. CPV systems at 2012 cost $1.50 - $2.20 a watt. Manufactured in Australia by Silex . – Bridgewater Power Station Mildura
- CPV concentrates the sun's light and delivers solar electricity for up to 20 percent less than traditional PV technology.

Marble Bar & Nullagine Power Stations - $27.7 m Project

Marble Bar's Pippunyah Power Station and the nearby Nullagine Power Station combine state-of-the-art technology to deliver clean energy to two of the country's hottest towns.
The power stations incorporate a single axis tracking solar farm with diesel technology and an energy storage system. This combination of technology can provide high levels of solar energy penetration and a reliable supply of power to the town.
During the day, the solar modules capture the solar radiation from the sun, converting it to electrical energy. This energy is sent directly to the distribution network. At certain times the solar modules will produce more energy than the local system can use so this excess energy will be diverted to the flywheel (a large spinning mass) where it will be stored as mechanical (kinetic) energy. When electricity production from the solar farm drops or demand from the local network increases, the energy stored in the flywheel is released into the network. In order to ensure power reliability and stability a diesel power station operates in conjunction with each solar farm. A specially designed control system manages electricity produced from both the diesel power station and solar farm to maximise energy from the solar modules, thus significantly reducing diesel usage.

The new power stations:
525 KWe Capacity, Generate 1048 MWh of solar energy per year
Provide 65 per cent of day time energy demand from solar power (90% actual achievement)
Save 1100 tonnes of greenhouse gas emissions per year
Save between 35-40 per cent diesel consumption per year (405,000 litres of fuel per year) .
The project cost $27.7 million. Horizon Power's analysis of the investment associated with installing the solar-diesel stations shows that the hybrid renewable solution delivers better value than equivalent diesel-only generation over the 20 year life of the asset. The system commenced delivering power in July 2011, Dec 11 review exceeded design and was producing 90% Solar with seamless integration and reliability.




Solar Precinct, Water Upgrades and Port Links Corridor

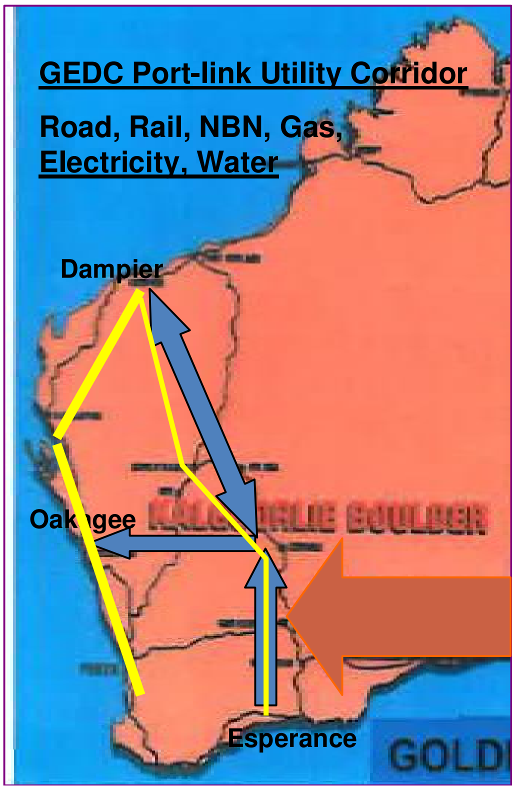
The Ultimate Solar Precinct in Kalgoorlie would generate 3,500MW of electricity (the equivalent of current SWIS Demand) and require approx 16 ML of water per day, the Kalgoorlie Pipeline currently delivers 25 ML to 40 ML per day to Kalgoorlie. The existing pipeline has the capacity to deliver the additional demand up to 60 ML/day with upgrades.

A future HV Transmission line could provide energy for Esperance Desalination. This also enables connection with and the future expansion of the Esperance Wind Farm as per the BZE document.

Future HV lines can be extended on the transport corridors to meet the needs for the future iron ore provinces in the Yilgarn and Menzies Areas.

This could provide Road, Rail, Gas, Communications , Electricity and Water Services along the Kalgoorlie-Esperance Infrastructure corridor and complete the first stage of the Goldfields Esperance Development Commission (GEDC) Port Links Corridor Plan to link up with Oakajee in the Midwest, Carnarvon in the Gascoyne, and Dampier in the Pilbara.

This could also free up capacity in the over-stretched Dampier to Kalgoorlie Gas Pipeline for other higher value uses for mining and industrial processing.

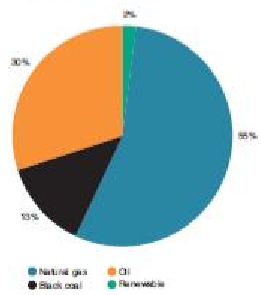


GOLDFIELDS RENEWABLE ENERGY LOBBY (GREL)

WA Govt Commitment to the Goldfields Solar Precinct

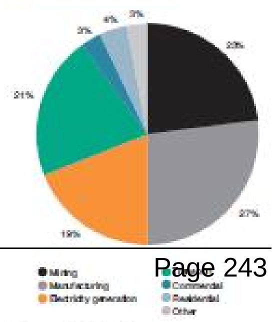
- Promote competitive advantages and opportunities available Kalgoorlie/Boulder.
- Commit to and support large scale generation precinct in Kalgoorlie/Boulder to realise Economies of Scale to attain competitive generation prices at below 13 cents/kwhr.
- Maintain capacity credits system to encourage private investors to source funds to build the Renewable Energy Generating Assets that have high establishment and construction cost but long term low operating cost.
- Establish a competitive renewable energy feed-in tariff that reduces over time to enable development of the renewable energy industry.
- Use the Royalties for Region Funding to upgrade Regional HV Lines to Bulk Transmission capacity to encourage Carbon Free Generation in the Regions and establish a Regional Industry.
- The Kalgoorlie HV line will reach capacity in 2013.
- Threat to increased competition from the WA Govt proposal to merge Verve and Synergy – may lock in a fossil fuel monopoly provider. CME, CCI are both critical of this proposal.

Figure 2: Primary energy fuel mix in Western Australia 2007–08



Source: ABARE 2008

Figure 4: Primary energy demand in Western Australia by sector 2008–09



Source: ABARE 2010

GOLDFIELDS RENEWABLE ENERGY LOBBY (GREL)

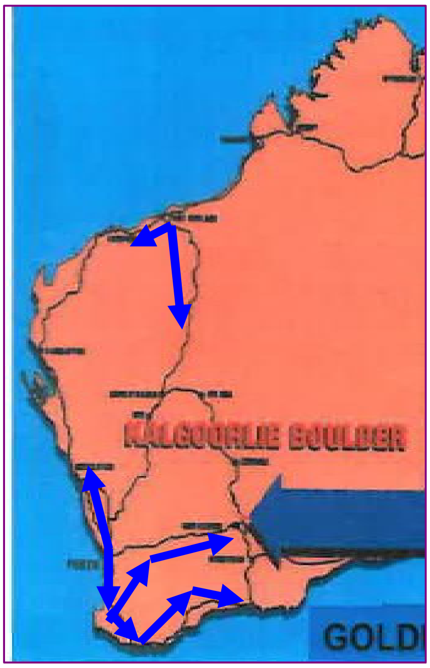
Investing in Western Australian Regional Bulk Transmission Lines

Regional Bulk Transmission Lines are necessary to facilitate Solar, Wind, Wave and Geothermal Generation in the Regional Areas and connect to Regional Industry Mining and Industry Base and the Perth Metropolitan Industry and Customer Base.

GREL proposes Regional Bulk Transmission Lines of 600 MW capacity each to facilitate renewable generation on the SWIS and NWIS.

1.Collie to Merredin/Kalgoorlie Line 700 km @ $700m
2.Collie to Albany/Esperance Line 750km@ $750m
3.Collie to Perth Upgrade 150km @ $200m
4.Perth to Geraldton/Oakagee Line 450 km @ $450 m
5.Upgrade the NWIS Newman to Port Hedland/Karratha 600km @ $600m

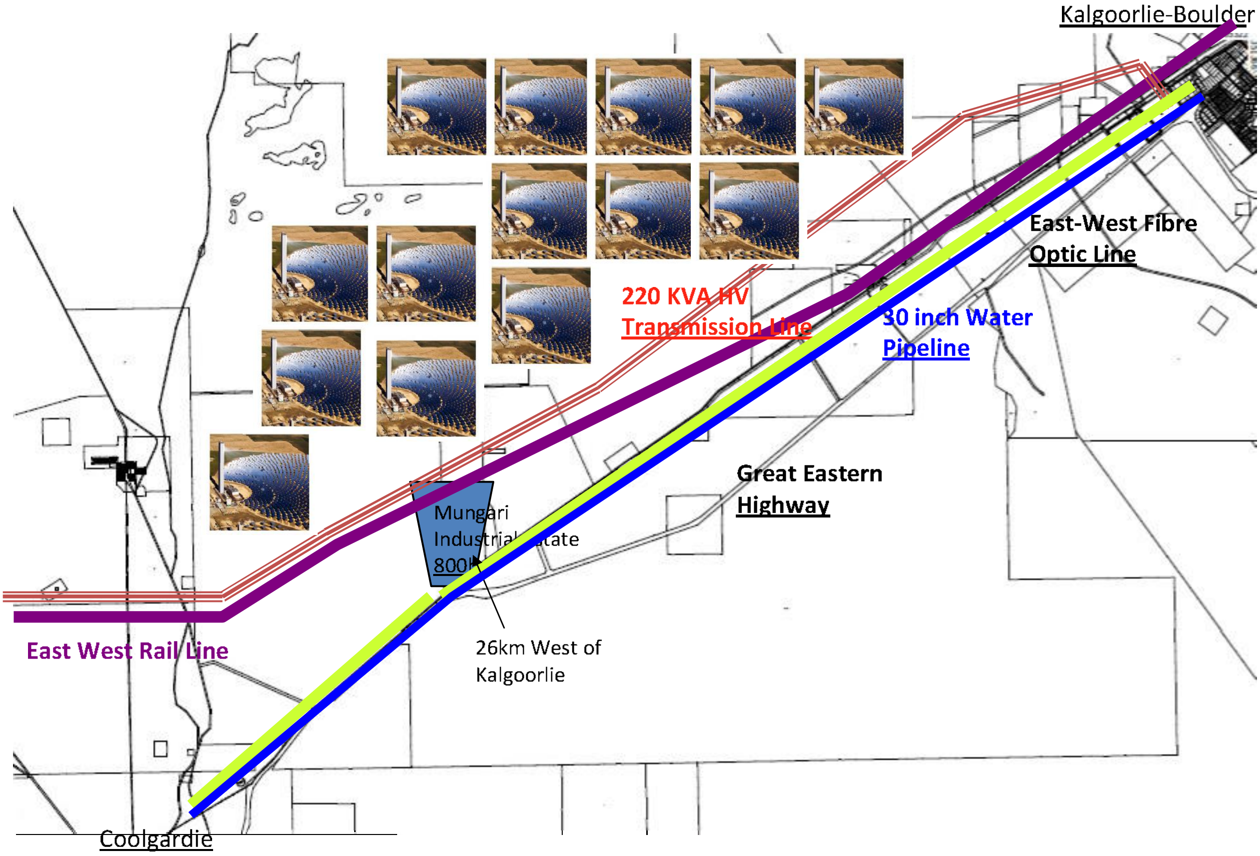
Prioritise funding by the Royalty for Region Program. $2.7 billion funded over 5 years will generate over $6 Billion in new generation projects. This will meet the projected increase in power demand outlined in the WA SEI Energy 2031 report from Renewable Energy Sourced from the Regions, strengthen the Regional Economic Base and mitigate against large Carbon Emissions impost to meet WA's growing energy demands.



Solar Precinct Land & Construction

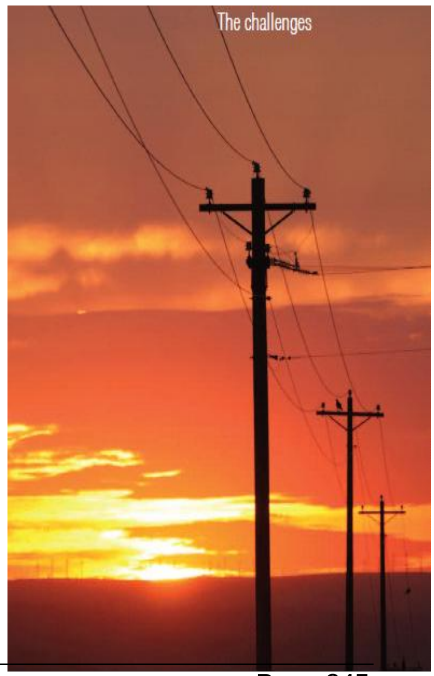
- The ultimate precinct of land area required would be around 240 SqKM (24,000 ha) enabling future growth capacity to supply the majority of new power demand in the South West Interconnected Scheme (SWIS) predicted to be 3,500MW over 20 years.
- The construction would be over 10 -20 years along lines similar to the recommendations in the BZE Plan, and utilising a 220MW CST Towers of Power installations as the optimum energy alternative.
- With this adaption comes the ability to install an additional 15 x 220MW installations to escalate generation to meet growing demands exceeding 3,500MW.
- Capital Cost are approx $1.2 billion for the first tower 220MW and $0.8 billion for each subsequent tower installation.
  Total Capital Cost = $13.2 Billion for 3,500 MW Generation Capacity.

Proposed Kalgoorlie Solar Precinct (24,000 ha)



Kalgoorlie to Muja HV Transmission Line Upgrades

- WA Govt commitment to upgrading of the Muja to Kalgoorlie 220 KVa HV Line to suit proposed Solar Precinct and scale up recommendations for an additional 150MW up to 3,200 MW ultimate plan over 10 years.
- Currently due to Gas Generation for Mining Companies, the Kalgoorlie line is under-utilised at 70MW of the total capacity of 130MW.
- The Colgar Windfarm provides 200MW into the line east of Merredin leaving Solar generation in excess of 100MW for Kalgoorlie/Boulder Power Demand Stranded by lack of line capacity.
- Need to determine the levels of demand for additional local generation capacity that Western Power require to proceed with the HV Line Expansion.



Goldfields Local Generation
both SWIS Grid and Off-Grid < 300kms

Local Generation –Grid Connected
(Area Shaded Yellow)

Cawse Nickel Mine (Natural Gas)	17
Kalgoorlie Townsite –Verve (Distillate)	82
Kalgoorlie Nickel Smelter (Natural Gas)	37
Kalgoorlie Parkeston (Natural Gas)	110
Kambalda Nickel Ops (Natural Gas)	37
Total Local Generation (MW)	283
Muja-Kalgoorlie HV (220 KVA) Transmission Line - 130MW	
Local Demand will exceed capacity by 2013	
40% Incr to 6,000MW in TOTAL SWIS Grid Demand by 2020	

Esperance (Natural Gas/Distillate) - 35MW

Esperance (Wind) – 6MW

Energy Generation Goldfields - NOT Grid Connected within 300km

Carosue Dam	10	Distillate
Darlot Gold Mine	12	LNG /Distillate
Gwalia Deeps	17	Natural Gas
Higginsville Gold Mine	11	Diesel
Jundee Gold Mine	22	Natural Gas
Laverton Town	2	Distillate
Granny Smith Gold Mine	31	Distillate
Leinster Nickel Mine	59	Natural Gas
Leonora Town	4	Natural Gas
Murrin Murrin Nickel Mine	78	Natural Gas
Menzies Town	1	Distillate
Mt Keith Nickel Mine	112	Natural Gas
Norseman	10	Distillate
Sunrise Dam	26	LNG /Distillate
Total Local Generation	395	MW

Cost of Solar Vs Fossil Fuels

Energy 2031 reports indicative Long Run Marginal Cost for comparable generation technology shows:

- Solar Thermal in2010 is $252 per MW, 2013 - $135 per MW (PPA)contract issued.
  (110MW Solar Tower Crescent Dunes Solar Energy Plant, located in Nevada, will commence operations in 2013 and generate enough electricity — 480,000 megawatt-hours annually – to power up to 75,000 homes, and will be the US's first commercial-scale solar power facility to fully integrate molten salt energy storage, as well as being the largest solar power plant of its kind in the world. Crescent Dunes has secured a 25-year power purchase agreement (PPA) with NV Energy. Electricity from the plant is projected to cost 13.5 cents per kilowatt-hour and will rise one percent per year during the 25-year PPA.)
- New coal and gas generation facilities is $90 per MW $90 MW and rising to$110 for gas, and $150, and $180 per MW for coal with carbon capture.
- Energy 2031 does not reconcile with costs in the BZE Report at $220 per MW for current operations and decreasing to $100 per MW for large for large scale solar thermal.
- Future innovation is predicted to lower solar thermal generation to $50 per MW.

Fossil Fuel Price and Supply Uncertainty

- Western Australia's Energy Fuel Mix 2007/08 – 55% Gas, 30% Oil, 13%Coal, 2%Renewable
- Only 4% is for Residential Use,
- Mining, Agriculture, Industry and Transport account for 96% of total WA Energy Use.

GREL submission to SEI *Energy 2031* includes

- Continued high dependency of Fossil Fuels will be problematical for future Western Australian Economic Development.
- Lock in a high cost and high risk energy future as Australia competes for fossil fuel resources at world parity prices and dealing with issues of supply vulnerability.
- Despite a large Gas export industry, WA has the highest gas prices in Australia.
- WA's Total GHG Gases Inventory of New Projects will double WA's current GHG Emissions from 75m tonnes/a to 150 m tonnes/a with new resource projects valued at $215.76B mooted in the next 5 years consisting of $133.45B approved projects and $82.31B not yet approved.

Source: WA Office of Energy Strategic Energy Initiative *Energy2031*:

Capital Value of Major Projects Approved next 5 yrs

Total Value ($B)	Total	WA	QLD	NT
Total Capital Value	$402	$216	$144	$42
Approved	$203	$134	$66	$3
Not Yet Approved	$200	$83	$78	$39

GOLDFIELDS RENEWABLE ENERGY LOBBY (GREL)

Merit Order Effect on Peak Power Generation and Prices

Why Generators are Afraid of Solar Power?

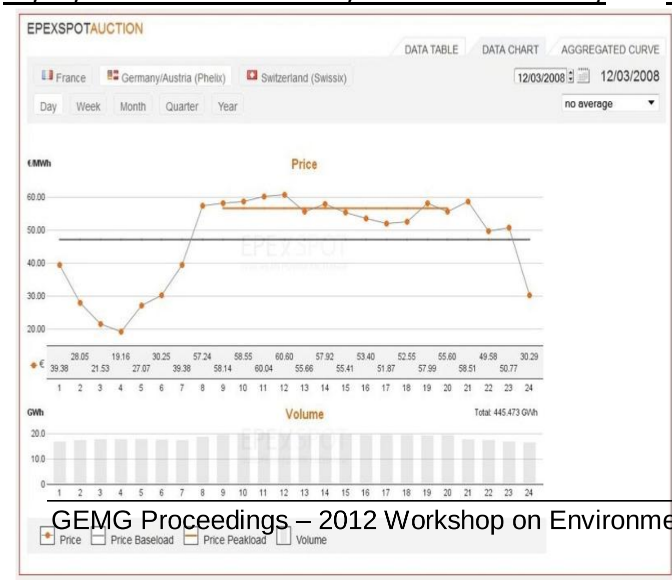
Germany has 25GW (19%) of Solar Generation in 2012 of 132GW Total Capacity

Saving E840million/a on peak power prices.

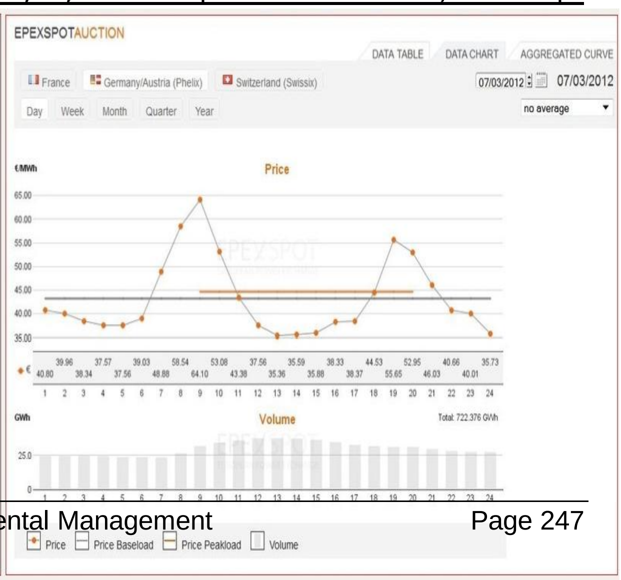
Cutting Peak prices by 40% in 2012 to E45/MW barely above the av generating price of E44/MW

Note: Av Generating Price drops from E49/MW in 2008 to E44/MW in 2012

12/03/08- Peak Prices at E60/MW most of the day



07/03/12 – Peak prior to 9:am at E65, then drops



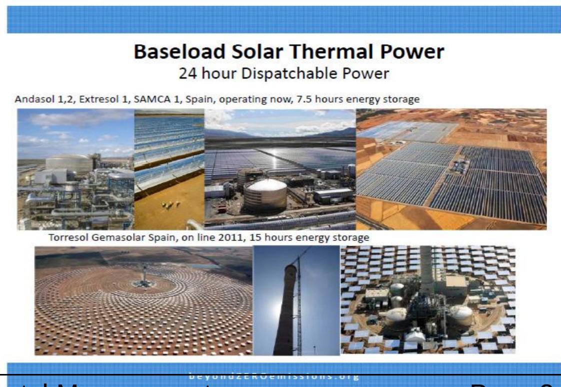
Goldfields Solar Precinct to Meet Future Energy Demands in SWIS

- WA Office of Energy Directions 2031 Report Figure 8 shows that the Independent Market Operator for Energy in WA estimates that 7147MW of generation will be required in the SWIS by 2020 requiring an additional 2275MW capacity in ten years.
- GREL intends to lobby the Minister to support a large scale Solar Precinct in Kalgoorlie to provide the majority (80%) of the additional 2275 MW capacity of Carbon Free Base load Power in one local energy precinct here, that will realise economies of scale and efficiencies of generating renewable energy to similar cost scenario to levels of new gas generation.
- Establish planning to achieve large scale solar generation by determining the milestones, trigger points and suggested timelines that Western Power would see to be feasible for the Kalgoorlie – Muja HV line upgrade to enable export of renewable energy back into the SWIS .
- Lobby the WA Govt and Western Power to commit to bulk transmission line augmentation by directing 50% of Royalties for Region Program to building Regional Bulk Transmission lines over a 4-5 year period.
- Support an EOI tender process of calling Private Business to fund and build the Solar Precinct and build private generation facilities to export renewable carbon free energy into the SWIS.
- Identify suitable and available land (24,000 ha) to be reserved and made available for Solar Generation purposes at minimal costs as a matter of urgency.
- When established the proposed Goldfields Solar Precinct can enable WA to exceed the 20% MRET by 2020 and significantly reduce Greenhouse Gases.
- It will ensure that power prices will become stabilised over the longer term as there is no scarcity of sunlight and allow the WA Market to be free of the fossil fuel cycle with rapidly increasing costs above inflation.

GOLDFIELDS RENEWABLE ENERGY LOBBY
(GREL)

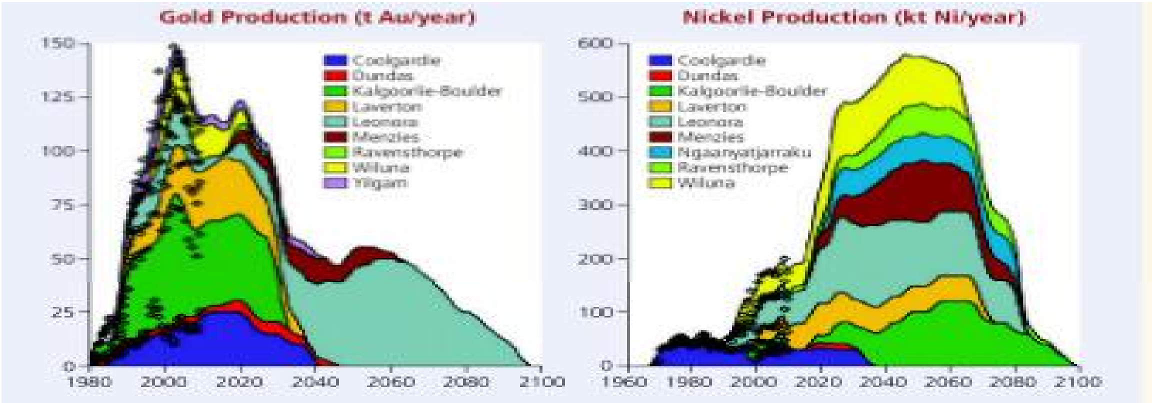
Solar Research Partnership Australian – German MOU

- Lobby the Australian Solar Institute and the national R&D Partnership with German Research MOU to seek out opportunities for collaboration to setup R&D facilities here.
- GREL has written regarding potential R& D Research capability with Curtin University Kalgoorlie Campus and the Proposed Solar Precinct.



GOLDFIELDS RENEWABLE ENERGY LOBBY
(GREL)

Decline of Goldmining Futures



•Gold Production peaked around 2005and projected to significantly decline by 2030.

•Nickel Production projected to grow to 2050 , then peak and decline by 2080.

•Planning is underway for the closure of the Superpit around 2022 with the prospective loss of 1800 jobs.

•Our gold miners will also have to consider the prospects, risks and rewards of deep vein mining.

The South African Gold Industry Lessons

- South Africa's gold companies, already mining at the world's deepest depths, are looking to plumb even deeper veins in a new gold rush spurred by record prices. The deeper miners go, the richer the ore being uncovered. The price in dangers, though, includes rockfalls, poisonous gas explosions, flooding and earthquakes.
- Miners do not need new technology to go deeper, but will have to use good refrigeration to cool temperatures in excess of 43.3 centigrade and for dewatering of these shafts. Chilled water or ice and water are pumped into reservoirs. In some cases, miners wear jackets padded with ice. Still, working conditions are sweaty. Meanwhile, water has to be constantly pumped out of the mine floor.
- The conditions require that deep vein mining requires vast amount of electricity to allow mining activity to occur at depth.

Energy Requirements for Future Deep Vein Mining

- Large scale generation for base load carbon free electricity will be demanded by industry, that is required for electrical motors to undertake deep vein mining in future years.
- Competitive Carbon Free Energy generation locally to service the mining industry direct from the Solar Precinct.
- We have abundant solar resources here and it will enable future energy prices to be stabilised as large scale solar thermal generation is undertaken. There is no scarcity of sunlight.
- Continued electricity generation using fossil fuel sources will lock the WA Economy into increasing generation cost spiral as we compete and pay world parity prices.
- Future solar thermal energy prices are projected to decline to less than 10 c/kwhr.
- Carbon free source means no CO2 Emission Prices (Tax) in a carbon constrained world production environment

GOLDFIELDS RENEWABLE ENERGY LOBBY
(GREL)

Environmental Offsets for Projects

The Commonwealth and Western Australian Governments have recently released new environmental offset policy documents. These policies are key indictors of how government will decide what environmental offsets will be required for project approval.

Commonwealth Offset Policy - Consultation Draft

•The Commonwealth Consultation Draft contains considerably more detail than the Western Australian Offset Policy and in some senses this is both a Policy and Guidance document. It is difficult to argue against any of the principles in the Draft and, like many similar high level documents, it will be how the Policy is implemented that will govern benefits or disadvantages to project proponents.

•Encouragingly, the following concepts are recognised:

•biodiversity banking

•proportionality of offset versus impact

•protection of existing bush as a potential offset

•that there must be a significant residual impact on a matter of national environmental significance before offsets will be required

•that third parties may, in certain circumstances, be best able to deliver offsets (which may include NGOs such as Bush Forever, Greening Australia, the Australian Wildlife Conservancy, Ecosystem Services and CO2).

•The Commonwealth has also created an Environmental Offset Assessment Guide. This Guide has an impact and offsets calculator, which should provide environmental practitioners with some practical guidance on how to formulate an offsets package for discussion with the Commonwealth.

•Unfortunately, the Commonwealth will not take into account, at the referral stage, any offsets package which has already been agreed with a State or Territory.

Western Australian Offsets Policy

•As a result of concerns expressed by industry and conservation groups around the application of offsets policy in Western Australia, the Department of Premier and Cabinet formulated a State Government Offsets Policy.

•The State Government Offsets Policy document is well balanced. It is proposed that Offset Guidelines will be produced. It will be the language of those, and how they are implemented at the officer level, which will determine how reasonably the Offsets Policy will be applied in practice.

•Many of the principles are similar to the Commonwealth Consultation Draft. In addition, Western Australia proposes to establish an offsets register to provide a public record of all offset

•Next steps and implications

•The Commonwealth Consultation Draft will be finalised on 21 October 2011 after a public comment period. Project proponents need to consider both documents very carefully in the formulation of proposed offset packages and at the outset of project planning.

•It is important to remember that offsets negotiations should be treated as commercial negotiations with government, so a well thought out negotiation strategy is critical. The strategy would deal with issues such as offset options (and values), what offset packages have been negotiated or imposed on existing projects, who should be in the negotiating team and when government should be engaged.

Contact Tony van Merwyk, Partner, Freehills Perth. 61 8 9211 7660 tony.vanmerwyk@freehills.com

Energy for future industry

- Carbon Fee energy for large Data Storage Warehouse
  ie Google, IBM
- Carbon Free Energy to sustain deep vein mining in Kalgoorlie/Boulder
- Carbon Free Energy for Minerals Processing in Kalgoorlie Boulder
- Production of Solar Fuels and Hydrogen Fuel Cells
- Minerals Fabrication Industry to replace depleted minerals in 50 plus years. Ie Silicon Based Metal Like Alloys and Compound Products.

GOLDFIELDS RENEWABLE ENERGY LOBBY (GREL)

Galaxy Resources Renewable Energy Mine - Ravensthorpe

100KW System

14 Tracking Solar Arrays – 15% efficiency gain over single axis system

2 x 1 MW wind turbines

Successful technology if rolled out on large industrial scale

Source Esperance Express Sept 2010

GALAXY Resources' Mt Cattlin mine is in the process of becoming Australia's first renewable energy-powered mine.

Green energy mine

By ALEX PAULL
alex.paull@ruralpress.com

GALAXY Resources is planning to establish the first mine in Australia to be completely powered by renewable energy.

The Mt Cattlin site in Ravensthorpe is the first mine site in Australia to have real-time solar tracking panels as part of its power generating requirements.

The solar tracking feature means the solar panels are able to follow the sun in all directions to maximise the [illegible] cent more power than a single axis system.

Galaxy's managing director of resources Terry Stark said at the moment Galaxy has a 100 kilowatt system in operation at the mine, which is made up of 14 tracking solar arrays, two one kilowatt wind turbines and a small battery storage.

Mr Stark said the move to power the mine solely by renewable energy was prompted by several factors.

"The increasing cost of diesel fuel used in the current diesel fired five megawatt power station was a factor, and the likelihood of a carbon tax being introduced by the Federal Government," Mr Stark said.

The move to renewable energy is set to cost $25 million, but Mr Stark said [illegible] number of issues to consider.

"The high capital cost per unit of capacity compared to conventional methods, suitable locations with reliable winds, storage of energy produced when the units are operating for use when they are not – these need to be taken into consideration," Mr Stark said.

While solar power is a relatively reliable source, Mr Stark said wind energy relied only on the vagaries of the wind, and was therefore not as reliable.

But Mr Stark said the use of renewable energy on mine sites could be successful on a large industrial scale in the future.

"The payback periods are long and currently the capital costs are high but this is likely to decrease over time," he said.

"The development of large scale energy storage batteries will improve the economics."

GOLDFIELDS RENEWABLE ENERGY LOBBY (GREL)

Solar Precinct Strengthens and Diversifies Kalgoorlie/Boulder Economic Base

- The Goldfields Renewable Energy Lobby (GREL) proposes the next ten years is the right time to get on and establish the large scale Solar Thermal Generation Precinct. Sufficient to meet all new demand on the SWIS over the next 10 years and to replace redundant coal plants.
- This will provide competitive base load power to keep mining sustainable in future years and also produce wealth in energy exports.
- **The precinct will generate 2,500 ongoing jobs in Kalgoorlie/Boulder**
- Provide the industry base to diversify the Goldfields economy and provide a bright economic future for our children.
- To achieve this goal we must start now.
- GREL is working with Barrick Gold to identify 24,000 of sterilised land suitable for solar farming to encourage future industry.

GOLDFIELDS RENEWABLE ENERGY LOBBY (GREL)

The Carbon Pricing Mechanism

- The carbon pricing mechanism will commence on 1 July 2012 with a fixed carbon price and will transition to a flexible price cap and trade scheme on 1 July 2015.
- 500 Companies emitting GHG >25,000 tonne/a pay the Carbon Tax direct. The rest pays through the price of electricity and fossil fuels. Incentive to lock in electricity prices from renewable sources to mitigate against future price rises.
- The carbon price will start at $23per tonne in 2012/13, increasing to $24.15 in 2013/14 and $25.40 in 2014/15.
- From 1 July 2015, the price will be flexible and determined by the market. A price ceiling and floor price will be in place over the first three years of the flexible price period.
- The price ceiling will be set at $20 above the expected international price for 2015/16 and will rise by 5 per cent in real terms each year. The price floor will be set at $15 in 2015/16, $16.00 in 2016/17 and $17.05 in 2017/18.
- More investment in local Renewable Energy Projects will mitigate against severe price rises in the Carbon Market as these project will create Carbon Permits that will become tradeable.
- A Large Scale Solar Generating Precinct in Kalgoorlie/Boulder will attract future investment as New project proponents will be seeking out Carbon Permits to Offset emission from their new projects which add to the overall Carbon Emissions Total.
- Some $200 Billion in new projects in Western Australia in the next 5 years, is expected to double Carbon Emissions in WA from 75M Tonnes/a to 150 M Tonnes/a,

Carbon Pricing Impacts of Western Australian Industry over the next 5 years

- WA GHG Emissions total 75 MT/a @ $23/ tonne = $1.7B/a and estimated to rise to 150M/ta = $3.4 B/a in 5 years.
- This rate of GHG growth indicated that carbon permits will become very expensive if industry emissions double in 5 years.
- Natural Gas price rises of 6% pa has been foreshadowed over the next 3 years,.
- Goldfields Miners will pay from $2m to $30m /a per minesite in Carbon Emissions Permits from 1 July 2012. Iron, Coal and Nickel Miners will pay much more.
- After 2015 Carbon Trading will occur with the market setting the prices that factors in growing scarcity as carbon emissions targets are tightened.
- Effective from 1 July 2012 the Stationery Diesel Rebate Reduces by 6 cents per year, until market parity is reached.
- Short term investment to reduce Carbon Liability in local mine site generation during day time hours. Solar PV and Concentrating PV Installations more readily deployable at individual mine sites and are cost effective,
- The 100MW Solar PV Generating Station will be constructed at Mungarie Industrial Park commencing late 2012.
- Longer term, we require shovel ready Renewable Energy Projects being 24 hour Solar Thermal Generation based in the Goldfields for local miners to invest in prior to 2015 when Carbon Trading commences and mitigate against future carbon permit rises
- GREL proposes that these miners invest in the Goldfields Solar Energy Precinct and benefit by directing carbon emissions costs to investment in Goldfields Energy Projects that will off-sett rising energy costs, secure carbon free energy supplies for future Goldfields Mining and Industry purposes, and reduce the increase on GHG Permit Costs.
- Secure Energy key to growth.

Capital Value of Projects in next 5 yrs

Total Value ($Billion)	Total	WA	QLD	NT
Total Capital Value	$402	$216	$144	$42
Approved	$203	$134	$66	$3
Not Yet Approved	$200	$83	$78	$39

Secure energy key to growth: CME

electricity needs would be met.

The South-West Interconnected System is the chief electricity network Western Australia, supplying electricity to the South-West, Albany, Geraldton and Kalgoorlie-Boulder.

But a Western Power spokeswoman said it was nearing its capacity limit for the Goldfields-Esperance region.

to the Energy Callachor was

"The Western Power network supplying the Goldfields area has sufficient capacity to cater for domestic and small commercial customers into future," the spokeswoman said.

"However, Western Power is aware the network is reaching its capacity limit, particularly for large industrial loads." Goldfields-Esperance Development Commission chief executive Robert Hicks said Western Power had told the commission peak load demand for the region could be reached by 2013.

"Forecasts for growth in the mining sector suggest the Goldfields-Esperance region will lead growth in WA," Mr Hicks said.

"If this is true, then the demand for power from various sources will only increase – this means future power security is a major issue for this region."

Mr Callachor said the SWIS would require an additional 14 per cent of additional generation capacity by 2015 and an extra 44 per cent by 2021, but the region would have an adequate supply of energy as long as the SWIS was expanded.

"A high percentage of the SWIS was constructed in the 1960s and 1970s and is reaching the end of its useful and safe life," he said.

"Significant investment is required to expand, maintain and replace much of the network to ensure it meets the growing need."

A spokeswoman for Western Power said there were a number of factors affecting the company's ability to implement solutions to rectify the region's capacity issue.

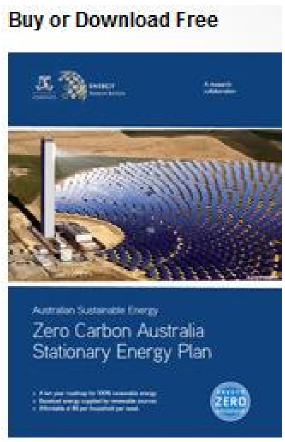
"One of the significant issues is a number of the large projects in the area are speculative, leaving Western Power to investment, the said.

She said Western Power had carried out comprehensive regarding meeting Eastern Goldfields, generators had preferred solution

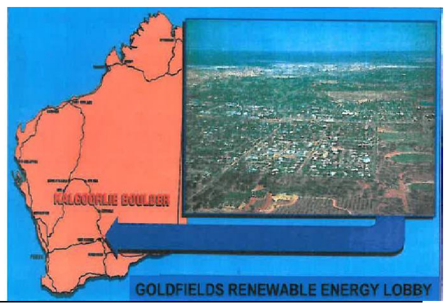
Mr Hicks said the region's energy requirements cussed at the commission's Friday.

Kalgoorlie Miner 6 Feb 2012

QUESTIONS ???



GREL are looking to willing Mining Industry and Community Partners to setup a "Kalgoorlie/Boulder Energy Precinct Foundation" to fund the reservation of the required 24,000ha of land for the future Solar Farming Industry.



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Mine Closure; The Forgotten Fauna

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Abstract

Fauna play a critical role in the re-establishment of near-natural, self-sustaining, functional ecosystems in rehabilitated mine sites. Yet, the Western Australian government's 'Guidelines for Preparing Mine Closure Plans' (DMP/EPA 2011) pay scant attention to re-establishing fauna assemblages in rehabilitated areas on mine sites. Many of the recently published mine closure plans indicate that mines have addressed the need to establish appropriate vegetation communities in their rehabilitated areas, but the fauna often seem to have been forgotten. There may be an assumption that if an appropriate vegetation community is established in the rehabilitated area, then the fauna will return. A review of the literature indicates that is not necessarily the case. Species abundance and richness are frequently lower in rehabilitated areas compared with analogue sites, and introduced species are often more abundant. Recolonisation of fauna into rehabilitated areas is dependent on many factors, including connectivity, appropriate soils, vegetation, invertebrate communities and the number of years since rehabilitation. We provide a review of issues involved with establishing pre-mining fauna assemblages in rehabilitated areas and suggestions on how the goldfields mining industry can improve rehabilitation in future closure plans.

Introduction

Mine rehabilitation, in one sense, is the treatment of post-mining areas to accelerate secondary succession towards the recovery of an ecosystem equivalent to that in an undisturbed area or pre-disturbance. It is generally assumed that this 'undisturbed area' supports a self-sustaining, functional ecosystem. It would be anticipated that this functional ecosystem is dynamic, complex and contains many biotic layers and facets. Fauna (i.e. microbial, invertebrates and vertebrates) are an important and necessary part of most functional ecosystems. Vertebrate fauna are often one of the last components to be established in the development of a functional ecosystem, as they are dependent on the soils, vegetation and invertebrates for the necessities of life (e.g. food and shelter).

Most of the recently available rehabilitation plans associated with mine closure that are focused on recreating a near-natural ecosystem address issues to do with clearing infrastructure, removing or neutralising contaminated and toxic materials, ensuring the site is safe, structures are stable, and that soils and vegetation are in place. Some go so far as to comment on the intended diversity and abundance of vegetation, but seldom is there any detailed commentary on the establishment of appropriate fauna communities. The recently released Department of Mines and Petroleum and Environment Protection Authority's (2011) Guidelines for Preparing Mine Closure Plans barely mentions the need to focus on re-establishing appropriate fauna assemblages in rehabilitated mine sites.

There seems to be an assumption that if an appropriate vegetation community is established in the rehabilitated area (see Majer 1984, Van Shagen 1986), then the fauna will return (Majer 1984, Van Shagen 1986, Block et al. 2001, Thompson and Thompson 2004). However, this is probably not the case in many situations, as a number of recent studies suggest a lack of correlation between vegetation diversity and fauna diversity (Crisp et al. 1998, Longcore 2003, Andersen et al. 2004, Flerishman and Murphy 2009). We have reviewed recently published Australian literature on fauna assemblages in rehabilitated mine sites and found as follows:

General Issues

- The focus of monitoring rehabilitation success has been on physical factors (e.g. water, erosion, land topography, stability, soil characteristics, etc) and flora (species richness and abundance) and there are many fewer examples of monitoring fauna assemblages (Smyth and Deardon 1998).
- Fauna species richness is more often used as a measure of rehabilitation success than the fauna assemblage (i.e. species richness, relative abundance, diversity and evenness, etc; Gould 2011);
- Which species are present rather than species richness is more important when comparing rehabilitated and undisturbed areas, as introduced species often replace native species in the species richness count in rehabilitated areas and the absence of particular species can provide information on aspects of the soils and vegetation that may need attention;

- Methods of rehabilitation, age of rehabilitated area and connectivity between source fauna populations and rehabilitated areas were the most highly correlated variables with recreating a near-natural, fauna assemblage (Gould 2011);

Fauna Indicators

- Ant assemblages in rehabilitated areas often bear little resemblance to undisturbed analogue sites (Andersen et al. 2003);
- Arachnid (i.e. scorpions, spiders, etc) recolonisation success is variable among studies (Brennan et al. 2003, Majer et al. 2007; and references therein);
- Increases in Collembola (i.e. springtails) and mite fauna densities are associated with increased flora diversity and vegetation cover (Majer et al. 2007);
- Birds are often the earliest of the vertebrate fauna to recolonise rehabilitated areas (Reeders 1985, Curry and Nichols 1986, Doyle and Kaeding 1986, McNee et al. 1995, Nichols and Grant 2007), however, hollow nesting birds are often late recolonisers of rehabilitated areas due to a lack of suitable breeding sites (Collins et al. 1985, Nichols and Grant 2007, Brady and Noske 2009);
- Crustaceans (i.e. slaters, landhoppers, etc) and Myriapoda (i.e. centipedes, millipedes, etc) are generally poor recolonisers (Collins et al. 1985, Van Shagen 1986, Majer et al. 2007);
- Some reptile species are generally slow to recolonise rehabilitated areas (Nichols and Grant 2007). The early reptile recolonisers are mostly the widely foraging, habitat generalists (e.g. Tiliqua rugosa; Underwoodisauris milii) and active predators (Pseudonaja affinis);
- Mammal recolonisation varies among species depending on the availability of preferred food sources and shelter requirements, and their distribution and abundance in adjacent areas (Nichols and Grant 2007);

Patterns of Fauna Recolonisation

- Rehabilitated areas often reach a plateau in recreating analogue undisturbed fauna assemblages, when the ‘early colonisers’ and ‘generalists’ were present but ‘habitat specialists’ have failed to colonise the area (Greenslade and Majer 1980, Andersen 1993, Majer and Nichols 1998, Moir et al. 2005, Craig et al. 2010);
- Early recolonisers were opportunists, generalists and thermophilics (Greenslade and Majer 1980, Majer 1984, Mawson 1986, Van Shagen 1986, Jackson and Fox 1996, Nichols and Nichols 2003, Moir et al. 2005);
- Introduced vertebrate species are frequently early colonisers and were often initially found in relatively high abundance (Fox and Fox 1978, Kabay and Nichols 1980, Andersen 1993) but their numbers declined as the rehabilitation matures (Fox and Fox 1978, Fox and Twigg 1991, Fox 1996, Nichols and Nichols 2003);

Fauna Monitoring Issues

- When predicting trajectories of rehabilitation fauna communities, species composition is a more meaningful parameter than species richness (Brady and Noske 2009, Gould 2011);
- Unambiguous and attainable outcomes should be established for mine rehabilitation and regular monitoring of progress is essential to inform adaptive management practices (Brady and Noske 2009);
- Exclusion of fire from mine sites, in areas where fires are prevalent, may affect the development and structure of the fauna assemblage (Brady and Noske 2009);
- Birds provide a useful early vertebrate indication of rehabilitation success, as they are relatively easily sampled, species rich and often abundant (Brady and Noske 2009); however, temporal variations need to be accounted for particularly in arid and semi-arid areas;
- Some invertebrate groups can provide a cost-effective means of generating information on rehabilitation progress and success but certain invertebrates groups can do it better than others (Majer et al. 2007);

Early Colonisers - Examples

Underwoodisaurus milii (Barking Gecko) is often found in high abundance in or near rehabilitated areas in the Goldfields (e.g. Gimlet South waste dump; Santa waste dump). These nocturnal geckos are typically found under rocks, sheets of iron, old building floors, etc, and newly established waste dumps often provide an abundance of crevices, few competitors and predators, so their numbers increase. As the ecosystem develops and approaches that in undisturbed areas, their numbers decline. *Mus musculus* (House Mouse), and to a less extent, *Sminthopsis crassicaudata* (Fat-tailed dunnart), behave in a similar fashion, and are often abundant in disturbed areas, with their numbers declining as succession progresses and other species become established in the rehabilitated area.

Ctenophorus nuchalis (Central Netted Dragon), a widely-distributed, dragon lizard that lives in burrows, is often found in abundance along disturbed road side verges, with its burrows in the windrows, but it is seldom found in the adjacent undisturbed areas. It is frequently reported in relatively high abundance in the early regeneration period after a fire, but as the vegetation matures its numbers decline (Pianka and Goodyear 2012). Whereas, *Ctenophorus isolepis* (Crested Dragon) almost disappear from the landscape after a fire and reappear as the vegetation regenerates and matures and as the number of *C. nuchalis* decline.

Late Colonisers – Habitat Specialists - Examples

Diplodactylus pulcher and *Rhynchoedura ornata* (Beaked Gecko) are small, widely distributed geckos that are present in most arid and semi-arid parts of Western Australia. These small geckos almost exclusively eat termites and as a consequence are infrequently found in rehabilitated areas due to the obvious lack of termites. Inclusion of mature trees, logs and decaying vegetation is therefore essential in the rehabilitated areas if these species are to form part of the fauna assemblage.

Translocations of Late Colonisers - Example

Napoleon's skink (Egernia napoleonis) is rarely caught in rehabilitated areas (Nichols and Grant 2007). Egernia napoleonis is a small skink that is relatively abundant in the south-west of Western Australia and has a preference for logs and stumps, which are often less available in rehabilitated mine sites. To understand why it was a late coloniser in Alcoa's rehabilitated areas in the jarrah forest, Christie et al. (2011) translocated six Napoleon's skinks into a five year old rehabilitated area and another six into unmined forest to be used as a control site. Skinks translocated into rehabilitated areas quickly moved into unmined area, and those in the rehabilitated areas moved greater distances than those in unmined areas. A lack of suitable micro-habitats in rehabilitated areas, such as ground logs and course woody debris, were probably the reason Napoleon's skink failed to recolonise rehabilitated area. The implication is that each species specific habitat requirements are essential before it will return.

Goldfields earlier vertebrate colonisers of rehabilitated areas

Species richness and abundance of reptiles and mammals on five rehabilitated waste dumps in the early successional stages (3 – 9 years old) around Ora Banda in Western Australia were compared with those in adjacent undisturbed areas (Thompson and Thompson 2007). Most small mammal species common in the undisturbed areas were also found in relatively high abundance on waste dumps, with the exception of Pseudomys hermannsburgensis (Sandy Inland Mouse). Mus musculus (House Mouse) and *Sminthopsis crassicaudata* (Fat-tailed Dunnart) were among the early colonisers, with both species being able to exploit a variety of habitats, tolerate open spaces, have a generalist diet and have good dispersal capabilities.

Underwoodisaurus milii (Barking Gecko), *Heteronotia binoei* (Bynoe's Gecko) and *Pogona minor* (Bearded Dragon) were among the early colonising reptiles that flourished in the developing ecosystems in rehabilitated areas. Of interest, *Pseudophryne occidentalis* (Western Toadlet) was relatively abundant on the top of a poorly rehabilitated waste dump, but was infrequently caught in the adjacent undisturbed area.

Goldfields late vertebrate colonisers of rehabilitated areas

In the same study discussed above (Thompson and Thompson 2007), fossorial and nocturnal skinks (Eremiascincus richardsonii, Hemiergis initialis, Lerista kingi, Lerista picturata) were seldom caught in rehabilitated waste dumps, although L. picturata was relatively abundant in five adjacent undisturbed habitats and L. kingi was relatively abundant in three adjacent undisturbed habitats. The loose surface sand that is characteristic of the preferred habitat for many of these fossorial species was mostly absent in the rehabilitated areas, although there was leaf-litter in which they could hide and forage.

Termite eating specialists geckos (e.g. *D. pulcher*, *R. ornata*) were seldom caught in rehabilitated areas due to a lack of suitable food. Two burrowing snakes, *Brachyurophis semifasciata* (Southern Shovel-nosed Snake) and *Simoselaps bertholdi* (Jan's Banded Snake), that have specialist diets (squamate eggs and fossorial skinks, respectively), were generally not caught in rehabilitated areas, probably because of a lack of a sandy substrate. Two species of blind snakes (*Ramphotyphlops* *australis*, *R. hamatus*) were also slow to colonise rehabilitated areas, possibly due to low dispersal capabilities.

Of particular interest was that Bolam's Mouse (*Pseudomys bolami*) was found on all waste dumps surveyed and often in greater abundance than in the adjacent undisturbed areas. Whereas, the ecologically similar Sandy Inland Mouse (Pseudomys hermannsburgensis) was only found on three of the five waste dumps, but was in all of the adjacent undisturbed areas and in lower abundance.

The typical successful rehabilitation process

Rehabilitation to a near-natural, self-sustaining, functional ecosystem is a sequence of steps that have been largely well documented, but worthy of summarising here:

1. Removal of toxic and contaminated materials.
2. Establishment of relatively stable substrate.
3. Provision of suitable top soils (i.e. structure, chemistry, pH, etc) including appropriate decomposing materials and moisture holding capabilities that enable the introduction and establishment of a functional microbial community and vegetation. It has often been argued that fresh, rather than stored top soil, is an important ingredient in this process (Grant et al. 2007).
4. Provision of logs, tree hollows, course woody debris and a surface texture similar to that in an adjacent undisturbed or analogue site is an important part of providing the appropriate infrastructure to enable fauna to return (Brennan et al. 2005).
5. Ensuring good connectivity with adjacent similar fauna habitats as this provides the necessary conduit for fauna to move from undisturbed areas into rehabilitated areas.
6. Seed and plant the area to ensure the ultimate vegetation community resembles that in adjacent undisturbed or analogue sites.

Monitoring Rehabilitation Success Using Fauna

The establishment of a fauna assemblage similar to that in the undisturbed or analogue site is the ultimate test of whether a near-natural, self-sustaining, functional ecosystem has been achieved in a rehabilitated area. The fauna assemblage is unlikely to mirror that in an undisturbed analogue site if the soils or the vegetation are inappropriate. Therefore, monitoring soils (including stability, structure, chemistry and erosion) and vegetation (including diversity and abundance) to measure rehabilitation success in the early stages of the rehabilitation process is important but will only tell the first part of the story. It cannot be assumed that if the soils and vegetation are similar to that in an analogue or adjacent undisturbed site that this will necessarily lead to the establishment of a near-natural, undisturbed fauna community within a reasonable time.

In the later stages of the rehabilitation program when the appropriate soils and vegetation community are in place, a suite of fauna should be considered as the primary monitoring focus. Invertebrates and birds should be the next monitoring focus. These assemblages are likely to be incomplete unless the soil microbes and vegetation assemblage is similar to that in the adjacent undisturbed area and well established in the succession process.

Reptiles and mammals should be the final focus of rehabilitation success, as a near complete assemblage of reptiles and mammals similar to those in the undisturbed analogue site is unlikely to be achieved unless appropriate soils and a mature vegetation community are in place.
Fauna present in the analogue undisturbed site but absent from the rehabilitated area can provide useful information about aspects of the rehabilitated area that require attention. For example, no or few hollow nesting birds in the rehabilitated area may indicate a lack of tree hollows, no or few fossorial reptiles (sand swimmers) in the rehabilitated area may indicate a lack of a sandy substrate, no or few termite eating specialists in the rehabilitated area may indicate a lack of dead and decaying wood, and no or a few of the log and crevice dwelling species in the rehabilitated area may indicate a lack of logs and course woody material.

An abundance of known earlier colonisers, including introduced species, should be anticipated to precede the establishment of fauna communities that are evident in undisturbed areas. The presence of these earlier colonisers and introduced species in the fauna assemblage can be a clear indication of how far along the succession trajectory the rehabilitation area has progressed.

In monitoring rehabilitation progress, the fauna assemblage should be measured in preference to species richness (Gould 2011). Typically, the vertebrate fauna assemblages present during the early stages of a rehabilitation program have less species than the more mature areas and the relative abundance of species alters as the area matures. The presence and abundance of large carnivorous predators can also appreciably alter the assemblage composition, as some predators focus on particular species or guilds of fauna.

KPI for Measuring Mine Site Closure

Toward the end of the rehabilitation process, the vertebrate fauna assemblage can provide a very useful key performance indicator (KPI) for measuring the success of the program. It is useful because the fauna assemblage should be approaching that in undisturbed or analogue sites and differences in the assemblages will often indicate deficiencies in the soils and vegetation. These differences often provide clear pointers to components of the rehabilitated area that are not present or are failing to perform as required (e.g. soils, vegetation, logs, course woody debris, termites, etc). They are relatively easily measured, and skilled and knowledgeable people are available to establish and assist with the monitoring and reporting program.

Like most monitoring programs, appropriate ‘control’ sites are an essential aspect of the monitoring program. Bird and mammal abundances fluctuate in arid and semi-arid areas based on rainfall and the availability of resources. These variations are both seasonal and from year-to-year. Some mammals are short lived, with males dying off after the first mating period (e.g. dasyurids), others are able to rapidly increase their numbers by having multiple litters in a short period when conditions are favourable. Many of the arid and semi-arid birds will shift foraging areas when food resources become scarce; others are nomadic and seem to continually move in search of abundant resources. Control sites are particularly important for these taxa, as changes beyond the rehabilitation program need to be excluded from the analysis. Reptiles show less year-to-year fluctuation, with many having established home ranges and living for multiple years, so they may provide more stable taxa for monitoring changes in the rehabilitation.

Small datasets and inadequate data are the curse of many Australian fauna monitoring programs. In small data sets, the common species are normally well represented but the rarer species are infrequently present. As the size of the dataset increases, there is an increased propensity of the rarer species to be represented. Larger data sets are therefore more likely to represent more of the species present and will provide a more accurate estimate of relative abundance. This is particularly important if the monitoring is based on species richness. Fauna assemblages are characterised as containing a few abundant species, a higher number of less abundant species and a large number of relatively rare species (Figure 1). A fauna monitoring program therefore needs to be developed that recognises the generic structure of fauna assemblages and resolves during the planning process which species will be used in the monitoring program. For example, if birds are to be used as the indicators, then the focus should be on the small birds that are mostly sedentary have defined home ranges and disperse after the fledging. Migrant and nomadic birds that are continually moving in search of better resources and whose numbers fluctuate due to non-local factors would be less suitable as indicator species.

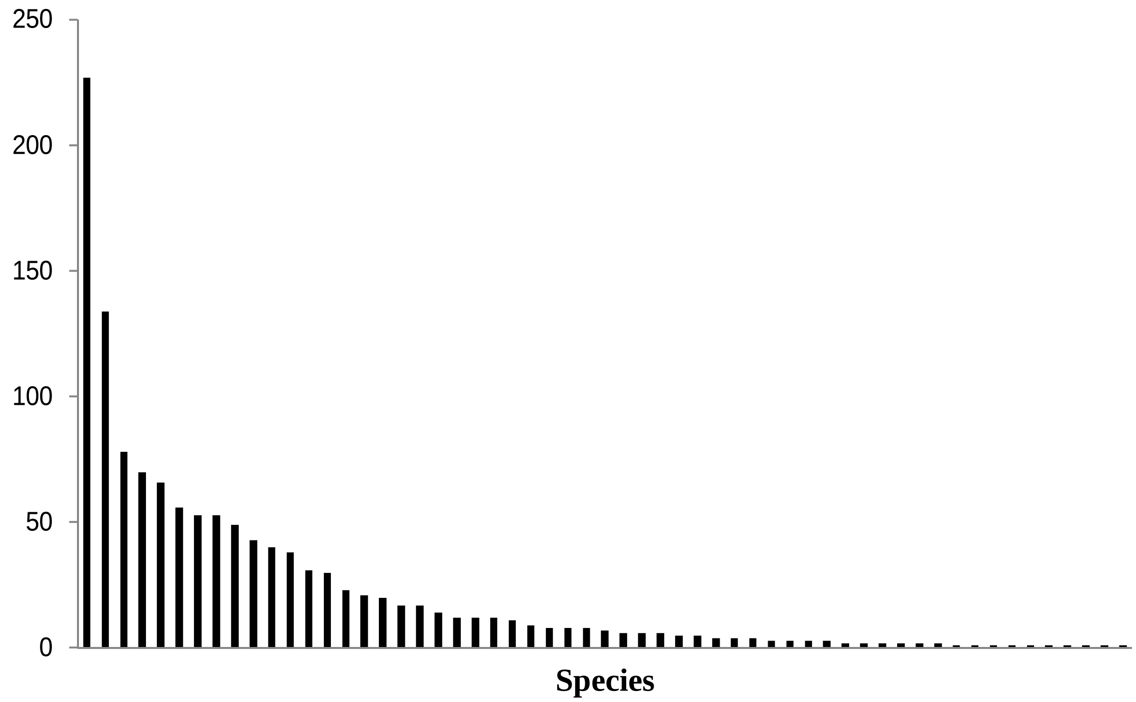

Figure 1. Typical trapped vertebrate fauna assemblage structure

Rehabilitation and Degradation Index

The Rehabilitation and Degradation Index (RDI; Thompson et al. 2007) was designed and developed for Western Australian conditions; in fact the primary data was multiple rehabilitated sites in the Goldfields of Western Australia. The RDI can be used to quantify either rehabilitation success or fauna habitat degradation for terrestrial environments using data on the reptile assemblage. It utilises metrics associated with diversity, assemblage composition and ecological parameters. Each of these parameters is further sub-divided and an overall weighted score out of 100 is calculated for a disturbed or rehabilitated area.

A completely disturbed area (e.g. newly constructed waste dump) that is devoid of reptiles will have a score of zero. The score will increase towards 100 as the reptile assemblage on the waste dump converges with that in the adjacent undisturbed area. The attributes for each of the stages in this progression are described in Table 1. These are not discrete stages but are a continuum of rehabilitation progress.

Table 1. Suggested reptile assemblage attributes associated with each class of RDI score (Thompson et al. 2007).

Attributes	RDI score
Comparable to the best situation without human impact; regionally expected species for habitat type; species present with a full array of age (size) classes; balanced ecological structure; self-sustaining functional ecosystem.	86-100
Species richness approaching expected levels; not all late succession species present, some species present with less optimal abundances or size distribution; ecological structure incomplete.	61-85
Species richness below that in the undisturbed area, some groups not well represented, some specialists not present.	41-60
Lack of specialists, fewer species than in the undisturbed area, skewed ecological structure and relative abundances.	21-40
Few vertebrates present; only early colonisers present, lack of community structure.	11-20
Only opportunistic early colonisers are present. No community structure.	0-10
No reptiles present.	0

So how can we move forward?

Structural Issues

For mine closure plans that intend to return an area to a near-natural, functional ecosystem, the rehabilitation program is mostly about accelerating secondary succession. Vertebrate fauna assemblages in rehabilitated areas will only be similar to those in the adjacent undisturbed areas if the soils and vegetation are similar, thereby providing a similar range of habitat niches. Unless during the rehabilitation process an appropriate vegetation community is established, including a range of logs of varying sizes and ages are placed in the area, it will take many years for the full range of fauna niches to develop. Under these conditions, only those species with very plastic diets and habitat requirements are likely to colonise rehabilitated areas during the early stages of development. Even when conditions are ideal, low dispersal capabilities and pressures of many vertebrate species may mean that some will take many years before they become established in rehabilitated areas. Continuous cleared aprons around rehabilitated areas (e.g. waste dumps) reduce connectivity and inhabit the movement of many small fauna into rehabilitated areas.

Policy Issues

There needs to be a greater focus on recreating a near-natural, self-sustaining, functional ecosystem when planning for mine closure. Achieving an appropriate vegetation community, although important, is only part way along the succession trajectory and does not necessarily ensure the end stages will be achieved. To this end, DMP/EPA might consider amending their '*Guidelines for Preparing Mine Closure Plans*' to provide a greater focus on achieving a near-natural, self-sustaining, functional ecosystem as the end point of mine closure.

The KPIs and the tools that we use to measure success largely drive our mine closure planning and the end results that we achieve. The recreation of near-natural fauna assemblage should be an integral part of all mine closure plans, for those intending to return the area to a near undisturbed natural situation. For this to occur, mine closure KPIs should include the creation of near-natural fauna assemblages.

Appropriate suites of birds and invertebrates are useful bio-indicators toward the end of the rehabilitation succession process, and reptiles and mammals are useful bio-indicators in the run-up to seeking sign-off and a return of outstanding bonds. The RDI is a useful, end of the succession process tool to demonstrate to the regulators the rehabilitation area is nearing an appropriate stage and is ready for sign-off.

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Assessment of Temporary Aquatic Systems in Flood:

Two Mine-Related Case Studies from the North-Eastern Goldfields

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Abstract

This paper presents two case studies of ecological studies completed for temporary aquatic systems from inland Western Australia, undertaken during flood events early in 2011, in relation to the different stages within the life of mining. The first was a baseline study of the ephemeral Jones Creek system, comprising six creekline and four terminal claypan sites. Sampling was conducted over two phases, corresponding to the initial flooding and subsequent drying of the system, and yielded a comprehensive suite of ecological data prior to proposed nickel mining. The second case study was an opportunistic wet sampling event of Lake Carey, and peripheral wetlands, also conducted in two sampling phases. Although distinct conditions were recorded in two claypans on the edge of the lake, the abiotic parameters and biotic assemblages were similar throughout the main playa and adjacent creekline. There were no differences identified between control sites and those influenced by dewatering discharge associated with mining operations. The findings of these studies highlight the importance of capturing data on aquatic ecosystems during their most productive phase following flood events, in order to accurately document conservation values and provide appropriate management strategies for mining companies.

Introduction

Temporary aquatic systems in the arid and semi-arid zones are rarely subject to large flood events, which tend to occur only after heavy rains associated with tropical low pressure systems. These events provide a rare opportunity to undertake ecological studies of temporary creeks and lakes that may be affected by mining activities, in order to provide a risk assessment prior to mining, or to monitor the resilience of the system following mine-related impacts. This paper presents two case studies undertaken during flood events in early 2011, and examines the ecology of aquatic systems either before or after mine development. Both systems are located in the north-eastern Goldfields, with one being an ephemeral creekline; Jones Creek, and the other a large salt lake; Lake Carey.

Jones Creek and Claypans

Located 25 km south of Mt Keith in the northern Goldfields, Jones Creek is a temporary creek system incised into the Barr-Smith Range that terminates into a number of claypans to the south-west (Figure 1). In order to develop an existing nickel resource, a small section of the creek in the northern part of the catchment requires diversion, which will result in reduced downstream flow. A large rainfall event in February 2011 led to substantial creek flow, flooding the claypans, and allowing for the ecological assessment of this system.

Lake Carey

Lake Carey, a large, temporary salt lake situated 25 km south-west of Laverton (Figure 2), has received ongoing hypersaline dewatering discharge from a number of mining operations on its periphery. The lake has been monitored on an annual basis since 2000, providing a comprehensive regional data set for comparison, although data from flood events has been lacking. Early in 2011, the lake completely flooded, providing a rare opportunity for sampling aquatic biota and abiotic parameters.

Methods

Jones Creek and Claypans

A baseline aquatic study of this system was undertaken over two survey phases in March and April 2011. Ten sites were established including six along the creekline and four within the terminal claypans and floodplain area (Figure 1). Abiotic and biotic components were assessed, and involved the collection of water and sediment for the analysis of an extensive suite of parameters. Biological samples, including algae (phytoplankton and diatoms) and aquatic invertebrates (zooplankton and macroinvertebrates), were also collected and were returned to the laboratory, where they were sorted and identified. Platyzoan and protozoan species were also identified from the zooplankton samples collected during the baseline study, and frog species were photographed and identified on site. Data collected was subject to univariate and multivariate statistical analysis, to discern trends between creek and claypan sites, and between the wet and drying sampling phases.

Lake Carey

An extensive regional monitoring program was conducted during the initial stages of inundation in March and April 2011, with 16 sites sampled, the majority of which occurred on the playa. Sites comprised of those affected by dewatering discharge, historic dewatering discharge sites and un-impacted sites. Water and sediment was collected for chemical analysis and biological samples, including algae and invertebrates, were also taken for assessment. Data collected was subject to univariate and multivariate statistical analysis, to determine differences between sites influenced by dewatering discharge, and un-impacted sites (controls).

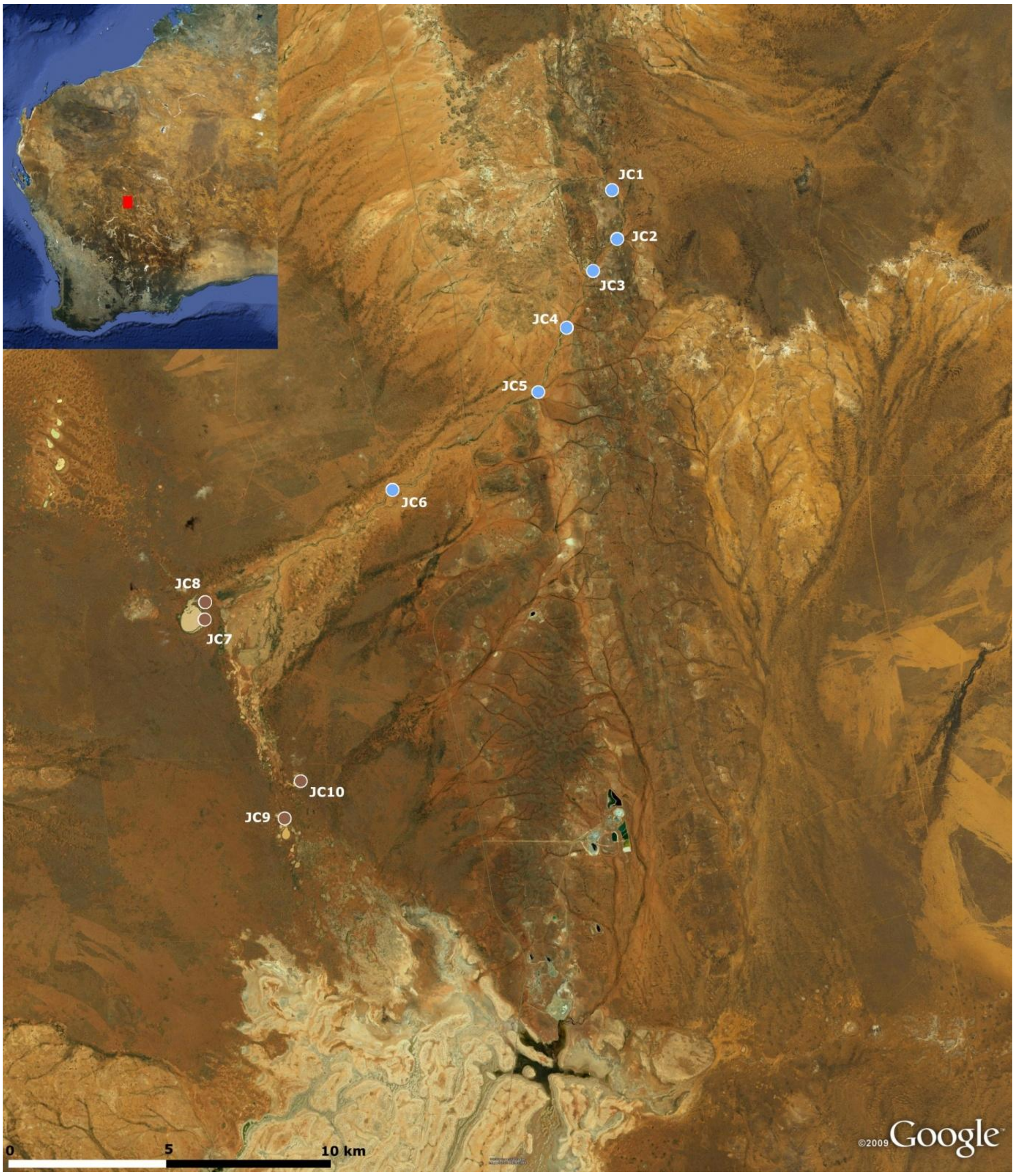

Figure 1. Location of the Jones Creek system, indicating the creekline (blue) and terminal claypan (brown) sites studied.

Figure 2. Location of Lake Carey, indicating the lake (green), adjacent creekline (blue) and peripheral claypan (brown) sites studied. Sites LC2 and LC10 were subject to dewatering discharge in 2011.

Results

Jones Creek and Claypans

Both the creek and claypans are freshwater systems, however the study showed the residence time of water in the creekline was short (<2 months) in comparison to the claypans (>6 months). Following heavy rainfall, the creek waters were characterised by numerous clear pools, while the claypans were highly turbid. The system was classified as fresh throughout, with the claypans having higher total phosphorus concentrations. High dissolved aluminum concentrations were also recorded in the claypans, exceeding the ANZECC guideline trigger value for the protection of 80 % of freshwater species (0.15 mg/L) (ANZECC 2000). Copper levels were also above the ANZECC trigger value (0.0025 mg/L) at many sites in both the creek and claypans (Figure 3).

The study identified 33 phytoplankton taxa, dominated by Chlorophyta (green algae). Bacillariophyta (diatoms) were also prevalent, with a further 35 taxa recorded from periphytic samples (Table 1). There were differences between the creek and the claypans, with higher phytoplankton productivity (dominated by the filamentous chlorophytes *Mougeotia* and *Spirogyra*) in the clear, still waters that pooled along the creekline. In contrast, there was a higher diversity of diatoms in the claypans, characterised by freshwater genera such as *Eunotia*, *Gomphonema*, *Nitzschia* and *Pinnularia* (Table 1). Up to 76 aquatic invertebrates were recorded (although some could not be identified to species level), with the creek dominated by transient insect taxa such as *Eretes australis* (coleopteran; water beetle), *Anisops stali* (hemipteran; backswimmer) and *Hemianax papuensis* (odonatan; dragonfly larvae), which have mobile adult stages (Plate 1). In the claypans, resident crustacean fauna were abundant, including several species of copepods, ostracods and branchiopods (Plate 2). A total of 55 protozoan and platyzoan species were recorded, primarily rotifers (49) with fewer species of amoebozoa (5) and a single gastrotrich (Table 1). Frogs and/or tadpoles were observed at all claypan and creek sites during the 2011 study, with three species verified, including *Cyclorana maini*, *Cyclorana platycephala* and *Litoria rubella* (Table 1). Tadpoles of a fourth species could not be identified due to their immaturity.

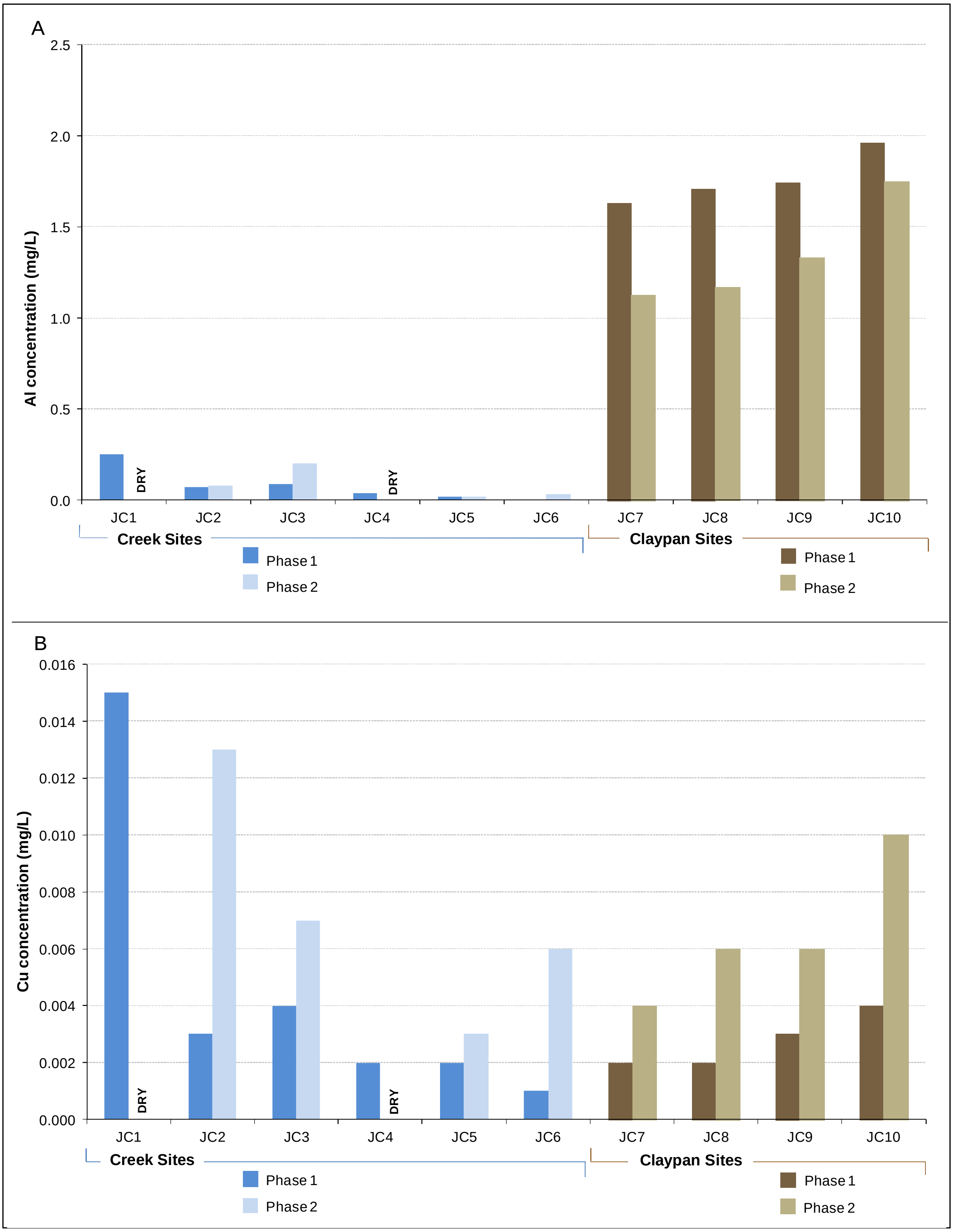

Figure 3. Concentrations of aluminium and copper in surface waters across the two survey phases.

Table 1: Biota recorded from the ephemeral Jones Creek system, 2011.

Taxa	Creek	Claypan	Total
Phytoplankton			
Bacillariophyta	5	8	9
Chlorophyta	19	12	21
Cyanophyta	0	1	1
Dinophyta	1	0	1
Euglenophyta	1	1	1
Periphyton	20	32	35
Invertebrates			
Platyzoan/Protozoan	41	42	55
Insects			
Coleoptera	9	4	10
Diptera	17	8	20
Hemiptera	4	5	6
Lepidoptera	1	0	0
Odonata	7	5	7
Trichoptera	1	1	2
Crustaceans			
Branchiopoda	2	12	12
Copepoda	3	5	6
Ostracoda	8	8	13
Frogs	4	2	4
TOTAL	**143**	**146**	**203**

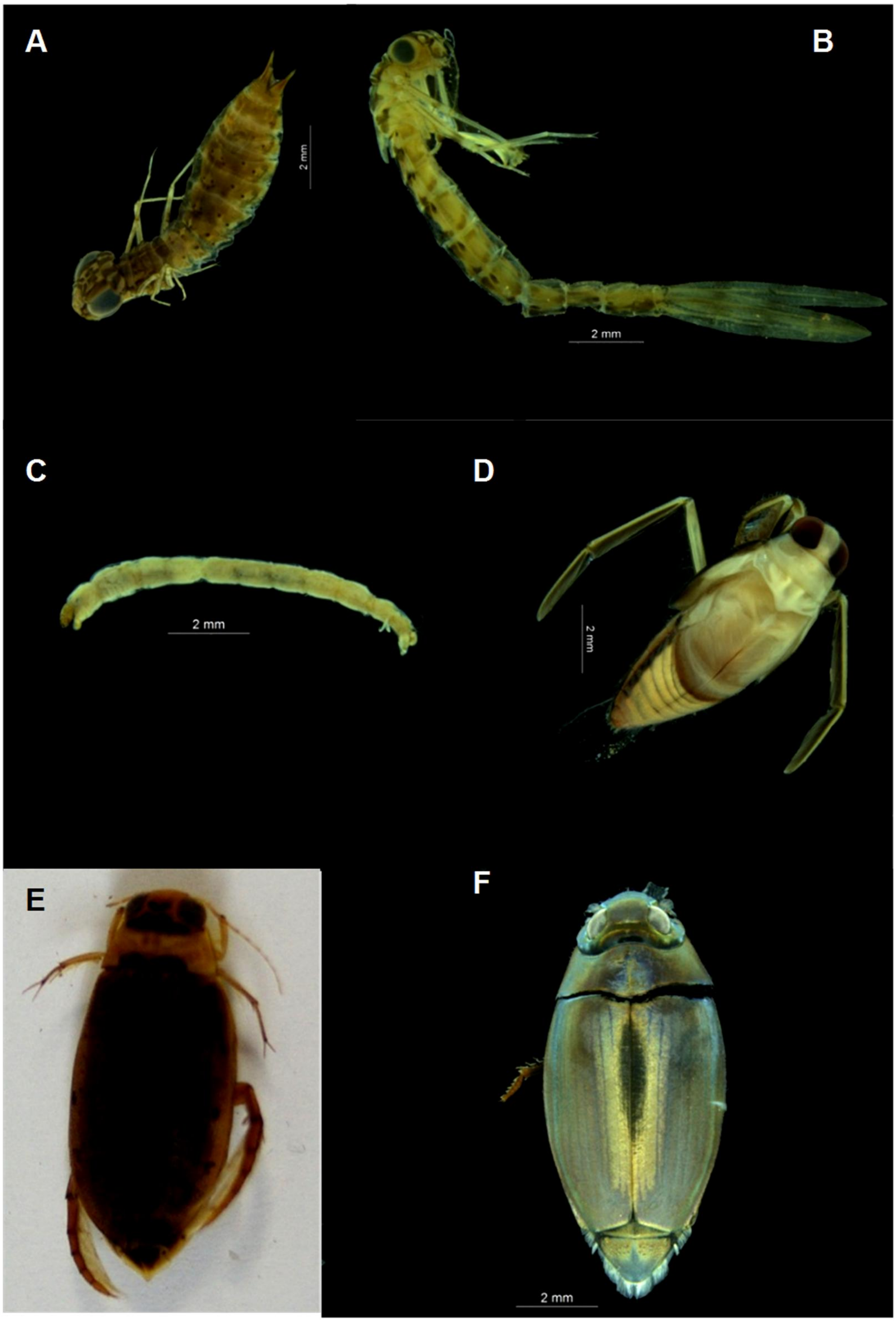

Plate 1: Selected invertebrates recorded from creek sites in the ephemeral Jones Creek system, 2011. (A) *Heminax papuensis*, (B) *Austrolestes analis*, (C) *Kiefferulus intertinctus*, (D) *Anisops stali*, (E) *Eretes australis* (length=1.7 cm) and (F) *Dineutus australis*.

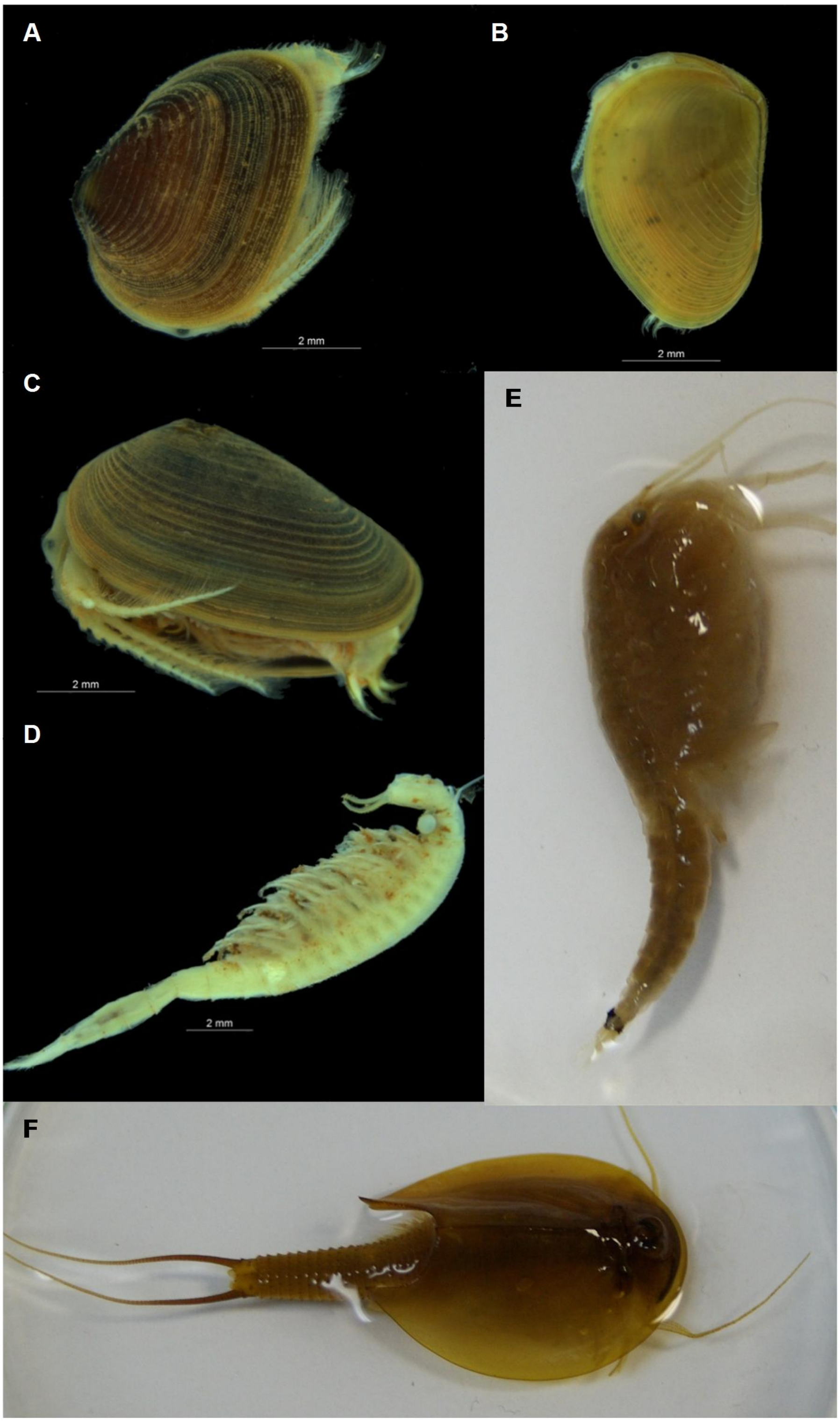

Plate 2: Selected invertebrates recorded from claypan sites in the ephemeral Jones Creek system, 2011. (A) *Caenestheriella* sp., (B) *Eocyzicus* sp., (C) *Caenestheria* sp., (D) *Branchinella halsei*, (E) *Branchinella occidentalis* (length=3.1 cm) and (F) *Triops* nr. *australiensis* (length=4.1 cm).

Lake Carey

The large flood led to relatively low surface water salinities in the initial stages of the hydroperiod, which were classified as hyposaline to hypersaline (Figure 4) as the lake entered the drying phase. Previous salt crusting associated with dewatering discharge had dissipated, and metal concentrations were generally low in comparison to historic trends. This was also the case for sites influenced by the dewatering discharge, which showed a decrease in salt and metal loads in contrast to past studies, where concentrations were elevated. Statistical analysis indicated there were no differences between sites affected by dewatering discharge and control sites. Conditions were similar throughout the lake, and adjacent creekline sites, although salinities were much lower at the two peripheral claypan sites.

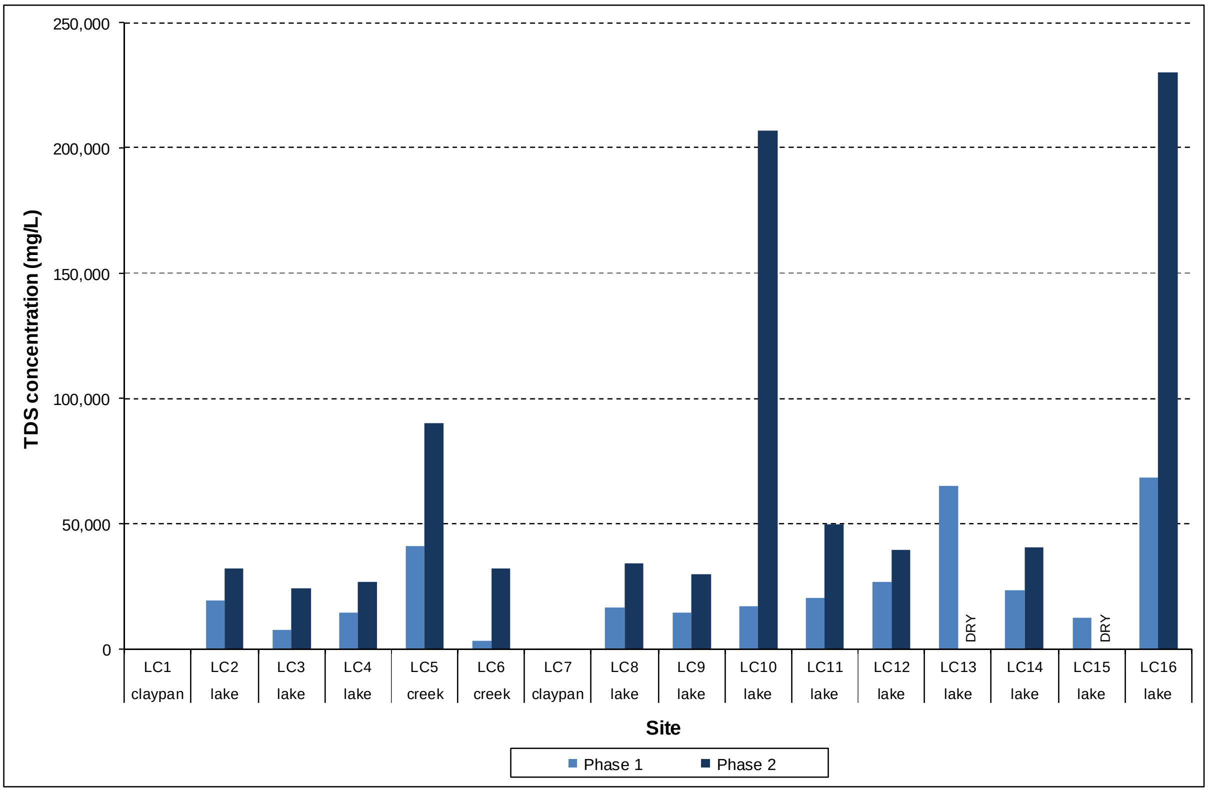

Figure 4. Salinity, measured as total dissolved solids (TDS), in Lake Carey across the two survey phases.

Productivity during the flood event was high, with a diverse array of algae and invertebrates found during the course of the hydroperiod. There was a decrease in diversity as water levels receded and surface water salinities increased. A total of 33 phytoplankton taxa were found, characterised by chlorophytes including *Mougeotia*. and diatoms. Further analysis of diatom assemblages identified 51 species, dominated by *Amphora*, *Hantzschia*, *Navicula* and *Nitzschia* representatives. As many as 57 aquatic invertebrate taxa were recorded, with crustaceans such as *Moina baylyi*, '*Dragoncypris oubtacki', Meridiecyclops platypus, Parartemia bicorna*, *Branchinella simplex* and *Triops* nr *australiensis* dominating assemblages (Table 2, Plate 3). Insects were uncommon in the lake, although they were recorded in two flooded claypans on the periphery of the lake in fresh water conditions (Plate 4). Statistical analyses found no differences between sites influenced by dewatering discharge and control sites. Due to the large amount of data collected during the study, salinity ranges were established for all groups of biota (phytoplankton, diatoms, invertebrates), which can be further refined in future flood events.

Table 2: Biota recorded from Lake Carey, 2011.

Taxa	Lake	Creekline	Claypan	Total
Phytoplankton				
Bacillariophyta	11	8	6	13
Chlorophyta	8	6	15	15
Cyanophyta	3	0	2	4
Euglenophyta	1	0	1	1
Periphyton	28	11	21	51
Invertebrates				
Insects				
Coleoptera	2	2	2	2
Diptera	2	5	2	6
Hemiptera	0	0	4	4
Odonata	2	2	1	4
Crustaceans				
Branchiopoda	18	4	13	24
Copepoda	3	3	7	9
Ostracoda	5	1	5	8
TOTAL	**83**	**42**	**79**	**141**

Plate 3: Selected crustaceans recorded from Lake Carey, 2011. A1, Eocyzicus parooensis; A2, Caenestheria sp.; B, Triops nr. australiensis; C, Branchinella simplex; D, Branchinella denticulata; E, Repandocypris austinensis; and F, Cyprinotus sp.

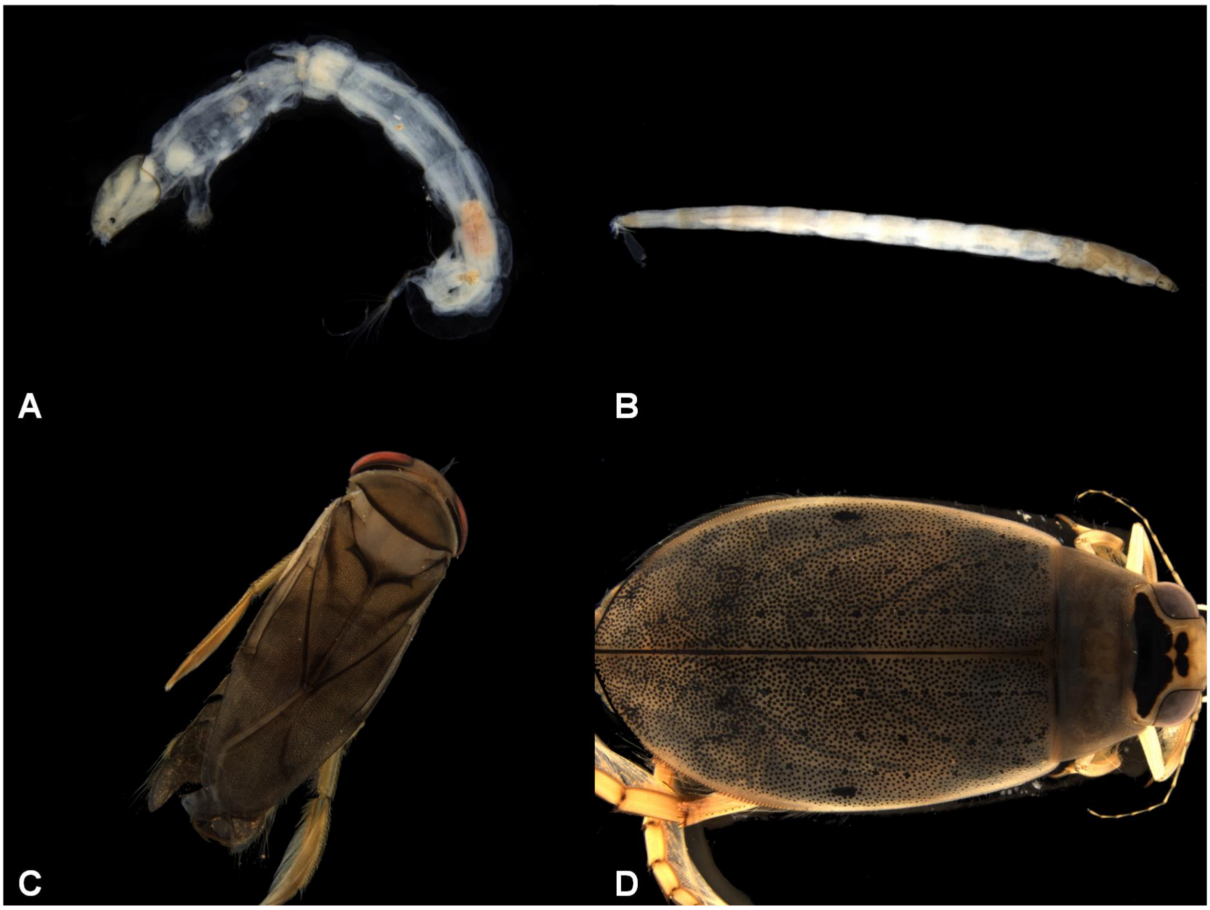

Plate 4: Selected insects recorded from Lake Carey, 2011. A, *Procladius paludicola*; B, Ceratopogonidae; C, *Agraptocorixa parvipunctata*; and D, *Eretes australis*.

Discussion

Jones Creek and Claypans

The baseline study of the Jones Creek system during the 2011 flood event indicated the presence of natural mineralisation within the catchment, demonstrated by the elevated aluminium in the claypans, and copper throughout the area. This is common throughout the northern Goldfields, where many catchment areas are highly mineralised (Gregory 2008). The hydrological regime and biogeochemical reactions that occur within the system are key drivers of changes in water quality (Reddy and DeLaune 2008). Significant increases in the concentrations of some parameters (copper, nickel and Chlorophyll a) were recorded between the sampling phases, and further investigation of water quality, particularly during later stages of the hydroperiod, could expand the natural range of background values prior to mine development.

The biota recorded reflected differences in water quality and habitat between the creekline and claypans. However, the algae (Bowling 2009, Entwisle *et al.* 1997, Taukulis 2007) and invertebrates (Pinder 2005, Timms 2004, Timms 2011, Timms *et al.* 2006, Williams 1980) that were recorded are mostly widespread throughout inland waters in the Goldfields, and elsewhere in Australia. In the claypans, some of the invertebrate taxa were considered new or undescribed (e.g. the clam shrimps *Caenestheria*, *Caenestheriella* and *Eocyzicus*), although given the high degree of regional connectivity during flood events, it is likely their distribution extends beyond the study area. The key change to the Jones Creek system from mining is expected to be a reduction in the upper catchment area, reducing flow to the creek and claypans. However, as the waterbody already receives increased flow and volume due to historic clearing, this was considered unlikely to have an impact on aquatic ecology. While there is also some inherent contamination risk from proposed mining, particularly to the resident crustaceans within the claypans, appropriate management and mitigation measures can minimise this risk.

Lake Carey

The findings from the 2011 Lake Carey study suggest that past impacts associated with dewatering discharge (such as elevated salts and metals) may be largely mitigated during a large flood event. Although the fate of salts and metals from dewatering discharge is unknown, it is likely that both horizontal and vertical re-distribution is involved in their movement. It is expected that, during the drying phase of the hydroperiod, salts and metals will increase in the sediments due to ongoing dewatering from mine operations, with groundwater in the area contributing to naturally high levels of some metals (Gray 2001, Mann 1983). Future monitoring during dry periods will provide a better understanding of the changes that occur within the system following a substantial flood.

Diverse algal and invertebrate communities were recorded from Lake Carey during flood. The majority of algal (Entwisle *et al.* 1997, Handley 2003, Taukulis and John 2006) and invertebrate (Pinder 2005, Timms 2004, Timms 2011, Timms *et al.* 2006, Williams 1980) taxa identified were considered cosmopolitan or widespread in their distribution, and are frequently recorded throughout inland waters in Western Australia. Due to the widespread nature of the flood, the ecological values of the lake do not appear to have been compromised by dewatering discharge to the lake. However, two invertebrates; *Branchinella denticulata* and *B. simplex* are recognised by the Department of Environment and Conservation as Priority 1 species (being poorly known). Another species, *Parartemia bicorna* also has a restricted distribution, being found only at Lake Carey. Further research is required to clarify the conservation status of these taxa (Timms 2010, Timms *et al.* 2009), although they are not considered at risk from current dewatering discharge to the lake.

Conclusions

Aquatic assessments conducted during flood events are vital to increasing understanding of the ecology and function of temporary inland systems and their management, in relation to the conservation significance of wetlands and the approval of new mines by regulatory bodies. This allows for more accurate monitoring programs to be developed, prior to mining, to detect potential future impacts. For established mines, increased ecological data provides more detailed information enabling targeted programs to be developed for parts of the ecosystem that may be most at risk. The aim of these studies is to collect appropriate data to conserve and manage the ecological integrity of receiving environments, which can be comparatively difficult in dry conditions; therefore comprehensive aquatic studies should be undertaken opportunistically as wet conditions arise. The Jones Creek and Lake Carey case studies show that temporary waters in the Goldfields are resilient, with a high degree of connectivity during flood, and similarities in water quality and aquatic biota. Differences in species composition are largely due to changes in water quality as the hydroperiod progresses, and potential mine-attributable impacts may be mitigated during large scale events.

Various tools are available to undertake ecological assessment of ephemeral waterbodies during the dry conditions that normally prevail, and these are routinely applied prior to, and during, mining. However, flood events such as the one in 2011 provide a valuable opportunity for the rapid collection of a wide range of ecological data, and are particularly useful to comprehensively examine water quality, phytoplankton and aquatic invertebrate assemblages, in relation to the conservation significance of wetlands. The breadth of data obtained provides a robust platform on which to base subsequent management strategies, and can be used to refine and optimise sampling and monitoring programs throughout the life of mine.

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Local Plant Strategy

Graeme Mitchell, Everlasting Concepts

Abstract

Our goal is to support behavioural change happening in Local Government Authority's (LGA), the land development industry and of value to the mining sector. Environmental imperatives are driving the need for greater biodiversity protection outcomes. In our view and experience, the implementation of tried and tested local plant strategies in peri-urban and urban regions lead to these outcomes.

Broadly, flora and fauna biodiversity and our terrestrial environment occur in either;

a) natural landscapes, or

b) modified landscapes

Natural Landscapes

The focus of biodiversity endeavours in respect o our natural landscapes is in preservation and conservation. This work includes revegetation, replanting, reforestation, quarantining areas of environmental significance and seeking to restore biodiversity balance in our bushlands. The preservation and conservation of natural landscapes is the domain of community groups, LGA, various government agencies (state and federal) and associations.

That is, bucket loads of public and community money are now being directed toward natural landscapes.

Modified Landscapes

The focus of biodiversity endeavours in respect of modified landscapes is establishing or retrofitting them with local plant species. This work has only just begun and remains an area of enormous, latent environmental value. However, the significantly negative environmental impacts from not adequately addressing this work are not self evident.

The creation and management of modified landscapes is the domain of the private sector (mining and land development), related stakeholder industries, local government authorities and various state or federal land planning agencies. We have not yet seen a modified landscape which has a positive, or at best, benign impact on the surrounding natural estate. The focus of attention in this sector (and its agreed purpose) is development and economic return. With the existing, significant financial investment directed toward modified landscape outcomes, the alignment of economic and environmental purpose can produce enormous, lasting change. If this investment is not channeled appropriately, it is our belief that it will pursue economic return only.

In other words, bucket loads of money tipped into modified landscapes by the private sector, however we are missing the environmental 'value creation' opportunities potentially available from this funding source.

It is our experience that modified landscapes, when planned and established collaboratively with land developers, industry stakeholders and relevant government agencies can, and do, produce outcomes which meet the economic and environmental needs of all parties. The knowledge and natural resources exist in abundance for this to be achieved.

Local governments across Western Australia are continually seeking help with the creation of a Local Plant Strategy suited to their regions. The Western Australian Local Government Association, via the Perth Biodiversity Project provides support to some LGA's with respect to this strategy, as do the Royalty for Regions initiatives. The templates, processes and the will, exist to create and implement this strategy, much of which has been created by Everlasting Concepts.

LGA's in collaboration with land developers and mining enterprises, hold the key to leading the way on local plant strategy implementation, and bridging the gap between biodiversity protection in both natural and modified landscapes.

Our presentation will stress the importance of 'getting it right' for both the mining and urban development sectors, with respect to biodiversity protection along with examples of how this is being achieved at present. We know the opinions we express resonate with many community groups, and influential environmental and business leaders.

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