2000 workshop on environmental management in arid and semi-arid areas

PROCEEDINGS

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Goldfields Lands Rehabilitation Group
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Environmental Standards for the New Millennium
FORWARD

The GLRG is a technical and professional body of people working toward standards of environmental best practice management in the Goldfields region of WA. The group was founded in 1988 with an initial focus on providing a source of expertise and promotion for good land rehabilitation practices. Over the past twelve years the group has met regularly and its focus has expanded to include the various environmental management issues facing the region.

The group aims to achieve environmental excellence through providing expert information and education to all sectors of the community and industry and the GLRG biannual workshops play a major role in achieving this outcome.

In keeping with the GLRC’s progressive focus, this years workshop theme "Environmental Standards for the New Millennium" sets the scene for presentations that focus on the need for proactive environmental management initiatives and continual improvement in the inclusion of environmental management in business planning. Topics such as mine closure planning, tailings and waste rock dump final land use, stakeholder communication, risk management and completion criteria all direct our attention to the need for inclusion of environmental identification and management practices in all planning processes. Taking a long term approach to issues management at an early stage of business planning will see companies achieve and maintain high levels of environmental performance more readily as we head into this new millennium.

The importance of proactive management to regulators, community groups and industry has been highlighted through the diversity and calibre of speakers presenting at this years workshop and the involvement of mine managers throughout the proceedings.

GLRG workshops promote the interaction between all stakeholders and it is this aspect of the workshop that assists in better promotion and implementation of environmental initiatives in the region.

Delta Gold is committed to achieving environmental excellence in its management of all operations and exploration activities. This is demonstrated through Kanowna Belle Gold Mine’s efforts in preparation for and intention to apply for a Best Practice Environmental Licence, from the WA Department of Environmental Protection, and Delta’s recent commitment to the MCA Mining Industry Code of Environmental Management. If successful, Kanowna Belle Gold Mine will be the first Mine in WA to achieve this licence. Delta recognises the importance of stakeholder participation in the maintenance of high standards of environmental management. It is through this commitment that Delta is pleased to sponsor the GLRG in their continued efforts to focus the community and industry in looking toward future standards to achieve successful management of the environment.

Brad Gordon

OPERATIONS MANAGER
KANOWNA BELLE GOLD MINE

(Main Cover photograph: Metallurgical Process Plant at Kanowna Belle Gold Mine)
GOLDFIELDS LAND REHABILITATION GROUP
2000 WORKSHOP ON ENVIRONMENTAL MANAGEMENT IN ARID
AND SEMI-ARID AREAS - PROCEEDINGS

Day One Wednesday May 24, 2000

Session One - Completion Criteria

Bill Biggs
Acting General Manager Environment
Department of Minerals and Energy
Of Western Australia

Developing a National Strategic Framework on Mine Closure

Darren Brearley & Joan Osborne
School of Environmental Biology
Curtin University of Technology

Developing Completion Criteria For Minesites In Arid And Semi-Arid Western Australia

WMC Resources Ltd
Kambalda Nickel Operations

Closure and Rehabilitation of Carnilya Hill Nickel Mine

Session Two - Waste Dumps for the New Millennium

Adrian Williams
Centre for the Management of Arid Environments

Carbon sequestration – an alternative use for rangelands and revegetated mine dumps?

Rob Loch and Garry Willgoose
LandTech Landform Technologies

Rehabilitated landforms: designing for stability

Session Three - Hydrology and Hydrogeology in Practise

Alan Wright
Supervising Hydrogeologist
Resource Information Services Division
Water and Rivers Commission

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Principal Hydrogeologist
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SESSION 3 - HYDROLOGY IN PRACTISE
SESSION 4 - THE FUTURE FOR TAILINGS

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NISSAN
DEVELOPING A NATIONAL STRATEGIC FRAMEWORK ON MINE CLOSURE

INTRODUCTION

Mining is a relatively short-term land use, therefore it is important that disturbed lands are returned to a safe, stable and productive post-mining landform that is both suitable and acceptable to the community. Coordinated planning for closure will provide the means and methods for site rehabilitation and restoration to ensure that mine closure will not compromise environmental quality in the future. It should also limit the extent of any prospective liabilities for the operator, the government and the community (Sasnoon, 1996).

Both government and industry are becoming increasingly aware of the need for a consistent and rigorous approach to dealing with mine closure to ensure that these needs are met. The broad objectives of closure planning must be to:

- to protect public health and safety by using safe and responsible reclamation practices;
- to reduce or eliminate environmental effects once the mine ceases operations;
- to establish conditions which maximise the post-mining land use options; and
- to reduce the need for long-term monitoring and maintenance by establishing effective physical and chemical stability of disturbed areas.

THE HISTORICAL PERSPECTIVE

Mine site closure is a significant issue for the minerals industry, governments and the community. The issue has two main aspects:

- adequacy of standards for mine sites which ceased operation in the past, including those for which the original mine owner no longer exists or is insolvent (abandoned mines) (MCA, 1997); and
- standards for decommissioning and rehabilitation of current and recently closed mine sites.

Abandoned or Orphaned Mines

Australia’s mining industry has a well documented history of mining operations which have left a legacy of substantial environmental damage. Well publicised examples such as Rum Jungle and Captains Flat are testament to the problems which abandoned sites can cause, and the cost to the Government of remediation (Farrell & Kratzing, 1996). Historically, land was seen as a relatively limitless resource, to be used at will, and then left to its own devices. The often made excuse, that such developments were consistent with their social context, is no longer true or acceptable.

The current situation in Queensland is indicative of the general position around Australia. The Queensland Department of Mines and Energy has been undertaking the rehabilitation of abandoned mine sites for a number of years to minimise the risk of environmental damage and to control pollution. Between 1985 and 1998, the Queensland Government has spent about $14 million on rehabilitating sites at Agricola, Charters Towers, Herberton, Horn Island, Irvinebank, Croydon, Gympie and Mount Morgan (QDME, 1998).

Despite significant advances in recent years abandoned mine sites continue to cause a significant problem for the Australian mining industry. Abandoned sites are not only a source of ongoing pollution and potential public danger, but their very existence is a source of embarrassment to the industry. Despite the fact that the majority of these sites were developed, exploited and abandoned in concert with prevailing social standards, they do not represent the standard that the modern mining industry would like to project.

Current Mine Closure

In relation to current practice, the minerals industry today is at the forefront of environmental impact minimisation techniques. Numerous case studies provide excellent testament to the industry's rehabilitation expertise. Minerals companies have successfully rehabilitated large and diverse areas of mined land, and their expertise has been recognised in Australia and internationally. However, the industry acknowledges that it must continue to improve its rehabilitation technologies and practices (MCA, 1997).

There are success stories that industry can point to. The Jerusalem Creek area in northern New South Wales, was the subject of mineral sands mining from 1969 until 1982. The adoption of structured rehabilitation techniques enabled the various vegetation communities, including paperbark swamps, to recover rapidly and successfully. The mined area is now part of the Bundjalung National Park and listed on the Register of the National Estate (Brooks, 1989). Likewise, Bridge Hill Ridge, another area of mineral sand mining, was included in extensions to the Myall Lakes National Park in 1980 (Lewis, 1987).

The Mary Kathleen uranium mine is another example of successful closure. Located in the arid region of western Queensland, it operated over the periods 1958-63 and 1976-82, during which time it produced 8887 tonnes of uranium oxide. The mine was permanently closed in 1982 due to the depletion of the ore reserves. In line with the proposals presented in the closure plan, the site was made safe for
THE MINE CLOSURE WORKING GROUP

The group formed in early 1998 and quickly realised that to be effective a National Strategy should not become involved in the fine detail of mine closure issues. The challenge was to identify the broad issues and leave the detail for the individual states and territories to develop. This could then be done in line with their own policies and guidelines but within the broad umbrella of the national strategy, the Chamber of Minerals and Energy of Western Australia have developed such a guideline for minerals operations in Western Australia.

The whole strategy was developed to satisfy three basic parameters, any outcome from mine closure had to be:

- Safe;
- Stable; and
- Sustainable.

It was a further requisite that the final document was concise and simple to follow, but at the same time identify all the issues that were relevant to mine closure.

The final draft was produced in mid 1999 and presented to both ANZMEC and MCA for their endorsement and approval to release as a discussion paper to stakeholders for comment. Both organisations approved this action and the strategy has been widely circulated to Australian stakeholders. The period for comment officially closes on February 29, 2000, however the working party does not meet until March 22 and are prepared to accept comment up to that date. Following review the strategy will be resubmitted to ANZMEC and MCA for their approval. It is envisaged that the strategy will be published as an official ANZMEC document and will be ready for release before the end of 2000.


- www.minerals.org.au

Comments on the strategy or requests for hard copies should be forwarded to the group coordinator:

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The Chamber of Minerals and Energy of Western Australia guideline “Mine Closure Guideline for Mineral Operations in Western Australia” is available on request from the chamber or can be found on their website:

Chamber of Minerals and Energy  
Locked Bag N984  
PERTH, WESTERN AUSTRALIA, 6844

Phone 61 8 9325 2955  
Fax 61 8 9221 3701  
Website www.mineralswa.asn.au
Management

All planned closure programmes consist of two distinct sequential phases; planning and implementation. Coordinating these stages will result in a well-designed, systematic, safe and cost-effective mine closure. In theory, closure is the converse of commissioning, requiring similar skills levels, operational experience and motivation. The concept of conducting the operation safely, cost-effectively, on budget and on time, remains fundamental to its success (Hordley, 1998).

Objective: to ensure that there is clear accountability, and adequate resources, for the implementation of the closure plan.

Principles:

1. The accountability for resourcing and implementing the closure plan should be clearly identified.
2. Adequate resources must be provided to assure conformance with the closure plan.
3. The on-going management and monitoring requirements after closure should be assessed and adequately provided for.
4. A closure business plan should include a schedule of actions, responsibilities, resources, and timeframes.
5. The implementation of the Closure Plan should reflect the status of the operation.

Standards

Completion criteria are an agreed set of environmental indicators which, upon being met, will demonstrate successful rehabilitation of a site. Completion criteria are specific to the mine being closed, and reflect the unique set of environmental, social and economic circumstances of the site. They should be developed and agreed with all stakeholders and, where possible should be quantitative and capable of objective verification. Criteria need to be established to enable closed-out sites to be returned to the State on an equitable and cost-efficient basis to both government and industry while ensuring long-term protection of the environment (WMI, 1994).

Objective: to establish a set of environmental indicators which will demonstrate the successful completion of the closure process.

Principles:

1. Legislation should provide a broad regulatory framework for the closure process.
2. It is in the interest of all stakeholders to develop standards that are acceptable to the majority and achievable.
3. An agreed set of environmental indicators is required to demonstrate successful rehabilitation of a site.
4. Completion criteria are specific to the mine being closed, and should reflect its unique set of environmental, social and economic circumstances.
5. Targeted research will assist both government and industry in making better and more informed decisions.

Relinquishment

Despite the magnitude and complexity of mine closure, the expectation is that over time most operators will be able to satisfy their obligations under Federal and/or State regulations. The Responsible Authority will accept the operator’s performance and release the surety, and accountability will revert to the State or a subsequent land owner. However, while it is one thing to expect to be released from mine closure obligations, it is quite another to expect to be discharged from further liabilities under broad environmental and civil laws (Williams, 1993).

Objective: to reach a point where the company has no further responsibility for the site.

Principles:

1. A responsible authority should be identified and held accountable to make the final decision on accepting closure.
2. Once the completion criteria have been met, the company may relinquish their tenement without further obligations.
APPENDIX I

Minerals Council of Australia

Mine Closure Policy

This Policy provides a framework within which the Australian minerals industry can develop solutions to actual, potential or perceived environmental, social, health, safety and financial issues associated with mine closure.

The expertise of the minerals industry in mine site rehabilitation has been demonstrated and recognised both within Australia and internationally. Nevertheless, the Minerals Council accepts that historic practices and changing expectations have resulted in some closed mine sites that do not meet the standards now expected by the community, regulators and industry.

The Minerals Council and its members recognise that responsibility for regulating mine closure rests primarily with the State and Territory Governments and will work with the State and Territory Minerals Councils/Chambers and these Governments to achieve effective regulatory and other approaches that recognise the needs of all interested parties.

The objective for closure is to leave sites in a condition which is safe, stable and limits further environmental impacts so that mining tenements can be relinquished for alternative land use.

In order to achieve this objective the Minerals Council of Australia will encourage the Australian minerals industry to:

- recognise that effective stakeholder involvement is essential for successful planning and implementation of mine closure;
- contribute to focused and relevant research into strategic issues of significance to mine closure;
- promote the integration of mine closure into planning and management of all phases of mine operations;
- make adequate provision for the costs of mine closure; and
- work with government and other stakeholders to address issues relating to abandoned mine sites.

The Minerals Council supports multiple and sequential land uses, and is committed to maximising future land use options through strategic closure planning.

June 1999
DEVELOPING COMPLETION CRITERIA FOR MINESITES IN ARID AND SEMI-ARID WESTERN AUSTRALIA

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SCHOOL OF ENVIRONMENTAL BIOLOGY
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ABSTRACT

Completion criteria were developed in three stages identifiable throughout any mining operation: Planning, Operational and Monitoring, and Post-Mining Hand Over. Standards were developed for a variety of criteria within each stage, and not simply based on the final rehabilitation outcome. Ultimately rehabilitation success in arid and semi-arid environments was found to require a high level of planning, along with the implementation of best practice techniques.

The two rehabilitation trials briefly outlined in this paper, emphasise the difficulty in accurately predicting revegetation outcomes in arid and semi-arid environments. As such revegetation standards focus on the presence of trends over time for a number of plant parameters, rather than specific quantitative end points. Trends in revegetation development and resilience were identified from the long term assessment of 27 rehabilitation trials. There was also comparisons made with assessments from 16 analogue sites (vegetation communities undisturbed by mining).

INTRODUCTION

Gold and nickel mining has historically been a major economic activity in the Yilgarn, Eastern and Northern Goldfields, and Murchison regions of Western Australia. Open-cut mining has generated large volumes of waste rock, much of which is relatively soft and subject to weathering. Mine operators are obligated to rehabilitate the waste rock dumps generated, along with all other disturbed areas.

Operators of open cut gold and nickel mines in arid/semi-arid Western Australia are putting increasing effort into rehabilitation activities. Following the recent good seasons in the interior of Western Australia, there are many examples where rehabilitation surfaces have been successfully revegetated. This has highlighted the situation that neither the operators nor the regulators know what to expect in the way of sustainability of the resultant ecosystems. No one knows what ecosystem objectives should be set for waste dump rehabilitation. Indeed there are examples where the objectives seem to depend on the personal opinions of individuals. This should not be surprising as currently we are unable to answer basic questions such as:

- what constitutes success in the rehabilitation
- is the vegetation likely to live to maturity
- how will the ecosystem develop, and will it be sustainable
- what is an achievable objective for revegetation in this region
- is this revegetation heading towards success or failure

Companies need answers to these questions to plan their rehabilitation programs, and both companies and regulators need to be able to set criteria to allow for bond recovery and lease relinquishment. The broad aim of this project was to provide answers to as many of the above questions as was possible, and in doing so develop staged completion criteria which were applicable to mining operations throughout the regions of arid and semi-arid Western Australia being studied.

DEVELOPMENT OF COMPLETION CRITERIA

A literature review prior to the commencement of this project suggested a number of aspects were important when developing completion criteria linked to the establishment of a self-sustainable and resilient vegetation cover. This included developing an end land use objective, acquiring knowledge of the local environment (constituents and function), and defining the constraints of the rehabilitation medium. Also important was the development of a monitoring scheme able to accurately record changes over time in the parameters being measured at both the analogue sites (distinct vegetation communities unaffected by mining), and rehabilitation sites.

Ecosystem recovery over disturbed areas is known to be a slow process, hence long term revegetation assessments were essential in identifying whether specific rehabilitation treatments were successful, and in determining how the revegetation developed over time. Prior to the commencement of this project, historical data sets had been accumulated from a variety of rehabilitation trials at mine sites throughout arid and semi-arid Western Australia. Assessments continued at these sites until the duration of this project, and new rehabilitation trials were established and subsequently monitored. The long term data sets (up to 9 years after seeding) provide an insight into revegetation development over time under a number of rehabilitation scenarios. Common trends in revegetation development became evident within 5 years of direct seeding, and were subsequently used to provide revegetation targets as part of the staged completion criteria developed.

In addition to the long term assessment of rehabilitation trials, rangeland communities undisturbed by mining (referred to as analogue sites) were also monitored. Comparisons were then able to be made between a variety of analogue sites of differing vegetation structure and composition, and rehabilitation treatments at specific ages following seeding.
The project also identified techniques found to benefit revegetation establishment, which should be integrated into any rehabilitation plan. The completion criteria developed are matched to currently achievable technology and best practice standards. It is acknowledged however, that rehabilitation techniques will change with technological advancement, and hence completion criteria will require updating in accordance with these changes.

Long term data from a total of 27 rehabilitation trials was analysed to determine changes over time in plant density, revegetation cover, species composition, and soil salinity and pH. The 16 analogue sites were monitored over a shorter period of time (’97 - ’99), and in some cases there was only one assessment per site. The vegetation and soil parameters measured at each of the analogue sites reflected the vegetation composition and structure. Parameters appear to remain relatively stable over time, with the exception of the annual vegetation component, which shows an immediate and rapid response to rainfall. Perennial species on the other hand are more stable, however significant responses were recorded at some sites due to overgrazing. Following disturbance, recovery of the vegetation followed similar trends to those recorded at rehabilitation sites following direct seeding.

Completion criteria have been addressed in three stages (Appendix 1), clearly identifiable throughout any mining operation:

- **STAGE 1.** Planning - prior to mining.
- **STAGE 2.** Operational Monitoring - during mining and up to a minimum of 5 years following the commencement of rehabilitation activities.
- **STAGE 3.** Post Mining Hand Over - at the conclusion of mining and a minimum of 5 years following the commencement of rehabilitation.

Specific criteria within each stage were identified as being important to the long term rehabilitation success. The process by which each criterion should be addressed was then stated, along with a required standard (see Appendix 1).

The basic methodology used to implement staged completion criteria is applicable to the mining industry throughout Australia. However specific areas of the methodology will always be site specific.

This includes:
- defining the end land use,
- developing the rehabilitation plan,
- identifying potential impacts from the mining operation on the surrounding environment (and vice versa), and
- identifying specific trends in revegetation development and ecosystem resilience, which indicate long term rehabilitation success.

### ANALOGUE SITES

Seven analogue communities occurring in rangeland between Granny Smith Gold Mine and Sunrise Dam Gold Mine were assessed in October ’97 and October ’98 (see Figure 1). For the Chenopod Shrubland sites, plant density typically ranged between 1.5 - 2.0 stems m⁻², with higher values recorded for grazed sites (up to 3.0 stems m⁻²). Foliage ground cover ranged between 12 - 34 percent. Soils were of neutral pH, but ranged from mildly saline (5 dS m⁻¹ ECE) to extremely saline (23 dS m⁻¹ ECE).

Plant density and vegetation cover for the Mulga Woodland community approximated 2.0 stems m⁻² and 50 percent, with the Mixed Acacia Shrubland site averaging 0.3 stems m⁻² and 25 percent. Soils for both sites were acidic and non-saline.

### REHABILITATION TRIALS

#### 1993 Rehabilitation - Granny Smith Gold Mine

The broad rehabilitation strategy employed for the 1993 Rehabilitation at Granny Smith Gold Mine is outlined in Table 1.

Surface soil salinity is a key factor controlling revegetation development in the arid and semi-arid zones. During the first growing season surface salinity over the 1993 Rehabilitation was similar to that recorded in the *Atriplex bunburyana* analogue community (mean ECE 5 and 8 dS m⁻¹ respectively, Figure 2). In the period since however, salts have been leached from the upper profile and salinity over the rehabilitation area has progressively decreased.

Elevated plant density recorded during the initial growing season (approximating 2.5 stems m⁻²) decreased over the following two years to average 1.0 stem m⁻² in October ’95, 30 months after seeding (Figure 3). Plant density between October ’95 and October ’98 remained stable. Revegetation cover responded differently to plant density. During the initial two growing seasons ground cover increased rapidly before stabilising at between 20 and 30 percent (Figure 3), a range typical for the analogue chenopod shrubland sites.

Revegetation cover is a good indicator of ecosystem stability. Variability of this parameter is typically within a narrow range, however high variability can occur in response to disturbances such as drought. Recovery following disturbance is usually rapid, but rainfall dependent. During the 1994 drought species richness in the 1993 Rehabilitation decreased, but overall revegetation cover increased. The increase was due to the drought tolerant *Atriplex bunburyana* which thrived under the low water regime and reduced competition, showing an increase in individual ground cover (Figure 4).
Between October '97 (54 months after seeding) and October '98 (66 months after seeding) however, overall revegetation cover decreased from 25 to 16 percent despite high average rainfall in the 6 months prior to the '98 assessment (Figure 3). The individual ground cover of *Atriplex bunburegana* decreased from 24 to 15 percent over the same period (Figure 4), with individual species density also decreasing from 0.92 to 0.57 stems m$^{-2}$. The decrease in density and ground cover occurred in response to the senescence and death of large numbers of mature *A. bunburegana* plants. A similar event was observed within the 1992 Rehabilitation over Waste Dumps at the Goldfan Site (Coolgardie), 78 months after seeding. Continued monitoring is now required to determine whether the two parameters continue to decrease over time, or recover.

There are high levels of similarity between *Atriplex bunburegana* in the 1993 Rehabilitation, and *Atriplex bunburegana* Low Shrubland analogue community (Figure 4).

*Atriplex bunburegana* is the dominant species in both communities, and appears to strongly influence the establishment of other plant taxa. *A. bunburegana* has been the dominant rehabilitation species from the first growing season (IVI 128.4, 1.0 stems m$^{-2}$, 6.2 percent) through to the sixth growing season (IVI 240.1, 0.6 stems m$^{-2}$, 15.1 percent).

The initial establishment of *A. bunburegana* in the rehabilitation was favoured by a high individual seeding rate (624 g ha$^{-1}$), the inherent light weight of the seed (high number of seed g$^{-1}$ - 377), and high seed viability (82 percent final germination). The dry conditions experienced throughout 1994 further benefited this drought tolerant species, providing a competitive advantage over the less tolerant species.

In October '93 *A. bunburegana* occurred with a suite of salt tolerant chenopods including *A. vesticaria* (IVI 68.8), *A. holocarpa* (IVI 39.8) and *A. codonocarpa* (IVI 33.5). In October '98 these chenopods are only minor components of the revegetation (IVI's 8.5), occurring with low numbers of woody perennials including *Senna, Eucalyptus* and *Hakea*.

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**Figure 4:** Percentage ground cover for important revegetation taxa recorded over the 1993 Seeding Trial (change over time) and *Atriplex bunburegana* Shrubland analogue community. Mean monthly rainfall for the six month period prior to assessment indicated.

- **Solid Square**: *Atriplex bunburegana*
- **Open Square**: *Atriplex codonocarpa*
- **Cross**: *Maireana* spp.
- **Dotted Square**: Other *Atriplex* spp.
- **plus symbol**: Mean Rainfall (mm 6 mths prior)
- **Grayscale Square**: Others

---

**Month After Seeding**

- Oct 93
- Feb 94
- Oct 94
- Oct 95
- Nov 96
- Oct 97
- Oct 98

**Rainfall (mm)**

- 0
- 10
- 20
- 30
- 40
- 50

**% Cover**

- 0
- 5
- 10
- 15
- 20
- 25
- 30
The broad rehabilitation strategy employed for the 1994 Rehabilitation at Granny Smith Gold Mine is outlined in Table 2.

The 1994 Rehabilitation was sown during February '94. In the following 8 months rainfall totalled just 21.6 mm, subsequently no seed germination occurred during the first growing season. In February '95 Tropical Cyclone Bobby dropped 197 mm of rainfall over the trial area. This was preceded by above average rainfall in December '94 (72 mm) and January '95 (46 mm). High intensity summer rainfall events in arid regions are important in breaking seed dormancy and allowing for the successful establishment of many hard seeded, slower growing species.

The first revegetation assessment occurred in November '96, 32 months after sowing. The surface revegetation medium was non-saline and alkaline (Figure 5). Plant density averaged 2.29 stems m² with 27 percent ground cover. Plant density progressively decreased to average 1.42 stems m² in October '98 (56 months after sowing). Revegetation cover remained relatively stable over this period, averaging 29 percent in October '98 (Figure 5).

Carrichtera annua (Ward's weed) occurred in high numbers during the first assessment, averaging 0.84 stems m². The extended period between seeding and the first rains provided an opportunity for a store of C. annua seed to become established between the rip lines, and subsequently compete with sown varieties. Ward's weed was rapidly out-competed by desirable local species, and now occurs in low numbers.

The high numbers of annual Atriplex spp. recorded in November '96 increased the relative importance of this taxa (Figure 6). The fast growing annual Atriplex codonocarpa (IVI 65.4) was a major component, occurring at an individual density of 0.61 stems m². The density and cover of this taxa has decreased over time in response to increased competition.

Maireana and Senna were recorded in low numbers, but provided high ground cover (Figure 6) during the first assessment. The relative importance of both taxa has progressively increased between November '96 and October '98. M. brevifolia (IVI 42.9), M. pyramidata (IVI 29.6), Senna helensis (IVI 25.0) and S. fitifolia (IVI 35.6) are important species from both taxa, and are well represented in the revegetation.

The importance of the Acacia spp. in the revegetation continues to increase over time. Although only present in relatively low numbers at present, this group will require a longer period to become established in comparison to other faster growing taxa. The non-saline revegetation medium and heavy cyclonic rainfall during the early stages of ecosystem development, may be important factors enhancing the establishment of desirable woody perennials (Senna, Acacia) in the revegetation. High individual seed rates for both genera was also beneficial.

**DISCUSSION**

 Numerous surveys throughout the arid interior of Western Australia indicate the recurrence of distinct vegetation communities, which have evolved in association with the underlying geology and soils. Although plant species richness within each community is typically low, overall diversity is increased by the large spatial heterogeneity throughout the rangeland (Noy-Meir 1981). It is this diverse range of undisturbed vegetation communities (analogue sites) on which site specific rehabilitation scenarios should be modelled. It is however important not to model one specific analogue community too closely, as in reality, there will always be a number of equally possible ecosystem trajectories. The final outcome is determined by the sum of inputs into the system, which are often difficult to predict e.g. rainfall.

This was observed for two rehabilitation sites at Granny Smith Gold Mine: 1993 Rehabilitation and 1994 Rehabilitation. For both sites the revegetation medium, ground preparation techniques, and seed mixture composition and sowing rates were similar, however the resulting revegetation composition and structure differed markedly. For the 1993 Rehabilitation, above average rainfall during the three months following sowing facilitated the germination of a variety of taxa, including salt tolerant chenopods and taller woody perennials. However drier conditions over the Summer months followed by drought tolerant chenopods succumbed rapidly to moisture stress, followed later by a majority of the chenopods. Only one species, the drought tolerant Atriplex bunburyana, was able to survive the extended dry period and subsequently became the dominant revegetation species. For the 1994 Rehabilitation, drought conditions throughout the first growing season inhibited seed germination. However high Summer rainfall in December '94, January '95, and from Tropical Cyclone Bobby in February '95, stimulated seed germination from a variety of taxa. Follow-up rainfall during Winter months further benefited plant establishment, particularly the woody perennials (acacias and sennas). In October '98 all of the major direct sown taxa were well represented in the revegetation.

The rehabilitation scenarios described above highlight the difficulty faced when establishing end point criteria for arid zone rehabilitation. Even under a prescribed rehabilitation formula, the resultant revegetation outcome cannot be predicted with a high level of certainty.
## APPENDIX 1:
The processes involved with establishing staged completion criteria for arid and semi-arid minesites, and associated standards.

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<td>1 PLANNING</td>
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| 1.1 Baseline studies of the existing environment | Implement appropriate baseline studies for the following areas:  
- terrestrial flora and fauna  
- aquatic flora and fauna (where appropriate)  
- surface hydrology  
- groundwater hydrology  
- anthropology / archaeology to determine conservation values, and the potential impact of mining. | All potential impacts are identified prior to mining, and appropriate monitoring programs implemented to assess changes over time. Commitments are made by the company prior to mining, and to the satisfaction of the relevant government authority. |
| 1.2 Determine the end land use | Based on what is realistically achievable given the constraints of the mining operation, and knowledge of local ecosystem function. Made in collaboration with all interested groups (previous land user, government, indigenous people, wider public) with a regional perspective. Determine what infrastructure, if any, the mining operation can contribute over the duration of operations to benefit the end land use. | End land use defined prior to mining. |
| 1.3 Ensure the rehabilitated landform compliments the natural landscape; and existing roads / tracks through the area remain accessible. | In reality, the position of the rehabilitation landform (waste dump) and exploration and mining disturbances, is determined largely by the location of the ore-body being mined.  
The shape and nature of the landform should compliment the surrounding landscape, and at the same time be compatible with the end land use. | Approved by the relevant government body. |
| 1.4 Development of a rehabilitation plan modelled on the attributes of 'matching' analogue communities. | Quantitative assessment of distinct analogue communities around the project area, and comparison of limiting factors within rehabilitated site.  
Subsequent formulation of a rehabilitation plan tailored to the achievement of a vegetation composition and structure similar to that of matching analogue sites. | Quantitative data from local analogue communities collected and analysed.  
A rehabilitation plan developed to address all important aspects including waste characterisation and waste dump design, topography and slope, topsoil handling, deep ripping, hydrology, soil fertility, and seed mixture composition. |
<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>PROCESS</th>
<th>STANDARD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.3 Resilience (cont.)</td>
<td>Ecosystem resilience relies on the soil resource supply, of which viable seed is an important component. Seed quality and germination testing is required to determine the potential of this resource.</td>
<td>Progeny seed should be of comparable viability to that of the same species collected at the same time from a surrounding analogue site.</td>
</tr>
<tr>
<td>2.4 Impacts from surrounding land uses on the rehabilitation, and from mining on the surrounding land uses.</td>
<td>Results from the monitoring plans implemented prior to mining are used to determine changes over time, and hence impacts.</td>
<td>If significant changes are found in the parameters being measured, appropriate management plans approved by the relevant government authority, will require implementation.</td>
</tr>
</tbody>
</table>

### 3 POST MINING HAND OVER

<table>
<thead>
<tr>
<th>3.1 Health and safety</th>
<th>Ground assessment to ensure all hazards, and potential for the generation of hazards, have been removed.</th>
<th>All areas are deemed safe by the relevant government authority.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.2 Revert to the end land use</td>
<td>The manager of the new land use is familiarised with the rehabilitated landscape, and management techniques required for it to remain sustainable over the longer term.</td>
<td>The rehabilitated area is capable of supporting the end land use. Rehabilitation remains functional and resilient under the end land use.</td>
</tr>
</tbody>
</table>
CLOSURE AND REHABILITATION OF CARNILYA HILL NICKEL MINE

ABSTRACT

WMC Resources Kambalda Nickel Operations (KNO) has had a history of over 30 years Nickel production and has been a major contributor to the economic prosperity in the Western Australian Goldfields. Environmentally, there have been some significant achievements at Kambalda over the years and there have also been some mistakes. The Kambalda site is a brown fields site which has a number of areas with opportunities to demonstrate Best Practice Environmental Management.

One such opportunity arose with the closure of the Carnilya Hill nickel mine site in June 1998. The mine was operated as a joint venture between WMC and BHP and it was decided that the closure was to be carried out to a "walk away standard" to allow WMC to retain the leases at cessation of the joint venture. A closure plan was prepared by WMC to include a comprehensive reporting framework and closure planning process and this was duly submitted to the Department of Minerals and Energy in May 1999.

The objectives of the Closure Plan were to:

- Ensure the long term physical and chemical integrity of site;
- Minimise any risk to the public and re-establish stable topographic conditions; and
- Use proven engineering practices for rehabilitation to minimise any off-site impacts

All site infrastructure was removed from site in late 1998 on a cost neutral basis and major rehabilitation earthworks began in June 1999. All raiseborels and shafts were backfilled with waste rock and a significant boxcut area (135,000 m²) was filled with potentially acid forming material from the disused sand plant and ROM pad as well as a small amount of material from fuel storage and waste disposal areas. The boxcut area was covered with benign material from the waste rock dump and additional topsoil was added prior to ripping and seeding with native plants at surface. The final engineered surface profile was designed to enhance surface drainage and sediment control as well as cater for the limited risk of long term subsidence due to underground workings.

A fully documented record of the closure and rehabilitation process was kept and included the use of a digital camera which more than paid for itself during the project. The project was completed in October 1999 just in time for some unseasonal rains which assisted greatly in the seed germination process. Ongoing monitoring is planned over the next five years including the use of ecosystem function analysis as developed by CSIRO and measurement of any localised subsidence or settlement.

The project is heading towards a successful conclusion and KNO now has a template for mine closure and rehabilitation that can be used in future closure projects. The intention is to develop the Closure Plan prior to mining development to allow a "cradle to grave" approach with integrated planning and budgeting. WMC and the mining industry in general is becoming increasingly aware that mining is only a temporary use of land and in order to maintain our license to operate and ensure access to new resources we have to raise our Standards of performance and ensure that all environmental management is carried out according to Best Practice.

1. SAFETY, ENVIRONMENT AND SYSTEMS MANAGER;
2. RESIDENT MANAGER;
3. ENVIRONMENTAL OFFICER;
4. ENVIRONMENTAL ASSISTANTS;
   4. WMC RESOURCES LTD KAMBALDA NICKEL OPERATIONS,
   PO, KAMBALDA WA 6442;
5. ENVIRONMENTAL MANAGER, WMC RESOURCES LTD,
   NICKEL AND GOLD BUSINESS UNITS;
   QVB BUILDING, 37TH FLOOR, 250 ST GEORGES TERRACE,
   PERTH WA 6000;
6. DIRECTOR, THOMPSON BRETTLTD
   6 BAYFIELD STREET, ROSY PARK, TASMANIA 7018.
1.0 INTRODUCTION

The Carnilya Hill Joint Venture (WMC 55.7%, BHP 44.3%) area is located in the East Coolgardie Mineral Field, 29 km north east of Kambalda (Figure 1). The Joint Venture (JV) covers an area of 2207 ha spread over 4 leases (M26/4749; 126/483) and contained an underground nickel mine located on Mining Lease M26/48. The deposit lies on low stony rises 8 km inland from the northern shoreline of the region’s dominant geographic feature, Lake Lefroy. The Lake forms part of a chain of internally draining lakes of various sizes which run the eastern edge of the Great Western Plateau.

Portal excavations for the mine commenced in September 1979 and the first nickel sulphide ore was produced in April 1980. The mine was placed on final mine closure status in June 1998 following an ore reserve assessment which reported there were not reasonable prospects for further economic exploitation of the known resource. The total recorded production was 1,399,116 tonnes at a grade of 3.38% nickel. The mining operation and exploration activities were undertaken and managed by WMC Resources Ltd on behalf of the JV.

WMC plan to continue exploration activities in their own right following dissolution of the Joint Venture Agreement. The closure of the Carnilya Hill nickel mine provided an opportunity to carry out the rehabilitation program according to the principles of Best Practice Environmental Management to a “walk away standard” to allow WMC to retain the leases at cessation of the JV. A Closure Plan was prepared by WMC to include a comprehensive closure planning process and reporting framework this was reviewed by the JV partners and submitted to the Western Australian Department of Minerals and Energy (DoME) in May 1999.

1.1 Surface infrastructure

Mine surface disturbances covered 42 ha encompassing 4 habitat types and include a portal boxcut (86,000 m²), waste rock dump (partially rehabilitated), former ROM pad, sewer lagoon, solid waste landfill, hydraulic sluicing plant and mine access roads. Mine openings include a 5x10 metre decline portal, five raise bored shafts (up to 2.4 m in diameter), an escapeway rise and six mine service holes.

Following closure of the mine in June 1998 all underground and surface infrastructure including concrete workshop foundations were removed.

TABLE 1: Surface disturbance

<table>
<thead>
<tr>
<th>Location</th>
<th>Total Area (ha)</th>
<th>GNEW</th>
<th>PEBW</th>
<th>PESW</th>
<th>PXHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>WRD</td>
<td>25</td>
<td>21</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sandplant &amp; Surrounds</td>
<td>5</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mine Site &amp; Surrounds</td>
<td>2.4</td>
<td>2.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portal</td>
<td>2.8</td>
<td>2.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dewatering Dam &amp; Surrounds</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sewer Dam</td>
<td>0.6</td>
<td>0.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raiseores (7)</td>
<td>0.6</td>
<td>0.2</td>
<td>0.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explosives Store</td>
<td>0.3</td>
<td>0.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gravel Pit</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Area (ha) :</td>
<td>41.7</td>
<td>33.2</td>
<td>4.5</td>
<td>2.4</td>
<td>0.6</td>
</tr>
</tbody>
</table>

TABLE 2: Status of Leases and Licences

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>M26/47, 48, 49, 453 Tenement Conditions</td>
<td>In good standing - DoME Inspections November 1999</td>
</tr>
<tr>
<td>Dangerous Goods Licence SO</td>
<td>Licence relinquished - DoME advised June 1998</td>
</tr>
</tbody>
</table>

1 GNEW = GREENSTONE NON-HALOPHYTIC EUCALYPT WOODLAND; PEBW = PLAIN EUCALYPT SALTIBUSH WOODLAND; PESW = PLAIN EUCALYPT BLUEBUSH WOODLAND; PXHS = PLAIN MIXED HALOPHYTE LOW SHRUBLAND.
The present topography is one of low relief with regional slope gradients of 1°-2° locally emerging with low undulating hills. Ephemeral streams drain the low rises into numerous salt lakes and clay pans. Generally these drainage lines are poorly defined except where they enter the major salt lakes. One of the largest ephemeral creek lines in the district (Monger Creek) is developed a kilometre to the east of the Carnilya Hill mine site.

The climate and the ecology of the area is characteristic of a transitional zone between the arid lands to the east and the more mesic regions to the west. Soils are poorly developed over the greenstone belts with calcareous red loams high in Ca and Mg, the most widespread soil group. Saline and subsaline soils are common adjacent to the numerous drainage channels. All soil types have low nutrient levels.

2.2 Geology and mineralisation

The Carnilya Hill deposit lies on the northern limb of an east-west striking antiformal structure. The Fe-Ni ore is associated with the basal ultramafic flow at its contact with a fine grained "footwall" meta basalt although the sequence has been overturned with the meta basalt now forming the hanging wall of the ore zone. Sulphide mineralisation commences approximately 25m below the surface, has a strike of approximately 320m and plunges to the east and west of a slinging antiformal structure. A clearly defined gossan outcrops at the surface. The oxidised/saprolite boundary is irregular varying between 20 to 65 metres below surface.

The economic Fe-Ni sulphide minerals in the contact ore zone include pyrrhotite pentlandite and traces of chalcopyrite and violerite. Supergene sulphide mineral phases such as violerite are a common mineral of the transitional (near surface) ore zone.

2.3 Hydrology

Ground water occurs in small volumes at the fresh rock / saprolite interface at a depth of approximately 50 metres below surface and in isolated fractured rock aquifer associated with structural elements. Run of mine water sampling since 1991 of the surface mine water dam has shown that water quality neutral (pH 7.2) and saline (TDS up to 53000 mg/l). Mine water production was not recorded because of the small volumes involved and re-cycling in the mine backfilling operation. The sites only water storage was the mine dam that has a capacity of approximately 12000m³.

The environment is arid, and in most periods of the year no natural potable water can be found except in scattered stock dams. Two dams, Bulong Dam and Government Dam are located to the south of the project area. The mine site is located in undulating terrain that forms part of a single catchment draining into the south east. Surface water movement is predominantly by overland flow following substantial rainfall. Post closure landforms were designed to be hydrologically compatible with surrounding topography.

2.4 Geochemical characterisation

Previous geochemical characterisation of typical Carnilya Hill lithologies assessed the potential for acid generation (through sulfide oxidation) and episodic metal leaching. Results indicated that waste rock materials were non acid forming although tailings materials produced at Carnilya Hill could have a low acid generating potential. Additional geochemical testing was undertaken in October 1999 for waste rock samples randomly gathered from the face of the Carnilya Hill waste rock dump.

### TABLE 3: Geochemical classification of waste rock samples

<table>
<thead>
<tr>
<th>Sample Code</th>
<th>Total S (% S)</th>
<th>MPa</th>
<th>ANC (kg H2SO4/l)</th>
<th>NAPP</th>
<th>NAG</th>
<th>Geochmical Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.16</td>
<td>5</td>
<td>46</td>
<td>-41</td>
<td>0.0</td>
<td>Non-acid forming</td>
</tr>
<tr>
<td>2</td>
<td>0.94</td>
<td>29</td>
<td>144</td>
<td>-115</td>
<td>0.0</td>
<td>Non-acid forming</td>
</tr>
<tr>
<td>3</td>
<td>0.10</td>
<td>3</td>
<td>43</td>
<td>-40</td>
<td>0.0</td>
<td>Non-acid forming</td>
</tr>
<tr>
<td>4</td>
<td>0.12</td>
<td>4</td>
<td>199</td>
<td>-195</td>
<td>0.0</td>
<td>Non-acid forming</td>
</tr>
<tr>
<td>5</td>
<td>0.31</td>
<td>9</td>
<td>171</td>
<td>-161</td>
<td>0.0</td>
<td>Non-acid forming</td>
</tr>
<tr>
<td>6</td>
<td>0.12</td>
<td>4</td>
<td>78</td>
<td>-75</td>
<td>0.0</td>
<td>Non-acid forming</td>
</tr>
</tbody>
</table>

2 AGC WOODWARD-CLYDE (1993) : CHARACTERISATION OF FLUSH WASTES AND ORES ON INFRASTRUCTURE PADS AND CAUSEWAYS, UNPUBLISHED REPORT FOR WMC RESOURCES LTD.
3 AMIRA (1995) PROJECT P387; MINE WASTE MANAGEMENT - PREDICTION AND IDENTIFICATION OF ACID FORMING MINE WASTE, VOLUME 1, ENVIRONMENTAL GEOCHEMISTRY INTERNATIONAL, BALMAIN, NSW.

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The total mine cover bund volume of 135,000 m$^3$ was made up of approximately 57,000 m$^3$ of sand and 78,000 m$^3$ of waste rock. Batter slopes were limited to 10 hoz:1 vert on the eastern side and 5 hoz:1 vert on the southern side. Dished swale drains were constructed on both sides of the bund and sized to cater for the 20 year ARI flood. Topsoil beneath the bunded areas was stripped and stockpiled prior to construction and used as part of the cover for the final surface.

3.4 Reshaping of the waste rock dump

The existing waste rock dump was successfully rehabilitated in 1992 on the southern side with vegetation becoming well established from seed. No erosion was apparent in 1999 and the existing slopes were considered to be stable.

Waste rock for bund construction was removed from the northern side of the dump to create a final batter of approximately 3 hoz:1 vert (18 degrees). The top of the dump was graded to take surface runoff into a single rock lined vertical drain to avoid water runoff over the batter. The runoff from the drain joins a swale drain which runs adjacent to the northern side of the waste rock dump. Additionally, the southern extremity of the waste rock dump was excavated to allow drainage around the southern side of the dump.

3.5 Raise bore and service hole backfilling and capping

Mine ventilation used five raise bores of up to 2.4 in diameter and up to 250 m in depth and one escape way at the sand plant area. Six service holes were also utilised by the mining operation. The bores and service holes were filled with selected well graded waste rock. The bores were then capped with pre-cast concrete caps and a 2 m mound of soil/rock placed over the site to ensure that drainage was directed away from the hole to prevent piping and allow for possible future settlement. Similarly, the six service holes were backfilled with waste rock, capped, and mounded on the surface. The escapeway at the sand fill plant was also filled and incorporated into the surface mound structure in that area. Settlement gauges were installed at each raise bore hole by cutting a hole in the concrete slab and inserting-fixing a metal tube to allow ongoing monitoring of fill settlement.

3.6 Site drainage including erosion and sediment control

The site is located in a small catchment area of 1.4 km$^2$ and is gently sloping allowing for good drainage. Any low local spots were filled and graded as part of the rehabilitation earthworks.

The original site drainage trend to the north and east and to the south and east was reinstated and post closure land forms were designed to be hydrologically compatible with surrounding topography.

Swale drains were constructed on both sides of the boxcut cover bund and waste rock dump to cater for the estimated 20 year ARI flood flow at the bottom of the site of 3.6 cumecs. The swale drains were made 1 m deep with 5 hoz:1 vert slopes and the majority of surface water from site was directed around the south side and then east of the waste rock dump in the direction of Monger Creek.

3.7 Backfilling of the mine dam

The mine dam (12,000m$^3$ capacity) was backfilled as part of the rehabilitation program. Sampling of the mine dam water and surface sediments was undertaken in May 1999 and the sediment results confirmed the requirement to backfill and cover the dam due to elevated levels of Chromium (310 mg/kg) and Nickel (9100 mg/kg).

3.8 Site preparation and Seeding

The objective of the site preparation and seeding program was to re-establish a self sustaining vegetation community consistent with the land use of pastoralism. The Carniya Hill site was rehabilitated in the following manner:

- All laydown areas, hardstand areas, the mine dam, landfill and sewer lagoon, and redundant minor roads and tracks were repaved or low gradient and rough surface with a dozer to remove any windrows or incompatible landforms.
- The waste rock dump was reshaped on the northern side to create a final batter of approximately 3 hoz:1 vert (18 degrees).
- The boxcut cover bund was shaped to limit batter slopes to 10 hoz:1 vert on the eastern side and 5 hoz:1 vert on the southern side.
- A 300 mm oxide cover (where required) and 100 mm of topsoil was spread along the contour.
- The surface was ripped across the contour to a depth of approximately one metre at two metre spacing using a dozer fitted with a double shank ripper.
- The ripped surface was sown with native shrub and tree seed. No fertilizer was used.

Local native plant seeds for rehabilitation works were supplied by Jims Seeds, Weeds and Trees Pty Ltd from Kalgoorlie. The establishment of a native vegetation cover facilitates the development of a sustainable site suitable for pastoralism. Seeding of the site was carried out by a community volunteer group (local swimming and rifle clubs).
TABLE 4: Total costs for Carnilya Hill mine site closure and rehabilitation

<table>
<thead>
<tr>
<th>Phase Description</th>
<th>Weeks</th>
<th>Cost $000</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Pre-Project costs, including site visits, Report preparation, Project Management</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>2. Detailed Project Execution Plan, Geotechnical Report, Rehabilitation Plan, Post Closure Management Plan and Audit Protocol, Site review and signoff</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>3. Approvals / negotiations with DoME, Pastoralist and internal WMC approvals.</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>4. Mobilise site crews, perform all necessary inductions and develop Safety Management Plan.</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>5. Rehabilitation Earthworks &amp; Seeding</td>
<td>20</td>
<td>529</td>
</tr>
<tr>
<td>6. Survey, Aerial Photography</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>7. Project Closure Reports, Records Management, Audit</td>
<td>4</td>
<td>15</td>
</tr>
</tbody>
</table>

5.0 COSTS

5.1 Rehabilitation earthworks costs

Little Transport and Processing Industries were selected as the preferred contractor and site rehabilitation earthworks were carried out from May to October 1999. The cost of mine site rehabilitation earthworks was $521,000. Major costs for the rehabilitation earthworks program were associated with the construction of the boxcut mound, reshaping of the waste rock dump, backfilling of the site water storage dam, filling and capping of the raise bores and service holes, and constructing drainage channels around the boxcut mound and waste rock dump.

The cost described above are solely for site rehabilitation earthworks and did not cover expenditure associated with the commercial elements (Legal, Asset Management) of Closure. The total costs for the overall project was $577,000.

6.0 REPORTING FRAMEWORK AND REGULATORY INSPECTIONS

A full set of documentation describing the proposed rehabilitation of the Carnilya Hill mine site was provided to DoME for approval in May and June 1999. The overall reporting framework, is presented in Figure 2.

A site inspection by DoME was carried out during the site rehabilitation earthworks on 31 August 1999. DoME have since inspected the Carnilya Hill mine site on a further two occasions (November 12 and 23, 1999). The first inspection was carried out by DoME's Environmental and Rehabilitation representative for the Kalgoorlie Inspectorate.

The site report received by WMC "acknowledged and commended the high standard of rehabilitation earthworks completed at the Carnilya Hill site". The second inspection by the District Inspector of Mines - Kalgoorlie Inspectorate confirmed that "the abandonment conditions of the Mines Safety and Inspection Act (Section 42 (1) (c) had been adequately met and that no hazard to public safety remained at the site".

Figure 2: Overall reporting framework for Carnilya Hill Closure and Rehabilitation Plan

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DAY ONE - SESSION ONE - COMPLETION CRITERIA
CARBON SEQUESTRATION – AN ALTERNATIVE USE FOR RANGELANDS AND REVEGETATED MINE DUMPS?

**Abstract**

While the ratification of the Kyoto protocol is still in doubt, in the longer term it appears that nations will be constrained to reduce their emissions of carbon, and national and international systems for trading in rights to emit carbon will be developed.

The mining and pastoral industries in the rangelands are both emitters and ‘fixers’ of gases that encourage the greenhouse effect.

The theme of this paper is that arid lands represent a vastly under-utilised resource for the capture of atmospheric carbon. Rates of sequestration by natural and manipulated stands of vegetation are reported. Whether or not that capture may be permitted in the national and international carbon accounting system relies on robust debate and lobbying.

The potential for carbon sequestration to provide an income source or emission offset for landholders is explored. The indications are that ‘carbon farming’ in rangelands will not be economical unless sequestration rates can be boosted by water harvesting or unless more categories of rangeland vegetation (other than woodland) become allowable carbon sinks.

**Introduction – Global Warming, Greenhouse and Reducing Net Emissions**

The Greenhouse Effect and global warming have been described and discussed for more than 15 years (e.g. Boyle and Ardill, 1989; O’Neill, 1988). It is postulated that the emission of gases including carbon dioxide, carbon monoxide, methane, oxides of nitrogen and chlorofluorocarbons (CFCs) form a ‘blanket’ in the upper atmosphere. This layer allows short wave solar radiation to enter the atmosphere, but increasingly reduces the amount of re-radiated energy that can leave.

The layer also reflects an increasing amount of the long wave radiation emitted by the earth. Therefore in a similar manner to a greenhouse, more energy is trapped and less is re-radiated than occurs under ‘natural conditions’. This causes higher temperatures.

Human-induced changes to the earth’s ‘natural conditions’ started with the clearing of large areas of woodland, and have accelerated since the start of the industrial revolution. On a worldwide scale net annual emissions are 3.6 Gt-C equivalents. (Hassall & Associates, 1999).

**Figure 1:** Annual rainfall totals and 10 year moving averages for Southern Cross 1889 to 1999

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He who plants trees loves others beside himself.  
English proverb
If they are not able to do this they may incur an emissions tax liability.

For any company that is a net greenhouse gas emitter and faced with the prospect of a tax an option would be to buy carbon credits from others who are net fixers of greenhouse gases – particularly carbon. This will usually involve the growing of trees.

Provided that companies can purchase carbon credits for a price lower than the tax they will seek to enter agreements with others who are increasing carbon sinks.

**Purchasing options in preparation for trading in carbon credits**

Carbon trading has not started in Australia. However, a number of companies are trading in options to purchase carbon credits against the day when a tax is introduced. Two trades in New South Wales announced in June 1998 had the following common features (from Hassall and Associates, 1999):

- They were for options to secure the rights to carbon in the future when the rules are defined.
- Both agreements were for future carbon – yet to be sequestered.
- Both agreements were between power companies and the State Forests of NSW.

**Emission licensing could bring enterprise closure and ‘carbon emission replacement’**

In certain cases the only way to reduce net carbon emissions will be to close down inefficient enterprises that produce high levels of carbon per unit of output. As an example, there is some indication that Russia might use this ploy to reduce its emissions in the commitment period 2008-2012 (Hassall & Associates, op cit).

Looking to future commitment periods (when Australia has made all the early, easy gains) there is discussion on ‘carbon emission replacement’. Here companies forego production that is greenhouse gas generating in return for payments for the reduction in greenhouse gas emissions.

**The problem with sheep and cattle**

Ruminant livestock produce methane through their natural digestive processes (enteric fermentation). There were 26,710,000 cattle and 119,579,000 sheep in Australia in 1998 (ABS, 1999). These produced 2.2 M tonnes of methane (CSIRO, 1994). Since methane is thirty times more ‘effective’ in trapping heat than carbon dioxide this is equivalent to a carbon emission of 66 M tonnes C/year. Using a conversion of 1 cattle unit = 10 sheep units this represents 170 kg C/year/sheep and 1.7 tonnes C/year/cow, steer or bull.

Livestock farming and pastoralism are seen as major greenhouse gas emitters. Replacing inefficient ruminant livestock production enterprises with enterprises that sequester carbon would have a double benefit to national carbon accounting.

It is important to remember that no firm rules have yet been formulated. Lobbying a particular point of view with the Australian Greenhouse Office will be possible until December 2000. Clarification of the rules for a national system of carbon accounting and carbon trading will depend on what will be allowable under the international protocol.

**POTENTIAL FOR NATURAL CARBON SEQUESTRATION IN RANGELANDS**

Carbon sequestration will obviously occur in all growing plants in the rangelands. The monetary benefit of that, and any incentive to reduce herbivores (ruminants, feral animals and control native species) will largely depend on what is deemed to be allowable internationally as part of the carbon accounting system. There are at least four good reasons why rangeland vegetation should be allowable in the carbon accounting system. These are that it would lead to more emphasis on feral animal control and conservative stocking rates, it would encourage actions to suppress wildfires, it would discourage further clearing, and it would help to promote rangeland rehabilitation.

**Background natural rates of carbon fixation**

Data on the weight and age of components of rangeland systems are limited. Shea et al. (1998) suggest an average figure for the pastoral rangelands of Western Australia (85 M ha) of 5 tonnes of carbon sequestered over a 30 year accounting period. At first sight this figure appears small, but it is assumed to take into account vegetation removed by grazing and carbon lost in wildfires. Yamada et al. (in press) developed an estimate of average Carbon in plants for Sturt Meadows Station of 4.3 tC/ha (range 3.03-4.15 tC/ha).

In the Goldfields we are fortunate to have some ‘woodline records’ to base estimates upon. Kealley (1991) states that the felling of Eucalyptus trees around Kalgoorlie yielded 7.9 tonnes/ha of usable timber. Further, Mulga woodland (Acacia aneura) around Leonora produced 5.7 tonnes/ha. Separate investigation (Yamada et al., in press) has shown that Eucalyptus camaldulensis near Leonora contained 38% moisture while Mulgas contained 19% moisture. These low moisture contents resulted in carbon contents in fresh wood of 43.3 - 51.7%. Kealley (1991) quotes figures for high quality charcoal production from Mulga of 1 tonne of charcoal from 3 tonnes of fresh wood.
Waste rock dumps on minesites that are free from the problem of acid drainage could be designed to minimise runoff, and maximise the rain that infiltrates where it falls. This will maximise the growth of the vegetation planted on that dump. Thus what is naturally an area of 200 - 250 mm MAR with 50% runoff could be designed to show plant response as if the plants were growing in a 400-500 mm MAR. Water supply to plants could be augmented in some situations by solar or wind-powered irrigation extracting water from flooded old pits.

In a broad rangeland context the simplest and cheapest method to enhance ‘effective rainfall’ is to use landscape modeling to identify areas in the landscape that are natural wet, run-on areas.

A further opportunity to increase ‘effective rainfall’ may arise in carefully selected locations by spreading runoff water out of channels and back onto inter-channel areas through the construction of water spreading embankments. Such work must be started at the head of any channel.

**Choosing tree species**

The correct choice of tree species will be essential for rapid growth and the hardiness to withstand the environmental conditions. Trees are required that have the ability to grow rapidly when water is available and to survive in the inevitable dry periods. This is likely to favour local, native species.

Research is required to compare the production of different tree species in the Goldfields environments under different ‘effective rainfall’ regimes. The research work at Sturt Meadows is a significant start.

**WHAT TO DO WITH MATURE TREES?**

First, this is not likely to be an immediate problem, and options for utilisation and re-planting will no doubt increase over the 20-30 years of a tree rotation.

The rules have not been finalised, but it is likely that selling the trees for combustion or for a purpose that will quickly lead to decay and release of the stored carbon will require the repayment of earned carbon credits.

The first option when the trees reach maturity is the ‘do nothing’ option. Parts of the trees will senesce at close to the rate of new growth and the trees will be effectively carbon neutral. However, trees sequester carbon most quickly when they are growing rapidly. If the intention is to take advantage of further rotations of trees the mature trees need to be removed.

The Goldfields is probably too far inland for the export of raw lumber to be economic.

Value adding in the region will be required in order to make export an attractive proposition.

A third option may be to produce high grade charcoal or to burn the timber for power generation. The logic of this is that it saves on the combustion of fossil fuels (which might maintain the carbon credit) and the carbon that is released by burning the timber can be seen to be part of a sustainable cycle of sequestering, release and re-sequestering.

**OPPORTUNITIES AND CONSTRAINTS IN CARBON SEQUESTRATION BY LAND-BASED INDUSTRIES IN THE RANGELANDS**

Opportunities will depend on the national system that is put in place to account for emissions and sequestration, and encourage a net decrease in greenhouse gas emissions. Favourable rulings are needed regarding what is allowable as a source of carbon credit for rangeland users. This is particularly important if the domestic carbon accounting system is to provide an opportunity to reduce or nullify a user’s own carbon emissions. For some land users it could result in income through future carbon credits trading.

Within the mining industry it may become possible for carbon reserves on dumps to become tradable. These might be sold to the government as a part of future mine closure arrangements or used to offset carbon emissions from the mine.

A system for carbon emission licensing is likely to result in a shift in enterprise away from ruminant livestock, possibly to more plant based enterprises or non-ruminant livestock (camels?).

**Constraints**

Land tenure is the most obvious constraint. Neither mining tenements nor pastoral leases are established to allow or assist the lessee to trade in carbon credits. Institutional and legal changes will be needed to allow future carbon credits trading in rangelands. Such changes will also be needed to address the looming conflict between reducing methane production from ruminants in rangelands and the need to maintain livestock or other enterprises to maintain rural communities.

The influence of native title claims is difficult to predict.

There is no indication yet of a minimum area that will be allowable for carbon sequestration. However, the cost of monitoring and verifying stored carbon will make areas below a certain size unviable. The formation of seller cooperatives may overcome this problem.

The establishment costs of carbon sequestration enterprises in rangelands are likely to be higher than in wetter areas.
REHABILITATED LANDFORMS: DESIGNING FOR STABILITY

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LANDTECH LANDFORM TECHNOLOGIES

ABSTRACT

This paper outlines soil erosion models that can be used to aid design of rehabilitated landforms. Erosion models include agricultural models (which consider a constant, unchanging, 1- or 2-dimensional landscape) and models which reflect the 3-dimensional landforms considered in response to predicted erosion and deposition. Models also vary in the time step used, in the range of management inputs that can be tested, and in the extent to which erosion processes are considered.

These differences have important impacts not only on model output, but also on the ease with which model parameters can be determined.

A range of model applications is discussed.

INTRODUCTION

Post-mining landforms typically consist of outer batter slopes, and a (relatively flat) top of greater or lesser magnitude. Landform design is largely concerned with gradient and length of the outer batter slopes, though potential impacts of discharge of runoff from the top of the landform should not be neglected.

For batter slopes, both length and gradient affect potential rates of erosion from the landform, and both also affect the costs of landform construction. Generally, there is a conflict between economic and environmental concerns. In many instances, steeper landforms will cost less to construct, and have the added benefit that the area covered by the final landform is also less. However, steeper slopes will also be likely to erode at higher rates, creating concerns with excessive erosion.

Therefore, selection of slope gradient and length parameters for a landform is generally a matter of finding an optimal solution for conflicting environmental and economic imperatives. As well, there is a range of management options available that are almost as important as are slope parameters in determining ultimate landform stability. Importantly, a landform design should be site specific - in equilibrium with climate, soil/spoil properties, and vegetation.

The design process generally involves comparison of alternatives, and selection or identification of some optimal design that best meets design requirements. A critical component of the design phase is the use of soil erosion models to assess erosion potential of various alternative landform designs.

A range of computer models can be used in landform design, including both plant growth/water balance models and also runoff erosion models. These can be linked with longer-term landscape evolution modeling to provide both short- and long-term assessments of landform stability, considering both 2- and 3-dimensional representations of the landform.

This paper describes the range of models suitable for minisite applications, and provides examples of their application, including estimation of slope profiles for minimum erosion. It will also highlight some of the limitations of older, simpler models.

Equally important is the need for suitable site characterisation, as the erosion models cannot be used without suitable input parameters. Rapid field and laboratory methods for measuring soil and spoil erodibility have been developed, and these will also be described.

COMPUTER SIMULATION OF RUNOFF AND EROSION

Short-term (agricultural) models

Soil erosion prediction for agricultural management has had a long history of development, beginning with an equation by Zing (1940) that was a forerunner of the Universal Soil Loss Equation (USLE) (Wischmeier and Smith 1956). The USLE has an annual time step, as does the Revised USLE (RUSLE) (Renard et al. 1997) which is a computerised and somewhat enhanced version of the USLE. Other developments produced USLE models using daily time steps, referred to as a Modified USLE (MUSLE) (Ontstad and Foster 1975). A number of modeling packages such as PERFECT (Littleboy et al. 1992) and PCM (Loch 1997) have linked MUSLE models to soil water balance and plant growth models. However, all the USLE variants consider a hillslope only, and give no information on sediment sizes or deposition.

A significant development was the CREAMS model (Chemicals, Runoff, and Erosion from Agricultural Management Systems) (Knisel 1981), which distinguished between rill and interrill erosion, and which explicitly considered sediment size and density and their impacts on erosion, deposition, and selective transport. CREAMS also runs on a daily time step, with the assumption that one rainfall/runoff event occurs in each day. Concepts of critical shear for rill initiation were introduced for the first time, and there was some scope to consider landscapes of hillslopes and channels.
Because parameters for the SIBERIA model are derived by optimisation to existing data, the model is restricted to considering variations in management methods or in soil erodibility for which data are available.

The SIBERIA model offers considerable advantages as a design tool. Apart from its ability to assess gully development and incision, it is the only model able to consider long-term impacts of areas of deposition and of overflows from a flat landform top onto the side batters. There is also the potential to use SIBERIA parameters (without running the model at all), to calculate slope profiles that will give minimum erosion. This comes from work by Willgoose et al. (1991) and Willgoose (1994) who found that SIBERIA parameters could be used to predict the long-term "equilibrium" slope profiles that landscapes would develop. These equilibrium slope profiles are essentially "minimum erosion" profiles. So, by forming them from the start, erosion and re-shaping of the slopes can be minimised.

The SIBERIA model is possibly best known for its use in assessing long-term stability of the above-ground tailings option at the Ranger Uranium Mine. However, SIBERIA has also been used for design of rehabilitated landforms at the Tom Price and Argyle mines in Australia, and for assessment of risks of exposure of buried nuclear waste in the US. It has been subject to considerable testing and validation.

**Taking a combined approach**

There are benefits in using two or more soil erosion models when considering landform design and stability.

There are advantages in using an agricultural model for primary assessment of a site, for testing a range of spoil types, and vegetation and management options. Once a model is set up, an extremely wide range of scenarios can be considered. It can also be useful to build understanding of rehabilitated systems, and to identify priorities for management and design. For example, Figure 2 demonstrates WEPP simulations of the impact of rill spacing on erosion of a topsoil batter for a mine in central Australia. Rill spacing is strongly affected by surface roughness, with deep cross-slope ripping tending to create large, widely-spaced rills. The figure shows rapid increases in erosion rate as rills form. For wider spaced rills, the amount of flow in the rill increases more rapidly with slope length, so that rills initiate at shorter slope lengths, and erosion rates increase more rapidly.

As well, provided the model output is suitable, it can be used as a data set for parameterisation of the SIBERIA model. The options are then to either use the parameters to estimate minimum-erosion slopes, or to run SIBERIA and to assess the long-term performance of the structure.

*Figure 2: WEPP model simulations of the impact of rill spacing on erosion of topsoil on outer batter slopes for a landform in central Australia*
REFERENCES


DO WE REALLY HAVE AN ISSUE WITH MINE VOIDS IN THE GOLDFIELDS?

INTRODUCTION

Improved earth moving techniques and more efficient processing methods of large low grade orebodies, has resulted in a dramatic escalation in the number of large scale open cast mining operations in Western Australia (WA). WA currently has more than 1800 mine pits/voids, the majority of which are to be found in the Goldfields (Figure 1). The size of these voids vary from the average borrow pit (100's metres in diameter) to the enormous iron ore mine pits in the Pilbara (Mt Whaleback, for example, will be some 5.5 km by 2.2 km by 460m). The Super Pit, with an ultimate size of 4.2 km by 1.5 km by 0.5 km, represents the largest mine void within the Goldfields region. In the past, mine voids received relatively little attention, the greatest interest being in the development phase with very little focus on what ultimately happens once mining ceases. Mine closure focussed on pit safety issues (structural safety) rather than on what the possible environmental impacts could be.

Many of the mine voids extend below the watertable and mining therefore entails dewatering operations. Once dewatering ceases, groundwater levels recover and the mine void becomes a "window" in the groundwater table. This exposure of the water table has the effect of creating an artificial lake, initiating geochemical and hydrological processes that evolve with time. The infilling of the void with water could take centuries, with chemical evolution continuing much longer if evaporative concentration is significant. This raises the question of whether these abandoned mine voids represent environmental time bombs? Is a simple safety bund and fence all that is necessary before walking away from a closed mine?

Over the past few years there has been increasing concern among WA water resource managers about the potential impact of mine voids on groundwater salinity. This has been of particular concern in areas like the Pilbara where the groundwater resources are generally fresh to brackish. The focus now is widening to include other areas such as the Goldfields. The fact that there are currently more than 150 WA mines operating below the water table and some 1000 existing mine voids, with the potential to host saline pit lakes, highlights the urgency for obtaining a better understanding of the issue. In particular,

What is the situation in the Goldfields?

Is there reason to be concerned?

HYDROGEOLOGICAL PROCESSES IN THE PIT

The creation of "great big holes" extending below the water table initiates a series of hydrogeological processes. During mining operations, groundwater is removed from the pit area, but once mining ceases and pumping stops, groundwater levels recover and flow is towards the mine void, resulting in the creation of the pit lake. During mining operations the rocks in the pit wall and floor are exposed to the atmosphere. Flushing of these rocks with water during lake filling can release constituents dissolved from the rocks into the lake water where they may be biologically available. Pit lakes in high sulfide rock tend to have poor quality water, which may or may not be acidic depending on the amount of limestone available to neutralize any acid generated. Oxidized rock that contains appreciable carbonate is likely to produce better quality, near neutral pit lake water. This flushing is not restricted to the mine pit itself but can extend into the surrounding rock formations. The water table cone of depression created during mining operations can extend a large distance from the pit. When the surrounding rock is exposed to air, reduced surfaces can be oxidized and generate soluble metal-bearing salts. When dewatering ends, water percolates through the newly oxidised rock surfaces and flushes the leachate into the pit lake.

The final water quality in the pit lake is dependant on a host of factors including the oxygen status of the lake, pH, the hydrogeologic flow system, composition of wall rock, evapo-concentration, biological activity and hydrothermal inputs (Figure 2). Understanding how the pit lake water quality evolves is difficult, as the hydrologic and chemical inputs are qualitatively different from those of most natural lakes. The circulation patterns of pit lakes are important because of the central role of oxygen, and thus the redox status, in many of the chemical reactions that affect water quality, for example iron and arsenic. The concentration of all constituents in a pit lake increases significantly in a semi-arid climate due to evapo-concentration. In areas where net evaporation greatly exceeds precipitation it can result in dramatic increases in the total dissolved solids content. This is particularly true where surface flow into the pit is limited to direct precipitation. The generation of relatively dense, saline water at depth and periodic addition of fresh rain water to the surface layers can result in a stratified water body. Most mine pit lakes are relatively young and insufficient data is available to support the testing and validation of available computer models.

The potential impact that pit lake water may have on the surrounding groundwater environment depends very much whether the mine void acts as a

- Groundwater sink
- Groundwater throughflow cell
- Groundwater recharge cell

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During rainfall, even with little or no runoff to the lake, the crustal salts are dissolved and some infiltration may occur. The infiltrating water will carry the salts down, such that, even though at times the surface water may be brackish the underlying shallow groundwater will always be hypersaline. The consequence of the variable and intermittent nature of the inflows of surface water to Lake Carey is that the salinity of any surface water in the lake will vary enormously. In the case of the more intense cyclonic events the lake will become a large fresh or brackish water body which would gradually become saline through evaporation. It can thus be concluded that any impact from the final void, if it is allowed to fill with water, will be negligible on the beneficial use (mine process water) of the groundwater resource. The final mine void is relatively small in comparison to the overall size of the lake. Lake Carey is a saltlake system and the regional groundwater resources are hypersaline. The prime void closure consideration must therefore be public safety and aesthetics.

The Argo mine pit at the St Ives Gold Mining operations is located in an area of extremely saline groundwater and is typical of many of the mine voids in the central Goldfields. The Argo mine pit, located 18km inland from the eastern shoreline of Lake Lefroy, is approximately 500m X 300m X 90m with the proposed Stage 3 extending the pit 150m to the south and deepening the existing void by 25m (Figure 7). The local topography is one of low relief with no defined natural surface drainage features in the immediate mine area. Salt lakes, eucalypt woodland and shrub thickets cover most of the region, with the dominant land use being devoted to pastoral and mining activities. Much of the land however remains as vacant Crown land or reserve.

The mine is within an Archaean greenstone belt and groundwater occurs in two aquifer systems: an alluvial lake system; and sub-vertical, disconnected fractured rock aquifers related to structural movement along the many faults in the area and the intrusion of porphyry and doleritic dykes. During Stage 2 of mining operations inflow to the pit reached 70 L/sec and comprised an accumulation of numerous discrete inflows at variable rates. The flows were via bedrock structural defects, particularly within deeper parts of the weathered zone at 20-50 metres depth and to a lesser extent directly from the palaeochannel sands. The palaeochannel sand deposits were found to be longitudinally segmented into zones with marked variation in thickness and permeability.

Following the completion of the Stage 2 pit, dewatering was continued and the inflow rate gradually diminished to 60 L/sec. Groundwater pumped from Argo pit typically had pH 6.5 and a salinity of 285 000 mg/L. There is distinct salinity stratification within the Tertiary sediments, with salinities as low as 69 000 mg/L at shallow depth. The palaeochannel sand aquifer is naturally acidic, with a pH of 3.5-4.0.

The palaeochannel at Argo is a relatively minor tributary to the Lefroy palaeodrainage system. Due to the low hydraulic gradients and segments of low permeability clayey sands, throughflow in the basal sands is very low, less than 100 KL/d. Significant permeability in the bedrock is primarily associated with the ore position and does not constitute part of a regional aquifer. The flat ground surface and absence of defined natural surface drainage means the pit is easily isolated from the surface water system.

After closure groundwater will continue to flow into the pit at a rate of around 60 L/sec until the water level rises above the base of the aquifer, after which the rate of inflow will be ever-decreasing. The pit water level will tend to stabilise below the pre-mining static lake level as increasing evaporation tends to match the decreasing rate of groundwater inflow. The Argo pit will remain a net water sink as evaporation will continue to exceed the very low rates of groundwater inflow. Because of its function as a groundwater sink, there is no apparent impediment to a continuous increase in pit water salinity by evaporative concentration of salt. The eventual result would be the gradual deposition of crystalline salt, particularly gypsum and halite. The mass of salt 'locked up' in the void will however be very small compared to the overall salt store of the Lake Lefroy sedimentary basin, at the margin of which the pit is located. The possible backfilling of the mine void although an attractive closure option, is only viable if the deposit can be considered as 'sterile' and if there are ongoing mining operations in close proximity to the void. It is thus most likely that the final void will be left to naturally fill with water.
Cumulative Impact

One aspect that has yet to be examined is the cumulative impact of a number of mine voids in a relatively small area. Many of the gold mining operations have resulted in a multitude of pits within one mining area. Individually the voids may not pose a significant danger, but collectively they may act as a diffuse pollution source. This is particularly relevant in the Murchison and Gascoyne Regions (Figure 5) where the deep laterite weathering profile and overlying colluvium and alluvium constitutes a shallow aquifer with fresh to brackish water that serves as either potable water supply or for stock watering. The gold mining operations Mt Magnet for example have resulted in some 32 pits within the same catchment as the town borefield located in the Genga Water Reserve (Figure 9). Most of the pits located on the plain to the southwest of Mount Magnet township (the area covered by Cainozoic sediment) have targeted mineralization within the lateritic duricrust and saprolite, although some extend down to the bedrock. Groundwater occurring in both the weathered rock and underlying fractured bedrock units. All the pits represent groundwater sinks and gradually fill with water once dewatering ceases. Should these voids be allowed to, become hypersaline pit lakes with time, there would be considerable risk of possible migration of a saline plume away from the pits. The most likely flow path would be along the major regional faults and within the more permeable zone at the base of the saprolite. In both cases the regional groundwater flow direction is towards the Genga Water Reserve.

This raises the issue of potential contamination of the town borefield which exploits both the shallow unconfined sedimentary aquifer and the deeper fractured bedrock aquifer.

The Agnew gold mines in the Northern Goldfields in turn serve to illustrate the potential dangers inherent in mining operations that involve a number of mine voids located in close proximity to each other along a linear geological feature (Figure 10).

The geological lineament has not only resulted in structurally controlled mineralisation, but also secondary permeability and preferred flow paths for groundwater. Each mine void appears hydrogeologically isolated and, as a groundwater sink, is expected to become more saline and eventually represent a point source of hypersaline groundwater. Being located in a hard rock terrain, the hypersaline plume would normally be expected to be effectively contained within the immediate vicinity of the void, however, the linear fracture pattern provides an ideal path for the salt plume to move along.

As a result of the fairly confined nature of the flow path the plume might be expected to move a considerable distance from the void and possibly even meet similar plumes from neighbouring voids located along the same geological structure. The end result could be the potential loss of any borefield located between the mine voids that exploits the fractured rock aquifer associated with the linear geological feature. In the case of the Agnew Mines the best closure strategy may well be to accept the inevitable and sacrifice the less important New Woman Borefield in order to protect the more important Emu Borefield.

Acidity

The generation of acidic waters, a major issue elsewhere in Australia, is not really an issue in WA, other than in the coal mining industry in the better watered south west, and to a lesser extent in a few of the metalliferous mines. The potential for the production of acidic waters in the metalliferous mines is relatively limited as Western Australia does not have an extensive history of production of ores from primary or sulphidic mineralisation (Williams, 1995). Nickel deposits have variable carbonate alteration associated with nickel mineralisation and the potential to produce acidic waters will vary widely from mine to mine. Most of the greenstone hosted gold mines in the Goldfields have limited potential for the development of acidic waters. The extensive carbonate alteration often associated with the gold mineralisation generally has the capacity to neutralise any acid produced by the weathering of sulphides contained in the orebodies. While this may limit the potential for acid production, the potential for the release of other metals will vary, depending on the specific geochemistry and environmental conditions of each deposit (Williams, 1995).

The St Ives gold mines south of Kambalda are typical of those gold mines that contain material with acid generating potential. The acid generating potential of the ore zones and overburden in most mine voids is low. Where the mining exposes such material, acidification of the final void lake water is not considered as a high risk due to the following characteristics.

- On completion of mining the final voids will become flooded to above the natural in-situ base of oxidation relatively quickly.
- The pH of the groundwater is 6.5 and the ionic strength of the hypersaline water will strongly buffer any tendency for changes in pH.
- The material with a high acid producing potential (sulphide bearing quartz veins) is associated with the ore surfaces and only very small areas will remain after mining.
- Materials with a high acid neutralisation capacity (including carbonate alteration minerals) are associated with the ore surfaces and will to a large extent remain in-situ.
Figure 1: Location of final mine voids expected to extend below the water table. (From Wright, 1999)

- Developing
- Operating
- Maintenance
- Closed

Hydrogeological subdivision
- Phanerozoic - Sedimentary basin (Sedimentary aquifers)
- Proterozoic - Harde rock province (Fractured rock aquifers)
- Archaean - Harde rock province (Fractured rock aquifers)

Scale: 4 km
Figure 4: Groundwater salinity at the water table in Western Australia. (After Allen, 1997)
Figure 6: Location and geological setting of the proposed Red October mine void.
Figure 8: Location and geological setting of Salmon and Perch mine voids.

Location of mine voids

Perch Mine

Salmon Mine

Schematic geological cross sections
Figure 10: Geological setting of the Agnew Gold mine voids and groundwater salinity in the vicinity of Ag mine void.
THE DISPOSAL OF EXCESS MINEWATER IN THE GOLDFIELDS

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ABSTRACT

During the mining development “boom” in the Goldfields in the early to late 1980’s, much exploration and investigation effort went into finding process water supplies. The new CIL/CIP gold processing plants were “thirsty” and there wasn’t much water around. However, they could use the saline to hypersaline groundwater in the local aquifers (fractured rocks and paleochannels), and numerous large and small-scale borefields were developed.

In recent years, however, with some mines going deeper into complex (and more permeable structures) and following a period of higher than average rainfall (with the odd cyclone thrown in), many of the mining operations are running with significant surpluses in their water balances. The sources of excess water range from dewatering discharges to tailings decant, with water quality ranging from fresh to hypersaline.

Some mines are now faced with the problem of developing and maintaining excess water disposal systems which are acceptable to the regulators and general public. To date these systems have included discharge to salt lakes and old mine pits, evaporation from specially designed ponds/basins and aquifer re-injection.

This paper provides a broad overview of the excess water disposal systems available including the technical, environmental and regulatory constraints. It will also provide examples of where these systems have been successfully implemented and examples of where systems will not work.

1. INTRODUCTION

The gold mining boom, which commenced in the early to mid 1980s was a result of rising gold prices and the advent of CIP/CIL processing technology. The new process allowed for cost effective gold recovery using hypersaline groundwater which had been known to exist for many years from industry sponsored regional exploration programmes, but which previously had little known practical use.

The CIP/CIL technology, which required around 1kL/d of raw process water per tonne of ore processed (after tailings decant return), allowed for the processing of large throughputs of low-grade ores. Initial mining was shallow, targeting oxide ores, with processing at mill throughput rates ranging from half a million to well over a million tonnes per year. The initial shallow mines required little to no dewatering and evaporative losses from tailings storage facilities and water holding facilities were high. As such there were large demands for raw process water supplies, and the local and regional hypersaline groundwater resources were investigated and developed at a rapid rate.

The development of new, large scale nickel mines (sulphide and laterite deposits) the 1990s has also seen the demand for process water increase, although the process water quality requirements for the pressure acid leach technologies associated with the laterite nickel projects are much more stringent.

There has been an increase in process water usage demands in the Kalgoorlie region alone from less than 1GL/yr in 1984 to almost 30GL/yr in 1999 (reported usage, which is currently only 50 to 60% of WRC licenced allocations).

However, in recent years the requirements for raw process water (per tonne of ore processed) have generally declined as a result of:

- higher rainfall; and
- deeper mines (requiring more dewatering).

Figure 1 shows annual rainfall plotted from 1984 to 1999 together with the longterm annual average and the five-year moving average. This shows significantly above average rainfall in 1992, 1995 and 1999 (partly as a result of cyclonic activity) and the five-year moving average being well above the long-term average since 1995. This has resulted in significant inputs of additional water to the mines’ water management systems as a result of incident rainfall to pits and tailings storage facilities, increased plant runoff to water management ponds and increased flood runoff to pits.

In addition to the above, many mines are now, and have been for several years, extending into deeper, more structurally complex and often more permeable rocks (as open pits and underground mines) and there has been an increase in dewatering production. Of the current licenced allocations for groundwater abstraction of around 150GL/yr, some 40GL/yr per year (or around 30%) are for dewatering operations (although it should be noted that actual abstraction is estimated to only be around 50 to 60% of licenced allocation). In 1984 the proportion of dewatering to total allocations is known to have been much smaller (although precise figures are not available). Again, the net result has been additional water in the mines’ water management systems.
For example:

- Discharge to abandoned underground mines or deep pits can result in recharging of the water table, and will therefore be similar to aquifer injection.
- Discharge to shallow pits in impermeable bedrock or residual soils will be similar to discharge to evaporation ponds.
- Discharge to deeper pits and underground mines and/or aquifer injection could raise water tables and induce increased baseflow to creeks, and so would be similar to river discharge.

However, for the purposes of this paper, the four broad categories will be described separately.

3. TECHNICAL, ENVIRONMENTAL AND REGULATORY ISSUES

3.1 Technical and Environmental

The main issues relating to whether each category of excess water disposal will be technically and environmentally feasible include the following:

Discharge to lakes/rivers

- Discharge pipeline sizing and route (pipelines are often several tens of kilometers in length).
- Shape, volume and spill capacity of immediate discharge zone in relation to volumes and rates of excess water discharge (i.e. is there potential for "back-flooding"?)
- Normal hydrological turnover in relation to discharge volumes (i.e. what is the mixing/blending potential and how long will discharged water stay in the discharge zone?)
- Normal drainage patterns and volumes (i.e. where will the discharge water end up and at what dilution factor?)
- Discharge water quality in relation to receiving water quality (when lakes/rivers are wet) and net mass/types of salts that are added to the lake/river (refer to above two points on mixing and dilution).
- Discharge water quality in relation to requirements for bunding of pipelines and provision of emergency containment.
- Tolerance of lake/river flora and fauna to increased salinity of lake/river water and residual salt loads.

Discharge to pits/underground mines

- Discharge pipeline sizing and route and implications for bunding and/or emergency containment.
- Volume of dry pit/mine below local water table (i.e. volume that can be discharged before there is any potential for outflow to groundwater). Note, however, if discharged water is hypersaline and local groundwater is fresh/brackish/saline, then there is the potential for density driven flow out of bottom of the pit/mine, even where there are apparent hydraulic gradients towards the pit/mine.
- Total volume of mine workings (i.e. total volume that can be discharged if pit/mine is not in hydraulic connection with local aquifers).
- Hydraulic properties of surrounding aquifers and unsaturated zone (i.e. what will be the outflow rate, and thus increased discharge acceptance rate, for various pit/mine water levels, and how will outflow effect water table levels?)
- Location of low lying areas, vegetation and creeks that may be affected by a water table mound (i.e. by water logging and/or increased baseflow).
- Discharge water quality in relation to ambient groundwater quality (i.e. what is the potential impact on water quality and beneficial use of outflow from the pit/mine?)

Discharge to Evaporation Ponds

Optimum surface area in relation to maximising evaporation while minimising direct rainfall recharge. This is the critical issue and the optimum area will change with changing rainfall patterns.

- Design (if possible) to allow for modification of surface area.
- Foundation conditions and potential for seepage losses (and possible need for liner).
- Potential for overtopping during extreme rainfall events.
- Discharge pipeline sizing and route and implications for bunding and/or emergency containment.
- Pond water quality and potential impacts on groundwater (if seepage occurs) and surface water (if overtopping occurs).
- Final salt load and design of pond closure to minimise remobilisation of above ground or near surface stored salt mass.
Some general examples of the process of regulatory approval and licensing are:

**Discharge to lakes**
- requires a licence
- conditions more onerous than for others
- more formal assessment for some lakes

**Discharge to pits**
- requires a licence if discharge exceeds 50,000KL/yr
- conditions generally not onerous
- WRC involved where potential impact on beneficial use of future resource

**Discharge to evaporation ponds**
- requires licence
- similar conditions to tailings storage facilities

**Aquifer injection**
- licence required
- DEP conditions generally not onerous
- WRC involved where potential impact on beneficial use of future resource

### 4. PRACTICAL EXAMPLES

#### 4.1 Discharge to lakes and/or river systems

**Cuddingwarra**

Dewatering of several pits at Cuddingwarra (a satellite operation to Newhampton Goldfields' Big Bell Operations) currently produces up to 3.5ML/d of hypersaline water. This water is not required for gold processing at the Big Bell plant, and has been discharge to Lake Austen (located some 14km to the southwest) since mid 1999.

As part of the investigation of the Lake, prior to the issuing of a Dewatering Discharge Licence, a detailed baseline study of the riparian flora and fauna was undertaken. Seven permanent monitoring transects were established at the time and have been monitored regularly since. Monitoring includes monthly evaluation of discharge volumes, discharge and receiving water quality and specific types of lake flora/fauna (rupia beds and crustacean taxa); six-monthly photo surveys of vegetation, and annual assessment of all flora/fauna species.

Newhampton Goldfields is currently applying to increase the licence to cover 6ML/d, as a result of increased dewatering requirements. As part of the proposal, the discharge point will also be extended a further 600m into the Lake to reduce the potential for discharge waters to effect fringe Lake flora/fauna.

**Kundana**

Excess water from pit dewatering operations at the Kundana Gold Mine has been discharged into White Flag Lake since 1991. The water is saline to hypersaline (80,000 to 130,000mg/L TDS) and has been discharged via a dedicated pipeline to the southwestern edge of the Lake, at rates ranging from 4ML/yr in 1993/94 to almost 400ML/yr in 1998/99. This discharge is now covered by a Dewatering Discharge Licence.

Kundana Gold Mine have initiated comprehensive Lake monitoring and ongoing impact assessment programmes, which are reported on each year in an Annual Dewatering Discharge Report, as part of the overall Annual Environmental Report. The results of ongoing monitoring indicate that the salts loads from discharge (current and potential future discharge) are not significant with respect to the total salt content of the Lake system.

However, notwithstanding the above, Kundana Gold Mine propose to divert all dewatering discharge, in the near future, to the recently mined out Kurrawang Pit. This will have even less environmental impact than the current Lake discharge system. Prior to discharge to the pit, monitor bores will be installed on the down-gradient side of the pit and a regular groundwater monitoring programme is planned.

#### 4.2 Discharge to abandoned open pits or underground mines

**Jubilee**

Newhampton Goldfields' Jubilee Operations comprises a number a satellite pits with all processing at the Jubilee Mill. In recent years, two adjacent pits, the White Hope and Dawns Hope pits located some 20km south of Jubilee, have been mined in tandem. While mining one pit, dewatering discharge was directed into the other and vice-versa. The water pumped from both pits is similar with salinities ranging from 19,000 to 24,000mg/L TDS. At times, dewatering rates have peaked at around 200KL/d, although total annual production has been less than 50,000KL. As such, no Dewatering Discharge Licence is required, and the only monitoring required is that to comply with the Groundwater Well Licence (from WRC). However, additional water quality monitoring of the discharge and receiving waters is carried out.

Newhampton Goldfields also operates a seepage recovery system (comprising bores and sumps) at the toe of the main Jubilee tailings storage facility. This system normally pumps back to the mill to provide process water. However, during mill shut-downs and/or during extreme rainfall events, the production capacity from the seepage recovery system exceeds demand.
One of the options considered for disposal of the seepage recovery water was aquifer injection using existing bores in the Kaltails Borefield. This borefield comprises fifteen production bores installed over a 15km length of a major hypersaline (100,00 to 150,000mg/L, TDS) paleochannel aquifer in the Roe Paleodrainage System. Investigation of this option indicated that the bore construction and aquifer hydraulics presented no real problems and that aquifer injection of the total seepage recovery, by gravity, would only require the use of up to five bores only.

There were some concerns expressed by the regulators (DEP and WRC) over the possible impacts of disposal on down-gradient water quality. The discharge water was less saline than the receiving water with salinities between at between 30,000 and 100,000mg/L, but had low pH and elevated levels of aluminium, WAD cyanide and ammonia. However, it was considered that these concerns could be satisfactorily addressed and were not considered a fatal flaw.

The main area of concern was related to the geochemical compatibility of the discharge and receiving waters. Geochemical modelling showed that, unless that discharge water was pre-treated, there was a strong risk aluminium hydroxides precipitating out in the aquifer adjacent to the injection bore screens as the low pH discharge water was neutralised by receiving groundwater. Various treatment options were considered, mostly relating to pH control and precipitation and filtration of aluminium compounds prior to injection. These options significantly added to the cost of the injection proposal.

Aquifer injection was eventually ruled out, and the seepage collection water is now being used by a nearby mining operation as a process water source.

Namuli
d

Proposed mining at Hamersley Iron's Namuli Project will extend up to 200m below the water table and investigations have indicated that some 12ML/d average (with up to 18ML/d peak) pumping will be required to dewater the pits. Most of this dewatering production will be surplus to water supply requirements, at least in the early part of the mine life.

Various methods of excess water disposal were investigated, and the results indicate that re-injection into the same aquifer system, but away from the mine, is feasible and will result in the minimal impact to the surface environment. Results to date have highlighted potential constraints to bore performance as a result of air entrainment, but that re-injection at individual bore rates of 2ML/d or more is feasible.

An added bonus of re-injection is that future on-site processing may require more water than might be available from dewatering and the shortfall could be made up by recovering some of the excess dewatering discharge re-injected in the early years.
INPIT TAILINGS DISPOSAL MARYMIA GOLD OPERATION: CASE HISTORY

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ABSTRACT

Inpit tailings disposal has been undertaken at a number of mining sites within Australia. This paper presents a brief history of the experience of inpit tailings disposal at the Marymia Gold Operation in Western Australia, including geotechnical aspects of the design. Regular monitoring of the inpit tailings disposal into the K1SE Pit at Marymia has allowed the operators of the mine to assess the performance of the tailings storage against its predicted performance during the design phase. Results of this monitoring indicated that the predicted performance was exceeded and the results have been incorporated into the design of another large inpit tailings disposal, the K1 Pit.

Monitoring of tailings disposal to both the K1SE Pit and K1 Pit has allowed the mine operator to make substantial savings from inpit tailings storage when compared with above ground tailings storage facilities.

The inpit method of tailings disposal at Marymia has proven to be acceptable from an environmental perspective by reducing the water resource requirements of the project, backfilling pits, which would otherwise collapse with time and eliminating the need for disturbing additional areas of mining leases, which usually accompanies construction of above ground tailings storage facilities.

INTRODUCTION

The Marymia Gold Operation is located approximately 200km north east of Meekatharra in Western Australia. The location of the site and project layout are presented as Fig. 1 and Fig. 2.

Climatic conditions are typically semi arid to arid, with average annual rainfall of approximately 230mm per annum and average annual evaporation of approximately 3,800mm per annum.

Figure 1: Site Location
Figure 2: Site Layout
The success of the operation of the KISE Pit prompted Resolute Limited to examine the option of in-pit tailings disposal into the K1 Pit. Evaluation of this option included:

(i) Geotechnical assessment of the K1 Pit.
(ii) Evaluation of the performance of the KISE Pit.

Approval to operate the K1 Pit as a tailings storage was granted in late 1996.

Tailings deposition into the K1 Pit commenced in June 1997. The K1 Pit was operated on an intermittent basis until November 1997, at which time tailings deposition into this storage was carried out on a continuous basis until suspension of milling at Marymia in February 1998.

Cycling of tailings deposition between TSF 1, the KISE Pit and the K1 Pit in the various periods of intermittent operation has had an impact on the consolidation of the tailings. Details of deposition periods and tonnes of tailings deposited in each storage are presented in Table 1.

**GEOTECHNICAL ASSESSMENT**

**Scope of Geotechnical Work**

The scope of the geotechnical work for the assessment of the KISE Pit tailings disposal comprised the following:

(i) A review of the stability of the existing KISE Pit and an inspection of the final pit walls.
(ii) Investigation of the engineering properties of the tailings, specifically their settling and consolidation characteristics, to optimise the design of the water recovery system by carrying out an appropriate laboratory testing programme.

A similar scope of work was required for the assessment of the K1 Pit which comprised the following:

(i) A review of the stability of the existing K1 Pit in the light of work previously carried out by other consultants and an inspection of the final pit walls.
(ii) Evaluation of the operation of the KISE Pit.
(iii) Reassessment of the engineering properties of the tailings, specifically their settling and consolidation characteristics, to optimise the design of the water recovery systems for the K1 Pit.
(iv) Preparation of a design concept for the K1 Pit with recommendations for its operation.

**Geological Setting**

The KISE Pit is located at the southern end of the K1 Pit. The geological setting of both the KISE Pit and the K1 Pit are similar with the four main geological units comprising:

1. **Talc Chlorite Schist:** Strongly sheared, highly foliated ultramafic, with thin discontinuous quartz lenses along the foliation and ranging from highly weathered at the top of the pit to slightly weathered at the base. This is the dominant rock type, especially in the east.

2. **Mafic Amphibolite:** Pervasively weathered, the leached ultramafic consists mainly of clays of mafic origin and some minor goethite and quartz. This rock is the host for the meta-sediments including a banded iron formation (BIF) unit, which is the main host of mineralisation. The mafic is partially mineralised adjacent to the BIF unit.

3. **BIF:** The BIF, which hosts the main mineralisation, is highly weathered and consists of alternating bands of haematite/goethite and quartz and occurs as sigmoidal shaped lenses of between 2.0m to 5.0m width.

4. **Hanging Wall Mafic:** The Hanging Wall Mafic, which occurs along the eastern margin of the pit is highly weathered and massive to weakly foliated.

Shearing along geological contacts is common and a pervasive foliation, which is subparallel to the shearing, occurs within the Talc Chlorite Schist. The shearing and foliation generally dips between 70° to 75° towards 218° to 232° magnetic, although the foliation dip varies up to vertical and to 70° towards 058° magnetic. A number of joint sets, comprising discrete joints up to 6.0m in length, and minor dip slip faulting have also been recognised.

Groundwater was only encountered during mining of the goodbye cut in the KISE Pit, where it appeared to be contained within the BIF. The water level in the base of the pit was RLS596. The regional groundwater was at RLS586.7, approximately 56m below ground level and well below the base of the KISE Pit.

A failure occurred along the western wall of the KISE Pit during mining. The failure was attributed to toppling and sliding along foliation in the talc chlorite schist.

The foliation in the K1 Pit generally dips between 60° to 85° to the east. Failures occurred along the eastern wall of the pit during mining.

Groundwater was only encountered during mining at a depth of RLS595 in the K1 Pit. The water level in the base of the pit prior to commencement of underdrainage construction was estimated to be RLS593. The regional groundwater is at RLS586.7, approximately 53m below ground level at the K1 Pit.
(iv) At the time of the inspection, 1996, the pit walls did not exhibit signs of stress such as tension cracking.

(v) Some minor wall failures may have occurred during deposition as tailings and free water pond against highly weathered clayey materials and waste materials, resulting in loss of strength due to material softening. Experience with tailings deposition in the R1SE Pit indicated that the wetted front above the supernatant extended for a height of between 100mm to 200mm.

Failures caused by loss of strength were considered more likely in the waste materials than in the pit walls. This is due to the potential for more rapid infiltration of moisture into voids within the waste, compared to the relatively slow horizontal infiltration into defects within the rock. Such failures were unlikely to affect the operation of the project, but close attention to the spigotting technique and size and position of the supernatant pond would be required to minimise potential for failures. Spigotting at the toe of the waste in the southern section of the pit to form a high beach, well above the supernatant pond, would provide buttress support to limit the potential for the failure of the waste as the tailings and supernatant pond rose.

It was noted that regular inspections should be carried out to ensure that if minor wall failures were to occur, they would not affect spigotting or water return points.

Tailings Testwork

General

Tailings testwork was undertaken to assist in determining the characteristics of the tailings in respect to water recovery and final dry density. Testwork for predictions of water recovery comprised, one undrained settling test and one drained settling test and the results are presented as Fig. 3 and Fig. 4.

One modified consolidation test in a Triaxial Cell, and one consolidation test were undertaken to establish a dry density and moisture content relationship for the tailings. Figure 5 shows the results of these tests.

It was assumed that water recovery from the tailings during consolidation would result in the dry density of the tailings being similar to that which can be obtained from the theoretical relationship of dry density and moisture content for tailings with an SG of 2.60. Figure 5 shows the results of the testing plotted on the relevant section of the theoretical curve, which provided a guide to the predicted behaviour of the dry density and moisture content.
TAILINGS DISPOSAL
DESIGN CONCEPT – K1SE PIT

Given the potentially high water return via the recovery of supernatant and the limited storage life of the K1SE Pit, installation of underdrainage was considered to be not warranted.

A pontoon mounted pump to recover supernatant water was to be initially located on the haul road in the southern end of the pit and gradually moved to the east and north as the tailings rose.

Spirogotting was to be initially carried out from the haul road then subsequently moved to the pit rim to cascade over the small bench on the southwestern side of the pit.

EVALUATION OF TAILINGS
DISPOSAL IN K1SE PIT

General

As part of the design of the K1 Pit tailings disposal system, an evaluation of the performance of the K1SE Pit was undertaken.

The objective of this evaluation was to:

(i) Inspect the operation of the K1SE Pit.
(ii) Assess the in situ density being achieved within the tailings in the K1SE Pit.
(iii) Assess the storage life of the K1SE Pit.
(iv) Assess the water recovery from the K1SE Pit.
(v) Assess the groundwater monitoring results.
(vi) Assess spigotting techniques.
(vii) Assess settlement predictions.
(viii) Reassess the tailings testwork.

The performance of each of these components was evaluated to ensure the design of the K1 Pit would incorporate experience gained from the design and operation of the K1SE Pit.

Inspection of K1SE Pit

An inspection of the K1SE pit was carried out on 12 January, 1996 as part of the tailings storage audit and management review for the Marymia Gold Operation.

At the time of that inspection, the K1SE Pit tailings disposal and water recovery system had been operating for approximately 3 weeks and some “teething” problems were being encountered with the water recovery system.

Another inspection of the K1SE Pit was undertaken on 21 June 1996.

A close examination of the K1SE Pit showed that the water recovery system was relatively successful with only a shallow depth of supernatant water present over the tailings.

Dry Density of Tailings

Recommendations, for a survey of the tailings within the K1SE Pit, provided at the time of the inspection on 12 January 1996, were adopted by Resolute Limited. The objective of the survey was to monitor the density of the tailings and compare the density achieved against the theoretical density curve prepared as part of the Geotechnical Assessment for the K1SE Pit at the time the Works Approval Application was prepared.

A hydrographic survey of the surface of the tailings was undertaken on 9 June 1996. The volume of the pit occupied by the tailings, 233,345 m³, was obtained by superimposing the tailings surface over the final survey of the excavated surface of K1SE Pit. Ore milled, since deposition commenced in the K1SE Pit up to the time of the survey, totalled 292,834 tonnes giving an average dry density of the in situ tailings of 1.25t/m³. The results of the June 1996 survey indicate the target average dry density of 1.60t/m³, from the consolidation testing could be achieved.

Storage Life

Tailings deposition commenced on 15 December, 1995, with a predicted storage life of at least 9 months. Based on the results of the survey of the 9 June 1996, the remaining storage life of the K1SE Pit was predicted to be at least another 3.9 months from 9 June 1996.

This meant that the K1SE Pit would be filled to RL645 towards the middle of October 1996, a storage life of approximately 10 months against a predicted storage life of 9 months. Errors in the original survey could account for the differences in the predicted storage life against the actual storage life, given the anticipated final dry density.

However, as the level of the tailings rises the average dry density of the tailings would also continue to rise, due to consolidation, increasing the storage life of the pit.

It was recommended that monitoring of the tailings surface be continued on a 3 monthly basis, even after the final deposition of tailings is completed.

Water Return

Water return from the K1SE Pit was via a pontoon mounted pump which pumps water back to a storage tank located near the plant. The storage tank is fitted with a control valve which closes the water return pipeline at the tank. The pipeline from the pump back to the plant is fitted with a bypass which allows water to be returned to the K1SE Pit when the tank is full.
(iii) Average evaporation data.
(iv) Rainfall data for the months of operation.
(v) The average in situ density and moisture content of the tailings.

Seepage was assumed to be very low (1 x 10^-8 m/sec) for the purposes of this water balance given that, the water levels in the adjacent monitoring bores have responded at a slower rate than the rise of tailings, with only those bores located along the shear zone responding to change in ground water level. Using this water balance it has been possible, by trial and error, to obtain an appropriate pan factor for the evaporation for this type of tailings disposal.

From the water balance for the KISE Pit, a prediction was made for water return for the proposed K1 Pit tailings disposal. The water return for the KISE Pit for 1996, the predicted water return from the K1 Pit and the predicted water return from TSF1 are presented on Fig. 6, together with actual returns where records are available.

**Groundwater Monitoring**

Figure 7 presents the results of groundwater level monitoring of bores KISE1 to KISE9. It should be noted that all bores have responded to the change in the groundwater regime as a result of the deposition of tailings into the KISE Pit, the greatest change being in boreholes KISE3, KISE4 and KISE5 which are located along the shear zone which passes through the KISE Pit in a north south direction.

Figure 8 shows the position of the groundwater monitoring bores around the KISE Pit.

**Figure 8:** Groundwater Monitoring Bores KISE Pit

All results of groundwater quality monitoring indicate the groundwater quality is within the limits assigned by the Department of Environmental Protection of Western Australia (DEPWA), with the exception of total dissolved solids (TDS). However, baseline monitoring indicated the TDS in bores on the eastern side of the pit was higher than the limits assigned by the DEPWA prior to tailings deposition in the KISE Pit. Figures 9, 10, and 11 show the results of water quality monitoring.

**Figure 9:** Groundwater Monitoring Bores KISE Pit - TDS
Spigotting Techniques

Spigotting of tailings has been carried out from a number of different points around the pit in an attempt to develop a uniform tailings surface. The most successful technique has been found to be an open end tailings line discharging onto the ground above the supernatant water level such that the tailings can spread and cascade into the pond at low velocity over a wide front rather than from a high velocity single point such as the open end of a pipe.

Settlement Predictions

Based on the results of consolidation testing of the tailings and computer modelling of the settlement, the total settlement was predicted as being in the range of 5.0m to 8.0m, with approximately 80% of this settlement occurring during the tailings disposal operation.

A comparison of the calculated dry density for the tailings, as derived from the survey on 9 June, 1996, and the predicted insitu dry density, indicated that the predicted performance was reasonably accurate and on this basis it was concluded that the computer modelled settlement would also be reasonably accurate.

Since June 1996, numerous other surveys have been carried out and the most recent survey of the K1SE Pit, January 1998, indicated that the average density of the partially consolidated tailings is 1.40t/m³.

Figure 12 shows the plot of tailings dry density and moisture content obtained from the laboratory testing against the theoretical dry density curve, together with the dry densities derived from the June 1996 and January 1998 surveys.

Reassessment of Tailings Testwork

General

Based on the evaluation of the performance of the K1SE Pit, the results of the original tailings testwork was re-evaluated prior to the design of the K1 Pit.

Discussion of Testwork

Undrained Settling Test

Predictions made with respect to the availability of supernatant water from the undrained settling tests were correct, in so far as a high rate of water return has been achieved from the K1SE Pit.

The dry density of the tailings within the pit to date would suggest that rapid settling of solids, particularly the coarse fraction, is occurring, allowing water to be recovered relatively quickly as consolidation occurs. Further monitoring of the settled density of the tailings is recommended, however, the results to date are encouraging and suggest that the predicted average dry density is readily achievable.

Figure 12: Density Performance
Spiigotting from the northern end of the pit would be required from time to time to control the position of the supernatant pond. Spiigotting down slopes or onto slopes, which have waste present, was not recommended, and should be avoided.

It was predicted that some fine tuning of the design may be required during the spiigotting and decanting procedures to optimise the water recovery.

Construction Costs

The final cost of the inpit tailings disposal system for the K1 Pit, including design and documentation was approximately $220,000.00.

BENEFITS OF INPIT TAILINGS STORAGE

General

The environmental impact of many mining practices can be reduced. However, quite often the costs involved in pursuing environmentally friendly practices are prohibitively expensive and therefore not widely practised. The inpit tailings disposal system developed at the Marymia Gold Project not only allows for environmentally responsible disposal of hazardous waste, but also results in substantial cost savings in most areas of tailings storage.

Environmental Benefits

General

Disposal of tailings to both the K1SE Pit and K1 Pit has significant environmental advantages which not only benefit the environment at the Marymia Mine Site but also have an impact outside the immediate vicinity of the site.

The direct benefits to the area immediately around the mine include:

(i) Storage of hazardous waste (Asbestiform materials).
(ii) Reduction in areas of natural vegetation to be cleared to provide alternative tailings storage facilities.
(iii) No aesthetic impact, which is normally associated with above ground tailings storage facilities.
(iv) Backfilling of pits which would otherwise collapse with time.

The direct benefits to areas beyond the mine include:

(i) Reduction in reagent consumption, which reduces the external resource requirements of the project.
(ii) Significant reduction in water resource requirements.
(iii) Significant reduction in greenhouse gas production from burning diesel fuel to operate the borefield pumping system.

Environmental Achievements

Handling of Asbestiform material

The nature of Asbestos materials (fibrous actinolite and tremolite) requires that the tailings waste is stored wet or under a constant cover of water until finally covered by fresh earth at the completion of tailings deposition. This has been consistently achieved from the commencement of tailings deposition and material will be safely and permanently capped during the rehabilitation process.

Water Recycling

Water balances were prepared for the three tailings facilities used at Marymia. TSF 1 is a conventional above ground facility, the K1SE Pit is a small scale inpit disposal system (without under drainage) and the K1 Pit employed inpit disposal combined with under drainage. Table 2 details the results of the predicted water losses, from the water balance, and actual site measurements.

Table 2. Water Balance – Predicted and Actual Losses

<table>
<thead>
<tr>
<th>Storage Facility</th>
<th>Predicted Losses</th>
<th>Actual Losses (measured)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSF 1</td>
<td>81.0%</td>
<td>83.7%</td>
</tr>
<tr>
<td>K1SE Pit</td>
<td>N/A*</td>
<td>46.0%</td>
</tr>
<tr>
<td>K1 Pit</td>
<td>36.0%</td>
<td>28.8%</td>
</tr>
</tbody>
</table>

* It should be noted that no prediction was made on the anticipated evaporation losses from the K1SE Pit.

From Table 2 it can be seen that there is a marked decrease in water losses in the K1SE and K1 Pits, compared with the losses from TSF 1. The difference is attributed to the decrease in surface area of the inpit tailings storage facilities and therefore a decrease per unit volume of tailings exposed to the atmosphere. Evaporation is greatly dependent upon exposure to sunlight, temperatures and wind movement across the surface of the tailings, all of which are decreased in a below ground, sheltered facility.

The increased water recycling achieved by use of the K1 Pit resulted in a reduction in water requirements from the borefield in the order of 400,000,000 litres per annum. Marymia is a small operation relative to industry standards (0.5Mtpa); in a larger operation (2.0Mtpa), with similar pulp densities, reductions in water demand could be expected to be in the order of 1.3 billion litres per annum.

Sanders (1973) indicates that groundwater recharge to calcrete aquifers, typical of the groundwater sources in the
Maintenance Costs

The K1 Pit storage requires very little maintenance, and is much simpler and cheaper to operate than the multi-point spigotting required for an above ground tailings storage facility. Table 5 shows maintenance costs for TSF 1 compared with maintenance costs during a period of K1 disposal:

<table>
<thead>
<tr>
<th>Period</th>
<th>Salaries, Mechanical/Electrical repairs and parts</th>
</tr>
</thead>
<tbody>
<tr>
<td>01 Jul 96 – 31 Dec 96</td>
<td>$104,992</td>
</tr>
<tr>
<td>01 Jul 97 – 31 Dec 97</td>
<td>$69,672</td>
</tr>
</tbody>
</table>

Rehabilitation

Not only does the K1 storage have a capacity almost 1.5 times larger than the original above ground storage but also the surface area is over 2.5 times smaller than the original storage, resulting in substantial rehabilitation savings (over 4 times less per tonne of tailings). Table 6 details the estimated savings in rehabilitation.

<table>
<thead>
<tr>
<th></th>
<th>TSF 1</th>
<th>K1 Pit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Area (m²)</td>
<td>250,000</td>
<td>93,000</td>
</tr>
<tr>
<td>Capacity (m³)</td>
<td>1.411 x 10⁶</td>
<td>2.114 x 10⁶</td>
</tr>
<tr>
<td>Area per unit volume (m³)</td>
<td>0.117</td>
<td>0.044</td>
</tr>
<tr>
<td>Cost of Rehabilitation</td>
<td>$375,000</td>
<td>$139,500</td>
</tr>
<tr>
<td>Rehabilitation cost per dry tonne of tails</td>
<td>$0.156</td>
<td>$0.038</td>
</tr>
</tbody>
</table>

Summary of Major Savings

A summary of the major savings estimated to total approximately $5.7M over the 6.3 year life of the K1 Inpit tailings storage is presented in Table 7.

<table>
<thead>
<tr>
<th></th>
<th>Cost Area</th>
<th>Saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction (initial and ongoing)¹</td>
<td>$1,780,000</td>
<td></td>
</tr>
<tr>
<td>Lime consumption²</td>
<td>$37,800</td>
<td></td>
</tr>
<tr>
<td>Rehabilitation on completion</td>
<td>$235,500</td>
<td></td>
</tr>
<tr>
<td>Additional Gold recovered (revenue)³</td>
<td>$2,730,000</td>
<td></td>
</tr>
<tr>
<td>Pumping cost (fuel)⁴</td>
<td>$483,000</td>
<td></td>
</tr>
<tr>
<td>Maintenance Savings</td>
<td>$420,000</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$5,700,000</td>
<td></td>
</tr>
</tbody>
</table>

Notes

1. Construction cost for the above ground storage is based on initial cost plus all lifts required until completion of tailings deposition. Construction cost for the K1 storage is based on initial cost as no further construction costs are anticipated.

2. Lime consumption is based on a laboratory test using two 43% pulp density solutions buffered to the average pH for K1 Return water and Bore water. The difference was calculated per tonne of ore and the savings were based upon 0.6 million tonnes per annum (Mtpa) for 6.3 years.

3. Gold recovered is based upon 0.6 Mtpa operation with an average head grade of 3.86g/t and a recovery of 95% in the treatment plant. Based on 28% of the gold, remaining in the tailings being recovered (as experienced to date), this equates to ~6500 ounces of gold at a nominal sale price of $4420 per ounce (January 1998).

4. Savings in pumping costs are based upon the fuel costs for 1996/1997 and an estimate that pumping requirements will be halved as a result of the water recycling achieved by the K1 storage.
TAILINGS REVEGETATION – ON NON-AMELIORATED SUBSTRATE

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ABSTRACT

The Westonia open pit gold mine, 320 km east of Perth, Western Australia (31°18'S, 118°42'E) was decommissioned in July 1991. Normandy Mining Pty Ltd seeded in May-June 1993, the entire surface of the tailings storage facility. The rehabilitation objective was to stabilise the tailings structure. Tailings slurry had been pumped into three Cells at different periods throughout mining operations. The near surface layer of tailings is most significant from a rehabilitation perspective, as it is where plants are growing. Vegetated areas have lower salinity than areas lacking vegetation (8.23 compared with 47.39 dS m⁻¹ ECe). Revegetation density averages 1.734 stems m⁻² in October 1999 and foliage cover is 30 percent. Nine chenopods were recorded in October 1999 with Maireana brevifolia, Atriplex undulata and A. lentiformis more prevalent. Grasses continue to show accelerated establishment. A cryptogamic cover prevalent over the upper surfaces of “raw” tailings appears to be enhanced under established vegetation where moisture levels and the soil nutrient status are inherently higher. The tailings profile in the centre of the third cell (vegetation absent) showed similar changes in salinity to previous samplings. The surface sample in April 1999 (102 dS m⁻¹) was less saline than the April 1998 sampling (225 dS m⁻¹). The layer between 0.1 m and 0.4 m remains extremely saline, i.e. range 83-150 dS m⁻¹ ECe. Around the perimeter of his cell the tailings is coarser, and sampling of the profile to 0.3 m depth gave salinities from 5 to 20 dS m⁻¹ ECe.

KEYWORDS: tailings, revegetation, chenopods, Western Australia

1. INTRODUCTION

The Westonia open pit gold mine, 320 km east of Perth, Western Australia (31°18'S, 118°42'E) was decommissioned in July 1991. The initial success of revegetation trials established on non-ameliorated tailings over the storage facility by Curtin University, prompted Normandy Mining Pty Ltd to seed the entire surface (40 ha) of the tailings storage facility using a suite of chenopod species (saltbushes and bluebushes). Seeding was at 2 kg ha⁻¹ or 4 kg ha⁻¹. The rehabilitation objective was to stabilise the tailings structure. Tailings slurry had been pumped into three Cells (A, B, and C) at different periods throughout mining operations. Cells A and B were used for initial deposition beginning in 1986, and Cell C was used in the last twelve months of operations. The process water used at Westonia was saline (TDS 35,000 ppm, approximate ECe 56 dS m⁻¹). A layer of precipitated salt mined a few metres above the water table further increased water salinity inside the processing plant. Most of this tailings had been pumped into the upper layer of Cell A and Cell B. Stockpiled low grade ore, stripped from the surface at the commencement of operations, was processed late in the mine life. This material was ground coarser than previous materials, and was deposited into the upper layer of Cell C. This near surface layer of tailings is most significant from a rehabilitation perspective, as it is where plants are growing.

To date a total of 12 assessments have been completed over the Westonia tailings storage facility, commencing in April 1994 (Table 1). The most recent assessment was in October 1999, 75 months after the large scale seeding in May - June 1993.

Table 1: Timing of revegetation assessments over the Westonia tailings storage facility, and revegetation age.

<table>
<thead>
<tr>
<th>Assessment Date</th>
<th>Revegetation Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 1994</td>
<td>10 months</td>
</tr>
<tr>
<td>April 1995</td>
<td>22 months</td>
</tr>
<tr>
<td>September 1995</td>
<td>27 months</td>
</tr>
<tr>
<td>February 1996</td>
<td>32 months</td>
</tr>
<tr>
<td>April 1996</td>
<td>34 months</td>
</tr>
<tr>
<td>September 1996</td>
<td>38 months</td>
</tr>
<tr>
<td>April 1997</td>
<td>45 months</td>
</tr>
<tr>
<td>September 1997</td>
<td>50 months</td>
</tr>
<tr>
<td>April 1998</td>
<td>57 months</td>
</tr>
<tr>
<td>September 1998</td>
<td>62 months</td>
</tr>
<tr>
<td>April 1999</td>
<td>69 months</td>
</tr>
<tr>
<td>October 1999</td>
<td>75 months</td>
</tr>
</tbody>
</table>

2. DATA AND COMMENTS

2.1 Rainfall

The Westonia Mine tailings storage facility lies within the eastern wheatbelt region of Western Australia. Annual rainfall is relatively low (320 mm average per annum) but sufficiently reliable to allow successful cropping of wheat, oats and barley (Fig. 1). At conclusion of mining and processing operations tailings was extremely saline.
2.3 Revegetation Cover and Density

Revegetation density (number of stems per m²) was greater in April 1999 than September 1998, encouraging after a summer period and likely facilitated by good rains in January to April (see Fig. 1); 2.44 stems m² in April 1999 compared with 2.35 m² in September 1998. Sampling in October 1999 gave a decrease in plant numbers (now 1.74 stems m²) (Fig. 4). However, plant cover over the tailing surface has remained at a highest level since seeding. On average, 30 percent of the vegetated area is covered by revegetation, and October 1999 gives the highest of the five post-winter readings (Fig. 4).

2.4 Revegetation Composition

Nine (9) chenopod species were recorded over the tailings storage facility in October 1999, along with two introduced grasses, and members of the families Asteraceae and Zygophyllaceae (Table 3). Considering all 26 assessment transects density averaged 1.74 plants m² and there was foliage over 29 percent of the areas sampled (noting random sampling with stratification of vegetated and non-vegetated areas).

Maireana brevifolia (mean IVI of 101), Atriplex undulata (mean IVI = 53) and Atriplex lentiformis (mean IVI = 40) are prevalent on the tailings impoundment after the summer period and there dominance is reflected in numbers present and percent of the foliage cover.

![Figure 4: Change in average revegetation density (per m²) and cover (%) values (Cells A, B, and C combined) over time.]

Table 3:

<table>
<thead>
<tr>
<th>FAMILY</th>
<th>Species</th>
<th>Common Name</th>
<th>Density (m²)</th>
<th>Cover (%)</th>
<th>Height (cm)</th>
<th>IVI</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTERACEAE</td>
<td>Sochotus oleraceus</td>
<td>common sowthistle</td>
<td>0.398</td>
<td></td>
<td></td>
<td>1.17</td>
</tr>
<tr>
<td>CHENOPODIACEAE</td>
<td>Atriplex amnicola</td>
<td>river saltbush</td>
<td>0.052</td>
<td>0.594</td>
<td>69</td>
<td>8.82</td>
</tr>
<tr>
<td></td>
<td>Atriplex bunburyana</td>
<td>silver saltbush</td>
<td>0.123</td>
<td>3.292</td>
<td>65</td>
<td>28.37</td>
</tr>
<tr>
<td></td>
<td>Atriplex lentiformis</td>
<td>quail bush</td>
<td>0.267</td>
<td>1.824</td>
<td>56</td>
<td>39.74</td>
</tr>
<tr>
<td></td>
<td>Atriplex nummularia</td>
<td>old man saltbush</td>
<td>0.050</td>
<td>0.610</td>
<td>94</td>
<td>7.34</td>
</tr>
<tr>
<td></td>
<td>Atriplex undulata</td>
<td>wavy leaf saltbush</td>
<td>0.387</td>
<td>2.232</td>
<td>38</td>
<td>53.06</td>
</tr>
<tr>
<td></td>
<td>Atriplex esesicaria</td>
<td>bladder saltbush</td>
<td>0.042</td>
<td>0.417</td>
<td>34</td>
<td>7.48</td>
</tr>
<tr>
<td></td>
<td>Enchytra alpensa tomentosa</td>
<td>ruby saltbush</td>
<td>0.010</td>
<td>0.096</td>
<td>15</td>
<td>1.43</td>
</tr>
<tr>
<td></td>
<td>Maireana brevifolia</td>
<td>small leaf bluebush</td>
<td>0.794</td>
<td>3.948</td>
<td>14</td>
<td>100.89</td>
</tr>
<tr>
<td></td>
<td>Sclerolaena diacantha</td>
<td>copper burr</td>
<td>0.010</td>
<td>0.025</td>
<td>11.5</td>
<td>2.43</td>
</tr>
<tr>
<td>POACEAE</td>
<td>grasses b</td>
<td></td>
<td>15.867</td>
<td></td>
<td></td>
<td>47.34</td>
</tr>
<tr>
<td>ZYGOPHYLLACEAE</td>
<td>Zygophyllum aurantiacum</td>
<td>shrubby twinleaf</td>
<td>0.002</td>
<td>0.075</td>
<td>9.75</td>
<td>1.48</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td>1.737</td>
<td>29.378</td>
<td></td>
<td>300.00</td>
</tr>
</tbody>
</table>

a direct seeded species; b includes Avena fatua (wild oats) and Bromus sp. (brone)

DAY ONE - SESSION FOUR - THE FUTURE FOR TAILINGS
REFERENCES


George, P.R. & Wren, B.A 1985. Crop tolerance to soil salinity. Western Australian Department of Agriculture Technote 6/85.

Green, J.W. 1985. (2nd edition) Census of the Vascular Plants of Western Australia. WA Herbarium, Department of Agriculture, Western Australia.

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SALINITY AFFECTS REVEGETATION CHARACTERISATION IN TSF CAPPING TRIAL

Brett Bassell
ENVIRONMENTAL COORDINATOR - REVEGETATION,
KALGOORLIE CONSOLIDATED GOLD MINE WA

Paper to be supplied.
OVERVIEW

Pollutant emissions data from across Australia was presented for the first time in January 2000 on the new National Pollutant Inventory (NPI) internet site. This paper describes the NPI program and its current status in Western Australia.

The NPI details the emissions of particular substances into air, land and water from various sources, including major industrial facilities as well as broader based, minor but collectively significant sources (emissions to airsheds from motor vehicles, aircraft, locomotives, commercial premises; and emissions of nutrients to water catchments). The website also includes results from a 12 month trial of the NPI carried out in the Kalgoorlie region, plus other pollutant emissions data collected from each Australian State or Territory.

Emissions data is estimated and reported by industry facilities (point sources), while State and Territory governments report emissions from aggregated sources to certain airsheds and water catchments. The program is developing over eighty industry handbooks to provide advice to particular industry sectors and facilities on how to estimate emissions as required for the NPI.

Results from the first year’s data (1998-99) indicate that emissions to the environment come not just from industry but also from community based activities contributing significant emissions.

The NPI enables the public to keep an eye on the sources of pollution within their local environment. The NPI program intends expanding over the next few years to include a greater number of substances, industries, airsheds, and water catchments.

To see what the NPI has to offer, the website can be accessed at <www.npi.ea.gov.au>

DEVELOPMENT OF NPI PROGRAM

National Environment Protection Measure (NEPM)

The NPI has been developed as a National Environment Protection Measure (NEPM) by the National Environment Protection Council. The Council is a national statutory body which aims to ensure that all people in Australia enjoy equivalent protection from air, water, soil and noise pollution. The Council is made up of the Commonwealth, State and Territory Environment Ministers.

A draft Measure for the NPI was released for public and key stakeholder consultation in 1997. To assist in the development of the draft Measure, a Non-Government Organisation Advisory Group was established to ensure industry, environment and community concerns were considered by the Council. Membership included environment, industry and union groups.

An independent Technical Advisory Panel was established to develop the NPI substances reporting list. The Panel produced a draft report which was the subject of national consultation in 1997. The Panel revised their report and the NPI reporting list, based on comments received during this national consultation process.

The National Environment Protection Measure for the NPI took effect from 1 July 1998. It includes two reporting lists of 36 and 90 substances, threshold categories, collection of data from reporting facilities, as well as enforcement provisions. A copy of the Measure is available on the NPI homepage at: <http://www.environment.gov.au/epg/npi/>

NEPM Goals

The environment protection goals for the NPI are set out in Clause 6 of the Measure:

6. The national environment protection goals established by this Measure are to assist in reducing the existing and potential impacts of emissions of substances and to assist government, industry and the community in achieving the desired environmental outcomes set out in clause 5 by providing a basis for:

- the collection of a broad base of information on emissions of substances on the reporting list to air, land and water, and

- the dissemination of information collected to all sectors of the community in a useful, accessible and understandable form.
Major potential NPI reporters have been identified in each NPI industry sector, and these companies have been contacted and advised of their NPI obligations. Many administrative and technical queries are being handled from the wide range of industries and companies involved. Procedures are in hand to process reporting information expected from industry due by 30 September 2000.

A series of workshops is being conducted in Perth and WA regional centres to advise and educate reporting organisations. These workshops are being well attended by industry and local government.

WA continues to contribute to NPI policy, technical and administrative issues at national level via NPI Implementation Working Group, NEPC Committee and Council activities.

Separately to NPI Implementation, WA (with funding from the Commonwealth DEP and WMC Resources) completed the Kalgoorlie NPI Trial - a project to apply the NPI in a regional mining setting. The project, completed in October 1999, was launched by the Minister for the Environment at the Kalgoorlie Nickel Smelter. Data from this trial is currently available on the NPI website.

**REPORTING MECHANISM FOR FACILITIES**

If a facility has a published industry handbook for their industry sector, and trips a reporting threshold as specified in the NPI Measure, then emissions of relevant substances from the facility to air, land and water must be estimated and reported each year to the State or Territory Environment Agency.

**Reporting list**

The NPI reporting list for the first and second reporting years (1998-99 and 1999-2000) is a list of 36 substances, chosen for their environmental and health effects. The list includes organic compounds and metals, products of combustion and certain trace substances of concern.

The reporting list is expected to expand by 54 to a new total of 90 substances already identified in the Measure. The expansion date has not yet been fixed.

**Reporting Thresholds**

Each of the substances on the NPI reporting list is grouped into threshold categories. Facility occupiers should carefully read the NPI literature to determine their reporting thresholds and reporting obligations.

**Reporting Timelines (in brief)**

- Second reporting year now underway: 1 July 1999 to 30 June 2000.
- Facility reports due in to DEP by 30 September each year.
- First year reporting period may vary, based on Handbook publication date.
  (e.g. Mining reporting period - first year - 1 month only and petroleum refining two months only).
- First year data was published on 28 January 2000.
- Facility reports - Year 2 due in to DEP by 30 Sep 2000, Published 31 Jan 2001.
- No penalties for first and second year data. Penalties to apply from Year 3 on.
- 36 substances for Years 1 and 2.
- 90 substances to come in at date to be determined.

**Industry Handbooks (in brief)**

Eventually over 80 handbooks covering major sectors of industry and processing in Australia will be published by the NPI program. Due to the timing of publication, in 1998-99 only 23 industry sectors were required to report. It is expected that the remaining handbooks will be published by June 2000 and that the majority of industry sectors will be required to consider NPI reporting for the second reporting year (1999-2000).

**WHAT'S ON THE INTERNET NOW?**

1. **Caveat**

It is important to note that there are limitations on what can be concluded from the current data. The database has a caveat on the first page and makes several points, including (paraphrased):

This is the first year of reported data, and the NPI is still a growing, evolving program. Users can expect to see improvements and further development with time. Emissions are estimates, and the accuracy of the emissions data will vary with technique and data used. The NPI substances span a range of toxicities, and a small amount of emissions may not necessarily imply an insignificant emission. It is also important to note that the numbers only reflect what is being released, and not what the public and the environment are exposed to.
ISSUES

The NPI program recognises the following issues and work is underway to provide solutions as soon as possible. Some issues will be covered during the scheduled NEPM Review, due to start in October 2000.

(i) Implementation of the NEPM-NPI has progressed more slowly than desired due to the time involved in developing the technically complex industry emissions estimation handbooks. Handbook development and publication has been expedited and now over 77 have been published.

(ii) Limitations to availability and accuracy of various emission estimation techniques in handbooks (e.g. dust, cyanide in mining context). Revisions to some manuals are being conducted or scheduled in 2000.

(iii) Debate over inclusion of transfers (where material is directed to sewer, landfill or reprocessing, but not directly released to the environment from the facility).

WHERE TO NOW

In 1999/2000, each State and Territory will continue to implement the NPI program. A larger number of facilities are expected to report from about 80 industry sectors. Aggregated emissions will be estimated from other airsheds (in WA the Pilbara airshed) and water catchments (in WA the Peel-Harvey and Avon catchments).

Environment Australia will shortly release both a CD-Rom version of the internet data and a summary report of 1998/99 data, for wide distribution.

NEPM Variation

A formal public consultation process is due for completion by June 2000, where the NEPC will consider a proposal to delay by one or two years the move from 36 substances to 90 substances to allow for industries and government to develop reporting systems. The proposed delay takes account of the extra time required to publish industry handbooks, while allowing a phase-in period for industry and government.

NEPM Review

The NEPM Review, starting in October 2000 will formally consider, by a process of national consultation, the points listed in clause 33 of the Measure, which include:

(a) The likely effectiveness of the Measure in achieving the national environment protection goals.

(b) The resources available for implementing the Measure.

(c) The need for any amendment of the Measure, including:

   (i) whether transfers of waste (including deposit of wastes into landfill; discharge of wastes to sewer; and any other removal of wastes from a facility for the purpose of disposal, treatment, recycling, reprocessing, recovery or purification) should be included;

   (ii) whether substances should be added to or deleted from the reporting list;

   (iii) whether any changes should be made to the thresholds or definitions which determine whether a facility is a reporting facility; and

   (iv) whether any changes should be made to improve the effectiveness of the Measure in achieving the national environment protection goals set out within it.

Future Years

In future years, the scope of the NPI is expected to broaden, with the inventory complementing other environmental protection strategies.
2000 workshop on environmental management in arid and semi-arid areas

PROCEEDINGS - DAY 2

TOURS OF THE PADDINGTON GOLD MINE AND BOTTLE CREEK

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# GLRG 2000 WORKSHOP - SITE TOUR
## 25 MAY 2000

### PLAN A

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
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<tbody>
<tr>
<td>8:00am</td>
<td>Depart Kalgoorlie WMC Conference Centre</td>
</tr>
<tr>
<td>8:30am - 10:30am</td>
<td>Paddington Gold Pty Ltd - Rainstorm + Paddington Gold Mine Tour, Eco Truck</td>
</tr>
<tr>
<td>10:30am</td>
<td>Depart Paddington</td>
</tr>
<tr>
<td>11:30am - 12:00n</td>
<td>Menzies Hotel - Lunch</td>
</tr>
<tr>
<td>12:00pm</td>
<td>Depart Menzies</td>
</tr>
<tr>
<td>1:15pm - 3:00pm</td>
<td>Bottle Creek Tour</td>
</tr>
<tr>
<td>3:00pm</td>
<td>Depart Bottle Creek</td>
</tr>
<tr>
<td>6:00pm</td>
<td>Arrive Kalgoorlie (including 15 minute Stopover at Menzies)</td>
</tr>
</tbody>
</table>

### PLAN B (In the event of rain)

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
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</thead>
<tbody>
<tr>
<td>8:30am</td>
<td>Depart Kalgoorlie WMC Conference Centre</td>
</tr>
<tr>
<td>9:00am</td>
<td>Paddington Gold Pty Ltd - Rainstorm + Paddington Gold Mine Tour, Eco Truck</td>
</tr>
<tr>
<td>10:30am</td>
<td>Depart Paddington</td>
</tr>
<tr>
<td>11:30am</td>
<td>Menzies - Lunch</td>
</tr>
<tr>
<td>12:30pm</td>
<td>Depart Menzies</td>
</tr>
<tr>
<td>2:00pm</td>
<td>Kalgoorlie</td>
</tr>
<tr>
<td>2:00pm</td>
<td>Bottle Creek Workshop Session    - Miner Rehabilitation contractor Regulator</td>
</tr>
<tr>
<td>3:30pm</td>
<td>Early finish</td>
</tr>
</tbody>
</table>
2000 workshop on environmental management in arid and semi-arid areas

PROCEEDINGS - DAY 3

SESSION 5 - REPORTING FOR THE NEW MILLENNIUM
SESSION 6 - MANAGING RISK & LIABILITY
SESSION 7 - INVOLVEMENT OF MINE MANAGERS

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COMMUNICATION - ESSENTIAL IN ACHIEVING DESIRED STANDARDS

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ABSTRACT

Adequate and appropriate communication is and always will be an essential part of any operation to achieve the desired result to the desired standard.

Poor communication has resulted in poor performance which then has received a poor assessment. The perceived poor assessment may be criticised by the recipient of the assessment but it was the poor result which lead to this outcome.

This paper will focus on and emphasise good communication practices to achieve the desired result. Communication, in the context of this paper, includes education, instruction and supervision.

INTRODUCTION

There is a plethora of papers and books dealing with human communication as it is such a significant aspect of being human. Appropriate and adequate communication can lead to the desired result both in our personal lives and in our work environment. The alternative can result in undesirable outcomes that then generate much angst as well as the need to redress the outcome.

There are many forms of communication and presently within our Department there have been 13 modes of communication noted. The general forms of communication will be mentioned later but not dealt with in detail.

There are no Standards of communication as such. However, Communication is mentioned in many Standards. Certainly the need to document just about all aspects of procedures and practices when drawing up Environmental Management Systems for which there are Standards means that some form of standardisation of communication would be adopted by the organisation.

To achieve the desired outcome good internal communication is essential. This aspect will be covered in more detail below.

External communication in these days of transparency is becoming a greater part of the day to day business of all organisations. Reports such as Annual Environmental Reports need to take note of and address the issues of concern raised by the regulatory agency. This aspect will also be dealt with in more detail below.

The onus is on each party to communication, the sender and the receiver, to understand what is being communicated and acknowledge that understanding to the other party. Unfortunately this is often just lip service and not full understanding and agreement with appropriate follow-up actions.

From the point of view of understanding and acknowledgment it would seem that written communication is the best form of delivery and/or follow up of delivery and response.

COMMUNICATION GENERAL

Managers and supervisors spend 75 - 95% of the working day undertaking direct communication. The rest is spent in reading and writing.

The purpose of communication is to achieve one or more of the following aims:
- PROVIDE INFORMATION
- GET OR GIVE AGREEMENT OR APPROVAL
- SEEK OR DIRECT ACTIONS
- BUILD OR EXCHANGE GOODWILL OR TRUST.

Effective communication is comprised of five elements:
1. Sender
2. Message
3. Channel for transmission
4. Receiver
5. Feedback.

The sender - receiver - feedback loop is very important to note. Communication is generally a two-way stream where one is requesting and hoping to have certain actions undertaken to achieve a specific outcome.

Extra care needs to be exercised when there is a “transmitter” in between.

Both the sender and receiver can have problems during communication. These problems involve the skills and abilities of each. Effective management courses deal with communication in detail and provide tactics for developing communication skills.

“Failing to see the need to communicate is the greatest barrier to effective communication” (AIM, 1999). Don't assume someone has the knowledge and ability to understand, interpret and implement your message.

Take misinterpretation and ambiguity out of the loop.

Communication, as any other task, requires planning which involves addressing the questions of:
what, who, when, where, how and why.
IMPROVING INTERNAL COMMUNICATION

Internal communication can be improved by:
1. Researching processes, functions, attitudes and behaviours. This can be done on a personal or organisational level.
2. Conduct a culture audit - observe person/people at work.
3. Outline communication plan - this requires a certain degree of research in itself. At what level is the communication aimed - do you do this for a one on one situation?
4. Educate the receiver.
5. Integration - the communication plan needs to be translated into action. Target with the correct message and the correct delivery.
6. Review and evaluate the result. (Harkness, J. 1999)

An example of internal communication and quality at the corporate level is provided by Michael Flynn (1993) in The Quality Magazine. (This was the most recent article on communication in The Quality Magazine.)

Flynn (1999) states that "effective communications are essential if an organisation is to establish and nurture a culture of continuous improvement..." and I would doubt anybody could argue successfully against that statement.

"For an educated person, especially in the same field as oneself, one would expect a level of cognition that accepts some level of presumption on the communicators part. Don't make that assumption - " (Loofe and Glick, 1996).

Novices do not know which questions to ask and may be embarrassed to do so.

EXTERNAL COMMUNICATION

In this instance I am referring to communication outside the organisation. However, there is a continuum between the internal and external communications and it sometimes breaks. The aims of this communication are the same as those outlined above.

External communication may or may not require some form of feedback. For instance, annual reports, stock reports, reports to shareholders generally would not, whereas those submitted for approvals, seeking advice or providing information on the status of operations may well require feedback.

In the case of the Department of Minerals and Energy WA (DME), feedback on submissions from companies will be provided by either written response or site inspection with written follow up. This feedback from the DME may contain one or all of the following:
- direction
- suggestion
- advice.

The first one would definitely require some action and feedback to the agency on the part of the recipient. The second may require some feedback and the third probably requires no feedback.

It is the outcomes of all this communication that I wish to focus on.

Frequently the DME finds that matters raised during inspections which require feedback from the company have not been attended to by the next visit. So what has happened?

The inspection and response by DME appears to get lost in the company's "system" once the agency personnel are off the site. In particular I refer to the communication processes required following Annual Environmental Report inspections. The message left with the managers following the inspection in some instances is apparently not being passed down the line for the follow-up action.

This suggests that company's internal communications processes are not designed appropriately or may not be adequate to cope with this external link.

My suggestion is that companies examine their communication processes, determine where the links are missing and implement corrective strategies so that actions required due to external communication are undertaken as necessary. In this way the desired/required outcome will be followed through and hopefully achieved. Thus the environmental standards of actions within an appropriate timeframe are less likely to be compromised.
STAKEHOLDER CONSULTATION: WALLABY PROJECT CASE STUDY

ABSTRACT

Placer (Granny Smith) Pty Ltd proposes to develop the Wallaby orebody located on the north-western shoreline of Salt Lake Carey, approximately 27km south-south-west of Laverton and 11km west south-west of the existing Granny Smith Mine processing plant. Following discovery of the orebody, Granny Smith commenced an extensive stakeholder consultation process under the umbrella of its Sustainability Policy. This paper presents a case study review of the stakeholder consultation process and subsequent incorporation of stakeholder issues in the mine development programme.

INTRODUCTION

Placer (Granny Smith) Pty Ltd manages the Granny Smith Gold Mine. The mine is a joint venture operation between Placer (Granny Smith) Pty Ltd, a wholly owned subsidiary of Placer Dome Asia Pacific (PDAP) owning 60% and the remaining 40% owned by Delta Gold NL.

Granny Smith Mine commenced operations in June 1989 in Grannys pit and continued with the development of Goanna and Windich pits. Following commencement of operations, five satellite pits respectively named Childe Harold, Phoenix, Keringal (Holland and Belgium) and Sunrise were also discovered and subsequently mined. Sunrise pit is currently the only active pit supplying ore to the Granny Smith processing plant. Figure 1.0 shows the location of the Mine and associated pits.

From the commencement of operations until the end of 1999, 235 million tonnes of ore and waste have been mined, 36 million tonnes of ore have been processed, and 3 million ounces of gold have been produced.

The Wallaby orebody was discovered in late 1996 and is located on the north-western shoreline of Lake Carey, approximately 27km south-south-west of Laverton and 11km west south-west of the existing Granny Smith processing plant. Following discovery of the orebody, Granny Smith commenced an extensive stakeholder consultation process within the framework of its Sustainability Policy.

THE WALLABY CONSULTATION MODEL

Prior to commencement of an internal scoping study for the Wallaby project, a stakeholder consultation model was developed and is shown in Figure 3.0. The model allows for a dynamic interface between a range of Granny Smith decision-makers, technical advisers, and a broad cross section of stakeholders with an interest in the project and region.

STAKEHOLDER IDENTIFICATION

The initial step in the model was to identify relevant internal, external, and technical expert stakeholders. Stakeholders identified included:

- Relevant Government Departments;
- Indigenous and non-indigenous communities;
- Members of the pastoral industry;
- Conservation groups;
- Mining companies in the region; and
- Internal stakeholders from Granny Smith Mine and corporate offices.

Following identification, each stakeholder group was contacted and the preferred style of consultation and participation discussed subsequently leading to the development of a stakeholder register. Additional stakeholders were added to the register at the request of attendees following commencement of the consultation process.

THE WALLABY BRIEFING DOCUMENT

Granny Smith prepared a Wallaby briefing document in late May providing a description of the project, associated impacts, existing baseline data, and proposed stakeholder consultation model for development of the project. Aims of the briefing document were to:

- Provide background information regarding the project to stakeholders prior to commencement of the Issue and Impact Identification Workshops; and
- Ascertain the level of environmental assessment assigned to the project by Government.
The duration for each workshop was for one full day. Stakeholder questions and corresponding responses by Granny Smith personnel were also recorded throughout workshops. Following each workshop, this record of questions and answers was collated and subsequently distributed to stakeholders. In addition, electronic or hard copies of environmental and project development reports for Wallaby were also made available at the workshops and distributed to stakeholders on request.

**WALLABY ENVIRONMENTAL REVIEW**

The process of stakeholder consultation through the Issue and Impact Identification Workshops ensured stakeholder concerns were incorporated and addressed by mine development programmes and ultimately assisted in the development of the EPS submission document known as the Wallaby Environmental Review (WER). The WER was submitted in two sections. Section A outlined Granny Smith’s commitment to the principles of Sustainability and reviewed the stakeholder consultation process used in development of the project and WER. Section B provided a description of the project and associated impacts, management, and monitoring required to a level that satisfies both an EPS and NOI level of assessment.

**STAKEHOLDER REVIEW OF THE DRAFT WER**

Granny Smith distributed a draft copy of the WER to stakeholders in January 2000 as part of the continued consultation process. Distribution of the draft WER was also facilitated through a series of small group workshops with respective stakeholders groups and focussed on individual areas of concern identified by the respective stakeholders. The small group workshops were conducted in an environment and location suitable to the stakeholders and with flexible meeting times to allow detailed input and a full understanding of the project details, responses, and comments by other stakeholders. Stakeholders were also requested to make comments regarding any aspect of the project to ensure any further concerns were considered in the mine planning process and subsequently incorporated into the final version of the WER.

**REFINING THE FINAL VERSION OF THE WER AND SUBMISSION**

In order to bring the WER closure to completion, all concerns, views, and ideas discussed during the small group workshops for the draft WER were analysed and integrated into the mine planning process and WER document. In addition, to ensure all identified stakeholders fully understood the aspects of the project another series of small group workshops were held in March 2000.

**INDEPENDENT CASE STUDY**

An independent researcher was engaged prior to commencement of the consultation process to review and comment on the process and the real ability of stakeholders to influence change in both the planning and development of the project following each consultation meeting. The independent researcher also ascertained the level of satisfaction experienced by stakeholders throughout each phase of the consultation process. The independent researcher determined this information through the degree of incorporation of stakeholder issues in the mine planning process and WER document and confidential interviews with internal and external stakeholders.

Feedback provided by the independent researcher following each phase of the consultation process was sent to Granny Smith personnel and all stakeholders on the register. Final results of the independent case study were not available at the time of preparation of the paper. However, feedback to date indicates the process has been highly effective in some areas and not as effective as hoped in other areas.

**IMPORTANCE OF INFORMATION DISSEMINATION AND SHARING**

Information dissemination and sharing is an important aspect in any stakeholder consultation process. Granny Smith developed a Wallaby Web Page linked to the Placer Dome Web Page that contained all data and reports associated with the project and consultation process. Stakeholders were able to make comments regarding project plans, consultation process, mine development reports, and WER via the internet and email and proved a valuable medium for information dissemination and exchange. Alternatively, stakeholders contacted Granny Smith using traditional communication methods such as mail, telephone, and facsimile.

Development of the WER also helped drive the need for enhanced information sharing between mining companies operating within the Lake Carey catchment. The Lake Carey Catchment Management Group (LCCMG) was formally developed in June 1999 with the objective of sharing non-commercially sensitive environmental management and baseline information for the Lake Carey catchment. This information was also made available to stakeholders.

**CONCLUSION**

At the time of writing this paper, it is difficult to objectively ascertain the level of success of the consultation process and the degree of satisfaction from external stakeholders. Internally the process has significantly assisted mine development programmes subsequently ensuring social, economic, and environmental issues are considered in the mine planning process. The Wallaby consultation process
SUSTAINABILITY POLICY

Introduction

Throughout human history, gold mining has contributed to the prosperity and progress of communities and countries around the world. Almost all the gold ever mined still circulates as a store of monetary value or a symbol of beauty, excellence and timelessness, making that metal the world’s most recycled material. At the end of the twentieth century, technology is advancing our ability to find mineable deposits, extract metal, and at the same time protect the environment. Gold mining has the potential to create wealth for many generations to come. Gold mining will continue to be profitable and to benefit nations and communities as long as we effectively integrate human skills, technology and capital into our business.

Mining cannot occur without an impact on the surrounding natural environment and communities. Responsible mine operators strive to limit negative environmental and social impacts. We view gold mining as a profit-making activity that benefits local communities and host countries. This view and our best practices lead Placer Dome naturally towards a policy of gold mining and sustainability.

Essential to all definitions of sustainability is a respect for the earth’s carrying capacity and a concern for future generations. Defining sustainability in a detailed manner that will fully satisfy all stakeholders is not possible. Our objective is to develop commonality of vision to support honest dialogue and co-operation with stakeholders in the development, operation and closure of mines.

In many countries and regions, the concept of sustainability has captured the imagination of governments, communities, non-governmental organizations and other institutions. They influence the ability to access land for exploration and to permit, develop and operate mines. We will be judged by performance, by how we operate mines and by what remains after mines close. We need to demonstrate that while mines are temporary and ore bodies are eventually depleted, mining can make contributions to sustainable economic and social development, while returning sites to a state compatible with a healthy environment.

Our vision of mining and sustainability reflects the values of Placer Dome’s employees and will contribute to our business success in many ways. Our sustainability policy will strengthen society’s support for mining and allow us to grow. By implementing the principles of sustainability, we will reduce social and economic risks; we will have a competitive advantage in acquiring new gold reserves; and we will gain public support for the permitting and development of new projects.

To think globally and act locally requires that every operating site and regional subsidiary translate our sustainability policy to fit their particular circumstances. The priorities and action plans that are specific to individual sites and regions should complement one another and collectively project Placer Dome’s global contribution to sustainability.

We want Placer Dome to lead the industry in implementing a global sustainability policy. As we progress and learn, we will periodically revisit our policy to refine our vision and refocus our direction. Looking to the future, we want our investors and all other stakeholders to experience the rewards of being associated with the Earth’s Gold Leader.
atives and performance to identify and effect improvements within the context of evolving legal requirements, technical innovations, scientific discoveries and stakeholder expectations.

- In all activities, comply with applicable laws and regulations providing for the protection of the environment, employees and the public.

- In instances where regulation is absent or inadequate, apply best management practices and corporate standards to achieve sustainability objectives.

- Limit negative impacts on livelihoods in local communities, and provide adjustment assistance as appropriate.

- Work actively with government, industry and stakeholders to improve public policy, laws and regulations in support of sustainability.

- Conduct or support research programs to expand knowledge on the impact of mining activities on the environment and the community.

PUBLIC RESPONSIBILITY

Communicate with stakeholders and work towards consensus based on honest discussion and a mutual understanding of concerns and needs.

- Provide for the effective involvement of communities in decisions which affect them, treat them as equals, respect their cultures, customs and values, and take into account their needs, concerns and aspirations in making our decisions.

- Consider as a stakeholder individuals, groups, communities or governments which may be directly affected by our activities, and provide them with information relevant to their concerns.

- Understand and respond to stakeholders’ concerns about specific impacts or risks, our sustainability performance or mining industry practices.

- Establish credible monitoring and verification programs to measure impacts and to ensure compliance with legal requirements and with our sustainability policy, and communicate the results in an effective manner.

SOCIAL PROGRESS

Contribute to the quality of life of employees, local communities and host countries, while respecting their cultures, needs and priorities.

- Assess conditions in communities affected by our activities, identify issues of community concern, and establish objectives and strategies for their management.

- Recognize the importance to communities of high standards of health and education and through cooperative programs contribute to improvements in medical services and educational opportunities.

- Work in a collaborative manner with communities, governments and, where appropriate, international institutions and non-governmental organizations, to improve social conditions and governance in local communities.

- Recognize and respect the importance of the land, and traditional knowledge to local indigenous or aboriginal communities and be sensitive to their cultural distinctiveness.

- Collaborate with communities and governments to plan for mine closure and the sustainability of social improvements.
THE ENVIRONMENTAL PROTECTION AUTHORITY'S POSITION ON TERRESTRIAL BIOLOGICAL SURVEYS FOR ENVIRONMENTAL IMPACT ASSESSMENT (EIA) IN WESTERN AUSTRALIA

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ABSTRACT

The Environmental Protection Authority (EPA) regards biological diversity as a key environmental factor and has an objective to ensure that biodiversity is protected under Section 15 of the Environmental Protection Act 1986 (WA).

The EPA is concerned that, at times, insufficient attention is given to the quality, appropriateness or relevant detail of biological surveys for the purposes of Environmental Impact Assessment (EIA), in relation to the scale and the nature of the impact, and the sensitivity of the receiving environment. This may mean that the information supplied is inadequate to allow the EPA to undertake a comprehensive assessment, resulting in potential delays in the progress of an assessment while additional or appropriate information is being collected. The EPA recognises that the absence of acceptable standard protocols may also result in inconsistency of effort and a reduction in the value of the data collected.

The need for improving terrestrial biological survey standards in Western Australia is essential because of international commitments on biodiversity made by Australia. Western Australia is now a signatory to the National Strategy for the Conservation of Australia's Biological Diversity (1996). Also, the EPA needs to take into account the introduction of the new Commonwealth Environment Protection and Biodiversity Conservation Act (1999) in July 2000 and any bilateral agreement on environmental assessments between the State and the Commonwealth.

The EPA is developing standard protocols for terrestrial biological surveys to enable and facilitate all proponents, and their consultants, to develop and implement practices that meet EPA's expectations of quality. These protocols will be detailed in a Preliminary Guidance Statement 51 – "Standard Protocols for Terrestrial Biological Surveys for Environmental Impact Assessment in Western Australia".

1. BACKGROUND

In recent years the Environmental Protection Authority of Western Australia has been preparing and publishing a series of position statements, which set out its views on some matters of environmental importance. These position statements provide an avenue for the Authority to inform the public about environmental values and visions for the future. They also provide a basis for the development of the associated series of statements entitled "Guidance for the Assessment of Environmental Factors".

Terrestrial biological surveys are an essential component of Environmental Impact Assessment (EIA), and the use of standard and improved protocols will improve the ability of assessments of the impacts of developments and projects on the environment of Western Australia. This will enable the Authority to provide adequate public and independent advice to the Minister for the Environment as required by the Environmental Protection Act 1986 (WA).

1 SECTION 15 OF THE ENVIRONMENTAL PROTECTION ACT 1986 (WA) STATES THAT THE OBJECTIVE OF THE EPA IS: "TO USE ITS BEST ENDEAVOURS – TO PROTECT THE ENVIRONMENT; AND TO PREVENT, CONTROL AND ABATE POLLUTION"

SECTION 16 OF THE ENVIRONMENTAL PROTECTION ACT 1986 (WA) STATES THAT THE FUNCTIONS OF THE EPA ARE:

(a) TO PUBLISH FOR THE BENEFIT OF PLANNERS, BUILDERS, ENGINEERS, OR OTHER PERSONS, GUIDELINES TO ASSIST THEM IN UNDERTAKING THEIR ACTIVITIES IN SUCH A MANNER AS TO MINIMISE THE EFFECT ON THE ENVIRONMENT OF THOSE ACTIVITIES, OR THE RESULTS THEREOF;

(b) TO SPECIFY STANDARDS AND CRITERIA, AND THE METHODS OF SAMPLING AND TESTING TO BE USED FOR ANY PURPOSE; AND

(c) TO PROMOTE, ENCOURAGE, AN COORDINATE OR CARRY OUT PLANNING AND PROJECTS IN ENVIRONMENTAL MANAGEMENT...

In view of the international significance of Western Australia's flora and fauna, the Environmental Protection Authority (EPA) regards biological diversity as a key environmental factor and has an objective to ensure that biodiversity is protected.

The EPA has prepared a Position Statement summarizing the principals and is currently finalising a Guidance Statement which will provide guidance and direction as to the EPA's expectations on Terrestrial Biological Surveys.

This paper summarizes the key points from the EPA Position Statement on "Terrestrial Biological Surveys for Environmental Impact Assessment (EIA) in Western Australia" (Position Statement 4, 2000).

The Position Statement highlights:

• the need for standard protocols;

• why there is a requirement to improve and upgrade standards in Western Australia;

• the principles that will be adopted by the EPA within the proposed EPA Preliminary Guidance Statement 51 – "Standard Protocols for Terrestrial Biological Surveys for Environmental Impact Assessment in Western Australia";

• the need for both a consolidated database and for data to be collected by the proponents or their consultants in a format to allow ease of assessment at the local, regional and national levels, and to facilitate transfer into State biological databases;
Relevant triggers (relating to terrestrial biodiversity) for referral to the Commonwealth (ie. "certain aspects of the environment") include:

- World Heritage areas;
- wetlands of international importance (eg: RAMSAR wetlands);
- listed threatened species and ecological communities;
- listed migratory birds (JAMBA, CAMBA Agreements); and
- additional matters as prescribed.

Penalties, including fines and/or imprisonment, may be imposed under the criminal code if:

(a) the person takes an action; and
(b) the action results in, or will result in, or is likely to have, a significant impact on any of the above:

Subsection 4B(3) of the Crimes Act 1914 lets a court fine a body corporate up to five times the maximum amount the court could fine a person under this subsection.

3. **WA REQUIREMENTS FOR STANDARD PROTOCOLS FOR EIA**

In recent years, it has become apparent to those operating in the environmental industry that the global community recognizes the high diversity of biological values in Australia. In considering the "footprint" or impacts that any future proposals may have on the biodiversity values of Western Australia, the EPA recognises that the proponents, and their consultants, play a major role in defining these biodiversity values.

The EPA Position Statement recognises that the Western Australian system has many positive strengths which will contribute to the protection of biodiversity. These include:

- the *Environmental Protection Act* (1986) that provides for an open and public process for assessment of the environmental impact of proposals;
- recent amendments to key legislation, government positions and/or land conservation practices which will work towards better protection of biological values (eg: the Biodiversity Act, 1999; the Land Act, 1999; EPA Position Statement No. 2 on Environmental Protection of Native Vegetation in Western Australia 1999; higher requirements for biodiversity information to be supplied during Notice of Intention to Clear assessment under the Soil and Land Conservation Act);
- the involvement of industry, and more specifically the mining industry, in many of the areas associated with developing best practice in environmental issues. Foremost amongst these is the development of the Australian Minerals Industry Code for Environmental Management (the Code) which was published by the Minerals Council of Australia in 1996;
- the presence of very good key people with a high level of technical expertise;
- an increasing level of community awareness and expectations;
- good library resources;
- high opportunities for developing comprehensive database integrated with GIS;
- comprehensive information collected to high standards in some areas; and
- relatively low population.

However, the EPA also notes difficulties experienced when undertaking assessments where an understanding of the impacts of a proposal on the biodiversity values of an area is an important factor. These concerns predominantly relate to a lack of appropriate, targeted information, which allows the EPA to clearly assess the impacts of a proposal on the local and regional significance of biodiversity values of a site.

The EPA Position Statement, summarizes the key issues contributing to this difficulty as including:

- a lack of appropriate scale baseline information, for most areas of the State, to allow proper assessment in a regional context;
- limited number of skilled and experienced botanists and zoologists;
- a lack of resources available from proponents for appropriate surveys;
- replication of previous databases (which may be acceptable in some instances) but without understanding how this data may be relevant in the context required for the current assessment;
- site-specific data being collected but not interpreted/analysed for biodiversity value (a site-only survey without being placed in a regional context is meaningless); a lack of standards/definitions for regional/local/intrinsic values;
- a lack of reference to current literature (both published and unpublished);
- a lack of a consolidated database;
- a lack of adequate accuracy of species identification (supported by herbarium specimens where appropriate).
4.2 Content of the Guidance Statement

The following summary is extracted from the EPA Position Statement and as such provides the EPA guidance for the preparation of the Guidance Statement for "Standard Protocols for Terrestrial Biological Surveys for Environmental Impact Assessment (EIA) in Western Australia".

The Guidance is intended to:

- clarify the EPA objectives in regard to biodiversity, for the purposes of EIA and reporting under Section 44 of the Environmental Protection Act, 1986;
- provide an easy-to-use decision making tree on the level of biological survey required, recognising that the level of impact of a proposal and its significance will vary according to the scale, significance of the site/specific environment impacted, nature of the proposal and its location within the State. To this end, the EPA has adopted the IBRA regionalisation as the largest unit for decision making, and has divided the 26 Bioregions of the State into levels of sensitivity to impact;
- provide a checklist of the factors that will be required to be reported on, once the level of sensitivity of the proposal has been determined;
- provide a reference inventory to ensure desktop information is derived from standard sources;
- provide additional references and data sources (including web sites, institutions, etc) which may provide additional information outside minimum requirements;
- define the preferred methodology for field surveys, including timing and frequency;
- describe the format for data collection to allow ease of assessment at the local, regional and national levels, and establish protocols to facilitate transfer of quality information into public biological databases;
- set expectations for the reporting of all biological survey data;
- identify the need for a limitations section to be included in each biological survey report; and
- identify the EPA as one of the intended users of the report.

5. CONCLUSIONS - THE EPA POSITION

In summary, the EPA has adopted a series of positions in relation to Terrestrial Biological Surveys, namely:

- The EPA adopts the definition of Biodiversity and the principles as defined in the National Strategy for the Conservation of Australia's Biological Diversity (1996), and will have regard for these in undertaking its role.
- The Environmental Protection Authority (EPA) requires proponents to demonstrate in assessment that all reasonable measures have been undertaken to avoid impact.
- The EPA aims to ensure that the information gathered for environmental impact assessment in Western Australia meets State, National, and International Standards and Agreements in regard to biodiversity conservation.
- The EPA requires that the quality of information and scope of the survey meets the standards and protocols which will be set out in the Guidance Statement 51 which will be available shortly from the Environmental Protection Authority (EPA).
- In the absence of information, which could provided the EPA with certainty that biodiversity will be protected, the EPA will adopt the precautionary principle.

As in the normal practice with EPA Position Statements, the Chairman of the EPA is keen for the public, industry and community groups to comment on the Position Statement as released by the EPA. The authors of this paper would encourage all the Conference attendees to participate in this process.
RISK MANAGEMENT AND
THE BOTTOM LINE

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ABSTRACT

Mining is a risky business, particularly when you consider the high up-front costs involved in exploration, feasibility studies, engineering design and project construction. All of this is done before any revenue is produced, based on limited geological information.

Many factors contribute to the risk of undertaking a mining operation including:

- unpredictable fluctuating commodity prices;
- uncertainty in resource and ore grade estimates;
- metallurgical and processing complexities
- challenging geological and hydrological conditions; and
- last but certainly not least, a wide range of environmental factors.

While it is understandable that most of the limited project resources are usually committed to resource estimation and design aspects, environmental issues are often under-rated in terms of their potential to significantly affect the bottom-line project economics. Some notable examples of situations where environmental factors have ultimately proved to have been major and expensive issues include: Mar Copper, Ok Tedi and countless U.S. Superfund sites.

The rule for minimising and managing risk is simple: The more information that is available, provides a higher level of certainty for decision making, and hence, lessens the risk.

Risk assessment is most effective when applied at key decision-making milestones during the life of a project. The risk assessment needs to include operational, financial and environmental constraints in the context company objectives, government requirements and community expectations.

This paper will consider the application of risk assessment at various stages of a project and demonstrate how good risk management can assist in both maximising operational efficiencies and avoiding costly ongoing liabilities.

INTRODUCTION

In recent times we have seen some high profile operations fall into economic and public relations difficulties due to environmental issues that were not fully realised at the outset of the projects. Some notable examples include: Mar Copper in the Philippines, Ok Tedi in New Guinea, Beemup in Western Australia, and the more recent cyanide spill Baia Mare in Romania. These projects have, at the very least, resulted in significant liabilities for the companies involved, and in some cases have resulted in demise projects and legal action against senior management.

While we are all wise in hind site, and could argue that such incidents could have been prevented with more rigorous risk assessment and management procedures, the fact of the matter is that environmental systems are often very complex as they are dependent on a wide range of variables. We can take measures to reduce risk but we will never entirely eliminate the all the hazards that contribute to risks.

Many of the variables that contribute to risk relate to specialised engineering and scientific principles and it takes more than just the project engineer’s or the environmental manager’s or consultant’s interpretation of a situation to adequately assess potential risks. An effective risk assessment must take into account environmental, engineering, financial, legal and community aspects of a project with the direct involvement of the project specialists covering these areas.

Risk assessment is also not just a one off exercise as part of the environmental impact assessment at the beginning of a project. It should be applied at successive stages of development as more is understood about the potential impacts on the environment and other factors influencing the development.

Environmental risk management is not just about avoiding disastrous consequences the can eventuate in extreme cases, it is mostly about improving the environmental performance and efficiency of day-to-day operations by systematically evaluating and applying the most beneficial options.
At this stage an environmental risk assessment would be relatively straight forward and risks could simply be listed and qualitatively ranked. An example of a risk evaluation matrix is presented as Table 1.

Environmental factors ranking as very high to severe would clearly represent potential fatal flaws as liabilities that could result from the project may far outweigh any benefits. It is also unlikely that a project in this category would receive environmental approval from the any responsible government.

High risk environmental factors indicate that alternative project designs need to be evaluated and substantial environmental studies are required to assess potential impacts and develop effective environmental management strategies. This ranking is likely to have a significant bearing on overall project economics and also indicates that the project would be subject to a high level of scrutiny by government and the community prior to being approved.

Environmental factors of significant risk are common to most mining projects and indicate that careful environmental management practices need to be developed and applied to reduce the impacts associated with such risks. Environmental studies and ongoing monitoring is required to manage such risks. The overall project economics are not usually compromised within this ranking.

Negligible to low risks generally do not have the potential to compromise the project economics but need to be considered in day-to-day management of operations.

### Bankable Feasibility Study

The outcome of a successful Preliminary Feasibility Study is a decision that the project is economically viable provided that certain factors can be confirmed through a Bankable Feasibility Study. The Bankable Feasibility Study is aimed at providing a high degree of certainty in order to obtain funding the proposed project and includes:

- Project design and engineering;
- Resource modelling, mining schedule and optimisation study;
- Environmental impact assessment and approvals; and
- Project cost estimate.

At this stage a risk assessment is critical to identify any factors that may compromise the overall project economics. The risk assessment needs to fully integrated taking into the following into account:

- Financial considerations
- Environmental objectives
- Legal obligations
- Community expectations
- Engineering constraints

The risk assessment process should commence at the outset of the Bankable Feasibility Study with the direct involvement of key project team member with responsibility for the above aspects. A facilitated review of fundamental aspects of the operation is the first step in the process in order to identify and prioritised the key risk issues in a qualitative manner.

A “systems modelling” approach can be adopted for this aspect of the work to assist in clearly defining the associations and dependencies between operational activities (such as mining, processing, tailings disposal etc.), and related inputs and outputs which may generate environmental impacts. Specific activities can be related to specific environmental “receivers” through defined environmental “pathways”. A simple example is provided below for seepage from tailings.

<table>
<thead>
<tr>
<th>Mining/Processing Activity</th>
<th>Environmental Pathway</th>
<th>Environmental Receiver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tailings Disposal</td>
<td>Seepage to groundwater</td>
<td>Stock Water</td>
</tr>
</tbody>
</table>

Once the associations and dependencies are mapped out, the significance of each environmental aspect should be determined using a matrix similar to the one previously presented as Table 1.

As a significant part of the Bankable Feasibility Study is the environmental impact assessment and approvals, the initial qualitative risk assessment can be used to determine priorities for environmental studies. For example, where a particular issue is rated as a high risk, rigorous environmental studies will need to be undertaken to provide a high level of certainty that the aspect can be effectively managed in a way that reduces the risk. In some cases this will also indicate that alternatives project designs need to be considered.

Prior to presenting the selected option in environmental approval documentation as a "late-accomplish", it is crucial that a range of alternative options have been explored to a sufficient level of detail to demonstrate that they are less desirable.

For most environmental factors rated as a significant risk, the "qualitative" risk assessment will be sufficient to develop management strategies and demonstrate that these can be managed in an acceptable manner.
Planning for mine closure is most effective if started at the earliest stages of a project. It should also be an integral part of assessing project viability as costs associated with closure can contribute significantly to overall project costs. Some aspects of closure planning can be incorporated in the operation, reducing eventual remedial works, double handling etc. Financial institutions should also include mine closure costs and potential ongoing liabilities for due diligence on project finance and terms for guarantees on unconditional performance bonds.

A systematic, risk-based, approach can be applied to define appropriate objectives and develop cost effective decommissioning strategies at various stages of the project. Such an approach would initially involve a qualitative risk analysis integrating all aspects of the project including: financial, legal, engineering, environmental and community issues. More complex issues identified through the risk analysis may require further quantitative risk assessment to compare various options based on relative costs and benefits over the life of a project.

CONCLUSION

In conclusion, environmental risk management is an effective means for evaluating the costs and benefits associated with all aspects of an operation that interact with the environment.

Risk assessment is also critical in identifying any environmental issues that may compromise the overall project economics. Many of the variables that contribute to risk relate to specialised engineering and scientific principles. To be most effective risk assessment needs to fully integrated taking into the following into account:

- Financial considerations
- Environmental objectives
- Legal obligations
- Community expectations
- Engineering constraints

Risk assessment is also not just a one off exercise as part of the environmental impact assessment at the beginning of a project. It should be applied at successive stages of development as more is understood about the potential impacts on the environment and other factors influencing the development.
A RISK-BASED APPROACH TO ACHIEVE ENVIRONMENTALLY ACCEPTABLE MINE CLOSURE

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ABSTRACT

The application of risk-based methods in the mining industry has become more popular in recent years. This paper describes a technique that can be applied to all phases of mine development, including closure design. It is a particularly useful tool to assist in decision-making and cost optimisation when considering the effects of mining on the environment. It can be used in quantitative, semi-quantitative or qualitative risk assessments, depending upon the level of the study, the amount of detail required, the necessary level of accuracy and the resources available.

The technique involves the development of fault and event trees to model the likely system conditions at the time of mine closure. Fault trees are used to model all potential causes of adverse effects of mining upon the environment and event trees are used to evaluate the consequences of the adverse effects. The fault/event trees can then be used to identify key areas of concern, to assist in the characterisation of risk to the environment and to facilitate comparison of several different approaches. In this way it is possible to justify a decision with respect to a chosen closure plan, by minimising adverse environmental impact through an optimally cost effective approach.

The technique is illustrated through a simplified hypothetical example of a mine closure plan in a semi-arid environment. The example demonstrates the effectiveness of the approach to the development of a solution that has a parity of risk throughout the system, through the avoidance of a solution that has some areas over-designed, with other areas being more susceptible to long term failure.

1. INTRODUCTION

Over the past 5 to 10 years, the majority of the larger mines (in particular) have been systematically developing closure plans. These closure plans are now commonly developed at conceptualisation/feasibility stage of mine development and are refined throughout the operational lives of the mining operations. The approach that is normally followed encompasses fundamental principles of “best practice” environmental management, the interpreted minimum standards set down by regulatory bodies and the establishment of some form of cost provision associated with implementing a conceptualised closure plan. Whilst this approach is a significant improvement over the previous methodology of developing a closure plan as (or after) economic mineral resources are exhausted, there is still some scope for improving the technique. The improved approach should aim to achieve a satisfactory long term environmental risk, whilst also optimising costs, such that any money spent is most appropriately directed at minimising or mitigating these long term risks.

A limited number of mining companies have more recently successfully adopted a technique that draws upon the principles of risk management. In broad terms, what this means is that some form of probabilistic assessment is used to assess and optimise the final solution. Both qualitative and quantitative techniques can be used. This paper presents one form of this technique (in semi-quantitative form) and illustrates its use through a simplified hypothetical example of a mine that is located in a semi-arid environment. It is evident, however, that the technique is equally applicable to any climate, and can be used to facilitate planning and design throughout any stage of mine development and closure.

2. DESCRIPTION OF PROBLEM

The hypothetical problem that is used to demonstrate the risk-based technique is illustrated on Figure 1 and described in the subsequent sections.

For the purpose of brevity, the example has been substantially simplified from most situations that prevail on operating mines of this nature. Nevertheless, the example is presented for illustration purposes with the objective of demonstrating that, once this type of procedure has been embraced, it can be modified to suit even very complex conditions.

The mine under consideration is located in a semi-arid environment. It is an open pit gold mine that has been operating for 8 years and is likely to cease production within one to two more years.

The open pit is approximately 60 m deep and comprises a weathered (oxidised) zone of up to 20 m and an unweathered zone below. The average slope angle is about 65°.

The waste rock and overburden dumps have been developed in two phases, the first of which was to place the material at angle of repose to a height of 20 m. The second, more recent approach included the formation of flatter slopes and contour berms in an attempt to minimise erosion on the outer slopes. No geochemical characterisation of the waste material has been carried out, but the less oxidised sections of the ore have been shown to have a low potential for long term acid generation.
Runoff from the slopes would be channelled to the creek via chutes (or "drop structures") lined with waste rock.

### 3.2 Open Pit

Public access, long term slope stability and a rising water table are identified as issues that need to be addressed in the closure plan.

Due to the close proximity of the watercourse to the pit, it is not practicable to construct a safety bund wall at the recommended location along the pit edge closest to the creek, as determined through an approach similar to that proposed in the Western Australian Guidelines (DME, 1999). An alternative approach of flattening the slope and using waste to buttress the slope is therefore proposed.

No specific measures are proposed to address the effects of rising water table after closure, as it is considered that the drowning of the exposed unoxidised material will minimise the potential for acid generation. The potential for long term salinisation of the lake that will form in the pit is not considered to be of major concern.

### 3.3 Waste Dumps

Erosion due to surface water runoff and long term stability are identified as issues that need to be addressed in the closure plan.

The dump that was formed at angle of repose will be flattened to about 20°, with an intermediate step-in to control surface water runoff and minimise erosion. A nominal "cover" of topsoil will be judiciously placed over the surface and watered in to create pockets for improved vegetation growth. The dumps will be hyroseeded to initiate a vegetative cover of pioneer species.

### 3.4 Infrastructure

It is envisaged that the plant and offices will be sold at the end of mining operations and that the area occupied by the infrastructure will be scarified and hyroseeded. All waste rubble is to be buried in a section of the waste dump, which will be reshaped to cover the rubble.
- **Sensitivity Analysis**

As many of the probabilities assigned to the fault/event tree will have a high degree of uncertainty, it will be necessary to carry out a sensitivity analysis to ascertain those faults and their probabilities of occurrence which have a significant impact upon the end result.

- **Focus on Key Areas and Refine Probabilities**

Only those areas revealed by the sensitivity analysis as having a significant impact on the end result need to be focused upon. Further work may be required to refine the probability distributions of those faults that have a significant impact. On completion, a fault/event tree with a sufficiently high confidence in the probability of occurrence of the top event will result.
It is emphasised that the fault/event tree as presented above is grossly simplified for the purposes of illustrating the technique. It has been assumed that all probabilities are assigned on the basis of an estimated likelihood of occurrence within 100 years after closure. It is evident from examination of the tree that:

- The overall probability of the conventional approach being adequate for 100 years after closure is approximately 1 in 3.
- The probability of discharge of unacceptable quality material (solids and/or contaminated water) from the site is almost equally contributed to through discharge from the waste dumps and from the tailings storage facility.
- The highest contributory risks are associated with breaches of the step-ins, or benches on the TSF and waste dumps.
- The drop structures provided to discharge stormwater off the slopes of the TSF present a high risk of releasing unacceptable volumes of solids over the first 100 years after closure.
- Progressive salinisation of the pit lake after closure is very likely over a period of 100 years, with an associated significant likelihood of contaminating the downstream stock bore.

After consideration of the above, the following adjustments to the conventional approach (illustrated on Figure 5) may be considered in order to achieve a higher probability of meeting post-closure objectives, establishing a more uniform risk profile across the system and apportioning expenditure more effectively.

1. Increase the crossfall on the step-in benches on the waste dumps and TSF to accommodate a more extreme rainfall event (>1,000 year event of short duration, high intensity).

2. Allow for a high level flood inflow to the pit (say after a 1 in 50 year event) to reduce the salinity level in the pit lake over a 100 year time frame. This measure will necessitate placement of additional waste in the pit to maintain adequate safety and stability levels. Nevertheless, this material could be placed in lieu of a cover layer of waste to the upper surface of the TSF, as there is less beneficial advantage or long term benefit in placing such a cover. The repeated inundation of vegetation in the lowermost section of the basin will inevitably result in a non-sustainable situation.

Figure 5: Mine After Implementation of Risk-based Closure Measures
CONCLUSIONS

The technique of assessing a conceptual closure plan through the use of a risk assessment procedure and development of fault/event trees allows for a potential to significantly reduce the long term post-closure risks of a mine without necessarily incurring additional cost. The method highlights areas in a conceptual plan that may require reconsideration and demonstrates the likely effectiveness of implementing an adjustment in one or more areas area on the overall risks.
INTRODUCTION AND MEMBERSHIP TO THE GLRG

INTRODUCTION

The Goldfields Land Rehabilitation Group (GLRG) is a technical and professional body of people working to achieve environmental best practice. The GLRG promotes good environmental management practices in arid and semi-arid areas by providing a source of expertise and resource for land rehabilitation.

This is achieved through providing information and education to the public and industry on vegetation and environmental management and by identifying areas where rehabilitation knowledge is limited and research will be beneficial.

The group 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 a solid membership from a broad range of backgrounds such as government organisations, consultants, rehabilitation contractors and minesite environmental personnel.

The aim of the GLRG is to promote sound environmental management practices throughout the region.

The GLRG has endeavoured to achieve these aims in several ways:
- Regular meetings with a guest speaker.
- Regular newsletters.
- Producing a plant identification handbook.
- Establishing the Goldfields Reference Herbarium.
- Conducting a biennial conference on relevant topics.

PROJECTS

This is the 5th environmental workshop that GLRG have held in Kalgoorlie. The workshops are among the projects GLRG has undertaken to forward the aim of promoting sound environmental management practices and information exchange.

Other projects past and current include:
- Publishing a series of guidelines on topics such as topsoil management, seed collecting, waste dump revegetation and hypersaline water management.
- Producing a plant identification handbook.
- Establishing the Goldfields Reference Herbarium in conjunction with the Kalgoorlie College (Curtin University) and the Western Australian Herbarium.
- Development of a website.

The upgrade of the Herbarium and the website to expand the services offered by both are among our current projects. Public outreach will remain a key goal of the GLRG.

AIMS

The overall aim of the Goldfields Land Rehabilitation Group is to promote sound environmental management and awareness in the Goldfields region, particularly by:

1. Providing a source of expertise and resources for land rehabilitation in the Goldfields. This includes areas such as revegetation techniques, seed technology and site planning.
2. Providing information and education to the public on revegetation and environmental management in the Goldfields.
3. Identifying areas where rehabilitation knowledge is limited and research will be beneficial.
4. Provide a forum for discussion and dissemination of information and knowledge regarding environmental issues.

INTERESTED?

To apply for membership to the Goldfields Land Rehabilitation Group, or to obtain further information about the group’s activities, send the following form to:

The Secretary
Goldfields Land Rehabilitation Group
PO Box 2412
BOULDER WA 6432

www.glrg.org.au
or www.emerge.net.au/~glrg

secretary@glrg.org.au

The GLRG meets regularly to discuss environmental management issues. Membership is $30 pa.
GLRG MEMBERSHIP

Please fill in the form below and return with payment to:

The Secretary
Goldfields Land Rehabilitation Group
PO Box 2412
BOULDER WA 6432

Please renew my membership: (Delete whichever is not applicable)

• Individual membership Jan-Jan..........................................................$30.00*
• Student membership Jan-Jan...........................................................$15.00*
• Corporate membership Jan-Jan......................................................$100.00*
  (Corporate membership allows for 3 voting members)
• Corporate supporting membership Jan-Jan.................................$500.00*
* these prices may be subject to GST

Surname:.................................................................................................
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Membership Fee enclosed: $........................................................................

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