Summary of Main Roads Vegetation Rehabilitation for the Station Street, Brixton Street (Roe Highway), Hale Road and Boral Quarry in Orange Grove as per field visit on the 24th June 2005.

Department of Environment Attendees: Mark Brundrett, Joan Payne, Bronwyn Keighery, Paul Watt, David Blake

McDowell STret (Station Street) Constructed Wetland (Not assessed)
This project was believed to be a local government initiative, with a contribution from MRWA as part of the Orrong road extension. General condition of site looks good. Plantings of a variety of wetland and upland species has been successful. Soil is of a clay nature and was waterlogged at time of visit.

The majority of vegetation is planted but some patches of *Acacia saligna* are possibly self-sown. There is little evidence of recruitment at this stage.

Terrestrial weed management appears to have been effective with little evidence of weed species in the rehabilitated area. There is a large colony of *Typha orientalis* (Bulrush) occurring within the aquatic zone. This species occurs in many Perth wetlands and would be very difficult to remove or exclude.

There appears to be relatively little current active management of this site by the responsible authority (believed to be the City of Canning), although it is understood that a "friends group" does exist.

The site may require supplementary planting to ensure the establishment of an adequate understory containing more species other than the pioneer species. In addition to this, monitoring of revegetation, weed management and water quality need to be undertaken to establish the effectiveness of the program and to determine if run-off from the road is affecting the natural functioning of the ecosystem.

Roe Highway/Welshpool Road Constructed Wetland (Ministerial Statement: 436?; MRD Project Orrong Road Extension / Roe Highway Stg 3-5)
This was a brief stop without detailed inspection of the vegetation. The constructed wetlands (retention basins) appear to have developed into functioning wetland environments. .

The absence of monitoring data makes it difficult to quantify the success or otherwise of the rehabilitation program. Visually waterbirds were seen to be utilising the wetland and comment was made that these areas are heavily utilised by avian species at different times of the year. Again there is little evidence to be able to determine water quality or the state of the benthic environment.

Brixton Street Wetlands (Ministerial Statement 436; MRD Project Roe Highway stage 3-5)
Only the Brixton Street overpass adjacent to high conservation value damplands was inspected on this visit. Visually the undisturbed portions of Brixton street wetlands appear to be in a very good condition. There is an abundance of *Viminaria juncea* (swishbush) in some areas of the wetland on the northern side of the bridge. Their abundance may have been promoted by fire.

Revegetation of the cleared areas within the building envelope (bridge) appears not to have occurred except for some plantings of *Corymbia calophylla* (Marri) in close proximity to the bridge). This species would not normally occur in such a damp habitat. A conversation with Dr Rob Howard suggested that they were going to allow the existing natural vegetation to revegetate these areas, but this is unlikely to be successful due to the presence of weeds. There is

a concern that these areas may become a source of weeds, which will impact on the wetland vegetation. There appears to be a lack of responsibility for monitoring of rehabilitation and who is responsible for the ongoing maintenance of the site.

There road verge along Alton Street facing the reserve was mulched, but has not been rehabilitated, as expected. This has been attributed to a communication problem with the contractor (Leightons).

Dinky Goble-Garrett, a consultant to Main Roads WA who deals with roadside vegetation, noted that she thought that the rehabilitation did not meet the completion criteria that were set. She suggested correspondence be sent from the DoE to request the contractor to rectify this.. However, it is expected that the responsibility of the contractor will end soon and Rain Roads would then have responsibility for the site, which is unlikely to remain weed free in the future. is. The management plan set targets for weed management and the planting of local native species, which according to the friends group, have not be achieved. We plan to to review the rehabilitation plan and any available monitoring information for this site to investigate its adequacy and the contractors compliance with it.

Boral Quarry Orange Grove (Ministerial Statement: 170)
Whilst I was not part of the tour of Boral Orange Grove Quarry (due to vehicle capacity restrictions) I am familiar with the site and the rehabilitation performance to date. My opinion is that revegetation practices to date have been very effective and monitoring of revegetated sites is performed in a timely manner.

There are some herbaceous weeds such as *Echium plantagineum* (patterson's curse) around the revegetation and woody weeds including *Nicotiana glauca* and *Phytolacca octandra*. These are most common in disturbed areas, as weed management in rehabilitated areas is generally effective.

Plant propagation and planting at this site by APACE has a high success rate. There is detailed monitoring of vegetation plots within these areas (Cardno BSD; contact David Coremans). The areas being restored are benches where mining has finished. A primary objective is to maintain visual amenity values. Compliance reports have been provided. Our key suggestion is that greater care should be taken to select local species for planting at the site. There is considerable flexibility in the original rehabilitation objectives and landform alteration must also be considered when selecting species which can grow at this site. However we recommend that greater consideration be taken the original survey data from the site for species selection and all seeds be collected locally if possible.

Current streamline monitoring indicates that there is sedimentation occurring once the creak/stream has passed through Boral's site. If this is the case it should be determined what effect this is having on down stream vegetation, etc.

Rocla Quarry (Armidale Road)
Stephen Elliott, the Ste Manager for WA, guided us on a tour of their site at Banjup. The first areas visited demonstrated current practices for Rocal Quarries operations. There were several key differences compared to other sites visited. 1. The use of topsoil respread immediately after stripping resulted in a fairly high diversity of plants from the soil seed bank. 2. Supplemental seed of species native to the site (but not necessarily of local provenance) is applied. 3. Results of a detailed monitoring program (BGPA; Deanna Rokich) are used to determine which species should be planted as tubestock. These are planted after vegetation has become established. Rola should be commended for this flexible approach and the constructive use of monitoring data.

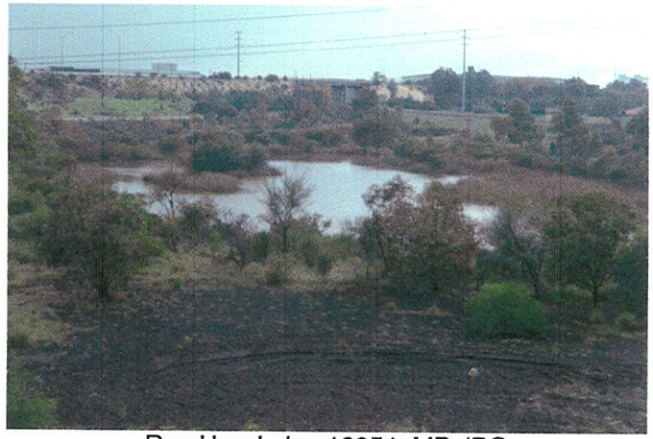
We were also shown a second area of older- style of rehabilitation nearby, with planted irrigated tubestock. This was clearly less successful than the current methods used (but would have had stringent completion targets). The major problems were sparse understorey species, weeds and the use of non-local species. The two Rocal Quarry examples show how important research into rehabilitation methods and the use of monitoring data are.

Tom Bateman Reserve Wetlands (Roe Highway at Nicolson rd)
The last stop was to see large artificial wetlands, which were similar to those seen earlier near Welshpool road. This ais a massive project but has only recently been completed.

Conclusions
From the meeting with representatives from Main Roads WA it was evident that there were issues that need to be addressed with regards to revegetation protocols for major roads and quarries and the use of offsets in relation to there design, implementation, future management and monitoring of outcomes.

There appeared to be a lack of commitment to post implementation monitoring and often uncertainty about the agency responsible ensuring that monitoring and management occurs (e.g. local government, proponent, contactor other government agency).

Notes Prepared By: David Blake 28/6/2005
Environmental Audit Section
Paul Watt 28/6/2005
Environmental Audit Section
Mark Brundrett & Bronwen Keighery
Terrestrial Biodiversity Section 4/7/05



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Rohb Site Visit
24-6-05

Roe Hwy @ Welshpool Rd + Railway

QUARRY REHABILITATION TECHNICAL WORKSHOP

ENVIRONMENTAL MANAGEMENT OF QUARRIES

JUNE 1999

PRESENTED BY

CHAMBER OF COMMERCE AND INDUSTRY
DEPARTMENT OF MINERALS AND ENERGY
WESTERN AUSTRALIAN MUNICIPAL ASSOCIATION

QUARRY REHABILITATION TECHNICAL WORKSHOP

ENVIRONMENTAL MANAGEMENT OF QUARRIES

JUNE 1999

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Introduction

Earlier this year, the Chamber of Commerce and Industry's Extractive Industries Committee, which represents the key companies extracting basic raw materials including sand, limestone, hardrock and clay, considered the benefits of staging a workshop with local government representatives, industry practitioners and people from State Government agencies.

The purpose of the one-day workshop was to create a forum to determine if the Department of Minerals and Energy's (DME) *Environmental Management of Quarries Guidelines* published in 1990, needs to be revised.

The workshop would also serve as an ideal meeting to generate fresh ideas, learn from experience and recommend changes to the guidelines.

The workshop became a reality on Friday June 11 1999.

According to the Department's Dr Colin Branch in his opening address, the publication of the guidelines has been worthwhile for those associated with the extractive industry. He said the challenge still remains to educate operators and land use decision makers about the merits of quarrying and the use of quarries after the resource has been extracted.

Dr Branch said the issues to be discussed at the workshop include defining end-uses of quarries and the types of rehabilitation that can be implemented.

"It may lead to the establishment of a group to revise the DME guidelines.

"Although the catalyst for this workshop was the revision of the nine-year old guidelines, the workshop will cover a large number of issues of concern. I trust that the proceedings will lead to an ongoing commitment to continually push forward the frontiers of best practice in rehabilitation and land-use planning, he added.

This report includes a summary section covering all the discussions at the workshop, copies of all the presentations and notes from the four workshops.

It is important that the momentum generated at the workshop is maintained and the findings and recommendations are considered and if feasible, implemented.

The consensus of many people at the workshop was that the day was very informative.

Summary of Presentations

The following is a list of key points raised by the eight speakers at the workshop.

- Rehabilitation needs to be carried out at a high standard.
- *Rehabilitation requirements vary widely from site to site depending on the end use.*
- Sites should be considered on an individual basis and prescriptive rehabilitation standards should be avoided.
- *The end use and ownership of land should have a strong bearing on the rehabilitation techniques adopted.*
- Proper management plans coupled with life of resource approvals will enable the extractive industry to approach rehabilitation issues from a longer-term viewpoint.
- *If basic raw materials operators are to become sound environmental managers, the issue of security of tenure must be addressed.*
- A uniform approach to environmental management by the regulatory authorities is required so all operators can develop a common industry response to community concerns.
- *Department of Minerals and Energy has put considerable emphasis on education rather than punitive regulation in the early development of its environmental management processes.*
- Industry should recognise that local government comes under considerable pressure to take control when things go wrong, it is therefore in industry's interest to maximise their performance and minimise government's direct involvement.
- *The future challenge will be to change the public image of this industry.*
- A best practice environmental management approach should focus on replicating as far as practicable, pre-mining environmental conditions unless a clear end use, which is incompatible with these conditions, is agreed to.
- *Community concern has been expressed that rehabilitation efforts have typically been well below expectations, with many operators making little effort to make rehabilitation part of their core business.*
- There currently appears to be little consistency with rehabilitation requirements between the range of regulatory agencies involved.
- *An opportunity exists for improved approaches both by the operators an by regulators to gain more consistent rehabilitation standards and results.*

- The conflicts arising from uncertainties about the eventual end use continue to cause problems between regulatory bodies and the industry.

- *There is a trend amongst some regulatory bodies to assume that the revegetation of a site to native woodland is the only acceptable rehabilitation standard, particularly when the end use is not known.*

- There are many examples of valuable woodland being clear felled for urban uses whilst nearby extractive industry sites either struggle to gain approval to operate or are subject to full environmental conditions.

- *Basic raw materials are critical to building and maintaining a city.*
- Quarries and earthworks are urban assets.
- *Integration of quarrying and urban development has valuable outcomes.*
- Quarrying should be seen as a means rather than an end in itself.
- *Zoning is unnecessarily restrictive to a temporary land use.*
- Rehabilitation should match permitted land uses chosen from the zoning applying to the site.
- *WA extractive industry companies should consider the unique, highly successful and proven smoke germination technique and develop closer relationships with local nurseries for the supply of "smoked" seeds for use in restoration programmes.*

- A typical area of land on the coastal plain measuring $1m^2$ and 10cm deep can contain up to 2000 seeds – a rich and valuable resource that can be effectively utilised in the restoration of quarries.

- *Research has shown that the survival of seedlings taken arising from soil seed banks have a far greater chance of survival when the stripping process is conducted in summer and autumn with replacement of top soil back to site being undertaken prior to winter.*

- Industry has the capacity to realise better rehabilitation practices by a commitment to best practice and research & development for providing solutions to problems

- *Industry should continue discussions with restoration ecologists to gain a better understanding of the topsoil techniques.*

- Industry should consider supporting a fund to provide finance for various research and development programmes improving rehabilitation practices in the extractive industries.

- *Greater recognition should be given by regulatory agencies for the progress made and the ongoing commitments by some companies.*

- Recognition should be given by regulatory agencies of diversity in quarry types and end uses- "default menu" prescriptions are not the way to go.

- *Not all operators are at the same point in the spectrum - both industry and government need to set minimum, achievable standards for each situation.*

- Industry is concerned over the number of agencies, complexity and duplication involved in the approvals process for extractive industry in the metropolitan area, and that the role of Local Government could become more constructive and streamlined.

- *There is a lack of consistency across and between Local Governments in the conditions placed on planning approvals.*

- Local Government believes it is not ready to support a longer-term tenure arrangement until there is greater confidence that improved rehabilitation outcomes can be achieved and other community concerns can be addressed.

THE FOLLOWING PAGES ARE THE PAPERS PRESENTED BY:

Opening Address
Dr Colin Branch
Executive Director
Corporate resources and land access
Department of Minerals and Energy

"The Challenge"
Hugh Jones
General Manager Environmental Branch
Mining Operations Division
Department of Minerals and Energy

"The Concerns"
Darren Walsh
Environment Manager
City of Cockburn

"The Response"
Stephen Elliott
Manager Rocla Quarries and
Chairman CCI Extractive Industries Committee

"Types of End-Use"
John Griffiths
Director
Development Planning Strategies

"Types of Rehabilitation"
Dr Kingsley Dixon
Director of Plant Science
Kings Park and Botanic Gardens

"The Industry Experience"
Paul Rokich
Development Manager
CSR Readymix

Closing Address
Mayor John Hyde
representing
Cr Jamie Edwards
President
WA Municipal Association

OPENING ADDRESS

BY
DR COLIN BRANCH
EXECUTIVE DIRECTOR
CORPORATE RESOURCES AND LAND ACCESS
DEPARTMENT OF MINERALS AND ENERGY

I am delighted to welcome you all to this Workshop.

It is a tribute to the organisers and their sponsoring agencies – the Chamber of Commerce and Industry, the Western Australian Municipal Association and the Department of Minerals and Energy – that so many of you from industry, local government, State agencies, environmental and conservation interest groups, and universities have been able to attend.

As some of you would already know, the Department of Minerals and Energy has had a long-term interest in the management and rehabilitation of quarries. Just over eleven years ago I chaired a large multi-disciplined Work Party to investigate conservation and rehabilitation in the quarrying industry and to advise State agencies, local governments and industry on how best to develop, operate and rehabilitate quarries.

One of the organisers of today's workshop, Tony Smurthwaite, was the secretary to the Work Party. The May 1990 report of the Quarry Rehabilitation Work Party led to the then Minister for Mines establishing the Quarry Rehabilitation Steering Committee as a way of promoting the cause of best practice in quarry rehabilitation.

That committee worked from June 1991 to July 1994 and was chaired by your first speaker, Hugh Jones. The principles established by both investigations were taken up by the State Gravel Supply Group and feature prominently in their September 1996 report to the Ministers for Transport and the Environment, and are still evident in the yet-to-be implemented Road Building Materials Strategy.

"This by-product of the main inquiry
has had a long and successful life."

Of more particular relevance for today's workshop is that the May 1990 report had an appendix entitled "Environmental Management of Quarries". This by-product of the main inquiry has had a long and successful life. John Quilty who was principal author of the guidelines is to be congratulated about this fine achievement.

The Department has reprinted the appendix three times and issued, free of charge, over 6000 copies to the Shires, small and large quarry operators, as well as to local residents and members of the general public. I gather that in the early days the guidelines may have generated awkward questions for some operators to answer!

About two years ago, discussions in the field with environmental managers from local government, plus technical exchanges at meetings of the Chamber of Commerce and Industry's Extractive Industries Committee led to a recognition that the 1990 guidelines needed to be updated.

It was agreed that this could be best achieved by holding a one-day workshop so that data and information relevant to quarry operations and rehabilitation could be examined and collated.

"...the catalyst for this workshop was the revision of the nine-year old guidelines..."

Although the catalyst for this workshop was the revision of the nine-year old guidelines, the workshop will cover a large number of issues of concern. I trust that the proceedings will lead to an ongoing commitment to continually push forward the frontiers of best practice in rehabilitation and land-use planning.

I must stress that it is absolutely essential for the continued existence of the quarry and mining industries that operational and rehabilitation performance not only meet the high standards expected by regulatory authorities and the local community but also goes well beyond them in both quality and sustainability.

"No passer-by can tell the difference between a quarry or an open-cut..."

Any extractive industry operation in the metropolitan region or close to a country town is in full view of the public. No passer-by can tell the difference between a quarry or an open-cut, or an operation conducted under the Mining Act, Local Government Act or any other Act. If the performance is inadequate then the bad image affects us all and has repercussions when new projects are proposed.

I believe that today's agenda of provocative and informative papers, together with workshops where you can all put your points of view, will enable everyone who is involved in quarrying (operators, rehabilitation experts, researchers, regulators and critics) to usefully share your knowledge and points of view.

In this way I trust we will all demonstrate our commitment to environmental excellence.

I wish you every success and look forward to the outcomes of this workshop which will set new benchmarks for excellence in quarry operations and rehabilitation.

"THE CHALLENGE"

by
HUGH JONES
GENERAL MANAGER
ENVIRONMENT MINING OPERATIONS DIVISION
DEPARTMENT OF MINERALS AND ENERGY

The challenge faced by all involved in the production of basic raw materials is to continue to produce cost effective basic raw materials for the Perth metropolitan area in the foreseeable future, allowing for the growth of Perth and the expansion of the metropolitan area.

To achieve the above goal, it is essential that maximum access be retained to all local sources of basic raw materials. Maintaining existing access and possibly increasing access can only occur if the industry operates within the standards that the community accepts. These community standards will affect both the daily operations of the basic raw materials industry and the final land form acceptable when the extractive operations have been completed.

It is almost a decade since the Environmental Management of Quarries Development, Operation and Rehabilitation Guidelines was published in 1990. Those Guidelines list areas of public concern and provide valuable advice on how to address the majority of those concerns. The concerns as listed in the document are:

- Destruction of vegetation.
- Reduction of landscape amenity.
- Water erosion and consequent sediment mobilisation and stream pollution.
- Wind erosion and dust generation.
- Noise and vibration.
- Impact on lifestyle and land values of neighbouring properties.
- Traffic generation; and depending on the adequacy and success of rehabilitation, possible long term aesthetic, ecological and erosion impacts.
- Long term changes in land use.

At about the same time as these Guidelines were issued, similar Guidelines were issued to the broader mining community which faced very similar concerns, all be they to a greater or lesser extent, depending on their proximity to local communities.

My position within the Department and my involvement with the Quarry Rehabilitation Steering Committee in the early 1990s gave me an opportunity to watch the development of the two extractive industries, namely the basic raw materials industry and the mining industry as they took up the challenges of meeting community environmental standards in the way they conduct their operations.

It is my view that at that time, in the early 1990s, the technical expertise available to the two industries was similar. Both had access to exactly the same consulting personnel and both had workforces relatively inexperienced in dealing with rehabilitation matters.

Both were subject to similar public pressures to conduct their operations in environmentally acceptable ways and both were faced with the ultimate sanction of not being allowed by the community to continue to conduct their operations if they did not get things substantially correct.

"there were many similarities between the two industries in the early 1990s but one major area of difference was the manner in which they were regulated."

Looking at the two industries now, at the end of the 1990s, I believe that the majority of the mining industry has been able to make the paradigm shift from simply being miners to being environmentally acceptable miners whereas significant sectors of the basic raw materials industry have not yet achieved that same paradigm shift.

Of major concern to this workshop, should be why?

As stated earlier, there were many similarities between the two industries in the early 1990s but one major area of difference was the manner in which they were regulated.

The mining industry has essentially one regulatory authority, whereas the basic raw materials industry operating in and around metropolitan Perth has approximately 20 individual regulatory authorities. Another major difference was the security of tenure available to the mining industry which effectively means that mining leases have a 42-year life before they require renewal.

On the other hand, producers of basic raw materials conduct their operations subject to annual licence renewals. There are probably many other differences, but I would address these two as I believe they are the major factors why the basic raw materials industry has not achieved the progress in environmental management that many in the community believe the mining industry has.

"I believe this issue of security of
tenure must be addressed"

In dealing firstly with the period of tenure, I think it is unrealistic to expect companies with only one year secure tenure to develop five and ten-year plans or develop even longer strategies. If the basic raw materials industry is to become sound environmental managers, I believe this issue of security of tenure must be addressed.

There are many possible solutions to this deficiency and all should be investigated as soon as practicable so that long term planning can become the basic raw material industry's norm.

The second issue is the issue of uniformity in regulatory approach. During the 1990s the mining industry has developed uniform legislation and, probably more importantly a series of administrative processes that allow the legislation to be effectively put into practice.

The advantage for the industry has been a consistent approach by the regulatory authority that has enabled good operators to develop cost effective environmental management techniques.

The basic raw materials industry on the other hand, is subject to the by-laws of the various local governments which, notwithstanding the development of a set of model by-laws by the Quarry Rehabilitation Steering Committee in 1994, do not appear to have a uniform approach to environmental management for basic raw material extraction.

I hope that this workshop in its deliberations will make significant progress towards achieving at least a uniformity of approach to environmental management by the regulatory authorities so that all basic raw material operators can develop a common industry response to community concerns.

"...the Department of Minerals and Energy put considerable emphasis on education..."

Experience in the West Australian mining industry and in other mining industries around the world indicates that the community assesses industry performance, not on a case-by-case basis, but rather on a worst-case basis. It was with this in mind that the Department of Minerals and Energy put considerable emphasis on education rather than punitive regulation in the early development of its environmental management processes.

The Guideline published in 1990 is a good example of this form of approach but it must be followed up by seminars, workshops and performance on the ground matching those Guidelines. There is a challenge there for all involved in the industry including local government, the operators and the educational organisations in this State.

Local governments have a rather onerous responsibility of ensuring extractive industries meet the requirements of the local community. In all cases, governments would like all operators to meet those community standards in a cost effective way, that is with minimal intervention by the regulatory authorities.

"Post operations rehabilitation is a major concern to the community.."

In practice, some operators will unfortunately never meet the required standards and one important thing that local governments need is an ability to access funds to fix up these unfortunate occurrences. In the mining industry, the State Government uses an Unconditional Performance Bond process that was developed from a simple risk analysis.

In any risk analysis, there are two elements that effect the overall risk, namely the consequence of an event and the probability of that event occurring. Post operations rehabilitation is a major concern to the community and a real risk to government is the chance that this cannot be done (for whatever reason) by the operator. The consequence in this case is the cost to government of doing the required rehabilitation works. This is a definable cost in dollars.

The Unconditional Performance Bond system insures the government by providing for non-government funding to cover the cost of the required rehabilitation work. The probability of the event occurring depends on the education, technical expertise, commitment and financial standing of the organisation undertaking the work.

The probability is mainly in the hands of the operating company but insurance against the consequence can be implemented by the local government so that unsightly orphan sites will not occur in the future.

I strongly recommend that the workshop consider these sorts of issues during your deliberations.

The problem of regulating is finding the right balance between "controlling" the organisation you are regulating and "trusting" that organisation. Within the mining industry we have progressively moved to trust companies more and more, mainly because we have been successful in the education programme and the industry has been very successful in taking up the environmental management challenge and reacting in a positive way.

There is a range of legislative and administrative controls available to any regulatory authority from total prohibition of any activity through to go-as-you-please approach with no controls whatsoever. In between, we have prescription regulations, codes of practices and guidelines.

These can be illustrated in the form of a table as shown below:

Community Response	Administrative Option	Control/Trust
Total Rejection ↑ | ↓ Total Acceptance	Total Prohibition Prescriptive Regulations Code of Practice Specific Guidelines Generic Guidelines Nothing	Control ↑ | ↓ Trust

Industry should recognise that local government comes under considerable pressure to take control when things go wrong, it is therefore in industry's interest to maximise their performance and minimise government's direct involvement.

Another matter that needs to be considered when looking at administrative options is that when regulations are highly prescriptive the regulatory, authoritative takes on the

responsibility to ensure that those prescriptions are in fact the correct prescriptions for any given situation.

Experience in managing environmental solutions is that there are many options available to arrive at the required outcome. There is therefore considerable risk in offering a single prescribed solution.

It is much better, from a regulatory perspective, to state clearly the desired outcome so that the operator can select the best method of achieving that outcome.

The message is *"If you wish to control some operation, you must be responsible for it. If you are prepared to trust an operator to some degree or another than the operator becomes responsible for that operation."*

In developing required outcomes, all involved in the basic raw materials industry should recognise that any extractive industry is a temporary land use. With this in mind, more attention should be given to the final outcomes, that is the new, post extraction land form.

"Perth has not yet experienced a land shortage similar to that in parts of Europe and North America"

Already, in Perth we have examples of old quarries being used as amphitheatres, housing development, public gardens and golf courses. This trend should be encouraged, with the community, local government and industry working together to gain common benefits.

While Perth has not yet experienced a land shortage similar to that in parts of Europe and North America which has resulted in some of the quarries and pits created by basic raw materials extraction having a land value similar to the value of the material extracted, but land values are rising.

The future challenge will be to change the public image of this industry from a low value, dusty, necessary evil to a land form creation industry that also provides useful products while developing the new land form to the community's specifications.

THE CONCERNS

by
DARREN WALSH
ENVIRONMENTAL MANAGER
CITY OF COCKBURN

Background

The issues outlined in this paper are reflective of the experiences of the City of Cockburn in relation to sand and limestone quarrying. The City has extensive silica, concrete and fill sand operations in Jandakot, with numerous limestone pits in Henderson and Wattleup.

Over recent years Council has become particularly active in pushing for improved rehabilitation results from operators. This has been an outcome of a generally poor standard of rehabilitation which has been achieved, coupled with a number of recent major applications for new quarries or extensions to existing operations. As part of this, the City has developed stronger standards and requirements for site rehabilitation.

Key issues and concerns from a local government and community perspective

- ***the impacts of quarrying*** - Operations have the potential for substantial local environmental impacts. These include loss of vegetation communities and associated fauna habitat – in some areas of Jandakot very good quality banksia woodland communities have been cleared for mining.

  Areas quarried may also be adjacent to conservation reserves and populations of rare flora. Added to this, quarrying results in major landform modification and landscape impacts. While these impacts are generally unavoidable, rehabilitation needs to be viewed as the key means offsetting these impacts.

  A best practice environmental management approach should focus on replicating as far as practicable, pre-mining environmental conditions unless a clear end use which is incompatible with these conditions is agreed to.

- ***footprint of quarry operations*** – Quarries typically occupy relatively large tracts of land and are often located adjacent to other quarries. This means that from a local landscape perspective quarry areas often a modify large areas of land and have a large "footprint" on the landscape unless well rehabilitated.

- ***rehabilitation performance of the industry*** – Unfortunately, the experience with sand and limestone operators within Cockburn shows a generally poor standard of rehabilitation. While there are some notable exceptions, rehabilitation efforts have typically been well below expectations, with many operators making little effort to make rehabilitation part of core business.

  This tends to tarnish the industry as a whole and can create an uneven playing field, with those who make serious efforts at rehabilitation potentially losing competitive advantage over those who make little effort.

  Difficulties are often experienced in getting smaller operators to adopt a serious approach to rehabilitation, particularly in terms of engaging professional advice in rehabilitation planning, implementation and reporting.

  "...a number of difficulties are faced by companies in rehabilitating sand and limestone quarry sites"

- ***difficulties in achieving good rehabilitation results*** – Even with a solid commitment to rehabilitation, a number of difficulties are faced by companies in rehabilitating sand and limestone quarry sites.

  These involve difficulties in being able to directly transfer topsoil due to staging, the alteration to natural landforms which occur following quarrying and the sometimes intermittent nature of operations. Added to this, the fragility of the vegetation communities associated with quarry areas makes their replication after mining extremely difficult, particularly given Perth's climate and soils.

  Many species will not grow from topsoil, seed for others is unavailable and growth is extremely slow. While still a desirable goal, the replication of native ecosystems following quarrying is likely to be highly improbable.

- ***rehabilitation and end-use*** - If the end use of a quarry site is known, the determination of rehabilitation standards and approach is made much clearer, with revegetation tailored to the type of end use environment.

  "A poor rehabilitation result will also potentially reduce the value of the land..."

  Unfortunately, end use is often unclear at the time of site establishment with many quarries having long life spans. This creates a major quandary-operators are often resistant to investing significantly in rehabilitation if it is destroyed by end use redevelopment, while regulators are keen to see rehabilitation focus on returning the land as close to the pre-development conditions as possible due to the end use being unclear.

  The cost of a "do nothing" or limited approach to rehabilitation can be significant in this situation with operators facing ongoing community and regulator pressure during the life of the site and major difficulties in improving the site when the end use has been determined.

A poor rehabilitation result will also potentially reduce the value of the land in terms of end use and limit the landuse options available.

The Jandakot sand area is a case in point with end use restricted by the Jandakot water mound and proximity to a major airport. While a range of end uses has been touted, the likely use for completed quarries will be special rural subdivision.

> *"Council's often have inconsistent requirements for different operators within their own areas..."*

Special rural subdivisions appear to be favoured as a compatible land use within groundwater initiatives of the State Government, particularly where site vegetation can be retained or enhanced and the resulting development is not intensive.

However, the lack of decent rehabilitation on many quarry sites will make land undesirable and of low value for this use whereas well rehabilitated sites will provide better returns and be more suitable for redevelopment.

- ***inconsistency in regulatory requirements*** – There currently appears to be little consistency with rehabilitation requirements between the range of regulatory agencies involved. Council's often have inconsistent requirements for different operators within their own areas, while major gaps are evident between the requirements of different local authorities.

  Similar observations are made for the various State government agencies involved with DME, Water and River's Commission, EPA and CALM having requirements which are often inconsistent with each other as well as the local authority. This clearly creates an uneven playing field and sends the wrong message to industry.

  > *"...current processes allow applications to be given serious consideration and require significant efforts..."*

- ***difficulties with enforcement and compliance*** – Local authorities face many difficulties in achieving compliance with statutory requirements by errant operators.

  This is due to legislative constraints, limited penalties and the long-winded and onerous nature of procedures available for enforcement. The use of legal deeds and bank guarantees to ensure that rehabilitation requirements are met is one means of assisting, however current approaches are often overly complex and result in disputes and long delays in having agreements finalised.

- ***mining in conservation reserves*** – A final area of concern is that currently the Mining Act allows applications for prospecting and mining in conservation reserves which are Crown land. This includes areas of

regional parks and local reserves that have been set aside for conservation purposes.

While mining is usually incompatible with the conservation values of these reserves, current processes allow applications to be given serious consideration and require significant efforts from affected agencies to prevent mining. This often becomes adversarial and serves to push local authorities and operators further apart.

Conclusion

While this paper outlines a number of concerns in relation to quarry rehabilitation, a good opportunity exists for improved approaches both by the operators and also by regulators, to gain more consistent rehabilitation standards and results. A stronger partnership role is seen as an important step toward this, with the development and implementation of realistic and consistent rehabilitation standards seen as crucial.

INDUSTRY RESPONSE

by
STEPHEN ELLIOTT
STATE MANAGER
ROCLA QUARRIES

I would like to welcome you here today on behalf of the members of the extractive industry committee.

This forum has the potential to provide an exchange of information and ideas that will help to resolve the many issues that confront the operation of extractive industry, particularly within the metropolitan area.

A clear understanding of the requirements of the extractive industry and the expectations of the regulatory authorities and the community should enable us to move forward in a common direction.

I intend to discuss the rehabilitation issues as perceived by the industry in a general manner.

Subsequent speakers this morning will give you more detail on specific issues. My experience is predominantly in the sand mining industry. However, limestone, clay and hard rock make up a much larger part of the industry and their requirements are often different.

I intend to discuss the following issues.

1. History and recent performance.
2. Operational Issues.
3. End use and land ownership.
4. Appropriate Rehabilitation Standards.
5. Regulatory Improvements.

History and Recent Performance

Until the late 1980's the general standard of operation and rehabilitation in the extractive industry could be classed as poor.

Recognition of the problems and higher standards imposed by the regulatory bodies has seen a vast improvement over the last 10 years. Although there are still poor examples in the metropolitan area the majority of operators have improved their performance.

It should be noted that many operations from that previous era, although poorly rehabilitated at the time, have now been developed into a variety of sequential uses including residential and industrial estates, and recreational areas.

In some respects the end use rehabilitation of extractive sites has had little impact on the final use of the land.

The conflicts arising from decisions about the eventual end use continue to cause problems between regulatory bodies and the industry.

Operational Issues

The operation of the extractive industry within the metropolitan area is vital for the continued supply of cheap basic raw materials. There is little development that occurs within Perth that does not call upon the use of rock, limestone, clay or sand.

I am sure that a review of complaints regarding the extractive industry would show that the majority of complaints revolve around the operation of the sites rather than the final rehabilitation of the area.

There are many ways to reduce the operational impact of the industry, although it is unlikely to ever be considered preferred operation by neighbours.

The use of thoughtful planning to reduce visual impact from an extractive site can make an operation far less intrusive.

"The stabilisation of finished areas
in some manner, is also important."

The use of life of mine plans to ensure that visual impact is minimised during the excavation period, gently sloping bunding, ancillary planting in buffer zone areas, sealing of access roads and retention of mine areas that shield the operation from view until the site's completion are all examples of planning issues that would reduce the impact of the operation during its working life.

Close attention to dust and noise control within the extractive site with clearly defined plans to address these problems is also necessary. The stabilisation of finished areas in some manner is also important.

The assessment of these operational issues for any new site, and possibly a review for existing sites will help to reduce complaints and improve the image of the industry.

It is important that these operational issues are not confused with the rehabilitation requirements of the site. Improved initial planning and assessment of site operation is an important and ongoing issue.

The end uses of a particular site may change over time and must not be confused with the working operation.

End Use and Land Ownership

There is a trend amongst regulatory bodies to assume that the revegetation of a site to native woodland is the only acceptable rehabilitation standard, particularly when the end use is not known. This is clearly not the case and clear definition of the varying rehabilitation options available should be better defined.

To a large extent there are two issues that affect the eventual end use of an extractive industry site. They are land ownership and constraints from government policy regarding land use in different areas of Perth.

Land Ownership.

This can be simply divided into freehold land and crown or government controlled land.

In the case of crown land the end use criteria for the land are currently (and should be) determined by the government body in which the land is vested. If this body wishes to return the site to native woodland the operator must be prepared to comply and should re-vegetate the land to the highest standard.

"It is also likely that a local government may wish to rehabilitate the land for recreational use such as playing fields..."

It is also likely that a local government may wish to rehabilitate the land for recreational use such as playing fields, a rifle range or amenity park area. Whatever, the planned use it is the operator's responsibility to rehabilitate to the standard and type of end land use stipulated by the owner.

In the case of private land the owner should be given similar consideration. In areas already zoned industrial, residential or urban deferred final contours are probably the most important end use issue.

"Costly rehabilitation that will again be cleared in the short to medium term is a waste of resources and effort"

The method of land stabilisation can vary, as the future development of the land is likely to preclude long term retention of native woodland. Costly rehabilitation that will again be cleared in the short to medium term is a waste of resources and effort.

Rural zoned land is the most difficult current issue. Regulatory bodies often maintain that as there is no defined end use the site should be returned to native woodland. Rural zoning is not synonymous with vegetation conservation.

It potentially has many end uses. History shows that over 90% of extractive industry sites on rural land are eventually developed for other purposes. Subsequent speakers will illustrate this point in more detail.

If areas of rural land are considered important for retention of native woodland an examination needs to be made of the overall community value. If there are two areas of rural uncleared land and one has a basic raw material resource of economic and the other does not, preference should be given to allowing development on the former case.

There are many examples of valuable woodland being developed for urban uses whilst nearby extractive industry sites struggle to gain approval to operate.

"The constraints of priority areas for groundwater cannot be overlooked."

The use of a site, firstly for extractive industry and then for subsequent development has a much greater value to the community than the site that is only developed for its end use. In essence this allows the extractive industry to operate without a requirement for extra clearing of land than normal development of other uses would need. These developments could range from special rural, through to landfill.

The constraints of priority areas for groundwater cannot be overlooked. It is necessary to protect this resource and operations over these areas may be subject to more vigorous control in terms of final rehabilitation and end use.

The sequential use of extractive industry sites is often overlooked but provides a clear added value to land development in the metropolitan area.

Appropriate Rehabilitation Standards

Regardless of the type of rehabilitation approved for any particular site the standard of that rehabilitation should be of the highest standard. Even in the case of a site requiring only pasture grass for stabilisation it is necessary to ensure that the cover is applied progressively and that the end result is satisfactory.

In the event of sparse cover the process should be repeated or the area upgraded to the standard undertaken in the development plan of the site.

"...it is necessary to utilise the best techniques and knowledge available to the operator in order to work towards a successful outcome."

Areas that require amenity type tree plantings should be carefully monitored to ensure adequate survival. This may include initial watering or supplemental planting in subsequent years. Operators who undertake to rehabilitate land to a particular standard have a responsibility to ensure that the final works comply with that undertaking.

In the case of areas, which are to be returned to native vegetation, it is necessary to utilise the best techniques and knowledge available to the operator in order to work towards a successful outcome.

It must be realised that there is little historical information that can ensure successful rehabilitation of Banskia woodland. Operators must be prepared to update and modify

their techniques, as information becomes available. This will ensure that the best practices are applied and the rehabilitated woodland will be as close to the original vegetation as possible. It is unlikely to ever replicate the original woodland completely.

Management of topsoil, soil compaction and seed collection from site are all areas that will greatly improve the success of rehabilitation if correctly applied to individual sites.

"There is no set formula and each new operation must be reviewed on its own merits..."

However, there is no set formula for rehabilitation of this nature. Techniques will vary widely depending on the landform. For instance rehabilitation techniques are not the same in sand, limestone and clay. The different makeup of these materials has a great impact on the methodology required and, to some extent the end result.

Operators should strive for a high standard of rehabilitation at all extractive industry sites.

However, it must be recognised that these standards will be different for different sites. There is no set formula and each new operation must be reviewed on its own merits and particular issues and problems.

The standards imposed for each site should be appropriate for its end use and the particular special conditions of that site.

Regulatory Standards

Operators must submit adequate and detailed mining and rehabilitation plans. If properly compiled these plans and undertakings will be for the life of the resource. Overall approvals should be given on this basis and not for the short term that is currently the case.

This will give operators a good reason to commit themselves fully to the rehabilitation standards agreed. Lack of continuous tenure is one of the greatest problems the extractive industry has with the current regulatory process.

"Bank guarantees should be updated to reflect the real cost of rehabilitation."

Bank guarantees should be updated to reflect the real cost of rehabilitation. They must be adequate to cover the amount of open area in any given operation. A site that has five hectares open should, for example has a guarantee of $50,000.

However, a site with 20 hectares of open area should have a guarantee of $200,000. This gives the operator a strong incentive to adhere to their undertakings in regard to rehabilitation. It also allows the regulatory body sufficient funds to carry out the work in the event of default by the operator.

Members of the extractive industry who are committed to operating their sites in adherence to their development plans will have not problem with this concept.

Summary

Rehabilitation needs to be carried out at a high standard.

Rehabilitation requirements vary widely from site to site dependent on the end use. Sites should be considered on an individual basis and prescriptive rehabilitation standards should be avoided.

The end use and ownership of land should have a strong bearing on the rehabilitation techniques adopted. Proper management plans coupled with life of resource approvals will enable the industry to approach rehabilitation issues from the longer-term viewpoint that they require.

Subsequent speakers will elaborate on some of these issues and the workshop this afternoon should enable all attendees to input their ideas and concerns.

TYPES OF END-USE

by
JOHN GRIFFITHS
DIRECTOR
DEVELOPMENT PLANNING STRATEGIES PTY LTD

Miners are a critical part of the process of urbanisation. As suppliers of basic raw materials to the city building processes their value is enormous.

Their limestone, sand, gravel, clay and stone products become the roads, piping, bricks, mortar, glass, tiles, fixtures and fittings of our city. Easy accessibility to these products in close proximity to the building sites has made Perth's urban development the cheapest and best in the country.

Without supplies of basic raw materials we cannot build a city!

I invite you to contemplate:

- roads without blue metal or bricks;
- houses without bricks and tiles and plaster;
- bathrooms without vitreous china bowls;
- drains without concrete pipes;
- railway lines without stone ballast; and
- buildings without glass windows.

Their products are clearly valuable. As an urban designer, I have found that in most cases their 'holes' and their capacity to make holes is also very valuable.

As urban raw material, the flat sand plain of the Perth Metropolitan Region is pretty boring.

There are very few natural dramatic hills, scarps, ravines and water bodies that can be used to create surprise in the urban landscape.

Urban designers in Perth get excited when presented with a discontinued quarry of some sort to change to a housing estate, a park or a resort.

Many of Perth's most popular and interesting projects have taken a quarry as the raw material.

Here is a quick collection of such examples:

- Joondalup Golf Estate - world famous resort in unrehabilitated limestone quarry.
- The Peninsular Estate Maylands – residential lakes and park and unrehabilitated clay pit.
- Quarry Amphitheatre - unrehabilitated limestone quarry.
- Woodlake Village Ellenbrook - converted sand mine.
- Buckland Hill Estate - residential in limestone and sand quarry.
- South Fremantle Refuse Dump - unrehabilitated limestone quarry.
- Cocos Drive - sand mine progressively converted to an industrial estate.
- Adventure World - sand mine converted to a theme park.
- Sanctuary Waters - sand mine converted to a residential estate lake and park.
- Leighton Beach - several land uses after sand and limestone excavation including wool stores, marshalling yards and new residential sites.

Other well-known quarries providing enjoyment or value to Perth are:

- Boya Quarries - abseiling etc;
- Edgewater residential estate;
- Queens Gardens East Perth;
- Tamala Park, Badgerup and Henderson rubbish dumps;
- Pexton Playing Fields, Guildford Grammar;
- Mt Claremont/Brockway – sand mine to rubbish tip to schools etc.

All of these examples give strong support to the argument that quarries can be largely left to be converted to a variety of exciting and useful land uses in the future. Safety and nuisance must be addressed but otherwise leave them as existing shapes.

Smoothing them over simply returns them to the original often boring landform.

It is also exciting to urban designers to work concurrently with miners and quarrymen to get them to shape things suitable to an urban outcome as they go:

- hills;
- lakes;

- parks;
- terracing etc.

The value of this to the city building process is threefold:

1. Creation of interest adds value to the finished end land use.
2. The cost of creating the finished land use is significantly reduced by the work of the miner.
3. Some of the raw material to the ongoing project is on site and therefore cheaper.

It is of interest to note that most large urban projects in South East Asia involve an on site timber mill to recycle trees into construction timber, form work, fencing and mulch and an on-site concrete plant using crushed rock on site, sand washing etc.

The raw materials should be extracted from any site whether the development is housing, industry, parks, recreation, institutional or rural.

I am working on several current projects where quarrying is preceding various forms of urban development.

- Small sand mine in Spearwood in preparation for industrial development.
- Very large sand mine in Wangara in preparation for industrial and recreation use.
- Very large sand mine in Southern River in preparation for residential and recreation development.
- Gravel excavation in preparation for tourism and recreational development in the hills.

I understand that the successful tenderers for the APM site in Bibra Lake will mine the site in preparation for industrial development.

Thus my theme is that quarrying can play an important role in supplying product, creating interest and implementing development.

Yet despite this, increasingly onerous requirements are being placed on operators. Examples of rehabilitation conditions are emerging which are almost requiring restoration of original (pre European settlement) vegetation despite a range of potential end land uses and despite the existing land use.

The whole of the Perth Metropolitan Region and most of the expanded area included in the Raw Materials Area is the subject of land use zoning.

The Metropolitan Region Scheme sets broad parameters and compulsory Local Authority Schemes set out detailed land uses for each zone and development standards applicable to those uses.

All land has a value based on that zoning (the range of permitted uses) and the costs and timing of when the use can be realised **plus** the value of any raw materials on/or under the land.

Responsible land management requires that:

1. The raw materials be removed; and

2. The residual value of the land is maximised according to the range of permitted land uses in the zone applying to the site.

This concept is easy to grasp where the zone is:

- Residential
- Industrial
- Commercial
- Institutional
- Recreation etc

where the range of permitted land uses is relatively small, precise and the physical development is understood.

This also applies on land reserved for public purposes such as freeways, schools, water treatment, plants etc.

Most of the problems quarrymen have in defining end use and hence setting the rehabilitation standard, applies in the Rural Zone and perhaps Forest Reserves.

I have taken as given that in the case of land now reserved or zoned as environmentally valuable, quarrying would not be permitted.

If excavation was permitted I also assume that restoration to original pristine standard could be expected!

A review of the lists of Rural Zone permitted uses in the Zoning Schemes of:

1. Cockburn City;

2. Swan Shire; and

3. Wanneroo.

reveals the following:

RURAL ZONE (AMALGAMATION OF COCKBURN/SWAN/WANNEROO)

PERMITTED USES

Dwelling House

Playing Fields

Rural Pursuits
- growing crops
- grazing animals in stables
- orchards & forestry
- processing & sale of produce

USES PERMITTED WITH SPECIAL COUNCIL APPROVAL

Aged Dwellings
Art Studio
Boatel
Caravan Park
Church
Cemetery
Civic Building
Clinic
Club
Garden Centre/Nursery
Hall
Hospital
Fuel Depot
Produce Store
Health Studio
Hotel
Holiday Cottages
Recreation
Extractive Industry
School
Veterinary Hospital

Transport Depot

Marina

Equestrian Centre

Prison

Zoo

URBAN ZONES (RESIDENTIAL, COMMERCIAL ETC)

Extractive Industry usually NOT PERMITTED.

The key issues to note are:

1. Extractive Industry is seen as a land use in its own right and is not permitted in most zones.

2. There is an enormous variety of end land uses for the miner and the landowner to choose from when nominating the basis of the rehabilitation of their quarry in a Rural Zone.

The problems facing the miner and the landowner in this process are:

1. In residential, commercial, recreation zones where extractive industry is not permitted, we must convince the authorities that quarrying is a useful interim or preparatory step in the development process.

2. In the Rural Zone a wide range of rural pursuits applies by the long secondary list potentially requires prior approval before one or more of the land uses can be nominated.

Clearly the rehabilitation will vary according to the land uses chosen.

Directions

The industry must accelerate its acceptance that land has raw material value **and** end land use value and to act accordingly.

Authorities must begin to accept that quarrying is a temporary activity modifying landscape as a step towards the agreed land use **not** a land use in its own right requiring restrictive management.

Landowners should examine their land for raw material value prior to purchase and prior to committing development whether it be for rural use or some form of urban use **THEN** consult your friendly quarryman and seek his help to shape the land!

In summary the following issues apply:

- Basic raw materials are critical to building a city.
- Quarries and earthworks are urban assets.
- Integration of quarrying and urban development has valuable outcomes.
- Responsible land management requires extraction of resources.
- Quarrying should be seen as a means rather than an end use.
- Zoning is unnecessarily restrictive to a temporary land use.
- Rehabilitation should match permitted land uses chosen from the zoning applying to the site.

TYPES OF REHABILITATION

BY
DR KINGSLEY DIXON
DIRECTOR OF PLANT SCIENCE
KINGS PARK AND BOTANIC GARDENS

Introduction.

At the workshop, Dr Kingsley Dixon, Director of Plant Science, Kings Park and Botanic Gardens could not deliver the paper and power point presentation he prepared for the occasion.

At the workshop, we promised to publish this paper. Here is an edited version of his proposed presentation prepared for the workshop.

Kingsley discusses the use of smoke seeds in the restoration process and new management strategies by using the rich seed resources in topsoil. He raised the question of securing financial commitment by extractive industry companies towards the development of R&D programmes for enabling more complete rehabilitation of post extracted sites.

Western Australia has a unique environment and a rich and wonderful floral heritage.

We know this because our research indicates that the State hosts more than 12,000 flowering species. At the same time, the south west corner of the state is considered as one of the international biodiversity hotspots.

Definitions

Revegetation – to grow with plants again. (Most WA extractive industry companies are in this category.)

Rehabilitation – to return a system to a good condition by controlling drainage and contour banking. (Some WA extractive industry companies are in this category.)

Restoration – bringing back to a former or original condition. This condition requires the use of local species and aspires to complete replacement of bushland species and functions. (Only one WA mining company is in this category.)

What category is your company in?

Key technologies for restoration

Our scientific staff at Plant Science in Kings Park and Botanic Gardens, have pioneered and developed a unique system to encourage better germination of seeds through the use of smoke.

Seeds exposed to intense smoke in an enclosed building for about an hour or soaked in smokey water, (smoke is pumped through water for about 1 hour) can substantially improve the germination rate of seeds of many native species.

The discovery of using smoke for germination resulted from extensive research and testing by our staff funded by the mining and extractive industry.

We encourage all WA extractive industry companies to consider this unique and highly successful and proven germination technique and to develop closer relationships with local nurseries for the supply of "smoked" seeds for use in restoration programmes.

Top soil

A typical area of land on the coastal plain measuring $1m^2$ and 10cm deep can contain up to 2000 seeds – a rich and valuable resource that can be effectively utilised in the restoration of quarries.

Our research has indicated that before the process of mining, this valuable top soil of no more than 10cm in depth needs to be stripped and stored undercover (preferably on location), as it is important this soil remains dry.

Our extensive research has shown that the stripping of the top soil to a greater depth such as 30cm or more for re-use in a restoration programme, will not provide substantial improvements in seedling recruitment. In fact, the amount of seeds in the top soil between 10-30cm is up to 75% less than the top 10cm and if mixed together, will subsequently decrease the germination capabilities of the top soil.

In order to adopt these practices in relation to the top soil and apply these proven techniques commonly used in the mining industry, extractive industry companies will be required to adjust their mining schedules and apply good mining planning to improve shipping, storage and replacement of top soil for revegetation.

Survival of seedlings from seed banks

Our research has shown that the survival of seedlings taken arising from soil seed banks have a far greater chance of survival when the stripping process is conducted in summer and autumn with replacement of top soil to site being undertaken prior to winter.

Seedling germination and survival is optimal if emergence of plants occurs in early winter – if seedling germination occurs at other times of the year i.e. top soil replaced in winter or spring, then survival of seedlings is substantially reduced.

Finally, in terms of commitment to biodiversity replacement, the extractive industries are generally achieving a rate of 20% whereas some mining companies are attaining results three times this rate and are committed to a process of continual improvement.

Your industry has the capacity to realise better rehabilitation practices by a commitment to best practice and research & development for providing solutions to problems in rehabilitation. Realistic targets can be set and achieved over the next decade that will be comparable with the performance of sections of the mining industry.

We recommend:

1. Industry holds discussions with restoration ecologists to gain a better understanding of the top soil techniques;

2. Industry adopts smoke technology for improving success in rehabilitation;

3. Industry considers establishing a research and development fund under the auspices of the Chamber of Commerce and Industry to provide finance for various research and development programmes aimed at improving rehabilitation practices in the extractive industries.

THE INDUSTRY EXPERIENCE

by
PAUL ROKICH
DEVELOPMENT MANAGER
CSR READYMIX

The focus of this presentation is to show some recent examples of;

- quarry operations
- past practices
- the range of operation types within the Basic Raw Materials quarries.

I don't think anyone would disagree that there is always room for improvement. I'm sure the quarry operators here today aren't here to say, "we're perfect". Continuous improvement is an ongoing process in all aspects of organisational operations - rehabilitation included.

Actual Examples

The basic raw materials industries quarry hardrock, limestone, sand and clay - all over the state, although the primary focus of this forum is the metro and near metro areas.

The operation and rehabilitation requirements of each of these activities are quite different.

A global rehabilitation prescription is inappropriate - which means each case should be looked at separately and a specific rehab program developed.

Topsoil has been mentioned as a critical factor in successful rehab - but it is a two edged sword - a point I will show later.

But there are also other factors which I believe are not getting the recognition they deserve in successful rehab. These are just as important.

Compaction

Limestone quarries especially have hard pit floors. Ripping prior to planting allows good root penetration in the surface layers and provides a better chance for the plants to find and exploit root channels and fissures in the deeper profile that the vehicle movements have collapsed in the surface

Nutrition

Quarry sites are highly disturbed environments - even with direct topsoil return. Especially in sand quarries, which have low water holding and nutrient holding capability soils, growth rate is very dependent on fertiliser application.

Many rehab prescriptions not only want successful germination and establishment - but they also want good site coverage ASAP. As any market gardener or agricultural scientist will testify - you need to fertilise to get growth.

Succession

I believe lack of acknowledgment of this issue is probably the single biggest failure in the rehabilitation requirements placed on quarry operators, especially when trying to achieve a "natural" rehab outcome.

Such prescriptions imply a high species diversity - to be achieved in a very short space of time (usually 1-2 years). Research in regeneration of natural areas disturbed by fire or logging show a succession of species before it returns to something like original - and that without removal of the topsoil.

There is little recognition that in some situations, a "first crop" coloniser suite of species may be appropriate - to build up soil biomass, nutrient levels and leaf litter.

This takes time.

An objective to rehabilitate to the species diversity of Banksia woodland within 2 years of mining may simply be unachievable.

Issues

Previous speakers have outlined many of the concerns. Some of these are:

- History of rehabilitation
- Operational impacts verses Rehabilitation impacts.
- Range of quarry types and operation size
- Land tenure

Limestone

- Resource located within the coastal development corridors of Perth.
- Many operational pits with lifespans from 2-5 years up to decades.
- Many examples of developed sequential use. Eg industrial, residential, landfill.
- Soil types / annual rainfall generally supports good rehab establishment
- Pit floors need ripping

Hardrock

Fewer nominated sites with resources measured in centuries.
Some sites were established 50+ years ago so there is a legacy of visual impact / lack of site planning.
Soil types / annual rainfall generally supports good rehab establishment
Soil depth on bench rehab can be a problem
End use planning given the quarry lifespan is an issue.

Sand

Widely spread resource in both the limestone (Spearwood) and Bassendean soil types, although technical specifications of each type differ.
Located within the coastal development corridors and underground water resource areas respectively.
Many operational pits with lifespans from 2-5 years up to decades.
Many examples of developed sequential use. Eg industrial, residential, landfill.
Soil types not supportive of good rehab establishment and growth.

Clay

Range of technical specifications depending on use
Resources can be very specifically located or extensive
Generally on the eastern side of the coastal plain and hills.
Associated with wetlands. Generally poorer capability for development.

Current Innovations

The above slides have shown some of the recent work done by companies. These innovations include:

- Direct topsoil return
- Topsoil screening
- Direct seeding; understorey and overstorey
- Ripping
- More proactive end use planning

Land tenure

Land Tenure is an issue probably left for debate in the afternoon workshop sessions. Broadly, I would propose two major types - Public and Private land.

I believe the sequential use expectations / rehab prescriptions and approval processes should reflect these differences.

Outcomes

- Greater recognition by regulatory agencies for the progress made and the ongoing commitments by some companies.

- Recognition by regulatory agencies of diversity in quarry types and end uses- "default menu" prescriptions are not the way to go.

- Not all operators are at the same point in the spectrum - both industry and government need to set minimum, achievable standards for each situation.

CLOSING ADDRESS

by

MAYOR JOHN HYDE

representing

CR JAMIE EDWARDS

PRESIDENT

WA MUNICIPAL ASSOCIATION

Thank you for the opportunity to close today's proceedings.

I would like to communicate the apologies of our President, Cr Jamie Edwardes for his inability to be here today. Although prior commitments meant I was unable to attend today's entire workshop, I have had the opportunity to read the papers from each presentation and offer these thoughts by way of closing the workshop.

I understand that there are two factors driving the need for greater discussions between industry, regulators and Local Government over the issue of Quarry Rehabilitation.

Firstly, the Environmental Management of Quarries Development, Operations and Rehabilitation Guidelines are now nine years old and are therefore in need of review.

These guidelines have proved to be a valuable source of information for addressing the major concerns of the public and Local Government is keen to ensure a strong representation in their review. Perhaps it is the process of review that will enable all players in the issue of quarry rehabilitation to address the second factor, which is the need for greater cooperation and trust between industry and Local Government.

"I have heard along the grapevine that some members of the industry feel that there are too many regulatory bodies involved in the extractive industry..."

I have heard along the grapevine that some members of the industry feel that there are too many regulatory bodies involved in the extractive industry in the metropolitan area and that indeed Local Government should not really have a role. Although this may be a minority view, I would strongly assert that Local Government will always be a crucial player, and that with the right circumstances, can potentially be industries strongest ally.

The Local Government Act dictates that Local Government provides good governance to its residents. It is these residents that are demanding better environmental performance from all sectors of society. Many in the community commit untold hours to the improvement of their local environments and, not unrealistically, expect that industry and government will expend complimentary efforts.

Although it may be unfortunate that there are so many involved in the regulatory aspects of quarrying, it must be recognised that Local Governments bears the brunt of community dissatisfaction. It is our phones that ring and our staff that must have the answers.

Hugh Jones is correct in stating that "maintaining existing access and possibly increasing access can only occur if the industry operates within the standards community expects." I would have thought that it was very much in the interested of industry to ensure a cooperative approach with Local Government.

" I don't wish to sound as though I am bashing industry and claiming the moral high ground for Local Government.

Having said that, I don't wish to sound as though I am bashing industry and claiming the moral high ground for Local Government. I recognise that there is a lack of consistency across and between Local Governments in the conditions placed on planning approvals.

The extractive industry has every right to expect a level playing field in this regard and it is a matter that could be taken up by WAMA. With the review of the guidelines, it may be appropriate to seek a commitment from metropolitan Councils to standards consistent with the guidelines as a minimum.

Hugh Jones raised the issue of annual licenses. Although it is appreciated that a one year secure tenure is not much of an incentive for companies to develop five or ten year plans, I do not believe that Local Government is ready to support a longer term tenure arrangement until there is greater confidence that improved rehabilitation outcomes and other community concerns can be achieved.

This comment is only valid in some cases as in fact, Local Governments are able, and do, issue licences of up to 10 years. The associated fees are due annually. Nonetheless, there is no denying that secure tenure is a significant issue. WAMA can and will act to facilitate the discussion required to improve the situation on the direction of our members.

"Councils are being increasingly pressured to secure locally significant bushland..."

Finally, I would like to highlight a number of strategies that Local Government should consider when discussing the issue of quarry rehabilitation. The release of Perth's Bushplan has heightened the debate over the management and protection of locally significant bushland. Councils are being increasingly pressured to secure locally significant bushland although the tools to achieving this outcome are fairly thin on the ground.

One of the processes currently being suggested is that each Local Government commit to undertaking a comprehensive inventory of all vegetation and then developing a priority list for the conservation of local areas. The determination of these priorities will be based on a variety of values, broader than ecological or scientific values.

"...the pressure on Local Government to ensure the protection of local biodiversity will increase."

Similarly, international commitments to biodiversity protection by the Federal Government have seen the recent development of a Local Government Biodiversity Strategy. Although in the early stages, the pressure on Local Government to ensure the protection of local biodiversity will increase.

I make mention of this strategy and Bushplan to demonstrate that the role of Local Government in environmental management continues to evolve and become more complex. Nonetheless, we also face the challenge of ensuring local economic development is fostered within our municipalities.

If we are to be in the best possible position to meet these new expectations and challenges, it is certainly in our interest to ensure cooperative partnerships and clear communications with key sectors, including the extractive industry sector.

I would like to thank the Chamber of Commerce and Industry's Extractive Industries Committee and the Department of Minerals and Energy for co-hosting today's workshop and encourage all stakeholders to continue these important discussions so that the balance between control and trust can be reached.

THE FOLLOWING PAPERS ARE OUTLINES OF THE OUTCOMES OF THE WORKSHOPS ON:

Approvals

Rehabilitation

Techniques

End-Use

APPROVALS WORKSHOP

This workshop discussed the following topics including

Existing approvals

The workshop listed the types of land and the types of approvals associated with various agencies that quarry operators need to secure approvals. They include:

Crown land

Mining leases and the issues of dealing with the Mining Act
Local Govt processes/applications in terms of development approvals
Department of Environmental Protection approval
Memorandum of Understanding between the Department of Minerals and Energy and the Department of Environmental Protection

Private land

There is a plethora of local government approvals for example, the mining of silica for export is subject to controls under:

- Mining Act
- Development application; and
- Extractive industry licence

Vacant Crown Land

Which is covered by Native Title legislation.

In addition to the local government process there are also a number of government licences/approvals to be considered including:

- Environmental Protection Authority / Dept of Environmental Protection approval;
- Mining lease;
- Dangerous Good licence;
- Agriculture WA approval;
- Water & Rivers Commission approval; and
- WA Planning Commission approval.

The consensus of this workshop found there is a large duplication of effort in this area and this matter requires addressing.

The Way Forward

Consistency of applications in dealing with local government as the rules varies from Council to Council. (Model prescriptions for the information to be provided are for example required).

The supply of sufficient written and standard information to operators that addresses the concerns of Council's and communities is required to avoid protracted discussions between Council representatives and quarry operators

There is a need to develop better relationships between Councils and applicants. Today's workshop is an excellent starting point from which we can move forward.

Revisit the 1987 approach on basic raw materials whereby extractive industry plans are reviewed by Regional Committees reporting to an Executive Council.

Industry needs to improve the public's/community's perceptions about its operations and performances. Councils and industry need to work together by compiling facts about quarrying operations in order to improve the community's understanding and appreciation of our industry. Industry (operators) can do this by providing the correct information from the outset that will then allow Council's to communicate these facts to communities/residents.

Achieving consistency of conditions and approvals for applicants is a big issue. How do we go about securing consistent approval mechanisms with local and State Government agencies/departments?

We believe there is a need for better distribution of information between authorities

Short-term industry development approvals should be removed. These should be replaced with a "whole of life" development approval for a period of up to ten years during which the operators have to prepare three yearly reports on their rehabilitation activities. These changes would remove the need for extractive industry licences.

"Extractive industry" as a land use becomes a precinct or zone within the town planning scheme in the new planning process perhaps under a WA Planning Commission 5AA policy.

There is a need to clarify the existing mining and planning laws and make changes to them. Relating to interaction between the mining and planning acts we have a Town Planning Development Act and Metropolitan Regional Scheme Act which means there is duplication and many overlays between local government and State Government planners. We need to clarify this matter in legislation.

Buffers for industry and realistic distances that should be applied.

A mechanism for securing buffers and protecting them requires further discussion. Rather than draw a line on a map 300, 500 metres or one km radius around the quarry site, the latest technology and models available to industry should be deployed on issues such as noise and dust. The onus is on the operator to design a suitable buffer zone.

Establish a forum/working party meeting between CCI, WAMA and others to discuss these issues and consider the way forward.

REHABILITATION WORKSHOP

Types of rehabilitation may include:

Permanent	– return to a vegetated landscape for conservation, pasture or parkland;
Temporary	– revegetation for stabilisation where end-use is not defined; and use local endemic species as much as possible; and
Developmental	– a defined end use for development of some kind – eg golf course, housing estate, water park etc

Standards

A meeting should be convened for all stakeholders to develop high standards.
Possible content – ISO 14000,
Achieve best practice standards
Staged sign off
Landscape function analysis
Completion criteria

To achieve these standards, requires:

- Preparation of a pre-distribution study
- Operational management
- Resources for rehabilitation
- Establishing a time frame
- Reporting/monitoring system
- Inspection/regulation/feedback procedures

Once developed, standards are to be applied and implemented by:

- Use of bond system.
- Local government authority a single body accountability
- Use of models such as the State Gravel Strategy
- WA Municipal Association should convene meeting to discuss issues
- Standards to apply statewide

Maintenance

- Developer is responsible with feedback from regulators
- Progressive review (annual reports) system
- Bonds adjusted as necessary

Acceptable/achievable/desirable?

These aspects would be dealt with by application of the standards in consultation with the stakeholders. The proponent must indicate a firm commitment once approval has been achieved and participate in an annual review process.

Outcome

Site is left safe, stable, non-erodible and end-use is sustainable.

TECHNIQUES WORKSHOP

Best topsoil management techniques include:

- Direct transfer of topsoil is the most optimal outcome
- Application of the 3 S's – stripping, storing and spreading
- Soil deteriorates in stockpile particularly if it gets wet
- Topsoil can be spread over a 10cm depth through the use of seeds in native vegetation

Initial topsoil

- Sharing the resource with operators at adjacent sites
- Topsoil management through re-seeding and storage in order to keep it active
- This soil can be used in progressive reclamation and requires better management by operators
- Keep in stockpile as long as possible

Habitat matching

- Quarrying may create new soil profiles therefore the original vegetation may not be suitable – operators need to increase knowledge about matching plants to different soil types

Seeding and greenstocks as options

- Some native species can be weeds if used incorrectly
- Acacias can dominate the site if used incorrectly
- Cover crops can be beneficial to reduce exposure of plants in sand mine areas caused by sand erosion and wind blasting
- Cover crops can be competitive if used carefully
- Cover crops does not mean exotic agricultural species – native species exist
- More knowledge is required

Seed

- Awareness of provenances and use of appropriate seed sources from within local areas rather than introduce substantially different genetic material
- Some seed collectors in the industry are not aware of these issues
- Lack of certainty and information about seed purity depending on the species
- Lack of knowledge exists about optimal storage environment/conditions for seeds
- Germination enhancement techniques for seeds including: smoke
  rapid ageing
  coating

- Timing of seeding should be immediately after soil preparation if possible rather than wait for seasonal conditions eg winter rainfall

Research and training

- Need to raise awareness and knowledge of operators and regulators about environmental management and rehabilitation eg botany and biology
- Today is the start of the education process but requires follow-up activities including field tours and short courses
- Industry to fund these activities and R&D
- Currently not all operators are contributing equally to R&D
- Possessive management approach to environmental management exists in the quarrying industry whereas the mining industry is open about sharing knowledge
- Access to latest information can be a problem especially for small operators and some Councils
- Update of Department of Minerals and Energy quarry guidelines is required

END-USE WORKSHOP

Problem

How do you define the end land use clearly?

Often quarrying is conducted without a proper management plan.

The following workshop notes discuss the need to develop a final end plan based on the requirement that a thorough understanding of Councils' requirements is necessary.

Councils need to develop a long-term plan for their respective basic raw materials areas and allocate zones around these sites.

Once prepared, these plans will assist Councils to decide on the outcome of a development application.

The proponent's end use plan needs to be complete so that a Council can readily access the plan.

The plan should include:

- Final land form – the shape of the land
- Rehabilitation requirements
- Consideration of groundwater/surface water
- Various land use constraints eg buffers
- Plan needs to be flexible

Concerns

- From a Council's viewpoint, how do they monitor the rehabilitation work and the return to end land use?

- Council's buffer zones limit the opportunities of operators and restrict your operations.

- Some operators on low value sites have greater problems in quarrying and rehabilitation compared to large companies.

CLOSURE STANDARD

Issue 1.0 **July 2004**

bhpbilliton

Poirier in Canada 1998 - 2001

Front Cover: TNC site in South Africa

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1.0 Introduction

1.1 Closure Standard Intent

All BHP Billiton investment opportunities and controlled operations shall have closure plans which are regularly reviewed and updated and which identify, mitigate where possible, and manage both current and future health, safety, environment and community (HSEC) and other business risks associated with closure.

1.2 Context

The Closure Standard should be read and used in conjunction with the BHP Billiton Charter, HSEC Policy, HSEC Management Standards, Investment Process Manual (IPM) and associated Standards, and the Accounting Policy Manual.

While stewardship for the Closure Standard is within the HSEC function, the Closure Standard contains elements that are applicable to Finance (Group Accounting and Risk Assessment and Assurance), Legal, Business Evaluation and Economics, and Project Development Services.

1.3 Objectives of Closure Standard

It is intended that the Closure Standard will assist BHP Billiton to achieve the following objectives:

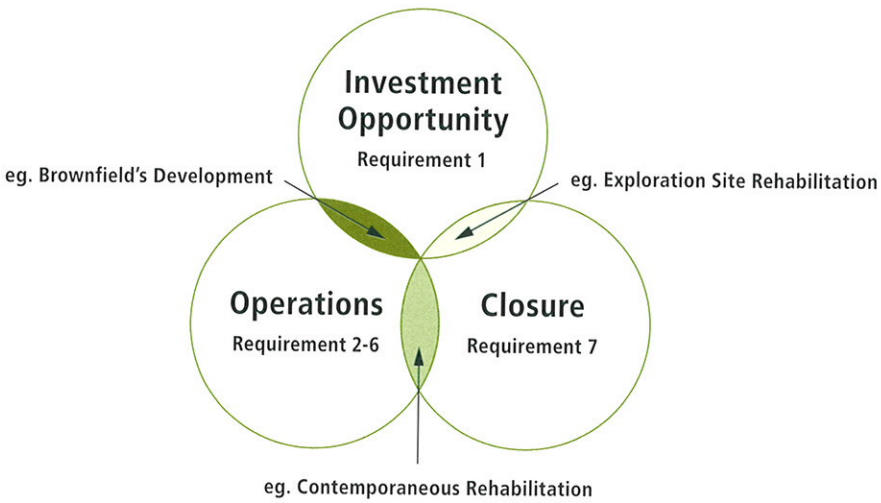
- protect and enhance the reputation of BHP Billiton as a responsible corporate citizen;
- ensure shareholder value is preserved;
- establish BHP Billiton management accountability and ownership of closure activity;
- ensure that stakeholders' needs, concerns and aspirations are taken into account when considering closure;
- comply with relevant or applicable legislative requirements;
- protect public and employee health, safety and welfare;
- limit or mitigate adverse environmental effects, including taking into account biodiversity;
- mitigate socio-economic impacts in relation to a particular area in which an operation is located following decommissioning and subsequent closure as far as reasonably possible;
- help protect indigenous values;

- provide a reasonable basis on which the financial consequences of closure can be estimated, recognised and managed including consideration of any tax consequences;
- avoid or minimise costs and long term liabilities to BHP Billiton and to the government and public;
- achieve sustainable land-use conditions as agreed with the applicable government regulator and affected communities; and
- ensure investment decisions include appropriate consideration of closure, including both quantitative and qualitative impacts of closure.

1.4 Application

The Closure Standard is mandatory to all BHP Billiton investment opportunities and controlled operations. Controlled operations are locations where BHP Billiton can set standards and directly supervise and enforce their application. Where BHP Billiton has no operational responsibility but has an equity stake, or where significant BHP Billiton assets are involved, this Standard will be made available to the operator and best efforts will be made to encourage full compliance.

BHP Billiton has operations in different countries throughout the world with varying legal frameworks. The Closure Standard does not take the place of legislative or regulatory requirements, therefore, when applying the procedures set out in the Closure Standard, relevant legal frameworks shall also be complied with.



The diagram illustrates the relationship between the life cycle of BHP Billiton operations and the Closure Standard requirements.

1.5 Closure Planning and Execution Process

The following table illustrates the life cycle of the closure planning and execution process established by the Closure Standard:

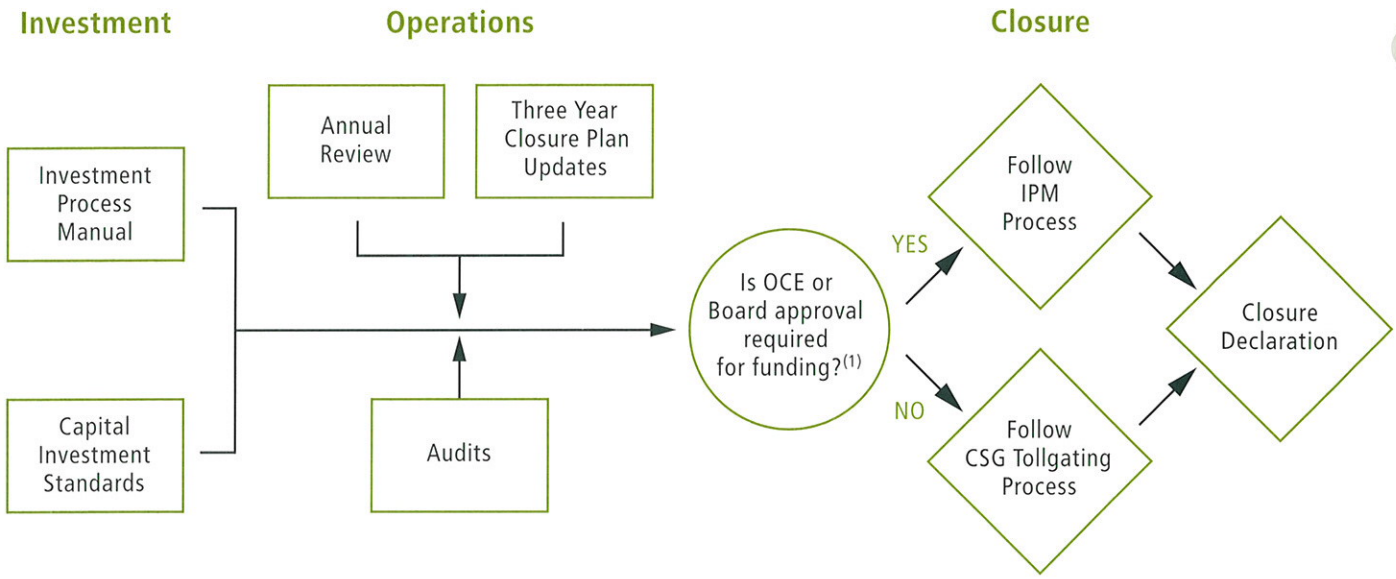
Closure Planning and Execution Process	
Closure Phase	**Scope and Focus of Closure Activities**
Closure Concept	The following is generally conducted during the front-end loading phases (Concept, Pre-Feasibility and Feasibility) of an investment opportunity in accordance with the Investment Process Manual prior to any major investment approval: 1. Identify and quantify any potential fatal flaws that would prevent BHP Billiton from Charter compliance or achieving positive investment outcomes as a result of closure. 2. Establish existing environmental baselines for potential facility / physical assets. 3. Ensure adequate understanding of relevant legislative requirements and / or HSEC Management Standards or other standards. 4. Based on the proposed concept(s) for facility / physical assets, conceptualise the final state of environment post eventual closure and identify any incremental differences between the closure concept(s) for the overall investment alternatives under consideration. 5. Determine the scope of activities to achieve conceptualised final state and the resultant cost, time and other impacts. 6. Conduct an appropriate stakeholder analysis as necessary. 7. Undertake risk and uncertainty analysis to ensure both qualitative and quantitative assessment. 8. Formal independent review as per Corporate or Customer Sector Group Investment Process or Tollgating Manuals. 9. Identify any technology development or other critical success factors for the planned eventual closure. 10. Establish financial provisions for closure in accordance with the Accounting Policy Manual.
Transition and Update	1. Post the investment approval and during the transition towards eventual closure, the closure concept plan must be updated regularly to ensure the appropriateness of a) the closure aspects of short, medium and long-term, business plans and b) financial provisions established and reported by BHP Billiton. 2. Review the closure plans established above to ensure the conditions are unchanged and quantify the impact of any variances on cost, time and other completion or quality outcomes. 3. Update financial provisions for closure in accordance with the Accounting Policy Manual.
Closure Prefeasibility	1. Review, revisit and / or revise as necessary the entire basis of the previously updated closure plan. 2. Check progress of closure plan implementation if progressive closure involved. 3. Update, revisit and / or revise stakeholder analysis work as necessary. 4. Update, revisit and / or revise closure objectives including completion criteria. 5. Undertake risk and uncertainty analysis to ensure both qualitative and quantitative assessment. 6. Engage formal independent review where expenditure expected above US$100M BHP Billiton share. 7. Seek formal BHP Billiton approval to proceed to next closure plan phase in accordance with the Approvals Framework. 8. Update financial provisions for closure based on expected closure costs in accordance with closure plan and the Accounting Policy Manual.
Closure Feasibility	1. Review, revisit and / or revise as necessary the entire basis of the previously updated closure plan. 2. Check progress of closure plan implementation if progressive closure involved. 3. Update, revisit and / or revise stakeholder analysis work as necessary. 4. Update, revisit and / or revise closure objectives including completion criteria. 5. Undertake risk and uncertainty analysis to ensure both qualitative and quantitative assessment. 6. Engage formal independent review where expenditure expected above US$100M BHP Billiton share. 7. Seek formal BHP Billiton approval to proceed to next closure plan phase in accordance with the Approvals Framework. 8. Update financial provisions for closure based on expected closure costs in accordance with closure plan and the Accounting Policy Manual.
Closure Execution	1. Execute closure plan as a project per formal approval from Closure Feasibility phase. 2. Monitor and control actual closure progress against closure plan. 3. Seek formal independent peer review as necessary to assure progress and forecast completion. 4. Progressively update accounting provisions for closure based on actual progress. 5. Validate closure plan outcomes against established criteria. 6. Seek formal acceptance of closure outcomes and completion criteria with stakeholders including sign-off of statutory authorities.
Post Closure	1. Continue with rehabilitation and remediation activities as per closure plan. 2. Validate compliance to closure objectives and project completion criteria. 3. Progressively update accounting provisions for closure based on actual progress. 4. Monitor post closure commitments. 5. Sign-off full relinquishment. 6. Conduct exit review and collect and / or disseminate key learnings.

*Guidance on methodology of estimating closure costs is available in the Project Control Toolkits (PT156D Guideline for the Development and Management of Contingency; and PT157D Capital Cost Estimating).

Timing and Deliverables	Class of Closure Cost Estimate*	Independent Reviews of Closure Plans	Overall Life cycle Phase of Investment
1. In accordance with the overall investment opportunity timetable present a closure plan as a part of the overall study report for the designated phase. 2. In accordance with Section 10 of the Capital Investment Standards for a Concept, Pre-Feasibility or Feasibility Study (dependent upon phase): "Develop a preliminary decommissioning, closure, remediation and rehabilitation plan for the project. Include stakeholder considerations in the development of the plan and provide preliminary cost estimates."	Concept Class with Basis of Estimate, key assumptions, and residuals risks identified and documented.	Independent Peer Review as part of reviews of overall investment opportunity in accordance with the Investment Process Manual. Customer Sector Group peer reviews of closure plans on an annual basis with formal independent review in line with three yearly full update.	Concept ↓ Prefeasibility ↓ Feasibility
1. Update closure plan annually with three year full complete revisit and update. 2. Prepare and submit Annual Closure Summary Report as per Appendix B.	Progressive update of Concept Class Estimate.	Fit-for-purpose Independent Peer Review on an annual basis with formal independent review in line with three yearly full update. Periodic audit by Group Audit Services and HSEC.	Execution
1. No later than five years prior to the expected commencement of closure execution review the previously updated closure plan to ensure Pre-Feasibility class of definition is sufficient to support a Pre-Feasibility Class of Cost Estimate. 2. Prepare and submit Annual Closure Summary Report as per Appendix B.	Pre-Feasibility Class with Basis of Estimate, key assumptions, and residuals risks identified and documented.	Fit-for-purpose Independent Peer Review prior to approval to proceed to Feasibility in accordance with the Investment Process Manual. Periodic audit by Group Audit Services and HSEC.	Operation (can include closure and / or exit as appropriate)
1. No later than one year prior to the expected commencement of closure execution review the previously updated closure plan to ensure Feasibility class of definition is sufficient to support a Feasibility Class of Cost Estimate. 2. Prepare and submit Annual Closure Summary Report as per Appendix B.	Feasibility Class with Basis of Estimate, key assumptions, and residuals risks identified and documented.	Fit-for-purpose Independent Peer Review prior to approval to proceed to Execution in accordance with the Investment Process Manual. Periodic audit by Group Audit Services and HSEC.	
1. Prepare and submit Annual Closure Summary Report as per Appendix B. 2. Final closure documents by relevant stakeholders. 3. Sign-off on formal document. 4. Regular progress reports during closure execution as per project frameworks.	Definitive Class with Basis of Estimate, key assumptions, and residuals risks identified and documented.	Fit-for-purpose Independent Peer Reviews on an as-required basis to assure progress and plan adherence but no less than six monthly. Periodic audit by Group Audit Services and HSEC.	
1. Prepare and submit Annual Closure Summary Report as per Appendix B. 2. Post closure monitoring plan execution as required. 3. Relinquishment document.	Actual costs established excluding ongoing monitoring.	Facilitation of exit reviews and key learnings capture on an as-required basis.	

1.6 Closure Plan Review Process

The following diagram provides an overview of the process for independent review of closure plans:



(1) The IPM process for closure for a site or business can be undertaken at an approval level less than Chief Executive Officer (CEO) approval if requested by CEO or Customer Sector Group (CSG) CEO.

2.0 Closure Standard Requirements

To comply with the Closure Standard, the following requirements shall be adhered to:

Requirement 1

Closure Plans required for all Investment Opportunities

Systems are in place to ensure that closure plans are developed for all investment opportunities in accordance with the requirements of the Investment Process Manual, Capital Investment Standards and this Closure Standard, irrespective of the estimated closure cost.

Application

A. Investment processes established by an asset, Customer Sector Group or group function shall require that a closure plan be developed for all investment opportunities (including exploration activities), irrespective of the initial estimated closure cost.

B. Closure plans, including those for exploration activities, shall be maintained throughout the life cycle of an investment opportunity - refer Closure Planning and Execution Process table in Section 1.5.

C. The closure timing and cost estimates shall be included in valuations prepared in accordance with the Investment Evaluation Standards.

Requirement 2

Closure Plans required for all Operations

Systems are in place to ensure that closure plans are prepared for all existing operations. Closure plans shall be reviewed annually and updated every three years to ensure that they continue to remain relevant and accurate, particularly with respect to the estimated cost of closure.

Application

A. A closure plan shall be developed for all operations.

B. The closure plan and associated documentation shall be reviewed by each operation annually or when there is a significant change to the operation.

C. The closure plan and associated documentation shall be updated throughout the life cycle of the operation. The frequency of update will depend on the remaining life of the operation. For an operation with an estimated life of greater than five years, the update shall be undertaken no less than every three years. For an operation with an estimated remaining life of less than five years, the closure plan shall be maintained to pre-feasibility standard and no later than one year prior to the expected commencement of the closure execution phase, the closure plan shall be further developed to feasibility standard.

D. The closure cost estimate and accounting provision shall be revised in accordance with the Accounting Policy Manual for inclusion in the relevant annual report and financial statements. The revision shall ensure that the cost estimate and resulting accounting provision match the closure activities identified in the closure plan.

E. As part of the three yearly update of the closure plan, the cost estimate and accounting provision shall be fully reassessed and revalidated, and where necessary, updated to reflect the current estimated closure cost.

Requirement 3

Identification of Risks and Potential Outcomes

The closure planning process must involve identification of the full range of risks and potential outcomes associated with the closure of an operation in order to control or minimise negative HSEC, financial and other impacts.

Application

A. The closure planning process shall include an assessment of all risks associated with the closure of an operation, including an assessment of risks relating to any residual liabilities post closure.

B. The risk assessment, as well as controls and management plans, shall be conducted and developed in accordance with the Enterprise Wide Risk Management methodology.

C. The risk assessment shall address, but not be limited to, the potential closure risks contained in Appendix A.

D. The closure risk assessment shall specifically consider the impacts arising from the risk of unanticipated delay, including intentional delay in the commencement or execution of closure or contemporaneous rehabilitation activities, including risk to the range of potential outcomes and the consequent impact on closure cost estimates.

E. Systems shall be in place to identify and engage stakeholders in order to develop closure plans that address stakeholder needs, aspirations and concerns.

F. Systems shall be in place to ensure that the issues and risks associated with closure are incorporated into an external affairs management plan, which is maintained and updated as appropriate throughout the life cycle of an operation and during closure execution.

Requirement 4

Estimating the Expected Cost of Closure

Systems are in place to ensure that closure plans have matched valuations in accordance with the Investment Evaluation Standards, and that the accounting provisions for closure comply with the Accounting Policy Manual.

Application

A. Closure plans shall contain sufficient descriptions of anticipated closure activities, commensurate with the appropriate accuracy specified in the Capital Investment Standards, to provide a reasonable basis for the determination, without bias, of an expected cost of closure - refer Closure Planning and Execution Process table in Section 1.5.

B. The impact of closure costs on the value of an investment opportunity or an operation shall be determined in accordance with the methodology contained in the Investment Evaluation Standards, and shall involve the use of both deterministic and probabilistic estimation techniques where appropriate to determine the expected cost of closure.

C. All closure plans shall include an estimate of the provision for closure in accordance with the principles specified in the Accounting Policy Manual, namely the principles detailed in the policies addressing decommissioning, restoration and closure provisions.

Requirement 5

Timely and Efficient Execution of Closure Plans

Systems are in place and key performance indicators are aligned to ensure that those parts of an operation that are available for closure and / or contemporaneous rehabilitation are attended to efficiently and without delay or deferral.

Application

A. Closure plans shall specify the time periods over which closure activities are expected to occur and any changes to timetables shall be subjected to auditable tests for legitimate operational issues.

B. Closure shall be executed in accordance with a closure plan timetable, such timetable shall only be modified where reasonable operational constraints prevent adherence.

C. Management shall establish appropriate key performance indicators for closure execution, including milestones relating to performance against the closure plan timetable, and monitor performance against these key performance indicators.

Requirement 6

Reporting, Audit and Governance Procedures

Closure planning processes and closure plans shall be subject to reporting, audit and governance procedures.

Application

A. Closure planning processes in place for the maintenance of closure provisions shall be evaluated and tested annually for their ability to adequately mitigate the risk of material misstatement to the relevant annual report and financial statements.

B. An Annual Closure Summary Report (Appendix B) shall be completed for all operations and each investment opportunity in execution phase. At the end of each financial year, the Annual Closure Summary Report shall be submitted to the Vice President HSE and the Vice President Group Accounting/Controller.

C. Closure plans may be periodically subject to independent audit by Group Audit Services (GAS) or HSEC Assessment and Review. The audit reports shall be forwarded to the Vice President HSE, the Vice President Risk Management and Assurance and the Vice President Group Accounting/Controller. In accordance with current GAS procedures any significant issues arising from such audits will be reported to the relevant Customer Sector Group and Board Risk Management and Audit Committees.

Requirement 7

Application of Project Management Practices

Operations in the closure execution phase shall employ appropriate project management practices.

Application

A. Approval of expenditures related to the closure execution phase shall be in accordance with the Approvals Framework. Planned expenditure shall comply with the corporate and Customer Sector Group budget processes.

B. Closure projects in the execution phase shall follow the approved closure plan and appropriate project management practices shall be employed such as:
    i. Project Control Toolkits; and
    ii. Small Project Management Framework.

C. Closure projects in the execution phase that are greater than US$100 million (BHP Billiton share) shall comply with the monthly project reporting requirements established in the Investment Process Manual.

D. Closure projects in the execution phase that are less than US$100 million (BHP Billiton share) shall comply with the monthly project reporting requirements established by the applicable Customer Sector Group and shall consider following reporting formats established in the Small Project Management Framework.

E. Closure projects in the execution phase that are greater than US$100 million (BHP Billiton share) shall be independently reviewed on a no less than six monthly basis in accordance with the Investment Process Manual. The review shall comply with the requirements detailed in Project Control Toolkit PT155D Project Execution Reviews. The requirement for independent reviews excludes contemporaneous rehabilitation, which is within normal operational expenditure budgets.

F. Closure projects in the execution phase that are less than US$100 million (BHP Billiton share) shall be independently reviewed on a no less than six monthly basis in accordance with applicable Customer Sector Group requirements. The requirement for independent reviews excludes contemporaneous rehabilitation, which is within normal operational expenditure budgets.

Terms used in the Closure Standard which are not defined in this Glossary shall have the meaning in the Glossary of Terms section in the Investment Process Manual.

3.0 Glossary

Audit

A systematic and documented process of objectively examining systems, procedures, information, practices or facilities to verify their compliance with a defined set of criteria or requirements and to assess the effectiveness of their implementation. Audits may be conducted on systems, compliance or technical aspects.

Closure

The process and activities commencing on cessation of the operating life of an operation following a decision by BHP Billiton management to close the operation which ends following decommissioning, rehabilitation and, if required, remediation.

Closure Execution Phase

The period of executing closure commencing from a decision to close an operation by BHP Billiton management and ending following decommissioning of the operation. The closure execution phase does not include rehabilitation.

Contemporaneous Rehabilitation

The ongoing rehabilitation activities occurring while an operation is active and is prior to a decision to cease the operation.

Decommissioning

The process that begins following a decision by BHP Billiton management to close an operation which involves removal of all unwanted services and infrastructure associated with an operation.

Expected Cost

The best estimate of the cost of implementing and executing closure of an operation.

Impact

Any change to the health and safety of people, the environment, the community or property, whether adverse or beneficial, wholly or partially resulting from an organisation's activities, products or services.

Independent Review

A review of the work undertaken in relation to closure by BHP Billiton employees or contractors not directly associated with the operation, the level of seniority of the BHP Billiton employees depending on the cost of closure.

Investment Opportunity

An opportunity to purchase or invest in an asset, that has been identified by BHP Billiton.

Key Performance Indicators (KPIs) — The parameters which give indications of the success of, or outcome of, closure.

Operation — A site or facility where mining, processing, refining, drilling, or other activities are occurring or have occurred. Examples of sites can include mine sites, processing plants, smelters, petroleum platforms, railroads, or loading areas and the ancillary structures associated with such sites and facilities.

Post Closure — The phase immediately following the closure execution phase during which rehabilitation (and, if required, remediation) is carried out and completed. Post closure can include but is not limited to, monitoring and maintenance activities.

Provision — A financial accrual based on the expected cost to implement and execute closure in accordance with a closure plan.

Rehabilitation — The return of disturbed areas to a safe, stable, productive and self-sustaining condition, consistent with the agreed end land uses.

Remediation — The activities carried out to clean-up or mitigate contaminated land or water.

Risk Assessment — The systematic evaluation of the degree of risk posed by an activity or operation. The process of using the results of risk analysis to rank and/or compare them with accepted risk criteria or goals.

Stakeholder — Any person or group that may be affected by the financial or safety, health, environment and community performance of BHP Billiton or its operations. Stakeholders may include: employees, contractors, suppliers, the Board of Directors, shareholders, investment analysts, lending and other financial institutions, governments and government departments, neighbours of our operations and minority groups.

System — Set of arrangements, responsibilities and authorities aimed at ensuring the achievement of defined outcomes.

Appendix A

Potential Closure Risks

#	Issue	Cause	Impact (s)	Potential Controls
1	**Safety or environmental issues that impact BHP Billiton's reputation**	• Poor safety performance • Poor environmental performance • Poor environmental impact assessments	• Loss of reputation for BHP Billiton • Financial loss • Injury • Loss of life • Environmental penalties and other statutory penalties • Increase in emission estimates • Legacy after closure • Loss of biodiversity	• Appropriately qualified statutory officials to monitor performance • Controlling of access to operation • Strict adherence to the BHP Billiton Policies, Standards and Fatal Risk Control Protocols
2	**Safety or environmental issues that raise legal implications for BHP Billiton**	• Poor safety performance • Poor environmental performance • Poor environmental impact assessments • Lack of appropriate indemnification in commercial agreements	• Loss of reputation for BHP Billiton • Financial loss • Injury • Loss of life • Environmental penalties and other statutory penalties	• Appropriately qualified statutory officials to monitor performance • Controlling of access to operation • Thorough environmental impact statements • Legal input to be obtained for all commercial agreements • Strict adherence to the BHP Billiton Policies, Standards and Fatal Risk Control Protocols
3	**Community reaction to activities**	• Changes to water quality and / or water quantity • Subsidence • Noise • Air emissions • Impacts on local flora and fauna • Proximity to regional towns	• Loss of reputation for BHP Billiton • Financial loss through payment of compensation • Loss of biodiversity	• Community relations plan • Consultations during planning stage • Biodiversity impacts incorporated into closure plan

#	Issue	Cause	Impact (s)	Potential Controls
4	**Market or other conditions or changes impacting the valuation basis of original decision**	· Changed market conditions · Unrealistic valuations	· Financial loss · Higher closure costs	· BHP Billiton interaction with Government and Non-Government Organisations · Business/financial risk assessment
5	**Legislative outcomes differ from expectations**	· BHP Billiton enters into agreement prior to outcome of legislation · Different government departments have different requirements	· BHP Billiton disadvantaged by not waiting for outcome of legislation ie. suffers financial loss	· Monitoring and influencing legislation · Change of regulators
6	**Changes in legislation**	· New legislation introduced suddenly with inadequate or no prior industry consultation ie. following a change in government · Regulations in place but not published definitively eg. some areas in Asia · Changes introduced during life of an operation	· Effort required to evaluate the impact on BHP Billiton · Financial loss	· BHP Billiton interaction with Government and Non-Government Organisations · BHP Billiton participation in industry forums · Abandon operation or project
7	**Inappropriate remediation**	· Poor execution of / by third party contractor · Contamination more serious than anticipated · Unplanned delay in commencement and execution of closure plans · BHP Billiton's closure objectives do not match those of other stakeholders · Inadequate local regulations	· Loss of reputation for BHP Billiton · Financial loss · Environmental penalties and other statutory penalties · Unanticipated delay	· Thorough due diligence in relation to third party contractor · Appropriate indemnities in agreement with third party contractor · Agree mutually acceptable closure completion criteria with other stakeholders · Devise a contingency plan to be implemented in the event of delay · Ensure best practice threshold used when carrying out remediation · Group Audit Services review · Proper planning

#	Issue	Cause	Impact (s)	Potential Controls
8	**Third party actions**	· Contamination of surface water, ground water, air · Migration of contaminants · Failure to understand environment · Failure to understand health impacts of asset while it is in operation	· Loss of reputation for BHP Billiton · Environmental penalties and other statutory penalties · Financial loss through payment of compensation	· Thorough remediation · External review of third parties and appropriate sign off · Use best available knowledge in business · Monitor potential contamination sources during operation
9	**Under-provisioning**	· Failure to consider all possible risks / contingencies including tax consequences	· Misstatement of financial report · Financial loss	· Enterprise Wide Risk Management process · Audit and other assurance activities · Accountability and legal appointment of management · Group Tax review
10	**Liability from Disposal of Assets**	· Lack of control and product stewardship	· Financial loss · Loss of reputation · Increased remediation responsibilities	· Group Audit Services to be involved in review of disposal plan · Appointment of personnel to evaluate stewardship issues
11	**Increased project cost and delayed completion**	· Poor project management · Ineffective contract management processes · Poor asset safeguarding and disposal practices	· Financial loss · Delays · Business conduct standards not met	· Group Audit Services and Project Development Services to be involved from the outset · Accountability and legal appointment of management

Appendix B

Annual Closure Summary Report

Download the Annual Closure Summary Report form via the intranet, please refer to Appendix C.

1. Key information

Operation Name		Location/ Country	
Asset Leader		Applies to Fiscal Year	
Life of Operation Remaining		Date of last Closure Plan Update	

2. Brief Description of Operations Covered by Closure Plan (include number of years of remaining life of operation and key changes in circumstances from previous year's report)

3. Operation Status (investment in execution phase, operating, temporary closure, closure execution phase)

4. Closure Plan and Cost Estimate Class (concept, pre-feasibility, feasibility, definitive)

5. Key Closure Risks (top three and corresponding mitigation strategy for each)

	Risk	Description	Mitigation Strategy
A			
B			
C			

6. Key Closure Opportunities (top three upside opportunities to potentially mitigate closure cost)

	Opportunity	Description
A		
B		
C		

7. Closure Cost Estimate, Present Value, and Accounting Provision (US$M real)

Confirm Estimating Methodology		*Describe here if estimating methodology used was only Deterministic or if Probabilistic analysis completed (provide support as necessary)*			**Accounting Provision Recognised**
Valuation Date for Discounting and Real Base Date		*30 June YYYY (of applicable BHP Billiton financial year)*			
Real Discount Rate employed		*X.X % real*			
Estimate Range (if Deterministic use:)		**LOW**	**MID**	**HIGH**	
Estimate Range (if Probabilistic use:)		**P90**	**Expected (or mean)**	**P10**	
A	**Total future real undiscounted expenditure**	*$X,XXX*	*$X,XXX*	*$X,XXX*	*$X,XXX*
B	**Discount to Present Value Terms**	*($X,XXX)*	*($X,XXX)*	*($X,XXX)*	*($X,XXX)*
C	**Present Value of real future expenditure**	*$X,XXX*	*$X,XXX*	*$X,XXX*	*$X,XXX*
D	**Variance between Accounting Provision and Mid or Expected estimate (in line C above)**	*Provide supporting detail with reconciling items to account for variance*			*$X,XXX*

Appendix C

List of Documents

All Company-wide Policies, Standards and processes, such as those mentioned in this document, are available via the intranet at

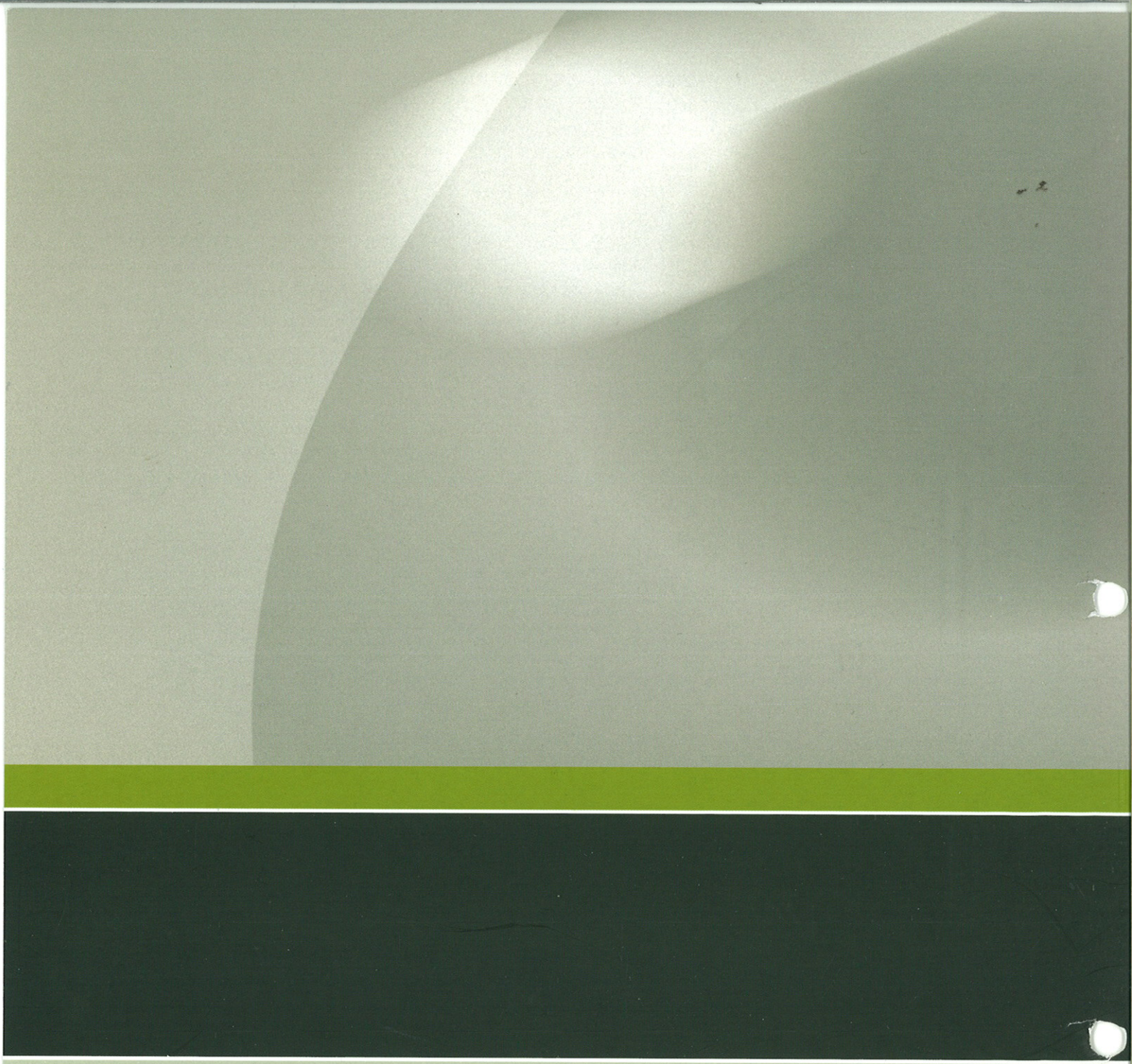
http://bhpbilliton.net/default.asp?content=/repository/companyInfo/commonStandards/globalPoliciesStandards/globalPoliciesStandards.asp

The specific intranet locations of the documents are as follows - please note that these are current at the time of printing this issue:

- **Accounting Policy Manual**
  http://bhpbilliton.net/docs/companyInfo/commonStandards/globalPoliciesStandards/BHPBillitonAccountingPolicyMay2004.chm
- **Approvals Framework**
  http://webhost.itmel.bhp.com.au/authority/
- **Capital Investment Standards**
  http://im.bhpbilliton.net/standards/index.asp
- **Charter**
  http://bhpbilliton.net/default.asp?content=/repository/companyInfo/commonStandards/charter/charter.asp
- **CSG Tollgate Manuals**
  http://im.bhpbilliton.net/policies/csg.asp
- **HSEC Management Standards**
  http://hsec.bhpbilliton.net/Bb/standards/standards.asp
- **HSEC Policy**
  http://hsec.bhpbilliton.net/Bb/policy/policy.asp
- **Investment Evaluation Standards**
  http://bee.bhpbilliton.net/bb/IEStandards.asp
- **Investment Process Manual and associated Standards**
  http://im.bhpbilliton.net/policies/investment.asp
- **Small Project Management Framework**
  http://pm.bhpbilliton.net/minorProjects/smallProjectFramework.asp
- **Project Control Toolkit TP155D Project Execution Reviews**
  http://pm.bhpbilliton.net/Docs/Library/NewBHPBTP/Toolkits/PT155D.pdf
- **Project Control Toolkit TP156D Guidelines for the Development and Management of Contingency**
  http://pm.bhpbilliton.net/Docs/Library/NewBHPBTP/Toolkits/PT156D.pdf
- **Project Control Toolkit TP157D Capital Cost Estimating**
  http://pm.bhpbilliton.net/Docs/Library/NewBHPBTP/Toolkits/PT157D.pdf
- **Annual Closure Summary Report form**
  http://bhpbilliton.net/docs/companyInfo/commonStandards/globalPoliciesStandards/ClosureStandardAnnualClosureSummaryReport.doc

If any of the specific intranet locations listed above are no longer current, please go to http://bhpbilliton.net/default.asp?content=/repository/companyInfo/commonStandards/globalPoliciesStandards/globalPoliciesStandards.asp

Rehabilitation of the Beenup mineral sands mine in Western Australia.



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DRAFT

NATIVE VEGETATION MONITORING AND EVALUATION OF PROJECT ACTIVITIES EXPLAINED

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I HARVEY

COMPLETION CRITERIA FOR MINESITE REHABILITATION IN THE ARID ZONE OF WESTERN AUSTRALIA

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ABSTRACT

The objective of this paper is to look at the use of completion criteria as part of the minesite rehabilitation process in the arid zone of Western Australia. Generally, appropriate rehabilitation techniques are already known and used, though the science of the rehabilitation process needs more time series data to be further developed, and to prove the success of the techniques. Key steps in the rehabilitation process, such as post-mining land use definition for the various mine site components, records of the site-specific techniques used at each mine site, regular monitoring, use of completion criteria and use of regional research need more rigorous application.

The main conclusions are:
1) The links between rehabilitation techniques, completion criteria and successful long-term ecosystem development have not been established in the arid zone of Western Australia.
2) The rehabilitation process in the arid zone is estimated to take at least 20 years to reach a stable, self-sustaining condition; most current minesites have a shorter life than 20 years and, hence, mining companies are aiming to relinquish responsibility prior to reaching this condition.
3) Completion criteria for minesite rehabilitation are milestones in the rehabilitation process; they should provide confidence that the process will reach completion with no further unusual management inputs.
4) Currently, the release of unconditional performance bonds and clearance of environmental conditions generally uses qualitative criteria; the bond release and condition clearance system needs more rigorous application of quantitative completion criteria.
5) To confirm that the completion criteria are confidently predicting the successful completion of the rehabilitation process, more research is required during the after-care period following decommissioning.

Industry self regulation in the rehabilitation process can be encouraged by the use of professional environmental staff, better use of regional knowledge, joint research and monitoring in the after-care period, and by industry involvement with progressive bond release based on attainment of more quantitative completion criteria.

Paper presented at "Green + Gold - Goldfields International Conference on Arid Landcare" 29 Oct - 1 Nov 1993 Kalgoorlie W.A. Dept of Agriculture, Kalgoorlie.

COMPLETION CRITERIA FOR MINESITE REHABILITATION IN THE ARID ZONE OF WESTERN AUSTRALIA

Warren Tacey, Jim Treloar and Richard Gordine

1.0 INTRODUCTION

The objective of this paper is to further the debate on a method for defining completion criteria as a key step in the rehabilitation process. The debate has most recently been carried along by papers by Mills *et al.* (1992), Lindbeck (1992), and Mohsen (1992). This paper draws upon the definitions and concepts presented in those papers.

The rehabilitation of land degraded during mining to a stable, productive condition is consistent with the sequential use of land as a wise use of resources. The demand for criteria to establish when rehabilitation is complete has been coming from industry, government authorities and the public. Industry wants clear end points; government wants to ensure that subsequent land users do not incur an ongoing liability; the public have a stake in knowing that the rehabilitation is effective and that completion criteria are achievable.

In the arid zone of Western Australia, we are not aware of comprehensive completion criteria for any minesite. Rather, a requirement to rehabilitate a minesite is made under the Mining Act, 1978, the Environmental Protection Act, 1986, or both. In assessing compliance with rehabilitation conditions, regulatory agencies have made judgements that rehabilitation is complete based on a range of factors such as the company's monitoring data, post-mining land user approval, and best judgement. This lack of consistency in approach and lack of a sound framework based on research indicates the need for a more structured approach to the rehabilitation process and a more positive identification of when the job is complete.

It is possible that we will not be able to say when rehabilitation is complete, either because the data do not exist or we cannot wait that long to make the decision. An important message of this paper, however, is to flag those areas where more hard data are needed and to examine the opportunities for developing methods of analysis which give us confidence that a rehabilitated site will progress to the desired condition.

This paper presents and discusses a methodology for deriving completion criteria and emphasises the need for the on-going monitoring of rehabilitated minesites following the cessation of the work there. It proposes an iterative approach to completion criteria development.

1.1 Definitions

It is important to define the two key concepts discussed in this paper - rehabilitation and completion criteria. Rehabilitation is defined by Bell (1990) as the process of stabilising disturbed land against the erosive forces of water and wind, and of returning the land to a form and productivity that conforms to a predetermined post-mining land use. This is one definition of rehabilitation and it should be noted that a variety of other definitions have been presented by Mattiske (1992), Reddell *et al.* (1992) and Mills *et al* (1992).

Completion criteria are here defined as rehabilitation performance objectives generated on a site-specific basis that enable regulatory agencies and mining companies to judge the success or otherwise of rehabilitation techniques

employed. They represent milestones in the biophysical processes of rehabilitation that provide a high degree of confidence that a rehabilitated minesite will eventually reach the desired, stable state. This state is characterised by stable, productive ecosystems with self-sustaining biophysical processes similar to their surroundings. No unusual management inputs should be required and the site should be manageable either as part of its surroundings or for a designated use.

1.2 The need for completion criteria

The mining industry has acknowledged that its goal is to return minesites to the State in an acceptable condition. Completion criteria represent the objectives set for that acceptability. They also increase the clarity of the regulatory process and make all parties more accountable in terms of having defined targets to achieve.

Completion criteria are also beneficial in focussing rehabilitation expertise at a target. This expertise is a marketable product not only for mine rehabilitation but for a wide range of applications where degraded land requires rehabiliation. The characterisation of the agreed milestones during the rehabilitation process is a key aspect of the product.

Completion criteria could be defined and fixed for each climatic zone in Western Australia. Such an approach would satisfy the demand for "clear, fixed and equitable goal posts". It is unlikely to be practical however, given the wide range of operations, environments and substrates present in Western Australia and the lack of a solid research base. We favour a more flexible approach for the present where criteria are agreed on a case by case basis.

1.3 Current regulatory framework

The regulatory framework under which mining proposals operate is administered by the Mining Act, 1978, the Environmental Protection Act, 1986, or an Agreement Act. Most mining proposals are assessed solely under the Mining Act and licensed under the Environmental Protection Act for pollution control matters. Very few mining proposals are assessed under the Environmental Protection Act. Hence, rehabilitation of mines in Western Australia is regulated mainly by the Department of Minerals and Energy (DOME).

The assessment of mining proposals involves the lessee preparing a Notice of Intent (NOI) for DOME, which may then become a document for formal assessment if the mining proposal is subject to assessment by the Environmental Protection Authority (EPA). Guidelines for NOI's emphasise consideration of the rehabilitation process at the pre-mining stage. Completion criteria are not normally nominated as such (Mills *et al,* 1992), but appear under the guise of the various conditions of approval under the three Acts.

The rehabilitation requirement is embodied in a condition that the rehabilitation must be to the satisfaction of the Minister for Mines and, for a few proposals, the Minister for the Environment. It is supported by a condition that a bond be lodged with DOME which provides the State with recourse to funds to ensure that the rehabilitation is satisfactory. The bond can be either a personal surety (for amounts under $5000) or an unconditional performance bond which can be annually adjusted depending upon the area of land currently disturbed.

Subjective assessment of rehabilitation success during the life of the mine occurs through annual reporting commitments and minesite visits by the DOME inspectorate. The bond system provides an incentive to minimise disturbance and to expedite rehabilitation, and the requests for progressive bond release require an assessment of the standard of rehabilitation. There are presently no clear guidelines for agreeing when rehabilitation commitments have been met. Completion criteria can meet this need.

Some large mines or those which raise a number of environmental issues or occur in sensitive environments are formally assessed under the Environmental Protection Act. These have conditions attached by the Minister for the Environment, and requests for the clearance of these conditions similarly triggers assessment of the rehabilitation. A similar need for completion criteria exists here.

The last decision point for rehabilitation assessment, under the present system of bond release operated by DOME, is normally two years after the start of the decommissioning phase of the mining operation. This allows only one or two years to evaluate the success of rehabilitation of some components of the minesite. It is obvious that judgements of the potential success of rehabilitation are often limited to guesswork within these timeframes. Completion criteria would enable a measure of the guesswork to be removed from the assessment process at that stage.

2.0 THE REHABILITATION PROCESS

The rehabilitation process involves the key steps outlined below and can be separated into four phases: a pre-mining phase, the mining phase, the decommissioning phase and an after-care phase. The first three phases are when active rehabilitation occurs and the fourth phase is when research and natural processes occur. Some of the key steps transcend these different phases and this list is indicative only:

1) Pre-mining phase
Conduct baseline studies of existing environment and mining proposal
Definition of post-mining landuses for the various minesite components
Mine planning including materials characterisation
Design of a rehabilitation plan including objectives
Derivation of site-specific, draft completion criteria

2) Mining phase
Implementation of the rehabilitation plan including trials
Monitoring of rehabilitation and trials
Evaluation of rehabilitation and, if necessary, modification of techniques
Definition of final completion criteria based on trials and monitoring

3) Decommissioning phase
Complete rehabilitation to objectives defined by completion criteria
Attainment of completion criteria

4) After-care and research phase
State or other legal land user assumes responsibility for maintenance
Research and monitoring of rehabilitated areas

These steps have been discussed at length in previous papers mentioned in the Introduction and only pertinent concepts regarding the structuring of these steps into a methodology for deriving completion criteria are discussed below.

2.1 Post-mining land uses

The first step in a rehabilitation plan is the characterization of the existing environment. The definition of the post-mining land use, which includes both human and non-human uses, is an important step in the subsequent process of defining completion criteria. Most Notice of Intent documents state a broad rehabilitation objective of a stable, revegetated landform. Identification of a specific post-mining land use, characterisation of its environment, and definition of the objectives which would permit that land use to be achieved would be more helpful.

Public expectations of rehabilitation should be a component of the decision regarding post-mining land use. These expectations could be expressed either through informal discussions with interest groups or via a more formal approval process such as environmental impact assessment by the Environmental Protection Authority. This can secure understanding of, and commitment to, the agreed outcomes and avoid criticism later.

Characterising the minesite environment and potential post-mining land uses should incorporate data from baseline studies, regional data from nearby minesites, and data from published and government sources. Different completion criteria for the various parts of a minesite may be required because, in some cases, each part may have a different post-mining land use; for example, the tailings dam may have a post-mining land use of bushland whilst the waste rock dumps may have a post-mining land use of rangeland grazing.

2.2 Monitoring

Monitoring is an essential component in the evaluation of the progress of the rehabilitation process. The provision of monitoring records should be included within annual environmental reports. The monitoring programmes need to be tailored to individual minesites and the involvement of environmental professionals in setting up the programmes, advising site staff on the implementation of the programmes, and in the evaluation of the results is advocated.

2.3 After-care and research

The term completion criteria, as part of the rehabilitation process, does not imply that the desired stable state has been achieved following decommissioning. The actual goal is to rehabilitate an area to the stage where biophysical processes can continue at a natural rate, with management inputs confined to those normally applied to the surroundings, in the expectation that the site will reach the desired stable state naturally. The completion criteria, therefore, apply to the successful completion of inputs required of the mining company, not to the final stable condition. Some after-care would usually be necessary by the subsequent land user and on-going research would be desirable to confirm the success of the rehabilitation.

At the bond release stage, certain completion criteria would be nominated for on-going monitoring to examine successional trends which could lead to a better scientific understanding of when rehabilitation is complete. In the arid zone of Western Australia, it is estimated that at least 20 years of monitoring data may be required to scientifically define trends.

The importance of this research would be to understand the reconstructed ecosystems characterised by the completion criteria, and feed this information

back into refined rehabilitation techniques and proforma checklists for various sub-regions in the arid zone. Currently, the long term status of rehabilitated minesites is not evaluated and the rehabilitation effort is often being compromised by invasion of native, feral and stock animals and other activities. It is suggested that the issue of after-care and research be addressed at a workshop, involving all relevant parties, as soon as possible. Because of the range of interested parties, we suggest that research sponsored by a jointly funded organisation may be the most appropriate approach; similar to the research carried out by the Minerals and Energy Research Institute of Western Australia.

3.0 COMPLETION CRITERIA METHODOLOGY

The methodology for the derivation of completion criteria should be a scientific process set within a regulatory framework. The steps involved in the methodology proposed here are generally known but currently are not being rigorously applied. This paper proposes a methodology and it is suggested that a workshop be held using it as a basis for discussions.

The start of the process for the derivation of completion criteria involves the description of both the existing environment and the mining proposal. The post-mining land uses can then be identified for each mine site component and the rehabilitation objectives and techniques determined which will achieve those land uses. At this stage, the draft completion criteria could be derived from a proforma checklist which encompasses a suite of biophysical parameters.

During the implementation of the rehabilitation programme, the draft completion criteria can be modified on the basis of an evaluation of the monitoring results until a final set of criteria are agreed upon as the basis for the decision on completion, leading to the release of the bond. This methodology can be accommodated within the requirements of the conditions administered by DOME, and for some mines by the EPA, using the existing annual reporting process (Table 1).

TABLE 1 : COMPLETION CRITERIA METHODOLOGY

PHASE	STEPS	REGULATORY FRAMEWORK
Pre-mining phase	Decide post-mining land use	Notice of Intent / environmental assessment documentation
	Develop rehabilitation plan	
	Develop draft completion criteria	Conditions of approval to mine
Mining	Implement rehabilitation	
	Monitor and evaluate rehabilitation	Annual rehabilitation reports
	Finalise completion criteria	
Decommissioning	Complete rehabilitation works	Compliance audit
	Satisfy completion criteria	Bond released / conditions cleared
After-care	Conduct research	
	Maintain rehabilitation works	
	Achieve desired, stable, rehabilitated state	

3.1 Draft completion criteria

Draft completion criteria need to be derived on a site-specific, consultative basis, preferably incorporating some public input. The role of the draft criteria is to ensure that the early stages of rehabilitation are directed towards nominated goals; for example, in the arid zone, compaction relief, erosion control works and seeding may be sufficient; germination and establishment would be dependant on erratic rainfall and could not reasonably be expected to occur in any one year.

Draft completion criteria may be derived from both baseline study information and proforma checklists designed to accommodate variations in mine scale, processing technology and environmental setting. The proforma checklist of potential criteria for each subregion of the arid zone could be derived by consultation between regulatory authorities, industry, other land users and environmental groups; they should be re-examined at regular intervals.

The most common post-mining land uses in the arid zone are:
1) rangeland grazing;
2) conservation reserves;
3) bushland;
4) townsites/public uses;
5) salt lakes; and
6) pits (with or without a lake).

The different minesite components are:
1) pits;
2) waste rock dumps;
3) tailings dams;
4) plant/office sites;
5) ore stockpiles;
6) borefields/pipelines; and
7) access roads.

Another important concept is that the different components of a mine site can have a range of different post-mining land uses. The post-mining land uses for a tailings dam, for example, could be either bushland, a salt lake or for rangeland grazing. The characteristics of each of these environments are different and, therefore, the rehabilitation objectives and completion criteria are different. Consideration at the planning stage would allow the the issue to be addressed in the NOI, or formal assessment documentation, and in subsequent annual reports. The methodology must be flexible enough to allow fine tuning of the criteria as the information base increases. An adaptive management approach is indicated.

3.2 Final completion criteria

Final completion criteria would be set during the mining phase as evaluation of the progressive rehabilitation leads to the nomination of quantitative completion criteria for appropriate parameters for a particular minesite. It is essential that the flexibility necessary to accommodate this approach be incorporated in any proposed methodology under the current regulatory framework.

A consistent approach to the derivation of completion criteria is important and it is recognised that a degree of consistency should apply over time for minesites located in similar environments. Flexibility and consultation are also required. Any methodology adopted must be flexible enough to accommodate a variety of mining operations of differing scales operating in a variety of arid zone environments. It must also be flexible enough to accommodate changes in site-specific completion criteria over the life of the mine. Consultations between the mining companies, regulatory agencies and other stakeholders is an integral part of ensuring the effective derivation of completion criteria.

Completion criteria should take the form of technically sound objectives for the more representative ecosystem parameters such as vegetation species composition, vegetation density, vegetation cover, fauna species composition and abundance, water quality, erosion rates, visual quality and land capability. A comprehensive checklist of possible completion criteria should be defined at the proposed workshop. A suite of possible completion criteria topics could include:

physical

visual objectives, erodibility (slope, drainage structures, soil structure), hydrology, land capability;

biological
vegetation species composition, vegetation density, vegetation cover, fauna composition, fauna abundance, microbiological status, weed/native plant ratio, proportion of woody perennials;
water quality
total suspended solids, total dissolved solids, trace elements and noxious compounds, quantity (infiltration), water depth and shoreline characteristics (for lakes in pits), pH; and
safety
fencing standard, risk.

4.0 CONCLUSIONS

This paper has reviewed the current situation regarding the use of completion criteria as part of the rehabilitation process. The main conclusion is that the links between rehabilitation techniques, completion criteria and successful long-term ecosystem development have not been established. Indeed, the scientific aspects of completion criteria are in their infancy in Western Australia.

Rehabilitation often consists of bringing in certain key 'ingredients', then letting nature take its course in shaping the result (Jordan *et al,* 1987). This is generally the current strategy being applied in the arid zone of Western Australia and anecdotal conclusions by researchers and operators indicate that the rehabilitation process takes at least 20 years to reach a stable, self-sustaining condition.

Long-term, after-care monitoring to progressively establish links between the rehabilitation techniques employed and successful ecosystem development is therefore advocated. Completion criteria can be regarded as milestones in the rehabilitation process which should provide confidence that the process will reach completion with no further unusual management inputs. Resources for the proposed after-care research could come from a joint industry and government fund and it is suggested that this issue be discussed in a workshop environment.

The methodology proposed for the derivation of completion criteria emphasises a site-specific, science-based, collaborative and flexible approach with the scope for wide discussions, particularly in this formative stage. Broadly, it is envisaged that the methodology operate within the current project assessment and approvals framework. A requirement that the issue be addressed in the Notice of Intent or formal assessment documentation, as well as any subsequent reports recording the progress of rehabilitation, is an important concept.

The basis for derivation of site-specific completion criteria is open for discussion. The concept of draft completion criteria derived from baseline studies and proforma checklists, and up-dated as progressive rehabilitation yields site-specific data, may be a useful starting point. This concept also requires discussion in a workshop environment.

Importantly, discussions on completion criteria represent an opportunity for both regulatory authorities and the mining industry to incorporate valid objectives into the rehabilitation process. The adoption of some degree of scientific rigour, backed-up by long-term, after-care monitoring, will establish an iterative process enabling the progressive refinement of rehabilitation techniques with time.

Progressive rehabilitation guided by a rehabilitation plan is advocated. Rehabilitation objectives for each minesite component should be clearly identified, taking account of the post-mining land uses. The rehabilitation techniques to achieve those objectives can then be prepared, perhaps as a practical operational manual.

The methodology must be site-specific and consistent but flexible. Linking progressive bond release to attainment of completion criteria is suggested, providing incentive to the industry to rehabilitate to objectives it nominates and ensuring that more objectivity is incorporated in the subsequent assessment of rehabilitation performance.

While it is important that completion criteria are specific enough to allow judgement of when they have been met, it is also important that the criteria and derivation methodology are sufficiently flexible and robust to accommodate changes in either technical knowledge, as rehabilitation technology develops, or changes in community expectations, as the demands on land change with time.

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MULTIPLE LAND USE AND MINERAL SANDS MINING ON AUSTRALIA'S EAST COAST (1990).

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ABSTRACT

Since 1934, mining for heavy mineral sands has occurred over 1,700 km of Australia's eastern coastline, from Gladstone in Queensland to Port Kembla in New South Wales. A survey of 109 localities, where 215 operations have been conducted over the past 56 years, revealed an extensive range of land uses now in place on these former mine sites. Thirty of the sites are now included in eight National Parks and seven Nature Reserves and 61 sites are used for recreation purposes. The range of land uses ranked from most to least common include recreation, urban, Vacant Crown Land, conservation, agriculture and tourism, infrastructure and extraction, Aboriginal Land Grants and forestry, and defence and water supply. A total of 17.9 Mt of heavy minerals valued at $11.9 billion (1990 values) has been produced during the 56 year period. Remaining available resources of 63.3 Mt of heavy minerals valued at $18.2 billion (1990 values) have been identified to date on Australia's east coast and a further 16.6 Mt valued at $6.7 billion are alienated in conservation reserves and other developments. These findings illustrate that the concept of sequential land use has been well tested by the heavy mineral sands industry over the past half century. The community stands to obtain maximum benefits by continuing development of its substantial heavy mineral resources in conjunction with sequential land use strategies with proper planning.

1. INTRODUCTION

The heavy mineral sands industry on Australia's east coast provides a classical case study of mining in a multiple land use context. Whilst many sequential land uses can now be demonstrated on areas previously mined for mineral

sands, the industry has not always had that luxury and has suffered many land use conflicts over the past four decades (Brooks, 1986). Morley (1981, p 92) reported conflicts with the shire council, local residents and tourists over mining of the beach and dunes at Burleigh in south-east Queensland by Mineral Deposits Syndicate as far back as 1951. This led to the Queensland Department of Mines requiring rehabilitation of the dune and the establishment of various amenities. Today, this area remains as a public park overlooking the beach and continues to be enjoyed by thousands of tourists each year. In a more recent example of sequential land use, excavation for the foundations of a number of high rise buildings on the Gold Coast has exposed rich placers of heavy mineral sands which were then recovered prior to construction of the buildings.

This paper details the extent of mining and the current land uses for mined areas, and documents the value of heavy mineral sands production to date from Australia's east coast. In this way, it demonstrates the compatibility of mining with other land uses. The paper further summarises the known remaining resources, including those alienated from mining due to decisions taken by all tiers of government and extending over a number of years, to preserve the land containing these resources in conservation areas.

2. LAND USE PRESSURES

Land use pressures involving mineral sands mining were probably inevitable, because of the coincidental concentration of population and heavy mineral sands deposits along the east coast of Australia. Coaldrake (1973, p 302) reported that three quarters of Australia's population lived within 40 km of the sea, whilst most of the remainder lived not far inland. One third of the total population lived within the narrow coastal strip between Wollongong and Rockhampton, which also contains many of the country's tourist resorts. This trend appears to have intensified to the present day. Brooks (1980) identified a wide range of potential land uses for the coastal zone including conservation, education, recreation, tourism, water supply, defence, forestry, agriculture, urban and industrial development, infrastructure, quarrying and mining.

Mining on the beaches commenced in 1870 with the recovery of gold at Ballina (Morley 1981, p 18). The gold was won from the immense sniggers of black sand (i.e. heavy minerals) that formed on the beaches after heavy storms. From 1870 to 1933, gold was the principal target for the miners without them realising the potential value of the host heavy mineral sands for their rutile and zircon content. Subsequently, it was realised that certain geological processes had placed deposits with the world's highest grades of rutile and zircon in the coastal sand masses along that part of Australia's coastline that now has the densest population (Shepherd, 1986).

The formation of Zircon-Rutile Limited in 1934 led to the first recorded recovery of heavy minerals from the beaches at Byron Bay (Morley, 1981, p 42), although small operations were cited as having started at Tugan Creek and Black Head as

early as 1932 by Winward (1975). In the early years of the industry, mining was confined to the rich seams on the beaches of northern New South Wales and southern Queensland, with relatively little environmental conflict.

Demand for rutile as a flux coating on welding rods during World War II and the Korean War provided the incentive for technological development and expansion of the industry. Consequently, mining began on the frontal dunes which then required rehabilitation. Because of limited knowledge of dunal functions and little public environmental awareness at the time, stabilisation was the main rehabilitation objective rather than ecosystems reconstruction (McDonald, 1964).

Rapid expansion of post-war economies during the 1960's heralded dramatic changes for the industry. Substantial increases in demand for the minerals were met by mining larger, lower grade ore deposits away from the coast. These deposits occurred under more complex heath and forest ecosystems, many of which were perceived by some sections of the community as having conservation value.

The concurrent development of the conservation movement spawned a long series of land use conflicts, especially between mining and conservation. These conflicts resulted in a number of landmark government decisions favouring conservation, thereby sterilising substantial deposits of mineral sands (Brooks, 1986). During this period, there were inadequate attempts by governments to resolve these conflicts within a multiple land use concept.

Most of the mineral in frontal dune and hind dune deposits occurred on Vacant Crown Land. Some areas of private land were mined, and these were largely rehabilitated for grazing purposes. Little consideration had been given to the sequential use of the Vacant Crown Land after mining, although some land had been designated for conservation reserves of varying status. In the absence of clear-cut post-mining land use guidelines, the industry adopted the general rehabilitation objective of re-establishing the native ecosystems, and developed its rehabilitation technology accordingly (Brooks, 1986).

However, land use pressures continued and a wide range of land uses can now be identified on the many areas that have been mined for mineral sands in New South Wales and Queensland, between 1934 and 1990.

3. EXTENT OF MINING

Heavy mineral sands mining has occurred over 1,700 km of Australia's eastern coastline, from Point Richards near Gladstone on the central Queensland coast, to Shellharbour, south of Port Kembla, New South Wales (Figure 1). Most mining has been confined to beaches, frontal dunes, hind dunes and near-coastal areas, but some has occurred further inland, e.g. at Clybucca near Kempsey (NSW), 15 kms from the coast. The greatest concentrations of mining activity have

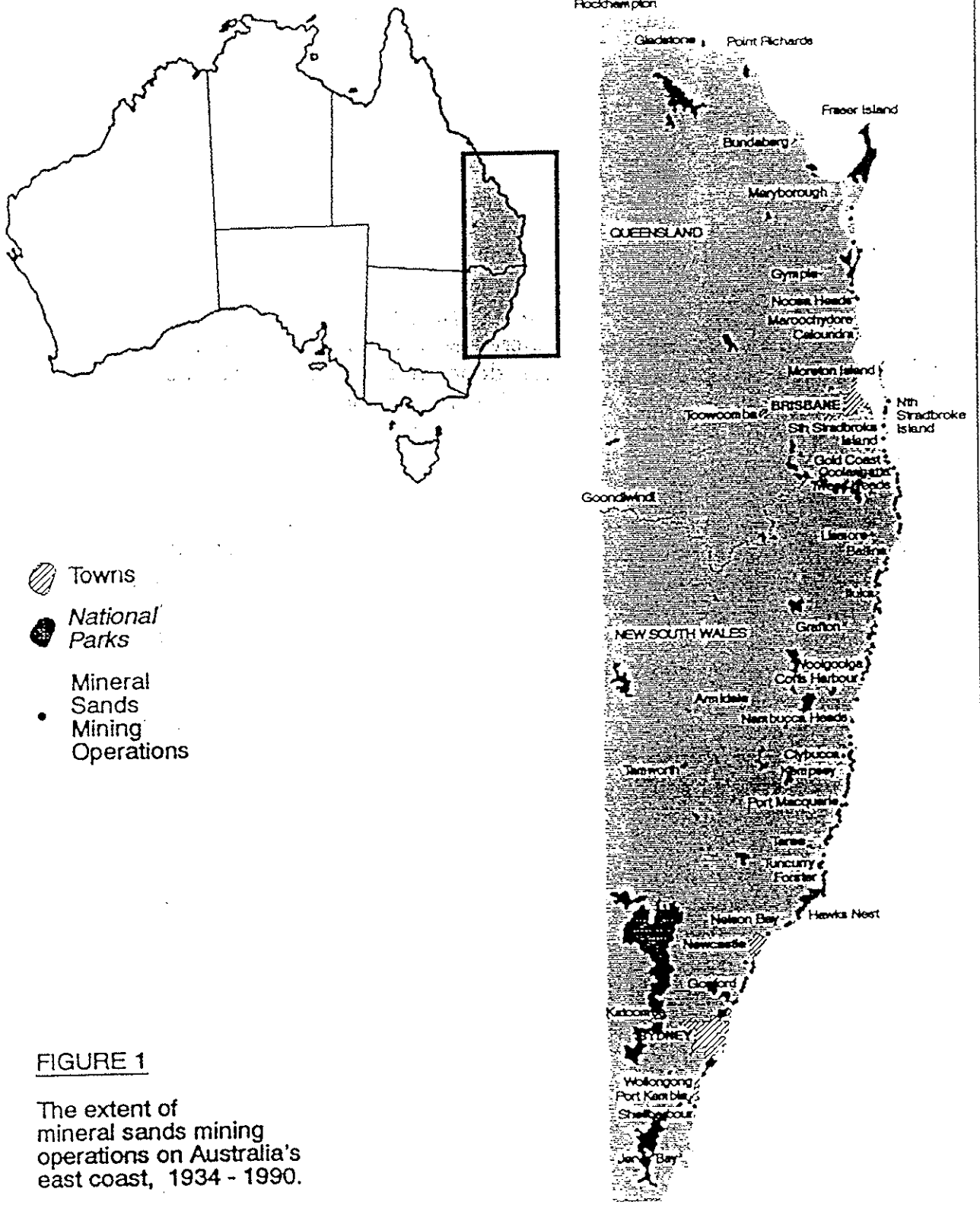

FIGURE 1

The extent of mineral sands mining operations on Australia's east coast, 1934 - 1990.

occurred between Queensland's Gold Coast and New South Wales' Coffs Harbour and further south between Kempsey and Nelson Bay, north of Newcastle.

Appendix A provides an inventory of the mineral sands mining operations that could be identified for the period 1934 to 1990 from Morley (1981) and industry and government sources. The Appendix details the general locations mined, the companies involved, the years when mining occurred and the current land uses for the mined areas. Some 215 individual mining operations carried out by 52 companies are identified for the 109 localities listed. Mining operations lasted from less than 12 months to nearly 40 years, with an average of just over four (4) years for each company's activities in a given area – 50% of operations lasted for only about one (1) year. In Appendix B a series of three strip maps provides the location of each of the areas listed in Appendix A and can be related, for more detail, to the locality maps of Morley (1981, Appendix V).

In terms of the number of individual mineral sands mines, four companies - which are still in operation - account for 60% of the mine sites: Mineral Deposits Limited, originally formed as Mineral Deposits Syndicate in 1940 to start the first Queensland mineral sands mine at Burleigh, and now a member of BHP Minerals; Associated Minerals Consolidated Limited, started as Associated Minerals Pty. Ltd. in 1946 and now a subsidiary of Renison Goldfields Consolidated Limited; Cudgen R-Z Ltd./Consolidated Rutile Limited, started as the Cudgen R-Z partnership in 1947; and R.Z. Mines (Newcastle) Pty. Ltd., originally formed as Rutile and Zircon Mines (Newcastle) Pty. Ltd. in 1962 from National Minerals started in 1956 (Morley 1981, Appendix IV).

4. CURRENT LAND USES

Thirty former mineral sands mine sites are now included in conservation parks and reserves and a further 61 are used for recreation purposes. This is a total of 38% of past mines; only 8 former mine sites (3.3%) are still used for further extraction purposes.

Table 1 summarises the current (1990) land uses identified for the majority of former mine sites listed in Appendix A. In some cases it was not possible to determine the current use for early mines as records were poor, or the precise location could not be determined. In other cases, a single mining area is now covered by a number of current land uses, e.g. for the Brunswick Heads to Byron Bay area (No. 32 in Appendices A and B), parts of two nature reserves, a shopping centre, residential housing, other private land, playgrounds, a picnic area and sections of Vacant Crown Land are all located on former mine paths or associated processing sites.

TABLE 1

Summary of current (1990) land uses identified for 240 sections of former mineral sands mine sites on Australia's east coast. See Appendix A for a detailed inventory of mining locations, companies involved, years of operation and current land uses.

CURRENT LAND USE		FORMER MINING SITES NUMBER	% OF TOTAL
Aboriginal Land Grant		3	1.3
Agriculture	farming/grazing	14	
	cane growing	1	
	hobby farms	3	7.5
Conservation	National Park[1]	21	
	Nature Reserve	9	12.5
Defence[2]		2	0.8
Extraction	gravel	1	
	pebbles	1	
	sand	6	3.3
Forestry		3	1.3
Infrastructure	road	3	
	airport/associated facilities	5	3.3
Recreation	beach	38	
	surf club	3	
	playground, picnic area, park	9	
	playing field	3	
	golf course	2	
	bowling club	1	
	camping area	1	
	boating facility	2	
	Recreation Reserve	2	25.4
Tourism	hotel/motel/hostel	5	
	caravan park	3	
	resort development	2	
	other	8	7.5
Urban	residential - low density	20	
	- high density	2	
	future subdivision	6	
	school	2	
	industrial	2	
	retail	6	
	sewage treatment facility	4	
	waste disposal	2	18.3
Vacant Crown Land	(undesignated use)	43	18
Water Supply Area		2	0.8

Notes:

1. Two (2) sites listed in the Register of the National Estate.
2. Two (2) Defence sites included in Infrastructure (airport/associated facilities)

From the synthesis of these data, current land uses for former mine sites can be ranked from most to least common as follows:

- recreation areas and facilities
- urban areas
- Vacant Crown Land (undesignated use)
- conservation areas
- agriculture/tourism
- infrastructure/extraction
- Aboriginal Land Grants/forestry
- defence/water supply areas.

Within the scope of recreation, reinstated beaches comprise 15.8% of former mines, with playgrounds, picnic areas and parklands the next most common use. Two New South Wales State Recreation Areas - Booti Booti and Lake Munmorah (see Nos. 77 and 102 in Appendices A and B) - also include previously mined lands within their boundaries.

In urban areas, low and high density residential developments are the most common land use at 9.2% of former mine sites, with future sub-divisions, retail areas and sewage and waste disposal facilities covering the bulk of the remaining sites.

Ranking fourth on the list of current land uses, the inclusion of rehabilitated mine sites in conservation areas (National Parks 8.7%; Nature Reserves 3.8%) is a significant finding. The sites are contained within the following parks and reserves:

- National Parks
  - in Queensland
    - Cooloola
    - Moreton Island
  - in New South Wales
    - Broadwater
    - Bundjalung
    - Yuraygir
    - Hat Head
    - Crowdy Bay
    - Myall Lakes;
- Nature Reserves
  - in New South Wales
    - Brunswick
    - Tyagarah
    - Iluka
    - Moonee
    - Goolawah
    - Limeburners Creek
    - Lake Innes.

Additionally, the Cooloola area, south of Fraser Island in Queensland (extending from Rainbow Beach in the north to the Noosa River in the south - Nos. 5 and 6 in Appendices A and B) and the mined area of Jerusalem Creek in Bundjalung National Park, have been listed by the Australian Heritage Commission in the Register of the National Estate (Fitzgerald, 1990, pp 19 and 272).

Of the remaining current land uses, farming and grazing (5.8%) make up the major portion of agricultural uses, with tourism uses spread over a number of areas. Three Aboriginal Land Grants have been identified in New South Wales at Stuarts Point and Crescent Head North and South (Nos. 58, 60 and 61 in Appendices A and B). The remaining uses of defence, forestry and water supply areas, although small in their percentage occurrence, cover significant mined areas at individual sites.

5. PRODUCTION TO DATE

A total of 17.9 Mt of heavy minerals valued at $11.9 billion (mid-1990 values) has been extracted during the industry's 56 year history on the east coast, with more than 50% won over the last 20 years. Table 2 summarises the quantity and value of heavy minerals produced from Queensland (1941-1990) and New South Wales (1934-1990).

Appendices C and D summarise the annual heavy minerals production for Queensland and New South Wales, respectively; these data are illustrated in Figure 2. Production of the first 51 t of concentrate was recorded in New South Wales in 1934, with the State's production lifting to more than 2,000 t in 1935 and to the maximum of 637,000 t in 1971. Production for the 1989/90 financial year was recorded at just under 140,000 t or 21% of the 1971 figures. In Queensland, 953 t were produced in 1941, lifting to nearly 3,500 t in 1942 and peaking at more than 509,000 t in 1986/87. Production in 1989/90 was reduced to 377,000 t.

There is a quite dramatic contrast in total annual heavy minerals production between Queensland and New South Wales from the mid 1970s on (Figure 2). While both sets of data show the influence of the 1972-76 and 1982/83 recessions, Queensland's production generally recovered by the late 1980's, while that in New South Wales remained at around 20% of the peak production. This latter situation can be directly attributed to the New South Wales Government's policy on Coastal Mineral Sands Mining released on 7 June, 1977, which effectively halted approvals given by the previous Government to the recommendations of the Sim Committee (1968).

The policy provided that no further approvals would be granted for mineral sands mining in the extended Myall Lakes National Park and existing and proposed National Park areas on the north coast of New South Wales. Further, it stated that existing operations within those areas with existing development consents would be permitted to continue mining to the extent of their approvals

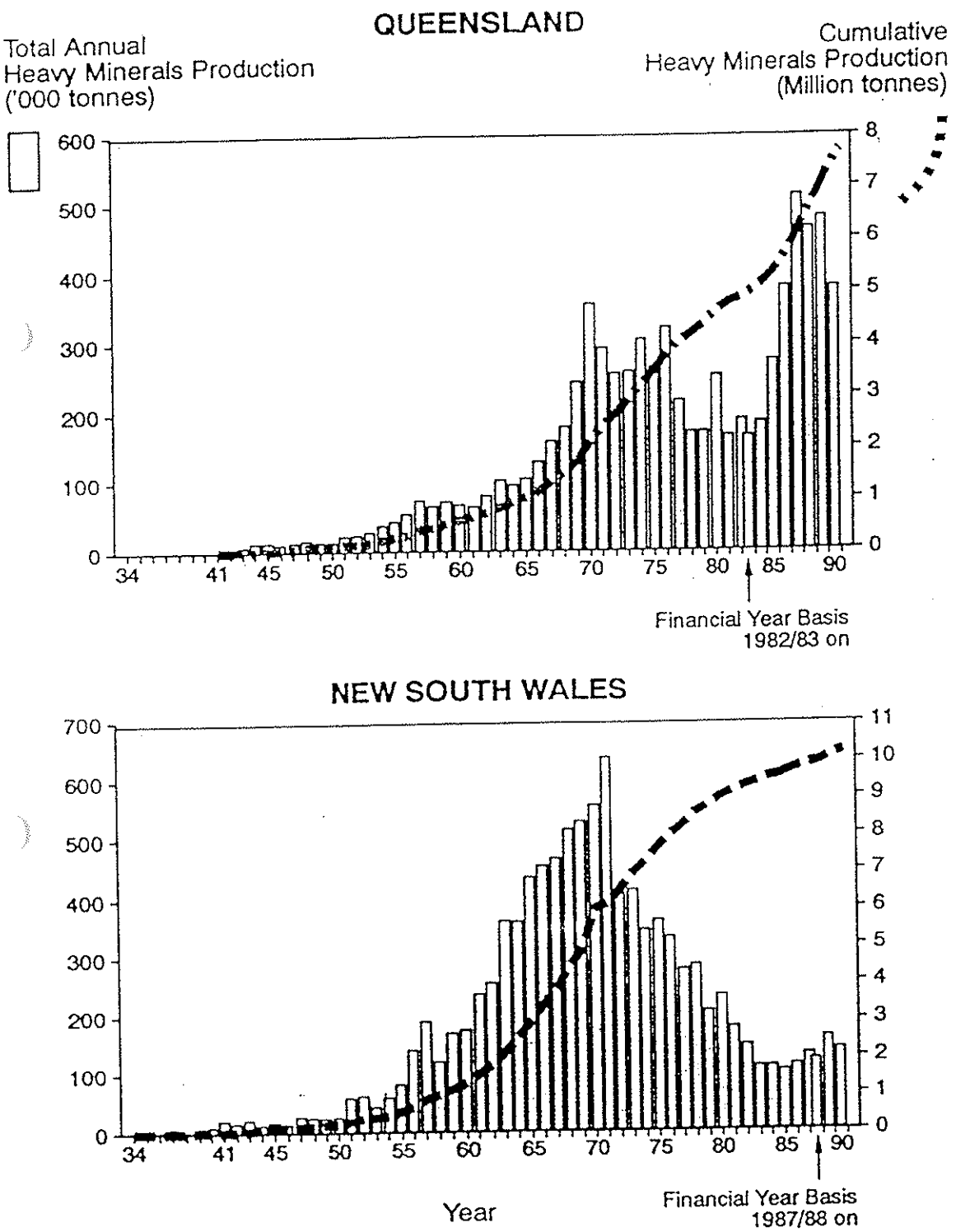

FIGURE 2

Total annual and cumulative heavy minerals production from mineral sands mining operations in Queensland 1941 - 1990 and New South Wales 1934 - 1990. Appendices C and D give a breakdown of the component minerals won each year.

TABLE 2

Heavy minerals production from Queensland (1941-1990) and New South Wales (1934-1990) and estimates of remaining resources.

RESOURCE		QUEENSLAND				NEW SOUTH WALES				TOTAL	
		Mt		Value[1] 1990 A$ Bill.		Mt		Value[1] 1990 A$ Bill.		Mt	Value[1] 1990 A$ Bill.
Production to mid-1990		7.7		4.5		10.2		7.4		17.9	11.9
		M	I/I	M	I/I	M	I/I	M	I/I		
Remaining Available Resources[2]	Z+R	2.5	11.7	2.0	9.1	1.8[4]	4.0[4]	1.4	3.1	20.0	15.6
	I[3]	2.1	41.2	0.1	2.5					43.3	2.6
Alienated Resources[2]	Z+R	2.4	3.4	1.8	2.7	2.2[4]		1.7		8.0	6.2
	I[3]	4.6	4.0	0.3	0.2					8.6	0.5

Notes:

1. Values derived from estimated approximate average export prices for mid-1990 based on Australian Bureau of Statistics data and industry sources - Zircon $800, Rutile $750, Ilmenite $60 per tonne (as upgraded product sold as Ilmenite). Note that current prices may be lower.
2. Divided into measured (M) and indicated/inferred (I/I) resources, with Zircon and Rutile (Z+R) summed separately from Ilmenite (I) for Queensland. Not all tonnage is economically mineable at current prices. Indicated/inferred resources have not been geologically proven as mineable reserves.
3. The bulk of east coast Ilmenite is not readily saleable because of its low TiO_2 content (around 50% or less) and its high chrome levels and other impurities. Under certain market conditions, some term contracts have been entered into for the product.
4. Based on onshore coastal NSW resources of Zircon and Rutile only.

Source:

See Appendices C and D for annual production to date; remaining available and alienated resources derived from Cooper (1990) for Queensland and Chamber of Mines, Metals and Extractive Industries (NSW) (1990) and industry and government sources for New South Wales.

but no further. All development consents expired by 1982. Under the Sim Committee recommendations, mining would have continued in these areas until December 1987. It was reported that the policy stopped the extraction of $87.7 million (1977 values) worth of heavy minerals subject to mining proposals at that time (Wilson, 1977). Additionally, over the 10 year period 1976/77-1985/86, average employment in the mineral sands industry in New South Wales dropped from 1,198 or 4.6% of the total employment in the New South Wales mining industry to 295 or 1.1%, the major drop occurring by 1982/83 (NSW Department of Mineral Resources, 1986).

The market opportunities foregone because of these developments on the east coast were taken up by increased production in Western Australia and by overseas competitors.

6. REMAINING RESOURCES

A total of 20 Mt of zircon and rutile valued at $15.6 billion (mid-1990 values) and a further 43.3 Mt of ilmenite valued at $2.6 billion have been identified as remaining available on Australia's east coast (Table 2). These together represent more than three times the quantity of heavy minerals already extracted, although the overall value is proportionally less because of the predominance of ilmenite in the Queensland deposits. The New South Wales component is probably conservative, as it is based on onshore coastal resources of zircon and rutile only. The figures do not take into account the potential value added impact of any downstream processing.

Total known alienated resources, i.e. those tied up in National Parks, Nature Reserves and other developments, amount to 8 Mt of zircon and rutile valued at $6.2 billion (mid-1990 values) and 8.6 Mt of ilmenite valued at $0.5 billion.

The Queensland resources are almost all concentrated in a series of deposits between the southern and central coast areas, with North Stradbroke Island and the Byfield - Shoalwater Bay areas containing over 92% of the available resources and 77% of all resources in Queensland. Areas alienated from mining are now largely in National Parks, most notably on Moreton and Fraser Islands and the Cooloola sand mass north from Noosa, these areas together containing some 1,000 Mt of raw heavy mineral bearing sand (Cooper, 1990).

In New South Wales, substantial resources are alienated within seven conservation areas, namely Broadwater, Bundjalung, Yuraygir, Hat Head, Crowdy Bay and Myall Lakes National Parks and Limeburners Creek Nature Reserve. These areas were all the subject of the 1977 Coastal Mineral Sands Mining Policy proclamation of the New South Wales Government.

7. DISCUSSION

The concept of sequential land use, with the associated benefits which flow on to the community, is well demonstrated in the history of the mineral sands industry on Australia's east coast over the last 56 years.

In return for transient occupation of what were mostly areas of Vacant Crown Land with undesignated uses, the industry has generated almost $12 billion (mid-1990 values) of export income for Australia, including an estimated $220 million in the 1989/90 financial year. This latter figure is more than the total estimated value of $190 million realised for exports of iron, steel and ferro alloys from Australia over the same period (ABARE, 1990). The industry has also employed a substantial workforce and contributed in large part to the now developed infrastructure of many formerly remote areas, particularly along the north coast of New South Wales.

Coincident with these developments has been the dynamic evolution of rehabilitation strategies in response to varying mine environments, government regulation and the developing expectations of the community. There are many demonstrable cases of a proactive approach on the part of the industry to often ill-defined guidelines for the end land use and environmental challenges encountered along the way. The industry is now recognised as a responsible manager of the environmental aspects of mining operations and a leader in post-mining rehabilitation. This is particularly well evidenced by the fact that two companies, Mineral Deposits Limited and RZ Mines (Newcastle) Pty. Ltd., received high commendations from the New South Wales Government in the November 1990 Inaugural Awards for Environmental Excellence in the New South Wales Mining Industry, for rehabilitation effected at their mine sites over many years. Further, in 1982 the Australian Heritage Commission specifically commended AMC Mineral Sands Ltd. for its success in re-establishing natural ecosystems on mined areas at Jerusalem Creek, now part of Bundjalung National Park.

The fact that former mineral sands mining areas are now included within eight National Parks and seven Nature Reserves spread along the Queensland/New South Wales coastline, and that two of these areas are also listed on the Register of the National Estate, is further recognition of the success of rehabilitation programmes conducted by the industry. In relation to the level of rehabilitation in these areas, Unwin (1988) has reported that studies at Crowdy Bay National Park (on the New South Wales coast north of Taree) have demonstrated that coastal ecosystems can be successfully rehabilitated after mineral sands mining, particularly areas identified as wetlands.

Other end land uses have been successfully planned for and achieved, catering for recreation, urban development, tourism, agriculture and a host of other uses, including areas for Aboriginal Land Grants, defence uses, forestry and water supply.

Substantial remaining heavy mineral resources have been identified along Australia's eastern coastline, and still more may be discovered. These represent a significant export earning potential for Australia, even without the value-added advantages of developing more downstream processing in this country. Additional resources have been alienated in conservation areas, leading to potential losses of over $6.7 billion (mid-1990 values) to Australia's export earnings. Any further alienation of resources will have a profound affect on our export potential.

8. CONCLUSION

This paper has documented the mineral sands mining industry's history on Australia's east coast and demonstrated that the concept of sequential land use has been well tested over the last half century. The industry has amassed a wealth of knowledge and experience in sound environmental management, together with the ability to plan for and develop techniques to cope with future environmental challenges. It is important that this history is taken into account when considering future land use pressures. This study has demonstrated that the community stands to obtain maximum benefits through implementation of multiple land use strategies with proper planning. Substantial economic returns can be generated from mining these valuable heavy minerals as a short term land use, whereupon the land can be returned to a myriad other uses, varying from conservation to intense forms of development.

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APPENDIX A

Inventory of mineral sands mining operations on Australia's east coast, 1934-1990, including the current uses for mined lands where known. Inventory runs from north to south from Queensland to New South Wales. Full names of listed companies are given at the end of the inventory. Refer to Appendix B for maps illustrating the locations of listed operations by locality number.

QUEENSLAND

	LOCALITY	COMPANY	YEAR/S	CURRENT LAND USE
1	Gladstone	Murphyores	1968-70	Plant site only. Unused industrial land.
2	Point Richards	Murphyores	1968-70	ni[1]
3	Fraser Island	QTM DM Minerals	1971-76 1975-76	State Forest
4	Inskip Point-Rainbow Beach	QTM	1965-75	Tourism, VCL[2], beach
5	Double Island Point	CRZ	1973-77	National Park (*Cooloola*[3])
6	Noosa River (Tewantin)	TCA Coastal Rutile CRZ	1956-61 1970-72 1976-77	Beach National Park (*Cooloola*) Beach
7	Sunshine Beach	East Coast Minerals	1956-57	Beach
8	Moreton Island	Moreton Island Mins. Tangalooma Minerals	1948 1957-60(?)	Resort (Tangalooma), beach, National Park (*Moreton Island*)
9	North Stradbroke Island	TAZI AMC Consolidated Rutile	1950-69 1969-85 1967-present	VCL. Beach. Area for caravan park at Amity filled at Council's request. Recreation - proposed playing fields, tennis courts, etc. on tailings from TAZI/AMC separation plant at Dunwich township (which had been re-treated by Currumbin Minerals).

1. ni - not identified
2. Vacant Crown Land
3. Listed in the Register of the National Estate

APPENDIX A (Cont.)

QUEENSLAND (Cont.)

	LOCALITY	COMPANY	YEAR/S	CURRENT LAND USE
10	South Stradbroke Island	AMC	1951-62 1967-70	Beach, VCL. Boat anchorage. Jetty
11	Southport	AMC MDL	1946-82 1941-66 (plant sites)	Shopping centre and industrial area on AMC plant site. Residential and sportsfields on MDL plant site.
12	Coombabah	MDL	ni	Residential
13	The Spit	MDL	ca. 1956	Tourism, public recreation
14	Surfers Paradise	AMC	1970s-80s	High density residential
15	Broadbeach	Moffat AMC MDL	1942 1947-49 1951-59	Tourism Beach Shopping centre, Broadbeach International Hotel, high and low density residential
16	Mermaid Beach	AOE AMC	1957 1947-67	Tourism Residential, hotels, motels, shops
17	Nobbys Beach	Casey & Neumann AMC	1945 1947- ni	Tourism
18	Miami Beach	AMC CRZ RCA MDL	1947-1950s ni 1957-58 ca. 1956	Tourism Residential
19	Burleigh	MDL	1941-61	Parkland, school, beach
20	Tugun	Aust. Ti. Co. AMC MDL	1943 1971 1943	Tourism, residential Residential Residential, public recreation
21	Tallebudgera/Kirra	Currumbin Minerals	1941-90	Tourism
22	Bilinga	Currumbin Minerals	1970s-89	Airport facilities
23	Coolangatta	MDL	ca. 1956	Airport

APPENDIX A (Cont.)

NEW SOUTH WALES

	LOCALITY	COMPANY	YEAR/S	CURRENT LAND USE
24	Fingal	CRZ TAMCO MDL NSW Rutile Mining RZM	1956-65 1943 1951-53, 1965-66 1956-70 1969	VCL, beach
25	Kingscliff-Cudgen-Bogangar	TAMCO[4] CRZ Currumbin Minerals Dillingham NSW Rutile Mining RZM? AMC	1940-65 1948-70 1979-present 1970s 1943-70 1969 1954-early 1970s	Largely private land undeveloped after mining. Proposed sub-division and tourist development. Playground, picnic area. Housing, shops, motel at Bogangar. Develop-mental road for public access. Pine plantation. Bridge at Kingscliff. VCL.
26	Bogangar-Hastings Point	TAMCO ZR/AMC	1941-64 1950s-60s	VCL and recreation
27	Hastings Point - Pottsville	ZR/AMC	1961-71, 77	VCL, beach. Private land developed as caravan park. Holiday hostel, service station. Bowling club.
28	Pottsville	CRZ Metal Recoveries MDL	1963-66 1935-60 ni	Beach, low density residential
29	Mooball	AMC Metal Recoveries MDL	1961-71 1935-60 1963	Playground on Metal Recoveries Mooball plant site
30	Wooyung ("Jones Road")	AMC	Early 1970s	Private land (grazing)
31	New Brighton	AMC Metal Recoveries	1964, 67-70 1935-60	Beach, housing on Metal Recoveries original plant site

4. TAMCO mined large areas of private land to the south of Kingscliff. The land was owned by "Ocean Paradise Estates" and had been surveyed for housing development, etc. Conditions of mining required that the land be left flat, with not too many trees planted, as they would hinder future developments.

APPENDIX A (Cont.)

NEW SOUTH WALES (Cont.)

	LOCALITY	COMPANY	YEAR/S	CURRENT LAND USE
32	Brunswick Heads-Byron Bay	ZR/AMC CRZ	1934-71 1963-70	Nature Reserves (*Brunswick* and *Tyagarah*). Shopping centre on Byron Bay plant site. Housing on tailings areas. Private land, VCL, playgrounds (3) and picnic area
33	Tallow Beach	ZR/AMC CRZ	1948-54 1963-69	Beach, VCL. School on Crown Land. Part of Byron Bay golf course.
34	Suffolk Park	ni	1965-66	Beach, VCL.
35	Broken Head	AMC	1965-66, 69-70	Beach
36	Seven Mile Beach-Lennox Head	ZR/AMC AMC Mineral Sands	1934-71 1967-68 1948	VCL. Parkland/picnic area, beach
37	Newrybar	Lennox Head Company AMC Dillingham Australmin Holdings	1956-58 1970-72 1976-77 1989 - present	Private land, VCL. Cane growing and grazing on private land.
38	Skenners Head	AMC Lennox Head Company	1969-70 1956-58	Private grazing land, beach.
39	Sharpes Beach	ZR/AMC CRZ	1965-66 1969	VCL. Private mining agreement area, now public recreation area.
40	Sand Point	ni	1965-69	Beach
41	Ballina South	AMC	1974-76	Private Land (farming), VCL
42	Broadwater-Wardell-Evans Head	AMC Dillingham Northern Rivers Rut. TAMCO	1976-77, 77-79 1968-70, 72-73 1965-66, 70-71 1962-65	Private land (grazing), VCL, National Park (*Broadwater*), defence (part of Evans Head Airport).

APPENDIX A (Cont.)

NEW SOUTH WALES (Cont.)

	LOCALITY	COMPANY	YEAR/S	CURRENT LAND USE
43	Jerusalem Creek	AMC	1969-82	National Park (*Bundjalung*[5])
		Heavy Minerals	1957-58	
		Silver Valley	1957	Defence (Evans Head bombing range)
		Roux A.P.	1948-59	
		Rusan Minerals	1956-57	
		Titanium Minerals	1953, 56-62	
		Dillingham	1974-76	
44	Woody Head	CRZ	1970	Private land
45	Iluka	CRZ	1969-72	Nature Reserve (*Iluka*)
		Dillingham	mid 1970s	
46	Yamba-Angourie	AMC	1969	National Park (*Yuraygir*)
		British Minerals	1943	VCL
		Dillingham	1971-72	VCL
		TAMCO	1935-40	VCL
47	Shelley Beach	CRZ	1970-71	National Park (*Yuraygir*)
48	Brooms Head	NSW Rutile Mining	1969	National Park (*Yuraygir*)
		CRZ	1970-75	National Park (*Yuraygir*)
		Dillingham	1976-78	Proposed extentions to Yuraygir NP.
		McGeary Brothers	1979	
49	Sandon	CRZ	1967	National Park (*Yuraygir*)
50	Minnie Water	TAMCO	1939	National Park (*Yuraygir*)
51	Wooli-Red Rock	CRZ	1969-70	National Park (*Yuraygir*)
		Freeman Titanium	1955-56	
52	Woolgoolga	Coffs Harbour Mins.	1943-44	Public recreation
		Freeman Titanium	1955-56	
		TAMCO	1952-56	VCL
	Corindi Beach	MDL	1969, 1975-76	
	Arrawarra	MDL	1968	Beach, VCL
	Hearns Lake	MDL	1968-69	Beach, VCL
	Sandy Beach	MDL	1968	Beach, VCL

5. Listed in the Register of the National Estate.

APPENDIX A (Cont.)

NEW SOUTH WALES (Cont.)

	LOCALITY	COMPANY	YEAR/S	CURRENT LAND USE
	Diggers Beach	MDL	1976-77	Beach, VCL
	Emerald Beach	MDL	1968	Beach, VCL
	Moonee North	CRZ	1972	Nature Reserve (*Moonee*)
	Moonee South	CRZ	1971	VCL, private land
	Korora Bay	CRZ	1966	Low density residential and VCL
	Charlesworth Bay	CRZ	1967-68	Resort (Pacific Bay)
	Macauleys Beach	CRZ	1967	Beach, VCL
53	Coffs Harbour	Pointon Rutile Coffs Harbour Rutile CRZ	1957 1957-59 1966-67	VCL, part of Coffs Harbour Airport, sewage treatment plant, RSPCA Pound.
54	Bonville (Pine Creek)	CRZ	1971	Private land (forestry).
55	Mylestom	CRZ Bellingen Titanium	1971 1956-58	Private land, VCL.
56	Macksville	MDL	1968-70	Mining for pebbles, private land (farming)
57	Middle Head	MDL	1980-81	VCL, beach
58	Stuarts Point	MDL	1980	Private land (farming), VCL, Aboriginal land grant.
59	Clybucca (inland from South West Rocks)	AMC CRZ	Late 1970s 1971-72	Private land (grazing)
60	Crescent Head North	MDL	1967-72, 74	National Park (*Hat Head*)
	"Edwards"	MDL	1972, 80-81	Private land (grazing), VCL, Aboriginal land grant.
61	Crescent Head South - Goolawah Beach	MDL	1957-67 1969-72 1978-79	VCL, Aboriginal Land Grant, farming, public roads, Nature Reserve (*Goolawah*).
62	Delicate Nobby	MDL	1960-63, 72-75	Nature Reserve (*Goolawah*).

APPENDIX A (Cont.)

NEW SOUTH WALES (Cont.)

	LOCALITY	COMPANY	YEAR/S	CURRENT LAND USE
63	Barries Bay	MDL	1967-68	Nature Reserve (*Limeburners Creek*)
64	Point Plomer	CRZ MDL	1971 1963-67, 74-79	Nature Reserve (*Limeburners Creek*), VCL, private land (grazing).
65	Tacking Point	ZR AMC	1955 1959-63	Surf club, beach, housing on ZR plant site.
66	Christmas Bell Plain	MDL	1966-68, 74	Nature Reserve (*Lake Innes* - area mined 1966-68)
67	Bonny Hills	AMC	1971	Private land (sewage works)
68	Grants Head-Camden Haven	N. Coast Beach Mins. Rye Park Scheelite MDL RZM	1954-55 1955-58 1970-72 1969-71, 72	VCL
69	Dunbogan-Laurieton	N. Coast Beach Mins. AMC CRZ RZM	1956-58 1966-71 1971-74 1974-76	VCL Housing at Dunbogan, sewage works, sand pits
70	Diamond Head	Laurieton Rutile AMC	1956-61 1961-78	National Park (*Crowdy Bay*). Camping ground on site of AMC dry mill.
71	Harrington	Clutha Development RZM CRZ	1958 1964-present 1971-74	National Park (*Crowdy Bay*), residential, future town extension.
72	Mitchells Island	RZM	1970s	Hobby farms, river gravel extraction.
73	Old Bar	RZM	1979-80	Hobby farms, sand extraction.
74	Saltwater Beach	RZM	1972-76	VCL, proposed future mining.

APPENDIX A (Cont.)

NEW SOUTH WALES (Cont.)

	LOCALITY	COMPANY	YEAR/S	CURRENT LAND USE
75	Tuncurry - Failford	MDL	1968-81	Future town extension, sewage works, hobby farms, waste disposal site, sand extraction.
76	Nabiac	MDL RZM	1973-81 1987-present	VCL, private land (car club activities).
77	Seven Mile Beach (South Forster)	MDL RZM	1969-72 1974-75	Recreation Reserve (*Booti Booti State Recreation Area*)
78	Elizabeth Beach-Blueys Beach-Boomerang Beach	RZM MDL RZM	1969-71 1970 1970-74	Beach, residential
79	Sandbar	MDL RZM	1970-73 1969, 73	Private land, VCL, beach, caravan park
80	Bridge Hill Ridge	MDL	1974-83	National Park (*Myall Lakes*)
81	Bulahdelah	RZM	1980	Private land (farming)
82	Treachery Beach	MDL	1978	National Park (*Myall Lakes*)
83	Yagon	MDL	1977-79	National Park (*Myall Lakes*)
84	Big Gibber	MDL	1971-77	National Park (*Myall Lakes*)
85	Bombah Point	RZM	1974-79	National Park (*Myall Lakes*)
86	Myall River	MDL RZM	1966-71 1973-77	National Park (*Myall Lakes*) Future subdivision
87	Viney Creek	MDL	1986-present	Private land, water supply area
88	Nerong Park	MDL	1988-present	Private land

APPENDIX A (Cont.)

NEW SOUTH WALES (Cont.)

	LOCALITY	COMPANY	YEAR/S	CURRENT LAND USE
89	Hawks Nest ("Baskets")	MDL	1981-82, 88	VCL, golf course, private land
90	Hawks Nest ("Crofts")	MDL	1968-69, 81	Beach
91	Salamander Bay ("Bobs Farm")	RZM	1969-77	Housing, shopping complex, future sub-division, farming.
92	Mallabula-Tanilba	AMC RZM	1964-66 1976-77	Housing Sports field
93	Big Swan Bay	AMC	1965-75	Housing, VCL, defence (target range)
94	Medowie - Tomago	AMC RZM	1980-82 1967-present	Future subdivision, water catchment area, defence (part of Williamtown Air Base)
95	Anna Bay	RZM	1970-71	
96	Stockton	MDL	1987-present	VCL, sand extraction, possible water supply area.
97	Fullerton Cove	RZM	1975-77	Private land (farming)
98	Redhead-Belmont	Linwood Sands Coffs Harbour Rutile National Minerals RZM	1957-67	Proposed resort and open space, sand extraction
99	Belmont South	Coffs Harbour Rutile RZM	1959 1969-71	Beach, private land, sand extraction.
100	Swansea - Caves Beach	RZM Catherine Products Linwood Sands	1962, 69-71 1947 1953-59	Beach, proposed tourist resort.
101	Catherine Hill Bay	Crescent Rutile Linwood Sands National Minerals/ RZM	1961 1947-57 1966	VCL

APPENDIX A (Cont.)

NEW SOUTH WALES (Cont.)

	LOCALITY	COMPANY	YEAR/S	CURRENT LAND USE
102	Budgewoi-Lake Munmorah	Wyong Minerals AMC Northern Rivers Rut.	1961-67 1967-79 1970-71	Recreation Reserve (*Lake Munmorah State Recreation Area*), major road, beach and surf club, with National Parks and Wildlife Service office at original AMC administration offices area.
103	Soldiers Beach	Northern Rivers Rut.	1965-66	Beach, surf club.
104	North Entrance	Linwood Sands AMC	1959 1969-77	Public recreation, proposed tourist development, sportsfields, waste disposal.
105	Terrigal	Beach Mining (National Minerals) Northern Rivers Rut.	1955-58 1965	Beach
106	Kincumber	Northern Rivers Rut.	ni-1986	VCL - old dry mill site.
107	Putty Beach (Kilcare)	Crescent Rutile	1959-60	Beach
108	Bulli Beach - Wollongong Beach	Upton Brothers (National Minerals)	1953	Beach
109	Barrack Beach & Shellharbour	Beach Mining (National Minerals)	1955-58	Beach

APPENDIX A (Cont.)

FULL NAMES OF THE 52 COMPANIES LISTED IN THE INVENTORY ARE AS FOLLOWS:

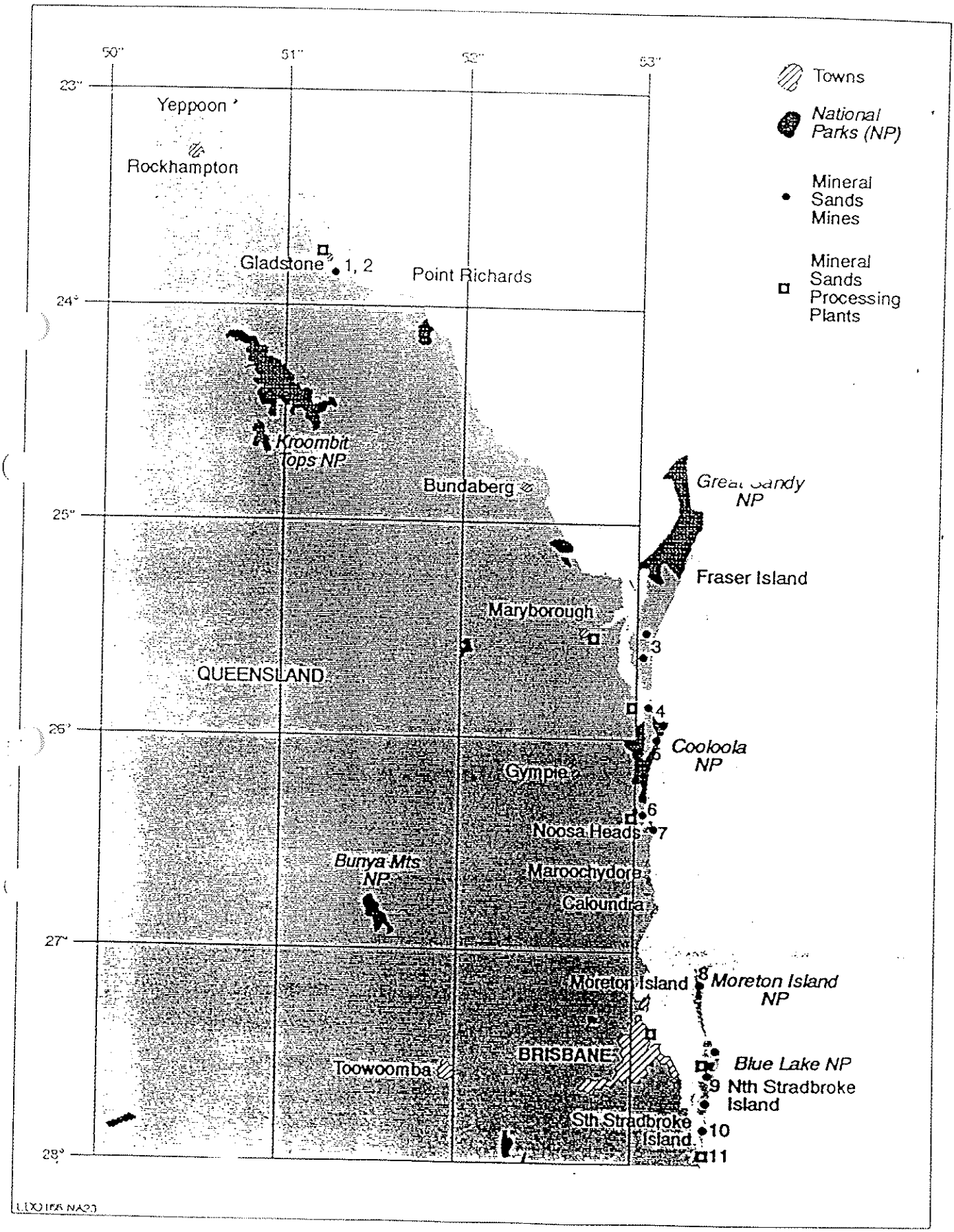
Associated Minerals Consolidated Limited (AMC)
Australian Oil Exploration Ltd. (AOE)
Australian Titanium Company
Australmin Holdings Limited
Beach Mining Australia Pty. Ltd.
Bellingen Titanium Pty. Ltd.
British Minerals
Casey and Neumann
Catherine Products
Clutha Development Pty. Ltd.
Coastal Rutile Ltd.
Coffs Harbour Minerals Syndicate
Coffs Harbour Rutile N.L.
Consolidated Rutile Limited
Crescent Rutile N.L.
Cudgen R-Z Ltd. (CRZ)
Currumbin Minerals Pty. Ltd.
DM Minerals
Dillingham Mining Company of Australia Ltd.
East Coast Minerals Pty. Ltd.
Freeman Titanium Pty. Ltd.
Heavy Minerals Pty. Ltd.
Laurieton Rutile Company
Lennox Head Company
Linwood Sands Syndicate
McGeary Brothers Contractors Pty. Ltd.
Metal Recoveries Pty. Ltd.
Mineral Deposits Limited (MDL)
Mineral Sands Pty. Ltd.
Moffat
Moreton Island Minerals Pty. Ltd.
Murphyores Incorporated Ltd.
National Minerals Pty. Ltd.
North Coast Beach Minerals Pty. Ltd.
Northern Rivers Rutile Pty Ltd.
NSW Rutile Mining Co. Pty. Ltd.
Pointon Rutile Pty. Ltd.
Queensland Titanium Mines Pty. Ltd. (QTM)
Roux A.P.
Rusan Minerals Pty. Ltd.
Rutile Corporation of Australasia Ltd. (RCA)
Rye Park Scheelite N.L.
RZ Mines (Newcastle) Pty. Ltd. (RZM)
Silver Valley Minerals N.L.
Tangalooma Minerals Pty. Ltd.
The Titanium Alloy Manufacturing Company (TAMCO)
Titanium and Zirconium Industries Pty. Ltd. (TAZI)
Titanium Corporation of Australia Pty. Ltd. (TCA)
Titanium Minerals Ltd.
Upton Brothers
Wyong Minerals Ltd.
Zircon-Rutile Ltd. (ZR)

The above companies have now largely been absorbed into the following companies:

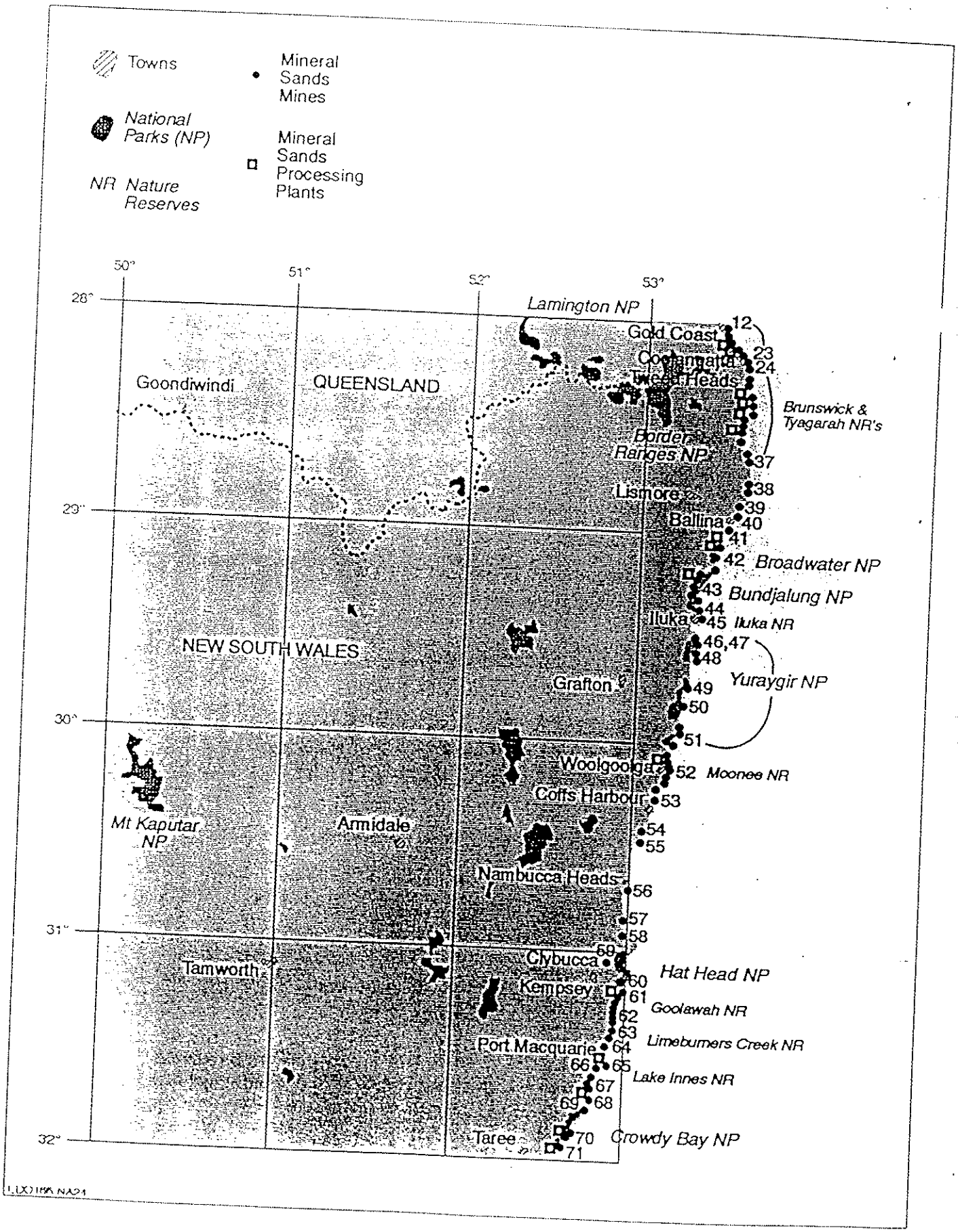
- Associated Minerals Consolidated Limited (Renison Goldfields Consolidated Limited)
- Australmin Holdings Limited (Newmont Australia Limited)
- Cudgen R-Z Ltd./Consolidated Rutile Limited
- Currumbin Minerals Pty. Ltd.
- Mineral Deposits Limited (BHP Minerals)
- RZ Mines (Newcastle) Pty. Ltd. (Nissho Iwai)

APPENDIX B

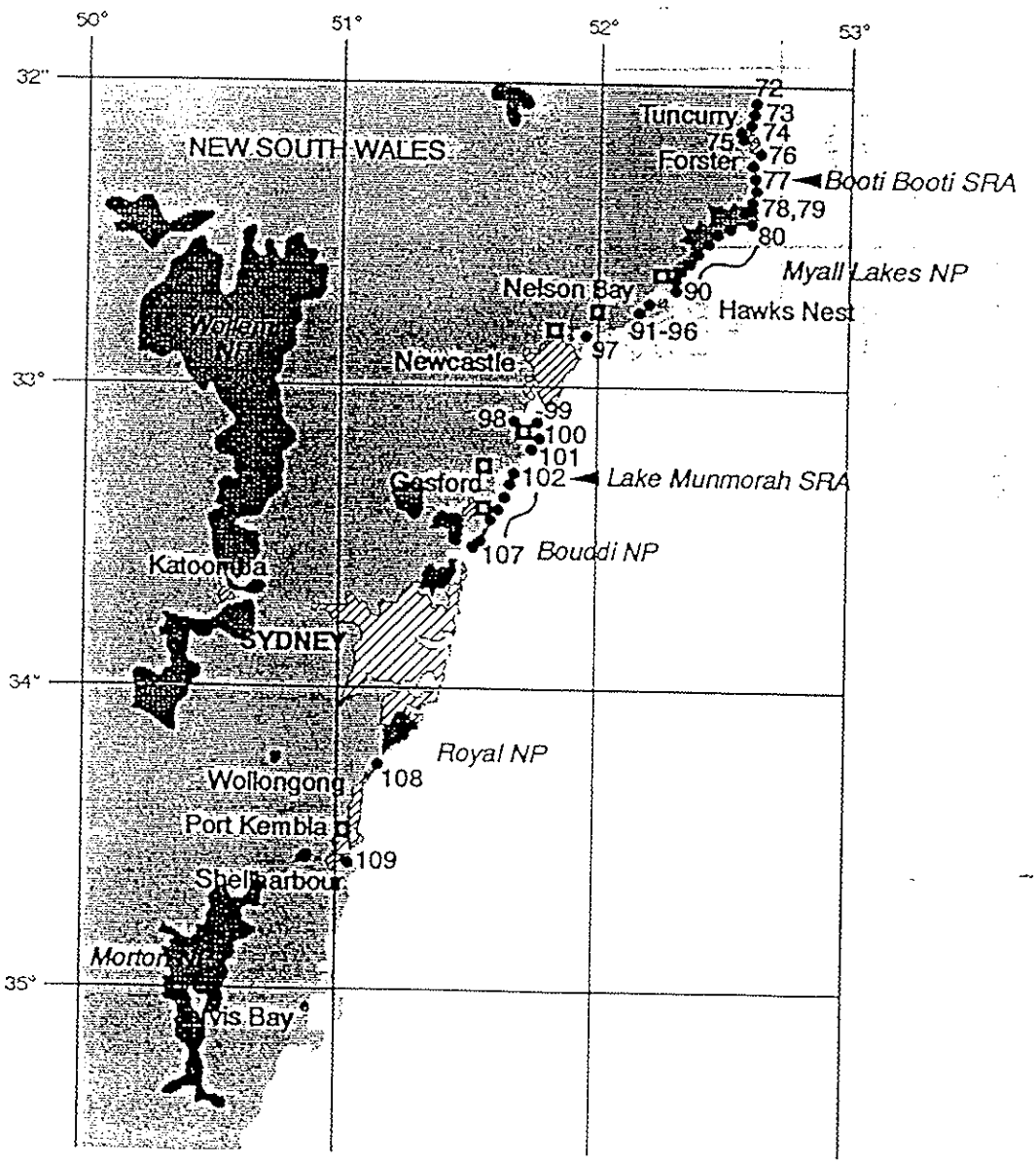
Maps showing the locations of mineral sands mining operations on Australia's east coast, 1934-1990. Appendix A lists an inventory of mining operations at each numbered location. Maps run from north to south from Queensland to New South Wales. See Figure 1 in text for overall mapped area.



APPENDIX B continued



APPENDIX B continued



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APPENDIX C

Summary of annual heavy minerals production in Queensland, 1941-1990, including values based on 1990 estimated prices.

Year	HEAVY MINERALS PRODUCTION (TONNES)							ESTIMATED VALUE (1990 Prices)	
	Ilmenite	Upgraded Ilmenite (from 1985)	Monazite	Rutile	Zircon	Annual Total	Cumulative Total	Annual A$ Mill.	Cumulative A$ Mill.
1941	258			267	428	953	953	0.55	0.55
1942	937			1,007	1,523	3,467	4,420	1.99	2.54
1943	1,655			1,902	2,976	6,533	10,953	3.84	6.38
1944	3,697			4,246	6,444	14,387	25,340	8.41	14.79
1945	4,186			4,592	5,523	14,301	39,641	7.95	22.74
1946	3,122			3,177	3,906	10,205	49,846	5.57	28.31
1947	3,761			4,004	6,157	13,922	63,768	8.00	36.31
1948	4,318			3,120	6,232	16,670	80,438	9.66	45.97
1949	4,013			4,941	6,213	15,167	95,605	8.76	54.73
1950			5	7,853	6,884	14,742	110,347	11.40	66.13
1951				12,324	10,292	22,616	132,963	17.50	83.63
1952	15		27	13,782	10,709	24,533	157,496	18.97	102.60
1953			81	16,383	11,866	28,330	185,826	21.85	124.45
1954	3		10	22,277	14,188	36,478	222,304	28.07	152.52
1955	66		48	25,615	16,100	41,829	264,133	32.13	184.65
1956			6	32,414	22,148	54,568	318,701	42.03	226.68
1957	152		90	43,434	29,656	73,332	392,033	56.38	283.06
1958			120	37,126	27,048	64,294	456,327	49.59	332.65
1959			82	36,092	35,350	71,524	527,851	55.42	388.07
1960	22		81	34,668	32,530	67,301	595,152	52.09	440.16

APPENDIX C (Cont)

Summary of annual heavy minerals production in Queensland, 1941-1990, including values based on 1990 estimated prices.

Year	HEAVY MINERALS PRODUCTION (TONNES)							ESTIMATED VALUE (1990 Prices)	
	Ilmenite	Upgraded Ilmenite (from 1985)	Monazite	Rutile	Zircon	Annual Total	Cumulative Total	Annual A$ Mill.	Cumulative A$ Mill.
1982/83	11,696		18	84,333	67,633	163,680	5,030,280	117.61	3,462.34
1983/84	41,696		452	76,046	65,315	183,509	5,213,789	110.50	3,572.84
1984/85	125,938			79,872	67,647	273,457	5,487,246	116.54	3,689.38
1985/86	195,840			100,397	82,513	378,750	5,865,996	145.22	3,834.60
1986/87	189,006	122,015	2	107,905	90,442	509,370	6,375,366	164.39	3,998.99
1987/88	48,229	240,325	518	95,612	78,849	463,533	6,838,899	150.61	4,149.60
1988/89	19,109	261,606	529	107,696	90,117	479,057	7,317,956	169.39	4,318.99
1989/90	18,000	200,000		81,000	78,000	377,000	7,694,956	135.51	4,454.50

NOTES:
1. * 50% 1982 total tonnes and estimated value used in cumulative totals as financial year figures presented from 1982/83 on.
2. In some cases, especially for Monazite, the data are for shipments.
3. Values derived from estimated approximate average export prices for mid-1990 based on Australian Bureau of Statistics data and industry sources - Zircon $800, Rutile $750, Ilmenite $60 per tonne (as upgraded product sold as Ilmenite). The total value for Monazite production is considered to have been insignificant in comparison to overall heavy mineral sands sales revenue and has not been included here.

SOURCES: Kalix, Z., Fraser, L.M. and Rawson, R.J. 1966 (Compilers and Editors): Australian Mineral Industry: Production and Trade, 1842-1964. Bureau of Mineral Resources Bull. 81 (for 1961 to 1964). Bureau of Mineral Resources: Australian Mineral Industry Annual Review 1979 (and other years) (for 1965 to 1987). Queensland Department of Mines: Annual Report 1984 (and other years) (for 1982 to 1989). Australian Bureau of Agricultural and Resource Economics Quarterly Mineral Statistics, June Quarter 1990 (for 1989/90 financial year).

APPENDIX C (Cont)

Summary of annual heavy minerals production in Queensland, 1941-1990, including values based on 1990 estimated prices.

Year	HEAVY MINERALS PRODUCTION (TONNES)							ESTIMATED VALUE (1990 Prices)	
	Ilmenite	Upgraded Ilmenite (from 1985)	Monazite	Rutile	Zircon	Annual Total	Cumulative Total	Annual A$ Mill.	Cumulative A$ Mill.
1961	4		140	34,452	29,482	64,078	659,230	49.54	489.70
1962			70	39,119	39,438	78,627	737,857	60.95	550.65
1963			239	48,108	53,566	101,913	839,770	79.14	629.79
1964	110		252	50,958	44,987	96,307	936,077	74.42	704.21
1965			261	56,164	47,439	103,864	1,039,941	80.30	784.51
1966			176	71,886	57,605	129,667	1,169,608	100.15	884.66
1967			253	82,019	76,419	158,691	1,328,299	122.86	1,007.52
1968	2,083		261	84,112	81,856	178,312	1,506,611	136.33	1,143.85
1969	26,336		197	124,674	92,251	243,458	1,750,069	168.00	1,311.85
1970	120,787		59	133,823	98,709	354,378	2,104,447	182.60	1,494.45
1971	60,804		53	135,446	95,296	291,599	2,396,046	179.08	1,673.53
1972	4,996		41	136,937	113,142	255,116	2,651,162	193.35	1,866.88
1973	13,807		64	135,602	108,287	257,760	2,908,922	188.66	2,055.54
1974	43,702		25	138,932	123,417	304,076	3,212,998	202.33	2,257.87
1975	35,531		14	125,968	101,626	263,139	3,476,137	176.50	2,434.37
1976	57,896		832	138,137	123,911	320 776	3,796,913	204.60	2,638.97
1977	55,449		622	84,634	74,809	215,514	4,012,427	124.96	2,763.93
1978	55,600			52,645	62,994	171,239	4,183,666	90.99	2,854.92
1979	2,982			90,928	78,377	172,287	4,355,953	130.96	2,985.88
1980	27,927		499	119,751	102,430	250,607	4,606,560	172.74	3,158.62
1981	6,411			85,195	74,141	165,747	4,772,307	123.34	3,281.96
1982	26,744			89,112	72,731	188,587*	4,866,600	125.55*	3,344.73

APPENDIX D (Cont)

Summary of annual heavy minerals production in New South Wales, 1934-1990, including values based on 1990 estimated prices.

Year	HEAVY MINERALS PRODUCTION (TONNES)								ESTIMATED VALUE (1990 Prices)	
	Ilmenite	Monazite	Rutile	Rutile/ Ilmenite Concentrate	Zircon	Zircon-Rutile Concentrate	Annual Total	Cumulative Total	Annual A$ Mill.	Cumulative A$ Mill.
1955	477	119	34,955		33,354	12,206	81,111	548,684	61.55	407.03
1956	996	98	65,956		51,473	22,324	140,847	689,531	106.37	513.40
1957	992	53	87,537		60,326	41,393	190,301	879,832	142.95	656.35
1958	133	230	47,237		33,064	34,688	115,352	995,184	86.36	743.71
1959	234	190	47,026		72,929	48,209	168,588	1,163,772	127.53	870.24
1960	1,211	41	54,869		67,392	51,117	174,630	1,338,402	130.91	1,001.15
1961	2,044	156	67,676		101,691	63,971	235,538	1,573,940	177.06	1,178.21
1962	4,357	147	81,457		92,763	73,731	252,455	1,826,395	187.13	1,365.34
1963	6,071	523	137,318		121,505	95,143	360,560	2,186,955	267.36	1,632.70
1964	6,297	677	133,660		120,192	98,764	359,590	2,546,545	266.23	1,899.93
1965	8,289	611	164,425		159,278	101,712	434,315	2,980,860	322.62	2,221.55
1966	11,898	472	175,300		156,263	108,909	452,842	3,433,702	333.36	2,554.91
1967	11,538	502	187,349		179,133	87,973	466,495	3,900,197	346.06	2,900.97
1968	11,925	537	230,023		191,650	80,664	514,799	4,414,996	383.00	3,283.97
1969	11,643	369	230,024		224,818	61,097	527,951	4,942,947	395.69	3,679.66
1970	19,171	406	226,229		229,856	79,032	554,694	5,497,641	409.61	4,089.27
1971	17,970	1,268	230,624		261,624	125,529	637,038	6,134,679	471.59	4,560.86
1972	8,092	2,324	172,441		221,576		404,433	6,539,112	308.73	4,869.59
1973	10,454	1,496	193,523		207,054		412,527	6,951,639	312.27	5,181.86
1974	10,798	1,003	166,107		166,107		342,750	7,294,389	257.52	5,439.38
1975	10,771	988	172,702		172,702		360,236	7,654,625	271.20	5,710.58

APPENDIX D

Summary of annual heavy minerals production in New South Wales, 1934-1990, including values based on 1990 estimated prices.

Year	HEAVY MINERALS PRODUCTION (TONNES)								ESTIMATED VALUE (1990 Prices)	
	Ilmenite	Monazite	Rutile	Rutile/ Ilmenite Concentrate	Zircon	Zircon-Rutile Concentrate	Annual Total	Cumulative Total	Annual A$ Mill.	Cumulative A$ Mill.
1934						51	51	51	0.04	0.04
1935					1,481	675	2,156	2,207	1.66	1.70
1936					250	2,645	2,895	5,102	2.05	3.75
1937				73	344	6,880	7,297	12,399	5.12	8.87
1938				460	160	1,011	1,631	14,030	1.01	9.88
1939				698	209	2,384	3,291	17,321	2.10	11.98
1940				1,320	1,327	6,643	9,290	26,611	6.22	18.20
1941				1,181	1,951	17,191	20,323	46,934	14.05	32.25
1942				1,690	2,070	14,177	17,937	64,871	12.23	44.48
1943			325	1,468	652	19,820	22,265	87,136	15.20	59.68
1944	1,309		3,292	199	6,102	3,859	14,761	101,897	10.15	69.83
1945			2,389	136	4,127	12,135	18,787	120,684	13.64	83.47
1946			5,146		7,829	1,727	14,702	135,386	11.33	94.80
1947	3,237		5,436		10,609	8,981	28,263	163,649	18.92	113.72
1948		828	7,194		12,699	5,694	26,415	190,064	20.24	133.96
1949		752	8,154		12,810	3,413	25,129	215,193	19.39	153.35
1950	50	30	10,752		15,271		26,103	241,296	20.31	173.66
1951	1,252	165	23,430		32,799	2,616	60,262	301,558	45.81	219.47
1952	31	153	24,842		19,485	17,206	61,690	363,248	46.37	265.84
1953		180	22,267		17,222	4,430	44,099	407,347	33.73	299.57
1954	473	834	23,099		27,930	7,890	60,226	467,573	45.91	345.48

APPENDIX D (Cont)

Summary of annual heavy minerals production in New South Wales, 1934-1990, including values based on 1990 estimated prices.

Year	HEAVY MINERALS PRODUCTION (TONNES)								ESTIMATED VALUE (1990 Prices)	
	Ilmenite	Monazite	Rutile	Rutile/ Ilmenite Concentrate	Zircon	Zircon-Rutile Concentrate	Annual Total	Cumulative Total	Annual A$ Mill.	Cumulative A$ Mill.
1976	13,168	457	163,140		155,731	125,529	332,496	7,987,121	247.59	5,958.17
1977	12,291	910	129,445		135,212		277,858	8,264,979	206.27	6,164.44
1978	67,743	233	104,583		109,923		282,482	8,547,461	167.93	6,332.37
1979	24,096	1,798	82,444		95,791		204,129	8,751,590	140.48	6,472.85
1980	33,453	290	91,872		105,087		230,702	8,982,292	153.89	6,626.74
1981	26,372	639	66,954		84,797		178,762	9,161,054	119.12	6,745.86
1982	31,502	198	47,669		66,017		145,386	9,306,440	89.36	6,835.22
1983	17,266	365	34,840		56,899		109,370	9,415,810	72.30	6,907.52
1984	15,753	668	36,006		56,631		109,058	9,524,868	73.19	6,980.71
1985	15,173	980	36,727		49,669		102,549	9,627,417	68.42	7,049.13
1986	20,213	75	42,579		48,239		111,106	9,738,523	70.99	7,120.12
1987	16,509	860	58,994		52,769		129,132*	9,867,655	87.52	7,163.88*
1987/88	15,627	924	52,738		50,389		119,678	9,927,497	80.96	7,244.84
1988/89	41,709	160	61,192		55,772		158,833	10,086,327	91.48	7,336.32
1989/90	31,062	349	61,878		46,291		139,580	10,225,907	84.36	7,420.68

NOTE:

1. *50% 1987 total tonnes and estimated value used in cumulative totals as financial year figures presented from 1987/88 on.
2. In some cases, especially for Monazite, the data are for shipments. Some data are for concentrates finally separated in Queensland.
3. Values derived from estimated approximate average export prices for mid-1990 based on Australian Bureau of Statistics data and industry sources - Zircon $800, Rutile $750, Ilmenite $60 per tonne (as upgraded product sold as Ilmenite). The total value for Monazite production is considered to have been insignificant in comparison to overall heavy mineral sands sales revenue and has not been included here.

SOURCE: Department of Mineral Resources and Development, Geological Survey of NSW, Mineral Industry of New South Wales Nos. 40, 44 and 38: Titanium Zirconium Thorium: Compiled by Cooper, P.F., MacNevin A.A. and Winward, K. (Manuscript updated 1973) (for 1934-1950). Bureau of Mineral Resources: Australian Mineral Industry Annual Reviews (for 1951-1987). Department of Minerals and Energy: Mineral Production New South Wales quarterly and annual reports (for 1986/87-1988/89). Department of Minerals and Energy pers. comm. (for 1989/90).

APACE AID Inc.

REPORT ON

DIRECT SEEDING TRIALS

WANNEROO

January 1996

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Karen Clarke

WARWICK OPEN SPACE

DIRECT SEEDING TRIALS

WARWICK OPEN SPACE

DIRECT SEEDING TRIALS

Seed was collected from Warwick Open Space during the months of November and December 1994 and January 1995. As diverse a range of species as possible was collected. The species and the total number of seed collected is shown in Table One.

The seed was processed, fumigated and stored at APACE. The seed was smoked prior to sowing.

The direct seeding was undertaken by Tony Dimazi of Home Green Turf using a Brillion seeder. *Atapulgite* was used as a bulking agent and fertiliser was also applied. The direct seeeding took place in July 1995.

Assessment of the trials was undertaken by APACE staff Tony Freeman and Sarah de Bueger on December 14th, 1995. The area was first walked over to identify seedlings and then five (5) random quadrats of 4m x 5 m were marked out. Each individual seedling was recorded. Approximately one third of the seeded area had top soil spread over it. There was no evidence of seed germination where this had taken place.

Table One **Warwick Open Space - Seed Collection 1994-95**

Species	Quantity (g)
Calothamnus quadrifidus	5
Daviesia divaricata	10
Eucalyptus marginata	1000
Eremaea pauciflora	20
Gompholobium tomentosum	15
Haemodorum paniculatum	146
Hardenbergia comptoniana	75
Kennedia prostrata	24
Patersonia occidentalis	11
Petrophile macrostachya	31
Petrophile linearis	40
Pimelia sp.	2
Ptilotus drummondii	3
Ptilotus manglesii	42
Ptilotus polystachyus	4
Stirlingia latifolia	421
Tetraria octandra	100
Tricoryne elatior	4
Xanthorrhoea preissii	3 000
TOTAL	4 953 g

Table Two **Seedlings per Quadrat - Warwick Open Space**

	Quadrat Number				
Species	1	2	3	4	5
Eucalyptus marginata	-	7	11	11	14
Eremaea pauciflora	-	-	-	2	-
Jacksonia sp.	-	-	-	2	-
Xanthorrhoea preissii	1	29	44	84	23

The total area seeded was approximately 0.4 of a hectare. At the time of the survey, the undisturbed area was approximately 2 500 m². From the quadrat data the following estimations of recruitment are made on 2 500 m² and 4 000 m². These are shown in Table Three.

Table Three **Estimations of Recruitment**

Species	2 500 m²	4 000 m²
Eucalyptus marginata	1 075	1720
Eremaea pauciflora	50	80
Jacksonia sp.	50	80
Xanthorrhoea preissii	4 525	7 240
Total	5 700	9 120

Other seeded species also noted, but which were not found in the quadrats were:

Kennedia prostrata, Ptilotus sp., Daviesia sp. and *Gompholobium tomentosum.*

The most common weed species noted were :

Pelargonium capitatum, Penniseeteum clandestinum, Anagallis arvensis and *Trachyandra divaricata.*

Discussion

Most of the seed sown, (82% by weight) was *Xanthorrhoea* and Jarrah - 3 kg and 1 kg respectively. In total 4 953 grams was sown which is equivalent to approximately 15 kg/Ha.

The following species show poor germination in a nursery environment, however, some germination may take place in the Winter of 1996:

Patersonia occidentalis, Petrophile macrostachya, P. linearis, Pimelia sp., Ptilotus drummondii, P. manglesii, P. polystachyus, Stirlingia latifolia, Tetraria octandra and *Tricoryne elatior.*

In terms of value for dollars, the quadrat analysis indicates that 9 120 plants have germinated. The value of this stock is in the vicinity of $18 240 planted ($2/plant). The spreading of top soil over the direct seeded area, however, has resulted in a recruitment of only 5 700 plants with a value of $11 400. Losses during summer 1995/6 are expected, however, as noted above, some recruitment is anticipated from these recalcitrant species.

A follow-up survey in late 1996 (October) will provide more reliable data on the number of plants successfully established by these trials.

HEPBURN HEIGHTS

DIRECT SEEDING TRIALS

HEPBURN HEIGHTS

DIRECT SEEDING TRIALS

Seed was collected from Hepburn Heights during the months of November and December 1994 and January 1995. As diverse a range of species as possible was collected. The species and the total number of seed collected is shown in Table One.

The seed was processed, fumigated and stored at APACE. Seed was smoked prior to sowing.

The direct seeding was undertaken by Tony Dimazi of Home Green Turf using a Brillion seeder. *Atapulgite* was used as a bulking agent and fertiliser was also applied. The direct seeeding took place in July 1995.

Assessment of the trials was undertaken by APACE staff Tony Freeman and Sarah de Bueger on December 14th, 1995. Five quadrats of 4 m x 5 m at 15 m spacings in the centre of the track were sampled for recruitment. The first quadrat is at the top of the hill and the last is near to the bottom. The results are shown in Table Four.

Table One **Hepburn Heights - Seed Collection 1994-95**

Species	Quantity (g)
Acacia pulchella	10
Acacia saligna	2
Allocasuarina humilis	200
Calothamnus quadrifidus	150
Daviesia divaricata	3
Eryngium pinnatifidum	11
Eryngium sp.	3
Eucalyptus marginata	20
Gompholobium tomentosum	5
Hakea lissocarpha	200 seeds
Hardenbergia comptoniana	4
Hypocalymma robustum	32
Jacksonia sternbergiana	1
Petrophile brevifolia	1
Petrophile linearis	8
Phyllanthus calycinus	10
Ptilotus manglesii	17
Ptilotus drummondii	40
Ptilotus polystachyus	9
Stirlingia latifolia	400
Tricoryne elatior	4
Thysanotus sp.	1
TOTALS	931 g 200 seeds

Table Two **Seedlings per Quadrat - Hepburn Heights**

	Quadrat Number				
Species	1	2	3	4	5
Acacia saligna	-	3	2	-	-
Allocasuarina humilis	16	87	91	27	23
Banksia attenuata	1	-	-	-	-
Calothamnus quadrifidus	9	46	15	9	1
Eucalyptus marginata	-	-	1	-	-
Gomphilobium tomentosum	1	1	1	-	-
Hakea lissocarpha	-	-	1	-	-
Jacksonia sp.	1	2	1	2	-
Phyllanthus calycinus	-	-	1	-	-
Pilotus manglesii	5	5	-	41	13
Stirlingia latifolia	-	1	-	-	-

Other species also noted which have presumably beeen recruited from the adjacent bushland included:

Hibbertia racemosa, Petrophile macrostachya, Hovea trisperma, and *Banksia attenuata.*

The total area seeded is approximently 1 500 m². From the quadrat survey the following total estimation of recriutment can be made:

Table Three **Estimations of Recruitment**

Acacia saligna	75
Allocasuarina humilis	3 660
Calothamnus quadrifidus	1 200
Eucalyptus marginata	15
Hakea lissocarpha	15
Gompholobium tomentosum	45
Jacksonia sternbergiana	90
Phyllanthus calycinus	15
Stirlingia latifolia	15
Total	5 130

Discussion

Most of the seed sown, (38% by weight) was *Allocasuarina humilis* and *Calothamnus quadrifidus* - 0.2 kg and 0.15 kg respectively. In total 931 grams and 200 seeds were sown, which is equivalent to approximately 6.2 kg/Ha. This is born out in the germination results shoown in Table Three.

The following species show poor germination in a nursery environment, however, some germination may take place in the Winter of 1996:

Eryngium sp., Hypocalymma robustum, Petrophile brevifolia, P. linearis, Ptilotus drummondii, P. manglesii, P. polystachyus, Stirlingia latifolia, and *Tricoryne elatior.*

In terms of value for dollars, the quadrat analysis indicates that 5 130 plants have germinated. The value of this stock is in the vicinity of $10 260 planted ($2/plant). Losses during summer 1995/6 are expected, however, as noted above, some recruitment is anticipated from these recalcitrant species.

follow-up survey in late 1996 (October) will provide more reliable data on the number of plants successfully established by these trials.

Stirling Harvey Redevelopment Scheme

Rehabilitation Monitoring Report

May 2005

ghems

environmental services

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2. EXECUTIVE SUMMARY

As a part of the Water Corporation's (WC's) Stirling Harvey Redevelopment Scheme (SHRS) rehabilitation program around the Harvey Dam, 23 monitoring plots and 24 transects were assessed by GHEMS Revegetation Environmental (GHEMS) in February/March 2005. Parameters assessed included percentage species representation, percentage understorey species derived from seed, approximate stems per hectare, weed burden and fire hazard risk.

The results of the monitoring suggest a number of things as outlined below:

(1) All rehabilitation areas meet the required criteria of 400 native stems being present per hectare.

(2) Direct Seeding results in general are not compliant with the established completion criteria. This can be expected given that much of the area has a history as pastureland resulting in problems for any direct seeding operation. For example competition for light, nutrients and moisture due to weed infestation.

(3) None of the rehabilitation areas show understorey development that is consistent with the established completion criteria for this parameter. The Stirling – Harvey Pipeline rehabilitation area is by far the best area in terms of understorey development.

If additional native species, not originally seeded or planted, but that have volunteered and are currently establishing within a number of the rehabilitation areas were taken into consideration in the monitoring results, a better outcome would be seen with regard to this criteria.

(4) With the exception of Paravicinni's and Nickup, there is evidence that the plants within all the rehabilitation areas are beginning to flower. A number of the *Acacia spp* and some of the *Eucalyptus spp* and several other understorey species had set seed over the 2004-05 spring summer period. This is consistent with the criteria for this parameter.

(5) Fauna species are also utilising the rehabilitation to some degree. Kangaroos were seen foraging throughout. Bird species are particularly prominent with many parrots and magpies present along with smaller species such as fantails and willy wagtails. This is consistent with the completion criteria for this parameter. Also, many invertebrates were observed, suggesting that an ecology was developing in the rehabilitation areas,

(6) Weed burden in the Stansfield, Paraviccini's, LoGrandes, Peppermint Park and Nicklup rehabilitation areas is above that set out in the established completion criteria. These high levels of weed burden are

almost certainly responsible for the poor levels of understorey development and direct seeding success seen in these areas. Residual nutrient build up within the soil may also be responsible for some poor results although this is not clear. In areas where weeds are not a problem understorey development and direct seeding success is much higher.

(7) High levels of weed infestation and in particular annual weeds in many areas will result in some degree of fire hazard throughout the site. Maintenance of firebreaks and continued strategic mowing in accessible areas showing high levels of grass weeds should reduce the fire hazard risk enough so that if a fire did occur it could be contained and controlled. The introduction of controlled grazing into the area could help to reduce the weed burden and help reduce the overall fire hazard risk within the rehabilitation areas.

(8) Erosion throughout the site is minimal even below the FSL. All areas appear to comply with the established completion criteria for erosion at the time of monitoring.

3. INTRODUCTION

Stirling and Harvey dams are located approximately 125kms south of Perth near the town of Harvey. Recently both of these dams have been upgraded as a part of the WC's SHRS initiative.

As a part of the WC's environmental commitment P17 under the SHRS the Stirling Harvey Redevelopment Scheme Environmental Offset, Vegetation Protection and Rehabilitation Management Plan (RMP) was drawn up.

The implementation of the RMP has seen the WC conduct large-scale rehabilitation activities within the immediate catchment of the Harvey Dam between 1999 and 2003. Rehabilitation activities within the immediate catchment of the Stirling Dam began in 2003. Since 1999 272 hectares of land has been rehabilitated around the Harvey and Stirling Dams.

The WC's Harvey Dam Project Team was responsible for conducting the rehabilitation works around the Harvey Dam. Ongoing maintenance and reporting of rehabilitation progress is the responsibility of the WC South West Region (SWR).

In May 2003 GHEMS were commissioned by the WC to undertake monitoring of rehabilitation sites around the Harvey dam over a 5 year period as part of the RMP. Monitoring is an essential part of any rehabilitation project, providing valuable feedback on the success or otherwise of both planting and direct seeding. Monitoring in 2004 through to 2007 will take place in February.

It is the purpose of this report to detail the findings of the 2004 monitoring activities and to compare them to the existing completion criteria set out in the RMP. Where the rehabilitation falls short of the rehabilitation completion criteria, management improvements are recommended.

This report will be used by the SWR to conduct WC reporting as required and as a resource for annual maintenance programs.

4. MONITORING METHODOLOGY

Monitoring of the SHRS rehabilitation areas has been conducted in accordance with the methodology and specifications set out in Schedule 3 – Scope of Services of the Tender Document (TD) for this task. Details of Schedule 3 from the TD can be found in Appendix 1 of this document.

All monitoring data has been collected specifically with the view to comparing it with the existing completion criteria for rehabilitation forming part of the RMP.

The general format of the monitoring is set out below.

4.1. Monitoring plots

The Water Corporation has positioned (23) established monitoring plots throughout the specified rehabilitation areas of the SHRS. The spread of monitoring plots within the rehabilitation areas is as follows:

Water Corporation Reference Area	Plot No.	Rehabilitation Year
Stirling – Harvey Pipeline	M1-M5	2000
Peppermint Park	M6-M13	2000
Chidlows West	M14	2001
Glentana	M15-M17	2001
LoGrandes	M18-M19	2002
Mummerts/Mellors Gravel Pits	M20-M21	2002
Paravicinni's	M22	2002
Nicklup	M23	2002

All monitoring plots are currently 9m x 9m in size except for the 5 Stirling Harvey Pipeline plots which are 27m x 3m. Each monitoring plot was assessed for native species representation, number of native stems present, degree of native establishment and maturity, fauna utilisation, percentage weed cover, soil stability and fire hazard risk. The number of Peppermint (*Agonis flexuosa*) stems within each of the Peppermint Park monitoring plots were also counted.

GPS points were taken at each of the plots to aid in their location during further assessments along with photographs. Photographs are included in Section 9 of this report. GPS points are listed in Appendix 4.

4.2. Transects

For monitoring this year (2004), 24 transects ranging in length from 30m – 200m by 3m wide were assessed. The same 23 transects used last year were used again this year with one additional transect being added in the Stansfield Rd area. The details of transects within each of the rehabilitation areas are as follows:

Water Corporation Reference Area	Transect No.	Transect Length
Mummerts/Mellors	T1-T3	3*100m
Paravicinni's	T4-T6	3*100m
Glentana	T7-T9	3*100m
LoGrandes	T10-T11	1*200m, 1*100m
Chidlows West	T12-T13	2*100m
Peppermint Park	T14-T16	1*150m, 2*100m
Nicklup	T17-T20	1*130m, 1*100m, 2*30m
Stirling-Harvey Pipeline	T20-T23	3*100m
Stansfield Rd	T24	1*100m

Each transect was traversed on foot. For each transect, an assessment was made of species representation and the number of seedlings derived from direct seeding operations. Subjective assessments of seedling health, survival and maturity, weed burden and fire hazard risk and erosion were also made.

During the transect assessments general observations and notes were made on the utilisation of the rehabilitation by native fauna (ie fauna sightings, presence of scats). No other monitoring was carried out with regard to fauna utilisation within the rehabilitation areas.

The start and end point of each transect was pegged and flagged and GPS points taken in order to aid in their location during further monitoring. An estimation of the bearing of each transect from the start point was taken using a compass. Photographs of the start point of each transect are included in Section 10 of this report. GPS points are listed in Appendix 4.

4.3. Monitoring Data Evaluation

Once the monitoring data had been collected it was collated and some basic calculations done to try and gain an overall insight into the rehabilitation success or otherwise within the SHRS area when compared to the established completion criteria. The following parameters were calculated:

4.3.1. Percentage Species Representation

This has been calculated by dividing the number of species present within the monitoring plots of those planted/seeded by the total number of species that were planted and/or seeded within the plot or transect originally. This parameter gives an idea of how the plot is performing in terms of species diversity with regard to the completion criteria.

4.3.2. Percentage Understorey Species

In order to gain an idea of the overall development of strata within the rehabilitation, the percentage of understorey species present in the monitoring plots and transects has been calculated.

This parameter was calculated by dividing the number of understorey species present of those seeded with the total number of species seeded originally. This figure was then converted to a percentage.

4.3.3. Approximate Stems per Hectare

The number of native stems present in each monitoring plot were counted and an estimation made from this of the number of stems that are likely to occur per hectare in the surrounding area. This gives an idea of how each rehabilitation area is doing in relation to the existing completion criteria for this parameter.

In addition to this the number of Peppermint (*Agonis flexuosa*) stems present within each of the Peppermint Park monitoring plots were counted and from this an estimation made of the likely number of Peppermint stems per hectare. From this a direct comparison can be made with regard to the established completion criteria for this rehabilitation area.

4.3.4. Number of Seedlings Derived from Direct Seeding

In order to determine the success of direct seeding activities in the rehabilitation areas as opposed to planting, the number of seedlings likely to have been derived from direct seeding activities were counted and compared to the completion criteria. A final figure was calculated showing the number of seedlings derived from direct seeding per $9m^2$.

This data has been derived from the results of the transect monitoring.

4.3.5. Weed Burden and Fire Hazard Risk

Weed burden within each of the rehabilitation areas was assessed by estimating the percentage cover of weeds within each of the monitoring plots. A subjective visual assessment of weed burden was made for each transect and field notes taken.

The weed burden occurring on exposed areas below the full supply level (FSL) was assessed in a similar manner to that of the transects.

In assessing fire hazard risk an assessment protocol was followed as specified in Hussey and Wallace (1993). This protocol assesses factors relating to likelihood of ignition, type and quantity of flammable material, continuity of fuel bed, topography and frequency of hazardous fire weather and availability of suppression forces.

4.3.6. Soil Stability

The soil stability within each monitoring plot and transect was assessed visually for signs of erosion and general degradation.

5. RESULTS

Raw monitoring results for the monitoring plots and transects can be found in Appendices 2 and 3 of this report. A summary of the average results for both the monitoring plots and the transects appear in Tables 1, 2 and 3 below. In order that a comparison of results can be made, a summary of the current established completion criteria relevant to the age of the rehabilitation that was assessed is outlined in Table 4 below.

TABLE 1 SUMMARY OF MONITORING PLOT RESULTS

SHRS Rehabilitation Monitoring 2005 Monitoring Plot Results (Mean)								
WC Reference Area	Rehab Year	Total spp planted / seeded	Max Tree height (m)	Total native spp rep	Spp rep of total spp planted / seeded	% Spp rep of total spp planted / seeded	Approx stems per hectare	% Weed cover
Stirling-Harvey Pipe	2000	32	5.1	14	12	36%	>6000	<5
Peppermint Park	2000	187	6	3	3	2%	1065	91
Chidlows	2001	45	6	6	6	15%	1235	60
Glentana	2001	45	7.3	13	12	30%	>6000	<5
LoGrandes	2002	45	6.5	9	9	23%	2901	97.5
Mummert/Mellor	2002	39	5	11	9	27%	3704	<5
Paravicinni's	2002	45	5	6	6	15%	2099	90
Nicklup	2002	45	5	5	5	12%	1481	100

TABLE 2 SUMMARY OF TRANSECT RESULTS

SHRS Rehabilitation Monitoring 2003 Transect Results (Mean)							
WC Reference Area	Rehab Year	Total No. spp seeded	Total spp rep of those seeded	% spp rep of total spp seeded	Understorey spp rep of those seeded	% Understorey rep of total spp seeded	Approx seedlings derived from seed / 9m^2
Stirling-Harvey Pipe	2000	32	14	45%	11	34%	>8
Peppermint Park	2000	182	3	2%	1	1%	0.4
Chidlows	2001	39	9	24%	8	19%	0.4
Glentana	2001	39	3	9%	2	4%	2
Stansfield Rd	2001	39	13	33%	10	26%	>5.4
LoGrandes	2002	39	12	31%	8	21%	1.8
Mummert/Mellor	2002	31	12	40%	8	26%	>2.5
Paravicinni's	2002	39	5	15%	3	7%	0.8
Nicklup	2002	39	3	8%	2	4%	0.2

TABLE 3 SUMMARY OF OBSERVATIONS AND COMPARISON OF RESULTS WITH COMPLETION CRITERIA

WC Reference area	Rehab Year	Meets criteria for no. of stems/ha	Meets criteria for no. of peppermint stems/ha	Meets overstorey height criteria	Meets seed germination criteria	Meets understorey diversity criteria	Meets weed coverage criteria	Resilience to fire	Significant erosion evident	Plants beginning to flower and set seed	Evidence of fauna utilizing area
Stirling-Harvey pipe	2000	Yes	N/A	Yes	Yes	No	Yes	Low	None seen	Yes	Yes
Peppermint Park	2000	Yes	Yes	Yes	No	No	No	Medium	None seen	Yes	Yes
Chidlows	2001	Yes	N/A	Yes	Yes	No	Yes	Low	None seen	Yes	Yes
Glentana	2001	Yes	N/A	Yes	Yes	No	Yes	Low	None seen	Yes	Yes
Stansfield Rd	2001	Yes	N/A	Yes	Yes	No	No	Medium	None seen	Yes	None seen
LoGrandes	2002	Yes	N/A	Yes	Yes	No	No	Medium	None seen	Yes	None seen
Mummerts/ Mellor	2002	Yes	N/A	Yes	Yes	No	Yes	Low	None seen	Yes	Yes
Parravicinni's	2002	Yes	N/A	Yes	No	No	No	Medium	None seen	None seen	Yes
Nicklup	2002	Yes	N/A	Yes	No	No	No	medium	None seen	None seen	Yes

N/A – Not Applicable

TABLE 4 SUMMARY OF THE HARVEY DAM REHABILITATION ESTABLISHED COMPLETION CRITERIA

parameter	1 year	3 years	5 years	10 years
Soil stability	- soil erosion - minimal - sediment movement – minimal -impact on downslope areas and streams to be minimal	- no soil erosion, sediment movement or water turbidity evident	- as for year 3	- as for year 5
Plant cover	- Forrestfield and buffer areas >= 400 native stems/ha - Peppermint Forest - >= 400 peppermint stems/ha - Average establishment of 1 native seed/9m^2 in any one area and areas greater than 250m^2 must show evidence of the establishment of at least one native seed	- Forrestfield and buffer areas >= 400 native stems/ha - understorey diversity = 50% of seeded species - Peppermint forest >= 400 pepperimint stems/ha - overstorey height > 1m in height	- Forrestfield and buffer areas >= 400 native stems/ha - Understorey diversity >= 70% of seeded species - Peppermint forest >= 400 peppermint stems/ha - Peppermint growth to be > than understorey - overstorey >2m in height	- Forrestfield and buffer areas >= 400 native stems/ha - understorey diversity >= 90% of seeded species - peppermint forest >= 400 peppermint stems/ha - peppermints to represent > 70% of overstorey - understorey cover < than that for year 5 - overstorey > 4m in height
Resilience of vegetation	- no area > 250m^2 demonstrating serious setback - rehab must be progressing to a stage whereby it can recover from natural stresses	- as for year 1	- as for year 3	- as for year 5
Weeds	- weeds <5% of ground cover - no significant impairment of native growth by weeds on areas larger than 250m^2	- no significant impairment of native growth by weeds on areas larger than 250m^2 - weed growth to represent no serious fire hazard on areas larger than 250m^2 - declared weeds to be less than No. allowed by Ag WA	- as for year 3	- as for year 3
Fire resilience	- rehabilitation areas not to present increased fire risk due to patterns of vegetation development	- as for year 1	- as for year 1	- as for year 1
Recruitment of fauna	- none applied	- presence of evidence that fauna is utilizing rehabilitation areas - understorey seedlings beginning to flower	- presence of evidence that fauna is increasingly utilizing rehabilitation areas - seedlings to be flowering and setting seed - leaf litter to build up, nutrient cycling beginning to occur	- as per year 5 - nutrient cycling recurring - seedlings to be flowering and setting seed - leaf litter beginning to build up and be >= 10mm deep
Ecological processes	- none applied			

5.1 Species Representation

5.1.1. Monitoring Plots

As was seen in the 2003 and 2004 monitoring, the Stirling- Harvey Pipeline rehabilitation area followed by the Glentana rehabilitation area have the highest species representation, showing an average of 36% and 30% respectively of species sown and planted. These results are very similar to those seen in 2004 and if anything show a slight improvement. Again the Peppermint Park area followed by the Nicklup area had the lowest levels of species representation with 2% and 12% respectively.

5.2. Understorey Species

Calculations were made to determine the percentage make-up of understorey species present within each transect of those that were seeded originally. These calculations suggest that the Stirling-Harvey Pipeline Stansfield and Mummerts/Mellors rehabilitation areas have the highest development of understorey species from seed, with the former having an average of 34% and the other two areas having 26%. Peppermint Park had the lowest average understorey development with only 1%.

5.2.1. Approximate Stems per Hectare

The approximate stems per hectare were highest in the Stirling-Harvey Pipeline and Glentana rehabilitation areas with >6000 stems per hectare expected. Mummerts/Mellors and Lograndes were next with >3704 and >2901 respectively. Paravicinni's and Nicklup were all next with between 2099 and 1481 stems per hectare while Chidlows West and Peppermint Park showed the lowest stems per hectare with 1235 and 1065 stems per hectare expected respectively.

Part of the specifications for this monitoring survey required that the average number of Peppermint stems per hectare within the Peppermint Park rehabilitation area be calculated. As per the results of the 2003 monitoring results from the 8 monitoring plots within the Peppermint Park area suggest that on average there are approximately 5 stems per $81m^2$. This equates to be on average, approximately 617 Peppermint stems per hectare.

5.2.2. Flowering in the Understorey

There is evidence that understorey species are flowering. A number of species including *Juncus pallidus, Paraserianthes lopantha*, *Acacia extensa, Acacia saligna, Acacia pulchella* and *Sollya heterophylla* have set seed in the 3.5 year old and 4.5 year old rehabilitation areas which is encouraging and consistent with the completion criteria for this attribute.

Number of Seedlings Derived from Direct Seeding

The average figures for the number of seedlings derived from direct seeding per $9m^2$ show that the Stirling-Harvey Pipeline area and the Stansfield Rd area have the best results from native seed with >8 seedlings/$9m^2$ and >5.4 seedlings per $9m^2$ seedlings derived from seed respectively. The other areas show reasonable results except for Nicklup and Peppermint Park that show on average 0.2 seedlings per $9m^2$ and 0.4 seedlings per $9m^2$ respectively.

As can be seen in Table 1 above, in two of the rehabilitation areas there has been recruitment of a number of native species from seed stocks either contained in the topsoil or dispersed to these sites from other areas by wind, water or wildlife.

5.3. Weed Burden

5.3.1. Monitoring Plots

The visual assessment of weed burden within each monitoring plot suggest that the Nicklup, Peppermint Park, LoGrandes and Paraviccini's rehabilitation areas are all heavily infested with weeds. The observed weed cover in these areas varied between 90% and 100%. Chidlows West was also very high, with an average of 60% weed cover.

Within the Stirling Harvey Pipeline, Mummerts/Mellors and Glentana monitoring plots weed burden was quite low and on average was <5% for each plot.

5.3.2. Transects

Similar results with regard to weed burden to those found in the monitoring plots were observed within the transect areas.

5.3.3. Weed Burden below the FSL

As can be seen in the general site photos in Section 10 of this report, couch grass is beginning to establish in many areas below the FSL. Weed species of note that have previously been identified below the FSL (eg Cotton Bush) appear to have died off and in some areas appear to have completely disappeared (eg below the FSL in Paraviccini's rehabilitation area).

Blackberry bushes have been noted below the FSL in the creekline adjacent to Stansfield Rd. Most of these bushes are quite large and should be controlled to reduce their spread. Some Apple of Sodom was noted along the creekline at Nicklup and should also be controlled.

5.4. Soil Stability

Soil erosion in general throughout all of the rehabilitation areas is at least at the time of this assessment not of great concern. There was little evidence of significant rill, gully of sheet erosion and damage from wind erosion was not evident.

5.5. Fire Hazard Risk

Hussey and Wallace (1993) have set out a fire threat analysis protocol that details a number of steps that should be gone through to assess the risk of fire to bushland areas. A subjective assessment using this protocol has been completed generally for the whole of the SHRS rehabilitation areas around the Harvey Dam and is as follows:

(1) Likelihood of ignition: Likelihood of ignition through natural means is low according to Hussey and Wallace (1993) and this is probably the case within the SHRS rehabilitation areas.

Ignition by anthropological means is more likely with the Harvey dam being a tourist attraction of sorts and also due to the presence of a relatively heavily trafficked road (ie the Harvey – Quindanning Road) running along the southern edge of the rehabilitation sites.

Ignition by the errant cigarette butt thrown from a window or from recreational users around the dam may be quite likely particularly over the summer period when recreational use is likely to be quite high and annual weeds have died off adding to potential fuel levels.

(2) Type and Quantity of Flammable Material: Hussey and Wallace (1993) note that grass weeds are the chief concern with regard to fuel loading in any area as they are extremely flammable once dry.

The high levels of weeds such as rye grass and wild oat within the rehabilitation areas constitutes a high risk as once a fire gets hold it will burn fiercely and be very damaging to young and establishing plants.

Peppermint Park in particular has a high level of infestation of these types of weeds.

(3) Continuity of fuel bed: Gaps between populations of weeds and other plants will slow the fire front according to Hussey and Wallace (1993). Firebreaks are important in this regard.

Most of the SHRS rehabilitation areas constitute relatively large continuous areas of rehabilitation that have been compartmentalised by a single firebreak. This means that if a fire where to start it may burn out a single block but could probably be controlled and its spread to other compartments avoided. Problems may arise where firebreaks are not maintained properly.

Observations from the monitoring this year suggest that firebreaks throughout the site were being maintained to a suitable degree.

There are a number of major roads throughout the rehabilitation areas that could also act as fire breaks. Examples include the gravel road 8 – 10 metres wide running through Peppermint Park, Stansfield Road and the Harvey Quindanning Road. The reservoir itself acts as a firebreak and also as a water resource for fire control.

Mowing has occurred below the FSL in some areas over the 2003/2004 spring-summer period. This will have served to at least reduce the burning speed and intensity of a fire if one were to occur.

(4) Topography: Fires spread much more quickly up steep slopes and are difficult to control in rough or steep topography according to Hussey and Wallace (1993).

Most of the areas in the immediate vicinity of Harvey Dam itself are only relatively mildly sloping. Problems will arise in areas such as Peppermint Park where there is a high level of grass weeds in combination with steep slopes. Weed suppression where feasible and proper maintenance of fire breaks in such areas are important to avoid destructive fires.

(5) Frequency of Hazardous Fire Weather and Availability of Suppression Forces: Harvey is well within the Mediterranean climate zone of the South West region of WA where long, hot, dry summers are expected. High Fire danger can be expected from December through too mid autumn (ie April) in some years depending on rainfall.

This combined with a likely high usage of the dam area over summer for recreational purposes means that fire danger might be quite high. Local volunteer bush fire brigades and fire fighting units from CALM etc are within close proximity to this area and should be on the scene quickly to suppress any fires that may occur.

5.6. Insect Attack

Leaf Miner/Thrips were observed on many of the trees along the transects and within the monitoring plots in a number of rehabilitation areas, particularly the Nicklup, Chidlows and LoGrandes areas. Some significant leaf damage was noted.

5.7. Fauna Utilisation

Fauna species are also utilising the rehabilitation to some degree. Kangaroos were seen foraging throughout. Bird species are particularly prominent with many crows, parrots and magpies present along with smaller species such as fantails and willy wagtails. A pair of swans were also observed in the Harvey dam (Section 11, photo 1). This is consistent with the completion criteria for this parameter. There is however evidence of pig diggings and droppings in Peppermint Park, although this damage is minimal.

A large diversity of both herbivorous and predatory invertebrate fauna were observed to be present throughout all the areas – including ants, butterflies, cicadas, grasshoppers, lerps, leaf minors, stink bugs and christmas and orb spiders. Many of these invertebrates were observed in Mummerts/ Mellors Gravel Pit. This indicates that an ecology is beginning to develop throughout the rehabilitatation areas.

6. OBSERVATIONS/DISCUSSIONS

Observations and discussions will be carried out in relation to the year each rehabilitation area was completed and in accordance with the corresponding completion criteria set out in the RMP.

6.1. Two and a Half Year Old Rehabilitation

Paraviccini's, Mummerts/Mellors, Lograndes and Nicklup are all areas that were rehabilitated in 2002. A discussion of the current status of these areas follows:

6.1.1. Soil Stability

Soil stability was good throughout the 2.5 year old rehabilitation areas with few visible signs of either channel erosion, sheet erosion or wind erosion. It would appear that once rainfall hits the ground it is absorbed quite quickly with minimal runoff. This is probably due to good surface preparation in the form of deep contour ripping, a generally high level of annual and in some cases perennial weed cover and a degree of establishment from planted native species. Soil erosion in these rehabilitation areas is not at the moment of major concern.

6.1.2. Plant Cover and Weeds

The 4 areas rehabilitated in 2002 all have a calculated average number of stems per hectare greater than the completion criteria of 400. Mummerts/Mellors gravel pits and LoGrandes show on average a level of direct seeding establishment higher than the established criteria of 1 seed per $9m^2$.

Mummerts/Mellors

The Mummerts/Mellors gravel pits also showed the highest average number of stems per hectare with more than 3704 expected. However this data is somewhat misleading in that the monitoring plot in the western section (ie around M21) showed very good results in terms of stems per hectare. The section surrounding M20 and the section toward the eastern side of the dosing plant did not show such good results and in fact were quite poor. The good results recorded near M21 tended to elevate the average results for this rehabilitation area.

The same can be said of the data collected for the species represented of those planted/seeded for this area and the percentage make-up of understorey species with the section surrounding M21 showing relatively good results and the other sections showing poorer results.

In the sections surrounding M20 and to the east of the dosing plant, *Eucalyptus* species, *Acacia latericola* and *Acacia pulchella* dominate with few other species being present. Species diversity is quite poor, as is the development of a range of vegetation strata within the area. The section adjacent to M21 on the other hand has a broad range of species present (not just tree species) and with further establishment is likely to develop relatively diverse strata within the plant community.

The average percentage of weed cover in the Mummerts/Mellors rehabilitation areas was at the time of monitoring below 5%. The section around M21 showed levels of weed infestation <5% when compared to the section east of the dosing plant and near M20. The M21 site is elevated and surrounded by relatively natural bushland and the weeds have not had the chance to establish where as the section surrounding M20 and the dosing plant that has a history of weed invasion being allowed to go unchecked prior to rehabilitation activities.

Weed species present in this rehabilitation area are mostly oats, rye and inkweed with a proportion of other species such as nightshade, cotton bush and couch grass. The annual grass species have finished their seasonal cycle and are now for the most part dead however these plants are likely to re-emerge from seed again next winter.

Pasture weed infestation in this section of Mummerts/Mellors along with the proximity to water and remnant bush has led to a large number of kangaroos inhabiting the area. They are no doubt having a negative effect on rehabilitation success in that they will be grazing on natives as well as palatable weed species.

Nicklup

Nicklup has on average one of the lowest results, being second lowest in number of stems per hectare and % understorey species and equal lowest in species representation with Peppermint Park. On average only 3 native species were recorded at this site and of these there were minimal understorey species present. *Eucalyptus spp* and *Agonis flexuosa* dominate the area. Results of direct seeding in this area were lower than expected and were well below the completion criteria of plant establishment from 1 seed per 9m2. On average only 0.2 seedlings derived from direct seeding were present per $9m^2$. Most plants present in this rehabilitation area have been planted as seedlings.

Weeds are a major problem at Nicklup with 100% weed coverage identified over most of the area. The majority of the weeds identified are perennial and invasive such as rye, oats, Couch and Kikuyu grasses and some dock weed and inkweed. These are particularly prevalent on the eastern side of the Nicklup area. These weeds have the potential and in fact are currently displacing and preventing native species establishment especially with regard to establishment from direct seeding. This type of weed infestation is directly attributable to this areas poor results with regard to direct seeding success and in turn plant diversity and likely stratum development and overall plant community structure.

Paravicinni's and LoGrandes

These two rehabilitation areas showed similar results with regard to stems per hectare, species representation and the percentage of understorey species. On average 6 species were represented per $81m^2$ in the Paravicinni's area, while an average of 12 species were represented in the LoGrandes area. These were generally made up of *Eucalyptus species* and *Agonis flexuosa,* with limited *Juncus pallidus*, *Acacia* and *Melaleuca spp.* making up the understorey. On the whole there appears to be a dominance of over-storey trees that have been planted and little in the way of understorey or mid storey species.

The percentage of weed cover was quite high in both these areas averaging between 90 and 97.5%. Mostly weeds were made up of pasture species such as couch, and kikuyu grasses, rye grass, wild oats and goosefoot. Cotton bush was also observed in both areas. The annual species have mostly died off over the summer period leaving a thick mat of material on the surface. LoGrandes was also observed to have large plants of Apple of Sodom present whenever the canopy was open.

The shear volume of annual weed species present in these areas though has no doubt led to the generally poor results that have been seen here particularly in terms of direct seeding success. It appears likely that a good overstorey will develop but understorey and midstorey species will be limited.

6.2. Three and a Half Year Old Rehabilitation

Chidlows West and Glentana are both rehabilitation areas that were planted and seeded in winter 2001. Slightly different completion criteria apply to these areas as they are now over three years old A discussion of the current status of these areas follows:

6.2.1. Soil Stability

Soil stability in both these rehabilitation areas is very good with little evidence of channel erosion, sheet erosion or wind erosion. As with the areas rehabilitated in 2002 site preparation in terms of contour ripping as well as weed establishment and general native plant establishment has meant that the soil is well held in place and that rainfall is quickly absorbed into the soil.

6.2.2. Plant Cover and Weeds

These two rehabilitation areas both have a calculated number of stems per hectare greater than the completion criteria of 400. However the Glentana area shows on average approximately four times the number of stems per hectare than Chidlows West within the monitoring plot at least. The monitoring plot results also tend to suggest that species representation in the Chidlows West area is much lower than that of the Glentana area.

Data derived from the monitoring plots also suggest that understorey development within the Glentana area is higher than that of the Chidlows West area. Glentana showed on average 18% of understorey species of those that were seeded originally while Chidlows West had only 5%.

This difference was also noticed when comparing with data collected from the transects. Transect data within both areas show on average, 2 Glentana was higher with 2 calculated seedlings derived from seed per $9m^2$, compared to Chidlows only having 0.4 per 9m2. However, Chidlows West has a greater number of understorey species that were direct seeded (26%) whereas Glentana only had 4%.

There are three monitoring plots and three transects within the Glentana area whereas in the Chidlows area there is only one monitoring plot and 2 transects. This may have had a bearing on the results as the one monitoring plot within Chidlows may be located in an area that does not show as good results as the surrounding area and is therefore not typical.

The observation that a number of species of understorey species are flowering and setting seed is encouraging in that it shows that plants are beginning to mature. A soil seed bank will begin to build up and given time new recruitment of native may begin to occur. A major disturbance such as a fire may be necessary to really encourage these seeds to germinate.

Results from the monitoring plots suggest that % weed cover in these 2 areas is also different; Glentana was low at <5% while Chidlows West was high at 60%. The difference in weed cover could be partially responsible for the different levels of direct seeding success seen within these two rehabilitation areas.

6.3. Four and a half Year Old Rehabilitation

The Stirling-Harvey Pipeline (SHP) and Peppermint Park areas were rehabilitated in winter 2000. A discussion of the current status of these areas follows:

6.3.1. Soil Stability

Soil stability within these areas is good. Again contour ripping, weed establishment and general native species establishment has meant that the effects of water runoff and wind are minimal.

The access track through the SHP and Peppermint Park areas is showing a degree of rill erosion in places and this will need to be monitored to ensure that the track remains in a useable state of repair.

6.3.2. Plant Cover and Weeds

These two rehabilitation areas both show an approximate number of stems per hectare greater than that of the completion criteria of 400 stems per hectare. However the percentage of understorey species represented of those seeded varies quite markedly with SHP showing on average 34% representation of those species seeded but still no where near the completion criteria of 50% while the PP area shows only 1%.

Peppermint Park shows an average overstorey height of around 6 metres while SHP shows a slightly lower average height of approximately 5.1m. Both areas exceed the completion criteria of between 1-2m.

Peppermint Park

The Peppermint Park rehabilitation area also has a requirement of on average between 400 and 800 Peppermint (*Agonis flexuosa*) stems per hectare. The average number of Peppermint stem calculated from data collected from the monitoring plots are 617, which complies with the completion criteria.

On the whole the results of direct seeding in this area are poorer than expected with an average of only 0.4 plants per $9m^2$ that can be attributed to direct seeding. This is equivalent to approximately 444 plants derived from seed per hectare. Species representation is also quite poor with only a 2% species representation of those that were seeded/planted.

Eucalypt spp and *Agonis flexuosa* dominate this rehabilitation area with very little in the way of understorey species coming through. In some areas *Acacia saligna*, *Acacia pulchella*, *Juncus pallidus* and *Melaleuca inccana* are common, but this is about the limit of understorey diversity. Given that this rehabilitation area was seeded and planted 3 years ago a much higher degree of strata development within the community should be evident by now.

Two sites show much lower results than would be expected in terms of both overstorey and understorey development. The sections adjacent to M6 and M13 show stunted development of both *Eucalypt spp* and *Agonis flexuosa* with very little in the way of understorey species being present. Some infill planting has occurred in these areas in subsequent years and this may help to explain why some of the tree species are stunted in comparison to adjacent areas.

Percentage weed cover in this area is almost always 100%, with the exception of monitoring plot being only 50%. Pasture weeds dominate to such a degree that they are no doubt having a negative impact on revegetation success particularly with regard to understorey development from direct seeding.

Stirling – Harvey Pipeline

This rehabilitation site shows consistently the best results with regard to the 5 monitoring plots located here. On average over 6000 stems per hectare can be expected along this corridor. Given that this area was seeded with native mix at 2kgs per hectare and not planted these results are very good. On average 36% of species seeded are represented. Well over a half these species represented are understorey species.

Although not reaching the required completion criteria of 50% understorey species of those seeded within this area, it would appear

that these figures are very encouraging considering that in most areas there is a tendency for 1 or 2 species to dominate. In particular, *Darwinia citriodora* and *Grevillea diversifolia* dominate and may in fact be excluding or reducing the establishment of other species. This may explain why the diversity of understorey is not greater, as would be expected.

Generally weed cover along the SHP is quite low. Most are annuals and have died off over the summer period. Consequently weed cover is 5% or less in all areas. Couch grass, rye, oats, cotton bush and broomrape were occasionally observed but are no real threat to the rehabilitation now that it is establishing well.

6.4. Resilience of Vegetation to Weeds, Fire and Disturbance

A general overview of all rehabilitation areas follows with regard to their resilience to weed invasion, fire and other disturbances.

6.4.1. Resilience to Weeds

Hussey and Wallace (1993) note that high levels of invasion of annual weeds generally leads to a very poor result with regard to direct seeding due to competition for space, nutrients, moisture and light. Weeds can change the soil acidity and it's nutrient cycling capability which may also have negative impacts. They also note that in one trial the presence of annual weeds effectively reduced native seedling survival to nil following the first summer after direct seeding activities took place.

Hussey and Wallace (1993) also note that weed species such as wild oats (*Avena spp*) will compete with natives very vigorously and will reduce their growth and development. They suggest that native plant regeneration will almost certainly fail if wild oats are not removed.

Weeds and in particular annual weeds are of concern within the rehabilitation areas of the SHRS particularly with regard to understorey development and direct seeding success. Weeds are no doubt reducing understorey development and in some cases are also reducing the establishment of planted seedlings.

Wild oats along with many other annuals are a major problem in the Peppermint Park rehabilitation area particularly around M6 and M13. A photo appearing in the General Site Photo's section (ie Section 11) of this report show this clearly. This may be the reason why in some areas, overstorey as well as understorey species are not performing well and appear somewhat stunted.

High levels of weeds can also harbour insect pests such as red legged earth mite and cut worm. These pests can seriously reduce the strike rate of germinating seedlings.

These observations are supported in that areas that have relatively low levels of weed infestation such as the sections adjacent to M21 and M1-M5 show higher success rates in terms of direct seeding success and understorey development.

A high percentage of the revegetation areas within the SHRS rehabilitation project have a history of use as pastureland and will have a high weed seed bank built up within them. This weed seed bank has been encouraged to establish due to the high degree of disturbance that has taken place during revegetation activities (ie deep ripping etc).

Given these two factors it is unlikely that these areas will develop any resistance to weeds until a degree of overstorey has developed to shade out the weeds and add a layer of native mulch over the surface. Without high levels of weed control the results of further direct seeding to improve understorey development are likely to be poor.

6.4.2. History of Fertiliser Use

Given that a high percentage of the area being rehabilitated in the SHRS project has a history of use as pastureland, it is reasonable to assume that there has also been a history of use of fertilisers. Products such as Super Phosphate may have been used to keep pasture in a condition suitable for animal grazing and hay production etc.

Main (1993) notes that within soils of low nutrient status, mycorrhiza (symbiotic fungi) are important in providing significant nutrient pathways. He suggests that phosphorous within the soil can be toxic especially to native plants. Main (1993) also notes that phosphorous in the soil can depress mycorrhizal development and plants with mycorrhiza are often more resistant to disease than those without.

Main (1993) suggests that given the above, plants re-introduced to land that has formerly been cultivated, may be exposed to sufficient residual phosphorous to inhibit mycorrhizal formation. He suggests that if this occurs then native plants may die, become prone to disease or fail to establish completely.

This factor may be a significant in the poorer establishment rates seen amongst native species within the rehabilitation areas of the SHRS previously used for pasture land, particularly with regard to direct seeding success and understorey development.

6.4.3. Resilience to Fire

With the high levels of weed establishment particularly annual weeds in many of the SHRS rehabilitation areas, if a fire should start by either natural or by anthropological means, it would most likely be very damaging to the rehabilitation.

Given the pastureland history of the rehabilitation areas and the fact that the native plants in most areas are not at a stage whereby they have set and dispersed seed, it is unlikely that there would be any surviving native seed within the soil. Even planted overstorey species that are 3 years old and quite well established may not survive a hot fire, as their trunk development will not be sufficient to withstand intense heat. It could be assumed that given the rehabilitation in the SHRS area is young and has not reached maturity a fire would no doubt destroy rehabilitation with little chance of regeneration.

Peppermint Park in particular is at risk of uncontrollable fire damage. The relatively steep slopes and high levels of grass weeds mean that if a fire were to occur here it could be potentially hard to control and very damaging to rehabilitation. These identified risks are countered to a degree by the fact that the Water Corporation has, in conjunction with the Shire of Harvey and the Harvey Hills Fire Brigade placed a fire hydrant on the Stirling – Harvey Pipeline in Peppermint Park. Public access to this area has also been restricted.

Property and infrastructure within the SHRS area that could be under threat from a fire are those private dwellings in close proximity to the rehabilitation area along with infrastructure associated with the dam itself (eg the dosing plant). In general, given that firebreaks bound all areas, suppression resources are available and access points are adequate, if a fire should occur, it could be controlled and damage minimised.

In addition to maintenance of firebreaks, practices such as mowing in the buffer zone areas should continue as this serves to tidy these areas up and should help to reduce the intensity and speed with which a fire would burn if one did occur. Mowing of road verges and any large open pasture areas should be considered for the same reasons.

6.4.4. Other Disturbances

Given that the Harvey dam is not a drinking water supply dam and recreational activities allowed to take place here are limited, further pressure may be put on the area through access by the general public (ie access by off-road vehicles and trampling etc). Access by the general public should be well controlled with appropriate signage and barriers etc to limit access to rehabilitation areas.

Grazing pressure from animals such as kangaroos should be limited particularly in the first few years following planting and seeding. This is currently being addressed by a local shooter and should continue.

Ground disturbance from wild pigs has been observed in the Peppermint Park area and their digging of the ground in search of invertebrate food sources may be adversely affecting the root zone of new germinants.

6.5. Fencing

Part of the TD required that fence lines be inspected to make sure that all fences are in good order. During the course of monitoring, cattle were observed in the Peppermint Park rehabilitation area and in the Chidlow's rehabilitation area. A deer was seen in the rehabilitation area adjacent to Stansfield Rd. Cow pats were also seen on the access tracks in state forest adjacent to the Stirling Dam.

It is unclear how cattle have come to be present in areas adjacent to Stirling Dam however upon further inspection a large gap where the fence posts had been pulled from the ground due to excess wire tension was found on the south east side of the Chidlows area. Although no hole could be found within the Peppermint Park fence lines it is likely that cattle may be gaining access through an old section of fence line on the eastern side of this area.

6.6. Erosion below the Full Supply Level (FSL)

Part of the TD required that areas below the FSL were inspected to ensure that erosion was not presenting a problem. Observations of the area below the FSL suggest that overall there is little evidence of major rill or sheet erosion and that erosion in general at the time of inspection is not a problem below the FSL.

6.7. Cotton Bush Infestations throughout the Rehabilitation Areas

The Water Corporation has carried out an extensive weed control program during 2003/2004. Cotton Bush (*Gomphocarpus fruticosus)* has been the major target of this program. The success of this program is evident throughout the site with a number of populations having reduced in size and the frequency of single plants encountered throughout the rehabilitation has also reduced. Success has also been made in removing cotton bush from below the FSL (Section 11, photo 2).

Areas still observed to have cotton bush in 2005 were Chidlows, Glentana, LoGrandes, Mummerts/Melliors, Paravicinni's and especially in Peppermint Park, particularly near monitoring plot M13 (Section 11, photo 3).

In the Harvey area the Department of Agriculture (2003) has declared cotton bush a P1 & P4 weed.

P1 - requires that a movement of the plants or their seeds is prohibited within the state.

P4 - requires that the infested area must be managed such that prevention of spread of seed or plant parts within and from the property on or in livestock, fodder, grain, vehicles and/or machinery. All plants must be treated to destroy and prevent seed set:

- within 100 metres inside of the boundaries of the infested property
- within 50 metres of roads and highwater mark on waterways
- within 50 metres of sheds, stock yards and houses.

Treatment must be done prior to seed set each year. Properties with less than 2 hectares of infestation must treat the entire infestation. Additional areas may be treated as required or programmed.

6.8. Blackberry Establishment near Stansfield Rd

There were a number of blackberry (*Rubus fruticosus*) bushes noted below the FSL in the creekline adjacent to Stansfield Rd. These bushes are a haven for feral animals such as rabbits and foxes and if allowed to go unchecked can take over entire valleys, displacing native species.

In the Harvey area Blackberry is categorised as P1, P4 by the Department of Agriculture WA. This means that blackberry must be treated in the same manner as cotton bush with regard to treatment. See the outline of requirements above under point 6.7.

6.9. Apple of Sodom within Rehabilitation Areas

Apple of Sodom (*Solanum linnaeanum*) has been noted growing in the LoGrandes rehabilitation area, particularly towards the eastern end. Several large bushes were observed growing and producing many fruit in openly sunlit areas (Section 11, photo 4). This plant is categorised P1 and P4 by the Department of Agriculture for the Harvey area. Apple of Sodom must be treated in the same manner as both Cotton Bush and Blackberry. See outline of requirements under point 6.7.

6.10. Couch Establishment below the FSL

Couch grass is establishing below the FSL in a number of areas such as Stirling Dam and Walkers Road (Section 11, photos 5 and 6). One advantage of allowing the couch to establish is that it will serve to reduce erosion in the FSL during periods when the FSL is exposed. Couch grass establishment should be allowed to continue. Spraying around the boundary between the rehabilitation and the FSL could be useful in preventing the establishment of couch grass in the rehabilitation.

6.11. Leaf Miner/Thrip within Rehabilitation Areas

Leaf miner/Thrip attacks were noted in a number of rehabilitation areas throughout the Harvey Dam site particularly Chidlows, Nicklup and LoGrandes. The main target species for attack appeared to be Flooded gum (*Eucalyptus rudis*). While these insects do appear to be doing some damage to the leaves of affected trees they are also acting as a food source for a number of native bird species including the Grey Fantail (*Rhipidura fuliginosa*). At the moment Leaf miner/Thrip attack is not considered to be a major threat to the success of rehabilitation in affected areas and affected plants should recover.

6.12. Volunteering Native Species

In a number of rehabilitation areas, additional native species are volunteering and establishing along with seeded or planted species. This is particularly the case in the Mummerts/Mellors area and along the Stirling Harvey Pipeline. The origin of these extra species is possibly topsoil related, however some may have dispersed to these sites through movement by wind, water or wildlife.

Native species observed that were not in the particular seed mixes have included *Chorizema sp, Daviesia cordata, Diplolaena sp, Hameodorum sp, Hakea amplexicaulis, Hakea lasiocarpa, Macrozamia riedei, Melaleuca incana, Patersonia occidentals* and *Ptilotus manglesii.*

This is very encouraging as the extra species that have been noted are local to the area and serve to boost the species diversity present at these sites. For the most part the species noted form part of the understorey. Native species additional to those, which were seeded/planted, should be included in the monitoring results as they form a part of the overall rehabilitation process.

CONCLUSIONS

A number of conclusions can be drawn from the data collected from the monitoring plots and transects and from the discussions and observations to do with the site in general. These are outlined below in terms of the age of the rehabilitation in point form.

6.13. Two and a Half Year Old Rehabilitation

(1) All two and a half year old rehabilitation areas meet, on average, the required completion criteria of 400 native stems per hectare.

(2) Of the two and a half year old rehabilitation areas both the Mummerts/Mellors area and the LoGrandes area meet the criteria for direct seeding establishment of 1 native seed germinated per $9m^2$.

(3) None of the one and half year old rehabilitation areas aside from the section around M21 are showing a degree of understorey and stratum development that is consistent with the required completion criteria.

(4) A number of species additional to those seeded planted are establishing in some of the rehabilitation areas particularly adjacent to the M21 monitoring site.

(5) None of the two and a half year old rehabilitation areas meet the completion criteria with regard to weeds except the section around M21.

(6) All two and a half year old rehabilitation areas show a considerable fire risk due to the establishment of annual weeds and their proximity to areas that may be used by the general public.

(7) Annual and perennial weed invasion is seen as the principle factor affecting the success of understorey development and direct seeding. Phosphorous build-up within the soil profile may also be a factor.

(8) The resilience and likely regeneration of native species in all the two and a half year old rehabilitation following a fire is minimal due to the pastureland history of these areas, the levels of weed infestation and the immaturity of natives present.

6.14. Three and a Half Year Old Rehabilitation

(1) All of the three and a half year old rehabilitation areas on average meet the required completion criteria of 400 native stems per hectare.

(2) On average the Glentana and the Chidlows West rehabilitation areas meet the criteria with regard to seed germination.

(3) The Glentana area on average shows a much higher degree of understorey and stratum development than the Chidlows West area but neither are progressing toward meeting the 5 year old rehabilitation criteria of 70% representation of seeded species.

(4) *Acacia spp* have set seed this season which is consistent with attaining the completion criteria for ecological processes for this age of rehabilitation.

(5) Weed establishment in the first year of rehabilitation in these areas may have greatly affected the success of understorey development from direct seeding.

(6) Fire risk in both areas is likely to be quite low as there is little in the way of grass weeds present. Leaf litter is beginning to build up within these rehabilitation areas but as yet do not pose a serious fire hazard.

(7) If a fire did occur in these areas it may not be as destructive due to the low levels of weeds within the rehabilitation area however the regeneration potential may be minimal due to lack of a native seed and immaturity of the native plants. Weeds will then re-establish because of the high levels of weed seed in the soil.

6.15. Four and a Half Year Old Rehabilitation

(1) All the four and a half year old rehabilitation areas meet on average the required criteria of 400 native stems per hectare.

(2) The Peppermint Park area on average meets the criteria with regard to the required number of peppermint stems per hectare.

(3) Both rehabilitation areas on average meet the overstorey height completion criteria of between 1 – 2 metres.

(4) *Acacia spp* are setting seed in the Peppermint Park area, which is consistent with the completion criteria for ecological processes for this age of rehabilitation.

(5) Neither rehabilitation area meets the criteria for understorey development (ie 70% species diversity of seeded species) but the SHP is still progressing to a far greater degree than the Peppermint Park area.

(6) The Stirling - Harvey Pipeline areas are largely dominated by 1 or 2 species. This may be affecting the overall results with regard to understorey development.

(7) Native species additional to those seeded planted are establishing along the Stirling – Harvey Pipeline rehabilitation area.

(8) Weeds and in particular wild oat infestation may be affecting the growth of planted seedlings in Peppermint Park and has no doubt reduced the success of understorey development and direct seeding.

(9) Fire risk within the SHP area is likely to be quite low due to the relatively low levels of grass weed infestation. However in the Peppermint Park area fire risk is high due to high levels of grass weed infestation and the steepness of the topography.

(10) The resilience to fire and likely regeneration potential along the SHP is likely to be quite high. As this area is largely within natural forest the native seed bank should be relatively good and many understorey species are established to a degree whereby they have reached maturity and can set seed.

(11) The resilience and regeneration potential following a fire in the Peppermint Park area is likely to be quite low due to its pastureland history and the immaturity of the dominant species here. A high weed seed bank within the soil is quite likely here.

6.16. General Comments

The above conclusions suggest that on the whole weed infestation and establishment is the primary factor affecting rehabilitation success at least in terms of the present established completion criteria, particularly in areas that have a history of use as pastureland.

Residual nutrient build-up within the soil profile and in particular phosphorous may also be limiting rehabilitation success in areas that were previously pastureland.

Understorey development within rehabilitated pastureland areas particularly those completed in 2002 and in Peppermint Park is not likely to progress to any degree given the current weed situation.

Cattle within the Peppermint Park area and in the Chidlows area may pose some threat to the rehabilitation here, particularly the understorey species that are present. Overstorey species in these areas are now at a stage whereby they should be resistant to grazing.

Further direct seeding is not likely to succeed now that planted overstorey species such as *Eucalypt spp* and Peppermints (*Agonis flexuosa*) are establishing well in most areas and given that weed spraying and surface preparation will be limited by native species already present. If understorey development is required then in most areas it will need to be planted as tubestock and the weeds suppressed to some degree.

7. RECOMMENDATIONS

The following recommendations are made with regard to further monitoring of the SHRS rehabilitation areas and to ways in which rehabilitation at the site could be improved in terms of the established completion criteria. Table 5 on page 40 and 41 outlines a summary of the Recommendations made below.

Recommendation 1 – Amend the rehabilitation objectives for rehabilitation areas with a pastureland history

Rehabilitation goals within areas showing a pastureland history should be amended so that the problems posed by this type of environment to rehabilitation are taken into consideration.

More realistic goals would be ones aimed at ensuring the catchment surrounding the dam address a balance of issues related to the proposed future use of the area. For example maintenance of water quality (ie sediment control), the aesthetics of the area, establishment of a "green

belt" to native fauna and use by the general public for any prescribed activities.

The expectation that these areas can be returned to a state approaching surrounding natural bush is unrealistic given the size of the project and complexities associated with the pre rehabilitation conditions that impact on the success of the works.

Recommendation 2 – Amend completion criteria for understorey development by direct seeding in pastureland areas.

With understorey development presenting a problem in many of the rehabilitation areas with a history of pastureland use it may be necessary to amend the required completion criteria for these areas to ones that are more achievable with regard to understorey development and direct seeding success.

GHEMS suggest that the criteria for understorey development by direct seeding (ie 50% species representation in year 3, 70% of species representation in year 5 and 90% of species representation in year 10) be reduced within areas that have a history of use as pastureland.

Such high species diversities will be very hard to achieve in areas such as Peppermint Park where in some sites more than 180 species were included in the seed mix sown into old pastureland.

Where 30 – 40 species have been seeded and selected from robust known species that can be successfully established by direct seeding it is reasonable to expect that 30% species diversity would be acceptable by year 3. The density of 1 seedling established from seed per $9m^2$ should be achievable in this situation.

The criteria for weed establishment should be so as to not substantially impact on the health and vigour of these establishing plants. Consideration should be given to the effect that any groundcover including weeds/ pasture or native has to minimising surface erosion and sediment control.

Recommendation 3 – Include native species additional to those that were seeded planted in the monitoring results.

Native plant species establishing in the rehabilitation areas that are additional to those that were originally seeded/planted should be included in the monitoring results and incorporated into the data.

These species still form a part of the whole rehabilitation process and hence the completion criteria should reflect this. Completion criteria for understorey species in particular should be amended to take consideration of volunteering species.

Recommendation 4 – Increased use of transects for data collection within each rehabilitation area.

Use of transects allows an assessment to be made of rehabilitation progress continuously over a greater range of sites (ie. upper slope, mid slope and lower slope) and therefore the information collected is more representative than that collected from relatively small isolated monitoring plots.

For this reason it is recommended that transects be used to gather the bulk of information during the monitoring process. Information collected using the transects should include that related to seed germination and establishment, understorey diversity, flowering and seed set, seedling health, fauna recruitment, percentage weed cover, fire resilience and erosion within the rehabilitation areas.

The monitoring plots are still useful however for calculating parameters such as number of stems per hectare, maximum overstorey height and total species diversity of those planted/seeded.

Recommedation 5 – Continue to maintain existing Fire Breaks

In order to keep any fires that may occur compartmentalised, accessible and controllable, existing fire breaks should continue to be maintained to a high degree especially considering the abundance of weeds in many areas and the accessibility of the areas to the general public.

Recommendation 6 – Continue mowing within the buffer zone and in other open accessible pastureland areas.

Mowing of pasture areas below the FSL that are unlikely to be inundated should continue in order to keep these areas tidy and to reduce the likely intensity and speed of spread of any fires that may occur there. This program should be expanded so that accessible road verge areas and other accessible open pasture areas throughout the rehabilitation are mown to reduce fire hazards.

Recommendation 7 – Fix fences in Peppermint Park to stop cattle accessing rehabilitation areas.

Problems with fences in Peppermint Park need to be identified in order to stop cattle grazing in this rehabilitation area. It is likely that an old section of fence along the eastern boundary of Peppermint Park is where the cattle may be getting through.

Recommendation 8 – Control Cotton Bush, Blackberry and Apple of Sodom throughout the site and around the FSL

As per the Department of Agriculture WA requirements Cotton bush (*Gomphocarpus fruiticosus*), Blackberry (*Rubus fruticosus*) and Apple of Sodom (*Solanum linnaeanum*) plants and populations will need to be controlled throughout the site and around the FSL. Only appropriate herbicides and wetting agents that are approved for use near waterways should be used.

Recommendation 9 – Continue to allow Couch Grass to establish below the FSL

In order to reduce erosion and sediment run-off into the dam in areas below the FSL during periods when it is exposed to the elements it is recommended that any couch and kikuyu grass establishing below the FSL at the moment be allowed to continue to establish. If spread of these grasses into adjacent rehabilitation is likely to become a problem then herbicide control around the border between the rehabilitation and the FSL should be considered.

Recommendation 10 – Ensure that maintenance works are carried out relative to the prevailing seasonal conditions

Seasonal conditions should be a consideration in all maintenance works programs. For example knockdown spraying for weeds in April is relatively pointless particularly in a dry year in that most of the weed seed bank will not have germinated by this time. Timing of works is paramount in achieving the best results with regard rehabilitation and in particular direct seeding.

TABLE 5 SUMMARY OF RECOMMENDATIONS FROM 2004 ANNUAL REHABILITATION ASSESSMENT

Recommendation	Description	Action
1	Amend rehabilitation objectives for areas with a pastureland history	Determine objectives more suitable to the prevailing conditions and final use of the rehabilitation areas.
2	Amend completion criteria for areas with a pastureland history	Reduce the understorey development criteria in pastureland areas to a level more consistent with the conditions.
3	Include native species additional to those seeded/planted in the monitoring results	Amened completion criteria to take account of volunteering native species. These form a part of the whole rehabilitation process.
4	Increase use of Transects for Data Collection within each Rehabilitation area	Use transects to collect data relating to seed germination and establishment, understorey diversity, flowering and seed set, seedling health, fauna recruitment, percentage weed cover, fire resilience and erosion. Use Monitoring Plots for calculating parameters such as number of stems per hectare, maximum overstorey height and total species diversity of those planted/seeded.
5	Continue to Maintain Existing Firebreaks	Firebreaks should be maintained in good order. Herbicide treatment should be carried out using a knockdown such as glyphosate or amitrole to kill off all pasture weeds during spring 2003. A residual herbicide such as Simazine could be used in Autumn 2004 to reduce weed germination over winter and spring. Other methods could include annual grading to keep weed material and other litter from building up.
6	Continue Mowing in the buffer zone and in Other Open Accessible Pastureland Areas	Mowing in the buffer zone should continue. This serves to tidy areas up and will reduce the intensity and speed with which fires may spread if they do occur.
7	Fix Fences in Peppermint Park and Chidlows	Access by cattle to these areas needs to be stopped.
8	Control Cotton Bush, Blackberry and Apple of Sodom Throughout the Site	These 3 weeds should be controlled using an appropriate herbicide as per Department of Agriculture requirements.
9	Allow Couch Grass to Establish below the FSL	In order to reduce erosion and movement of sediment below the FSL during periods when it is exposed it is recommended that couch and kikuyu grass be allowed to establish here.
10	Ensure works are carried out relative to the prevailing seasonal conditions	Gain independent advice on the best timing for works to be carried out.

8. REFERENCES

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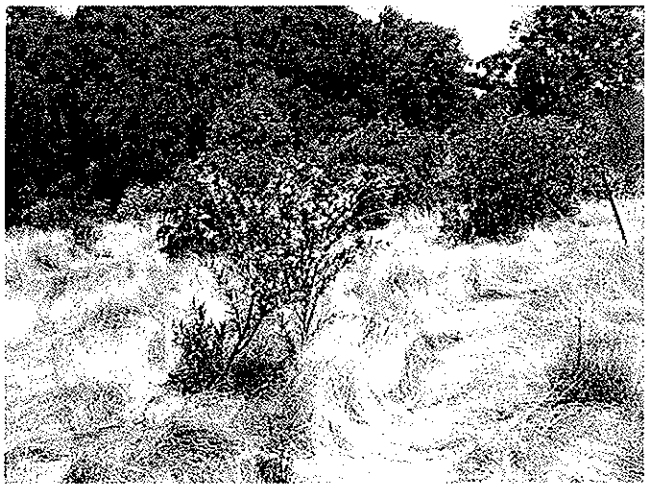


M13 Peppermint Park

M14 Chidlow's West

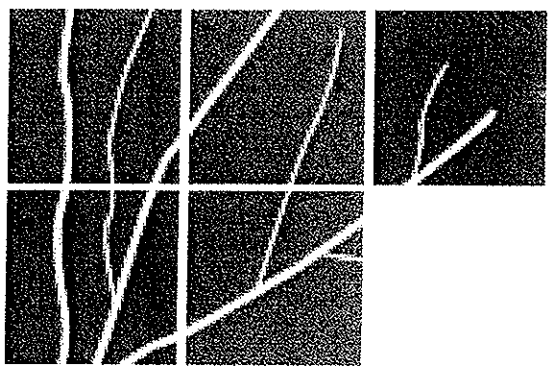
M15 Glentana

Neerabup Revegetation Trials

Mining Lease M70/717

August 2004

Prepared For:
RCG Technologies



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Introduction

The following plan forms the basis of ongoing monitoring of the revegetation program to be conducted at the RCG Technologies quarry on Mining Lease 70/717, Reserve 27575, Quinns Road, Neerabup during 2004. The total area of initial direct seeding program is approximately 3.6 hectares. A total of nine monitoring plots (labelled A to I) of 100 to 200 m^2 size have been pegged on this area. The monitoring plots have been established to assess the influence of different soil surface preparation treatments, fertilising application rates and direct seeding rates.

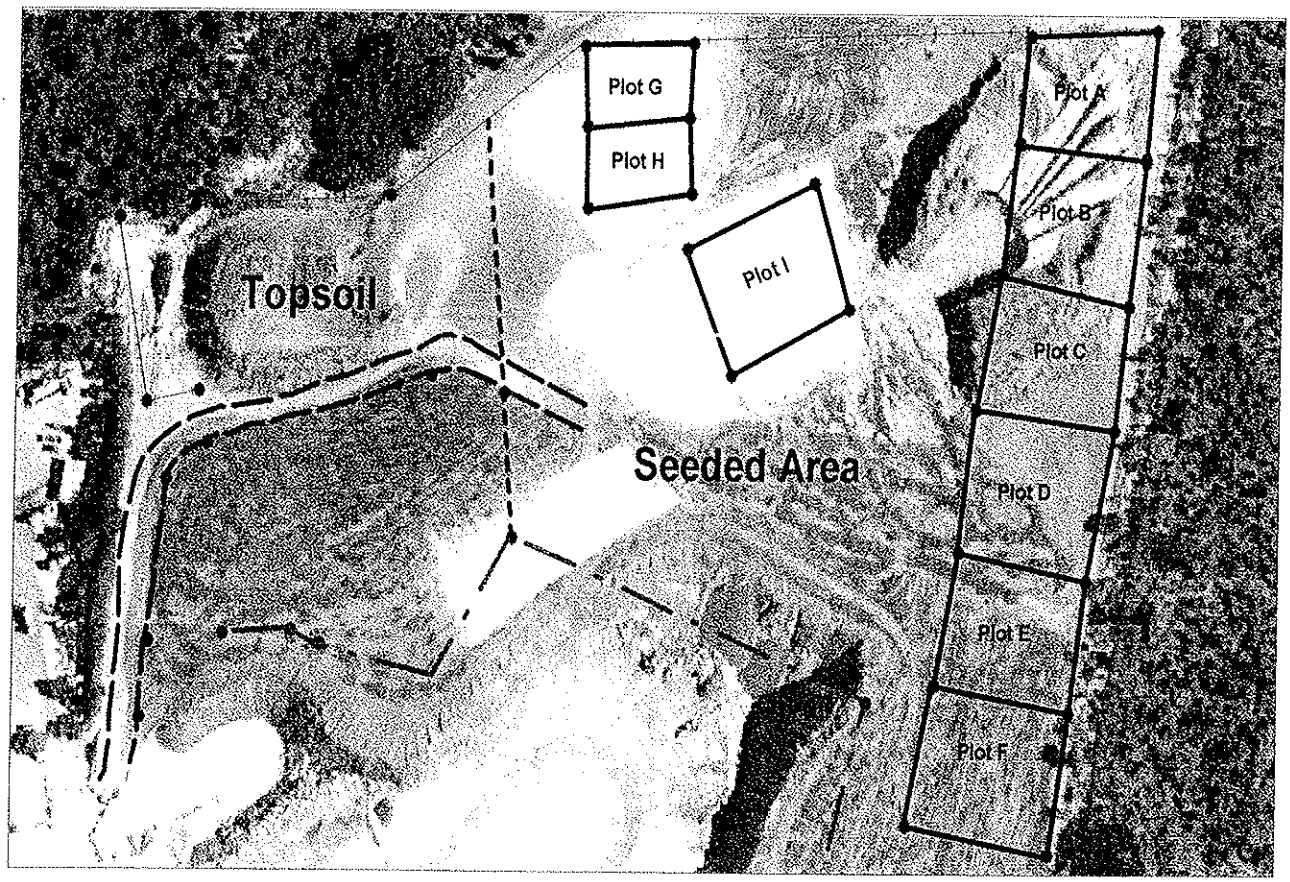


Figure 1: Orthophoto of the site showing the Monitoring Plots

Soil treatment

Combinations of different soil treatments have been applied over the site to determine the most successful method of revegetation. Overburden surfaces have been either covered with single or a combination of mulch, topsoil and limestone mix treatments. NPK standard fertiliser has also been applied at rates of either 0, 150 or 250 kg per hectare to each of the plots. Lastly each plot was given seed mixes of either 4.5 or 6 kg per hectare. The plots will be assessed to ultimately determine whether the presence, quantity and interaction of mulch, topsoil, limestone, fertiliser and seed greatly improves the revegetation process. The most successful treatment may then be applied in future revegetation efforts in the lease.

Figure 2: The site has been part covered with mulch

Monitoring Plots

Monitoring Plot A

Plot Size: 50m x 40m = 200m^2
Description: Coarse limestone and topsoil mix on overburden
Seed Coverage: 6kg per hectare
Fertiliser Application Rate: Fertiliser applied at 150kg per hectare
(See Figures 3 to 5)

Corner	Easting	Northing
1	380418E	6495079N
2	380457E	6495081N
3	380453E	6495048N
4	380415E	6495052N

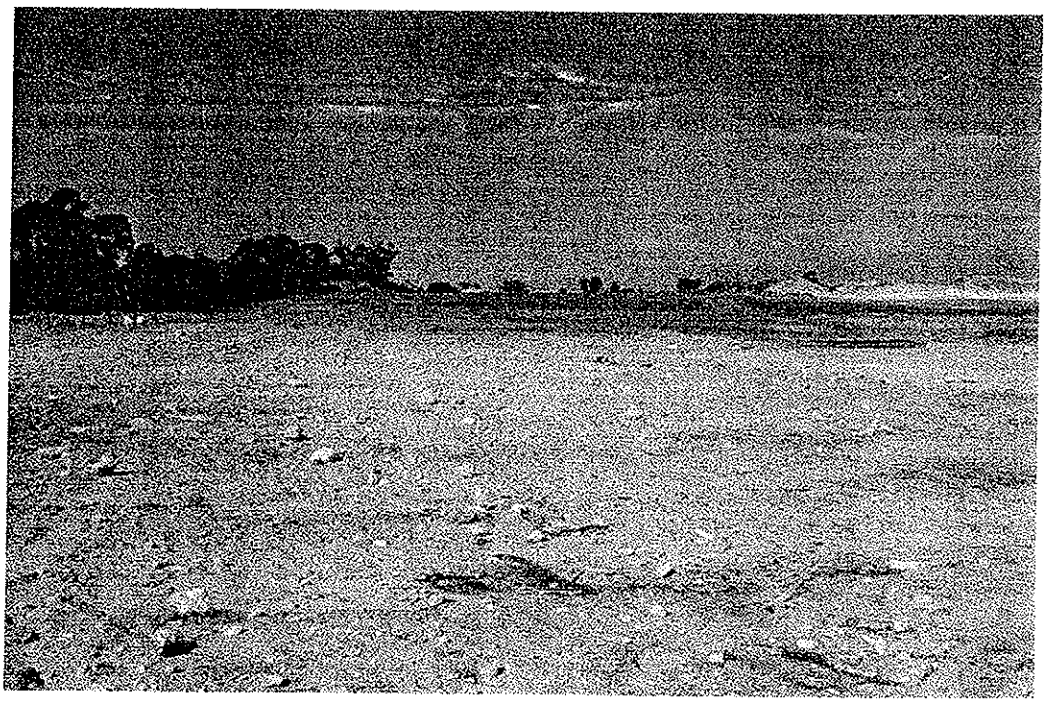


Figure 3: View from Plot A to Plot F

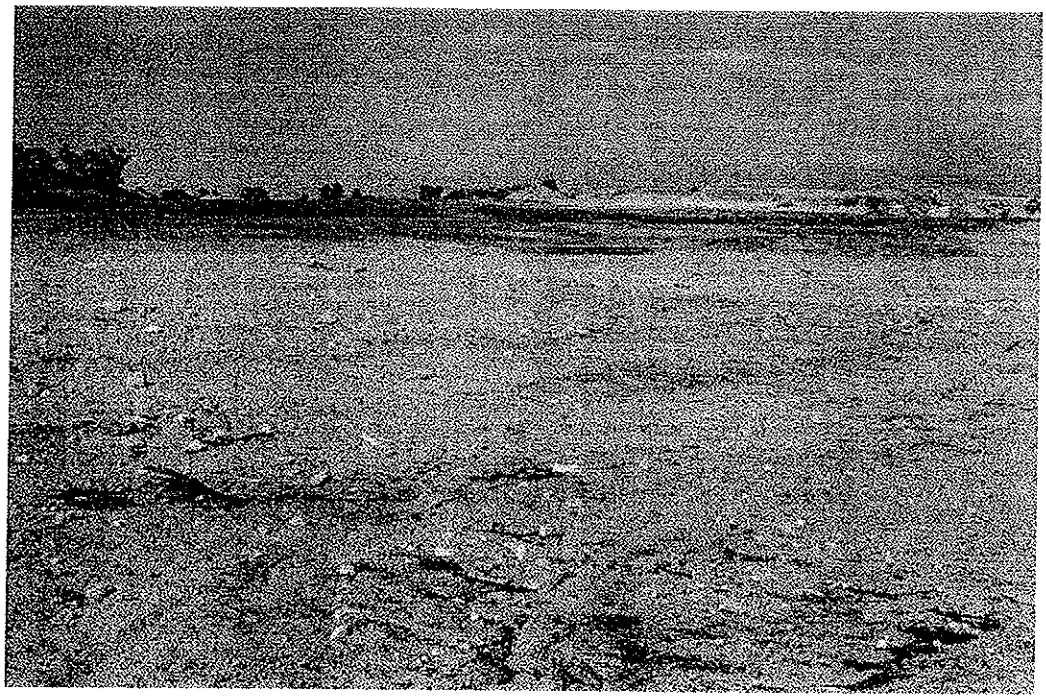


Figure 4: View from Monitoring Plot A. looking towards the South West

Figure 5: View from Monitoring Plot A. looking towards the South West

Monitoring Plot B

Plot Size: 50m x 40m = 200m^2
Description: Coarse limestone and topsoil mix on overburden.
Seed Coverage: 6kg per hectare.
Fertiliser Application Rate: Fertiliser applied at 250kg per hectare.

Corner	Easting	Northing
1	380454E	6495047N
2	380415E	6495052N
3	380410E	6495019N
4	380449E	6495011N

Monitoring Plot C

Plot Size: 50m x 40m = 200m^2
Description: There is a cover of topsoil over the site.
Seed Coverage: 4.5kg per hectare.
Fertiliser Application Rate: Fertiliser applied at 150kg per hectare.

Corner	Easting	Northing
1	380410E	6495019N
2	380447E	6495012N
3	380445E	6494979N
4	380403E	6494984N

Monitoring Plot D

Plot Size: 50m x 40m = 200m^2
Description: The site has a 60% cover of mulch on the topsoil. The southern side has been harrowed.
Seed Coverage: 4.5kg per hectare.
Fertiliser Application Rate: No fertiliser has been applied to the site.
(See Figures 6 and 7)

Corner	Easting	Northing
1	380445E	6494979N
2	380403E	6494984N
3	380398E	6494948N
4	380437E	6494941N

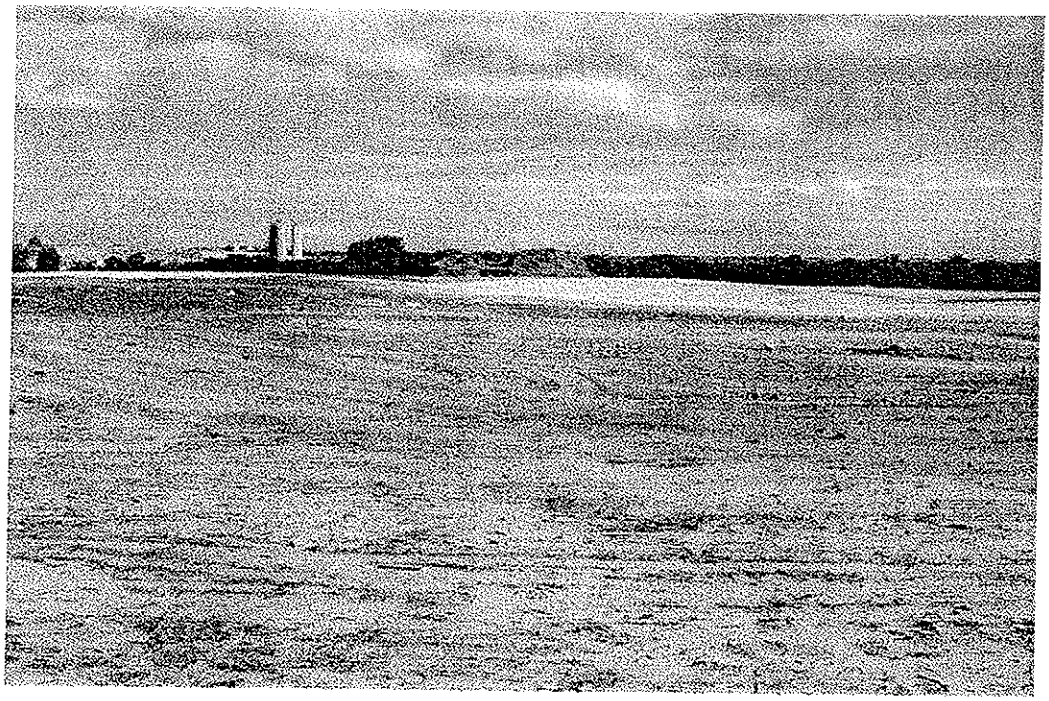


Figure 6: The view from Monitoring Plot D looking South

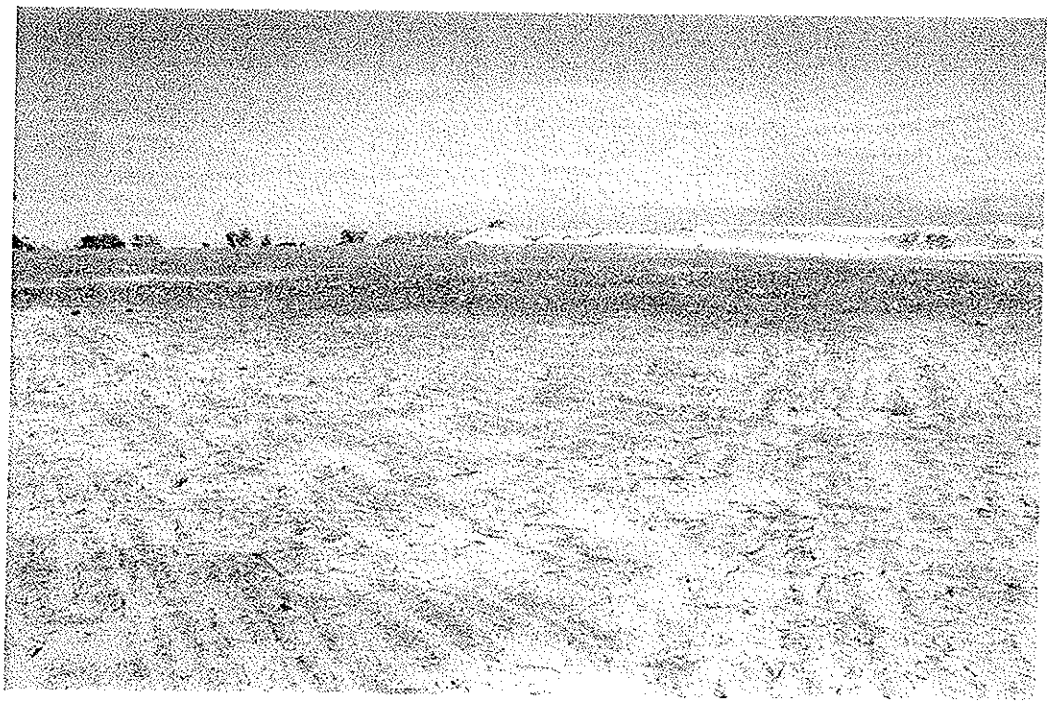


Figure 7: The view from Monitoring Plot D looking East

Monitoring Plot E

Plot Size: 50m x 40m = 200m^2
Description: The site has a mulch cover on the topsoil. The site has been harrowed.
Seed Coverage: 6kg per hectare.
Fertiliser Application Rate: Fertiliser applied at 150kg per hectare.

Corner	Easting	Northing
1	380398E	6494948N
2	380437E	6494942N
3	380432E	6494907N
4	380391E	6494914N

Monitoring Plot F

Plot Size: 50m x 40m = 200m^2
Description: There is a cover of topsoil over the site with one section being mulched. The site has been harrowed.
Seed Coverage: 6kg per hectare on balance of the area. 4.5kg per hectare applied to mulch area.
Fertiliser Application Rate: Fertiliser has been applied at a rate of 150kg per hectare while no fertiliser has been applied to the portion covered with mulch.

Corner	Easting	Northing
1	380432E	6494907N
2	380391E	6494914N
3	380383E	6494879N
4	380426E	6494871N

Monitoring Plot G

Plot Size: 25m x 40m = 100m^2
Description: There is a cover of topsoil and some mulch in the North West corner of the Plot with approx. 80% of the remainder of the site being limestone. The site was harrowed and is devoid of weeds.
Seed Coverage: 6.0kg per hectare.
Fertiliser Application Rate: No fertiliser was applied to the site.
(See Figure 8)

Corner	Easting	Northing
1	380410E	6495019N
2	380447E	6495012N
3	380445E	6494979N
4	380403E	6494984N

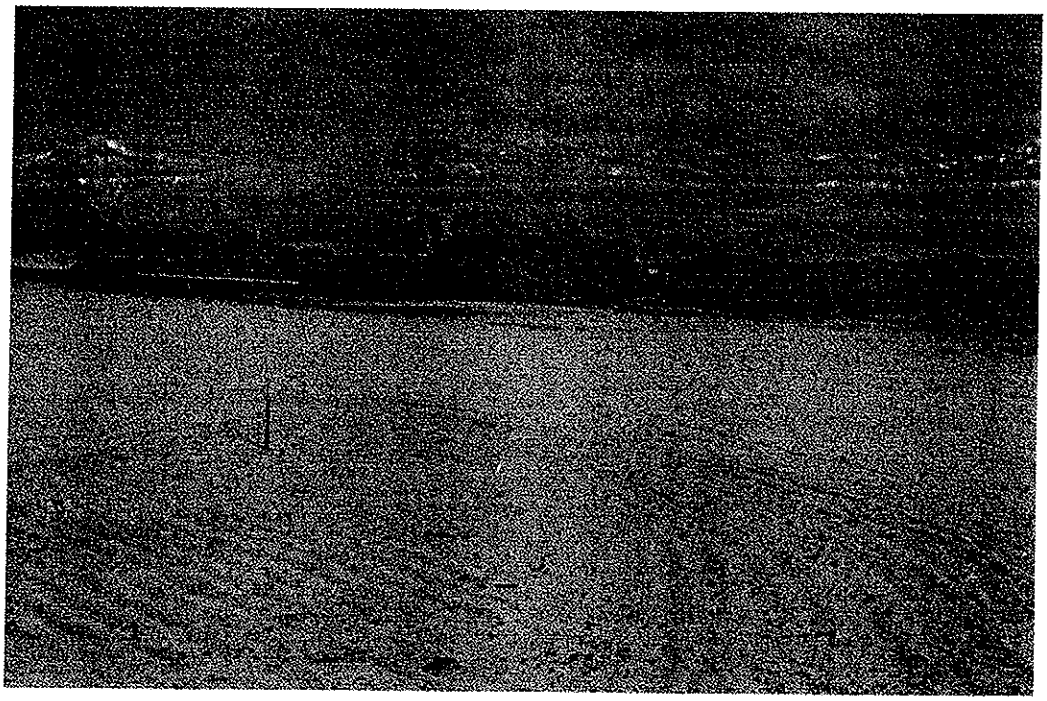


Figure 8: View of Monitoring Plot G looking West (Topsoil mound in the background)

Monitoring Plot H

Plot Size: 25m x 40m = $100m^2$
Description: 100% of the site is covered with limestone. The site was harrowed.
Seed Coverage: 4.5kg per hectare.
Fertiliser Application Rate: No fertiliser was applied to the site.
(See Figure 9)

Corner	Easting	Northing
1	380314E	6495039N
2	380283E	6495035N
3	380282E	6495056N
4	380313E	6495058N

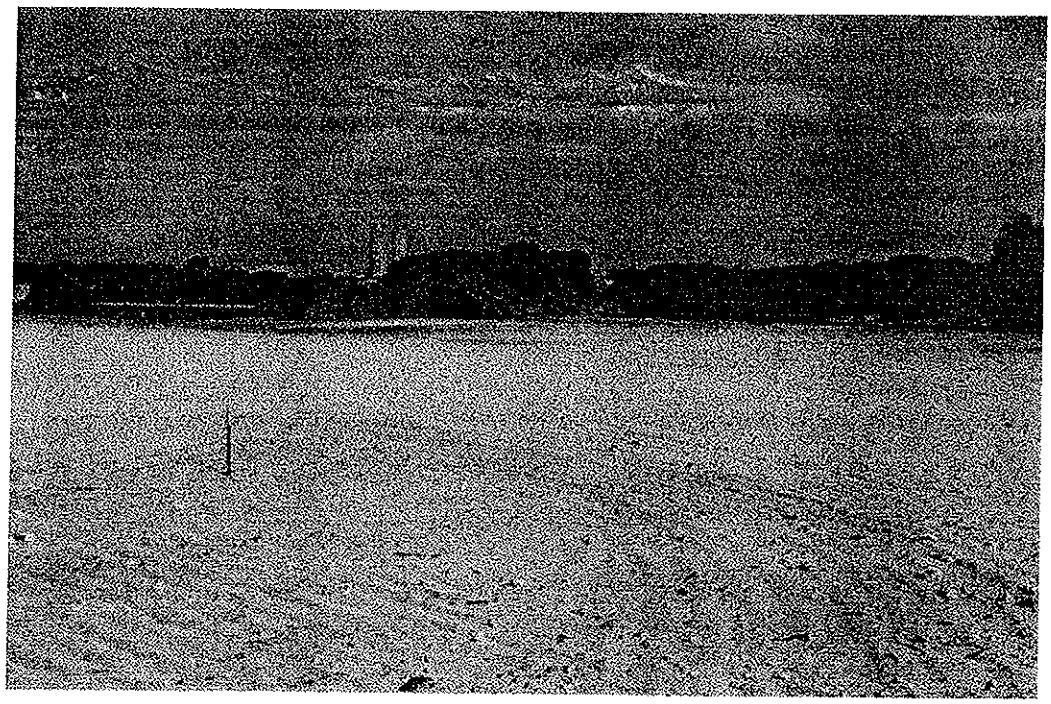


Figure 9: View of Monitoring Plot H looking West (Topsoil mound in the background)

Monitoring Plot I

Plot Size: 50m x 40m = 200m^2
Description: 100% of the site is covered with limestone. It is devoid from weeds and has a small sump in the centre.
Seed Coverage: 6kg per hectare.
Fertiliser Application Rate: Fertiliser was applied to the site at a rate of 150kg per hectare.
(See Figure 10)

Corner	Easting	Northing
1	380327E	6494995N
2	380313E	6495025N
3	380352E	6495042N
4	380363E	6495010N

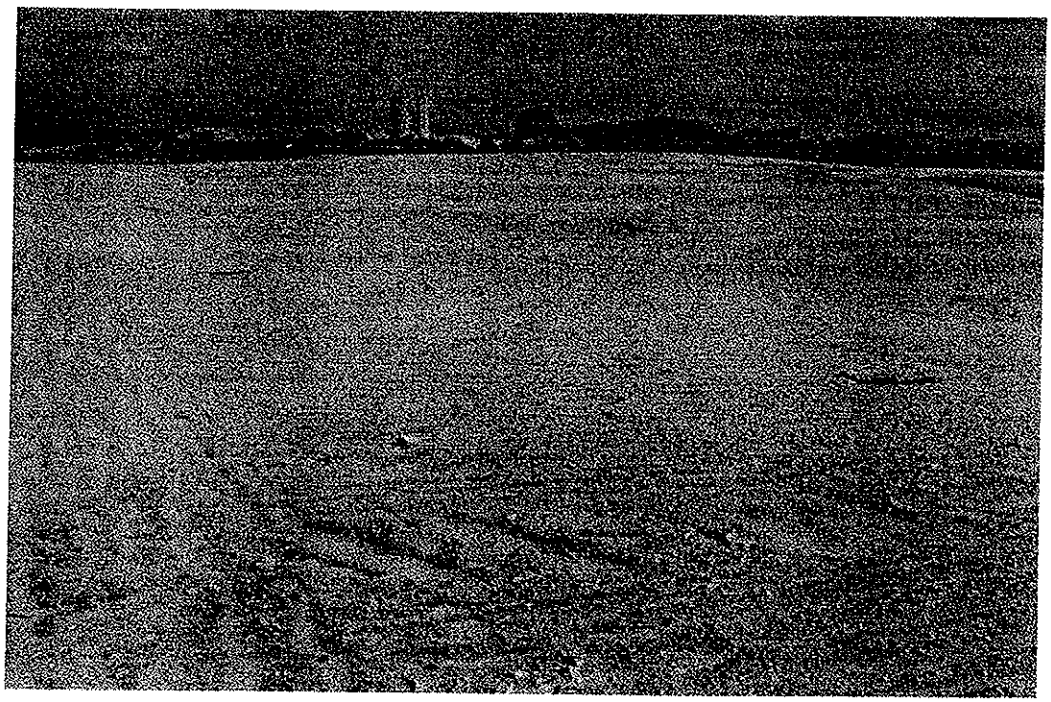


Figure 10: View of Monitoring Plot I looking West showing slight sump

Recommendations

Monitoring

Monitoring will be conducted during April or May 2005 to assess the revegetation progress within each of the plots. Three 20 m transects will be randomly placed in each plot and marked with surveying stakes. Seed germination, species diversity, abundance, density and survival will all be recorded in each transect and compared. Any weed identification and infestation will be carried out as required. In addition, photographic records will be maintained for each of the monitoring sites from a marked reference point to provide a visual representation of progress. A set of procedures and standardised reporting systems will be employed to ensure consistency of the transect results. Any significant problems in the revegetation process noted during monitoring will be addressed as soon as the situation allows, such as weed control and inadequate seedling density.

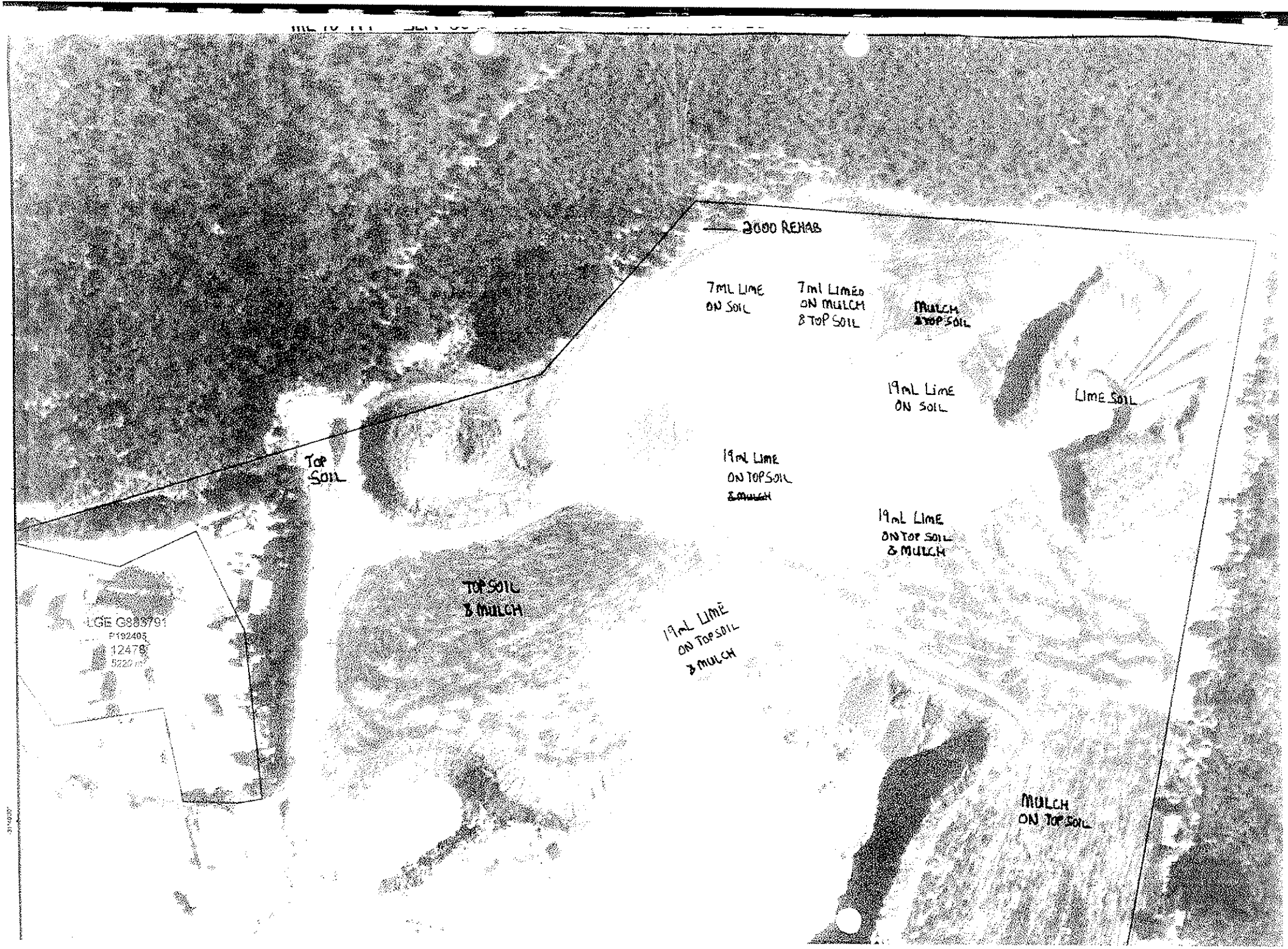
Weed control

Successful weed management is the single biggest controllable factor that will determine the success of the rehabilitation plan for M70/717. Previous attempts at revegetation within the lease have failed due to weed species dominating the areas that have been spread with topsoil and then seeded with native seed. The weed species germinated rapidly following the first autumn rains, out competed and dominated the newly germinated native seedlings for light, water and nutrients. Without efficient initial weed control, most native seedlings will most likely not survive the first year. Successful revegetation can only occur when the native seedlings have developed a significant root system so they out compete the weed species.

The lease needs be monitored for weed infestation and any outbreak controlled to ensure minimal impact. Weed control may be in the form of either manual removal or spot spraying with appropriate herbicides. Spot spraying will only occur on days that are not windy to avoid spray drift impacts to native seedlings.

Remedial work

A significant amount of remedial work may be expected to ensure that the revegetation programme complies with the set completion criteria. Areas determined not to have revegetated successfully will be reseeded appropriately during the following winter. Only small areas will be considered as the cost may be excessive for larger areas.


2000 REHAB
7ML LIME ON SOIL
7ml LIMED ON MULCH & TOP SOIL
MULCH & TOP SOIL
19mL LIME ON SOIL
LIME SOIL
TOP SOIL
19mL LIME ON TOPSOIL & MULCH
19mL LIME ON TOP SOIL & MULCH
TOPSOIL & MULCH
19mL LIME ON TOP SOIL & MULCH
LGE G883791
P192405
12478
MULCH ON TOP SOIL

Mining Lease M70/717
Rehabilitation Plan

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BSD Consultants Pty Ltd

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1. INTRODUCTION

RCG Technologies Pty. Ltd. (RCG) have commissioned BSD Consultants to prepare this Rehabilitation Plan to guide future revegetation activities at their limestone quarry and landfill facility located on Quinns Road, Neerabup. The rehabilitation plan has addressed revegetation activities to be undertaken at the quarry site for the remainder of the operation's lifetime.

1.1 BACKGROUND

The quarry has been in operation since the early 1970's, and is located within Mining Lease 70/717 on Reserve 27575, Quinns Road, Neerabup. The total area of Mining Lease 70/717 within which the quarry/landfill activities are undertaken is 25.54 hectares.

Mining Lease 70/717 was applied for in 1991 and granted in 1992 by the then Department for Minerals and Energy (now Department of Industry and Resources –DoIR). A very small amount of rehabilitation has been carried out on the northern boundary of the site, but most of the site is currently not rehabilitated.

The primary need for the rehabilitation plan has arisen from advice provided to the DoIR by the Department of Conservation and Land Management (DCLM), specifically requesting that the condition to prepare a rehabilitation plan be added to the list of conditions imposed on the lease. As the site is adjacent to the Neerabup National Park, DCLM would like to see the site rehabilitated on a progressive basis so that the habitat value to local flora and fauna species extends over the site in the long term, particularly when the quarry/landfill site ceases to be operational, and the lease area is added to land which is part of the Neerabup National Park.

1.2 PURPOSE

The plan addresses the main issues associated with the rehabilitation within the site, and aims to achieve an agreed rehabilitation process to the satisfaction of the DCLM. It will then form the basis for ongoing rehabilitation operations and management on the site by RCG Technologies for the remainder of the quarry's lifetime.

This plan also includes some trial areas on the site, which will assess the influence of different soil surface preparation treatments on seed germination and seedling establishment. The treatment that is found to have the greatest success rate for revegetation on the site will be adopted as the future soil preparation treatment.

There will, however, be the need to review and revise the rehabilitation plan after two years to incorporate any significant outcomes of the first years.

2. OUTLINE OF EXISTING OPERATIONS

The RCG operation functions as both a limestone quarry and a landfill site for inert (construction and demolition) waste. The general location of this operation is shown on **Figure 1**. The excavation work and landfill operation is undertaken on a staged basis, and following the completion of these operations the stages will be progressively rehabilitated.

2.1 LIMESTONE QUARRY

The land has been quarried for limestone by RCG Technologies, supplying limestone during the construction of major infrastructure projects and road construction material throughout the City of Wanneroo and beyond. The extent of the quarry lease and its surrounding area is shown in **Figure 2**.

The excavation of limestone from Mining Lease 70/717 is expected to continue for another 15 years. The development of the quarry proceeds in stages, which are shown on **Figure 3**. These stages will be the basis for the revegetation of the site progressing in stages. It is estimated that at the end of the quarry's life 2,000,000m^3 of material will have been removed from the site (Koltasz Smith and Partners, 1998).

2.2 LANDFILL SITE

Landfill operations are being undertaken concurrently with the excavation of limestone, with recently excavated areas being backfilled with inert waste. The waste is then covered with overburden (imported fill) to a depth of 1 metre, and revegetation plantings are carried out on this top layer.

Landfill operations will continue for another 15 to 16 years, for the duration of the quarry excavation activities.

2.3 REHABILITATION WITHIN THE EXISTING OPERATION

The revegetation works will progress in stages, following the completion of excavation and landfill operations for each of the stages.

Figure 4 shows the proposed progressive staging of revegetation works, which is based on the staging of excavation and landfill operations. The revegetation activities in the areas identified as Stages 1 and 2 are currently scheduled for 2004 and 2005.

RCG has completed quarry excavation and landfill activities within Stages 1 and 2, and is currently excavating Stage 3 of the operation. The revegetation of Stage 3 is proposed to be undertaken between the years of 2008 to 2012. Stage 4 has three to four years of excavation proposed and Stage 5 has four years of excavation proposed. Revegetation in the Stage 4 and 5 areas will be undertaken following the completion of the excavation and landfill activities.

Revegetation in Stages 1 and 2 has been attempted in the past, but has not been successful due to a high level of weed infestation competing with the native species, and resulting in the death of the majority of germinated seeds.

There is a small area of previous rehabilitation plantings (undertaken in 2001) located on the northern boundary of Mining Lease 70/717 with the Neerabup National Park (Stage 2 area). This revegetation is discussed in more detail in the following section (**Section 3.1**).

The soil surface in Stages 1 and 2 has been prepared for the future rehabilitation programme scheduled for 2004. This preparation includes covering the landfill areas with clean, imported fill to a depth of 1 metre and then spreading topsoil (from the stockpiles on the site) to a depth of 30 - 40 cm. on top of this layer. Mulch, which is also stockpiled on the site, is then spread on the top of the topsoil layer to a depth of 10 – 15 cm. The mulch has been spread on top of the topsoil over most of the area that is scheduled for revegetation in 2004. Some of the trial area has not been spread with mulch over the topsoil to look at the influence mulch will have on seed germination and seedling establishment following seeding in 2004.

3. ISSUES, CONSTRAINTS AND OPPORTUNITIES

3.1 EXISTING REHABILITATION PROGRAMME

An area of revegetation approximately 5 to 8 metres wide by 100 metres long is located on the northern boundary of the quarry lease with the Neerabup National Park.

The rehabilitation has been seeded directly onto overburden, with a good level of germination success and a low level of weed invasion in this rehabilitation area. The principal species present are trees and medium to large shrubs, with two groundcover/creeper species.

Tree Species: *Eucalyptus gomphocephala* (Tuart).

Medium to Large Shrub Species: *Acacia cyclops, A. lasiocarpa/pulchella, A. rostellifera, A. truncata, Calothamnus quadrifidus, Dryandra sessilis, Grevillea crithmifolia, Hakea lissocarpha, H. trifurcata, Melaleuca huegelii, M. systena* and *Templetonia retusa.*

Groundcover/Creeper Species: *Hardenbergia comptoniana* and *Kennedia prostrata.*

Adjacent to this area of rehabilitation (on the Neerabup National Park boundary) is a clump of planted ornamental Eucalypts (six or seven individuals), which may be remnants from a time when the area was part of a livestock route (Colin Zampatti *pers. comm.*). The Eucalypts have been identified as *Eucalyptus petrensis,* a small tree/mallee species that occurs locally in coastal areas of sand over limestone.

Discussion and correspondence with DCLM indicates that the current selection of species is not considered diverse enough to ensure continuity with the adjacent Neerabup National Park. In particular, DCLM would like to see a higher proportion of smaller shrub and groundcover species included in the species mix for future revegetation work to improve rehabilitation form and diversity.

A botanical assessment undertaken within the Neerabup National Park (adjacent to the Mining Lease) by BSD Consultants in early October 2003 shows that there is a higher level of species diversity in both the overstorey and understorey strata of the Park compared to the number of species used in the existing rehabilitation. Based on the commercial availability of the species recorded as present in the Park, the list for future revegetation will be expanded to include a number of these species.

3.2 TOPSOIL AND MULCH STOCKPILED ON THE SITE

3.2.1 Topsoil

Two very large topsoil stockpiles are located on the site, which have been stockpiled for twelve months. This topsoil was imported from an area, which was cleared of native vegetation for the extension of the Mitchell Freeway and for the construction of a new bridge. The topsoil was imported

from areas with signage stating the areas were disease (Dieback) free, although these areas were not weed free as indicated by a high level of weed infestation on the top layer of the stockpiled topsoil.

The weed species present are annual and perennial species, which may have been introduced into the topsoil after it was stockpiled on the site, but it is probable that the area from which the topsoil was imported already had a significant level of weed infestation.

An indication of the presence of the Dieback fungus in the topsoil will be possible in the first year following revegetation. The results from the trial areas where no topsoil has been spread can be compared to results from the areas that have topsoil spread, to assess whether there is a significant difference between seed germination rates and seedling survival in the two areas, particularly of those species known to be susceptible to Dieback.

3.2.2 Mulch

A stockpile of mulch is present on the site, which was imported from mulched vegetation that was cleared for the Mitchell Freeway extension and construction of a new bridge. The mulch does not show a high level of weed infestation compared to the stockpiled topsoil, but its weed free status cannot be guaranteed.

The mulching of areas prior to seeding for revegetation may actually act in a more detrimental rather than a beneficial manner. This is possibly due to a combination of reasons

- Mulch is contributing to the spread of weeds on the areas where it is spread prior to any seeding activities,
- Mulch consists of different ingredients with varying pH levels which may be detrimental to newly germinated seeds,
- Mulch has a biological demand for soil nitrogen as it decomposes, thereby making nitrogen unavailable to developing seedlings following their germination, and
- Seeds need to be in contact with the topsoil to initiate and sustain germination, and when they are sitting on top of a layer of mulch there are possibly too many air pockets, which can prevent proper root development.

3.3 WEED CONTROL

Successful weed management is the single biggest controllable factor that will determine the success of the rehabilitation plan. It is essential that weeds are monitored and controlled at all times to ensure their impact is minimised.

The infestation of areas with annual and perennial weed species is the main issue facing the success of the proposed rehabilitation programme on Mining Lease 70/717. Previous attempts at revegetation within the Lease have failed due to weed species dominating the areas that have been spread with topsoil and then seeded with native species. The weed species germinate rapidly following the first autumn rains, out compete with and dominate the newly germinated native seedlings, for light, water

and nutrient resources. Without adequate weed control, it is unlikely that the native seedlings will survive past the first year following seeding. Once the native seedlings have developed a significant root system and vegetative canopy, they can out compete with weed species and hence the impact from weeds is reduced.

Previous revegetation works on the site have incorporated the use of Superphosphate in the topsoil as a fertiliser for the establishing seedlings. When this fertiliser was used, the revegetation area was dominated by annual and perennial weed species in a relatively short time period, with which the native species from the seeding programme could not compete. Due to this outcome, Superphosphate will not be used in this revegetation programme.

3.4 FINAL LANDFORMS FOR REHABILITATED AREAS

The final topography levels on the quarry site will be continuous with the surrounding topography in the Neerabup National Park, to the satisfaction of DCLM.

It is not expected that the rehabilitated areas on the site will be prone to water or wind erosion, due to the final topographical contours and the lack of any steep batters or sloping areas. The contours of the future rehabilitation areas will be only mildly sloping, and due to the nature of the porous sandy soils, water can readily infiltrate through the soil profile rather than along the soil surface. The areas, which have already been spread with topsoil on the site, have also been spread with mulch, which will assist in controlling water and wind erosion on the soil surface.

Wind erosion may possibly be an impact to consider in the revegetation programme, particularly during the first summer following seeding, when there are strong easterly winds in the morning and strong southwesterly winds in the afternoons and evenings. Strong winds can cause 'wind blast' to small seedlings as a result of loose sand being blown about and causing abrasion to the seedlings.

4. PROPOSED REHABILITATION PLAN

4.1 MANAGEMENT OF SITE PRIOR TO REVEGETATION

4.1.1 Topsoil Management

The existing topsoil stockpiles exhibit a high degree of weed infestation, and material from these stockpiles may be detrimental to successful establishment of native species if spread onto areas prior to seeding. The emerging native species will not be able to compete with weed species that are likely to germinate in areas spread with this topsoil resource, following autumn rains, if the weeds are not sprayed before seeding.

Rather than using topsoil as the uppermost layer, it may be possible to use crushed limestone to reduce weed emergence. Based on background research and information, trials will be undertaken using a layer of crushed limestone as the uppermost soil surface in three different ways:

- As the top surface for direct seeding activities, in an area of the site where no topsoil is used in the revegetation areas, and the limestone is placed directly on top of the 1m overburden layer,
- As the top surface for direct seeding activities, in an area where only topsoil has been spread to a depth of 30 – 40 cm on top of the overburden layer, and
- As the top surface for direct seeding activities, in an area where both topsoil and mulch have been spread on top of the overburden layer.

Topsoil has been spread in Stages 1 and 2 of the operations, proposed for revegetation in 2004. Following seeding in the trial areas in 2004, the results from these areas will be used as the basis for whether topsoil should be spread on future revegetation in Stages 3 to 5.

All native vegetation and topsoil has been removed from within the mining lease, therefore the only source of topsoil is that which is stockpiled on the site and any which may be obtained from offsite. No further topsoil will be spread on the site until results are obtained from the trial areas, showing whether the spread of topsoil is a beneficial or a detrimental practice to the success of the revegetation programme.

4.1.2 Mulching of Areas to be Revegetated

Mulch has already been spread over an area of approximately 4 ha (native vegetation mulched from nearby land clearing activities for the future Quinns Road railway line bridge crossing).

No further mulch will be spread on the site until it can be established whether mulching of areas to be seeded is a beneficial practice, in respect to seed germination rates, seedling establishment and survival post-germination. A comparison will be made of areas, which have been spread with mulch and then seeded and areas that have no mulch and then seeded with native species. The treatment with the most successful rate of seed germination, seedling establishment and survival will be used as the basis for future revegetation activities.

4.1.3 Erosion Control

Following the recontouring and revegetation, there will be no steeply sloping areas that will become susceptible to erosion as a result of rain events. Wind erosion is unlikely to be an issue on those areas that have been mulched, or in the areas that have been spread with crushed limestone due to the size of the mulch particles and the aggregate size of the limestone.

The assessment of revegetated areas for water and wind erosion will be undertaken as part of the rehabilitation monitoring in the first spring following seeding. The soil surface will be assessed for any signs of water erosion, and seedlings will be inspected for any signs of 'windblast', which occurs when strong winds blow soil (particularly loose sand) around which causes damage on young plants due to its abrasive nature.

To reduce impacts to seedlings from wind erosion, temporary windbreaks will be adopted as a protective measure to the developing seedlings until they are large enough to withstand strong winds and potential 'windblast'. Brush vegetation or rows of star pickets with shade cloth attached will be used as the temporary windbreaks.

4.2 REVEGETATION METHODOLOGY

4.2.1 Staged Approach to Revegetation on the Site

Eight hectares (8 ha) of stages 1 and 2 will be seeded in autumn 2004. The 8 hectares will be treated with different soil preparation techniques in 2003/04 to find out which of these works best for future rehabilitation purposes. The soil preparation methods will be assessed to see which gives the best results in terms of seed germination rates and seedling survival post-emergence.

The principal soil surface treatment that has been undertaken on the areas proposed for revegetation is covering the landfill with overburden (imported clean fill) to 1m, with topsoil and mulch spread on top of this overburden layer. Based on the past practices and on background advice and information, this soil surface treatment may not be the best for successful rehabilitation due to the high level of weed seed germination in the topsoil once the autumn rains commence.

The soil surface preparation trials that will be trialled in the proposed seeding exercise in autumn 2004 are:

- Two hectares of the seeding area will be spread with crushed limestone, divided into six areas with each of the areas given a treatment as described below, and then seeded at a rate of 8 kg/ha with 100 kg/ha of fertiliser added:
    1. A layer of overburden (imported clean fill) to a depth of 1m, with a layer of crushed limestone (aggregate size of 7mm) to a depth of 100mm spread directly on top;
    2. A layer of overburden that has been covered with topsoil only, and then covered with a layer of crushed limestone (7mm) to a depth of 100mm;
    3. A layer of overburden that has been covered with topsoil and mulch, and then covered with a layer of crushed limestone (7mm) to a depth of 100mm;

4. A layer of overburden with a layer of crushed limestone (aggregate size of 19mm) to a depth of 100mm spread directly on top;
5. A layer of overburden that has been covered with topsoil only, and then covered with a layer of crushed limestone (19mm) to a depth of 100mm; and
6. A layer of overburden that has been covered with topsoil and mulch, and then covered with a layer of crushed limestone (19mm) to a depth of 100mm.

- One hectare of the seeding area will be spread with topsoil and mulch, seeded at a rate of 8 kg/ha with no fertiliser applied (control);
- One hectare of the seeding area will be spread with topsoil and mulch, seeded at a rate of 8 kg/ha with 100 kg/ha of fertiliser applied;
- Two hectares of the seeding area will be spread with topsoil and mulch, seeded at a rate of 8 kg/ha with 150 kg/ha of fertiliser applied; and
- Two hectares of the seeding area will be spread with topsoil and mulch, seeded at a rate of 6 kg/ha with 200 kg/ha of fertiliser applied.

The remainder of Stage 1 will be revegetated in 2005, adopting the trial that shows the best results for seed germination and survival in 2004/05.

4.2.2 Control of Access to Revegetated Areas

Vehicle access to areas that have been seeded and have young, establishing seedlings will be restricted to allow for successful growth and development of the species in their juvenile stage.

4.2.3 Pre-seeding Weed Control

The principal method of weed control will be by the application of a broad-spectrum herbicide (Glyphosate), sprayed in areas to be seeded on two occasions prior to the seeding of the area with native species. The herbicide applications will occur at the end of summer (mid to late March) and at the beginning of autumn (early to mid April). The broad-spectrum herbicide is the most suitable to ensure that annual (grass and broadleaf) and perennial (grass, broadleaf and bulbous) species are killed prior to seeding of the revegetation areas.

Weed control on the boundaries of, and within Mining Lease 70/717, will be undertaken to ensure that the revegetation efforts in the excavation areas are not re-infested as a result of weed seeds blowing in from the weed dominated areas within the quarry/landfill site and the property boundaries.

There are no restrictions on the use of herbicides associated with 'Underground Water Pollution Control Areas' (UWPCA), as the quarry/landfill site is not located within any of these areas (Gnangara, Wanneroo or Mirrabooka).

RCG and/or the rehabilitation contractor will liase directly with Swan Coastal DCLM office in relation to herbicide application, so as to minimise impact on non-target species.

4.2.4 Species Selection

The choice of species for the rehabilitation programme has been based on a selection of species, which are locally found in the area, and are present in the adjacent bushland in Neerabup National Park. These species are suited to growing in sandy soils over limestone, and will provide sufficient ground cover and soil surface protection.

4.2.4.1 Suitable Species To Be Used For Revegetation

The species selected are based on a preliminary botanical survey undertaken in the adjacent sections of the Neerabup National Park, and comprise tree, shrub, groundcover and herbaceous species, which are listed below:

Tree Species: *Allocasuarina fraseriana, Banksia attenuata, Banksia grandis, Banksia menziesii, Eucalyptus decipiens, Eucalyptus gomphocephala* (Tuart) and *Eucalyptus marginata* (Jarrah).

Medium to Large Shrub Species: *Acacia cochlearis, Acacia pulchella, Acacia rostellifera, Allocasuarina humilis, Calothamnus quadrifidus, Daviesia divaricata, Dryandra sessilis, Grevillea crithmifolia, Hakea costata, Hakea lissocarpha, Hakea prostrata, Hakea trifurcata, Jacksonia sternbergiana, Melaleuca huegeli, Spyridium globulosum* and *Templetonia retusa.*

Small to Medium Shrub Species: *Bossiaea eriocarpa, Gastrolobium capitatum, Gompholobium tomentosum, Macrozamia riedlei, Melaleuca systena, Olearia axillaris. Petrophile machrostycha, Petrophile serruriae and Xanthorrhoea preissii.*

Groundcover/Creeper Species: *Hardenbergia comptoniana, Jacksonia sericea* and *Kennedia prostrata.*

Herbaceous Species: *Conostylis aculeata, Conostylis candicans, Orthrosanthus laxus and Patersonia occidentalis.*

4.2.4.2 Seed Collection

Wherever possible, the propagation of the species to be used for the revegetation programme will be from locally collected seed (within a radius of 20km) in the summer of 2003/04. This will be conducted by external contractors or seed suppliers, and will be arranged well in advance of seeding.

4.2.5 Seed Pre-treatment

Seed pre-treatments (aerosol smoking, scarification, hot water treatment, etc.) will be conducted to the relevant species requirements (the leguminous species, i.e. *Acacia* and pea species) by qualified and experienced contractors immediately prior to broadcasting, to stimulate germination.

4.2.6 Direct Seeding And Seeding Rates

The seeding rate will be 8kg/ha to ensure that the establishment densities are acceptable and the maintenance requirements are minimal. There is also one 2 ha. trial area that will be seeded at a rate of 6 kg/ha. Seeds will be broadcast by hand in autumn following the first significant rainfall event. **Table 1** contains the details of the relative proportions and application rates for the species used in the revegetation programme.

Table 1: Species and Seeding Quantity for Mining Lease M70/717

Species	Habit	Seeding Application Rate (kg/ha)
Acacia cochlearis	Large shrub	0.150
Acacia pulchella	Medium shrub	0.400
Acacia rostellifera	Large shrub – Tree	0.150
Allocasuarina fraseriana	Tree	0.250
Allocasuarina humilis	Medium shrub	0.200
Banksia attenuata	Tree	0.300
Banksia grandis	Tree	0.200
Banksia menziesii	Tree	0.250
Bossiaea eriocarpa	Small shrub	0.200
Calothamnus quadrifidus	Medium shrub	0.200
Conostylis aculeata	Perennial herb	0.400
Conostylis candicans	Perennial herb	0.400
Daviesia divaricata	Medium shrub	0.200
Dryandra sessilis	Med. – Large shrub	0.200
Eucalyptus decipiens	Tree	0.050
Eucalyptus gomphocephala	Tree	0.075
Eucalyptus marginata	Tree	0.150
Gastrolobium capitatum	Small shrub	0.250
Gompholobium tomentosum	Small shrub	0.150
Grevillea crithmifolia	Med. – Large shrub	0.150
Hakea costata	Medium shrub	0.050
Hakea lissocarpha	Medium shrub	0.100
Hakea prostrata	Med. – Large shrub	0.100
Hakea trifurcata	Medium shrub	0.075
Hardenbergia comptoniana	Climber/Groundcover	0.400
Jacksonia sericea	Small shrub	0.200
Jacksonia sternbergiana	Medium shrub	0.050
Kennedia prostrata	Climber/Groundcover	0.500
Macrozamia riedlei	Small – Med. Shrub	0.400
Melaleuca huegelii	Large shrub	0.050
Melaleuca systena	Small shrub	0.500
Olearia axillaris	Small – Med. shrub	0.100
Orthrosanthus laxus	Perennial herb	0.150
Patersonia occidentalis	Perennial herb	0.300
Petrophile macrostachya	Small – Med. shrub	0.100
Petrophile serruriae	Medium shrub	0.200
Spyridium globulosum	Large shrub	0.050
Templetonia retusa	Medium shrub	0.200
Xanthorrhoea preissii	Medium shrub	0.150
Total		**8.02**

The list of species in **Table 1** may change depending on the availability of seed from some of the species, and the rate of germination following seeding.

The 2 ha. trial area, which is seeded at a rate of 6 kg/ha, will be seeded with the species in **Table 1,** with the proportions of each species adjusted to 75% of the total application rates listed.

4.2.7 Fertiliser Application

An alternative fertiliser to Superphosphate is Macrocote Grey Plus. This is a coated, slow release fertiliser specific for native species, which releases the nutrients available over an 8 to 9 month period. This will give the developing seedlings a better chance for survival, and due to its slow release, will not provide a large quantity of nutrients when the large proportion of weed species germinate.

Different rates of fertiliser application will be trialled in the areas to be seeded in 2004. There will also be one control area, 1ha in size, which will not have any fertiliser added. The application rate, which has the greatest success in terms of seed germination and seedling establishment and survival, will be used as the application rate for all future seeding activities. The three application rates of Macrocote to be trialled in 2004 are 100 kg/ha, 150 kg/ha and 200 kg/ha.

4.3 MAINTENANCE OF REHABILITATION

Rehabilitation maintenance will be implemented in conjunction with the monitoring programme.

This maintenance will address:

- Weed control,
- Fertiliser application, and
- Reseeding of areas.

A maintenance budget provision of approximately 30% of the initial rehabilitation budget in the first year after seeding and 15% in the second year will be set aside to cover the cost of maintenance under normal conditions.

4.3.1 Post-seeding Weed Management

Weed control by chemical means in areas that have been seeded and have germinated will be difficult due to the potential for herbicide impacts to native seedlings. The best time for chemical control of the majority proportion of weeds is therefore prior to any native seed dispersal (to prevent seed set in areas to be revegetated), and then followed up with spot spraying of future infestations. Spot spraying will be carried out on days that are not windy to avoid spray drift impacts to native seedlings. RCG and/or the rehabilitation contractor will liase directly with the Swan Coastal District DCLM office in relation to herbicide application, so as to minimise impact on non-target species.

For infestation of areas with grass species (for example, Perennial Veldt Grass, *Ehrharta calycina*), a selective herbicide such as Fusilade ® can be used. This herbicide only targets grass species, and will not impact the native species used in the revegetation programme.

4.3.2 Surface Condition

The soil surface condition must be maintained to a high standard for newly emerging seedlings to survive. If the soil surface is too loose, germinating seedlings are easily buried or 'sand blasted' during strong winds, which can strip the leaves and kill the plants.

A water truck is used on the quarry site during the drier months, to wet down areas that become dry and cause the spread of limestone dust to neighbouring areas. The areas that are seeded will be wet down during periods of windy conditions, which will keep the soil surface damp and not susceptible to being blown around during windy conditions.

4.3.3 Plant Health

Unhealthy seedlings may require additional inputs such as slow release fertiliser (specifically formulated for native species) or water to help them recover. These maintenance applications will only be provided in the first summer following seeding (if necessary). If they are continued for a longer period, the plants are likely to develop a reliance on these inputs and not develop a sufficiently vigorous and deep root system, which would be detrimental once maintenance ceases.

4.3.4 Poor Germination and Survival Rates

A significant allowance for remedial works is recommended to ensure that the rehabilitation programme complies with the set completion criteria. Most of the remedial action should be required in the first year while the site has very little vegetative cover on it. Once the vegetation establishes, the site will become more densely covered and protected.

In the second year (2005) a limited amount of reseeding will be considered, if areas of seeding from 2004 are not completely successful in terms of vegetative cover. This will only be considered for smaller areas as the cost may become excessive for larger areas.

4.3.5 Provision for Predation

Monitoring of the first years operations should provide information on predation rates, which will be taken into account in the following years maintenance plan. Due to the neighbouring Neerabup National Park, there may be predation of newly rehabilitated areas by kangaroos and/or rabbits. Maintenance provisions account for a need to reseed and possibly replant (tubestock) areas, however, it is difficult to estimate the effect predation will have over the entire site.

Insect predation will also be recorded during the rehabilitation monitoring and maintenance stages. Pest control will be carried out accordingly on an 'as needs' basis, if predation is seen to impact on more than 10% of the total revegetation, or if it lowers the forecast average density. Any application

of pesticides will be carried out according to the manufacturers instructions, and during weather conditions (not windy), which will reduce the likelihood of chemical spray drift to the neighbouring bushland in the Neerabup National Park. RCG and/or the appointed contractor will liase with the Swan Coastal District office of DCALM to ensure that impact on non-target species is minimised.

4.4 REHABILITATION MONITORING

The aim of the monitoring programme is to measure the progress and relative success of the rehabilitation operations. Irrespective of the completion criteria, the rehabilitation on the Mining Lease will be based on routine maintenance (i.e. repairs, weed management, soil amendment, reseeding/replanting etc.) and regular assessments throughout the revegetation programme. If at any time it is likely that the completion criteria may not be met, RCG Technologies will undertake suitable remedial action.

4.4.1 Completion Criteria

At the end of the maintenance period (the third year following the first seeding activities) the following completion criteria will be addressed:

- Plants are healthy in appearance, there is a good level of species diversity with no areas of mass deaths or species dominance;
- The species diversity and average seedling height has increased between the assessments;
- At least 75% – 80% of the species seeded are represented; (we said 90% but this looks OK)
- The density of understorey averages two plants per square metre or greater;(we said 4 per sqm)
- An overstorey density of at least 500 plants per hectare is present, calculated independently of understorey density;
- The level of weed species should not exceed levels present in adjacent native woodland, should not be detrimental or restrictive to rehabilitated germinates and should not be of a highly invasive nature;
- Where forecast average density is not achieved, RCG Technologies will undertake remediation by appropriate methods.

These criteria are considered practical and realistic based on other rehabilitation works for similar areas and the direct seeding rates provided. These expectations are for a period of normal Perth weather conditions (long, hot, dry summers and brief, mild winters).

4.4.2 Monitoring

Formal vegetation monitoring, to record the progress and success of the revegetation programme, will be undertaken in the first spring season following seeding, and in consecutive autumn and spring seasons for the following two years.

Table 3: Monitoring Assessment Schedule

Assessment	Timing	Factors to Monitor
1	After 16 weeks	Seed germination and species diversity
2	End of November season 1	Seed germination, seedling survival and species diversity
3	Autumn season 2	Survival, plant size, density and species diversity
4	Spring season 2	Survival, plant size, density and species diversity
5	Autumn season 3	Survival, plant size, density and species diversity
6	Spring season 3	Survival, plant size, density and species diversity

The monitoring assessments will be conducted in two randomly placed 5m x 5m quadrats per hectare. It is recommended that these quadrats are permanently located once the rehabilitation operations have been completed. In addition to the data collected for each quadrat, a complete photographic record will be maintained for each of the monitoring sites (from a marked reference point), to provide a visual representation of progress.

Two smaller quadrats of 1m x 1m will also be marked out in each of the soil surface preparation trial areas for monitoring in the first two years following seeding of the plots in 2004.

A set of procedures and standardised reporting systems will be employed to ensure consistency of the results. The following sections contain guidelines on the timing and contents of reports.

4.4.2.1 Bi-monthly Reviews

Informal reviews of the following factors should be conducted on a bi-monthly basis:

- Weed infestation levels and the species present;
- General plant health of the native species seeded in the revegetation areas; and
- The soil surface condition – erosion and the provision of niches for germinating seeds.

These observations should provide an early indication of factors stressing the native seedlings, which can then be controlled. Without a regular review, losses may be encountered and the cost of remedial works will increase. This review would not require formal reporting.

4.4.2.2 Monitoring Assessments 1 and 2

The first formal assessments will measure and compare the total number of germinating native seedlings (from the seed mix used in seeding) within each of the quadrats. At this early stage of development it is generally difficult to differentiate between the species, particularly as some native species have juvenile foliage, which looks quite different to the adult foliage. Any species that are identified should be noted, as well as the total number of different species found in each quadrat.

Monitoring Assessment 1 will be undertaken in September of the year following seeding, and Monitoring Assessment 2 will be undertaken at the end of November in the year following seeding activities.

4.4.2.3 Monitoring Assessment 3

The third assessment is possibly the most important, as it measures the seedlings survival rates over the first summer (the most stressful period for seedlings, especially if they have not developed a sufficiently deep root system). This assessment will indicate whether additional seeding, weed management and any erosion control or repairs are required. Recommendations can then be provided for the upcoming season. A general assessment can then be made on the success of the entire operation.

Monitoring Assessment 3 will be undertaken in May of the next year after seeding is complete.

4.4.2.4 Monitoring Assessment 4

The assessment at the end of the second season should focus on species numbers and representation and hence provide a quantitative measure of the diversity. In each of the quadrats, every seedling should be recorded, taking into account average plant heights and the general health. This will provide survival data when compared with the first assessment completed at the end of the first season. The survival rate is generally expected to be low due to the high level of seed germination in the first year following seeding.

Monitoring Assessment 4 will be undertaken in October of the year after seeding activities.

4.4.2.5 Monitoring Assessments 5 and 6

These assessments should be conducted in the same manner as the third and fourth respectively. The data from the autumn assessment will determine the maintenance requirements. The sixth assessment will be the last, and should be a quantitative measure of site performance compared with completion targets. This final assessment should demonstrate progress towards ecosystem restoration, which is comparable to the neighbouring ecosystem in the Neerabup National Park.

Monitoring Assessment 5 will be undertaken in May of the second year after seeding, and Monitoring Assessment 6 will be undertaken in October of the second year after seeding.

4.4.3 Long-term Monitoring

Following the completion of the rehabilitation works on the site, RCG Technologies will undertake long-term rehabilitation monitoring, in the monitoring plots used for assessments following seeding. Four Star pickets will mark the boundary of the monitoring plot and a GPS reading of the northwest corner will be taken to assist in relocating the plot. Information regarding the area, plot number and year rehabilitated will be recorded on the northwest peg. Long term monitoring will continue until the completion criteria stipulated in Section 4.4.1 are fulfilled.

A field survey will be undertaken once a year, in spring (October to November), to assist in the identification of species present and to target any opportunistic species occurring in the area. In each monitoring plot, the field survey should record the presence of species and the number of individuals of each species, height and percentage cover (of living and dead individuals). The field recordings should be used to statistically analyse the performance of the rehabilitation.

4.4.4 Reporting of Rehabilitation Results

The annual report submitted to DoIR under the conditions of the lease will contain details regarding the performance of the rehabilitation, statistical analyses, as well as any management or remedial actions required.

5. ONGOING REHABILITATION PLAN REVIEW

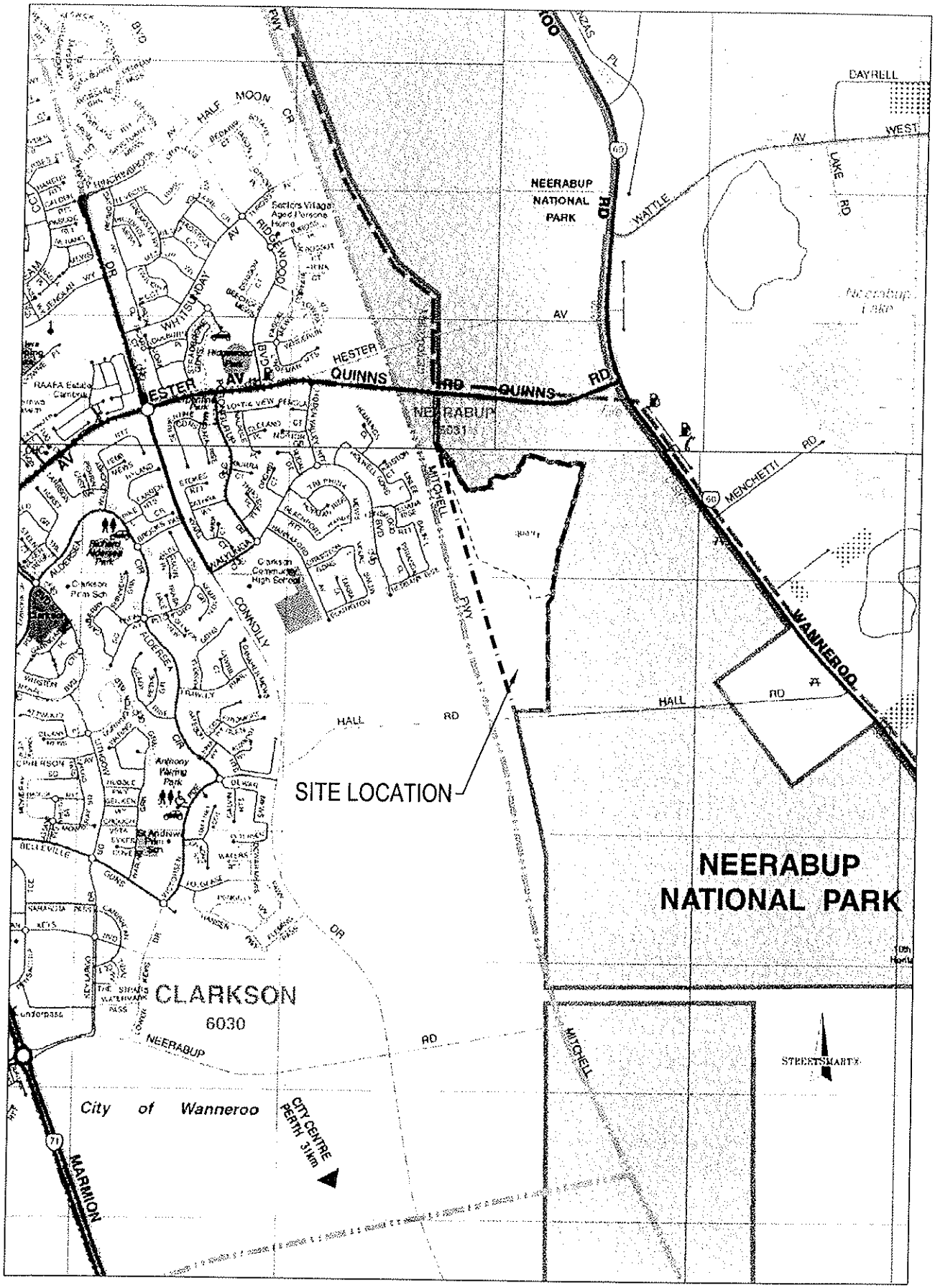
The results from the revegetation activities undertaken in Stages 1 and 2 in 2004 and 2005 will be used as the basis for the revegetation activities proposed for the remainder of the site (Stages 3, 4 and 5).

This will ensure the best outcomes for the future rehabilitation areas for the remainder of the lease period, in order to satisfy DCLM that the lease area has been rehabilitated to a level that is acceptable as a future addition to the Neerabup National Park.

6. REFERENCES

Koltasz Smith and Partners (1998): **Limestone Quarry Management Programme – Mining Lease 70/717 Quinns Road, Quinns Rock**. Report prepared for R.C.G Pty. Ltd.

FIGURES



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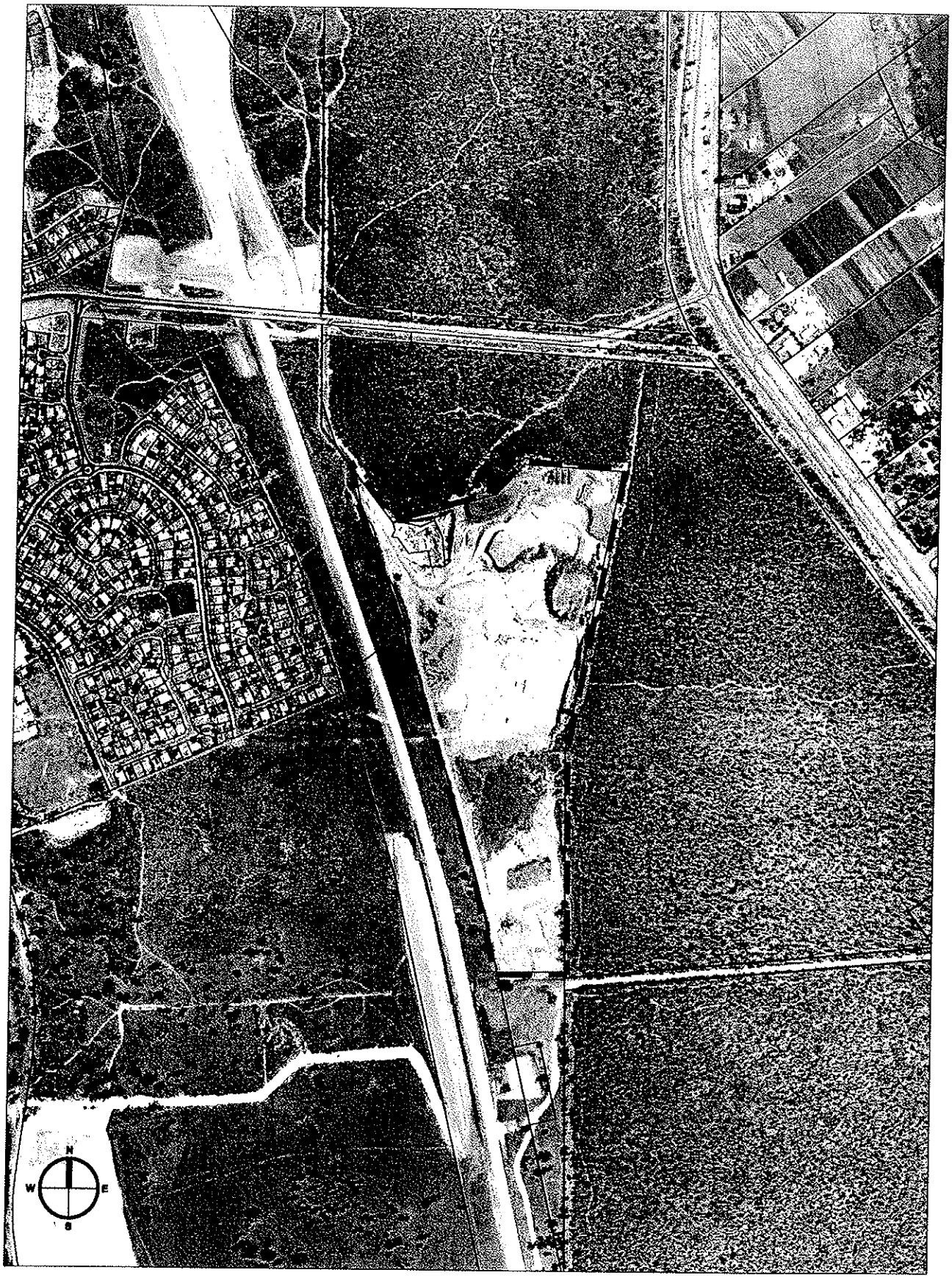
MINING LEASE 70/717 REHABILITATION PLAN

FIGURE 1 - LOCALITY PLAN

BSD CONSULTANTS

Project Number	Original
V03020	A4
Drawing Number	Revision
V172-SK01	



Quarry Boundary

Aerial Photograph courtesy of DLI 2003

1:10,000 0 200m 400m

MINING LEASE 70/717 REHABILITATION PLAN

FIGURE 2 - AERIAL PHOTO

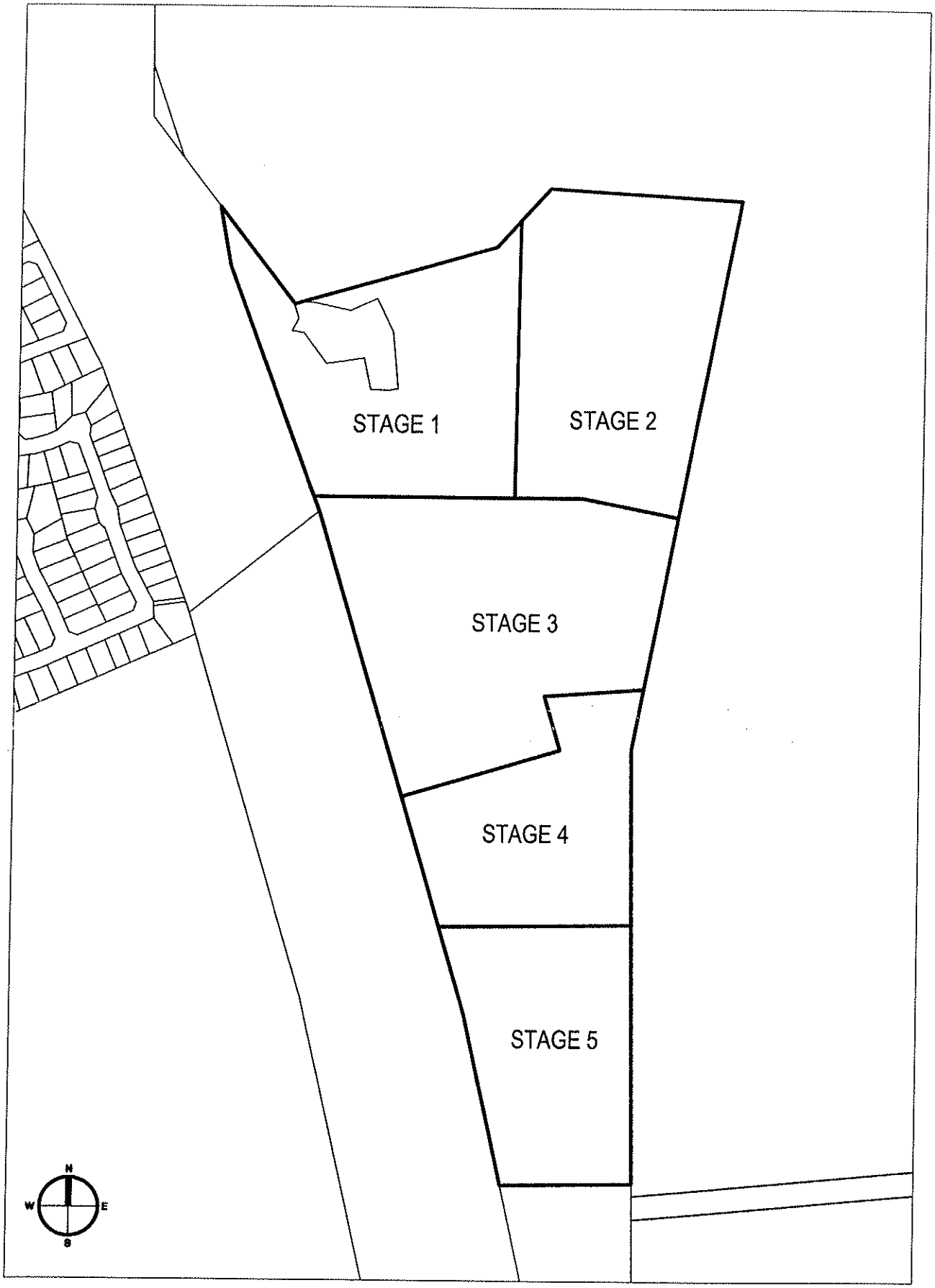
BSD

Project Number V03020

Original A4

Drawing Number V172-SK02

Revision

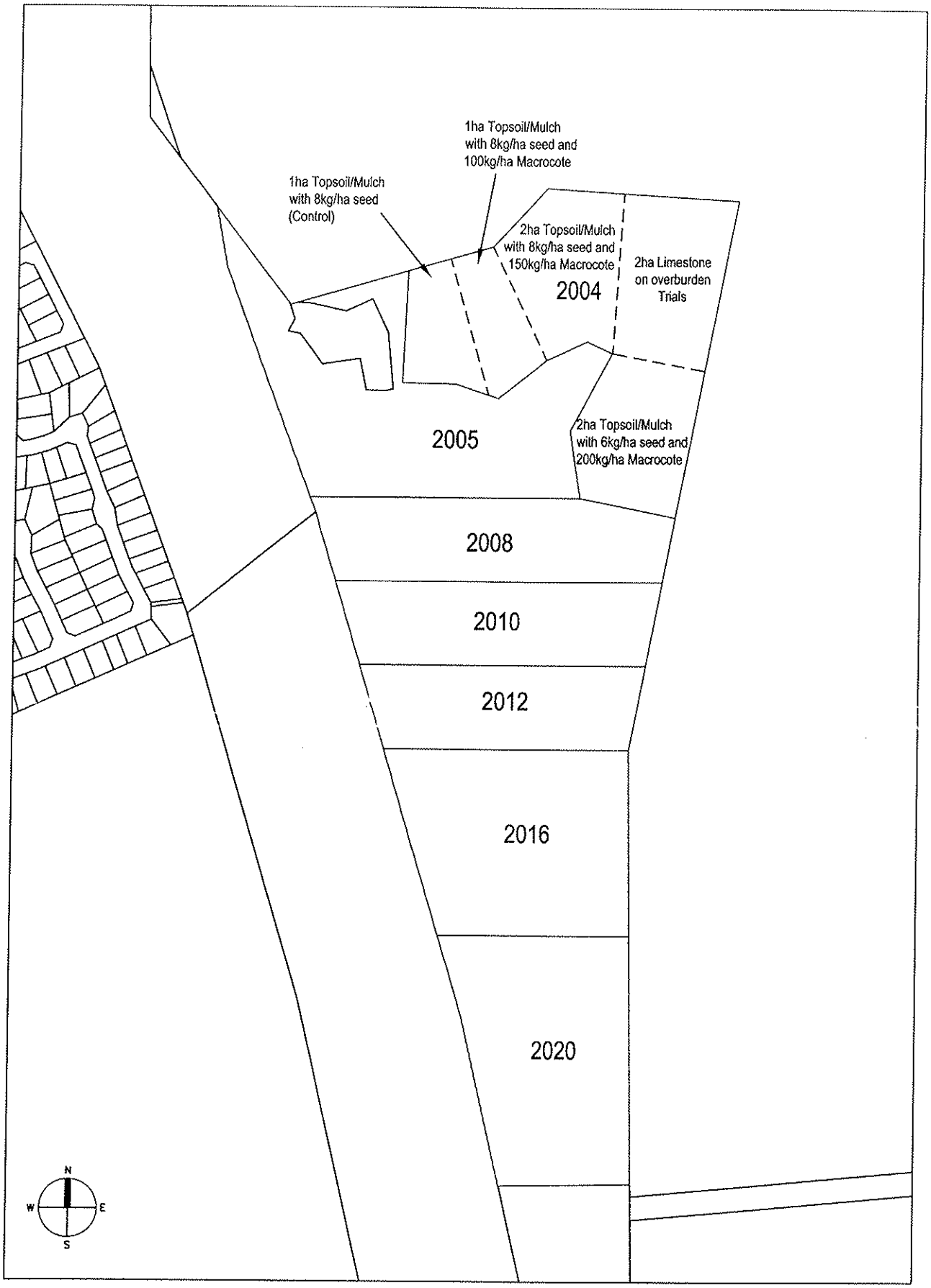


MINING LEASE 70/717 REHABILITATION PLAN

FIGURE 3 - QUARRY STAGING PLAN FOR EXCAVATION & LANDFILL ACTIVITIES

BSD CONSULTANTS

Project Number V03020	Original A4
Drawing Number V172-SK03	Revision



MINING LEASE 70/717 REHABILITATION PLAN

FIGURE 4 - STAGING OF QUARRY REHABILITATION WORK

BSD CONSULTANTS

Project Number V03020

Original A4

Drawing Number V172-SK04

Revision A

LAND IMPACTS BRANCH

Western Australian
Department of Agriculture

ISSN 0083-8675
Agdex 332/31

Technical Bulletin

Screening shrubs for establishment and survival on salt-affected soils in south-western Australia

No. 81

C.V. Malcolm
T.C. Swaan

Full document available on request

S76 Vol 1

Ass # 826
Bull # 737
State # 435

MINISTER FOR THE ENVIRONMENT WESTERN

STATEMENT THAT A PROPOSAL MAY BE IMPLEMENTED (PURSUANT TO THE PROVISIONS OF THE ENVIRONMENTAL PROTECTION ACT 1986)

MINING OF GYPSUM WITHIN CHINOCUP A CLASS NATURE RESERVE PINGRUP, SHIRE OF KENT (826)

P G PATTERSON
SHINER

This proposal may be implemented subject to the following conditions and procedures:

1 Proponent Commitments
The proponent has made a number of environmental management commitments ("the commitments") in order to protect the environment.

1-1 In implementing the proposal, the proponent shall fulfil those commitments made in the Consultative Environmental Review, those made in response to issues raised following public submissions and subsequently, all of which are consolidated and contained in Schedule A hereto; provided that the commitments are not inconsistent with the conditions or procedures contained in this statement.

2 Implementation
Changes to the proposal which are not substantial may be carried out with the approval of the Minister for the Environment.

2-1 Subject to these conditions, the manner of detailed implementation of the proposal shall conform in substance with that set out in any designs, specifications, plans or other technical material submitted by the proponent to the Environmental Protection Authority with the proposal.

Under sections 48(3) and 48(4) of the Environmental Protection Act, the Minister for the Environment shall cause such steps as are necessary to ensure compliance by the proponent with the relevant conditions and procedures contained in this statement.

2-2 Where, in the course of the detailed implementation referred to in condition 2-1, the proponent seeks to change the designs, specifications, plans or other technical material submitted to the Environmental Protection Authority in any way that the Minister for the Environment determines, on the advice of the Environmental Protection Authority, is not substantial, those changes may be effected.

Published on

15 DEC 1995

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3 Proponent

These conditions legally apply to the nominated proponent.

3-1 No transfer of ownership, control or management of the project which would give rise to a need for the replacement of the proponent shall take place until the Minister for the Environment has advised the proponent that approval has been given for the nomination of a replacement proponent. Any request for the exercise of that power of the Minister shall be accompanied by a copy of this statement endorsed with an undertaking by the proposed replacement proponent to carry out the project in accordance with the conditions and procedures set out in the statement.

4 Rare Flora Management Plan

4-1 The proponent shall ensure the protection of rare and endangered flora within the project area.

4-2 To achieve the objective of condition 4-1, prior to any ground-disturbing activity and in consultation with the Department of Conservation and Land Management and the King's Park Board, the proponent shall prepare a Rare Flora Management Plan which addresses, but is not limited to the following:

1 further surveys of rare and endangered flora on the site at appropriate times; and

2 trials to propagate identified rare and endangered flora,

to the requirements of the Minister for the Environment on advice of the Environmental Protection Authority (also see commitment 18).

4-3 The proponent shall implement the Rare Flora Management Plan required by condition 4-2.

5 Mining

5-1 The planning and conduct of mining operations shall be carried out in accordance with the commitments and with the requirements of this statement.

5-2 Subject to condition 5-4, the period permitted by this statement for carrying out mining operations is five years commencing from the date when the relevant mining lease is granted to the proponent under the Mining Act.

5-3 Subject to condition 5-4, mining operations shall be limited to a total area not exceeding 10 hectares, with a maximum of 3 hectares in any one year or 5 hectares in any two years of the mining operations.

5-4 The Minister for the Environment may approve an extension of the period referred to in condition 5-2 for a further period of five years and may approve of the addition of a further 10 hectares to the mining area referred to in condition 5-3 if the Minister is satisfied on the advice of the Department of Environmental Protection, the Department of Conservation and Land Management, the Commissioner of Soil and Land Conservation and the Department of Minerals and Energy, that this statement has been complied with by the proponent and in particular, without limiting the generality of that requirement, if he is satisfied that the proponent has suitably met the obligations assumed by the proponent under the heading "Landcare" in the commitments which are attached to this statement.

6 Rehabilitation

6-1 Within three months following commencement of mining, the proponent shall submit a Rehabilitation Plan to the requirements of the Minister for the Environment on advice of the Department of Conservation and Land Management and the King's Park Board.

This plan shall address, but not be limited to the following:

1 re-establishment of rare flora species within the mined area;

2 stockpiling and re-use of top-soil to maximize species diversity; and

3 baseline flora and fauna assessments to ensure that the success of rehabilitation is adequately monitored.

Also see proponent commitments, section "Vegetation Retention and Rehabilitation Programme".

6-2 The proponent shall implement the plan required by condition 6-1.

7 Decommissioning

7-1 The proponent shall carry out the decommissioning of the project, removal of the plant and installations and rehabilitation of the site and its environs to the requirements of the Minister for the Environment on advice of the Department of Environmental Protection, the Department of Conservation and Land Management and the Department of Minerals and Energy.

7-2 At least six months prior to decommissioning, the proponent shall prepare a decommissioning and final rehabilitation plan to achieve the objectives of condition 7-1.

7-3 The proponent shall implement the plan required by condition 7-2.

8 Time Limit on Commencement

The environmental approval for the proposal is limited.

8-1 If the proponent has not substantially commenced the project within two years of the date of this statement, then the approval to implement the proposal as granted in this statement shall lapse and be void. The Minister for the Environment shall determine any question as to whether the project has been substantially commenced.

Any application to extend the period of two years referred to in this condition shall be made before the expiration of that period to the Minister for the Environment.

Where the proponent demonstrates to the requirements of the Minister for the Environment on advice of the Department of Environmental Protection that the environmental parameters of the proposal have not changed significantly, then the Minister may grant an extension not exceeding two years for the substantial commencement of the proposal.

9 Performance Review

9-1 Following the commencement of ground-disturbing activities, the proponent shall carry out annual audits of environmental performance.

The proponent shall provide the audit reports to the Department of Environmental Protection, the Department of Conservation and Land Management and the Department of Minerals and Energy each year.

9-2 Within four years following the commencement of ground-disturbing activities, the proponent shall prepare a major review of the following:

1 environmental protection, including but not limited to consideration of the environmental objectives;

2 the audit of performance against the environmental objectives; and

3 the annual audits required by condition 9-1,

to the requirements of the Environmental Protection Authority on advice of the Department of Environmental Protection, the Department of Conservation and Land Management and the King's Park Board.

These environmental objectives shall include, but not be limited to those identified by the Environmental Protection Authority.

The environmental objectives may be changed by the Environmental Protection Authority following the review.

10 Compliance Auditing

To help determine environmental performance and compliance with the conditions, periodic reports on the implementation of the proposal are required.

10-1 The proponent shall submit periodic Performance and Compliance Reports, in accordance with an audit programme prepared by the Department of Environmental Protection in consultation with the proponent.

Note: The Department of Environmental Protection will consult with the Department of Conservation and Land Management and the Department of Minerals and Energy in the preparation of this programme.

Procedure

1 Unless otherwise specified, the Department of Environmental Protection is responsible for assessing compliance with the conditions contained in this statement and for issuing formal clearance of conditions.

2 Where compliance with any condition is in dispute, the matter will be determined by the Minister for the Environment.

3 No mining operations may be commenced until the Minister for the Environment notifies the proponent that he has received from the Lake Chinocup Catchment Resource Management Committee a satisfactory plan of landcare management in respect of the impact on the Nature Reserve of land degradation within the Lake Chinocup sub-catchment.

4 No part of the proposal may commence prior to the approval of both Houses of Parliament as required under section 24(4) of the Mining Act in respect of the grant of a mining lease.

Hon Peter Foss QC MLC
MINISTER FOR THE ENVIRONMENT

12 DEC 1996

Schedule A

Environmental Management Commitments

MINING OF GYPSUM WITHIN CHINOCUP A CLASS NATURE RESERVE

PINGRUP, SHIRE OF KENT (826)

operation in accordance with this map.

Before any site is mined, mining commences, the proponent shall submit a map which defines the areas of deposits to be mined in years one to five, the boundaries of the mining area, and all pegs will be coloured in accordance with Figure 2).

P G PATTERSON

Before any site is mined, mining commences, the proponent shall submit a map which defines areas of planted trees which are to be retained, the boundaries of the mining area, 1:5 batter slopes, in accordance with CALM, and submit this map to the DME.

This map will be modified as Figure 3 and the proponent shall undertake mining operations in accordance with this map.

PROPONENT'S ENVIRONMENTAL MANAGEMENT COMMITMENTS (826)

LAKE CHINOCUP "A" CLASS NATURE RESERVE No. 28395 MINE PLAN-EXTRACTION OF AGRICULTURAL GYPSUM

The following are the commitments which the proponent puts forward for the purpose of obtaining approval to implement the proposal and the proponent undertakes that where in these commitments an action will occur, unless otherwise specified, the proponent will ensure that it will occur.

MINE SITE DEVELOPMENTS

1 Before any siteworks or mining commences, the proponent will consult with and provide a map to the Departments of Environmental Protection (DEP), Conservation and Land Management (CALM) and Minerals and Energy (DME) showing the distribution and level above high water mark of the main gypsum deposits which would be mined over the five years. In consultation with DEP, CALM and DME, an establishment datum will be defined, below which gypsum will not be removed.

This map will be defined as Figure 1.

2 Before any siteworks or mining commences, the proponent will prepare a map, in consultation with DME, showing the total area within the reserve that would be subject to mining for the 5 year period of this proposal, including access tracks and stockpile areas, and submit this map to the DEP, CALM and DME.

The position of permanent water table monitors will be defined on this map and the relationship to areas of natural drainage.

Also outlined on this map will be an appropriate area for stockpiling the 15cm of topsoil which will be removed preceding the commencement of mining activity.

This map will be defined as Figure 2 and the proponent will implement the mining operation in accordance with this map.

3 Before any siteworks or mining commences, the proponent will mark out on the ground which pegs the area of deposits to be mined in years 1 to 5, with a setback of 10 metres from the high water mark, and all pegs will be co-ordinated using Global Positioning Satellite data (to be shown on Figure 2).

4 Before any siteworks or mining commences, the proponent will prepare a map that defines areas of plants and trees which are to be retained, surrounded by an area with a 1:5 batter slope, in consultation with CALM, and submit this map to the DEP, CALM and DME.

This map will be defined as Figure 3 and the proponent will implement the mining operation to protect these areas.

MINE OPERATION

5 The proponent will carry the mining operation in a manner that will ensure that the conservation values of the reserve are protected in consultation with CALM.

6 The proponent will implement measures to prevent unauthorised public access to the mining area.

7 The proponent will monitor and record public access into the mining area, in consultation with the Shire of Kent.

8 Before any siteworks or mining commences, the proponent will establish water table and salinity monitors around the boundary of the Nature Reserve and around the area to be worked, to the requirements of the Water and Rivers Commission, DEP and CALM.

The proponent will monitor all water levels and salinities on a monthly basis at all stages of the mining operation and all data will be included in an annual report to the DEP.

Monitoring sites will be shown on Figure 2 to be to the satisfaction of DEP.

9 The proponent will remove topsoil to a depth of 15cm within the area marked out to be mined during the first season and stockpile in an adjacent designated area (to be shown on Figure 2).

This overburden may contain vegetable matter and will be stockpiled in an area not subject to water intrusion.

As the seed bank and other organisms within this topsoil are subject to degeneration, it will be respread as quickly as is practicable on the mined out areas.

10 The areas to be mined will total 10ha over 5 years with a maximum of 3ha in any one year and the proponent will provide estimates of the total mineable tonnage of gypsum contained in those individual deposits.

The proponent will survey the mine areas and will provide the total tonnages to be mined in each year. In mining each section the proponent's preference is:

1 to intensively extract gypsum from the areas of highest mineralisation, in order to satisfy the determined annual production rate, and

2 to retain the balance of each section in its natural state.

11 The proponent will carry out the excavation of gypsum sand by a rubber-tyred front-end loader and loading into a multi-axle truck or semi-trailer for delivery to a stockpile area within the Chinocup townsite reserve.

Product sold from the mining operations will be in-situ gypsum sand and no processing is proposed or necessary.

This will ensure that no liquid wastes are generated.

12 The proponent will ensure that all trucks, loaders and light vehicles which have access to the mine site are cleaned down before entry to ensure no ingress of weeds or other plant species (doublegees, clover etc).

13 The proponent will not excavate gypsum anywhere on the site below an established datum which is above the maximum known high water mark of Lake Chinocup on the datum established by CALM and DME (shown on Figure 1).

14 This measure and the replacement of 15cm of topsoil will ensure that no worked area will be below the high water mark at the completion of site rehabilitation.

15 The proponent will ensure that there is no excavation of gypsum or other material below the determined level.

16 The proponent will engage a licensed surveyor to verify excavation levels and parameters of areas subject to mining activity, on an annual basis.

17 The proponent will similarly ensure that no saline groundwater is exposed at any time during mining activity.

VEGETATION RETENTION AND REHABILITATION PROGRAMME

18 The proponent will prepare a vegetation retention and rehabilitation programme and seek the advice of CALM and the King's Park Board on all aspects of revegetation retention and rehabilitation.

19 The proponent will seek the approval of the Minister for the Environment before any removal of rare plants, or for the collection of seed and/or cuttings for revegetation purposes.

20 Where such seed collection or taking of cuttings is required, a nursery operator with local knowledge and experience will be employed by the proponent to review the option and to undertake all work.

21 The proponent will focus on the stockpiling and subsequent sale of gypsum through the summer months and up to the commencement of seeding for the region's wheat and coarse grains.

22 Rehabilitation of the entire mined area, up to 3 hectares, will be undertaken in early autumn of each year.

23 The proponent will re-contour the worked-out areas and spread the stockpiled topsoil to a minimum depth of 15cm above the established datum. This will assist in revegetation and maintenance of pre-mining hydrology.

24 Pre-existing hummocks and contours within the mined area will be restored as near to original as possible to encourage the regeneration of micro-environments.

25 The proponent will ensure that the distribution of collected seed and the planting of seedlings is undertaken.

26 As part of the revegetation programme, appropriate weed and feral animal (especially rabbit) control will be implemented by the proponent within the mined area and mine access road.

27 The proponent will monitor and control weed and feral animals within the mined area and mine access road for a minimum of 3 years, and up to 5 years if necessary, after mining and rehabilitation is completed, to the satisfaction of CALM.

ACCESS PROVISIONS AND ENVIRONMENTAL CONTROLS

28 The proponent expects that road upgrading will comprise the use of gravel (possibly from the immediately adjacent railway reserve) in the construction of a causeway if used during the operating period.

29 The proponent will ensure that no substantial earthworks will be undertaken and the road will be capable of being removed upon completion of mining.

30 The seasonal nature of mining will not require the track to be upgraded to an all weather road; appropriate dust control measures will be put in place during the mining operation, in consultation with CALM.

31 Should two-way access or passing bays be required as agreed with DME and CALM, additional road surfaces will only be developed by the proponent on the existing railway formation.

32 If small areas of native vegetation need to be removed in order to link the railway formation with the existing track, the proponent will engage an experienced botanist to survey the Declared Rare and Priority species that may be affected, prior to the start of construction, and report to the DEP and CALM. The route of any proposed linking track will be agreed with CALM prior to the start of construction.

While no new roads or upgrading of existing roads is likely to be required outside the reserve, the proponent will implement minor road improvements in consultation with the Shire of Kent.

33 Should the proponent seek permission to develop access from the eastern side of the nature reserve, a proposal will be submitted for assessment and approval from the EPA in consultation with the National Parks and Nature Conservation Authority (NP & NCA) and CALM.

34 The proponent will not develop the existing access track (unmade road 8315) through the Nature Reserve and will assist CALM in discouraging its use.

35 The proponent will establish a stockpile area on a gravel-covered 0.4 hectare area within the Chinocup townsite, such that trucks will not have to enter the Nature Reserve to be loaded with gypsum.

Use of the existing gravel area at the former railway station site will eliminate the need to clear additional vegetation for stockpiling mined gypsum.

36 The proponent will allow their employees to use only the access track to enter the mining area.

37 A small storage facility for diesel fuel will be needed to supply the proponent's front-end loader and truck. The proponent will install this facility in accordance with standard DME guidelines, including a base and bunds of suitable impervious material.

The proponent will locate the diesel fuel facility at the old Chinocup townsite.

38 A simple portable toilet unit will be purchased by the proponent and installed at the stockpile area and disposal of wastes will be to the requirements of NP & NCA, CALM and the Shire.

LANDCARE

Background

- The proponent puts forward the following commitments with the objective that the environment which surrounds the site of the proposal (namely the Lake Chinocup sub-catchment within the Nature Reserve) will secure a net environmental gain resulting from the carrying out of the actions referred to in these commitments in conjunction with the proposal.

- The EPA has confirmed that "land degradation" in the catchment represents the major threat to that environment and in particular to the long term viability of the Lake Chinocup sub-catchment within the Nature Reserve.

- The EPA has stated as follows-
"The EPA considers that the development of an integrated catchment management plan for the Lake Chinocup sub-catchment would be a positive outcome from the assessment of the Lake Chinocup gypsum mining proposal. It would bring the various interest groups together to manage the land and drainage systems in an integrated manner for the benefit of both the Chinocup Nature Reserve and sustainable agricultural productivity".

- The proponent recognises that if the actions set out below, to be taken by the proponent or which the proponent will facilitate and use its best endeavours to have carried out by the relevant community, are not progressed so as to demonstrate to the satisfaction of the Minister for the Environment an overall net environmental gain for the Lake Chinocup sub-catchment within the Nature Reserve then no extension of mining beyond the initial 5 years will be approved.

39 The proponent will use all reasonable endeavours to promote and bring about the use of gypsum by owners of agricultural properties within the Lake Chinocup sub-catchment as a means of contributing to landcare objectives likely to be beneficial to the Lake Chincoup sub-catchment and the Nature Reserve in the sub-catchment.

40 The proponent will use all reasonable endeavours to ensure that a landcare plan prepared by the Lake Chinocup Catchment Resource Management Committee ("the LCCRMC") and accepted by the Minister for the Environment is implemented by the community within the Lake Chinocup sub-catchment.

41 The proponent has signed a heads of agreement with the LCCRMC, a copy of which is attached hereto, and the parties intend to proceed to a full deed of agreement with an Association to be incorporated by the LCCRMC. The proponent will carry out and give effect to the heads of agreement and the deed of agreement in the course of fulfilment of commitment 40.

INCLUSION OF LAND WITHIN THE CHINOCUP "A" CLASS NATURE RESERVE

42 The proponent agrees to promote and facilitate the inclusion of 50 hectares of the Chinocup townsite reserve (which the Shire of Kent has agreed to surrender to the National Parks and Nature Conservation Authority) within the Chinocup "A" Class Nature Reserve.

The inclusion of this land is referred to in section 6.11 of the document "Consultative Environmental Review - Mining of Agricultural Gypsum from Lake Chinocup A Class Nature Reserve No A28395, Pingrup, Shire of Kent" (November, 1993).

The area to be included shall be of equivalent environmental value.

43 The proponent agrees to promote and facilitate the grant of 32ha of uncleared land abutting the Lake Chinocup Reserve offered by Mr B Sutherland as a gift to the Department of Conservation and Land Management for inclusion in the Lake Chinocup Reserve and referred to in the document "The Lake Chinocup Catchment Management Plan - May 1996".

P G Patterson
Date: 4 December 1996

HEADS OF AGREEMENT

BETWEEN

P G PATTERSON, W PATTERSON, P SHINER, D SHINER, ("PATTERSON GROUP")

AND

THE LAKE CHINOCUP CATCHMENT RESOURCE MANAGEMENT COMMITTEE ("THE LCCRMC") (ON BEHALF OF AN ASSOCIATION TO BE INCORPORATED)

The parties hereby agree-

1. Patterson Group will pay to the LCCRMC annually on 31 August an amount equivalent to fifty cents per tonne of gypsum mined from Lake Chinocup Class A Nature Reserve.

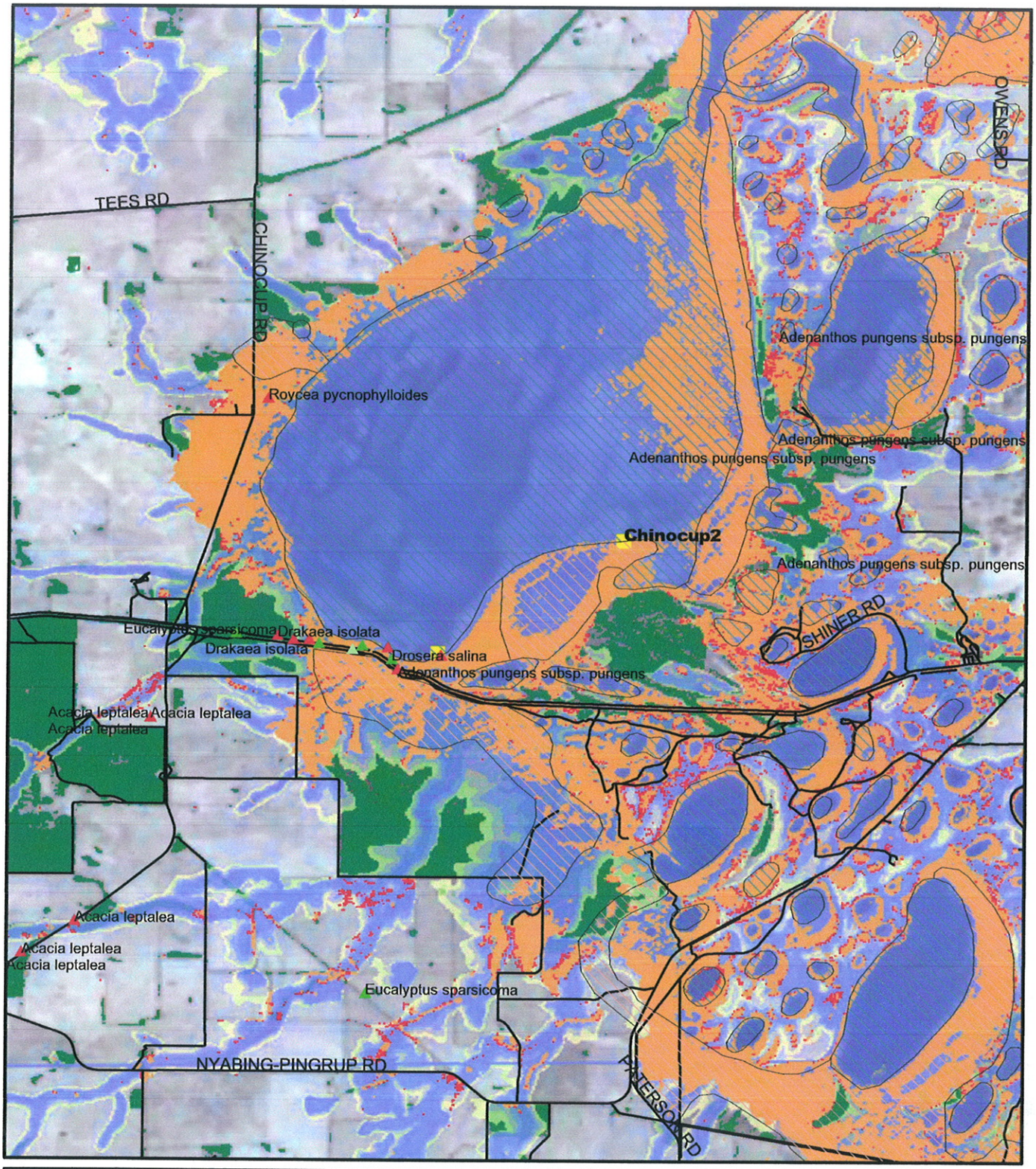
2. Patterson Group will make the payment to a trust account to be held and managed by the Shire of Kent on behalf of the LCCRMC.

3. In consideration of the payment made by Patterson Group the LCCRMC will use its best endeavours to achieve the objectives of the landcare plan for the Lake Chinocup sub-catchment approved by the Minister for the Environment and to meet as a minimum the targets identified by the LCCRMC in the landcare survey attached hereto.

4. The parties agree they will take all steps necessary to finalise and have the Minister for the Environment approve the Lake Chinocup Sub-Catchment Landcare Management Plan based on the indicative plan of May 1996 and that the plan is to include but not be limited to consideration of:

- Best practice agricultural production methods covering tillage methods, fertilisers, sprays, rotations;
- Revegetation including an agreed minimum of endemic vegetation for conservation of biodiversity;
- Protecting remnant and revegetation areas through fencing and on-going management;
- Alternative crops in consideration of restoring the water balance of the Catchment;
- Farm plans;
- Monitoring the implementation and efficacy of the Plan, particularly the groundwater across the catchment;
- The establishment of baseline values for all key indicators such as the current area of remnant vegetation, the watertable;
- Details on how the plan is to be funded;
- Provision for annual reports on progress against targets using a state of the environment format; and
- Keeping of records of individual purchases of gypsum, sale date, quantities purchased and intended end-use to enable the environmental effectiveness of the gypsum used to be evaluated.

5. The parties agree to have a deed of agreement prepared and executed so as to embody the matters agreed to herein and that deed will further provide a right of first option for a nominee of the LCCRMC to purchase the mining lease at market value as determined by independent valuation in the event of any proposed sale of the mining lease.



LEGEND

Salinity Mapping LM 25m - DOLA 00

Road Centrelines - DLI 1/5/04

Cadastre - DLI 1/09/04

Threatened Ecological Communities - CALM 15/7/03

ANCA, Wetlands - CALM 08/01

- lake
- mangrove
- reservoir
- saln_cst_flt
- sub_to_inund
- swamp

(cont)

- w_body_void
- watercours_a

Declared Rare and Priority Flora List - CALM 13/08/03

- 1
- 2
- 3

(cont)

- 4
- R
- X

N

0 ~2 km

Scale 1:82064

(Approximate when reproduced at A4)

Geocentric Datum Australia 1994

Note: the data in this map have not been projected. This may result in geometric distortion or measurement inaccuracies.

Prepared by: brundrm
Prepared for:
Date: 08/04/2005 11:47:46 AM

Information derived from this map should be confirmed with the data custodian acknowleged by the agency acronym in the legend.

Department of Environment

TERRESTRIAL ECOSYSTEMS BRANCH
POLICY AND COORDINATION DIVISION
Memorandum

ATTENTION:	**Lisa Chandler**
FROM:	Mark Brundrett/
DATE:	4 May 2005
SUBJECT:	Chinocup Gypsum Mine Site Visit April 13 2005
FILE NO.:	

You requested an assessment of restoration attempts at Chinocup Gypsum Mine following our site visit with Paul Shiner and CALM on Wednesday, 13 April 2005. The following points concerning rehabilitation areas accompany the PDF slideshow of images which illustrate points (\\DEPNTD02\public\DEP Transfer\Land Restoration\Chinocup Gypsum Mine April 05.pdf).

Two rehabilitation areas were visited; the smaller area was about 4 years old and the larger area was 2 years old or younger, with the majority of the new site having been recently ripped.

A. Older rehabilitation area (western area)

1. This area has had all of the gypsum removed so a very thin or nonexistent topsoil layer remains over the subsoil.
2. The soil surface in this area is similar in elevation to the adjacent salt lake and appears to be saline.
3. One small area near the lakeshore has trees growing on deeper soil, but most of this site is dominated by salt tolerant samphires (*Halosarcia* spp.).
4. Patches of salt are common, but some are also visible in natural areas nearby.
5. At this stage, rehabilitated vegetation is relatively sparse with many bare patches.
6. At this stage, rehabilitated vegetation is dominated by small shrubs (*Halosarcia* spp.), in contrast to adjacent vegetation which is dominated by tall shrubs (*Melaleuca* spp.) and trees (*Eucalyptus* spp.).
7. It is unlikely that the existing vegetation will be replaced by other plants (as a result of succession), because of soil salinity.
8. In conclusion, rehabilitation of this area is unlikely to succeed.

B. New rehabilitation area (eastern area)

9. This area utilized some improved practices based on lessons learned from the older rehabilitation areas. Gypsum was returned after mining to produce a soil layer approximately 1-2 m over the subsoil. This area is at a higher elevation than the adjacent salt lake and should be less saline.
10. It is anticipated that rehabilitation of this area will be more successful than in the areas without returned gypsum, but vegetation is unlikely to attain the same density or height as occurred previously due to expected changes in hydrology.
11. It is not yet possible to assess the probability of successful rehabilitation here, due to the early state of rehabilitation and the recent re-disturbance (ripping) of older sections.

C. Issues concerning both areas

12. It seems likely that the pre-existing vegetation on the mined gypsum dunes was dependant on a layer of non-saline soil in the gypsum layer over deeper saline soil. Thus, removal of 5 m of gypsum from these dunes has substantially altered the hydrology of the site, making successful rehabilitation extremely unlikely, especially in the older area.
13. Mining has resulted in the loss of substantial area of a Threatened Ecological Community (TEC) in a nature reserve which included suitable habitat for a Declared Rare Flora species (*Adenanthos pungens* subsp. *pungens*) and this TEC is unlikely to be restored successfully.

14. An assessment of the probability of successful rehabilitation during pre-approval environmental impact assessment should have identified that there was a high probability that rehabilitation would fail or be far more time consuming and expensive than anticipated by the proponent.
15. Some respreading of topsoil and cleared vegetation has occurred, but there seems to have been little use of seeds, which may be required to achieve even a partial return of plant species diversity to previous levels.
16. This site does not seem to have substantial problems with weeds, so should be relatively easy to mange in the future, providing rehabilitation can be achieved.
17. All of these comments assume that the objectives of the rehabilitation plan were to achieve a stable, self-sustaining plant community dominated by species that were present at the site before mining, as is normally the case.
18. Monitoring for a further 5 years or longer will be required to determine if restoration is successful (proponent, DoE and CALM).

D. Proposed actions?

19. Establish and approve revegetation completion criteria.
20. Decide if revegetation should be deemed to be unsuccessful now (especially in the older area).
21. Establish how monitoring should occur, who is responsible and how long is should continue. If monitoring is to continue beyond closure of the mine which seems likely consideration will need to be given as to how any further remedial action is funded, especially if this is expected to be the responsibility of the proponent.
22. Obtain data from reference plots of the same type of vegetation to allow the outcomes of rehabilitation to be assessed.
23. Establish the feasibility of changing landforms in the newer rehabilitated area by moving some of the remaining gypsum to produce sizable dunes likely to support the original vegetation in some areas. The minimum size (height) characteristics of dunes that support the TEC should be used as a guide in considering the feasibility of this approach, along with info from 25 below.
24. Make some attempt to understand the hydrology of the site post and pre mining.
25. Obtain information on the existing and likely future impacts of changes to watertables and salinity in Chinocup Nature Reserve.
26. ~~Estimate the size of the remaining area of TEC that could be mined, relative to total area remaining.~~ If successful rehabilitation of the TEC has not been demonstrated we should not be considering further mining.
27. ~~Establish if further mining is likely to be economically viable given the difficulty and cost of rehabilitation~~ I don't believe this is our role.

NOTE : Some of these actions fit more into a category of a recovery plan for the TEC than an audit role and should involve CALM. A meeting with the WA Threatened Species and Communities Unit of CALM may be appropriate.

TERRESTRIAL ECOSYSTEMS BRANCH
POLICY AND COORDINATION DIVISION
Memorandum

ATTENTION:	
FROM:	Mark Brundrett
DATE:	8 April 2005
SUBJECT:	Lake Chinocup Environmental Matters
FILE NO.:	

CALM Rare Flora contacts:

Beth Loudon (Conservation Officer) contact CALM's Katanning office on 9821 1296; beth.loudon@calm.wa.gov.au

Greg Keighery (Plant diversity and Melaleuca decline at site) CALM Woodvale: 9405-5142; greg.keighery@calm.wa.gov.au

Andrew Brown (Rare Flora) CALM WATSCU Woodvale: 9405-5166; andrewbr@calm.wa.gov

Val English (TEC's) CALM WATSCU Woodvale: 9405 5161; vale@calm.wa.gov.au

Rare Flora and plant communities at site (near mine workings):

DRF
Drakaea isolata (only location)
Adenanthos pungens ssp. *pungens*
Roycea pycnophylloides

Priority
Eucalyptus sparsicoma (P2)
Astartea clavifolia (P2)
Drosera salina (P2)

TEC
Chinocup 1
Chinocup 2

Mark F41

The Centre for Ecosystem Management Seminar Series Semester 1, 2006

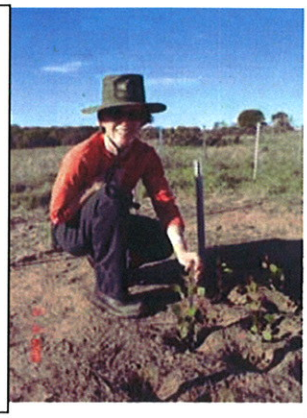
CENTRE *for* ECOSYSTEM MANAGEMENT
EDITH COWAN UNIVERSITY

Friday 12th May 2006

Dr Rachel Standish

Postdoctoral Research Fellow,
School of Environmental Science, Murdoch University

Old-fields forever young: Plant and soil barriers to the natural regeneration of abandoned farmland.



Summary

Abandoned farmlands offer a significant opportunity for restoration of native vegetation in the fragmented agricultural landscape of south-western Australia. In Western Australian, fields that have been abandoned tend to be dominated by non-native annual grasses, even 30 to 40 years after farming has ceased. We have just completed a three-year research project to determine the barriers to native recolonisation of wheatbelt old-fields. We found that the availability of seed limited recolonisation on two of three old-fields that were studied. On these two old-fields, there was a marked decline in the species richness of the native seed in the soil seed bank with distance from the nearest woodland remnant. Seedling recruitment was rare at these sites also, which was mostly due to competition with the dominant non-native annual grasses. In stark contrast, seed dispersal and recruitment have not limited native recolonisation of the third old-field—91 % of the species present in the adjacent remnant have recolonised this old-field. In addition to an adequate seed supply, the lack of invasive grasses and chance natural disturbance events (i.e. cyclone, fire) have probably contributed to this result. The results of this project define the physical constraints to the natural recovery of wheatbelt old-fields, and therefore indicate in ecological terms, what is needed to restore them. Their future fate will be determined by the capacity and willingness of society as a whole to undertake the giant steps necessary for meaningful, landscape-scale restoration. The goal perhaps, as restoration scientists and practitioners, should be not only to understand how to manage old-fields, but to encourage the idea that managing old-fields is an essential part of restoring ecological connectivity in highly fragmented landscapes.

ALL WELCOME!

Location: Building 19 (Room 19.143) Joondalup Campus
Time: 3.00 – 4.00 pm

The Centre is the research arm of the **School of Natural Sciences**

ECU EDITH COWAN UNIVERSITY

REHABILITATION BENCHMARKING

Preliminary Findings

7 February 2005

Topics

- Rehabilitation Plan Preparation
- Rehabilitation Benchmarking
  - How sites were selected
  - Preliminary Findings
- Discussion of suggested pilot rehabilitation study

Rehabilitation Planning

- Rehabilitation Plan will be prepared with reference to:
  - Baseline studies
  - Project description
  - Rehabilitation benchmarking study
  - Comparative study of sand dune mobility in the SBWHP and Coburn Project Area
  - Completion criteria
  - Stakeholder consultation
- Independent peer review by Alan Payne

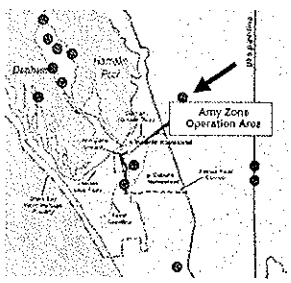
Benchmarking Background

- Rehabilitation has been identified as a critical issue for the Coburn Project
- Gunson proposed rehabilitation benchmarking study to identify examples of rehabilitation outcomes under similar conditions
- Independent assessment and peer review sought

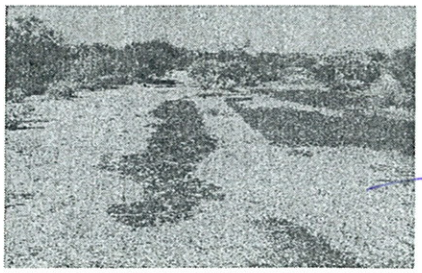
Benchmarking Site Selection

- No one totally comparable site
- Selected a range of sites to cover all aspects
- Aspects addressed were:
  - Similar type of disturbance
    - Mineral sand mines
  - Similar environmental conditions
    - Mineral sand mines and regional sites

Regional Sites



Woodleigh Station



Coquina shell strips

Woodleigh Station

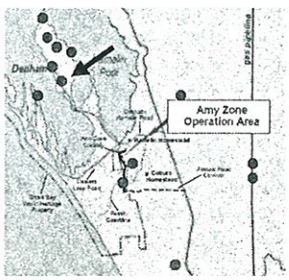
Undisturbed

40 year old natural regrowth

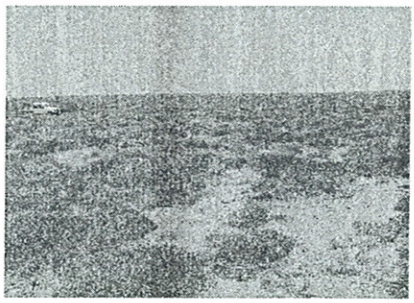
No rehab ~~exp~~ except ± Legumes on 1/4 to 1/6 sites. ~~Ag~~ Trial - abandoned after 1 year.

Found no difference after ~~40~~ years from undisturbed & cleared sites.

Site Selection



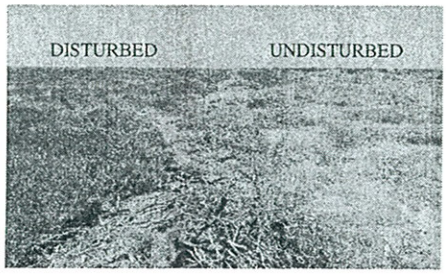
Denham Airstrip



15 year old natural regrowth

Cleared, raked + graded and compacted for airship use.

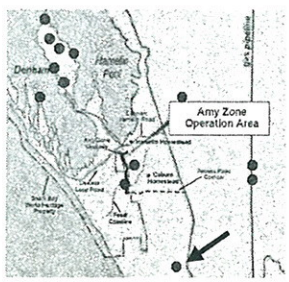
Denham Airstrip



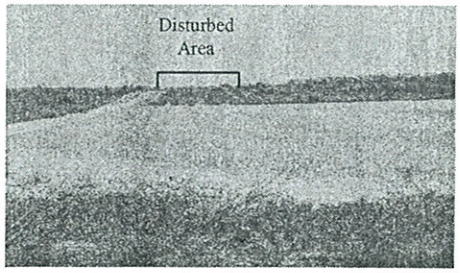
15 year old natural regrowth

Dominant sp differed Across Ligistal dominates but smaller sp mix

Site Selection



Eurardy Station

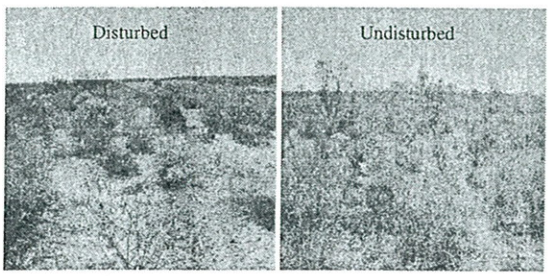


6 year old natural regrowth

Disk plant x2 Seed Retard fertiliser + Lucerne crop sprayed with Simazine. Then abandoned.

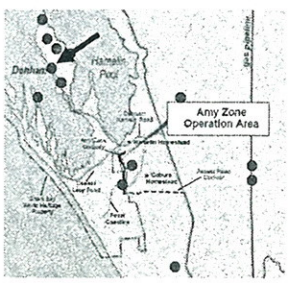
Weeds - Wild Turnip present in most sites. Disturbed / Undisturbed but grazed.

Eurardy Station

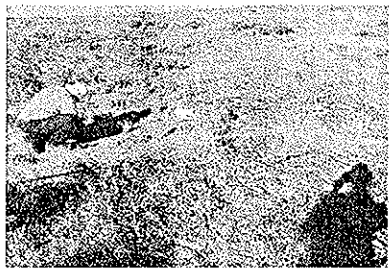


6 year old natural regrowth

Site Selection



Denham Tip

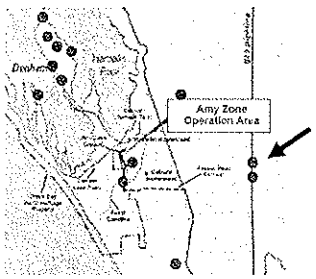


2 year old rehabilitation

Namakwa Sands

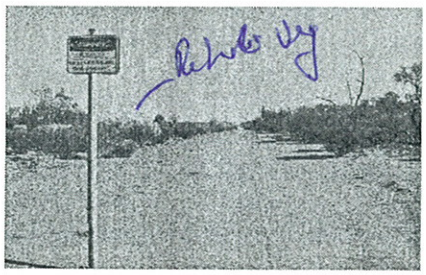
4 year old rehabilitation

Site Selection



Namakwa Sands project 8 years
Use stormwater for growing / rain leaches salt from the surface
75 cm windbreaks - slow wind velocity capture fog water. 5-6 m apart
Similar sand silts to Coburn site.

Gas Pipeline



12 year old rehabilitation

Rehab veg

East of Mine Site

Issue Summary

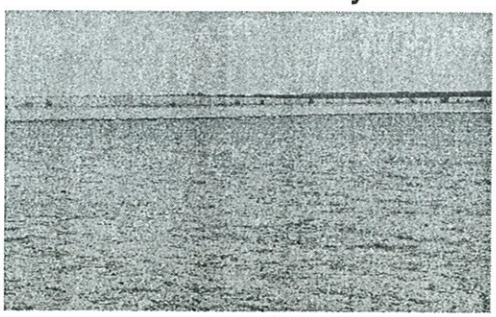
- Wind erosion

Coburn test pit – 1 year after disturbance

Soil
+ Forms a crust on soil following one year of disturbance
Protects + Fabens important for protecting the site crust. Forms after winter rains

Red/Yellow sands similar soil particle size = expect similar separate crusts developed @ all sites looked at.

Issue Summary



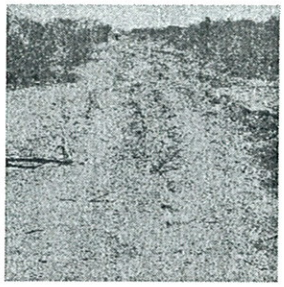
Eurardy Station – constant disturbance – no erosion

Look @ water penetration of disturbed + undisturbed sites.

Nanga Land System

Issue Summary

- Soil compaction



Peron Peninsula road – 1 year after ripping

to be avoided / rectified

Issue Summary

- Importance of topsoil

Monkey Mia gravel pit – 2 years after disturbance

Need topsoil
Wells bottomed only @ this site.

Issue Summary

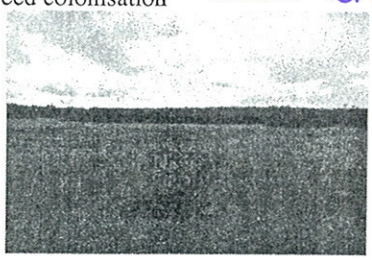
- Brushing (respreading cleared vegetation)

Denham gravel pit – 2 year rehabilitation

important ✓

Issue Summary

- Weed colonisation Wild Turnip

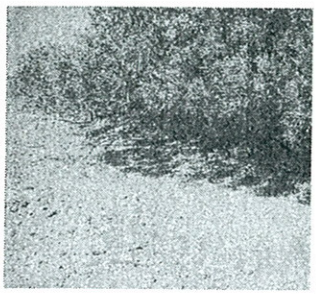


Coburn test pit – 6 month rehabilitation

Weeds present in native vegetation.
Have a place in holistic soil.
Could use selective herbicide to control it.
Native colonisers grow through it

Issue Summary

- Grazing pressure

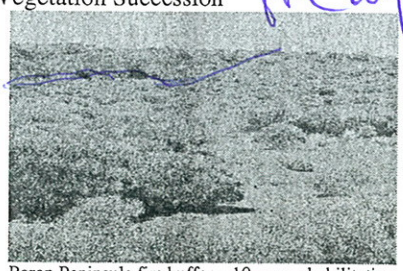


Useless Loop Salt Mine – 11 years rehabilitation

Rabbits.
Feral herbivores on site in the mine area.
Need to control pests to protect water sites.

Issue Summary

- Vegetation Succession fire buffer

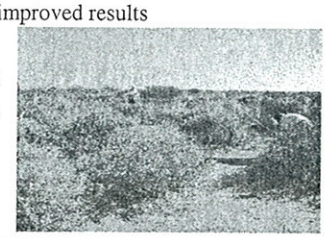


Peron Peninsula fire buffer – 10 year rehabilitation

Fire buffer - cleared + burnt.

Conclusion

- Disturbed sites will revegetate naturally
- Active rehabilitation programmes should result in better outcomes/improved results
- Research and development can be used to refine rehabilitation techniques



- Slimes to be returned to trench in the same pit not mixed
- 'Top soil' 10cm depth to be respread 10 cm Top soil 90 cm subsoil
- Direct return of topsoil proposed
- Draft Rehab plan prepared as part of PER
- Mineheard will be purchased. Rehab to 'pastoral' condition.
- Lilley looking at rehab treatments – mulch water + revegetation from seed veg
Lilley ppt – Rehab in Coal Mining industry. – Seminar

One heap now broken up into strips of 10 pits. one parallel pits with undisturbed veg within parallel pits + bunds up to 1 km wide.

URS

Briefing Note

Date: 7 February 2005

To: Dr Walter Cox

From: Sonia Finucane

Subject: Briefing Note for Coburn Mineral Sand Project Rehabilitation Benchmarking

Dear Dr Cox,

Following your letter to Gunson Resources Limited (Gunson) dated 18 January 2005, we provide this Briefing Note in order to outline the topics to be discussed during our meeting on Monday 7 February 2005.

1. Objective of Meeting

The objective of our meeting on 7 February is to obtain clarification on your suggestion that Gunson "....consider establishing a pilot rehabilitation program area in the winter of 2005.", as outlined in your letter to Gunson dated 18 January 2005. We wish to discuss this matter with you in order to understand and meet this requirement. To facilitate this discussion, we propose to present the preliminary findings of our recent rehabilitation benchmarking study.

2. Issues

Gunson is aware of the EPA's concern about rehabilitation, and that the rehabilitation of the mining area to an acceptable level is a critical issue to be addressed within the Public Environmental Review (PER) document. As the proposed mining area is situated on the border of the Shark Bay World Heritage Property, care has to be taken to sustain the current environmental conditions within this area. In addition, the mining area is located within a semi-arid environment, in the transition between the South-west and Eremaean Botanical Provinces, and contains sandy soils that may be subject to wind erosion.

3. Rehabilitation Benchmarking Study

3.1 Objectives

In order to address the above concerns, Gunson has reviewed a range of sites in Australia and overseas that have undergone disturbance of a similar degree, or have similar rehabilitation constraints, to those expected for the Coburn Mineral Sand Mine. Attention was given to sites that had similar soil disturbance, were on similar land systems, or in similar environmental extremes, and with a range of time since disturbance so that predictions of rehabilitation over time can be made.

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3.2 Methods

When assessing the rehabilitation progress of these sites, a scientific methodology was used where data collection was acceptable and/or feasible. These methods included the use of:

- Soil Surface Assessment techniques and calculations, refined from methods described by Tongway & Hindley (Landscape Function Analysis, CSIRO, 2004),
- Analysis of vegetation and litter cover using 10m x 10m quadrats;
- Identification of four dominant species per quadrat, including percentage foliage cover; and
- Transect lines identifying soil erosion features at 1m intervals.

Where this sampling was not possible, the case study comprises information supplied by the company concerned, desktop reviews and photographs taken during site visits identifying rehabilitation methods or state of rehabilitation.

Each of these rehabilitation reviews will be written up as separate case studies and appended to the PER. A selection of draft case study reports has been attached to this Briefing Note in order to provide further detail.

3.3 Preliminary Findings

A range of information and techniques on the most appropriate measures to be used for the rehabilitation of the Coburn Mineral Sand Mine were collated. A summary of the preliminary findings is provided below:

- Soil erosion within disturbed sites in the Shark Bay region is negligible. None of the sites visited showed any signs of significant soil erosion. After disturbance, the sand forms a thin crust which provides protection to the topsoil and decreases the volume of mobile soil particles. This crust is most likely formed during the winter season rains. Water erosion is not a concerning factor, given the high infiltration rates of the sandy soils present.
- The addition of brush (or cleared vegetation) to the rehabilitation site is likely to increase the success of germination and early survival for seedlings, as well as providing soil protection from wind.
- Soil compaction may significantly decrease the rate of rehabilitation by decreasing success of seed germination and seedling survival.
- Weed species, such as wild turnip (*Brassica tournefortii* - sometimes mistaken for wild radish *Raphanus raphanistrum*), are present throughout the region and are likely

to be a primary disturbance coloniser in the area. Sites that have undergone rehabilitation for more than 15 years show decreased signs of weeds, suggesting that weeds struggle to remain entrenched in stable communities.

- Native species such as *Acacia ligulata* and *Stylobasium spathulatum* are also primary colonisers and can out-compete the weed species over a period of time.
- Protection of rehabilitation sites from grazing and soil disturbance by herbivores can increase floristics and density of vegetation, and is likely to increase the rate of rehabilitation.
- Research and development programmes will be important in refining rehabilitation techniques, as part of a commitment to continual improvement.

Thank you for the opportunity to discuss this aspect of the Coburn Project with you. We look forward to meeting with you on Monday.

Yours faithfully

URS Australia Pty Ltd

S Finucane

Sonia Finucane

Principal Environmental Scientist

Attachments

Case Study A: Namakwa Sands Mineral Sand Mine

Case Study B: Woodleigh Station

Case Study C: Planned Shark Bay Airport

Attachment
Selected Rehabilitation Case Studies

DRAFT

CASE STUDY A
NAMAKWA SANDS MINERAL SANDS MINE

1. LOCATION

Namakwa Sands, a division of Anglo American plc Base Metals (Anglo), is a heavy minerals mining and beneficiation business operating along the west coast of South Africa. The operation comprises a mineral sands mine at Brand-se-Baai (385 km north of Cape Town), a Mineral Separation Plant (MSP) 7 km from Koekenaap and a smelter near Saldanha Bay.

This case study focuses on the mineral sands mine at Brand-se-Baai. The mine covers an area of 14,892 ha of the Namakwaland coast. The 5 km long western boundary of the mine is located roughly parallel to, and approximately 300 m inland of the high water mark, whilst the eastern boundary is located almost 14 km inland.

2. ENVIRONMENTAL SETTING

The mine site is located on the Namakwaland coast, at the farm Graauwduinen. Prior to mining, the site was used for small stock farming.

The Namakwaland coast is situated in a transitional zone between the Namib Desert (to the north) and the Cape Mediterranean region (to the south). It forms part of a unique winter rainfall desert ecosystem which falls within the Succulent Karoo Biome, one of 24 biodiversity hotspots of the world (Hälbich, 2003).

The mine site has a Mediterranean climate with hot dry summers and cool wet winters. It has an average annual rainfall of 150 mm, which falls mainly in the winter months of April to July. The low rainfall is supplemented by sea fog (which occurs year round) and heavy dewfall (Hälbich, 2003).

The site experiences one of the strongest wind regimes in the world with wind speeds of three metres per second (m/s) to 9.5 m/s and gusts up to 16 m/s. Anglo has estimated that wind speeds of 4 m/s are required to entrain and transport sand particles - these winds occur on 27% of all summer days and 8%of all winter days (Hälbich, 2003).

The mine site is characterised by vegetated sand dunes. There are no visible surface water features within the site and groundwater is scarce. The soil types present at the site vary according to the nature of the underlying bedrock, the position of the soil in the landscape and the annual rainfall, but tend to saline and alkaline, with a pH greater than 8. The amount of water and nutrients available to the plants is affected by soil texture and salinity (Hälbich, 2003).

The vegetation of the Namakwaland region is categorised as Strandveld Succulent Karoo and Lowland Succulent Karoo. The Succulent Karoo is a low open shrubland (Plate 1) comprising chamaephytes (woody plants), geophytes (plants growing from bulbs) and therophytes (annuals).

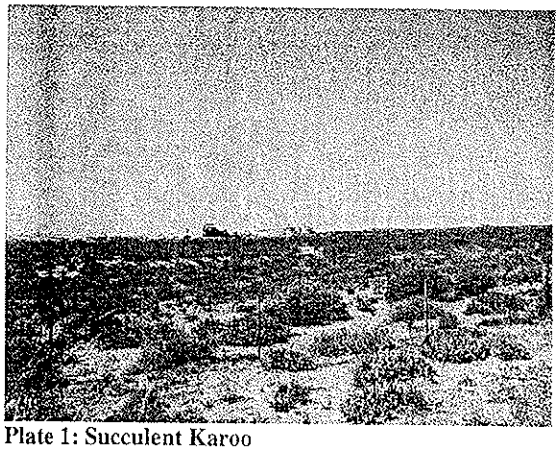

Plate 1: Succulent Karoo

There is also a rich diversity of succulents (Plate 2), many of which are endemic or near endemic (Cowling, 2001; Hälbich, 2003; Namakwa Sands, 2003).

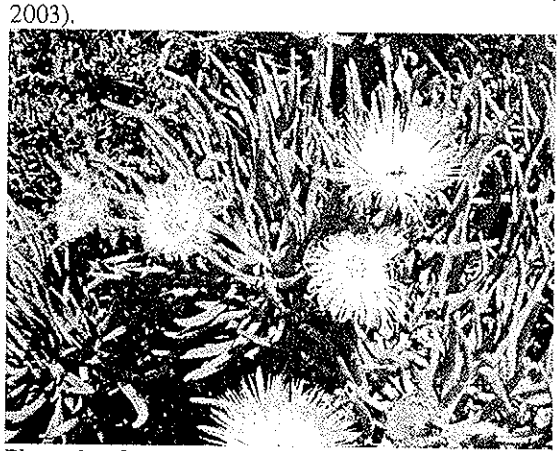

Plate 2: One of the succulent species in the rehabilitation areas.

Vertebrate fauna at the site includes 107 resident bird species, 35 species of mammals and 39 species of amphibians and reptiles. No rare or threatened species have been recorded at the site (Hälbich, 2003; Namakwa Sands, 2003).

3. TYPE OF ACTIVITY/DISTURBANCE

The heavy mineral deposits at Brand-se-Baai were discovered during the 1980s and mining commenced in 1994. There are two active mining areas, known as the eastern mine and the western mine. Strip mining is used to excavate the alluvial sand plains at the eastern mine, whereas at the western mine the aeolian sand is removed before the deeper strandlines are mined (Plate 3).

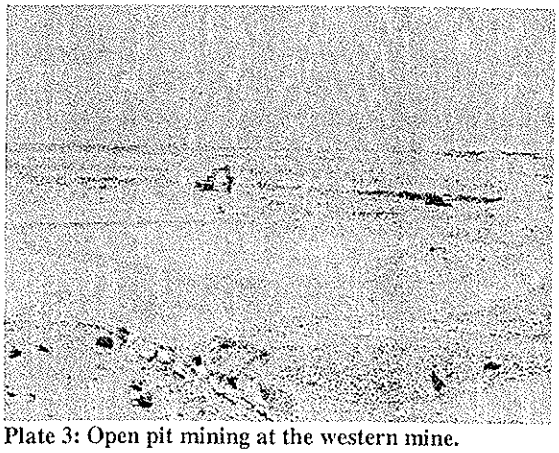

Plate 3: Open pit mining at the western mine.

Seawater is added to the mined sand as part of the primary (gravity) separation process. The tailings from the primary separation plant are dewatered before being used to backfill mined-out areas of the pits. The clay fines (slimes) are disposed of to separate storage facilities. Rehabilitation processes are then implemented (see Section 4).

Concentrate from the primary separation plant undergoes secondary (magnetic) concentration. Magnetic and non-magnetic concentrates are then trucked to the MSP, approximately 60 km south of the mine site (Namakwa Sands, 2003).

Namakwa Sands operates in accordance with an approved Environmental Management Programme Report, which includes a detailed closure plan. The mine site, along with the MSP and smelter sites, were awarded ISO 14001 certification in October 2003.

4. REHABILITATION TECHNIQUES

The objective of the Namakwa Sands rehabilitation programme is to return the land to its former use as small stock farming land (Hälbich, 2003). The rehabilitation programme has been developed based on the findings of research and small-scale field experiments conducted from 1995 to 1999, as outlined in Table 1.

Table 1
Summary of Rehabilitation Trials

Experiment	Outcome
Sowing rye	Competes with local plant species
Rye under irrigation	Only effective in winter
Sorghum under irrigation	Established well in summer with irrigation
Atriplex numularia	Established well, but an invader species
Topsoil and vegetation removal	Organic matter and seeds are transferred
Mulching with reeds	Low profile and covered by sand
Emulsion binder	Does not trap seeds and easily damaged
Mulching with straw	Covered with sand
Shadecloth windbreaks	Most effective way to reduce wind speed

Source: (Hälbich, 2003)

Hälbich (2003) outlines the key objectives of Namakwa Sands' current rehabilitation programme as:

1. To ensure the successful re-establishment of a range of indigenous species in the mining area.

2. Manage the natural vegetation and rehabilitated vegetation so as to avoid the loss of species diversity and habitats by mining activities.

3. To ensure that rehabilitated land is stable in the long term, both in relation to soil erosion and self-sustaining vegetation cover, and can be used for sheep grazing.

Prior to mining, topsoil is cleared to a minimum depth of 50 mm. This depth was identified based on research conducted at the University of Pretoria, which found that 90% of the seed reserve occurs in the top 50 mm of soil in undisturbed areas (Hälbich, 2003). The topsoil is stockpiled for no more than three months to ensure the maintenance of soil and seed viability.

The method used to excavate the ore and backfill the mining areas with sand tailings results in a gently undulating landscape. Topsoil is respread over these areas and shadecloth windbreaks are established. The windbreaks comprise shadecloth of 40% density supported by iron droppers erected every 2.5 m along the windbreak. They are 230 m long and 750 mm high, and are installed 6 m apart at right angles to the prevailing winds. The windbreaks are removed once the sand has stabilised.

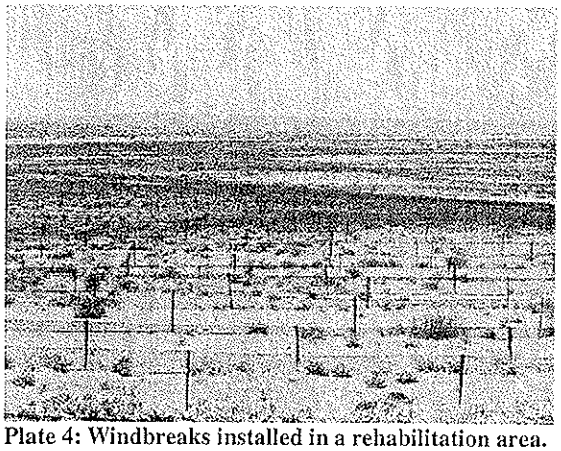

Plate 4: Windbreaks installed in a rehabilitation area.

The revegetation programme includes:

1. Sowing of seed from native Sandveld species. Seed from these species is vacuum harvested from adjacent undisturbed veld during the dry months of the year and immediately seeded in stabilised rehabilitation areas.

2. Transplanting of small-seeded perennials, mainly from the Mesembryanthemaceae family. The seeds of these species are not well adapted to long-range dispersal, so plants (and most of their root systems) are recovered from pre-mining areas using shovels. The plants are then transplanted during the wet season.

3. Planting of nursery cuttings. Cuttings of *Chrysanthemoides monilifera* are made and nurtured in a nursery with sprinkler irrigation. The cuttings are planted in rehabilitation areas during winter after the first good rains.

Rehabilitation Backlog

A slightly different rehabilitation programme is implemented for the phase one mining operation at the western mine, as no topsoil was collected prior to mining in this area. In these areas, topsoil is placed in windrows and windbreaks are installed. The use of topsoil, although limited, stimulates development of native vegetation (Hälbich, 2003).

Backlog areas are sown with a pioneer species such as sorghum during the summer months and a local seed mix before the onset of the winter growth season. The pioneer species stabilise the sand and ameliorate soil conditions, which helps to create a micro-environment suitable for the establishment of native species.

5. REHABILITATION OUTCOMES

Namakwa Sands' rehabilitation monitoring programme comprises flora biodiversity audits of control and stabilised areas. The audits commenced in 2001 and are conducted annually to provide an indicator for rehabilitation progress. The parameters measured are species composition, crown cover and basal cover. Monitoring has demonstrated encouraging results with good basal area and species composition recovery (Hälbich, 2003).

Much of the rehabilitation programme's success can be attributed to the use of recently cleared topsoil as a source of seed and nutrients, and the use of windbreaks to reduce wind erosion. Field observations suggest that vegetation initially becomes established adjacent to the windbreaks (Plate 5) before colonising the areas between the windbreaks (Plate 6). It is suggested that, in addition to reducing wind speed and sand mobilisation, the shadecloth used to construct the windbreaks captures moisture from dew and fog, which drains to the base of the windbreak, encouraging germination and plant growth adjacent to the windbreak.

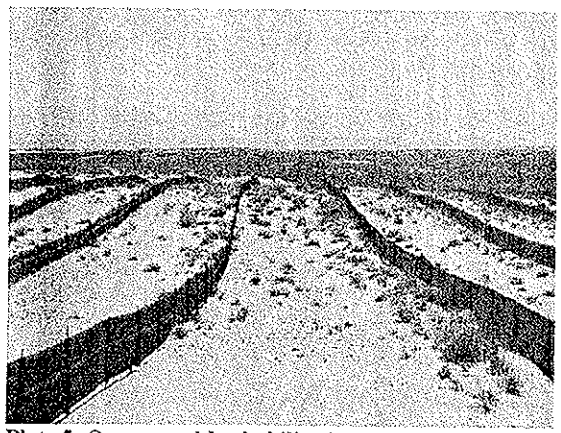

Plate 5: One year old rehabilitation.

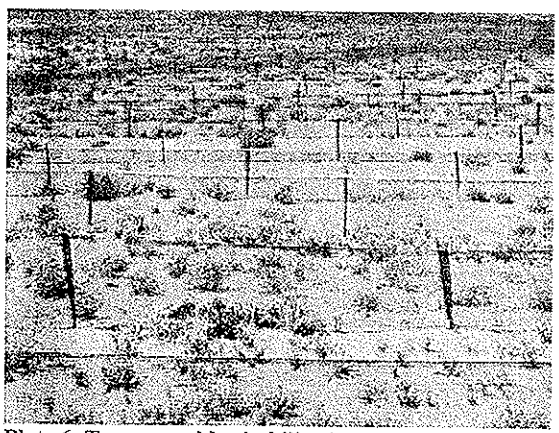

Plate 6: Two year old rehabilitation.

With time, soil stabilisation improves and revegetation progresses. It was observed in the field that a thin crust was present on the sand supporting four-year old rehabilitation, which facilitates stabilisation. Once the soil has been stabilised, the windbreaks are removed and reused

in other rehabilitation areas at the site (Plates 7 and 8).

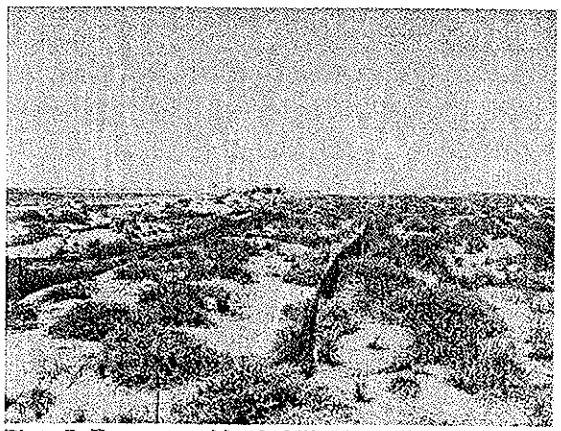

Plate 7: Four year old rehabilitation prior to removal of windbreaks.

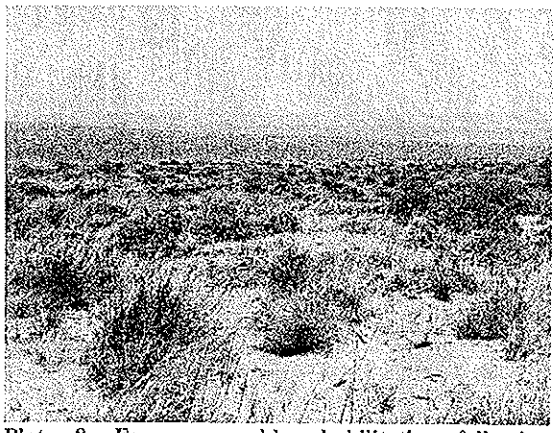

Plate 8: Four year old rehabilitation following removal of windbreaks.

Monitoring of the rehabilitation sites continue until the rehabilitation objectives agreed to for the site have been achieved.

6. APPLICABILITY TO THE COBURN MINERAL SAND PROJECT

This case study was triggered by a request from the Western Australian Environmental Protection Authority to find examples of where rehabilitation has worked under similar conditions to those that the Coburn Project is expected to encounter. Despite being on different continents, there are a number of similarities between Namakwa Sands and the Coburn Project, as follows:

- Both sites are located in the transition zone between arid/desert conditions and more Mediterranean conditions. They have similar climates, though the Namakwa Sands site has a lower average annual rainfall and a higher occurrence of sea fog than the Coburn site.
- Both sites regularly experience strong winds. The Namakwa Sands site has one of the strongest wind regimes in the world with average wind speeds of 3 - 9.5 m/s and gusts of up to 16 m/s. During summer in the Shark Bay area, southerlies consistently blow over 25 km/hr (approximately 7 m/s) for several days.
- There are similarities in landform and surface soil characteristics. Both sites comprise dunal systems with surface aeolian sands. However, the southern portion of the Coburn Project Area has a more hilly terrain than the Namakwa Sands Project Area.
- The mining and processing operations proposed for the Coburn Project are similar to those conducted by Namakwa Sands at the mine site, and will result in similar tailings. However, Namakwa Sands' use of seawater in the primary and secondary concentrators means that the tailings produced at this site are significantly more saline than those expected to be produced by the Coburn Project.

It is recognised that there are differences between the sites (such as the difference in the vegetation types and proximity to the ocean), but these do not preclude the transfer of information and lessons learned about rehabilitation under these conditions. The key aspects in this regard are:

- Rehabilitation can occur successfully in windy areas if appropriate wind erosion controls are implemented. Shadecloth windbreaks are used effectively at Namakwa Sands, but field maintenance is labour-intensive.
- Topsoil is an important source of seed and nutrient reserves, and should be conserved for use in rehabilitation.
- Topsoil should not be stockpiled for more than three months. Stockpiling this resource for longer periods of time results in a loss of soil and seed viability. Direct return of topsoil to rehabilitation areas is preferred.
- Most of the seed reserve occurs in the uppermost layer (5 cm) of topsoil at Namakwa Sands.
- Disposal of clay fines (slimes) with the sand tailings is preferable to disposing of this material in separate storage facilities due to difficulties associated with rehabilitating these facilities.

7. REFERENCES

Cowling, S. (2001) Succulent Karoo. www.worldwidelife.org. Accessed on 10 January 2005.

Hälbich, T.F. (2003) Mine Rehabilitation in the Arid Succulent Karoo Vegetation Zone on the South African West Coast, Namakwa Sands -- Case Study. In: Heavy Minerals 2003. South African Institute of Mining and Metallurgy.

Namakwa Sands (2003) Namakwa Footprint 2003. Sustainability Report.

8. ACKNOWLEDGEMENTS

Gunson Resources Limited and URS would like to thank Anglo American plc Base Metals and Namakwa Sands for the opportunity to visit the mine site and prepare this case study for use in developing the Coburn Mineral Sand Project rehabilitation programme.

CASE STUDY B
WOODLEIGH STATION

1. LOCATION

In 1965, National Aeronautics and Space Administration (NASA) identified a site on the Woodleigh Station, Shark Bay, which was to be changed so significantly to be observable to astronauts with the naked eye whilst orbiting the Earth in the Gemini Titan space craft. This disturbed area lies approximately 70 km from the Coburn Mineral Sand Project Area (Diagram 1).

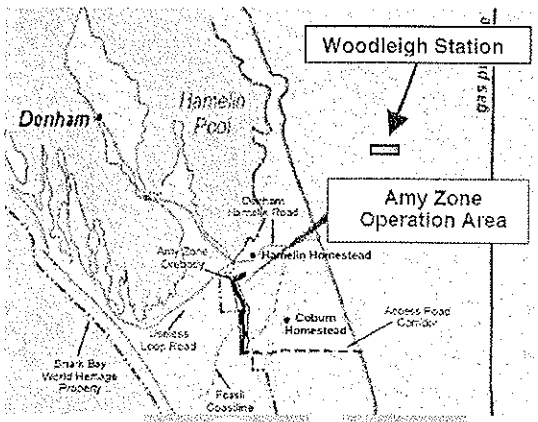

Diagram 1 Location Map.

2. ENVIRONMENTAL SETTING

The disturbed site is part of the Woodleigh pastoral lease, which primarily runs sheep and goats.

Woodleigh Station is part of the Shark Bay region and is classed as having a hot semi-desert Mediterranean climate (Beard, 1976), with an average yearly rainfall similar to that of Denham (244 mm - B. Wake *pers comm.*): approximately 70% of this falls between May and August. Average midday temperatures are likely to be more extreme than those at Denham due to its location away from the tempering maritime influence (Denham range 5.5 - 47°C). Dew often forms overnight. The vegetation is predominantly tall open shrubland comprising mixed *Acacia* species growing on sand soils (Sandplain land system).

The soils at the site are red sands, with slight clay accumulation at depth. The pH is 6 at the surface, tending to 6.5 at the bottom of the profile (1m).

3. COMPARISON WITH THE COBURN PROJECT AREA

Despite being located approximately 70 km north-east of the Coburn Project Area, there are a number of similarities between the disturbed sites and the proposed mining site. These similarities include:

- Both sites are located within the semi-arid Shark Bay region, and have similar vegetation and soil characteristics. However, the Woodleigh site is likely to experience slightly greater environmental extremes, such as higher temperatures and lower annual rainfall.
- The Woodleigh site has experienced the removal of topsoil and its associated seed bank, loss of vegetation biomass and thus wind protection, and likely soil compaction. Further, the Woodleigh site was, and still is, used as part of the pastoral lease and routinely grazed by sheep and goats throughout the entire rehabilitation process.

4. TYPE OF DISTURBANCE

A review of aerial photography has identified 16 sites that have undergone major disturbance. Each site is square in shape and 100 acres in area. Within this square a range of patterns was produced by laying highly reflective *Coquina* shell on the surface.

The vegetation and topsoil at each site was chained and pushed into windrows, then the vegetation roots were raked to a depth of nine inches and added to the windrows, where it was burnt. The resulting charcoal was then buried to a depth of >1 ft. The area was again chained to flatten the surface, before being disc-ploughed to a depth of five inches. No vegetation litter remained within the disturbed site. The *Coquina* shell was then placed on the surface in a range of patterns to test astronaut visual acuity (Plate 1).

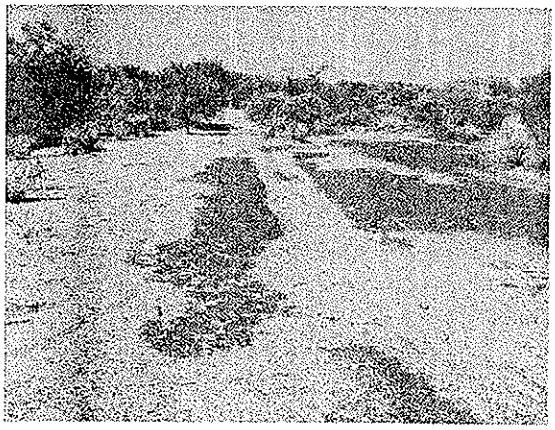

Plate 1. *Coquina* patterns on disturbed Woodleigh site.

Once the orbiting of the space craft was complete, the majority of the sites were then left in their disturbed state and subsequently abandoned with little or no rehabilitation.

5. REHABILITATION TECHNIQUES

Rehabilitation was attempted for only one of the 100 acre areas. This area was fenced, seeded with a range of introduced grasses and legumes, and fertilised to assess the benefits for pastoral use. However, this initiative was deemed to have failed as very few introductions persisted for more than two years. The fence was removed and the area was left to rehabilitate naturally with no further assistance. It is not known in which disturbed plot this work was conducted as it was not evident from aerial photography.

6. SAMPLING METHODOLOGY

When assessing the rehabilitation progress of these sites, a scientific methodology was used. These methods included the use of:

- Soil Surface Assessment techniques and calculations, refined from methods described by Tongway & Hindley (Landscape Function Analysis, CSIRO, 2004).
- Analysis of vegetation and litter cover using 10m x 10m quadrats; and,
- Identification of four dominant species per quadrat, including percentage foliage cover.

7. REHABILITATION ASSESSMENT

The study aimed to determine the extent of rehabilitation at the Woodleigh sites over the 40 years since disturbance. These results were compared with those from adjacent undisturbed sites.

No differences were found between the three soil surface assessment indices (Diagrams 2, 3 and 4). However, in all three indices the disturbed site data produced slightly higher results, suggesting that the soil was better able to withstand erosion, water infiltration occurred at a higher rate, and organic matter is infiltrated back into the soil more efficiently.

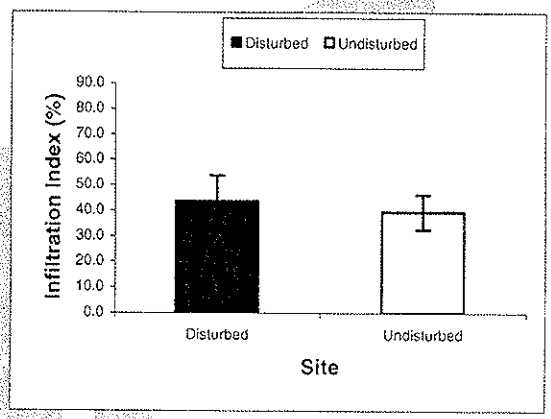

Diagram 2. Zone Infiltration comparison for disturbed plots and undisturbed analogue sites.

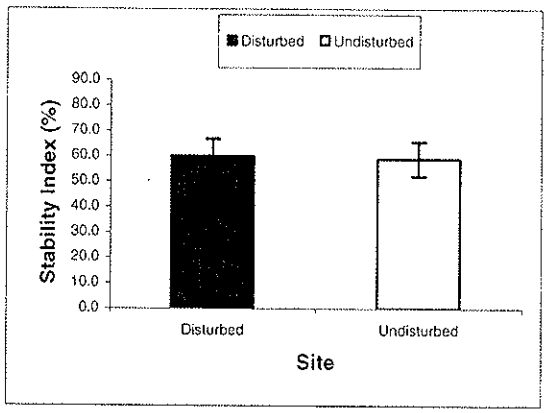

Diagram 3. Zone Stability comparison for disturbed plots and undisturbed analogue sites.

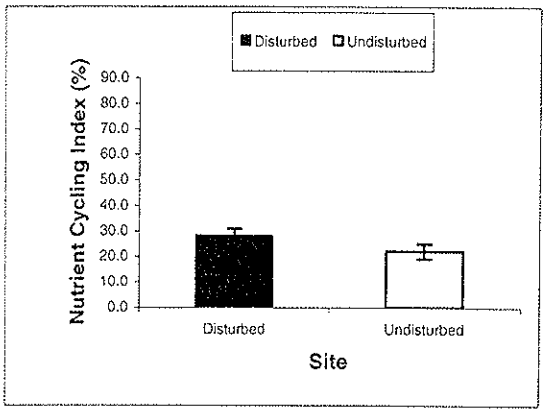

Diagram 4. Zone Nutrients comparison for disturbed plots and undisturbed analogue sites.

No difference was found in the amount of vegetation covering the soil (mean % ± SE) between disturbed (n=6; 28.8 ± 7.2) and undisturbed sites (n=6; 33.8 ± 9.0). In addition, the sites were not found to differ in maximum height, with the vegetation in the disturbed plots (292.5 cm ± 32.5) found to be of similar height to that in the undisturbed quadrats (275 ± 10.4).

There was no difference in species diversity between the disturbed (10.3 ± 1.3) and undisturbed sites (9 ± 0.7). The vegetation species dominance within the sites was also similar, comprising a tall open shrubland (comparable with Coburn Project Area Community S7; Mattiske, 2004) with overstorey dominated by *Acacia sclerosperma* and *Eremophila maitlandii* over *Ptilotus obovatus* (Plates 2 & 3).

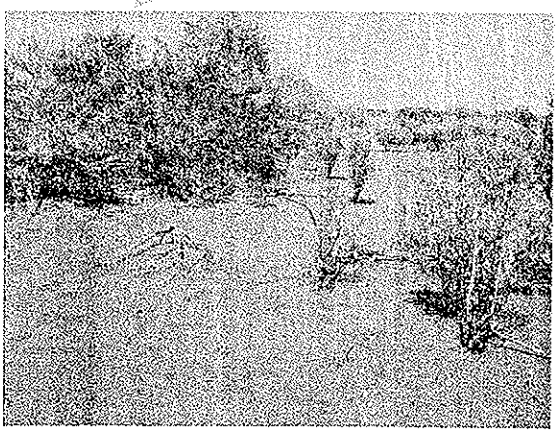

Plate 2. Woodleigh Station disturbed site.

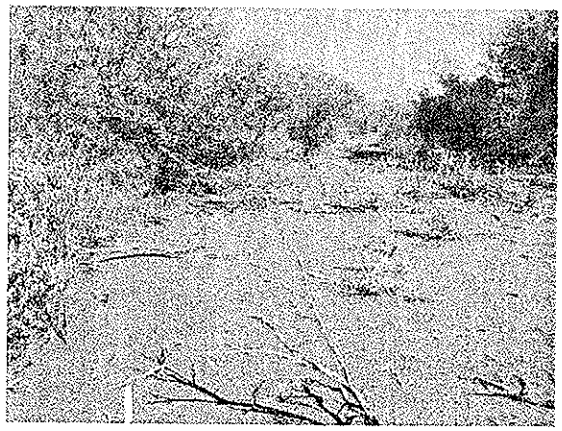

Plate 3. Woodleigh Station undisturbed site.

Both sites contain only small litter cover (avg. 6.5%), with large open interpatches found between large *A. sclerosperma* patches. Both sites have been heavily grazed by sheep and goats prior to and since disturbance, and according to the manager of the Woodleigh Station, the pastoral value of the area "could not be any better".

8. REHABILITATION OUTCOMES

The Woodleigh site suggests that over a rehabilitation period of 40 years, a disturbed site can return to a similar condition to that found in its pre-disturbed state. There was no discernable difference in any of the tested factors, and the areas are currently being used to their maximum pastoral potential.

9. APPLICABILITY TO THE COBURN MINERAL SAND PROJECT

This case study was identified as applicable to the proposed Coburn Mineral Sand Mine due to the extreme disturbance events that it incurred and the subsequent lack of rehabilitation measures applied. In addition, a period of 40 years since disturbance allows for some form of prediction as to the extent of rehabilitation likely to occur at the mine rehabilitation sites over this time period.

The lessons learnt from the Woodleigh Station case study include:

- Vegetation can colonise severely disturbed areas and return to a compable state to an analogue area in a period of less than 40 years.

- No primary colonisers were evident, suggesting that the vegetation had formed a stable community. This state is able to cope with the sustained pressure of pastoral grazing.
- The vegetation was able to return to a vegetation community comparable with analogue sites without protection from grazing pressure. However, it is unknown whether grazing protection would have changed the rate of rehabilitation.

10. REFERENCES

Beard, J. S. (1976). *Vegetation Survey of Western Australia – Murchison.* University of Western Australia.

Mattiske Consulting Pty Ltd (2004). *Flora and vegetation in the proposed Coburn Mineral Sand Mine: Coburn and Hamelin Stations – Shark Bay.* Report prepared for URS Australia Pty Ltd.

11. ACKNOWLEDGEMENTS

Gunson Resources Limited and URS would like to thank the managers of the Woodleigh Station for allowing access to the property. In addition, the Department of Agriculture provided information on the history of the NASA project, which assisted in preparing this case study for use in developing the Coburn Mineral Sand Project rehabilitation programme.

DRAFT

CASE STUDY C
PLANNED SHARK BAY AIRSTRIP

1. LOCATION

In 1990 the Shark Bay Shire identified a site on the Peron Peninsula, Shark Bay, which was to be designated as an airstrip. Located approximately 2 km from the coast, and approximately 10 km south of Denham, it is open to the prevailing south-westerly winds (Diagram 1).

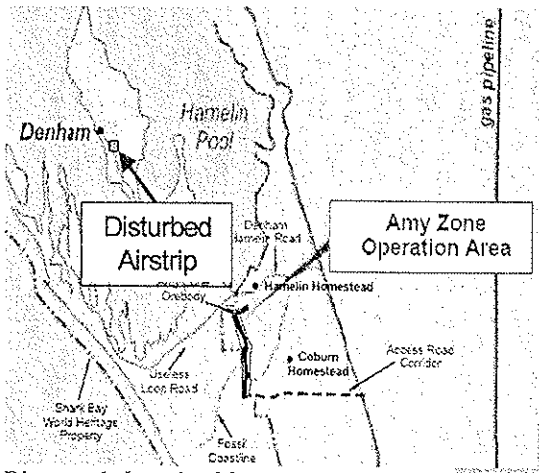

Diagram 1: Location Map

2. ENVIRONMENTAL SETTING

The airstrip site was historically part of the Peron pastoral lease, which was a property primarily stocked with sheep and goats. In 1990, the Department of Conservation and Land Management (CALM) purchased the lease to the property. The land was integrated into the state-wide conservation project "Western Shield", whereby all sheep were removed and a goat de-stocking programme was initiated.

The peninsula is classed as having a hot semi-desert Mediterranean climate (Beard, 1976), with an average yearly rainfall of 244 mm: approximately 70% of this falls between May and August. Temperatures range between 5.5 - 47°C and dew often forms overnight. The vegetation is predominantly low heath and scrub comprising mixed *Acacia* species and patches of spinifex grass (*Triodia* sp.), living on sand dunes and sandplain soils (Taillefer land system).

The soils at the site are a red/brown calcareous sand, with slight loam accumulation at depth. The pH is 8 at the surface, tending to 8.5 at the bottom of the profile (1 m).

3. COMPARISON WITH THE COBURN MINERAL SAND PROJECT AREA

Despite being located approximately 80 km north-west of the Coburn Mineral Sand (CMS) Project Area, there are a number of similarities between the decommissioned airstrip and the proposed mining site. These similarities include:

- Average wind speeds of 21.9 km/hr, with gusts of up to 81.4 km/hr for the airstrip site. The CMS Project Area is also likely to experience similar high wind speeds, although there are liable to be less extreme due to its distance from the coast and protection by land topography.
- Both sites are located within semi-arid Shark Bay region, experiencing similar vegetation and soil characteristics, as well as similar environmental extremes.
- The airstrip site has experienced the removal of topsoil and its associated seed bank, loss of vegetation biomass and thus loss of wind protection, and soil compaction. It is likely that this disturbance provided greater difficulty for rehabilitation than is expected for the planned Coburn mining project.

4. TYPE OF DISTURBANCE

The airstrip site comprises an area of 2,000 m x 100 m, and was cleared of vegetation (chained), raked, graded and compacted in order to provide the necessary surface for large aeroplane traffic. All mobile topsoil was removed and no vegetation roots or debris remained on the surface. However, once this element of the construction was completed, the requirement for an airstrip at that site was downgraded, and the designed airstrip was no longer required. At that stage, all that was

required to complete the airstrip was the removal of windrows of vegetation, and placing an erosion retardant on the ground surface. Once it was decommissioned, the site was then left in its completed state and subsequently abandoned with no management programme, nor assistance, for rehabilitation.

5. SAMPLING METHODOLOGY

When assessing the rehabilitation progress of these sites, a scientific methodology was used. These methods included the use of:

- Soil Surface Assessment techniques and calculations, refined from methods described by Tongway & Hindley (Landscape Function Analysis, CSIRO, 2004).
- Analysis of vegetation and litter cover using 10m x 10m quadrats; and,
- Identification of four dominant species per quadrat, including percentage foliage cover.

6. REHABILITATION TECHNIQUES

Post disturbance, the airstrip has received no assistance towards rehabilitation.

7. REHABILITATION ASSESSMENT

The study aimed to determine the extent of rehabilitation at the airstrip site over the 15 years since disturbance. These results were compared with those gained at an adjacent, undisturbed site (Plate 1).

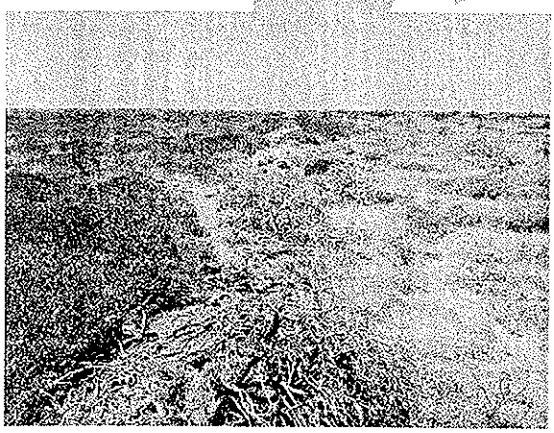

Plate 1. Windrow down the centre of photo. Rehabilitated site to the left, undisturbed site to the right.

There was no difference between infiltration indices at the disturbed and undisturbed sites (Diagram 2). Both sites contain sandy soils that allow water infiltration and therefore decrease water, soil and nutrient loss from the local area.

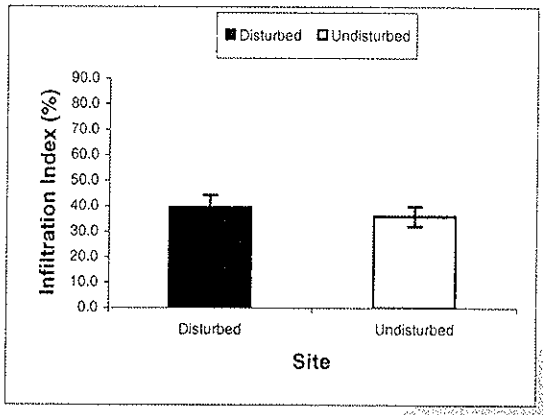

Figure 2. Zone Infiltration comparison for disturbed airstrip and undisturbed analogue site.

A comparison of soil stability between the two sites showed no difference (Diagram 3). No erosion was observed at either site suggesting that the soils were able to withstand the environmental pressures.

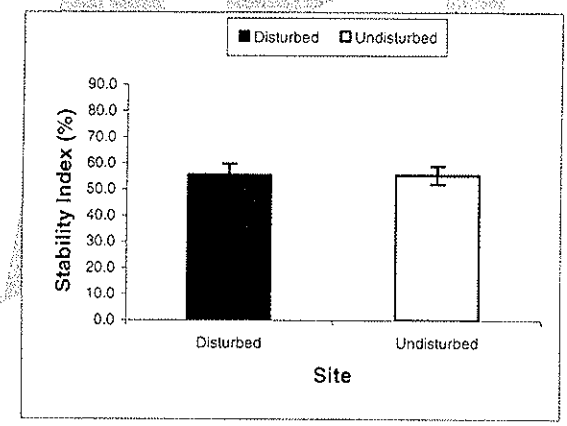

Diagram 3. Zone Stability comparison for disturbed airstrip and undisturbed analogue site.

The potential for nutrient cycling did not differ between sites (Diagram 4), suggesting that both sites retain similar abilities to return organic matter and nutrients to the soil.

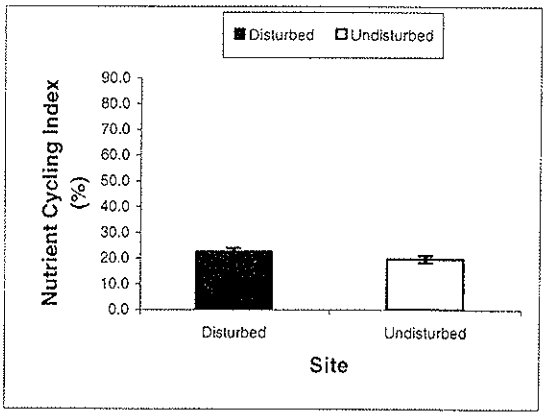

Diagram 4. Zone Nutrients comparison for disturbed airstrip and undisturbed analogue site.

No difference was found in the amount of vegetation covering the soil (mean % ± SE) between disturbed (n=6; 56.7 ± 5.7) and undisturbed sites (n=6; 65 ± 3.2). The vegetation on the sites differed in maximum height, with the vegetation in the undisturbed quadrats (131.7 cm ± 15.4) found to be taller than that in the disturbed plots (63.3 cm ± 7.2).

There was no difference in species diversity between disturbed sites (7 ± 0.5) and undisturbed sites (8 ± 0.6). However, the dominant species within the quadrats differed. The disturbed area had a high prevalence of *Acacia ligulata*, which had an average foliage cover of 45.8% (Plate 2). The understorey was predominantly *Triodia plurinervata* (3.8%), with the topsoil containing a low litter cover (2.8%).

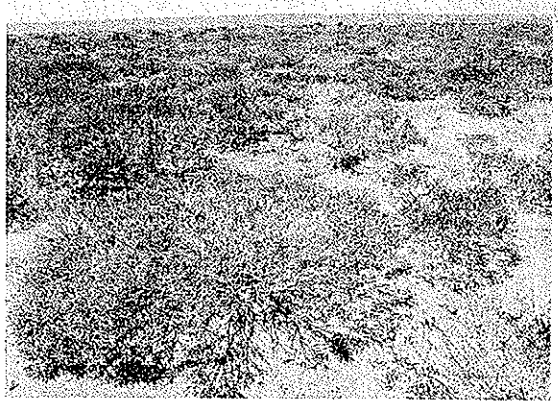

Plate 2. Disturbed site showing a predominance of *Acacia ligulata*.

In contrast, the undisturbed sites were dominated by *T. plurinervata* (25%), with *A. ligulata* (12.3%) and *Thryptomene baeckeacea* (8.3%) providing further soil protection (Plate 3).

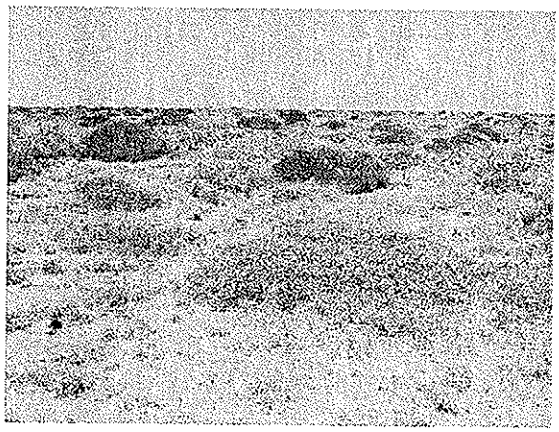

Plate 3. Undisturbed site.

Both sites are likely to have undergone high grazing pressure over the 15 year period, with rabbits particularly common throughout the area during the case study field research. Fresh echidna tracks, scats and diggings were also present within the disturbed area.

8. REHABILITATION OUTCOMES

The disturbed airstrip site has shown to have returned to a soil stability comparable with the adjacent undisturbed region. The vegetation has also returned to a similar density and diversity, although the dominant species vary between sites.

The dominance of *A. ligulata* in the disturbed area, together with its lack of dominance in the undisturbed area, suggest that this species is an effective primary colonizer that prefers disturbed soils for germination and survival.

This case study has shown that comparable vegetation can return to an area that has been significantly disturbed, and that it does not require assistance to rehabilitate. It is not known whether this disturbed area will return to the species dominance and vegetation height shown by the analogue sites, however it currently retains significant value by retaining nutrients and providing protection for soil, fauna, and seedlings.

9. APPLICABILITY TO THE COBURN MINERAL SAND PROJECT

This case study was identified as being applicable to the proposed Coburn Mineral Sand Mine due to the soil at the disturbed site having undergone significant degradation, extreme wind conditions, and being located on

a similar sandplain land system. The vegetation on the proposed airstrip location was similar to Community S3 (Mattiske, 2004), which is found throughout a large area of the proposed CMS Project Area. The site was also of interest as it may provide some insight into what form the rehabilitated areas of the proposed mine might take after a period of 15 years.

Though the similarities between this case study site and the CMS Project Area have been identified, it is important to recognize that there remain some differences that may influence rehabilitation success on the Amy Zone.

The lessons learnt from the disturbed airstrip include:

- Vegetation can colonise a severely disturbed area without assistance. However, after a period of 15 years post-disturbance the rehabilitated area is likely to have a different vegetation structure and dominance to analogue communities.
- *Acacia ligulata* is a primary colonizer and disturbance specialist. The cover and protection it provides is likely to improve soil stability.
- Protection from grazing is not a prerequisite for return of vegetation, although grazing protection may have improved or changed the rate of rehabilitation of the current vegetation community.

10. REFERENCES

Beard, J. S. (1976). *Vegetation Survey of Western Australia – Murchison.* University of Western Australia.

Mattiske Consulting Pty Ltd (2004). *Flora and vegetation in the proposed Coburn Mineral Sand Mine: Coburn and Hamelin Stations – Shark Bay.* Report prepared for URS Australia Pty Ltd.

11. ACKNOWLEDGEMENTS

Gunson Resources Limited and URS would like to thank the Shark Bay Shire for their support in locating the proposed airstrip and providing information on its history, which assisted in preparing this case study for use in developing the Coburn Mineral Sand Project rehabilitation programme.

DRAFT

REPORT

A Review of the Rehabilitation at Worsley Alumina's Boddington Bauxite Mine

Full document available on request

Prepared for

Worsley Alumina Pty Ltd

PO Box 344
COLLIE WA 6225

6 October 2004

42905347 / WLPL-SW-R0001.0

URS

Mark Bradsett

A REPORT TO:

THE AUSTRALIAN MINING INDUSTRY COUNCIL

7th November 1990

MINING AND ENVIRONMENTAL MANAGEMENT - SOME CURRENT TRENDS

by

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SUMMARY

Public involvement in matters associated with mining and the environment has increased dramatically in recent years, which reflects growing public anxiety about environmental degradation generally. Mining, like most private and commercial activities, was once carried out with minimal regard for the environment. The central aim of this report was to assess the impact of the mining industry on the conservation, habitat and genetic diversity of Australia's flora and fauna, and thereby evaluate whether the 'negative' image of mining, derived from these earlier times, applies today. Information from twenty-six major mining operations, together accounting for 40 percent of Australia's export earnings from mining (excluding oil and gas), are reviewed. Additional insights are gained from questionnaires sent to 86 Government agencies involved with environmental matters. The results are reported in eight sections.

1. **Public opinion and environmental opposition to mining**

   There appear to be no mechanisms available at present to enable the public to be adequately educated about the costs and benefits of proposed mining operations. Different ground rules apply to the proponents (mining companies) and antagonists (such as conservation organisations), inasmuch as actions by the former are subject to an array of legal obligations whereas actions by the latter are not. The public is frequently placed in the position of agonising over minor environmental matters, while remaining completely unaware of the solutions that have been derived for major ones.

2. **Case histories**

   Twenty-six mining operations are described with regard to their locations, areas (and value) of land involved, previous forms of land-use, types of mining and processing, the environmental impacts that result, and the levels of environmental management applied.

3. **The nature of impacts**

   On the basis of the case histories and visits to mine sites, the following are discussed: land surface impacts; fauna and flora; land forms; rehabilitation aims; atmospheric emissions; noise and vibration; water impacts.

4. **Environmental responsibility**

   Given that mining cannot be carried out without impacting on the environment, the public expectation should be that mining companies will act responsibly in managing the natural environment. The case histories provide unequivocal evidence that a large section of the mining industry demonstrates a high level of environmental responsibility.

Minimising environmental impacts has become a specialist part of mining technology with wide application to solving environmental problems outside the industry. Environmental management within the mining industry is inherently dynamic and is continually improving with research and innovation.

5. The relative 'importance' of environmental impacts

Actions which reduce the productivity of lands, waterways and the sea are considered the most important impacts, followed by genetic diversity considerations; both affect the ability to sustain life. Mining impacts on productivity are minor, and no species are known to have become extinct because of mining, although the status of some plants and fish may be affected by mining in some areas.

6. Aesthetic impacts

Although less important than productivity and genetic diversity, aesthetic impacts can be a prime reason for objecting to a mining operation, although often masked by various 'secondary' reasons. A variety of strategies are employed by the mining industry to reduce aesthetic impacts, especially in or near urban areas.

7. Positive impacts

The major positive impact is an indirect one, through the economic benefits that flow from mining. The mining industry is responsible for generating a good deal of the funds devoted to environmental research and management. Direct benefits include:

- The development of new technologies for describing and monitoring environments.
- The development of techniques for the re-establishment of pre-mining land productivity (which in some cases results in productivity increases).
- Research associated with the environmental assessment and on-going review process, which provides new information on the distribution and abundance of flora and fauna.
- Research on land rehabilitation which has broad application to the repair of land degraded by causes other than mining.
- The extension of post-mining land-use options, including opportunities to increase habitat diversity following mining.
- Sponsorship of research at universities and other independent scientific institutions.

- The enhancement of public education about environmental awareness, research, management and responsibility, particularly at and in relation to remote areas.

- The extension of company resources to the environmental management of regions within whose ecological boundaries mining occurs.

8. Conclusions

Environmental awareness within a large segment of the mining industry is increasing exponentially, to the extent that the mining industry is becoming pre-eminent in some areas of environmental management, particularly rehabilitation. Many operations voluntarily commit to a degree of environmental management over and above that required by regulation and mechanisms should be found to encourage this trend. Maintaining a view that mining represents environmental vandalism, wherever it is undertaken, lacks supporting evidence and is counter-productive. The public should have every confidence that the technology is now available to greatly minimise the impacts of mining.

INTRODUCTION

A large segment of the Australian public view mining and the responsible management of the environment as mutually exclusive activities. Such attitudes are understandable, given that historically, mining was often carried out with little regard for the environmental consequences of actions taken - significant impacts resulted. These impacts concern environmentalists today, to the extent that few would argue against Zarsky's (1990) observation that mining remains *the bogeyman of Australian conservationists.* Many environmentalists appear committed to the view that mining, past and present, is environmental vandalism - the physical, chemical and biological degradation of delicate, natural ecosystems, with little in the way of public benefits to offset the public costs. But is this a reasonable "image" of the mining industry in the 1990's? All activities undertaken by Australians in Australia were *once* carried out with minimal regard for the environment. Yet dramatic changes in environmental awareness and legislation, particularly over the last 30 years, have altered the way we behave with regard to the environment at all levels of private and commercial activity. Even a cursory examination indicates that the mining industry has not been completely shielded from such changes.

Coronation Hill, within the Northern Territory, affords a good example. The Environmental Impact Statement (EIS) for Coronation Hill, prepared in 1989, had to address 31 separate Acts of legislation aimed at minimising impacts on the environment and on people (CHJV 1990). This can be compared with Rum Jungle, a uranium mine initiated in the Northern Territory in the 1950's, which was controlled by 2 Acts. In the Kalgoorlie region of Western Australia, where mining has been the backbone of the local economy for almost 100 years, new environmental regulations were introduced in 1988. Some miners greeted them with disbelief and a feeling of "helplessness", yet research undertaken in this report indicates that their spirit is being accepted and acted upon, particularly by larger companies. The Australian Mining Industry Council (AMIC) has been running environmental conferences and workshops for the mining industry, for the last 15 years (AMIC 1990b).

In contrast to the negative environmental "image" of mining, AMIC maintains that today's mining industry is at the forefront of environmental management. That over and above the many regulations that mining companies now comply with, often

willingly, that the industry is environmentally active and responsible. That more and more companies are adopting strict environmental policies and audits, leading to a high degree of self-regulation. That they have developed a proven and formidable "problem-solving" capacity with regard to environmental problems, that has wide application to environmental management and rehabilitation outside their industry.

If the economic benefits that mining bestows on all Australians (which indirectly funds many national conservation efforts), are to be foregone on the basis of a negative public "image" of mining, then commonsense dictates that the "image" must be both current and correct. It is in the interests of everyone, including the average environmentalist, to ensure that we do not simply replace one set of myths and legends (*that mining causes no significant environmental problems anywhere*) with another (*that mining causes catastrophic, irreversible environmental problems everywhere*). If mining companies are developing along the lines suggested by AMIC, then it would seem important to recognise and encourage those trends. If some of the impacts of mining are environmentally positive (as against negative or neutral), then they should be recognised as such by the public.

This report examines the operations of some of the most significant mines in Australia, which together account for some 40% of Australia's mineral exports (excluding oil and gas); $9 billion of an estimated $21.4 billion. It looks at the manner in which mining and processing occur, and the ways in which these actions impact on the environment. It examines the significance of those impacts at a national level, and the efforts being made to minimise, manage and control them. It is not a definitive review of the impacts of *all* mining operations, but it does describe the level of environmental responsibility that exists definitively within a significant segment of the industry today. This level is attainable and achievable by new operations given appropriate planning.

There are sound philosophical reasons for the advocates in a mining-environment debate to propose null propositions or hypotheses and attempt to reject them (Webb 1990): for environmentalists to propose that the benefits of mining would far outweigh the environmental costs; for miners to propose that the environmental costs would far outweight the benefits. Although we do not test hypotheses as such within this report, the evidence gathered is contrasted against generalised null hypotheses and propositions along the broad lines that mining is associated with some of the most serious environmental problems in the country;

that miners and mining companies show total disregard for the environment, and that they make no positive contribution to the solving of environmental problems. This is the view that more and more children and adults seem to be accepting somewhat uncritically, and its ramifications for the nation would seem profound. If they can be easily rejected, it adds support to the proposition that the "negative" image of today's mining operations is in need of review.

ACKNOWLEDGEMENTS

This report was assisted by a number of mining companies and by Government departments with responsibility for our national interest in wildlife, conservation, environmental protection, forestry, fisheries and agriculture. It was also assisted by herbariums and museums, who are at the "frontline" of collecting and collating information on the natural environment. I would like to take this opportunity to thank all the individuals and organisations involved. The report in its entirety would not have been possible without financial support from AMIC, and without their involvement in co-ordinated the flow of information from the mining companies.

Drafts of the report were reviewed by various people involved in both conservation and mining, and their comments and perceptions improved the final report greatly. Nevertheless, the views expressed are my own, and are not necessarily shared by AMIC, the mining companies, the reviewers nor the various Government departments that assisted.

BACKGROUND AND METHODS

When the possibility of doing this report was first discussed with AMIC, it was within the context of providing information to both the mining industry and the Resource Assessment Commission (RAC) Kakadu Inquiry. Although recognising that the RAC charter was very specific with regard to the issues being addressed (RAC 1990), it was equally recognised that a broader perspective on "mining and the environment" could be of assistance to the Commissioners.

Given time constraints, it was decided to pursue a single line of primary evidence: an analysis of the operations of at least 20 major mines and/or mining companies (26 in the final analysis). As a secondary line of evidence, information on the "significance" of mining with regard to environmental impacts would be sought from

Government agencies responsible for environmental management and protection.

Mines managed by larger mining companies were considered the ones directly relevant to the RAC's inquiry, and the final sample was chosen with a view to different mining techniques, different minerals, different histories of operation, different States/Territories of operation and an ability to provide the information required (co-ordinated by AMIC). They were thus not a random sample of mines within Australia, but a representative sample of the operations of larger mining companies. The information provided from the mines was generally in the form of a report, sometimes brief and often very detailed with numerous attachments. It was subsequently reduced to separate CASE HISTORIES within this report.

This information was provided with full knowledge that the results would be published and open to public scrutiny, but as an additional check, a sample of the mines was visited with little prior warning. These visits confirmed that the reporting was accurate (to the extent of understating the level of environmental management being practiced in some cases). Within the different forms of mining examined, the mines sampled were not equally representative. For example, the bauxite mining operations (CASE HISTORIES 21 to 24) cover most of the operations in the country - they represent that aspect of the mining industry comprehensively. In contrast, the gold mining operations in the Kalgoorlie region (CASE HISTORIES 6, 7 & 8) and the open cut coal mining operations examined in the Bowen Basin (CASE HISTORIES 10 and 11) are not representative of all mines in the respective areas.

Questionnaires for Government agencies with experience and legislative responsibility in environmental matters were prepared with a view to allowing them to use their experience to essentially rank what they considered the most significant causes of environmental degradation within Australia; mining was included amongst a range of other factors. They were not designed with a view to extensive quantification of results, but rather to obtain a "glimpse" of professional thought on the matter. Four general questionnaires, broadly categorised as "Environmental Productivity", "Genetic Diversity", "Fauna" (for museums) and "Flora" (for herbariums) were prepared, and depending on the area of expertise of a particular organisation, all, some or parts of some were sent to 86 separate organisations (Appendix I). Sample sizes for any particular question were by necessity small (there are limited numbers of herbariums, museums, environmental

protection agencies etc.), but the results did act as an independent check on information provided in the case histories. The responses to the questionnaires are summarised in Appendix II (1,2,3 & 4).

In compiling the report, I drew freely on my previous submission to the RAC (Webb 1990b), which examined a series of philosophical issues and assumptions involved in the debate over mining in Kakadu.

1. PUBLIC OPINION AND ENVIRONMENTALIST OPPOSITION TO MINING

On 5 October 1989, the Prime Minister (Hawke 1989a) issued a press release containing the Federal Government's decision on mining in the "Conservation Zone", within the Northern Territory of Australia. Ninety-eight percent of the 2500 square kilometre Conservation Zone, purportedly rich in mineral resources, was incorporated into Stage III of Kakadu National Park and effectively closed to mineral exploration and mining. A decision on whether to allow mining in the remaining 2%, which includes Coronation Hill, was deferred pending independent assessment by the Resource Assessment Commission.

The Government's decision was welcomed by environmental groups generally, and afforded relief to those in the public who felt that mining would cause significant environmental damage in Kakadu. It was described by the Director of the Australian Conservation Foundation as "*a clear victory for environmentalists*" (whose next task would be to prevent mining within the remaining 2%); a "*testament to the effectiveness of the ACF*"", who played a "*key role in the final decision*" (Humphries 1989).

For the Coronation Hill Joint Venture Partners (CHJV) (CHJV 1990), for the mining industry as a whole (AMIC 1990a), for some Cabinet Ministers (Toyne 1989) and for many in the public, the Government's decision was greeted with neither confidence nor optimism. Most concerns were economic ones, but there was widespread comment on the extent to which public opinion had influenced the Government's decision - "*the very great importance Australians properly attach to Kakadu*" (Hawke 1989a) - the perception that mining would destroy Kakadu's environmental values.

Public opinion is becoming an important aspect of environmental debates, and is central to the reasons this report was undertaken. If a large segment of the public "thinks" that mining is fundamentally

"bad", and has the impression that the environmental impacts of mining will always be serious, then any new mining development will result in fear, anxiety and concern in the community. This results in public confusion and spirited opposition to development, some of which may be informed but some of which is often uniformed. If the basis of public concern is spurious - if it results from misinformation or is established around an outdated perception of the likely impacts of development - then unnecessary costs can be incurred by the people involved, the companies involved and by the community as a whole.

This is by no means a suggestion that all areas within the country should be mined or used for the production of other resources. The costs and benefits of each development project need to be assessed objectively to ensure that a net "benefit" to society results. But it does mean that assessments need to be based on objective criteria. The weight that decision-makers put on "public opinion" needs to be balanced against the extent to which that opinion is "informed". If environmentalist opposition to a mining project is based on aesthetic considerations, which are a valid area of concern, then these should be clearly identified and not be masked by secondary concerns of dubious validity. The events surrounding Coronation Hill afford an example.

Environmentalists opposed to mining at Coronation Hill ran a very effective campaign. They injected their fears and concerns into the community, and made the political system consider seriously the electoral ramifications of allowing mining within the Conservation Zone to proceed. Yet part of this success was due to their program not being met with a strong, *formal* opposition in the public arena (even though the mining industry advertised the merits of their arguments to some extent). The central objectives of the CHJV were to conform with the legal requirements of 8 Commonwealth and 23 Northern Territory Acts (CHJV 1990). Their efforts were largely and correctly devoted to solving problems directly related to minimising the environmental impacts of mining at Coronation Hill. None of those Acts obliged them to address "public opinion" *per se*, although they were obliged to, and did, address such written public criticisms as were received. They were also under no obligation to mount a campaign to retain the Conservation Zone as a whole, which in the final analysis, was clearly being decided upon. Thus environmentalists were raising "potential" problems continually within the public arena, and at best the CHJV were answering some and saying nothing about others - in the opinion of the CHJV there was nothing to be gained from engaging in public debate with committed antagonists.

Without a strong, formal opposition, or a legal obligation to be "truthful", any group attempting to win public support can "bend" the truth in any direction they like. This applies to both mining companies and environmentalists. They can do so with impunity if the public has limited experience with the issue - if the media is their sole source of information. The Australian public at large lives in high density coastal cities and has little first hand experience with Kakadu, environmental management, mining, Aboriginals, terrestrial vertebrates, current international trends in environmentally responsible resource use, or the many other variables involved in a rational decision about mining within the Kakadu area - an area the size of Israel. With neither the time, the resources, nor the inclination to research the problem in detail, the public is vulnerable to being misinformed.

Under current legislation the antagonists involved in complex resource utilisation issues such as Coronation Hill, operate under different rules of debate. Companies promoting the use of a particular resource are legally responsible for the veracity of their evidence, whereas those in opposition have no such legal obligations. There is no strategy in place for allowing "public opinion" to reflect well-balanced, rational conclusions based on an objective assessment of potential costs and benefits. The risks of trying to solve such problems rationally, on the basis of 51% public support, are great. The weight that Government places on public opinion in resource utilisation issues, needs to be evaluated on the basis of how well the public has been educated about the issue. It perhaps needs to be approached with the same degree of caution that Treasury economists may place on public opinion about the desirability of potential wage increases!

Identifying and solving environmental problems is in reality a specialist area of scientific endeavour, involving interdisciplinary efforts and qualified experts. In the Coronation Hill case, one of the most important areas of environmental concern should have been the engineering calculations associated with the retaining wall of the proposed tailings dam. The calculations were carried out by qualified experts, and they were evaluated by qualified experts in Government: they were revised until both parties were satisfied that sufficient margins of safety and error had been incorporated. A multitude of other technical problems, including aesthetic issues, were handled using the same, general procedure, although they were rarely mentioned in public.

Environmental protection and the whole concept of environmental responsibility, has its roots at this expert level of examination. This is the level where the public interest is protected legally. It is evidence gathered at this level that forms the basis of the legal processes through which approvals to mine are either given or withheld. But it makes "poor" television viewing. And because both sides eventually agree on the conclusions, it does not generate lengthy debates in the printed media. The general public may well be largely unaware that it exists. What they see as the most important "environmental problems", which mould their opinions, are often quite different.

Within a mining-environment debate, the aims of environmentalists are usually to sway public opinion against mining - it is not to educate the public about the issue such that they can develop an informed opinion themselves. This is presumably the Government's responsibility and should not be the responsibility of mining companies. To sway public opinion, key aspects are selected, partly on environmental grounds and partly on the basis of how the public can be expected to respond to them after presentation by the media (just as in advertising). They often fall into the class of myths and legends - but they *are* effective at altering public opinion, largely through fear of irreversible losses.

In the Coronation Hill case, public opinion was moulded by images of the coastal flood plains, escarpment, wildlife and waterfalls contrasted against images of mining - the implication being that one would replace the other. Yet in reality this was impossible. An array of terrestrial vertebrates was projected to the public as being endangered by mining - yet most experts agree that impacts will be primarily aquatic. The extinction of the pig-nosed turtle within Australia became a potential impact of mining - yet it is impossible to derive a mechanism through which this could be achieved. And the list went on!

The ability to promote spurious issues in the media is intimately related to the nature of the media. As explained elsewhere (Webb 1990a,b) there appear to be sound survival reasons why our attention is attracted to "bad" news rather than "good" news. By selecting which source of media we will access, we *buy* current affairs from organisations that are *selling* it; that are selecting and packaging it partly on the basis of what will interest us - what will stimulate us to keep buying. It appears to be a response of the "old mind", still fundamentally concerned with primitive survival, over the "new mind" which struggles to adapt to the present (Ornstein and Ehrlich 1990). Even a remotely low probability of an animal

going extinct meets all the criteria for "good" television viewing. By way of contrast, the design specifications of a tailings dam wall, which everyone agrees is sound, makes "bad" television viewing. It is not the media that is at fault, *we* dictate what we want (although we may not be sure why), and are increasing viewing the world around us with depression and despair as a consequence. But we have created a situation in which spurious environmental issues can be promoted easily.

The difficulty with spurious environmental issues in a mining debate is that they cloud the real issues and confuse public opinion. The public increasingly demand solutions to problems they believe exist, yet scientists and technicians cannot find solutions, because the problems don't exist! Because the mining industry is projected as being totally unscrupulous, there is an expectation that mining companies will deny the importance of the problems. When and if they do deny them, their arguments (and often data) are typically ignored or treated with contempt. If they do *not* respond to them, their silence is treated with suspicion. The list of potentially bogus environmental problems is infinite, whereas the resources available to address them are finite. It does not matter how many bogus problems are addressed, nor how they are addressed, there will always be more awaiting public exposition - more that can be used to sway public opinion about an issue with which the public has little first-hand experience.

There are very sound reasons why public awareness about environmental issues is increasing exponentially (Brundtland et al. 1987), and increased public participation in resource issues will surely become more common in the future, and should be welcomed by all. Ensuring that the participation is constructive, logical and rational (as against "humbug") is the problem to which we must find a solution. It is fundamentally an education problem - it cannot be solved overnight and nor would it seem desirable for the responsibility of solving it being passed on to the antagonists.

No country, least of all Australia, with its dependence on resource exports and high foreign debt, has much to gain by diverting huge resources to cosmetic environmental issues - there are lots of real issues to solve! Similarly, as mining (including oil) is responsible for some 50% of Australia's merchandise exports (ABARE 1990), there is nothing to gain and much to lose by constraining mining activities for bogus reasons. It is important that the public understands the impacts of mining, appreciates the environmental issues involved, has a realistic view of the environmental costs of mining relative to other forms of land-use, and has a realistic view

of the level of environmental responsibility exercised by mining companies today.

2. CASE HISTORIES

CASE HISTORY 1 - URANIUM
Ranger Uranium Mine

Situated within the N.T. (Ranger Uranium Mines Pty. Limited), and surrounded by Kakadu National Park, the open cut mine operates within a project area of 79 km^2; the area of direct disturbance is 4 km^2, increasing at 5 ha per year. The land was originally used for hunting and gathering and open range grazing by cattle and buffalo, which caused considerable damage; its value is less than $1000 per km^2 for this purpose. Over the last 10 years, $1.9 billion in export earnings has been earned; $300 million in taxes, $412 million in shareholder's profits and $110 million in royalties.

The ore is blasted and trucked to a crusher or stockpile. Crushed ore is mixed with water and ground, before an acid leach circuit involving sulphuric acid. The resulting liquor is decanted and the uranium is separated in a solvent circuit after which it is concentrated and converted to yellowcake (ammonia, amine and a kerosene product are used), which is then calcinated. Lime is added to all waste streams and tailings are sent to tailings dams (1 km^2) where solids settle and the water is recycled. Runoff from stockpiles (ore and waste) is monitored and controlled. The two wastes, tailings and sub-economic ore, are the focus of rehabilitation research involving CSIRO. The Company plans to construct a stable landform progressively, with progressive rehabilitation. The major environmental concerns were chemical and/or radionuclide contamination of groundwaters and runoff, which has been avoided by skilled management and extensive monitoring. Secondary concerns about depletion of ground waters have proved groundless. Strict standards for atmospheric emissions, noise, vibrations etc., have been met.

No plants or animals are restricted to the lease area, and management of lease areas not mined (fire, feral animal control, weed control) has resulted in a more "pristine" environment than outside the lease (Kakadu). Collections for baseline studies and monitoring, by various agencies, is perhaps the most significant impact. The company spends some $5 million p.a. on environmental management and protection programs. Capital costs of environmental work to date is about $25 million. An environmental staff of 23, 14 of which have formal qualifications, are employed. Environmental research undertaken or sponsored by the Company has resulted in a series of publications addressing environmental management. Some 20,000 visitors per year are provided with conducted tours in which environmental management is a key issue.

A rehabilitation trust fund currently contains some $50-60 million. All disturbed areas are being progressively rehabilitated as mine use ceases, and at the completion of activities the land will be returned to the Traditional Aboriginal owners. At that time it should be equally if not more "productive" than surrounding lands.

CASE HISTORY 2 - URANIUM
Nabarlek Uranium Mine

Situated within the N.T., in the Arnhem Land Aboriginal Reserve, the Nabarlek mine operates within a total lease area of 1.3 km^2; the area of disturbance is 0.1 km^2 and the mine itself is 4 hectares. The land was originally used for hunting and gathering with some impact from cattle and feral buffalo; its value based on nearby pastoral properties

is less than $1000 per km^2. Aboriginals did not generate a significant income from the lands and its potential for grazing is minor.

The deposit of particularly high grade ore was found in 1970 and due to a series of inquiries was not mined until 1979. The ore was mined out in 4 months. Mill operation started in 1980 and continued through to 1988. It generated approximately $1 billion. The original intention was to use the mill for other local deposits, but this has not proved possible due to land rights difficulties and Government policy on the exploitation and export of uranium. The Nabarlek operation was "moth balled" in 1988. Care and maintenance operations, directed largely at environmental management, still involves a staff of 39 people (6 with environmental responsibilities). An estimated $2 million per year is still being allocated to environmental management.

The significant areas of potential environmental impact were addressed through the application of technology. Radiation levels and atmospheric emissions are 10% or less of recommended limits. No groundwater has been contaminated to the extent as to render it impotable.

The migration of some salts (SO_4, NO_3, NH_4) into a small creek has been detected and approximately 10 hectares of bushland were adversely affected by excess salts in irrigation waters. Impacts from ammonia and nitrates were totally unforseen by all parties involved in the EIS process and have required additional monitoring and technological development. There are no significant impacts in the area in terms of productivity or genetic diversity. There is no known threat to any species of plant or animal. There has been no contamination of animals eaten by Aboriginal people. Rehabilitation and revegetation of disturbed areas (other than roads, airstrips and village) is being undertaken. With the exception of deep excavations into radioactive tailings, most forms of land-use will be possible in the future.

CASE HISTORY 3 - URANIUM, COPPER, GOLD, SILVER
Olympic Dam

Located at Roxby Downs, 520 km NNW of Adelaide, operations (Olympic Dam Operations) started in late 1988. Underground mining and subsequent processing and refining of ore to produce copper, gold, uranium oxide and silver (624 staff) are now underway. The lease is 178 km^2 and adjoins a municipal lease of 100 km^2 of land formerly used for rangeland grazing (maximum $2000 per km^2). Total area of disturbance (mine, plant, tailings, town, etc.) is 8.5 km^2.

The ore (130,000 tonnes per month) is ground and milled and a flotation process is used to release the majority of the copper. Copper concentrates are dried and fed into the smelter furnaces. Electrorefining separates pure copper from impurities. These impurities are further leached and refined to produce gold and silver bullion. Flotation tails containing uranium and some residue copper are subject to a tailings leach process where soluble uranium is extracted by leaching with sulphuric acid. The uranium is then precipitated to ammonium diuranate (yellow cake) and calcined at 760°C to uranium oxide.

The project was subject to extensive EIS procedures and environmental conditions were derived on the basis of compliance with 14 State and Commonwealth Acts and agreements. Realized impacts equate with those predicted in the EIS and 2 areas where impact levels exceeded predicted performance (SO_2 and NaCl emmissions) are being addressed through technological innovation. The largest single area of direct disturbance is the tailings dam (185 ha), which will be rehabilitated. Exploration activities involve 2.5 ha per year; drill sites and disused roadways are ripped and left to regenerate naturally.

To date $16.8 million has been spent on environmental management ($3.4 million on the EIS). The Environmental Department has 23 staff. Detailed annual and triennial reports are made to the SA Government detailing general monitoring results. There are no permanent water bodies or aquatic ecosystem in the area. Atmospheric emissions are monitored, and dust reduction is achieved through soil stabilisation and revegetation. Habitats on site are widespread in SA and do not harbour unique communities. Water is drawn from mound springs on the perimeter of the Great Artesian Basin (that contain unique communities) and regular monitoring of water and local fauna and flora, indicate negligible impacts. Major impacts on the lease are *positive*. Removal of stock, and rabbit fencing and control is relieving sources of stress. Botanical surveys have resulted in the plant list of 660 species, with specimens lodged in the Olympic Dam Herbarium and the South Australian Herbarium. Plants of special interest (one species previously thought to be extinct) have been located in the mound springs area, and fencing has increased their abundance. No unique fauna occur on the mine area. Hydrobliid snails unique to the mound springs are monitored.

The Company co-operates with various Departments, local pastoralists, researchers and the public in environmental matters. New employees undergo an environmental induction process and visitors (15,000 per year) are shown the environmental aspects of the mine. Staff have started a local Field Naturalist Club and regularly give public talks on environmental management.

CASE HISTORY 4 - URANIUM AND COPPER
Rum Jungle

The Rum Jungle mine does not operate today, but it represents a well known historical example of significant environmental impacts. In the not too distant future it will be a site where tourists and the public can learn first hand about the how significant environmental problems occurred in the past, and how they were eventually controlled. Situated within the N.T., 65 kilometers south of Darwin, the mine operated within a total lease area of 0.7 km^2 with a direct disturbance area of 204 hectares. The land was originally used primarily for low density grazing, hunting and gathering. Adjoining land in the area today has a UCV of about $5000 per km^2 and principal uses within a 10 km radius are water catchment (29%), low density grazing (13%), hunting and gathering (Aboriginal land claim; 31%), rural living and investment (19%) and urban (Batchelor Township; 4%).

Deposits of uranium ore and copper were located (1949-52) and mine construction began in 1952. Mining and processing operations began in 1954 and extended to 1971. Some 3,500 tonnes of uranium oxide and 20,000 tonnes of copper concentrate were produced.

Contamination in the East Finniss River from tailings and acidic effluents was first observed in 1960, but a policy of complete retention of waters was not implemented until 1969. The main pollution problem was the oxidation of mine waste in the overburden piles, particularly pyrite (FeS_2), which produces sulphuric acid, which in turn combines with various metals. This results in acidification and heavy metal pollution in the groundwater and runoff. Within the mine site, a low level radiation hazard existed in the old tailing dam area, a source of direct pollution to the East Finniss River. Some 10 km of East Finnis River was polluted to such an extent that aquatic flora and fauna were virtually completely destroyed; these effects continued a short distance into the Finniss River itself. Loss of bank vegetation in turn led to accelerated erosion. During the mining and treatment operations, about 100 km^2 of the Finniss River flood plain were affected by contaminants, mainly concentrated in near surface layers. Their significance was unclear, in that heavy metal and radium concentrations in beef and buffalo grazing the plains remained well below international standards. The contamination problem was greatest during the annual wet season, and its extent varied from year to year.

A serious "clean up" of the mine site area, directed mainly at aesthetics, was carried out in 1977 ($0.3 million). Between 1982 and 1986, a major rehabilitation project ($16.8 million) was undertaken, and an ongoing environmental management and monitoring program was instigated. This sophisticated technological program effectively contained the pollution. The area of river previously devastated is now returning to its original state, with plants and animals re-establishing themselves. Some areas need ongoing management (for example to prevent tree growth on the caps over the overburden piles), but the effects on outside lands and waterways have been contained.

CASE HISTORY 5 - GOLD
Stawell Joint Venture

One of the largest gold mining operations in Victoria, at Stawell, 230 km W of Melbourne; 162 employees. Current activities (from 1981) are on tenements of 797 ha and 125 ha have been disturbed (mining, project area, processing etc.). Tailings dam increases at 4.8 ha in a year and rehabilitation of tailings and mullock dumps at 15.8 ha (41.8 ha rehabilitation to date). Gold mining in this area began in 1853. From 1923 to 1981 there was virtually no mining in the area. The areas now utilised were open space, flora reserve, gold mining reserves, degraded bushland, abandoned mines, public rubbish dump, Crown Land reserve and farmland. Surrounding lands (10 km) are agriculture (70%; $650-$1000 per ha), urban (10%), forestry (10%) and bush reserve (10%).

Mining is by open cut and undergound, and includes treatment of old low grade ore stockpiles (from previous open-cuts) and an option on old tailing sands exists. The ore is crushed, milled, ground and processed using the carbon-in-leach method involving cyanide and caustic. Tailings are contained in a clay-walled dam (3 km away), with underdrains for seepage and decant towers to collect surface water; 70% of water is recycled back to the treatment plant. Waste rock from the Wonga open-cut (1983-85) was stored in a dump, part of which is used for construction and earthworks in the area including erosion control; parts are revegetated. The Wonga underground mine (1985) opens from the pit floor. Waste from the Davis open cut (1986-87) was shaped, contoured and completely revegetated. Undergound waste is used to backfill Davis and for construction. Low grade ore (for potential future treatment) is currently stored by backfilling underground cavities, lessening the environmental impact of surface stockpiles. Revegetation efforts avoid rapid aesthetic cover with non-indigenous species and strive for better long term results with native species.

Detailed environmental management procedures accompanied the original proposal to mine, and an Environmental Effects Statement (EES) was required for the second open cut. In most cases perceived potential impacts were similar to those anticipated. Water, air and noise effects are monitored and have been within predicted limits. Vegetation clearing is compensated for by rehabilitation. Cyanide management and tailings disposal have been conducted as originally planned. The volume of mullock from the first open-cut exceeded predictions and the excessive height and steep slopes has made revegetation difficult; it received a poor reception from local residents. This experience led to the very high standard of the Davis mullock heap storage and rehabilitation. Blasting effects (noise, vibration) were greater than predicted but are maintained well within regulatory standards; they have drawn some public criticism. Land surface disturbances have been screened to some extent by bunding and native flora plantations. Buildings are not permanent structures. There was a strong public perception that exploration activities would impact on terrestrial wildlife and thus regional authority supervision, flora and fauna surveys, operator education and close supervision were implemented. The Company allocates $100,000 per year to environmental management and control. Public education about mining and environmental responsibility is actively pursued.

CASE HISTORY 6 - GOLD
Boddington Gold Mine

Situated 13 km WNW of Boddington, W.A., the mine (managed by Worsley Alumina Pty. Limited) began operations in 1987 and now employs 140 people. Areas of direct disturbance to the end of 1990 are 825 ha, which will increase to 1,595 ha by the termination of the project (about year 2000). The mining area was located in forested areas that had been subjected to timber harvesting. Clearing has been kept to a minimum and earthworks constructed with the specific aim of minimising impacts on surrounding forest.

Mining is by selective open-cut and processing of the gold orebody is on-site. This involves crushing, milling, leaching and gold extraction by the carbon-in-leach process. Residue slurry from the processing plant is pumped to a Residue Disposal Area (230 ha), where residue settles and supernatant waters are recovered for reuse. Operation of the mine in its entirity is in accordance with an initial detailed Environmental Management Program (EMP) and various Notices of Intent (NOI) assessed by the Environmental Protection Authority (EPA). Botanical and faunal surveys were undertaken as part of the environmental assessment, and they provide baseline data for rehabilitation efforts. The stream which drains the project area (34-Mile Brook) was also subjected to biological survey, as well as hydrological and chemical monitoring; the stream and the Hotham River (to which it drains) both have elevated salinities and this is reflected in the aquatic fauna.

Rehabilitation is planned to commence in 1990-91, when 10 ha of a pit will be prepared for seeding and planting in the 1991 winter; 30 ha per year will be rehabilitated in the following two years. The procedures to be followed are within the EMP and involve deep ripping of pit floors, backfilling pits with mine waste, battering pit walls, landscaping and contouring, replacement of gravel overburden and topsoil, scarifying and revegetating. The land form will be changed, but productivity is expected to be returned. Water releases from the Residue Area will be prevented unless water quality monitoring by the Water Authority indicates the quality meets desirable standards. The Residue Area will be covered with gravel overburden and topsoil and vegetated with a short-rooted cover crop. A detailed monitoring program is incorporated within all aspects of water management on the site and is the basis upon which environmental impacts will be minimised.

CASE HISTORY 7 - GOLD
Jubilee Gold Mine

Located 35 km south of Kalgoorlie, W.A., the Jubilee Gold Mine operates both mine and ore processing facilities within a project area of 173 hectares. The surrounding lands within a 10 km radius are used primarily for open range sheep grazing (94%) and mining (6%), with land values currently about $500 per hectare. Mineral value is $12.1 million per ha in the pit and $2.0 million per ha over the total lease area. The environment within the general area was degraded historically by intensive timber gathering, heavy grazing and early mining historically, but improved control generally has resulted in regeneration to what seems to be an environmentally "sound" state.

Mining on the Jubilee Lease took place around the turn of the century and again in the 1930's, mainly by underground methods. The current activity started in 1987 and is mainly open pit mining, with some 1.03 million tonnes of gold bearing ore and 6 million tonnes of waste rock removed annually. Milling and processing (using cyanide, caustic and hydrochloric acid) occurs on site. Tailings are transferred to two dams, with approximately 40% water recovery back to the plant.

Environmental concerns are mainly aesthetic. The waste rock and tailings storage areas are creating hills where none existed, the pit a valley. Rehabilitation occurs at the same rate as mining, using local plants and trees to reduce visual impacts. Limited emissions of HCN, dust and low noise occur but have no effects beyond the bounds of the operation. The operation was once temporarily stopped due to unforseen dust problems which were overcome by construction of dust covers over ore stockpiles and the development of a dust collection system. Environmental procedures for new mining operations were implemented (WA Mines Dept. and W.A. Environmental Protection Authority) in 1989 and although not required at Jubilee, these practices are followed.

Surveys of flora and fauna were conducted by the University of W.A. and the W.A. Museum prior to operation and identified two plant species of interest (because they were poorly known); there was no data indicating they were under any threat. It was recommended that sandlewood in the area be harvested prior to clearing. No fauna was considered specific to the area. No significant impacts have occurred outside the site.

Concerns about run-off from the waste dump and groundwater contamination have been addressed through controlling the water flow and an active and continual revegetation program designed by environmental consultants. Groundwater is saline and of limited use for stock or irrigation. The possibility of groundwater contamination through the tailings dam is considered minimal by the Water Authority due to the soil structure. Expenditure on environmental activities is about $100,000 per year and most work is carried out by existing mine staff. Some 87 staff are employed on site.

CASE HISTORY 8 - GOLD
Karoni Gold Mine

Located 100 km east of Kalgoorlie, W.A., the Karonie Gold Mine operates both mine and ore processing facilities within a project area of 2.5 km^2. The surrounding lands within a 10 km radius are used primarily for open range sheep grazing and land values are currently about $100 per hectare. Mineral resources are valued at about $5.5 million per ha within the pit area. Exploration activities extend over an area of some 200 km^2.

The current operation is 2.5 years old and 2-6 million tonnes of rock are extracted from open pits annually. Milling and processing (using cyanide extraction) occurs on site, with waste rock (free of leachable heavy metals) stored in dumps and contaminated tails stored in earth dams. Waste dump rehabiliation was commenced in 1989. Saline water from bores, tails dams and road wetting has a deleterious effect on vegetation, which is often severe, which may take several years to leach naturally.

The habitats within the area mined are widespread and no unique or notable plants and animals are known from the area. At the termination of mining the ground will be ripped to promote natural revegetation. Only a small area of land in the actual pit and tails dam area is anticipated as being unusable for sheep grazing in the longer term, such that almost full pastoral use is anticipated. Approximately $100,000 per year is spent on environmental control and a graduate zoologist attends to environmental matters among other duties. Some 50 staff are employed on site.

CASE HISTORY 9 - GOLD AND SILVER
Kaltails Gold and Silver

Located 10 km SE of Kalgoorlie, W.A., the operation (Kaltails Mining Services Pty. Ltd.) reprocesses old tailings. Started in 1989, with 65 employees, the plant processes 6 million tonnes per year, producing bars (40% gold; 60% silver) separated and refined in the Kalgoorlie Refinery. Current licences are to treat 275 ha of tailings; process plant

and tailings dam involve 300 ha within a tenement of 480 ha. Expected production over the life of the project (10 years) is $288 million; $0.96 million per ha of disturbance. The removal of old tailings will decrease dust in the town and improve aesthetic appearance and land-use options. The plant is sited in a section of woodland and sandalwood reserve, with clearing an obvious surface impact. The site was selected for a variety of reasons, including hydrological and land-form features related to reducing environmental impacts. A borefield was constructed 10 km SE of the plant on a pastoral lease and it involves some 40 ha of disturbance in pipeline corridors. Surrounding lands are mostly pastoral (70%; UCV about $1.00 per ha.), reserve (5%; Sandlewood reserve $1150 per ha), urban (10%) and mining (<15%).

The old tailings arrive at the plant as a slurry, passes through a series of leach and absorption tanks, involving cyanide and caustic. Spent tailings are contained in a tailings dam designed to last the full length of the project. Areas of disturbance will decrease as progressive revegetation of the tailings dam commences in 5 years time. Some rehabilitation efforts are already underway (small areas in borefield and areas disturbed during project construction).

The project was subject to a Public Environmental Report (PER) to the Environmental Protection Authority (EPA). Environmental conditions for the project include liaison with Department of Conservation and Land Management (CALM) about revegetation trials, and a commitment to construct the tailings dam in a secure manner, monitor its performance, lay pipelines in an environmentally "friendly" fashion, monitor ground water and rehabilitate the project site at termination. Upon commissioning, some areas of seepage from the dam wall were detected, due to the deposition strategy, and these are thought to be under control and increased hydrological and botanical monitoring have been implemented. System failures, subsequently rectified, also led to a saline water (3 ha) and tailings (1 ha) spills, now rectified with the affected areas under rehabilitation. The project in its entirety is inspected regularly by EPA and Mines Department representatives.

Over and above historical changes associated with the long history of clear felling and mining in the area, no significant long-term effects on unique species of fauna and flora have been identified. The section of sandalwood reserve involved about 7% of a reserve, with 7 other reserves in the area. The ground water in the area is highly saline and used mainly for mining.

Current expenditure is $100,000 per year, but given future rehabilitation efforts, the total environmental budget is estimated at $3 million over the 9 year life of the project. A permanent environmental Officer is on staff. Research is being undertaken into air sampling, groundwater recharge and dust abatement.

CASE HISTORY 10 - COAL
Norwich Park

Located in the Bowen Basin of Central Queensland, 225 km NW of Rockhampton, the mine is managed by BHP-Utah Coal limited. Leases occupy 178 km^2, of which 22 km^2 have been disturbed by mining - the annual rate of disturbance is 75 hectares. Annual production is 4.3 million tonnes of coking coal, which is exposed by dragline within open cuts. The coal is crushed and washed on site, before being railed to an export terminal. This mine employs 550 staff and is one of 16 in the Bowen Basin, which produce 60 million tonnes per year from direct disturbance of 30 km^2 per year. The Norwich Park lease was previously used for low intensity grazing. Immediate surrounding lands are used for cattle grazing (90%) and cropping (10%). Within 100 km radius there is grazing (50%), farming (40%; some with irrigation), mining (5%) and urban development (5%). Grazing land is worth about $5000 per km^2 and farming land about $15,000 per km^2. Productivity degradation in this area is occurring through

erosion and salination in irrigated areas. Coal resources are valued at approximately $1.14 million per ha of land surface disturbance.

Norwich Park was subjected to EIS assessment and began operations in 1979. The mining procedure involved removing the overburden and casting it into a pit, creating parallel ridges of spoil. Some 2.8 km^2 are in various stages of rehabilitation with a current program to rehabilitate up to 1 km^2 per year and reduce a backlog of 3 km^2. The aim is to return the land, at the end of its life back to cattle grazing land with similar or improved production potential. Impounded water has increased available habitat for aquatic fauna.

The impacts identified with the EIS proved largely to be the ones that deserved attention. Water quality issues are considered the most significant, perhaps for the coal mining industry as a whole. The management of water at the mine has benefited some landowners (through controlled releases in dry seasons), and recent concerns about water quality were addressed with improvements to the water management system. No unique plants or animals were known from that site, and thus no significant faunal or floral conservation issues are associated with it. Direct annual expenditure on environmental management is estimated at $0.97 million. Environmental management duties at the mine are undertaken by a graduate chemist with access to additional expertise and staff as required. Some 11 papers concerning rehabilitation at Norwich Park mine have been published.

CASE HISTORY 11 - COAL
Gregory Mine

Located in the Bowen Basin of Central Queensland, 215 km WNW of Rockhampton and 45 km NE of Emerald, the mine leases occupy 115 km^2, of which some 28 km^2 have been disturbed by mining - the annual rate of disturbance is 1 km^2. Annual production is 3.5 million tonnes of coking coal, which is exposed by dragline within open cuts. The coal is crushed and washed on site, before being railed to an export terminal. The mine employs 434 staff. The Gregory lease was scrub and low intensity grazing land. Immediate surrounding lands are used for cattle grazing (25%) and cropping (75%). Within 100 km radius there is grazing (50%), farming (40%; 15% irrigation), mining (5%) and urban development (5%). Grazing land is worth about $10,000 per km^2 and farming land about $20,000 per km^2. It is clearly evident that farming and grazing practices are degrading land through erosion and salination.

Gregory Mine was subjected to EIS assessment and began operations in 1979. The mining procedure removes the overburden and casts it into a pit, creating parallel ridges of spoil. Some 4.6 km^2 are in various stages of rehabilitation at present. The rehabilitation program was developed through research and has been very successful. Some 6 research papers and three post-graduate theses have been associated with it. The central aim is to return the land, at the end of mine's life, back to cattle grazing land with similar or improved production potential. The topographic features will have been altered.

The impacts identified with the EIS proved largely to be the ones that deserved attention. The water management strategies employed, which prevent releases, have resulted in negligible water quality effects downstream. The impounded waters are used by fauna. No unique plants or animals were known from the lease, and no faunal or floral conservation issues are associated with it. Direct expenditure on environmental management is estimated at $0.7 million per year. Environmental management duties at the mine are undertaken by a science graduate (geology), with access to additional expertise and staff as required.

CASE HISTORY 12 - COAL
Hunter Valley Coal Mine

The Hunter Valley Coal Mine (Coal & Allied Operations Pty. Limited) is located at Lemington, N.S.W. and commenced operation in 1979; it now has 501 employees with a further 151 at the preparation plant. The lease is 1212 ha, excluding 31 ha infrastructure and 15 ha preparation plant. At present 60 ha are mined annually and 60 rehabilitated, with 365 ha mined but not yet rehabilitated. Annual production is 7 to 7.5 million tonnes. The land was originally used for grazing pastures, and the original diversity of fauna and flora had been altered greatly prior to mining. The Company's acquisition of buffer zones has led to more natural native habitats becoming established.

The mine is open-cut. Vegetation is removed and topsoil stripped and stored for rehabilitation. Overburden (19.6 million m^3 per year) is mostly placed in decoaled pits, although some out-of-pit dumps have been used; all are subject to rehabilitation in accordance with an approved plan, and it has been most successful. Coal with some interburden bands is trucked to the preparation plant. After washing and separating, solid reject is returned for placement with overburden. Tailings are pumped to settling ponds from which water is reclaimed for the preparation plant. Coal is transported by conveyor to rail heads.

The operation has developed in three stages, with three EIS's. Environmental mananagement has always been a Company priority and the Environmental Management Program (EMP) has not required significant alteration (increased pollution monitoring). Annual reports are now made to the local council, the Dept. of Planning, the State Pollution Control Commission and the Dept. of Minerals and Energy (with regard to rehabilitation).

Some low permeability groundwater aquifers (along coal seams) are eliminated by mining. Surface waters from undisturbed areas are diverted away from disturbed areas (into natural drainage systems) wherever possible. Water in the pit is pumped to sedimentation dams, where the principal disposal route is dust suppression; discharge (controlled under the Clean Waters Act) only occurs when storage capacity is exceeded due to high rainfall conditions. Runoff from dumps and rehabilitated areas goes to sedimentation dams, which will ultimately be stockwater dams. All industrial runoff is directed to a pollution control facility (grit traps, oil separators, sewerage treatment and maturation ponds). A variety of strategies are employed to minimise dust and noise. Efforts are made to reduce blast noise impacts by taking account of weather, location, charging etc.; resolution requires technology and practice.

Rehabilitation aims to reinstate improved pastures, and is subject to a comprehensive plan approved by Government. Experience has shown that rehabilitated pasture is up to *twice* as productive as original pastures. Some $1.0 million has been allocated to EIS's and the annual environmental budget (excluding capital costs) is $150,000 per year. Two full-time environmental specialists are employed on site.

CASE HISTORY 13 - ZINC, LEAD, COPPER
Woodlawn

The Woodlawn Mine, 40 km S of Goulburn and 70 km NE of Canberra has operated since 1978; since 1987 under its current owners (Denehurst Ltd.). The mine employs 240 people. The total lease area is 2,368 ha which was primarily cleared grazing land, with erosion and salination problems in some parts. The mine and workings are within 360 ha, and the remainder is softwood plantation (360 ha), remnant vegetation (390 ha) and commercial farming (1,258 ha). The Woodland farm is a declared Wildlife Refuge. Land

values are about $1000 per ha. Surrounding lands (10 km) are cleared agricultural land (91%), native vegetation (8%) and tree plantation (1%).

Worked as an open cut operation until 1987, the mine is now exclusively underground, with some 650,000 tonnes of ore removed per year. The metals occur as sulphide minerals. Iron sulphide (pyrite) has no commercial value at the site. Zinc, lead and copper-iron sulphide (chalcopyrite), and silver bearing minerals, are realised through milling and flotation processing. Tailings are stored in tailings dams.

Overburden from the previous open cut operation is stored in a valley, where management involves the collection of seepage and runoff and transfer to evaporation dams. Rehabilitation trials demonstrated the need to isolate waste rock from overlying vegetation, and techniques developed are now being applied: almost 50% of the dump has been rehabilitated in the last 12 months, using trees and shrubs that will approximate habitat diversity of remnant vegetation in the area. Vegetation on the site will be improved relative to premining cover. Tailings dam seepage was identified and is now managed (drains, sumps and relocation into dams). Water (runoff and ground), dust and noise are monitored and dust levels managed. The NSW Soil Conservation Service designed and constructed contours to divert runoff from the site. Equipment utilising fuel is chosen and maintained to reduce atmospheric emissions.

The mine was subject to EIS procedures in 1973 and 1976, when concerns were more qualitative than quantitative. Generalisations about control of seepage did not prove correct, even though technological innovation has prevented adverse environmental impacts. Water management, although now in hand, was originally underestimated as a management problem. The present Company allocated $3 million to environmental control in 1989/90 and $2 million is budgeted this year (9% total operating budget). Three staff and 10 contractors are employed on environmental duties, and a strong commitment to environmental awareness is asociated with all aspects of the mine. There is close liaison with Government and research experts, and for example students from the University of Sydney, as a project, are assessing the effectiveness of monitoring and examining the hydrology of groundwater flows. At the termination of mining it is anticipated that the mine site will be well suited to the original form of landuse (grazing) and that environmental impacts will be negligible.

CASE HISTORY 14 - COPPER
Mt. Lyell Copper Mine

The Mt. Lyell mining lease (The Mount Lyell Mining & Railway Company Ltd.) is located between Queenstown and Gormanston, on the west coast of Tasmania. Gold mining commenced in 1883 and attention shifted to copper mineralisations in 1892. Numerous orebodies within the lease area have been mined during the last 107 years and work on the current orebody started in 1935. Current mining and processing operations (450 employees) are based on 110 ha of a 1236 ha lease, the majority of which has been subject to mining and/or exploration over the last 100 years. The current mine is underground (sub-level open stoping) and 1.8 million tonnes of ore per year produce some 100,000 tonnes of copper concentrate (with significant amounts of gold, cobalt and molybdenum) and 80,000 tonnes of pyrite concentrate after processing. Waste rock (currently 300-400 tonnes per day) is placed in waste rock dumps. Prior to mining in the area the land was uncleared forest. Today, within a 100 km radius, land use is mostly conservation (50%), uncommitted Crown Land (28%), Hydro-electric (10%), agriculture (10%), mining and urban (2%).

The impacts at Mt. Lyell are severe and obvious, and they reflect in part the antiquity of mining; it was developed and operating well before obligations to protect environments were considered important. Queenstown and Gormanston are themselves impacts of mining, having been developed to service the mining industry. Extensive logging in the

1890's, frequent fires and high SO_2 emissions from pyritic smelting (1896-1969) resulted in broad scale destruction of vegetation around the site, affecting some 3500 ha. The fauna and flora which may have occupied the site originally can only be guessed at. Shallow topsoils, high rainfall and devegetation enhanced erosion and restrained natural revegetation, even after smelting stopped. Some 425 ha is affected by past open cut mining and waste and overburden dumps. The legacy of direct disposal of tailings and from acid mine drainage (pyrite oxidation products), is 32 km of the Queen and King Rivers made unsightly and unproductive - damaged to the extent that aquatic fauna and flora cannot exist there. Effects extend into Macquarie Harbour, where some 35 km^2 are unsuitable for fish farming. Concerns have been expressed that effects may be realised in Lake Burbury (to be filled in 1991), and this possibility is being investigated with various Government research authorities.

Expenditure on environmental controls (excluding staff costs) has increased by an order of magnitude in the last two years ($0.27 million in 1990/91). Topsoil for the consolidation and revegetation of waste dumps is being gathered from areas of Lake Burbury to be inundated. Research into consolidating waste dumps and preventing pyrite breakdown has been initiated, and a separate research program into revegetation is being negotiated.

Rehabilitation efforts at Mt. Lyell will improve greatly the effects of mining over more than a century, but it is considered unlikely that "restoration" would be an achievable aim. Tourist development of the site is considered the most likely form of future land-use.

CASE HISTORY 15 - SILVER, LEAD AND ZINC
Broken Hill

Pasminco Mining now controls two major operations at Broken Hill, N.S.W. (1000 km W of Sydney and 510 km NNE of Adelaide), the "North Mine" and the "ZC Mine" based on 360 ha and 460 ha of direct disturbance for mining activities. It involves some 1500 employees and through multiplier effects is a major indirect source of employment within Broken Hill. First discovered in 1883, the orebody consists of discrete lodes or lenses with economic quantities of lead and zinc sulphides with silver minerals and traces of gold and copper. Lead loads are in both areas whereas the main zinc lodes are in the ZC Mine. Currently, underground mining and lead-zinc concentrators are at both sites; an open pit also occurs at the North Mine. Mining has occurred between 1886 and 1990 with 2 small breaks. The principle form of surrounding landuse is grazing, on land with a current value of approximately $1000 per km^2. Carrying capacities for agriculture are 12.5 sheep or 1.6 head of cattle per km^2.

Some 2.5 million tonnes of ore are removed annually. It is crushed, screened and ground then entered into flotation circuits, after which the lead (with silver) and zinc concentrates are thickened, filtered and discharged into rail wagons for transporation to smelters at Port Pirie (S.A.) and Risdon (Tas.). At both mines a sand fraction is separated from residues for backfilling underground excavations while the fine fractions ('slimes') are pumped to tailings dams; 60-65% of residues are disposed of underground.

Waste rock is also used for backfilling underground, placed in dumps, used to armour the side batters of tailings dams or in road construction. There have been no acid-drain problems and none are expected. The management of dust, particularly leaded dust, has been an ongoing area of monitoring and control and is an area where public concern is sometimes expressed. Rehabilitation reduces dust problems generally, and a variety of strategies are employed at different potential sources. Water management is an area of concern, in that efforts are directed at trapping and using all waters that become available from run-off etc. There are no permanent creeks in the area and sampling from

seasonal flows indicates no significant contamination is occurring. Lead levels in some areas appear to reflect natural erosion of lead-bearing rocks in the past, that is not directly related to the mining activities. Noise levels are maintained within standards and effects of blasting are minimised, although the close proximity to Broken Hill township causes public comment from time to time. There are no major environmental problems with the current operations.

Major rehabilitation and beautification efforts were initiated in 1936, to address the harsh aridity of the area caused by uncontrolled timber cutting and grazing, together with the effects of rabbits and goats. Fencing was found to be a key ingredient. This has been responsible for the green belt around Broken Hill today. Nurseries, orchards (produce for charity) and research have continued since then, contributing to national and international revegetation problems, and to our general understanding of arid vegetation. Since the 1930's large numbers of papers and reports have resulted from research at the mines. Significant funding was made available to CSIRO to research vegetation establishment. Rehabilitation of tailings dumps has been a major research initiative, needing special technology to cope with the minimum utilisation of scarce water supplies. Annual expenditure on environmental management and control is around $2 million.

CASE HISTORY 16 - SILVER, LEAD AND ZINC
Hellyer Mine

Aberfoyle Resources operates the Hellyer underground zinc-lead-silver mine at Waratah, on the Murchison Highway, 90 km SW of Burnie, Tasmania. The ore body was discovered in 1983, and after a period of intense delineation drilling, mine development and bulk sampling, a 1 million tonne mine and concentrator came on line in 1989. The lease is 1695 ha, of which less than 100 ha is disturbed by mining and associated activities. The area is timbered crown land, selectively logged prior to mining. Market value of uncleared land is abour $2500 per ha. The in-ground metal value of minerals is $6.02 billion at current prices. The mine has an estimated life of 15 years and concentrates produced at present are worth $150 million per year.

A relatively new operation in Tasmania, now employing 240 people, the operation was subject to some of the most strict environmental requirements yet required of a mining operation in Tasmania. Annual compliance reports are made to the Government Environment Department and the operation is subject to review and public comment each three years.

The mine is located in a high rainfall area (1800 + mm/yr) and water management receives a high priority. Site drainage controls divert, as far as practical, the natural waters. Run off, mine drainage and any accidental spillage are all directed through the tailings dam and effluent control system.

The locality is increasingly being used by tourists and the site is partly overlooked by National Park (Cradle Mountain/Lake St. Clair). Visual impacts have been eliminated by careful selection of facility, locations, maintenance of tree screens and revegetation. The long-term objective is to return the land to pre-logging native temperate rain forest. Site-clearing has been kept to an absolute minimum, with rehabilitation of disturbed areas carried out as soon as possible after disturbance. Three permanent employees and six contractors and various consultants are assigned full or part time to environmental management duties.

During the 1989-90 year, $0.7 million was spent on environmental management, revegetation and monitoring. Research in wetlands technology has been initiated to determine whether an artificial wetland system can be used for the biological removal of metal concentrates from waste waters. Plans are in place for a visitors centre, a major

function of which will be public education about environmental management. Senior staff regularly give talks on environmental managment to local councils, service clubs etc.

CASE HISTORY 17 - MINERAL SANDS
Eneabba Sand Mine

The Eneabba leases (AMC Mineral Sands Ltd.) are located 300 km N of Perth, some 60 km inland from the coast; it is an amalgamation of two previous mines started in 1973 and 1977. Historically, the land was natural heath on vacant Crown land or agricultural land generally considered of poor quality ($100 to $250 per hectare). To date some 14 km^2 of old beach strand have been subject to direct disturbance and 8 km^2 have been rehabilitated; current rate of use is 140 hectares per year. Shallow (1.5 to 20 m) open cut mining and suction dredging are currently the methods of extraction used although a bucketwheel system is being implemented. The topsoil is removed and stored in windrows. The sand is removed, processed (by physical rather than chemical means), the tailings are returned and the topsoil replaced prior to rehabilitation. The minerals produced are: ilmenite, rutile, zircon, leucoxene, monazite, xenotime and synthetic rutile made from ilmenite.

The main impact of mining is direct disturbance of land. Potentially important impacts are on the water table. At Eneabba the mining operation is above the water table such that impacts are negligible. However the dredge mining results in water loss to the lower water table, and interception bores are currently being planned to recycle water and prevent adverse rises in ground water level.

There are no specific concerns associated with fauna at Eneabba, and research undertaken by AMC indicates that the 3 notable mammal species, and birds and arthropods in general, return to rehabilitated sites within 3 years. Vegetation surveys revealed some 40 species that were poorly known or considered rare. Some of these have proved difficult to propagate and research has been commissioned into 3 families, particularly 2 that are major structural components of the heathland. Tissue culture research on one species considered endangered (*Leucopogon obtectus*) has allowed successful propagation and it will now be replanted; the research has broader application to other related species.

The Eneabba rehabilitation objectives are to regenerate a functioning self sustaining ecosystem, and towards these ends they may surpass the completion criteria that exist for the site. Rehabilitated areas will be younger than surrounding areas of heath but with time are expected to approach it in diversity. Considerable effort is expended to stablise the lands and replant with both seed and nursery stock. Rehabilitation efforts will involve $1.7 million (operating) and $0.45 million (capital) this year. There are 10 salaried staff and 8 on wages, plus 3-30 seasonals working primarily on environmental matters at Eneabba and Capel. Some 82 scientific papers, journal papers, theses and reports have resulted from AMC activities related to minimising environmental impacts at Eneabba and Capel.

CASE HISTORY 18 - MINERAL SANDS
Capel Sand Mine

The Capel Mine (AMC Mineral Sands Ltd.) is located 200 km S of Perth, some 5 km inland from the coast; operations started in 1956. Originally, the land was private farmland and State Forest giving generally poor productivity. Land values today are approximately $1000 per hectare for farmland and up to $20,000 per hectare for "hobby" farms. To date some 6.8 km^2 have been subject to direct disturbance and over 80% has been rehabilitated; current rate of use is 25-30 hectares per year. A

bucketwheel excavation system has been used since 1982. The topsoil is removed and stored in windrows. The sand is removed, processed, the tailings are returned and the topsoil replaced prior to rehabilitation. The minerals produced are: ilmenite, rutile, zircon, leucoxene, monazite, xenotime and synthetic rutile made from ilmenite.

The main impact of mining has been direct disturbance of land. Water management is required to prevent potentially important impacts. At Capel, $1.3 million was spent on a neutralisation and effluent treatment system such that discharges into the Ludlow River met EPA requirements. During summer, the quality of discharge is higher than natural waters (which are affected by nutrients and saline run off from farms); rains result in the natural flow superceding discharge standards in the winter. Past dumping of waste from the synthetic rutile plant has caused local areas of contaminated ground water near the plant which are in the process of being located and treated. Emissions of sulphur from the synthetic rutile plant occurred, but the "odour" problem to local residents was addressed through altering procedures.

There are no specific concerns associated with fauna or flora at Capel. Two species of *Acacia* were of interest but both regenerated in abundance following disturbance. The Capel rehabilitation objectives generally are to return agricultural land to agricultural purposes. Since 1981 grazing of rehabilitated pasture areas has occurred, although earlier rehabilitation efforts with pastures have been greatly improved by mixing clay and sand fractions prior to rehabilitation. The carrying capacity of current improved pastures is twice that of surrounding farmlands.

A section of the mining lease that was previously forest is being rehabilitated into a series of wetlands for the conservation of waterbirds in the South West of W.A. The AMC Wetlands Centre is a major conservation initiative being undertaken in co-operation with the Royal Australian Ornithological Union. Wetland habitats have been steadily decreasing since European settlement and the Centre co-operates with various expert organisations. and involves a high level of student and volunteer assistance with rehabilitation. This development was an initiative of AMC, whose only obligation was to return the land to farmland or pine forest. Rehabilitation efforts at Capel will involve $1.5 million in the 1990/91 year.

CASE HISTORY 19 - MINERAL SANDS
Hawks Nest

The operation (Mineral Deposits Limited) is based at Hawks Nest, 60 km N of Newcastle, N.S.W., and utilises mineral sands from three leases in the general area [Stockton (from 1985), Viney Creek (from 1986) and Viney North (from 1988)]. The operations employ 145 persons on site. The Hawks Nest Separation Mill has operated from 1966. The Viney Creek sites were on a private pine plantation that had lapsed into disrepair. The Stockton site was 50% private lands taken up but not used for grazing, and 50% crown land. The surrounding lands (10 km radius) at Viney Creek are predominantly rural [cattle grazing 40%, forestry (exotic and native) 50%] and at Stockton are dairy farming (15%), military base (40%), Tomago Water Supply (40%) and dunes on crown land (5%). The lands being mined are valued at approximately $700 per ha. (if offered as large holdings).

All mining is carried out by cutter suction dredging. The surface is cleared, the humus bearing surface layers are retrieved and stockpiled for restoration, water is pumped into an excavation, and a floating dredge draws up the ore, separates the heavy elements (which are trucked to the mill), and replaces the tailings which are then contoured, and rehabilitation started. The mill produces rutile, zircon, ilmenite and monazite, without chemical reductions. Currently, 92 ha have been used for mining and processing and the annual rate of mine progress will be about 155 ha. Some 2000 ha are required for a viable lease.

A proposal to mine high dunes near Smith's Lake in the 1970's resulted in one of the first major confrontations between mining and conservation interests; a compromise position allowing access to 50% of the area resulted. The main impacts of sand mining are visual - aesthetic considerations. It takes 10-15 years before regeneration is complete to the extent that lands are returned to public use, although restored areas are utilised by an increasing diversity of plant and animal life from year one.

Expenditure on environmental management has increased from less that $1000 p.a. in 1973 to $230,000 p.a. in the 1990/91 year. The Company now employs graduate and post-graduate scientists, an engineer and a variety of technical staff for rehabilitation and restoration, in addition to consultants. It has often been necessary to control pest species in surrounding lands (to minimise impacts on rehabilitated sites) and environmental awareness is projected to all staff. The mining pathways are now examined with a view to minimising impacts on specific bird colonies, camps and the like. A nursery established at Hawks Nest produces up to 200,000 native plants per year for rehabiliation.

CASE HISTORY 20 - MINERAL SANDS
North Stradbroke Island

The operation (Consolidated Rutile Limited) is based on three sites on North Stradbroke Island, near Dunwich and Amnity, with processing on a 10.4 ha site at Brisbane. The Company generated $120 million in exports (1989/90) and is the largest export earner from the Port of Brisbane. Operations at the Gordon lease (5.3 km^2) started in 1985, and involve 45 employees. Bayside (5.9 km^2) and Amnity leases (2.5 km^2) (since 1978) have 79 employees. Leases are conditional upon rehabilitation to open bushland; Council valuations are $100 per ha.

All sites were originally open bushland, and surrounding areas are urban, open water, proposed National Heritage Listing, industry and recreation. Sand dredging and primary separation takes place at each site, and gravity separation of concentrates (rutile, zircon, ilmenite, monazite) in Brisbane; no chemical processing is involved. To date, at all three sites, 7.5 km^2 have been disturbed and rehabilitated and 2.3 km^2 await rehabilitation. One hundred hectares are prepared, mined and rehabilitated at a time. The mining procedure is the same at all sites. The surface is cleared, topsoil (40 cm) removed and stockpiled (stabilised by seeding and bitumastic compound), a floating dredge draws up the ore, separates the heavy elements. Tailings are contoured to near pre-mining form. Topsoil is respread and rehabilitation started with fast growing cover crops and native seed mixes. Shelter areas are constructed to encourage repopulation by native fauna. Public concerns centre on disturbance to natural communities of plants and animals, but the significance in terms of "uniqueness" is conjectural. No species are known to be threatened by the operation and the Company accommodates requests considered reasonable and economically feasible (environments, haulage hours, plant processing times, etc.). Significant flora are sometimes removed manually and replanted at alternative sites prior to clearing.

Variations in ground and surface water levels are monitored and reported; untoward or unusual variations are investigated and remedial actions taken. At Bayside, mine use lowered water levels in Lake Kounpee, which was corrected. Concerns about water level effects at Amnity have been overcome by monitoring and action when necessary. In 1982 a sand slip occurred at Bayside such that tailings entered Moreton Bay. A major restoration and rehabilitation program was undertaken successfully (creating a recreational area). Noise and dust emissions at the mine sites are now within standard acceptable levels, although complaints are received from time to time. Within the processing facilities, dust and atmospheric emissions from the rotary drier are ongoing problems being addressed with expert assistance.

Expenditure on environmental management is $1.7 million p.a. and involves 10 employees and 9 part-time employees. Continual expansion and improvement of rehabilitation efforts has resulted from innovation and research into soil microbiology and rehabilitation technology. This has involved a variety of contracted expertise. The visual aspects of the Gordon mine, as seen from Moreton Bay and Redland Bay has attracted adverse publicity; these are temporary. The Company has a public education program and guided tours of the operations and rehabilitated areas are conducted.

CASE HISTORY 21 - BAUXITE
Comalco - Weipa

Bauxite has been the major product mined and exported by the Comalco operation at Weipa (NW Cape York) (shipments commenced in 1963). Kaolin, used in the manufacture of paper, has been mined on previous bauxite areas (4-5 hectares annually) since 1985. Mining leases occupy some 2559 km^2, with the current economic ore body in 102 km^2. Processing areas and tailings disposal occupy about 12 km^2. Originally the area had a Mission Station supporting some 151 people. The area was used primarily for hunting and gathering and for some small scale farming. The surrounding lands were originally unused or used for ranging cattle. Based on a recent sale, pastoral land values are about $70-80 per km^2.

Bauxite removal involves strip mining in which 60 cm of top soil is removed in two layers to expose the bauxite (3 m deep). These surface layers are either replaced in correct sequence on adjoining mined areas being rehabilitated (85%) or are stored for later rehabiliation (15%). About 2.8 km^2 are disturbed and regenerated annually. The kaolin operation is restricted to 4-5 hectares per year, with rehabilitation commencing in 1990. The principle processing of bauxite is washing and screening such that the large tailings of washings are benign and are being vegetated and stabilised before decommissioning. The smaller kaolin tailings dams contain salty acidic wastes, and their management requires additional environmental awareness. Total production involves 10 million tonnes of bauxite and 0.1 million tonnes of kaolin annually. The complete operation involves some 1200 staff. Environmental staff is 15 plus <10 seasonal workers.

No EIS process was required when these operations commenced, but Comalco has voluntarily carried out most studies normally required, with the assistance of a range of outside experts, and has acted to minimise impacts when possible. Expenditure on environmental matters has increased in recent years ($1.08 million in 1989; excluding topsoil handling costs).

Woodland areas mined are cleared, which exerts a significant impact. Edge effects on a variety of other habitats occur from time to time. Active management aimed at ensuring the long-term integrity of different habitats in the region occurs. A system of native forest corridors and islands have been preserved and it is Company policy to actively conserve uncommon habitats. No species are threatened with extinction from mining, but some poorly known plants and animals occur in the area, and concerns have been expressed from time to time. Rehabilitation efforts, with native species in the majority of areas, are continually restoring productivity. Genetic diversity is similar to natural sites although changes in individual species abundance occur. The major obvious impact is a topographic one - lowering the ground level by 2-3 m.

A variety of research projects have been undertaken with regard to future land-use (e.g. cashew production) and horticultural crops, pastures, forestry, natural forests, recreation parks, urban and industrial development are all possible. The Company has recognised water quality as a potentially important area of environmental impact in the

future and has instigated research into ground water flows and characteristics within the peninsula. A waste oil recovery program is being implemented.

CASE HISTORY 22 - BAUXITE
Boddington

Situated 15 km S of Boddington, W.A., the mine (managed by Worsley Alumina Pty. Limited) began operations in 1983. It is linked by an overland conveyor to a refinery, 15 km NNW of Collie. Employees total 140 at the mine and 760 at the refinery. The lands were originally private and State lands, mainly forest with various histories and some agricultural land. To date, 440 ha have been cleared and 217 ha rehabilitated: the grounds have yielded 26 million tonnes of bauxite. The refinery is based on a lease of 2500 ha, of which 90 ha are allocated to the plant site and 600-700 to residue areas; 1.0 to 1.3 million tonnes of alumina are produced per year. In collaboration with the Department of Conservation and Land Management (CALM) the Company maintains a large undisturbed buffer zone of forest around the site.

Mining is by open-cut, and overburden is stockpiled in disused sections of pit for rehabilitation. Some forest islands are retained for environmental management. Processing involves caustic digestion, separation of dissolved alumina and recovery of caustic, precipitation and filtering of alumina hydrate and calcination resulting in the final product - aluminium oxide (alumina). A refinery power station provides most requirements of the plant, conveyor and mine.

Environmental concerns at the mine related to the salinity of surface waters being enhanced by clearing and turbidity of mine run-off effecting local aquatic ecosystems. Clearing was minimised and perimeter drains and silt traps have greatly reduced turbidity. At the refinery, filtered bauxite residues are contained in the residue storage area. The containment of sodium compounds and caustic has been possible through an innovative treatment system, allowing final rehabilitation.

Operation of both the mine and the refinery comply with conditions derived through various agreements. Local emission standards for the refinery were based on the comprehensive Victorian EPA standards. A variety of monitoring programs (dust, atmospheric chemicals, vibrations, noise, water quality) are undertaken, and attention to and improvements in environmental impacts (e.g. noise levels, blasting procedures) are being made continually.

Detailed botanical and faunal surveys, including vertebrates and invertebrates, have been undertaken to provide baseline data for environmental management and the monitoring of rehabilitation efforts. Regular biological monitoring programs are now undertaken as part of the rehabiliation process. Through these programs it is proving possible to quantifying the survival and growth rates of rehabilitated trees, and the re-establishment of fauna within rehabilitated areas. It has also been possible to quantify the relationship between faunal re-establishment and plant species with some groups. The overland conveyor area is also subject to biological monitoring. The rehabilitation project has been developed with the assistance of CALM, ultimately to fulfill CALM's land management priorities. The Companies environmental philosophy is one of co-operation whenever possible, and it has produced handbooks and has tours which enhance public education about mining and the environmental management.

CASE HISTORY 23 - BAUXITE
Nabalco - Gove

Situated at Gove Peninsula, NE Arnhem Land, N.T. (Nabalco Pty. Limited), the operation (started 1970) is centred on leases of 200 km^2, in which the bauxite ore body lies

within 60 km^2. The lands were originally utilised for Aboriginal hunting and gathering and after mining, that form of land use will continue. The Nabalco operation (836 employees excluding contractors) has led directly to the development of Nhulunbuy as a modern township within a remote area, the infrastructure and services of which are used by many people.

The mining procedure involves timber clearing (some years in advance to allow understory propogation), and the removal of top layers in two levels, which are redeposited in sequence over mined out areas. Mining occurs in an expanding perimeter with 250 ha of disturbance at any one time. The exposed ore (4 m deep) is broken by large bulldozers and transported (by road) to a crushing station. The ironstone floor is ripped to promote drainage and root preparation and silt traps are constructed to control run off and promote vertical drainage in rehabilitated areas. These areas are broadcasted and scarified prior to the annual wet season to promote growth. At present, 1.3 km^2 are mined and rehabilitated annually.

The crushed ore is transported by conveyor to the processing plant, where 3.7 million tonnes is processed into alumina; 2.8 million tonnes is exported as raw bauxite. Processing involves a hydrometallurgical process using caustic soda, and caustic waste is stored in closed dams with no effluent to the environment. Dust is controlled through watering and noise standards are adhered to. No significant long-term impacts on fauna and flora are known or suspected.

The development of mining methods has aimed towards minimising real impacts and impacts perceived by residents. A buffer zone is placed around creek lines to reduce impacts and a steady increase in dozer size has meant that ripping rather than blasting is now possible. Rehabilitation costs are $4000 per ha (excluding capital costs) and an ecologist, 2 operators and 8 casual employees are involved. The Company gives weekly presentations on Aboriginal culture and local ecology, and has tours of the project highlighting environmental management and rehabilitation procedures.

CASE HISTORY 24 - BAUXITE
Alcoa

Alcoa of Australia Limited operates 3 bauxite mines and alumina refineries in W.A. As part of an integrated mining, refining and smelting complex employing 6,500 people (876 directly in mining). The mines are situated at Jarrahdale (from 1963), Huntly (1972) and Willowdale (1984) in the Darling Ranges S of Perth; refineries are nearer the coast at Kwinana, Pinjarra and Wagerup. The W.A. operations and Victorian smelters generated $2.39 billion in export earnings in 1989, and paid taxes and royalties of $523 million. All mines are located on land that was originally State forests, and environmental care and management, in co-operation with the Department of Conservation and Land Management (CALM) and other authorities, has been a major Company commitment. Some $12 million is spent annually on research, planning, environmental operations and rehabilitation. Some 450 ha are mined and rehabilitated each year. In 26 years of mining, 6130 ha have been cleared and 4406 (72%) rehabilitated. The United Nations Environment Program recently (1990) awarded Alcoa the "Global 500" award for the excellence of its reforestation program; the only mining company in the world to have been recognised in this manner.

Mining involves open cut methods. Topsoil and overburden are removed and conserved for rehabilitation and a topping cemented caprock is blasted so that it and more friable material below can be accessed. Sophisticated blasting technology has been developed to reduce impacts. The ore is trucked to primary crushers and either railed or taken by conveyor to the refinery. Sodium hydroxide is used to dissolve the alumina, and after settling, filtering, precipitation and drying aluminium oxide is produced. Some smelting takes place in Victoria but almost 80% of WA's production is exported.

Residues are disposed of as wet slurry or after separation of red mud and sand residue, by dry disposal (dewatering and solar drying). Impoundments for wet slurry are up to 160 ha and 20 m deep, with leakage of caustic minimised by clay seals and in one case a synthetic membrane. All impoundments (post 1983) have gravity underdrains to aid residue consolidation, improve caustic recovery and reduce the potential for leakage.

Alcoa has a team of 30 environmental employees including biologists, botanists, industrial hygienists, soil scientists, ecologists and environmental scientists. They aim for the highest standards of environmental care and collaborate with a variety of outside specialists. Alcoa assists environmental research undertaken by various organisations and engages in environment awareness programs both within and outside the Company. They have contributed significantly to the knowledge base on "dieback", which effects forest conservation generally. "Dieback" is a major environmental problem in the local forests and all operations are carried out with a view to restricting its spread Rehabilitation has involved steadily improving techniques and diverse communities of native trees are now the normal approach. There are some indications that "dieback" is enhanced by poor drainage, and the removal of the impervious caproack layer may well retard the disease on rehabilitated. areas. A considerable effort has been expended on reducing siltation and erosion on rehabilitated areas. There is an extensive public education program with tours (<25,000 p.a.), educational kits, lectures, publications etc. A recent publications list (Alcoa 1990) contains 136 environmental papers, articles and reports associated with Alcoa since 1975. Liaison with land management authorities has led to substantial areas being set aside for specific conservation purposes, regardless of the orebodies they contain.

CASE HISTORY 25 - IRON ORE
BHP-Utah

The Newman and Koolan Island operations, in the NW of WA, have been operating for 21 and 25 years respectively. They are based on leases of 746 km^2 and 20 km^2 respectively. Current disturbance is about 22 km^2 at Newman and 6 km^2 at Koolon Is. with annual increases of 2.2 km^2 and 0.3 km^2. A railroad between Port Hedland and Mt. Newman, constructed for ore transport, involves about 9 km^2 and facilities at Port Hedland about 1.5 km^2. The original land-use was open-range cattle grazing (Newman) or essentially no commercial land use (Koolan Island); pastoral lease fees for land are less than $1.00/ha/year. Some 30 million tonnes of ore (and 4 million tonnes of beneficiated ore) are recovered from Newman and 4 million tonnes from Koolan Island annually. Most land will eventually be available for pastoral use again. At the termination of mine life, the major pit at Mt. Whaleback may be better suited to a recreational lake.

At all sites, open-cut mining occurs. On-site processing is restricted to crushing and screening of the run of mine product. A benefication plant, using heavy media separation processes, converts some 6 million tonnes of low grade shaly ore per year to 4.5 m.t. of high grade product. At Mt. Newman, most waste is stored in dumps, with topsoil recovered for rehabilitation. One (of 3) orebodies now has waste returned to the pit for rehabilitation. Koolan Island waste is in dumps for which a 3-year rehabilitation program is planned. The company has researched rehabilitation techniques intensively and has developed policies and guidelines for rehabilitation and most other aspects of environmental control and management.

Various EIS's have been made, and the Company has worked within the spirit of new Acts concerning the environment. It has co-operated with, contracted and financially supported environmental researchers from a variety of institutions. The areas being mined are arid, with limited pastoral potential. Main impacts are land form changes, small mountains being converted to pits with revegetated shorelines, or rises levelled. The railway impeded drainage in some low lying areas, which was rectified. The Port

Hedland site is largely dredge-filled low lying areas, and one mangrove creek was filled. Dredging dumps at sea have provided new habitat for marine life and no adverse effects on reefs have occurred. A five year study concluded that iron ore dust was enhancing rather than constraining mangrove "health".

Water for all sites is from underground aquifers, and the Ophthalmia Dam was constructed (Newman) as a supplementary source. Some localised groundwater - salination problems were overcome by natural flushing; general affects on groundwater are under investigation. All operations generate waste waters, which are segregated and treated in line with recognised standards. Diesel power stations are run to high standards to reduce emissions. The implementation of dust control measures has resulted in a steady reduction in levels over the last 13 years. No species of fauna and flora are restricted to the areas being mined, or are endangered by mining. Real concerns at all sites related more to the effects of feral animals - cats, foxes, rabbits, donkeys, goats etc. The Company has undertaken internal environmental audits on all aspects of its operations. Annual expenditure on environmental controls is $0.75 million.

CASE HISTORY 26 - DIAMONDS
Argyle

The Argyle Diamond Mine (managed by Argyle Diamond Mines Pty. Limited) is located 100 km SSW of Kununurra, in the Kimberley region of W.A. The operation involves site disturbance of 13 km^2, with an annual increase of about 1 km^2, within a total lease area of 670 km^2. The leases are located on a pastoral lease, used mainly for open range cattle grazing; pastoral land is valued at some $500-$1500 per km^2. Some 6 million tonnes of diamond bearing ore and 30 million tonnes of waste are removed annually. The mining operation is linked to Argyle Diamond Sales Limited for marketing, which has an overseas sales centre in Antwerp (Belgium), and a representative office in Bombay. A small-scale cutting and polishing facility is located in Perth (6000 carats annually). Total employment is 916.

There are two quite distinct and separate components to the mining operation. The Argyle Lamprite pipe (AKI pipe) is the world's largest diamond producer (30 million carets annually), and accounts for 30% (by volume) of total world production. It is mined by conventional open pit methods, with drilling, blasting, transportation to crushers and waste transport to adjacent dumps. Drainage from waste dumps is retained behind sediment banks to reduce sediment transport into local drainage systems. Processing involves crushing, scrubbing, screening and gravity separation with final diamond recovery using X-ray machines. The second component involves alluvial gravels. The topsoil is removed and stockpiled (for rehabilitation), and an hydraulic excavator, front end loaders and trucks are used to move the ore to the processing plant, which involves screening to 0.8-18 mm particles (finer particles go to tailings dams and coarser particles to mined area for rehabilitation). Heavy media separation using cyclone separators concentrates the diamonds, which are then recovered using X-ray machines. Cleaning involves acids (hydrochloric, hydrofluoric, nitric), which are neutralised with caustic.

Site operations in their entirety are subject to the requirements of 20 separate Acts of Government legislation that reflect environmental issues. The project was subject to a comprehensive Environmental Review and Management Program (ERMP). Baseline studies aimed at describing and understanding the physical and biological environment were commenced in 1980. The ERMP was submitted and approved in 1982-1983. The company sees environmental planning as a cost-saving exercise rather than a burden. The operation is subject to annual reports and triennial detailed reports on environmental aspects. Rehabilitation has started on alluvial deposits and borrow pits, with seeding and fertilisation carried out mechanically. Trials are underway for revegetating both

tailing areas and overburden stockpiles. A nursery concentrating on native plants has been established. Sediment/erosion control has been a high priority. Run-off monitoring, rehabilitation, drainage control and sediment control barriers are some of the strategies employed, although land degradation due to the pastoral industry is increasing siltation in the general area at a very significant rate.

Where possible, local Aboriginal labour is used in the rehabilitation work and to 1990, some $2 million has been spent on community assistance programs for Aboriginal settlements in the area. All contractors and sub-contractors are informed about the environmental protection regulations that govern their activities on-site. Current expenditure (operating and capital) for the Environmental Department, with 4 permanent staff, is $0.64 million per year. A variety of outside consultants are used for specific tasks. There are no known plants or animals totally restricted to the mine site, and environmental impacts have largely been those predicted in the ERMP.

3. THE NATURE OF IMPACTS

The mining operations examined here impact on the environment in a number of ways. They also employ a variety of strategies to control or minimise those impacts. The extent to which specific impacts are "important" at different mines varies from area to area, and depends on many variables, but some generalisations are possible:

Land Surface Impacts. Mining, mineral exploration and mineral processing disturb the land surface wherever they are conducted. The area involved may be a few hectares (underground mining or small pits) or thousands of hectares (large pits and/or strip mining). But it is a definitive impact and is sometimes visually dramatic at the time it occurs (regardless of the extent to which time and rehabilitation efforts may ultimately show the disturbance was temporary).

Fauna and Flora. The land surface vegetation is typically destroyed in the course of mining, which impacts directly on the plants and animals in that area, at that time, regardless of whether the previous land-use was agriculture or wilderness. The majority of mines examined here eventually replace vegetation (through rehabilitation) after mining. This can be a continuing process, in which areas are disturbed and revegetated annually, with a constant, expanding or decreasing area of disturbance in between, or it can be two actions: mining followed by rehabilitation. Regardless, mining involves a period of time in which no vegetation (and hence few animals) exist on some or all of the lands being mined.

Land Forms. Some mining operations (CASE HISTORIES 17 to 20) do not cause significant net losses in the amount of substrate, such

that post-mining land forms may be similar to pre-mining land forms. In other cases significant amounts of the land form are actually utilised, for example iron ore (CASE HISTORY 25), bauxite (CASE HISTORIES 21 to 24) and coal (CASE HISTORIES 10 to 12). What was once a hill or part of a hill may eventually become level ground, a depression or a valley; what was essentially level ground may be lowered, or it may be given topography. A considerable technology has been developed to create and stabilise "new" landforms, taking the aesthetic aspects into consideration.

Rehabilitation Aims. The rehabilitation aims of operations examined here were mainly to re-establish the pre-mining land use. With agricultural lands, this involves improved pastures, which in some cases have doubled previous carrying capacity (CASE HISTORY 12), and/or experimentation with new crops (CASE HISTORIES 21 and 25). With Aboriginal lands used for hunting and gathering, natural revegetation aims to make this land-use possible once again (CASE HISTORY 1, 2 and 23). Forest lands are often returned to forest use (CASE HISTORIES 22 and 24), and reserves, parks and coastal open space areas to genetically diverse communities approximating the original (CASE HISTORIES 17 to 20). Clearly, the options available for rehabilitating agricultural lands are greater and successful rehabilitation is perhaps "easier" to achieve, than is the case for "natural " habitats. The whole concept of reinstating natural ecosystems is patently difficult and has required heavy investment in research and technology (e.g. CASE HISTORY 17).

Atmospheric Emissions. Chemical emissions and dust were significant areas of impact at some and most mines respectively. Their importance at individual mines and processing plants depends on the type of mining and the chemicals being used, and in part on the proximity of the mine or processing operation to people (there is an element of nuisance value). Chemical atmospheric emissions have caused very significant environmental losses historically (CASE HISTORY 14), and their regulation and monitoring is by no means cosmetic.

Noise and vibration. Noise and vibration were significant in terms of on-site occupational health and management requirements, and at some mines their control was also directed at minimising off-site impacts. The blasting of rock and ore can potentially cause serious impacts, through noise, vibration and physical changes in the blasted area. A refined technology is being developed to reduce or minimise these impacts at some sites (CASE HISTORY 24), and in some cases alternatives strategies [e.g. ripping by very large

bulldozers (CASE HISTORY 23)] has been possible. However it remains an area subject to strict regulation, control and monitoring.

Water Impacts. Perhaps the major area of potential environmental impact, common to most mines examined here, was the maintenance of the pre-mining status of ground and surface waters, and in some cases the sea. Surface waters have the potential to cause physical effects such as erosion and siltation, or they can be contaminated (through various routes) and pollute environments both on- and off-sites. The use of water by mines can impact on available water supplies for other purposes, or it can lead to the construction of dams which improve water availability, but which impact on the environment in other ways. Saline ground waters, which occur in many areas (e.g. CASE HISTORIES 7 to 9), can themselves impact on environments when brought to the surface. As a consequence of mining activities, ground water levels can be raised or lowered, and are susceptible to contamination through various routes. Water flow through overburden dumps has the potential to exert profound impacts on both surface and groundwater contamination levels (CASE HISTORY 4). Minimising the impacts of mining on ground and surface waters is perhaps the major challenge being addressed by the mining ventures examined here.

4. ENVIRONMENTAL RESPONSIBILITY

Australians expect the products of mining to be provided to them, or to be sold internationally to maintain and enhance their quality of life. Yet mineral resources are part of the natural environment and cannot be obtained, processed, provided nor sold without impacting on the environment, often in a dramatic fashion. We thus essentially demand mining companies impact on the environment for our benefit, but are becoming increasingly critical and obstructive because they do so!

Other than a vocal minority who appear opposed to any impacts of mining (whose preferred option seems to be no mining at all), community awareness about environmental issues in general should translate into an expectation or desire that mining companies will act "responsibly" in their treatment of, and attitudes towards, the natural environment. It is not directly related to the environmental "significance" of impacts, which is discussed below, but rather to ensuring that the environmental consequences of actions are not simply ignored.

That they were in the past is without doubt - they were in virtually all past activities that Australians undertook. In fact one suspects that few in Government, commercial enterprise or in the public at large, would have been prepared to tolerate large resources being allocated to rehabilitation at the turn of the century, especially in remote, arid areas whose income earning capacity by any other means was low or negligible. It would have been seen as a waste of resources that should have been spent on other "worthwhile" activities. That this attitude prevailed until recent times is well exemplified by Rum Jungle (CASE HISTORY 4). It was mined on behalf of the Federal Government by Territory Enterprises Pty. Limited (TEP), on a costs plus 10% basis. There would have been sound economic reasons for TEP to pursue rehabilitation work at that time (1971) had Government, and thus the people of Australia, realised its significance.

Regardless, some significant contributions to environmental management were made by mining companies long ago. The mining industry at Broken Hill recognised the effects of environmental degradation in the 1930's, and the significant rehabilitation efforts they initiated at that time, correcting impacts of agriculture, feral animals and mining, are responsible for Broken Hill's green belt today (CASE HISTORY 15).

Some of the operations examined for this report were clearly devoting massive resources to rehabilitation and environmental management in general. It is demonstrated in a profound way by the Uranium mining industry. Ranger (CASE HISTORY 1), Nabarlek (CASE HISTORY 2) and Olympic Dam (CASE HISTORY 3) together involve less than 15 km^2 of direct disturbance, in what was otherwise low productive land previously used for rangeland grazing and/or Aboriginal hunting and gathering. Its "value" as grazing land (based on nearby Stations) is less that $15,000 in total. Areas not subject to direct disturbance on these leases, are in fact managed with a high degree of environmental awareness; to the extent that animals and plants outside the lease areas are at a decided disadvantage relative to those inside! The combined annual expenditure of these companies on environmental management is $10-15 million. Kakadu's annual budget (for some 20,000 square kilometres) is around $10 million. The Conservation Commission of the Northern Territory, responsible for conservation on parks and pastoral lands, environmental protection, soil conservation, land conservation, heritage conservation, the herbarium and botanic gardens and bush fire control, within the whole of the Northern Territory (1.3 million square kilometres), has an annual budget of $36 million.

Annual expenditure on environmental management and control in the mines sampled here ranged from $100,000 per year to millions of dollars per year; from 0.2% to 9.0% of annual operating budgets. The environmental budgets of some companies have increased by an order of magnitude within the last few years (CASE HISTORY 14). It is somewhat independent of whether they are recent mines, legally obliged to meet specified standards, or are well established mines that commenced operations before the concept of EIS's, and indeed, before the "nature" of many environmental impacts, was fully realised. The United Nations has acknowledged the environmental contribution that Alcoa has made (CASE HISTORY 23); the only mining company in the world ever to recognised in such a fashion.

If the mining operations examined here showed no environmental responsibility, the "null hypothesis" would receive considerable support. That they provide unequivocal evidence of a high level of responsibility, indicates that the null hypothesis can be rejected for a significant segment of the industry. There may well be miners and mining companies who still consider environmental concerns to be largely cosmetic, with little real benefit to the community. Yet there definitely is a large section of the industry which recognises that the pathway to the future lies in minimising environmental impacts, to the extent that it is economically possible.

It can be argued that environmental responsibility was "forced" upon the mining industry by the conservation movement, which to some extent is true. The conservation movement played a significant role in stimulating environmental awareness in all segments of Australian society. However, this may well be largely irrelevant today. Legislation is the standard tool used for improving all aspects of environmental awareness in all aspects of our life, and the mining industry *is* now subject to an array of environmental legislation, regardless of how that legislation came into being. However, it would be a mistake to consider that mining companies accept environmental responsibilities begrudgingly, nor that compliance with minimum standards is their only environmental objective. It is becoming increasingly obvious within the industry that environmental awareness reduces operating costs. For example the costs of exploration drilling are being greatly reduced by minimising roadworks into sites and the size of drill sites. At the Western Mining Kambalda Nickel Mine, visited opportunistically (no case history), access to drill sites is now by rolling over vegetation rather than by grading roads; it results in rapid rehabilitation and reduces costs.

In reality, the challenge of minimising environmental impacts is becoming a specialised part of mining technology in its own right. Just as the development of mining and processing technology has been pursued in the past, so minimising environmental impacts is becoming a disciplined, specialist field within the industry. There is considerable interchange of ideas between companies, and there are conferences devoted to research results and the spread technology. The field is inherently dynamic, having passed through the stage of *investigating* and *describing* environmental issues, and into the area of management and control. Solutions applied to a rehabilitation problems in 1990, are often considerably advanced over those applied by the same company, to the same problem, 5 years previously (CASE HISTORY 25).

If there is an area of "responsibility" that is unclear, it lies in the extent to which resources should be allocated to "blind" rehabilitation efforts back to original forms of land-use. Mining often involves earthworks at a scale that would be impossible to duplicate for most purposes. Where specific park or forest reserves are not involved, it offers an opportunity to improve drainage (CASE HISTORY 24), improve pastures (CASE HISTORY 12), improve water availability (CASE HISTORY 25), create a variety of different wetland habitats for wildlife (CASE HISTORY 18) and stimulate totally new areas of production (CASE HISTORY 21).

5. THE RELATIVE "IMPORTANCE" OF ENVIRONMENTAL IMPACTS

All activities of all people in the world impact on the environment to some degree. We can thus strive to minimise human impacts, but we cannot stop them. Because the term "environment" covers a multitude of different aspects of the world around us, both natural and unnatural, "environment impacts" mean different things to different people. A major environmental problem to an individual may revolve around a neighbour's tree - it can obstruct views or enhance views, it can harbour wildlife that is appreciated and loved or it can harbour wildlife that are a continual source of annoyance. To a group of people with common interests, a major environmental problem may be something that impacts on their local recreation activities: the rezoning of a recreation park; the re-routing of a road through a recreation area; the loss of a heritage building, etc.

Important as these issues may be to individuals, on a national and global scale they are rather insignificant. The major environmental problems are not aesthetic ones, but rather the steady erosion of

the environment's ability to *sustain life on earth* - plants and animals including humans. As detailed within the Brundtland Report (Brundtland et al. 1987), our lives depend on utilising renewable resources. Yet unsustainable management practices are reducing the productive potential of the lands, waterways and the sea, and they are increasing the rate at which the diverse plants and animals that we use now or may use in the future, are becoming extinct. Impacts on productivity and genetic diversity are the most "important" impacts associated with any human activity.

5.1. PRODUCTIVE POTENTIAL

The role that mining plays in reducing the production potential of lands, waterways and the sea, is a key determinant of the environmental significance of mining impacts. The null hypothesis or negative proposition, would be that mining contributes very significantly to the erosion of Australia's productive potential.

The earth's surfaces (land and water) are areas upon which solar energy is collected and trapped in plants - the first trophic level of all food chains. This trapped energy is the basis of all life and of all renewable resource production through agriculture, forestry, fisheries, national parks and wilderness areas. Some 40% of Australia's export earnings are derived through the solar-energy collecting capacity of our land being allocated to agriculture (Hawke 1989b). Some 60% of Australia's land surface is allocated to grazing.

From this perspective, the fact that Kakadu is a National Park, Arnhem Land (which adjoins it) is an Aboriginal Reserve and adjacent stations are pastoral leases, becomes somewhat insignificant. They are all parcels of Australian land in which the production potential is exploited for different purposes (benefits). Areas allocated to commercial production within the country provide the funds that support those retained for non-commercial purposes.

To adopt a position that the production potential of *all* lands should be allocated to non-productive purposes is totally unrealistic. The continued harvesting of renewable resources, derived ultimately from the sun's energy, is critical to the maintenance of our lives and the quality of life we have come to expect. Reducing our quality of life is not necessarily in the interests of the environment - poverty is linked directly to some of the most unsustainable land-use practices in the world, and is perhaps the single most important environmental problem facing the world today (Brundtland et al. 1987). Whether we like it or not, the productive potential of our

land must be used for our benefit now, and safeguarding its potential to produce in the future is a prime obligation we have for future generations of Australians.

Mining, like agriculture, forestry, wilderness and urban development, is another form of land-use, which effects production to some degree. Mining typically interrupts production of renewable resources on the land's surface, while non-renewable resources are extracted. On-site processing can involve the use of toxic chemicals, and the impacts of both mining and mineral processing can be incurred outside the local areas of disturbance. There can and have been very severe impacts within some local areas. But how significant are the impacts of modern mines relative to impacts being incurred from other activities? To what extent does mining today constrain, in the long-term, our ability to use lands for other purposes? To what extent does mining impact directly on the manner in which we are using the productive potential of our lands for the benefit of all Australians?

These were embodied within the questions on "productive potential", answered by 3 to 8 departments. The results (Appendix II.3) indicate that some human activities were consistently rated as having high significance with regard to impacts on productivity, whereas mining (Table 1), mineral exploration (Table 2), and mineral processing (Table 3) were generally ranked as "low" or "negligible". Impacts of mining on the productivity supporting fisheries operations in N.S.W. were considered high and medium.

Sand and gravel mining in rivers and coastal systems in N.S.W. are considered to be a continuing source of habitat alteration and declining productivity for some species of fish with declining status. The concerns about the status of riverine fish in Australia have been reviewed by Pollard et al (1990). Man-made changes to aquatic habitats have affected the fish fauna in numerous ways, and some 34% of 192 species which spend significant portions of their life cycles in freshwater, appear to have declining status; 6 are classified as endangered. Water conservation, hydro-electric and irrigation schemes, dams, weirs, flood mitigation, desnagging, channelisation, deforestation, grazing, pollutants, overfishing by commercial and recreational fishermen and competition with introduced fish are all listed as significant contributing causes.

Table 1. The "importance" attributed to the role of "mining" as a causal factor reducing the primary production potential of lands, waterways and the sea used for other purposes.

	High	Medium	Low	Negligible
AGRICULTURE				
Horticulture	0	0	1	2
Cereal Crops	0	0	1	3
Other Crops	0	0	1	3
Livestock-Improved Pastures	0	0	1	3
Livestock-Rangelands	0	0	1	2
FORESTRY				
Native Forests	0	0	4	3
Plantations	0	0	3	5
FISHERIES				
Commercial Freshwater	1	0	3	0
Commercial Estuarine	0	1	2	1
Commercial Coastal	0	1	2	2
Commercial Offshore	0	1	0	4
NATIONAL PARKS & RESERVES				
Marine	0	0	1	2
Non-marine	0	1	2	1
TOTAL	**1**	**4**	**22**	**31**

Table 2. The "importance" attributed to the role of "mineral exploration" as a causal factor reducing the primary production potential of lands, waterways and the sea used for other purposes.

	High	Medium	Low	Negligible
AGRICULTURE				
Horticulture	0	0	1	2
Cereal Crops	0	0	1	3
Other Crops	0	0	1	3
Livestock-Improved Pastures	0	0	0	4
Livestock-Rangelands	0	0	1	2
FORESTRY				
Native Forests	0	0	3	4
Plantations	0	0	1	7
FISHERIES				
Commercial Freshwater	0	0	1	3
Commercial Estuarine	0	1	0	3
Commercial Coastal	0	0	1	4
Commercial Offshore	0	0	2	3
NATIONAL PARKS & RESERVES				
Marine	0	0	1	2
Non-marine	0	1	1	2
TOTAL	**0**	**2**	**14**	**42**

Table 3. The "importance" attributed to the role of "mineral processing" as a causal factor reducing the primary production potential of lands, waterways and the sea

	High	Medium	Low	Negligible
AGRICULTURE				
Horticulture	0	0	1	2
Cereal Crops	0	0	0	4
Other Crops	0	0	1	3
Livestock-Improved Pastures	0	0	2	2
Livestock-Rangelands	0	0	1	2
FORESTRY				
Native Forests	0	0	2	5
Plantations	0	0	0	8
FISHERIES				
Commercial Freshwater	0	1	2	1
Commercial Estuarine	0	1	2	1
Commercial Coastal	0	1	1	3
Commercial Offshore	0	0	1	4
NATIONAL PARKS & RESERVES				
Marine	1	0	0	2
Non-marine	0	0	0	4
TOTAL	**0**	**3**	**13**	**41**

These opinions reflect in part the relatively small areas of land typically involved in mining. There is no pathway through which mining could effect the productive potential of *vast* tracts of Australia, because a relatively small segment of the country both contains minerals and is suitable for mining. Whereas 60% of Australia is used for grazing, some 0.02% is used for mining.

Clearly, mining can and has impacted seriously on production potential with localised areas (CASE HISTORIES 4 and 14), but in some cases an historical perspective is important. The impacts at Mt. Lyell are a legacy of land-use practices over the last 107 years; they will not be "rectified" overnight, nor does it seem likely that they will be repeated (CASE HISTORY 16). The extensive impacts of Rum Jungle (CASE HISTORY 4) were eventually contained, and rehabilitation is now well underway. Of importance to this study, it is becoming increasingly difficult for new mining ventures to avoid environmental responsibility - to repeat what happened historically.

Most Australian lands are used for agriculture, which generates large export incomes, but small returns per unit area of land. There are significant environmental costs of agriculture in much of Australia (Appendix II.3) - the steady degrading of our soils and the loss of productive potential. Mining, by its very nature, gives us the option of extracting very significant benefits from small areas of land. Those areas can be altered dramatically, but they are *small*

and the benefits are *large*. By bringing rock to the surface, productivity can be reduced, yet it can also be restored and sometimes improved through rehabilitation efforts. The same suite of plant species may not become established in the same abundances (there may be genetic diversity costs), but in many areas of Australia this is not a significant environmental cost; genetic diversity on most Australian lands is being continually altered for agriculture, urban development etc. In essence, modern mining techniques involve interrupting production on the land surface, while another resource is tapped. With careful planning, that interruption can be used to improve land-use options.

The majority of mines examined here were in fact situated in areas that are being used primarily for agriculture, forestry or Aboriginal hunting and gathering. It was consistently reported that surrounding agricultural lands were subject to a variety of activities that were reducing productive potential on a broad scale (erosion, salination, feral animals), independent of any impacts of mining. These observations are consistent with the answers to the questionnaires (Appendix II.3).

The value of agricultural and forestry lands are related to their income earning capacity through renewable resource production. But no forms of agriculture can compete in any way with the returns per unit area from mining. For example, Ranger (CASE HISTORY 1) has disturbed 400 ha of land that was used previously for hunting, gathering and open range grazing, and it will be rehabilitated such that those activities can occur again (although the area will probably be incorporated into Kakadu); those 400 ha have generated $1.9 billion in export earnings over the last 10 year, of which $300 million has been paid in direct taxation. Some forestry lands in Western Australia are being mined for bauxite and rehabilitated to forestry use. Through this form of land-use each hectare generates $1.6 million and provides 8.9 person years of direct employment (Alcoa 1990; CASE HISTORY 24), and forestry is being pursued commercially on the rehabilitated lands now.

Nabarlek (CASE HISTORY 2) caused disturbance to an area of 110 hectares of land used for hunting and gathering; it created new wealth of $1 billion. Consolidate Rutile Ltd. (CASE HISTORY 20) generated $100 million or more annually from within sand mining leases of 1370 ha on North Stradbroke Island; the local Council values the land at $100 per hectare. AMC Mineral Sands Pty. Limited, whose leases encompass land previously used for agriculture, forestry and bushland reserve ($100-1000 per hectare), extracted $0.8 million, $1.5 million and $3.6 million per

hectare - yet within 5 years the rehabilitated area at Capel (CASE HISTORY 18) was again used for grazing and at Eneabba (CASE HISTORY 17) was being repopulated with native fauna. Gold mines in the Kalgoorlie region (CASE HISTORIES 7-9) are based largely on lands whose productive potential for renewable resources is very low. The Jubilee Mine (CASE HISTORY 7) involves resources valued at $2 million per hectare over the complete lease area. Coal mining in the Hunter Valley region and at Bowen (CASE HISTORIES 10- 12) are based on agricultural land, and the productivity of those lands is in some cases being doubled after rehabilitation (CASE HISTORY 12); coal resources return $1.1 million per hectare.

In any overview, mining has the potential to affect the long-term productivity of the relatively small parcels of land it utilises. It also has a proven capacity to affect the productivity in waterways draining those lands. There is also the potential for those effects to spread to the sea. Yet mining is not a *major* cause of lost productivity within Australia; many mines are surrounded by lands in which land-use practices are reducing productivity continually.

5.2. GENETIC DIVERSITY

The role that mining plays in reducing genetic diversity within Australia, would seem to be a key determinant of the environmental significance of mining impacts generally. The null hypothesis or negative proposition, would be that mining contributes very significantly to the loss of genetic diversity within Australia - that it contributes significantly to the extinction of plants and animals.

Genetic diversity considerations are intimately associated with the productivity issues discussed above, and they are usually discussed together. However there are differences between the two, and I have argued (Webb 1990) that productivity is fundamentally the *more* important. If the productivity of land is maintained, we can opt to use it for natural communities of organisms (wilderness), for selected communities of organisms (e.g. agriculture, plantation forestry) or for no organisms at all (housing, roads, airport etc.). However if the productivity is eroded or lost, those options are reduced.

From a productivity point of view, the loss or replacement of any one species is not of major concern given that some other way of maintaining the energy flow through the system exists. But given that each animal and plant is a unique piece of genetic material, each loss is irreversible. Extinction is not simply a matter of losing

animals that may "look" attractive - it is the loss of a unique structure. Most of our foods and medicines come directly and indirectly from such unique structures in the natural world and the potential uses of most living animals and plants have not even been investigated. With extinction, any potential they may have is automatically lost to humanity. As valid as this argument is, it rests on the *uses* of wild plants and animals by humans for the benefit of humans. How one "justifies" genetic diversity considerations within Australia, where the emphasis is on using products made from non-renewable resources (there is public opposition to utilising wild plants and animals in order to benefit humans), is an interesting issue in its own right!

One to five departments answered questions on genetic diversity, and the answers (Appendix II.1) indicate that whereas some factors (e.g. agriculture, predators) are consistently considered as highly significant with regard to genetic diversity declines, mining (Table 4) was "low" or "negligible" for most groups. Exceptions were plants and fish.

Table 4. The "importance" attributed to the role of "mining" as a causal factor reducing genetic diversity within specific groups of fauna and flora.

	High	Medium	Low	Negligible
FAUNA				
Mammals	0	0	1	4
Birds	0	0	1	4
Reptiles	0	0	1	4
Amphibians	0	0	1	3
Freshwater Fish	0	2	0	3
Marine and Estuarine Fish	0	1	0	4
Terrestrial Invertebrates	0	0	0	2
Aquatic Invertebrates	1	0	0	4
FLORA				
Terrestrial Plants	2	2	2	3
Aquatic Plants	1	0	2	3
TOTAL	4	5	8	34

Nevertheless, no species of plants or fish were known to have become extinct through mining by the 13 agencies which answered the question summarised in Table 5, although it was known or suspected to be have been involved in the declining status of some species.

Table 5. The manner in which departments responded to a question related to the number of species where mining and/or mineral processing were known or suspected to have played a causal role (direct or indirect) in the attainment of the current "status". **E** = extinct, **PE** = possibly extinct, **IDE** = imminent danger of extinction, **SDS** = seriously declining status, **GDS** = general declining status.

	E	PE	IDE	SDS	GDS	TOTAL
Mammals	0	0	0	0	0	0
Birds	0	0	0	1	0	1
Reptiles	0	0	0	0	0	0
Amphibians	0	0	0	0	0	0
Freshwater Fish	0	1	2	5	12	20+
Marine and Estuarine Fish	0	0	0	4	0	4
Terrestrial Invertebrates	0	0	0	0	0	0
Aquatic Invertebrates	0	0	0	0	0	0
Terrestrial Plants	0	0	5	4	1	10
Aquatic Plants	0	0	0	0	1	1
TOTAL	**0**	**1**	**7**	**14**	**14**	**36+**

The results for plants reflect the localised known distributions of some species, and thus their particular susceptibility to status changes from different forms of land use. For example, in Victoria, 4 species considered in imminent danger of extinction are known only from gypsum flats that are also subject to mining. Mineral sands mining often occurs in areas where the vegetation communities are genetically diverse and contain rare species. For example it was reported that at Eneabba (CASE HISTORY 17), surveys revealed some 40 species of plants in the coastal heathlands that were poorly known or considered rare. Some of these proved difficult to propagate (for rehabilitation), and research was commissioned into plants of 3 families, 2 of which were major structural components of the heathland. Tissue culture research was undertaken on one species considered endangered (*Leucopogon obtectus*) in order to achieve successful propagation: the research has broader implications. At Capel (CASE HISTORY 18), species of special interest occur, but they have readily regenerated during rehabilitation.

At Weipa (CASE HISTORY 21) 11 plant species in the region have been classified as "rare or threatened", but none occur in the areas mined, and management of the areas in which they do occur may well enhance their status. Claims that mining may caused the extinction of one species (*Heterachne baileyi*) have now been found

to be incorrect, and the conservation status of this species has been amended (Briggs and Leigh, 1988). Research is now proposed for some poorly known terrestrial vertebrates within stringybark woodland, as this is the main habitat destroyed during bauxite mining in that area.

The results for fish were not apparent in the mines sampled here, perhaps because none of those sampled were directly involved in river or estuary mining. The single species considered possibly extinct as a consequence of mining in South Australia, is thought to reflects the effects of stream pollution. The heavy pollution of some aquatic systems as a consequence of mining in the past (CASE HISTORIES 4 and 14) would clearly have influenced the status of local fish populations, and localised species could have been threatened as a consequence. The concern expressed about birds refers to the decline of hole-nesting species (such as the scarlet-breasted parrot) in the Kalgoorlie region, thought to be related to the historical harvesting of timber, which was used for mining and early desalination plants.

In overview, no species of plants or animals are definitively known to have become extinct because of mining, and thus the null proposition, that mining has been a highly significant cause of lost genetic diversity within Australia can be rejected. Clearly, mining has the potential to contribute to declining status, especially with plants and fish, and environmental management has an ongoing role to play. Nevertheless, most mines, even Ranger (CASE HISTORY 1) which is surrounded by Kakadu National Park, were of the opinion that the total obliteration of *all* fauna and flora within the project area would not result in one species of plant or animal going extinct - that relatively few animals and plants were so restricted in their distribution as to be known only from the mining leases.

Rehabilitation programs undertaken by the mining industry have stimulated research on rare and poorly known species, and mining companies are contributing to baseline studies aimed at clarifying the status of "notable" plants and animals on mining leases (e.g. CASE HISTORIES 17, 21). The comprehensive fauna and flora report from the Worsley Alumina Project (CASE HISTORY 22), is a prime example of detailed ecological research having been undertaken by a mining company (Worsley Alumina Pty. Ltd, 1985).

6. AESTHETIC IMPACTS

Public opposition to mining often seems to reflect genuine concern that significant productivity and genetic diversity costs will be

involved. Yet as stated above, the industry now has the technology to reduce such impacts in many areas - there may well be *no* long-term, biologically significant impacts. So why are they promoted by those opposed to mining? Or perhaps more important, what lies at the root of fundamentalist opposition to mining anyway?

It could be argued that a good deal of opposition to mines and mining companies reflects fundamental opposition to individuals and corporations that are "wealthy" - a "cut the tall poppies" syndrome. Or it could reflect anxiety over mining companies profiting through resources that are a national asset - a failure to be satisfied with or recognise the numerous routes through which the nation gains financially from mining (taxes, royalties etc.); a failure to appreciate that *all* profits do not simply accumulate in the pockets of the "tall poppies".

However, over and above these, most public relate fundamentally to aesthetic impacts. Regardless of whether land surface impacts are biologically insignificant and temporary, they do occur and to many people they are perceived as being "ugly". Dust, noise and vibrations are things that will occur with mining - they are an "unpleasant" change for those subjected to them for the first time. As all lands within Australia are used for something, and are valued by someone, there will always be genuine concerns about the aesthetic impacts of mining. The null hypothesis or proposition would be that mining companies simply ignore those impacts.

Most mines examined here implemented active management of noise, vibration, dust and visual impacts. Within densely populated areas, where the impacts affect more people, levels of control may be improved accordingly (e.g. CASE HISTORY 20). Nevertheless, few major mining operations are initiated today without considering screening from the public view to reduce aesthetic impacts. The early rehabilitation programs at Broken Hill (CASE HISTORY 15) were initiated largely to improve the aesthetic environment by controlling dust and "beautifying" what had become a harsh, arid landscape. Local opinion about the visual impact of a waste dump at Stawell (CASE HISTORY 5) was directly implicated in developing a new strategy for the next dump. The visual impact of the Stawell operation in its entirety was reduced by screening the operation with bunds and native flora plantations. The Kaltails operation (CASE HISTORY 9) is removing historical waste dumps that have been visually unattractive and a constant source of dust for years.

Reducing the impact of blasting has been a technological development pursued by many mines (e.g. CASE HISTORIES 5, 12,

24). Sand mining operations are concentrating more on reinstating the original topography of the dune systems rather than just the vegetation (e.g. CASE HISTORY 19), so that rehabilitated areas eventually merge back into the landscape. At BHP-Utah's iron ore operations (CASE HISTORY 25), company policy establishes guidelines for the construction of burrow-pits and the like, reducing their visual impact.

The whole concept of rehabilitating mining lands, which is embodied in the operating procedures of the majority of mines examined here, is a major contribution towards improving the aesthetic qualities of the environment. In any overview, the proposition that mining companies pay *no* attention to aesthetics can be easily rejected - there are clearly many mining companies that devote tremendous resources to minimising them. Nevertheless, there will always be aesthetic impacts, and one suspects there will always be opposition to mining, especially in populated areas, because of them.

An important aspect of aesthetic impacts is related to the degree to which they can be a fundamental cause for objecting to a development, although not be recognised as such.

The potential exists for *all* of us to respond strongly to proposed changes in our aesthetic environment. There are many individuals with strong philosophical positions along the lines that the nation *needs* mines, agriculture, sewerage treatment plants and airports. But those attitudes can be moderated with all manner of justification should plans be announced to construct them in the bushland reserve "next door"! There may be direct monetary costs involved (real estate values may decline), or there may simply be a desire to retain the surroundings as they were - to prevent change - at the level of an individual's personal perceptions.

However the argument "I do not like the idea of a mine next door" is unlikely to constitute an acceptable reason for preventing a mine from going ahead, especially if only one person or family expresses that view - it is perceived as being somewhat selfish. It carries more weight if a group of people (a resident's committee) oppose the mine, and one individual with strong ideas has often been the catalyst for such committees. But a committee will soon recognise that whether they "like" or "dislike" a development, may also be a fairly weak argument - it smacks of selfishness. Reasons that are rational, logical and objective, that are ideally altruistic, are likely to be far more effective at stopping a development - this creates a "need" for what are essentially secondary reasons.

With publicity, secondary reasons, especially if they involve genetic diversity considerations, stimulate support from a wider segment of the community; from people genuinely concerned about those "reasons". So an even larger confrontation may loom. It may create a political dilemma for local politicians, and if enough support is generated, for federal politicians. It can also result in major scientific and technical debates, raging for months or even years, about the validity of what are essentially secondary reasons.

That aesthetic impacts of mining are important to the community, especially within urban Australia, is undoubtedly the case. The problem lies in how we identify them if indeed they are primary causes of concern, and how we "weight" them if they are. A technology is being developed to quantify "costs" associated with aesthetic impacts (e.g. Pearce et al. 1989), such that appropriate compensation may be possible in the future. But it is not readily available at present.

7. POSITIVE IMPACTS

Most discussions about the environmental impacts of mining centre on *negative* impacts, partly because these are the ones that generate conflict and debate. The proposition that there may be a suite of mining impacts that are environmentally *positive*, is a concept that few in the public seem to consider. Yet it is clearly an important area of investigation if we are to balance the "costs" and "benefits" of mining. This section of the report examines whether the null proposition, that *all* environmental impacts of mining are negative, can be readily supported.

7.1. INDIRECT POSITIVE IMPACTS

The Brundtland Report (Brundtland et al. 1987) clarified in a rather profound manner the direct association that exists between development and the maintenance of environmental values. Although many in the public see development and environmental goals as being totally independent and mutually exclusive, this simplistic and and perhaps superficial view may have little basis in fact. The extent to which any country can pursue environmental goals is linked inextricably to the resources that can be allocated to those pursuits - those resources are generated mostly through development, and in Australia's case, mostly through mining and agriculture.

Australia's ability to pursue environmental conservation programs, to maintain parks and reserves, to survey remote areas, to combat the environmental effects of introduced animals and natural catastrophes, to detect endangered animals, to implement recovery programs for them, to arrest soil erosion, to research fauna and flora generally, etc. are all being compromised today by funding shortages. Even major new environmental initiatives by Government typically involve a small fraction of what is needed - there are simply not the financial resources available to allocate to the environmental problems already identified.

The mining industry is one of the major indirect sources of the funds that are allocated to the environment now, and that will be allocated in the future. In addition to direct taxation on profits, mining companies like all other companies contribute significantly in terms of sales tax, payroll tax etc. If the Government revenues generated from mining were foregone, our ability to pursue environmental goals would be very seriously curtailed. The *positive* impact that the mining industry has on our national economy, is perhaps the single most important contribution, made by any industry group within the country, to the protection and management of environmental values - all mines that generate tax revenue contribute to it.

A special case exists where royalty payments are made to Aboriginal people (e.g. CASE HISTORY 1) or where mining companies undertake a special responsibility to local Aboriginal communities (e.g. CASE HISTORY 26). Ranger Uranium Mine (CASE HISTORY 1) for example, has so far paid some $85 million dollars of royalties to Aboriginals (ERA 1990). These have allowed the traditional owners to purchase businesses in the area, which will continue to provide a cash income after the mine is exhausted. Funds from royalties also assist the Land Councils, who represent the Aboriginal people at local and national forums.

7.2. DIRECT POSITIVE IMPACTS

1. Describing the Environment.

The development of environmental impact assessments for mining operations has led directly to the development of techniques for describing the environment of a given area in terms of its major components: geology, landforms, soils, surface hydrology, vegetation, flora, fauna, sediment yields, climate, erosion, etc.

2. Productivity

Rehabilitation of lands that are mined, especially agricultural lands, can result in the net productivity being reinstated or improved relative to the pre-mining condition (CASE HISTORIES 12 & 18). In the Bowen Basin operations examined here (CASE HISTORIES 10 and 11) there is an expectation that grazing capacity will be improved relative to the pre-mining status. This is clearly a positive impact.

3. Genetic Diversity

The procedures associated with assessing and describing the environments of an area, regardless of whether it is undertaken for a formal EIS or not, result in surveys of plants, animals, habitats and archeological material within areas that until that time have often been ignored. The areas are selected on the basis of geology rather than biology or archeology, and are thus not necessarily areas that would receive detailed study. Mining companies have also contributed significantly to the development of survey techniques for describing and monitoring environments (e.g. Worsley Alumina Pty. Ltd. 1985; Allen 1989). The significance of information on genetic diversity provided to the community, by mining companies, is difficult to assess. However, an indication was obtained through questions answered by 3 to 7 museums and herbariums (Table 6). Recipients were asked to categorise generally what they considered the significance of contributions from mining companies, in specific areas, over the last 25 years.

Table 6. The significance of distributional data obtained through environmental impact studies associated with mining

	FAUNA	FLORA	FOSSILS	ARCHEOLOGY
Insignificant	0	3	3	1
Minor	2	2	0	0
Significant	1	0	1	1
Important	0	2	0	0
Very Important	1	0	0	1

In addition to providing new distributional data, some companies establish and nurture areas of natural bushland (e.g. CASE HISTORY 13) contributing directly to the preservation of genetic diversity.

4. Environmental Management

Rehabilitation is a developing area of expertise within the mining industry (e.g. AMIC 1990c). In addition to rehabilitation, some mining companies have gone to considerable lengths to manage the

environments within lease areas that are not being mined. Ranger (CASE HISTORY 1) and Olympic Dam (CASE HISTORY 3) are two notable examples where the standard of environmental management within a lease area exceeds that outside the lease and that originally undertaken on the lands. The simple reality is that Ranger can afford to devote more resources per hectare of country than is available to the managers of Kakadu. The importance of recognising that mining companies can and do manage habitats in a professional and efficient manner, has significance in the current debate over Coronation Hill and the Conservation Zone. Forty seven square kilometres of country could be managed in a very efficient manner by mining companies, for the benefit of the flora, fauna and habitats concerned. Should that same 47 square kilometres be incorporated into Kakadu, it will simply become a minor extension to a huge area, with few resources per unit area to manage it.

5. Improving land-use options

Mining gives the opportunity for a variety of alternative land-use options to be pursued that would otherwise not be economically possible. For example, the Opthalmia Dam at Newman (CASE HISTORY 25) and the detailed groundwater testing undertaken as part of the mining project, may eventually allow forms of agriculture to be pursued that would otherwise have been impossible.

6. Creating Habitat Diversity

The AMC Wetland Centre at Capel (CASE HISTORY 18), the construction of Opthalmia Dam at Mt. Newman (CASE HISTORY 25), the impoundment of waters at the Norwich Park Mine (CASE HISTORY 10), are all examples of wetland habitats being created. These extend refuges available to wildlife and are a positive contribution to wildlife conservation.

7. Research

The contribution that mining companies have made towards geological research, which is implicitly environmental, often seems to be overlooked by those who express concern for the environment. Yet geology is clearly and fundamentally associated with the physical and chemical structure of soils, landscape features etc. That Coronation Hill contains gold, platinum and palladium together, in the one matrix, is a unique geological find worthy of geological research in its own right.

Most mines examined here were involved in research and monitoring of the environment to some degree, often through using private or Government consultants. Water management (ground and surface) is perhaps one of the most widespread areas of research, and the results have application to other environmental management problems. Comalco (CASE HISTORY 21), for example, has commissioned a research project on ground water flows in the peninsula. Strategies for reducing erosion, reducing dust levels, and reducing the visual impacts of a mine, are all areas that advance our knowledge of a particular environmental problem, and the results have application outside the industry. At the Hellyer Mine (CASE HISTORY 16) research is being undertaken into the use of artificial wetlands for extracting heavy metals from solution.

Rehabilitation research (AMIC 1990c) is perhaps the major area where the impacts of mining have been positive. All mines examined in this study were involved in rehabilitation to some degree. Challenging tasks such as those associated with the rehabilitation of Rum Jungle (CASE HISTORY 4), resulted in a significantly better understanding of the nature of impacts and of the methods needed to contain them; it had application to the planning of other mines. There were cases in which a rehabilitation strategy was developed and has been used without significant change since (e.g. CASE HISTORY 21), whereas rehabilitation efforts at other mines are in a dynamic state of advancement. AMC Mineral Sands Pty. Limited (CASE HISTORIES 17 and 18) have been responsible for some 82 publications dealing with various aspects of minimising the environmental impacts of mining. Alcoa (CASE HISTORY 24) has produced some 136 environmental publications. The rehabilitation techniques applied at Norwich Park Mine (CASE HISTORY 10) are the subject of 11 papers. Environmental technology is clearly being developed within the mining industry.

Mining companies also assist a variety of Universities and other agencies with research, especially in remote areas, and they often fund research projects. In the questions sent to museums and herbariums, we asked for information on the extent of assistance received for their specific activities (Table 7). It is clearly not major, yet mining has contributed significantly to the reference collections of some groups (Appendix II.2, question 21; Appendix II.4, question 9).

Table 7. The significance of funding and facilities made available by mining companies for different areas of research in museums and herbariums.

	FAUNA	FLORA	FOSSILS	ARCHEOLOGY
Insignificant	2	4	4	1
Minor	1	2	1	0
Significant	0	0	1	1
Important	0	1	0	0
Very Important	1	0	0	1

8. People in remote areas.

The development of mining in an area, particularly a remote area, is often associated with the development of communities well distanced from the major cities. Mining company staff can be the most environmentally trained people in such communities, and at Roxby Downs, for example, they have been instrumental in stimulating naturalist clubs and the like (CASE HISTORY 3). However by simply being in a remote area, significant aspects of the natural environment come to the attention of people, and often to the public at large - it is a contribution to our knowledge and understanding of the environment (Table 8).

Table 8. The significance of records and findings within particular disciplines made by people stationed in "mining towns".

	FAUNA	FLORA	FOSSILS	ARCHEOLOGY
Insignificant	2	3	3	0
Minor	1	1	1	3
Significant	1	2	1	0
Important	0	1	0	0
Very Important	0	0	0	0

9. Public Education

Many of the larger mines in Australia (e.g. CASE HISTORIES 1, 3, 22, 23, 24) are open to the general public or to select groups of people (school children etc). In all of those examined here, environmental management was a key issue discussed and explained to visitors. Some mining companies (e.g. CASE HISTORY 3) make staff available for public lectures and to address community groups, increasing environmental awareness in the community. The Western Mining Kambalda Nickel Mine has implemented a program through which much of the seeding and monitoring associated with rehabilitation is done by the local school children and parents, increasing their awareness of "mining and the environment". They are investigating a scheme for involving children from Perth in the exercise, which would have significant educational benefits.

Virtually all mines examined in this study have environmental guidelines, principles and codes of behaviour that apply to staff, permanent employees, casual workers and contractors. An environmental indoctrination course is undertaken at a number of mines, and this typically prevents staff from undertaking activities such as hunting, fishing, camping etc, on lease areas. The existence of such regulations assists on-site environmental management, but perhaps more important, enhances environmental awareness in the community.

8. CONCLUSIONS

On a global scale, it has become increasingly apparent that the environment is not a limitless resource to be used and abused in any way people may desire from time to time. As human populations have increased, the consequences of this approach have been revealed as being disastrous (Brundtland et al. 1987); it has contributed directly to the poverty and low quality of life that is the norm for perhaps most people in the world. Within Australia, environmental degradation has occurred, but the quality of life of the majority of people has not declined greatly as a direct consequence. Our immediate problem seems to be one of maintaining and improving the quality of life to which we are accustomed (as high as that is relative to most people in the world), because reducing the quality of life is unlikely to be desirable or acceptable to the majority of Australians.

It is difficult to see how this could be achieved if we continued to sanction unnecessary environmental degradation - if we continued to reduce the productive potential of our lands, waterways and territorial seas, and lose the future options available to us from preserving the genetic diversity that is our national heritage. Australians are not starving as a consequence of environmental degradation today, but unless old attitudes to the environment changed, as they have done dramatically over the last 30 years and are continuing to do, it could have been an option for the future.

The environmental movement has played a major role in educating the public about the consequences of ignoring the environmental impacts. Yet the fundamental dilemma remains. We need to utilise renewable and non-renewable resources to survive, to maintain our quality of life, and ideally to improve our quality of life. Yet it is impossible to utilise *any* resources without impacting on the environment. Thus although *utilising resources* is the fundamental cause of environmentalist objections to many development projects, the option of *not* utilising resources is unavailable to us. We must

develop strategies for utilising resources in such a way that the negative impacts are minimised, and if possible, that *positive* impacts result. This is at the heart of the concept of sustainable development (Brundtland et al. 1987) and the hope that it offers Australia (Hawke 1989b) and the world.

Public concern about the environment today, and specifically about the environmental impacts of utilizing resources, has brought mining into the public spotlight. However the environmental aspects of mining are but one aspect of the mining industry. The mining industry has played a vital historical role in opening up Australia, in stimulating the development of roads, towns and railways, in supporting the nation economically such that we can achieve the quality of life we have now. It is playing that same role today. It would be a tragedy if these benefits are forgotten by the public, because today we are focussed on environmental costs. Historically, during the settlement of Australia, obtaining resources rather than environmental impacts was at the centre of public interest; mining was stimulated as a consequence. As we know today, mining should not have been evaluated purely from that perspective - neither should it be evaluated *purely* from an environmental perspective today.

Regardless, the mines examined in this study provide unequivocal evidence that a high degree of environmental responsibility and awareness exists within the industry today. There would seem to be more than enough evidence to reject the null proposition that mining companies *per se* show no regard for the environment. A technological capability for identifying and solving environmental problems is well entrenched, and it is advancing continually, through research and development. The environmental impacts of mining do not appear to be particularly significant from a biological point of view, at a national level. The economic gains would seem to far outweigh the environmental costs. Given current legislation and a desire from within the industry to minimise impacts, the public should be able to view new mining operations with confidence that the environmental values of an area will not be ignored.

The extent to which the mines examined here apply to the mining industry as a whole was not examined. Yet it was made clear within the reports and from discussions with some mining company representatives, that while they considered major advances had taken place in many of the larger companies, and that the "spirit" of environmental responsibility was spreading throughout the industry as a whole, there remained a need to encourage and enhance its acceptance generally. There would seem to be three

main tools available for doing this. Firstly, realistic environmental legislation has and will continue to be important, just as it is in all other environmental issues. Secondly, objective public education about sustainable development and the need to combine environmental responsibility with resource use, will gradually lead to a more rational approach to environmental responsibility in all aspects of resource use. Thirdly, and perhaps most important, there is a need to derive incentives for environmental management within the industry such that it can be pursued for profit, and does not become dependent on legislation alone.

Strategies for enhancing care and responsibility for the environment vary greatly from issue to issue and country to country. A somewhat standard approach is to make people "like" a particular animal or aspect of the environment, such that they feel guilty about its neglect in the past, become sensitive about anything threatens to its survival, and become more conscious about looking after it in the present. But if the aim is to promote environmental responsibility in any area, then at a pragmatic level, there are sound reasons for separating the desire to *conserve* from whether one *likes* or *dislikes* what is being conserved. The most powerful incentives to achieve environmental goals in the real world are commercial ones. If it can be made commercially attractive to be environmentally responsible within the mining industry, so environmental responsibility will spread quickly and effectively, regardless of legislation and education. That the reverse is true should be patently obvious. If companies devote significant resources to environmental responsiblity and are *still* denegrated as environmental vandals in public and restricted from mining, it must surely stifle the incentive for change.

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APPENDIX I

Organisations to which complete or selected sections of different questionnaires were sent: 1 = Genetic Diversity; 2 = Fauna; 3 = Productivity; 4 = Flora.

QUESTIONNAIRE No.	1	2	3	4
Western Australian Herbarium, WA	X	.	.	X
Fisheries Div., Dept. of Conservation and Environment, Vic	X	.	X	.
Australian National Parks and Wildlife Service, ACT	.	.	X	.
Australian Institute of Marine Science, Qld	X	.	X	.
Royal Botanic Gardens, NSW	X	.		X
Fisheries Branch, Dept. of Primary Industry, Qld	X	.	X	.
Western Australian Fisheries Dept., WA	X	.	X	.
CSIRO Div. of Forestry and Forest Products, ACT	.	.	X	.
Western Australian Museum, WA	.	X	.	.
Queensland Museum, Qld	.	X	.	.
Environmental Protection Authority, WA	.	.	X	.
Great Barrier Reef Marine Park Authority, Qld	X	.	X	.
Western Australian Dept. of Agriculture, WA	.	.	X	.
CSIRO Div. of Forestry and Forest Products, Qld	.	.	X	.
Div. of Environment, Dept. of Environment and Heritage, Qld	.	.	X	.
CSIRO Div. of Tropical Crops and Pastures, Qld	.	.	X	.
CSIRO Div. of Tropical Crops and Pastures, NT	.	.	X	.
Queensland National Parks and Wildlife Service, Qld	X	.	X	.
CSIRO Div. of Fisheries Research, Qld	X	.	X	.
Dept. of Arts, Sport, Environment, Tourism and Territories, ACT	.	.	X	.
Herbarium, Conservation Commission of the N.T., NT	X	.	.	X
Widlife Research, Conservation Commission of the N.T., NT	X	.	.	.
ACT Parks and Conservation Service, ACT	X	.	X	.
Fisheries, Dept. of Primary Industry and Fisheries, NT	X	.	X	.
Australian Museum, NSW	.	X	.	.
Tasmanian Museum and Art Gallery, Tas	.	X	.	.
Flora Survey Group, Vic	X	.	.	X
CSIRO Div. of Forestry and Forest Products, Vic	.	.	X	.
NSW National Parks and Wildlife Service, NSW	X	.	X	.
CSIRO Div. of Forestry and Forest Products, WA	.	.	X	.
CSIRO Div. of Fisheries Research, Tas	X	.	X	.
Dept. of Sea Fisheries, Dept. of Primary Industry, Tas	X	.	X	.
Australian National Botanic Gardens, ACT	X	.	.	X
Div. of Forests, Dept. of Conservation and Land Management, WA	.	.	X	.
Dept. of Agriculture and Rural Affairs, Vic	.	.	X	.
National Parks, Dept. of Conservation and Land Management, WA	.	.	X	.
Australian National Parks and Wildlife Service, ACT	X	.	X	.
Arid Zone Research, Conservation Commission of the N.T., NT	X	.	.	.
Dept. of Plant Science, Uni. of Tas., Tas	X	.	X	.
State Herbarium of South Australia, SA	X	.	.	X
Fisheries Branch, Dept. of Primary Industry, Qld	X	.	X	.
CSIRO Div. of Forestry and Forest Products, Tas	.	.	X	.
Dept. of Geography, Uni. of Tas., Tas	X	.	X	.
Forests, Dept. of Conservation and Land Management, WA	.	.	X	.
Australian National Herbarium, ACT	X	.	.	X
Forestry Commission of NSW, NSW	.	.	X	.
South Australian National Parks and Wildlife Service, SA	X	.	X	.
South Australian Dept. of Fisheries, SA	X	.	X	.
Land Protection Division, Dept. of Conservation and Environment, Vic	X	.	X	.
Queensland Herbarium, Qld	X	.	.	X

Agriculture Branch, Dept. of Primary Industry, Qld	.	.	X	.
Woods and Forests Dept., SA	.	.	X	.
Land Resources and Environment, Dept. of Agric. and Fisheries, NSW	.	.	X	.
Museum of Victoria, Vic	.	X	.	.
CSIRO Div. of Animal Production, Qld	.	.	X	.
CSIRO Div. of Animal Production, NSW	.	.	.	.
Wildlife, Dept. of Conservation and Environment, Vic	X	.	X	.
State Pollution Control Commission, NSW	.	.	X	.
Tasmania Herbarium, Tas	X	.	.	X
Australian National Parks and Wildlife Service, NT	X	.	X	.
Fisheries Div., Dept. of Agriculture and Fisheries, NSW	X	.	X	.
CSIRO Div. of Fisheries, WA	X	.	X	.
Dept. of Parks, Wildlife and Heritage, Tas	X	.	X	.
Museums and Art Galleries of the N.T., NT	X	X	.	.
CSIRO Div. of Plant Industry, ACT	.	.	X	.
Environment Protection Authority, Vic	.	.	X	.
Forestry Commission of Tasmania, Tas	.	.	X	.
Bureau of Flora and Fauna, ACT	X	.	.	.
National Herbarium of Victoria, Vic	X	.	.	X
Agriculture Branch, Dept. of Agriculture and Fisheries, NSW	.	.	X	.
Queensland Forest Service, Qld	.	.	X	.
Dept. of Agriculture, SA	.	.	X	.
South Australian Museum, SA	.	X	.	.
Environment Unit, Conservation Commission of the N.T., NT	X	.	X	.
Dept. of Environment and Planning, Tas	.	.	X	.
Dept. of Primary Industry, Tas	.	.	X	.
CSIRO Div. of Forestry and Forest Products, SA	.	.	X	.
Pollution Management, Dept. of Environment and Planning, SA	.	.	X	.
Lands and Forests Division, Vic	.	.	X	.
Primary Production, Dept. of Primary Industry and Fisheries, NT	.	.	X	.
Queen Victoria Museum, Tas	.	X	.	.
Bureau of Rural Resources, ACT	X	.	X	.
CSIRO Div. of Wildlife and Ecology, ACT	X	.	X	.
Fishing Industry Research and Development Council, ACT	X	.	X	.
Nature Conservation, Dept. of Conservation and Land Management, WA	X	.	X	.
Wildlife Unit, ACT Parks and Conservation Service, ACT	.	.	X	.

APPENDIX II

The questionnaires used to gather general information from Government Departments and agencies on various aspects of mining and the environment. Specific organisations were asked to address the questions within a particular questionnaire that were relevant to their area of expertise. The questionnaires were posted to the relevant organisations after discussing the survey generally on the telephone.

Returns to 7 November 1990 were:

	QUESTIONNAIRES				
	1	2	3	4	Total
SENT	43	6	64	10	123
RETURNED	18	5	21	7	51
%RETURN	42%	83%	33%	70%	42%

Four organisations declined to fill the questionnaires in and three indicated that the questions were out of their particular area of expertise and recommended other more appropriate contacts. Delays within some departments were lengthy, such that completed questionnaires are still being returned at the time of finalisation.

Appendix II.1 Genetic Diversity (questions 1 to 12)

Appendix II.2 Fauna Distribution and Abundance (questions 1 to 21)

Appendix II.3 Environmental Productivity (questions 1 to 13)

Appendix II.4 Floral Distribution and Abundance (questions 1 to 9).

QUESTIONNAIRE 1

"GENETIC DIVERSITY"

G. Webb Pty. Limited,
Wildlife Research and Management Consultants,
P.O. Box 38151,
WINNELLIE, N.T. 0821

Tel: 089 221355 (w)
089 831675 (ah)
089 470678 (fax)

PREAMBLE

This survey is being funded by AMIC (the Australian Mining Industry Council). The information requested will be used for a general analysis of how researchers and Governmental agencies responsible for preventing extinction and the loss of genetic diversity, are currently viewing the relative importance of different potential, causal factors, including mining and mineral processing. It is one of a number of surveys being supported by AMIC.

While recognising that the causes of extinction and declining status are seldom known precisely, and may vary from area to area and species to species, there appears to be general agreement that some factors are more important than others. If one was placed in the position of having to allocate limited resources to researching the "causes of extinction", such assessments would need to be made on the basis of available data, however equivocal it may be. New information may well change the priorities as they are seen at any given point in time, but if we are to solve the problems associated with extinction and the loss of genetic diversity some commitment to priorities is necessary.

The recent draft "Australian National Strategy for the Conservation of Species and Habitats Threatened with Extinction" (ANPWS 1989) calls for such allocation of resources, and highlights some of important potential causes of extinction.

It could be argued that all forms of land-use and human activity listed below have the POTENTIAL to cause the extinction of species or habitats within specific areas, if allowed to operate unchecked. It is for this reason that many such activities are subject to environmental controls and legislation in one form or another.

Whether these controls are adequate or not is an important public issue, but one that is beyond the scope of the present survey. This survey is aimed at clarifying what we know about the potential causes of the extinctions that have occurred, and situations which have arisen where a species' status is in serious decline. It is about REALIZED changes in status, and the probable causes of them.

As is evident to many people, use of the terms rare, endangered, vulnerable, etc. can lead to a considerable amount of confusion, depending

on the reference source and context. For the purposes of this questionnaire, we have defined exactly what we mean by specific terms. In placing "time limits" on a category (10 years, 50 years) it is on the assumption that general development will proceed in one form or another, but that there will be no unforeseen drastic change that impacts on the environment of a particular species.

1. **Extinct (E).**
A species or habitat that authorities generally agree has become extinct in the last 200 years and its unique genetic material has been lost.

2. **Possibly Extinct (PE).**
A species or habitat that some authorities feel is "probably" extinct but others feel remnant populations may exist in remote or little known areas; the unique genetic material may well have been lost.

3. **Imminent Danger of Extinction (IDE).**
A species or habitat about which authorities generally agree there is sufficient evidence to indicate that it may become extinct within 10 years unless rehabilitation and protection initiatives over and above those currently in existance are implemented.

4. **Serious Declining Status (SDS).**
A species or habitat whose distribution and abundance is known to have declined relative to past reference points and the decline is sufficiently serious that most authorities consider there is a possibility that the species will be in danger of extinction within the next 50 years.

5. **General Declining Status (GDS).**
A species or habitat whose distribution and abundance is known to have declined relative to past reference points but authorities consider there are no reasonable grounds to predict that it will be in danger of extinction within the next 50 years.

There may be instances where a particular animal or plant group does not fall within the area of expertise of the person filling out the form, or the area of responsibility of the Government Department. Please mark the sheet "not applicable" and if possible direct us to the correct Department, with suggested contacts if known.

By necessity, the questions are general and require value judgements. We ask that the potential causes be allocated to whole groups of animals (mammals, birds, reptiles etc). In cases where a specific cause of extinction may be considered "low" with the group as a whole, but "high" with one species, then tick the "low" category as being representative of the group, and write the number of species that are considered "high", with appropriate brief notes.

Contact Officer .....
Title .....
Organisation .....
Address .....
.....
Telephone no. .....
Facsimile no. .....

1. With reference to <u>known</u> cases where MAMMALS have become **extinct**, are **possibly extinct**, are in **imminent danger of extinction**, or are in a **serious declining status** within your State or Territory, how would you categorize the following with regard to their suspected involvement as <u>primary causes</u> of that status.

	High	Medium	Low	Negligible
Amateur collecting				5
Chemical wastes			1	4
Climate changes	2	1	2	
Commercial utilisation			2	3
Dams				5
Dry land farming	3			2
Dry land grazing	4	1		
Fertilisers			2	3
Fire management	3		1	1
Fishing- incidental catch				5
Forestry			2	3
Industral development			2	3
Introduced predators	5			
Introduced competitors	5			
Irrigated farming			2	3
Irrigated grazing			2	3
Natural parasites			1	4
Manufacturing industries			1	4
Mining			1	4
Mining exploration			1	4
Natural extinction			2	3
Noise pollution			1	4
Parasites/Disease	1		3	1
Pest Control		1	1	3
Pesticides			2	3
Petroleum exploration			1	4
Poaching			1	4
Recreational hunting			1	4
Recreational fishing				5
Road/Rail construction			1	4
Salination		1	1	3
Scientific collecting				5
Siltation			1	4
Tourism				5
Urban development			2	3
Urban wastes			1	4
Other.. Drought	1			
Other.. Wetland Drainage			1	
Whaling, Sealing	1			
Disruption of Aboriginal Lifestyles	1			

NOTES .....

(Add additional pages if necessary)

2. With reference to known cases where BIRDS have become **extinct**, are **possibly extinct**, are in **imminent danger of extinction**, or are in a **serious declining status** within your State or Territory, how would you categorize the following with regard to their suspected involvement as primary causes of that status.

	High	Medium	Low	Negligible
Amateur collecting			1	4
Chemical wastes		1		4
Climate changes	2		1	2
Commercial utilisation			1	4
Dams			1	4
Dry land farming	2			3
Dry land grazing	4	1		
Fertilisers			1	4
Fire management	3		1	1
Fishing- incidental catch			1	4
Forestry			1	4
Industral development		1		4
Introduced predators	5			
Introduced competitors	3	1		1
Irrigated farming			1	4
Irrigated grazing			1	4
Natural parasites			2	3
Manufacturing industries			1	4
Mining			1	4
Mining exploration			1	4
Natural extinction			1	4
Noise pollution			1	4
Parasites/Disease	1	1	2	1
Pest Control		1		4
Pesticides		3		2
Petroleum exploration			1	4
Poaching		1	1	3
Recreational hunting		1	1	3
Recreational fishing				5
Road/Rail construction			1	4
Salination	1		1	3
Scientific collecting				5
Siltation			1	4
Tourism			1	4
Urban development			1	4
Urban wastes			1	4
Other....Drought.....	1			
Other...Wetland..Drainage.....		1		

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(Add additional pages if necessary)

3. With reference to known cases where REPTILES have become **extinct**, are **possibly extinct**, are in **imminent danger of extinction**, or are in a **serious declining status** within your State or Territory, how would you categorize the following with regard to their suspected involvement as primary causes of that status.

	High	Medium	Low	Negligible
Amateur collecting			1	4
Chemical wastes			1	4
Climate changes	1	1		3
Commercial utilisation	1			4
Dams				5
Dry land farming	1		1	3
Dry land grazing			1	4
Fertilisers			1	4
Fire management			1	4
Fishing- incidental catch		1		4
Forestry				5
Industral development		1		4
Introduced predators	1	1		3
Introduced competitors			1	4
Irrigated farming		1		4
Irrigated grazing		1		4
Natural parasites			1	4
Manufacturing industries			1	4
Mining			1	4
Mining Exploration			1	4
Natural extinction			1	4
Noise pollution				5
Parasites/Disease			1	4
Pest Control			1	4
Pesticides			1	4
Petroleum Exploration			1	4
Poaching		1		4
Recreational hunting			1	4
Recreational fishing			1	4
Road/Rail construction			1	4
Salination			2	3
Scientific collecting			1	4
Siltation			1	4
Tourism				5
Urban development	1			4
Urban wastes		1		4
Other..Wetland...Drainage			1	
Other.....				

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(Add additional pages if necessary)

4. With reference to known cases where AMPHIBIANS have become **extinct**, are **possibly extinct**, are in **imminent danger of extinction**, or are in a **serious declining status** within your State or Territory, how would you categorize the following with regard to their suspected involvement as primary causes of that status.

	High	Medium	Low	Negligible
Amateur collecting			1	3
Chemical wastes			1	3
Climate changes	1	1		2
Commercial utilisation			1	3
Dams		1		3
Dry land farming	1			3
Dry land grazing	1			3
Fertilisers			1	3
Fire management			1	3
Fishing- incidental catch				4
Forestry			1	3
Industral development				4
Introduced predators		1		3
Introduced competitors				4
Irrigated farming			1	3
Irrigated grazing			1	3
Natural parasites				4
Manufacturing industries				4
Mining			1	3
Mining Exploration			1	3
Natural extinction				4
Noise pollution				4
Parasites/Disease				4
Pest Control			1	3
Pesticides			1	3
Petroleum Exploration			1	3
Poaching			1	3
Recreational hunting				4
Recreational fishing				4
Road/Rail construction				4
Salination	1			3
Scientific collecting			1	3
Siltation		1		3
Tourism			1	3
Urban development			1	3
Urban wastes			1	3
Other.....				
Other.....				

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(Add additional pages if necessary)

5. With reference to <u>known</u> cases where FRESHWATER FISH have become **extinct**, are **possibly extinct**, are in **imminent danger of extinction**, or are in a **serious declining status** within your State or Territory, how would you categorize the following with regard to their suspected involvement as <u>primary causes</u> of that status.

	High	Medium	Low	Negligible
Amateur collecting				5
Chemical wastes			1	4
Climate changes				5
Commercial utilisation			1	4
Dams	2	1		2
Dry land farming	2	1		2
Dry land grazing	1	1		3
Fertilisers	1		1	4
Fire management			1	4
Fishing- incidental catch				5
Forestry			1	4
Industral development			1	3
Introduced predators	2	1		2
Introduced competitors	2			3
Irrigated farming		1	1	3
Irrigated grazing		1	1	3
Natural parasites				5
Manufacturing industries			1	4
Mining		2		3
Mining exploration				5
Natural extinction				5
Noise pollution				5
Parasites/Disease			1	4
Pest Control			1	4
Pesticides		1		4
Petroleum exploration				5
Poaching		1		4
Recreational hunting				5
Recreational fishing	1			4
Road/Rail construction		1	1	3
Salination	1		2	2
Scientific collecting				5
Siltation	1	1		3
Tourism			1	4
Urban development			2	3
Urban wastes			2	3
Other... River regulation	1	1		
Other... Water Abstraction	1			

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(Add additional pages if necessary)

6. With reference to known cases where MARINE OR ESTUARINE FISH have become **extinct**, are **possibly extinct**, are in **imminent danger of extinction**, or are in a **serious declining status** within your State or Territory, how would you categorize the following with regard to their suspected involvement as primary causes of that status.

	High	Medium	Low	Negligible
Amateur collecting			1	4
Chemical wastes		1		4
Climate changes				5
Commercial utilisation	2	1		2
Dams		1		4
Dry land farming		1		4
Dry land grazing				5
Fertilisers		1		4
Fire management				5
Fishing- incidental catch	2	1		2
Forestry				5
Industral development		1		4
Introduced predators			1	4
Introduced competitors	1			4
Irrigated farming		1		4
Irrigated grazing				5
Natural parasites				5
Manufacturing industries			1	4
Mining		1		4
Mining exploration			1	4
Natural extinction				5
Noise pollution				5
Parasites/Disease				5
Pest Control				5
Pesticides		1		4
Petroleum exploration			1	4
Poaching		1	1	3
Recreational hunting				5
Recreational fishing	1	1	1	2
Road/Rail construction				5
Salination				5
Scientific collecting			1	4
Siltation	1			4
Tourism			1	4
Urban development	1			4
Urban wastes	1			4
Other... Beach Netting		1		
Other.....				

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(Add additional pages if necessary)

7. With reference to known cases where TERRESTRIAL INVERTEBRATES have become **extinct**, are possibly **extinct**, are in **imminent danger of extinction**, or are in a **serious declining status** within your State or Territory, how would you categorize the following with regard to their suspected involvement as primary causes of that status.

	High	Medium	Low	Negligible
Amateur collecting			1	1
Chemical wastes			1	1
Climate changes		1		1
Commercial utilisation			1	1
Dams		1		1
Dry land farming	1			1
Dry land grazing	1			1
Fertilisers			1	1
Fire management		1		1
Fishing- incidental catch				2
Forestry			1	1
Industral development		1		1
Introduced predators			1	1
Introduced competitors	1			1
Irrigated farming		1		1
Irrigated grazing		1		1
Natural parasites				2
Manufacturing industries			1	1
Mining				2
Mining exploration				2
Natural extinction			1	1
Noise pollution				2
Parasites/Disease			1	1
Pest Control			1	1
Pesticides			1	1
Petroleum exploration				2
Poaching			1	1
Recreational hunting				2
Recreational fishing				2
Road/Rail construction				2
Salination	1			1
Scientific collecting			1	1
Siltation			1	1
Tourism				2
Urban development		1		1
Urban wastes			1	1
Other.....				
Other.....				

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(Add additional pages if necessary)

8. With reference to known cases where AQUATIC INVERTEBRATES have become **extinct**, are **possibly extinct**, are in **imminent danger of extinction**, or are in a **serious declining status** within your State or Territory, how would you categorize the following with regard to their suspected involvement as primary causes of that status.

	High	Medium	Low	Negligible
Amateur collecting			1	4
Chemical wastes	1			4
Climate changes				5
Commercial utilisation			1	4
Dams		1		4
Dry land farming	1	1		3
Dry land grazing				5
Fertilisers	1	1		3
Fire management				5
Fishing- incidental catch			1	4
Forestry				5
Industral development		1		4
Introduced predators			1	4
Introduced competitors			1	4
Irrigated farming	1			4
Irrigated grazing			1	4
Natural parasites			1	4
Manufacturing industries	1			4
Mining	1			4
Mining exploration	1			4
Natural extinction				5
Noise pollution				5
Parasites/Disease				5
Pest Control				5
Pesticides	1			4
Petroleum exploration			1	4
Poaching		2		3
Recreational hunting				5
Recreational fishing			1	4
Road/Rail construction				5
Salination	2			3
Scientific collecting			1	4
Siltation	1			4
Tourism		1		4
Urban development	1			4
Urban wastes	1			4
Other.....				
Other.....				

NOTES .....

(Add additional pages if necessary)

9. With reference to known cases where TERRESTRIAL PLANTS have become **extinct**, are **possibly extinct**, are in **imminent danger of extinction**, or are in a **serious declining status** within your State or Territory, how would you categorize the following with regard to their suspected involvement as primary causes of that status.

	High	Medium	Low	Negligible
Amateur collecting			4	5
Chemical wastes		1	1	7
Climate changes	1		1	7
Commercial utilisation		4		5
Dams	1	2	1	5
Dry land farming	7	1		1
Dry land grazing	7	1		1
Fertilisers	1	3	1	4
Fire management	1	2	3	3
Forestry	1		4	4
Illegal collecting		1	2	6
Industral development	1	2	2	4
Introduced predators	5	1	1	2
Introduced competitors	4	1	1	3
Irrigated farming		2	4	3
Irrigated grazing		2	4	3
Natural parasites			1	8
Manufacturing industries			2	7
Mining	2	2	2	3
Mining exploration			2	7
Natural extinction	1			8
Noise pollution				9
Parasites/Disease			1	8
Pest Control			2	7
Pesticides			1	8
Petroleum exploration				9
Recreational hunting				9
Recreational fishing				9
Road/Rail construction	1	3	2	3
Salination	3	1		5
Scientific collecting			1	8
Siltation			1	8
Tourism		1	3	5
Urban development	2	2	3	2
Urban wastes			4	5
Other....Herbicides			1	
Other....				

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(Add additional pages if necessary)

10. With reference to <u>known</u> cases where AQUATIC PLANTS have become **extinct**, are **possibly extinct**, are in **imminent danger of extinction**, or are in a **serious declining status** within your State or Territory, how would you categorize the following with regard to their suspected involvement as <u>primary causes</u> of that status.

	High	Medium	Low	Negligible
Amateur collecting	.....	.....	.....	7
Chemical wastes	1	1	1	4
Climate changes	1	.....	1	5
Commercial utilisation	1	.....	.....	6
Dams	1	1	1	4
Dry land farming	.....	.....	1	6
Dry land grazing	.....	.....	1	6
Fertilisers	1	1	1	4
Fire management	.....	.....	.....	7
Forestry	.....	.....	.....	7
Illegal collecting	.....	.....	.....	7
Industral development	1	1	.....	5
Introduced predators	.....	.....	2	5
Introduced competitors	.....	1	1	5
Irrigated farming	.....	1	2	4
Irrigated grazing	.....	1	1	5
Natural parasites	.....	.....	.....	7
Manufacturing industries	1	.....	1	5
Mining	1	.....	2	4
Mining exploration	.....	.....	1	6
Natural extinction	1	.....	.....	6
Noise pollution	.....	.....	.....	7
Parasites/Disease	.....	.....	.....	7
Pest Control	.....	.....	2	5
Pesticides	.....	1	1	5
Petroleum exploration	.....	.....	.....	7
Recreational hunting	.....	.....	.....	7
Recreational fishing	.....	.....	.....	7
Road/Rail construction	.....	.....	2	5
Salination	1	1	.....	5
Scientific collecting	.....	.....	1	6
Siltation	.....	.....	2	5
Tourism	.....	.....	2	5
Urban development	.....	2	1	4
Urban wastes	1	.....	2	4
Other.....	.....	.....	.....	.....
Other.....	.....	.....	.....	.....

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(Add additional pages if necessary)

11. With reference to the primary causes of extinction and declining status in general, of both FAUNA and FLORA within your State or Territory, how would you categorize the following with regard to their suspected involvement.

	High	Medium	Low	Negligible
Amateur collecting	.....	.....	2	2
Chemical wastes	.....	.....	1	3
Climate changes	2	1	1	.....
Commercial utilisation	.....	2	1	1
Dams	.....	1	.....	3
Dry land farming	4	.....	.....	.....
Dry land grazing	3	.....	.....	1
Fertilisers	.....	1	1	2
Fire management	2	.....	1	1
Fishing- incidental catch	.....	.....	2	2
Forestry	.....	.....	2	2
Illegal collecting	.....	.....	2	2
Industral development	.....	.....	2	2
Introduced predators	4	.....	.....	.....
Introduced competitors	4	.....	.....	.....
Irrigated farming	.....	1	1	2
Irrigated grazing	.....	1	1	2
Natural parasites	.....	.....	.....	4
Manufacturing industries	.....	.....	1	3
Mining	.....	.....	1	3
Mining exploration	.....	.....	1	3
Natural extinction	.....	.....	1	3
Noise pollution	.....	.....	1	3
Parasites/Disease	1	.....	3	.....
Pest Control	.....	1	1	2
Pesticides	.....	.....	2	2
Petroleum exploration	.....	.....	1	3
Poaching	.....	.....	2	2
Recreational hunting	.....	.....	1	3
Recreational fishing	.....	.....	.....	4
Road/Rail construction	.....	.....	1	3
Salination	1	1	.....	2
Scientific collecting	.....	.....	.....	4
Siltation	.....	.....	2	2
Tourism	.....	.....	.....	4
Urban development	.....	1	1	2
Urban wastes	.....	.....	1	3
Other... wetland Drainage	.....	.....	1	.....
Other... Whaling, Sealing ..... Disruption of Maorig. Lifestyles	1	1	.....	.....

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(Add additional pages if necessary)

12. Note the number of species if any, within each group, where mining and/or mineral processing are known or suspected to have played a causal role (direct or indirect) in the attainment of that status within your State or Territory. The status categories are those listed in the preamble. For example, a "2" under SDS for mammals would indicate that there are 2 species of mammals considered to be in "serious declining status" where there is sufficient evidence to indicate that mining and/or mineral processing was involved in causing that decline.

	E	PE	IDE	SDS	GDS
Mammals	.....	.....	.....	.....	.....
Birds	.....	.....	.....	1	.....
Reptiles	.....	.....	.....	.....	.....
Amphibians	.....	.....	.....	.....	.....
Freshwater Fish	.....	.....	.....	.....	.....
Marine and Estuarine Fish	.....	.....	.....	.....	.....
Terrestrial Invertebrates	.....	.....	.....	.....	.....
Aquatic Invertebrates	.....	.....	.....	.....	.....
Terrestrial Plants	.....	.....	.....	.....	.....
Aquatic Plants	.....	.....	.....	.....	.....

NOTES (briefly describe the basis for any entries) .....

(Add additional pages if necessary)

QUESTIONNAIRE 2

"FAUNAL DISTRIBUTION & ABUNDANCE"

G. Webb Pty. Limited,
Wildlife Research and Management Consultants,
P.O. Box 38151,
WINNELLIE, N.T. 0821

Tel: 089 221355 (w)
089 831675 (ah)
089 470678 (fax)

PREAMBLE

This survey is one of a number being conducted by AMIC (the Australian Mining Industry Council), in order to clarify the impacts of mining (negative and positive) on Australia's fauna and flora.

The information requested in this particular survey will be used for a general analysis of how researchers and Governmental agencies responsible for cataloguing and describing Australia's fauna, past and present, currently view contributions the mining industry may have made from time to time.

By necessity, the questions are general and require a degree of value judgement. There may be instances where a particular question does not fall within the area of expertise of the Institution. Please mark the question "not applicable" and if possible, direct us to the correct Institution.

We are greatly interested in your professional views and comments upon issues relevant to this questionnaire. If you would like to discuss any aspect of the questionnaire, please contact Charlie Manolis (089.221355).

Contact Officer .....
Title .....
Organisation .....
Address .....
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.....
Telephone no. .....
Facsimile no. .....

1. Over the last 25 years, environmental impact assessments have become a routine activity associated with mining exploration, mining, and mineral processing. One possible consequence of EIS's is that information on the distribution and abundance of extant fauna is obtained from areas that are chosen on the basis of geological rather than biological criteria. How would you describe the significance of FAUNAL DISTRIBUTIONAL DATA obtained through EIS's associated with the mining industry?

Insignificant	.....
Minor	....2.....
Significant	....1.....
Important	.....
Very Important	....1.....

NOTES (explain as considered necessary)

(Add additional pages if necessary)

2. Over the last 25 years, environmental impact assessments have become a routine activity associated with mining exploration, mining, and mineral processing. A consequence of this is that funds and facilities have been made available to biologists from a variety of organisations, so that they can visit and the examine the FAUNA in target areas which are often remote. How would you describe the significance of this ADDITIONAL SOURCE OF SUPPORT for environmental research with regard to your organisation?

Insignificant	....2.....
Minor	....1.....
Significant	.....
Important	.....
Very Important	....1.....

NOTES (explain as considered necessary)

(Add additional pages if necessary)

3. Townships in remote areas, established for agricultural activities, mining, etc., serve as a nucleus for obtaining information from what would otherwise be a little-known area biologically. The distribution of musuem records often reflects the concentrations of people. How would you describe the significance to your Institution of FAUNAL RECORDS obtained from what are essentially "mining towns" (towns that would probably not exist unless there was a central mining operation) over the last 25 years?

Insignificant	2
Minor	1
Significant	1
Important	
Very Important	

NOTES (explain as considered necessary)

(Add additional pages if necessary)

4. Over the last 25 years, environmental impact assessments have become a routine activity associated with mining exploration, mining, and mineral processing. One possible consequence of EIS's is that information on the distribution and abundance of fossil fauna is obtained from areas that are chosen on the basis of geological rather than biological criteria. How would you describe the significance of FOSSIL DISTRIBUTIONAL DATA obtained through EIS's associated with the mining industry?

Insignificant	....2.....
Minor	.....
Significant	....1.....
Important	.....
Very Important	.....

NOTES (explain as considered necessary)

(Add additional pages if necessary)

5. Over the last 25 years, environmental impact assessments have become a routine activity associated with mining exploration, mining, and mineral processing. A consequence of this is that funds and facilities have been made available to biologists from a variety of organisations so that they can visit and the examine the FOSSILS in target areas, which are often remote. How would you describe the significance of this ADDITIONAL SOURCE OF SUPPORT for environmental research with regard to your organisation?

Insignificant	3
Minor	
Significant	
Important	1
Very Important	

NOTES (explain as considered necessary)

(Add additional pages if necessary)

6. Townships in remote areas, established for agricultural activities, mining, etc., serve as a nucleus for obtaining information from what would otherwise be a little-known area biologically. The distribution of musuem records often reflects the concentrations of people. How would you describe the significance to your Institution of FOSSIL RECORDS obtained from what are essentially "mining towns" (towns that would probably not exist unless there was a central mining operation) over the last 25 years?

Insignificant	2
Minor	1
Significant	1
Important	
Very Important	

NOTES (explain as considered necessary)

(Add additional pages if necessary)

7. Over the last 25 years, environmental impact assessments have become a routine activity associated with mining exploration, mining, and mineral processing. One possible consequence ofthis is that information on archaeology is obtained from areas that are chosen on the basis of geological rather than biological criteria. How would you describe the significance of ARCHAEOLOGICAL FINDS obtained through EIS's associated with the mining industry?

Insignificant	....1....
Minor	.....
Significant	....1....
Important	.....
Very Important	....1....

NOTES (explain as considered necessary)

(Add additional pages if necessary)

8. Over the last 25 years, environmental impact assessments have become a routine activity associated with mining exploration, mining, and mineral processing. A consequence of this is that funds and facilities have been made available to archaeologists from a variety of organisations so that they can visit and the examine the ARCHAEOLOGICAL FINDS in target areas which are often remote. How would you describe the significance of this ADDITIONAL SOURCE OF SUPPORT for environmental research with regard to your organisation?

Insignificant	....1.....
Minor	.....
Significant	....1.....
Important	.....
Very Important	....1.....

NOTES (explain as considered necessary)

(Add additional pages if necessary)

9. Townships in remote areas, established for agricultural activities, mining, etc., serve as a nucleus for obtaining information from what would otherwise be a little-known area biologically. The distribution of musuem records often reflects the concentrations of people. How would you describe the significance to your Institution of ARCHAEOLOGICAL RECORDS obtained from what are essentially "mining towns" (towns that would probably not exist unless there was a central mining operation) over the last 25 years?

Insignificant	.....
Minor	....3.....
Significant	.....
Important	.....
Very Important	.....

NOTES (explain as considered necessary)

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10. With reference to acquisitions of MAMMALS in your Institution, over the last 25 years, how would you rate the significance, in terms of new information (distribution records, new species, etc.) of specimens acquired directly or indirectly from the following sources. These include consultancies and research projects initiated by those sources, and infrastructural developments associated with those sources. (This analysis excludes internally initiated and funded collecting trips by your own Institution). (See also Question 21):

	High	Medium	Low	Negligible
Amateur Collectors	1	1	2	
Farmers & Graziers			2	2
Fisheries Activities			3	1
Forestry Activities			2	2
Mining Activities	1		1	2
University Researchers		2	2	
Wildlife Departments	3	1		
Other... Museums		1		
Other... CSIRO		1		

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(Add additional pages if necessary)

11. With reference to acquisitions of BIRDS in your Institution, over the last 25 years, how would you rate the significance, in terms of new information (distribution records, new species, etc.) of specimens acquired directly or indirectly from the following sources. These include consultancies and research projects initiated by those sources, and infrastructural developments associated with those sources. (This analysis excludes internally initiated and funded collecting trips by your own Institution). (See also Question 21):

	High	Medium	Low	Negligible
Amateur Collectors	2		1	
Farmers & Graziers		1		2
Fisheries Activities			1	2
Forestry Activities		1		2
Mining Activities			1	2
University Researchers				3
Wildlife Departments	1	1		1
Other.....				
Other.....				

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(Add additional pages if necessary)

12. With reference to acquisitions of REPTILES AND AMPHIBIANS in your Institution, over the last 25 years, how would you rate the significance, in terms of new information (distribution records, new species, etc.) of specimens acquired directly or indirectly from the following sources. These include consultancies and research projects initiated by those sources, and infrastructural developments associated with those sources. (This analysis excludes internally initiated and funded collecting trips by your own Institution). (See also Question 21):

	High	Medium	Low	Negligible
Amateur Collectors	2	1	1	
Farmers & Graziers		1	1	2
Fisheries Activities			1	3
Forestry Activities			1	3
Mining Activities	1		1	2
University Researchers	3	1		
Wildlife Departments	3	1		
Other.....				
Other.....				

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(Add additional pages if necessary)

13. With reference to acquisitions of TERRESTRIAL VERTEBRATES in your Institution, over the last 25 years, how would you rate the significance, in terms of new information (distribution records, new species, etc.) of specimens acquired directly or indirectly from the following sources. These include consultancies and research projects initiated by those sources, and infrastructural developments associated with those sources. (This analysis excludes internally initiated and funded collecting trips by your own Institution). (See also Question 21):

	High	Medium	Low	Negligible
Amateur Collectors	1	2	1	
Farmers & Graziers		1	1	2
Fisheries Activities			1	2
Forestry Activities			1	3
Mining Activities	1		1	2
University Researchers	2		2	
Wildlife Departments	3	1		
Other..... Museums	1			
Other.....				

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(Add additional pages if necessary)

14. With reference to acquisitions of FRESHWATER FISH in your Institution, over the last 25 years, how would you rate the significance, in terms of new information (distribution records, new species, etc.) of specimens acquired directly or indirectly from the following sources. These include consultancies and research projects initiated by those sources, and infrastructural developments associated with those sources. (This analysis excludes internally initiated and funded collecting trips by your own Institution). (See also Question 21):

	High	Medium	Low	Negligible
Amateur Collectors	1		2	
Farmers & Graziers			1	2
Fisheries Activities	1	1	1	
Forestry Activities			1	2
Mining Activities	1	1		1
University Researchers		2	1	
Wildlife Departments	1	2		
Other...Museums		1		
Other...CSIRO			1	

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(Add additional pages if necessary)

15.With reference to acquisitions of MARINE AND ESTUARINE FISH in your Institution, over the last 25 years, how would you rate the significance, in terms of new information (distribution records, new species, etc.) of specimens acquired directly or indirectly from the following sources. These include consultancies and research projects initiated by those sources, and infrastructural developments associated with those sources. (This analysis excludes internally initiated and funded collecting trips by your own Institution). (See also Question 21):

	High	Medium	Low	Negligible
Amateur Collectors			3	
Farmers & Graziers				3
Fisheries Activities	3			
Forestry Activities				3
Mining Activities			1	2
University Researchers		2	1	
Wildlife Departments	1	1	1	
Other...Museums	1			
Other...CSIRO		1		

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(Add additional pages if necessary)

16. With reference to acquisitions of TERRESTRIAL INVERTEBRATES in your Institution, over the last 25 years, how would you rate the significance, in terms of new information (distribution records, new species, etc.) of specimens acquired directly or indirectly from the following sources. These include consultancies and research projects initiated by those sources, and infrastructural developments associated with those sources. (This analysis excludes internally initiated and funded collecting trips by your own Institution). (See also Question 21):

	High	Medium	Low	Negligible
Amateur Collectors	.....	2	1	1
Farmers & Graziers	.....	.....	1	3
Fisheries Activities	1	.....	.....	3
Forestry Activities	.....	2	.....	2
Mining Activities	.....	1	.....	3
University Researchers	1	2	.....	1
Wildlife Departments	1	.....	2	1
Other. Museums	1	.....	.....	.....
Other. Natural History Organisations	.....	1	.....	.....

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(Add additional pages if necessary)

17. With reference to acquisitions of FRESHWATER INVERTEBRATES in your Institution, over the last 25 years, how would you rate the significance, in terms of new information (distribution records, new species, etc.) of specimens acquired directly or indirectly from the following sources. These include consultancies and research projects initiated by those sources, and infrastructural developments associated with those sources. (This analysis excludes internally initiated and funded collecting trips by your own Institution). (See also Question 21):

	High	Medium	Low	Negligible
Amateur Collectors	.....	1	1	1
Farmers & Graziers	.....	.....	1	2
Fisheries Activities	.....	.....	2	1
Forestry Activities	.....	.....	.....	3
Mining Activities	1	.....	.....	2
University Researchers	.....	2	.....	1
Wildlife Departments	.....	.....	1	2
Other.....	.....	.....	.....	.....
Other.....	.....	.....	.....	.....

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(Add additional pages if necessary)

18. With reference to acquisitions of MARINE INVERTEBRATES in your Institution, over the last 25 years, how would you rate the significance, in terms of new information (distribution records, new species, etc.) of specimens acquired directly or indirectly from the following sources. These include consultancies and research projects initiated by those sources, and infrastructural developments associated with those sources. (This analysis excludes internally initiated and funded collecting trips by your own Institution). (See also Question 21):

	High	Medium	Low	Negligible
Amateur Collectors	.....	2	.....	2
Farmers & Graziers	.....	.....	.....	4
Fisheries Activities	2	1	1	.....
Forestry Activities	.....	.....	1	3
Mining Activities	.....	.....	.....	4
University Researchers	2	1	.....	1
Wildlife Departments	.....	2	1	1
Other.....	.....	.....	.....	.....
Other.....	.....	.....	.....	.....

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(Add additional pages if necessary)

19. With reference to acquisitions of FOSSIL MATERIAL in your Institution, over the last 25 years, how would you rate the significance, in terms of new information (distribution records, new species, etc.) of specimens acquired directly or indirectly from the following sources. These include consultancies and research projects initiated by those sources, and infrastructural developments associated with those sources. (This analysis excludes internally initiated and funded collecting trips by your own Institution). (See also Question 21):

	High	Medium	Low	Negligible
Amateur Collectors	.....	2	1	1
Farmers & Graziers	1	.....	2	1
Fisheries Activities	.....	.....	.....	3
Forestry Activities	.....	.....	.....	3
Mining Activities	1	2	.....	1
University Researchers	.....	3	.....	1
Wildlife Departments	.....	.....	2	2
Other.....	.....	.....	.....	.....
Other.....	.....	.....	.....	.....

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(Add additional pages if necessary)

20. With reference to acquisitions of ARCHAEOLOGICAL MATERIAL in your Institution, over the last 25 years, how would you rate the significance, in terms of new information (distribution records, new species, etc.) of specimens acquired directly or indirectly from the following sources. These include consultancies and research projects initiated by those sources, and infrastructural developments associated with those sources. (This analysis excludes internally initiated and funded collecting trips by your own Institution). (See also Question 21):

	High	Medium	Low	Negligible
Amateur Collectors	1			1
Farmers & Graziers			1	1
Fisheries Activities				2
Forestry Activities				2
Mining Activities	1		1	
University Researchers	1	1		
Wildlife Departments			1	1
Other.....				
Other.....				

NOTES .....

(Add additional pages if necessary)

21. With reference to acquisitions of specimens in your Institution, over the last 25 years, what percentage [known precisely (K) or a guesstimate (G)] would have been acquired, directly or indirectly, from mining activities (including consultancies, infrastructure, etc.):

%	Mammals	Birds	Reptiles	Amphibians	TERREST. VERT.
0-1	G	KK	G		GG
2 5			GG	G	G
6-10	G			G	
11-20					
>20					

%	Freshwater Fish	Marine Fish	Terrest. Invert.	Freshwater Invert.	Marine Invert.
0-1	G	GGG	GGG	GG	K.GGG
2-5	GG			G	
6-10					
11-20					
>20					

NOTES .....

(Add additional pages if necessary)

QUESTIONNAIRE 3

"ENVIRONMENTAL PRODUCTIVITY"

G. Webb Pty. Limited,
Wildlife Research and Management Consultants,
P.O. Box 38151,
WINNELLIE, N.T. 0821

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089 831675 (ah)
089 470678 (fax)

PREAMBLE

This survey is one of a number being conducted by AMIC (the Australian Mining Industry Council), in order to clarify the impacts of mining (negative and positive) on the conservation of Australia's fauna, flora and environments.

The information requested in this particular survey will be used for a general analysis of how researchers and Governmental agencies responsible for renewable resource management and the prevention of environmental degradation, currently view the relative importance of existing causes (including mining) of declining primary productivity.

The exploitation of renewable resources (agricultural products, native flora and fauna, fish, forests, etc.) on a sustainable basis, is fundamentally dependent on the environment maintaining or increasing its potential for "useful" primary production. This process involves the "trapping" of the sun's energy and its conversion to plant products (the first trophic level in all ecosystems) that can be used by people, stock and wildlife. For example, insect pests may reduce the production of an agricultural crop, but not the potential of the land to produce a crop - desertification, on the other hand, reduces the productive potential and closes off options for exploiting renewable resources in the future.

Actions which degrade irreversibly the primary productive potential of land, waterways and territorial seas, or which require extensive rehabilitation to restore productive potential, have profound ramifications for the future, especially with regard to sustainable development.

Clearly, the preservation of genetic diversity (the subject of a separate questionnaire) is an issue closely allied to the preservation of productive potential. However, there are fundamental differences. For example, the productive potential of land may be allocated to either agricultural production or wildlife production (genetic diversity considerations), but if the potential of that land to engage in useful primary production is eroded or lost, options are limited - it may be of use for neither.

Although it is recognised that activities such as mining may have significant effects on the local environments in which they are based, the aim of this questionnaire is to obtain an holistic view of the major causes of environmental degradation of Australian environments as a whole, and to

place mining in that perspective. Therefore, the questions in this survey are general, and may require a degree of value judgment. There may be instances where a particular question does not fall within the area of expertise of the Institution. If so, please mark the question "not applicable" and if possible, direct us to the correct Institution.

QUESTIONS

Contact Officer .....
Title .....
Organisation .....
Address .....
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Telephone no. .....
Facsimile no. .....

In "Our Country Our Future - Statement on the Environment" issued by the Prime Minister (July 1989), it was pointed out (p15) that Australia has an unusual economic status within the world. It is "...a developed economy...[with] an export base more akin to one found in the developing world".

Australia earns its "international income" largely through the export of raw materials, derived from both renewable and non-renewable resources. This income is important to the maintenance of our quality of life and our ability to devote economic resources to environmental problems. Agriculture, forestry and fisheries account for the majority of export earnings from renewable resources [at least 40% of total export earnings (Hawke 1989)], and are the areas where long-term maintenance of productive potential may well be critical to Australia's economic well-being.

In addition, some 5.5% of Australia's land mass is included within National Parks under State and Teritory control (Hawke 1989), where maintenance of productive potential is "important", but is difficult to estimate in economic terms. The questions below attempt to highlight the relative importance of various factors that are known or suspected to be reducing productive potential (as against production itself) in agriculture, forestry, fisheries and on parks and reserves.

We are greatly interested in your professional views and comments upon issues relevant to this questionnaire. If you would like to discuss any aspect of the questionnaire, please contact Charlie Manolis (089.221355).

AGRICULTURE

1. On the basis of current knowledge and experience, classify the following with regard to the role they have played, directly or indirectly, in reducing the productive potential of lands used for HORTICULTURE (fruit, vegetables, flowers, etc.) in your State or Territory.

	High	Medium	Low	Negligible
Air pollution	.....	.....	2	1
Climate changes	.....	.....	.....	3
Desertification	.....	.....	1	2
Excessive clearing	.....	2	1	.....
Industrial activities	1	.....	1	1
Industrial wastes	.....	.....	2	1
Fertiliser residual effects	.....	.....	3	.....
Fire management effects	.....	.....	1	2
Forestry effects	.....	.....	1	2
Mining effects	.....	.....	1	2
Mineral exploration effects	.....	.....	1	2
Mineral processing effects	.....	.....	1	2
National parks/reserves	.....	.....	.....	3
Overgrazing - stock	.....	.....	1	2
Overgrazing - feral	.....	.....	1	2
Overproduction	.....	1	.....	2
Pesticide residual effects	.....	.....	2	1
Public attitudes to land-use	1	1	.....	1
Recreation activities	.....	1	1	1
Sewage contamination	.....	.....	.....	3
Soil degradation	.....	2	1	.....
Soil erosion	.....	3	.....	.....
Soil acidification	.....	1	.....	2
Soil salinisation	.....	2	.....	1
Urban development	1	1	1	.....
Urban wastes	.....	.....	1	2
Water quality	.....	1	1	1
Water quantity	.....	.....	2	1
Other.....	.....	.....	.....	.....
Other.....	.....	.....	.....	.....

NOTES (explain as considered necessary)

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2. On the basis of current knowledge and experience, classify the following with regard to the role they have played, directly or indirectly, in reducing the productive potential of lands used for CEREAL CROP (wheat, maize, sorghum, etc.) production in your State or Territory.

	High	Medium	Low	Negligible
Air pollution	.....	.....	.....	4
Climate changes	.....	.....	1	3
Desertification	.....	.....	1	3
Excessive clearing	1	1	2	.....
Industrial activities	.....	.....	1	3
Industrial wastes	.....	.....	.....	4
Fertiliser residual effects	.....	.....	3	1
Fire management effects	.....	1	3	.....
Forestry effects	.....	.....	1	3
Mining effects	.....	.....	1	3
Mineral exploration effects	.....	.....	1	3
Mineral processing effects	.....	.....	.....	4
National parks/reserves	.....	.....	.....	4
Overgrazing - stock	1	1	2	.....
Overgrazing - feral	.....	1	3	.....
Overproduction	1	1	.....	2
Pesticide residual effects	.....	.....	3	1
Public attitudes to land-use	1	.....	.....	3
Recreation activities	.....	.....	.....	4
Sewage contamination	.....	.....	.....	4
Soil degradation	1	1	1	1
Soil erosion	.....	2	2	.....
Soil acidification	.....	1	2	1
Soil salinisation	1	1	1	1
Urban development	.....	.....	2	2
Urban wastes	.....	.....	.....	4
Water quality	.....	.....	1	3
Water quantity	.....	1	2	1
Other.....	.....	.....	.....	.....
Other.....	.....	.....	.....	.....

NOTES (explain as considered necessary)

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3. On the basis of current knowledge and experience, classify the following with regard to the role they have played, directly or indirectly, in reducing the productive potential of lands used for OTHER CROP (sugar, cotton, oilseeds, etc.) production in your State or Territory.

	High	Medium	Low	Negligible
Air pollution	.....	.....	.....	4
Climate changes	.....	.....	.....	4
Desertification	.....	.....	1	3
Excessive clearing	1	.....	1	2
Industrial activities	.....	.....	.....	4
Industrial wastes	.....	.....	.....	4
Fertiliser residual effects	.....	.....	1	3
Fire management effects	.....	2	.....	2
Forestry effects	.....	.....	1	3
Mining effects	.....	.....	1	3
Mineral exploration effects	.....	.....	1	3
Mineral processing effects	.....	.....	1	3
National parks/reserves	.....	.....	.....	4
Overgrazing - stock	1	.....	2	1
Overgrazing - feral	.....	.....	3	1
Overproduction	1	.....	1	2
Pesticide residual effects	.....	.....	3	1
Public attitudes to land-use	1	1	.....	2
Recreation activities	.....	.....	1	3
Sewage contamination	.....	.....	.....	4
Soil degradation	1	1	2	.....
Soil erosion	1	1	2	.....
Soil acidification	.....	.....	2	2
Soil salinisation	1	.....	1	2
Urban development	.....	.....	1	3
Urban wastes	.....	.....	.....	4
Water quality	.....	.....	2	2
Water quantity	.....	.....	1	3
Other.....	.....	.....	.....	.....
Other.....	.....	.....	.....	.....

NOTES (explain as considered necessary)

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4. On the basis of current knowledge and experience, classify the following with regard to the role they have played, directly or indirectly, in reducing the productive potential of lands used for LIVESTOCK - IMPROVED PASTURE production in your State or Territory.

	High	Medium	Low	Negligible
Air pollution	.....	.....	.....	...4...
Climate changes	.....	.....	...1...	...3...
Desertification	.....	.....	...1...	...3...
Excessive clearing	...1...	...1...	...2...	.....
Industrial activities	.....	.....	.....	...4...
Industrial wastes	.....	.....	...1...	...3...
Fertiliser residual effects	.....	...1...	...1...	...2...
Fire management effects	.....	...2...	...1...	...1...
Forestry effects	.....	.....	...2...	...2...
Mining effects	.....	.....	...1...	...3...
Mineral exploration effects	.....	.....	.....	...4...
Mineral processing effects	.....	.....	...2...	...2...
National parks/reserves	.....	.....	.....	...4...
Overgrazing - stock	...2...	.....	...2...	.....
Overgrazing - feral	.....	...1...	...2...	...1...
Overproduction	...1...	.....	.....	...3...
Pesticide residual effects	.....	...1...	.....	...3...
Public attitudes to land-use	...1...	.....	.....	...3...
Recreation activities	.....	.....	.....	...4...
Sewage contamination	.....	.....	.....	...4...
Soil degradation	...2...	.....	...1...	...1...
Soil erosion	...2...	...1...	.....	...1...
Soil acidification	...1...	...1...	...1...	...1...
Soil salinisation	...2...	.....	...2...	.....
Urban development	.....	...1...	...1...	...2...
Urban wastes	.....	.....	.....	...4...
Water quality	.....	.....	...1...	...3...
Water quantity	.....	.....	...1...	...3...
Other.....	.....	.....	.....	.....
Other.....	.....	.....	.....	.....

NOTES (explain as considered necessary)

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5. On the basis of current knowledge and experience, classify the following with regard to the role they have played, directly or indirectly, in reducing the productive potential of lands used for LIVESTOCK - RANGELAND production in your State or Territory.

	High	Medium	Low	Negligible
Air pollution	.....	.....	.....	3
Climate changes	.....	.....	.....	3
Desertification	.....	1	1	1
Excessive clearing	.....	1	.....	2
Industrial activities	.....	.....	.....	3
Industrial wastes	.....	.....	.....	3
Fertiliser residual effects	.....	.....	.....	3
Fire management effects	.....	1	1	1
Forestry effects	.....	.....	1	2
Mining effects	.....	.....	1	2
Mineral exploration effects	.....	.....	1	2
Mineral processing effects	.....	.....	1	2
National parks/reserves	.....	1	1	1
Overgrazing - stock	.....	3	.....	.....
Overgrazing - feral	1	1	1	.....
Overproduction	.....	.....	1	2
Pesticide residual effects	.....	.....	.....	3
Public attitudes to land-use	.....	.....	3	.....
Recreation activities	.....	.....	2	1
Sewage contamination	.....	.....	.....	3
Soil degradation	.....	.....	3	.....
Soil erosion	.....	2	1	.....
Soil acidification	.....	.....	.....	3
Soil salinisation	.....	.....	1	2
Urban development	.....	.....	.....	3
Urban wastes	.....	.....	.....	3
Water quality	.....	.....	1	2
Water quantity	.....	1	1	1
Other.....	.....	.....	.....	.....
Other.....	.....	.....	.....	.....

NOTES (explain as considered necessary)

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(Add additional pages if necessary)

FORESTRY

6. On the basis of current knowledge and experience, classify the following with regard to the role they have played, directly or indirectly, in reducing the productive potential of lands used for FORESTRY - NATIVE FORESTS production in your State or Territory.

	High	Medium	Low	Negligible
Air pollution	.....	.....	1	6
Climate changes	.....	2	.....	5
Desertification	.....	.....	2	5
Industrial activities	.....	.....	6	1
Industrial wastes	.....	.....	1	6
Fertiliser residual effects	.....	1	2	4
Fire management	.....	3	4	.....
Mining activities	.....	.....	4	3
Mineral exploration	.....	.....	3	4
Mineral processing	.....	.....	2	5
National parks/reserves	2	2	2	1
Overgrazing - stock	.....	1	2	4
Overgrazing - feral	.....	2	2	3
Overharvesting	.....	1	4	2
Pests/diseases	.....	5	1	1
Pesticide residual effects	.....	.....	1	6
Public attitudes to land-use	2	2	2	1
Recreation activities	1	.....	3	3
Sewage contamination	.....	.....	1	6
Soil degradation	.....	2	2	3
Soil erosion	.....	1	2	4
Soil acidification	.....	1	1	5
Soil salinisation	.....	1	2	4
Urban development	.....	.....	5	2
Urban wastes	.....	.....	2	5
Water quality	.....	1	1	5
Water quantity	.....	1	1	5
Other... Agric. Develop.	1	.....	.....	.....
Other... Wildlife Grazing Competition for landuse	.....	1	.....	.....

NOTES (explain as considered necessary)

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7. On the basis of current knowledge and experience, classify the following with regard to the role they have played, directly or indirectly, in reducing the productive potential of lands used for FORESTRY - PLANTATIONS production in your State or Territory.

	High	Medium	Low	Negligible
Air pollution	.....	.....	1	7
Climate changes	.....	1	.....	7
Desertification	.....	.....	.....	8
Industrial activities	.....	.....	1	7
Industrial wastes	.....	.....	.....	8
Fertiliser residual effects	.....	.....	1	7
Fire management	.....	2	3	3
Mining activities	.....	.....	3	5
Mineral exploration	.....	.....	1	7
Mineral processing	.....	.....	.....	8
National parks/reserves	.....	1	2	5
Overgrazing - stock	.....	1	1	6
Overgrazing - feral	.....	2	.....	6
Overharvesting	.....	.....	1	7
Pesticide residual effects	.....	.....	2	6
Pests/diseases	.....	3	2	3
Public attitudes to land-use	1	3	.....	4
Recreation activities	.....	.....	2	6
Sewage contamination	.....	.....	.....	8
Soil degradation	.....	2	1	5
Soil erosion	.....	1	2	5
Soil acidification	.....	1	.....	7
Soil salinisation	.....	.....	1	7
Urban development	.....	1	4	3
Urban wastes	.....	.....	1	7
Water quality	.....	.....	2	6
Water quantity	.....	1	1	6
Other..... Agric. Develop.	1	.....	.....	.....
Other.....	.....	.....	.....	.....

NOTES (explain as considered necessary)

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(Add additional pages if necessary)

FISHERIES

8. On the basis of current knowledge and experience, classify the following with regard to the role they have played, directly or indirectly, in reducing the productive potential of waterways used for COMMERCIAL FISHERIES FRESHWATER production in your State or Territory.

	High	Medium	Low	Negligible
Agricultural effects	3		1	
Air pollution			1	3
Chemical pollution		1	2	1
Climate changes			1	3
Excessive clearing	2		2	
Industrial activities		1	2	1
Industrial wastes		1	2	1
Fertiliser residual effects	1	1	2	
Fire management		1	1	2
Forestry activities	1	1	1	1
Mining activities	1		3	
Mineral exploration			1	3
Mineral processing		1	2	1
National parks/reserves		1		3
Overharvesting	1	2	1	
Pesticide residual effects		1	2	1
Public attitudes to fisheries	1	3		
Recreation activities	2		2	
Sewage contamination	1		2	1
Siltation	1	1	2	
Soil degradation	1		2	1
Soil erosion	2		2	
Soil acidification	1		1	2
Salinisation	1	1		2
Urban development	1		2	1
Urban wastes	1		2	1
Water quality	2		1	1
Water quantity	2	1		1
Weeds - aquatic	1		1	2
Weeds - terrestrial				4
Other....Drainage.....	1			
Other....Barriers to fish.....	1			

NOTES (explain as considered necessary)

(Add additional pages if necessary)

9. On the basis of current knowledge and experience, classify the following with regard to the role they have played, directly or indirectly, in reducing the productive potential of waterways used for COMMERCIAL FISHERIES - ESTUARINE production in your State or Territory.

	High	Medium	Low	Negligible
Agricultural effects	3		1	
Air pollution			1	3
Chemical pollution	1		1	2
Climate changes			1	3
Excessive clearing	1	1	1	1
Estuary degradation	2		1	1
Industrial activities	1		1	2
Industrial wastes	1		2	1
Fertiliser residual effects	1	1	2	
Fire management			1	3
Forestry activities			1	3
Mangrove elimination	1		3	
Mining activities		1	2	1
Mineral exploration		1		3
Mineral processing		1	2	1
National parks/reserves		2	1	1
Oil pollution		1	1	2
Overharvesting	1	1	2	
Pesticide residual effects	1		1	2
Public attitudes to fisheries	1	2		1
Recreation activities	2		2	
Sewage contamination	1		1	2
Siltation		2	1	1
Soil degradation			2	2
Soil erosion		2	1	1
Salinity changes	1	2		1
Urban development	1	1	1	1
Urban wastes	1		2	1
Water quality	1	1	1	1
Water quantity	1	1	1	1
Other... Drainage	1			
Other...				

NOTES (explain as considered necessary)

(Add additional pages if necessary)

10. On the basis of current knowledge and experience, classify the following with regard to the role they have played, directly or indirectly, in reducing the productive potential of coastal waters used for COMMERCIAL FISHERIES - COASTAL production in your State or Territory.

	High	Medium	Low	Negligible
Agricultural effects	.....	1	2	2
Air pollution	.....	.....	1	4
Chemical pollution	.....	1	1	3
Chemical waste disposal	.....	1	1	3
Climate changes	.....	.....	.....	5
Estuary degradation	1	2	1	1
Industrial activities	.....	1	2	2
Industrial wastes	1	1	1	2
Fertiliser residual effects	.....	1	3	1
Forestry activities	.....	.....	1	4
Mangrove elimination	1	1	2	1
Marine parks	.....	.....	.....	5
Mining activities	.....	1	2	2
Mineral exploration	.....	.....	1	4
Mineral processing	.....	1	1	3
National parks/reserves	.....	.....	.....	5
Oil pollution	.....	1	.....	4
Oil exploration	.....	.....	1	4
Oil extraction	.....	.....	.....	5
Overharvesting	1	2	2	.....
Pesticide residual effects	1	.....	2	2
Public attitudes to fisheries	.....	1	1	3
Recreation activities	1	1	1	2
Sewage contamination	.....	2	1	2
Siltation	.....	1	2	2
Soil erosion	.....	1	2	2
Salinity changes	.....	.....	1	4
Urban development	.....	1	3	1
Urban waste disposal	.....	2	1	2
Water quality	.....	1	3	1
Other.....	.....	.....	.....	.....
Other.....	.....	.....	.....	.....

NOTES (explain as considered necessary)

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(Add additional pages if necessary)

11. On the basis of current knowledge and experience, classify the following with regard to the role they have played, directly or indirectly, in reduction potential of COMMERCIAL FISHERIES - OFFSHORE production in your State or Territory.

	High	Medium	Low	Negligible
Agricultural effects			1	4
Air pollution				5
Chemical pollution			1	3
Chemical waste disposal			2	3
Climate changes				5
Estuary degradation		1	1	3
Industrial activities			2	3
Industrial wastes			2	3
Fertiliser residual effects			1	4
Forestry activities				5
Mangrove elimination			3	2
Marine parks				5
Mining activities		1		4
Mineral exploration			2	3
Mineral processing			1	4
National parks/reserves				5
Oil pollution		1	1	3
Oil exploration			1	4
Oil extraction				5
Overharvesting	1	1	1	2
Pesticide residual effects			2	3
Public attitudes to fisheries		1		4
Recreation activities		1	1	3
Sewage contamination			1	4
Siltation				5
Soil erosion				5
Salinity changes				5
Urban development				5
Urban waste disposal			1	4
Water quality				5
Other.....				
Other.....				

NOTES (explain as considered necessary)

(Add additional pages if necessary)

NATIONAL PARKS & RESERVES

12. On the basis of current knowledge and experience, classify the following with regard to the role they have played, directly or indirectly, in reducing the primary productive potential (first trophic level) of areas included within MARINE PARKS in your State or Territory.

	High	Medium	Low	Negligible
Agricultural effects	1		1	1
Air pollution				3
Amateur collecting	1		1	1
Chemical pollution	1			2
Chemical waste disposal	1			2
Climate changes		1	1	1
Commercial fisheries	1		1	1
Estuary degradation		1	1	1
Industrial activities		1		2
Industrial wastes		1		2
Fertiliser residual effects	1		1	1
Forestry activities				3
Mangrove elimination			2	1
Mining activities			1	2
Mineral exploration			1	2
Mineral processing	1			2
Natural predators				3
Oil pollution			2	1
Oil exploration			1	2
Oil extraction			1	2
Pesticide residual effects		1		2
Recreation fishing		1	1	1
Sewage contamination		1	1	1
Siltation		1	1	1
Soil erosion		1	1	1
Salinity changes			1	2
Tourist visitation		1		2
Tourist facilities		1	2	
Urban development	1		1	1
Urban waste disposal	1		1	1
Water quality changes		1	1	1
Other.....				
Other.....				

NOTES (explain as considered necessary)

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13. On the basis of current knowledge and experience, classify the following with regard to the role they have played, directly or indirectly, in reducing the primary productive potential (first trophic level) of areas included within NATIONAL PARKS AND RESERVES in your State or Territory.

	High	Medium	Low	Negligible
Agricultural effects	.....	2	1	1
Air pollution	.....	.....	.....	4
Amateur collecting	.....	.....	1	3
Chemical pollution	.....	.....	1	3
Chemical waste disposal	.....	.....	1	3
Climate changes	.....	.....	1	3
Excessive clearing	.....	1	1	2
Industrial activities	.....	.....	.....	4
Industrial wastes	.....	.....	.....	4
Farming	.....	.....	1	3
Feral animal effects	2	1	1	.....
Fertiliser residual effects	.....	.....	2	2
Forestry activities (past)	.....	.....	.....	4
Forestry activities (present)	.....	.....	.....	4
Grazing effects	.....	2	2	.....
Mining activities	.....	1	2	1
Mineral exploration	.....	1	1	2
Mineral processing	.....	.....	.....	4
Oil/Gas exploration	.....	3	.....	1
Oil/Gas extraction	.....	1	1	2
Pesticide residual effects	.....	.....	1	3
Pests/diseases	1	.....	1	2
Recreational fishing	.....	.....	1	3
Sewage contamination	.....	.....	.....	4
Siltation	.....	.....	.....	4
Soil acidification	.....	.....	.....	4
Soil erosion	.....	.....	3	1
Soil salination	.....	1	1	2
Salinity changes	.....	1	1	2
Tourist visitation	.....	1	3	.....
Tourist facilities	.....	.....	2	2
Urban development	.....	.....	1	3
Urban waste disposal	.....	.....	1	3
Water quality changes	.....	.....	1	3
Weeds - aquatic	.....	2	.....	2
Weeds - terrestrial	1	2	1	.....
Other.....	.....	.....	.....	.....
Other.....	.....	.....	.....	.....

NOTES (explain as considered necessary)

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(Add additional pages if necessary)

QUESTIONNAIRE 4

"FLORAL DISTRIBUTION & ABUNDANCE"

G. Webb Pty. Limited,
Wildlife Research and Management Consultants,
P.O. Box 38151,
WINNELLIE, N.T. 0821

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PREAMBLE

This survey is one of a number being conducted by AMIC (the Australian Mining Industry Council), in order to clarify the impacts of mining (negative and positive) on Australia's fauna and flora.

The information requested in this particular survey will be used for a general analysis of how researchers and Governmental agencies responsible for cataloguing and describing Australia's flora, past and present, currently view contributions the mining industry may have made from time to time.

By necessity, the questions are general and require a degree of value judgement. There may be instances where a particular question does not fall within the area of expertise of the Institution. Please mark the question "not applicable" and if possible, direct us to the correct Institution.

We are greatly interested in your professional views and comments upon issues relevant to this questionnaire. If you would like to discuss any aspect of the questionnaire, please contact Charlie Manolis (089.221355).

Contact Officer .....
Title .....
Organisation .....
Address .....
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Telephone no. .....
Facsimile no. .....

1. Over the last 25 years, environmental impact assessments have become a routine activity associated with mining exploration, mining, and mineral processing. One possible consequence of EIS's is that information on the distribution and abundance of extant fauna is obtained from areas that are chosen on the basis of geological rather than biological criteria. How would you describe the significance of FLORAL DISTRIBUTIONAL DATA obtained through EIS's associated with the mining industry?

Insignificant	.....3.....
Minor	.....2.....
Significant	.....
Important	.....2.....
Very Important	.....

NOTES (explain as considered necessary)

(Add additional pages if necessary)

2. Over the last 25 years, environmental impact assessments have become a routine activity associated with mining exploration, mining, and mineral processing. One consequence of this is that funds and facilities have been made available to biologists from a variety of organisations, so that they can visit and the examine the FLORA in target areas which are often remote. How would you describe the significance of this ADDITIONAL SOURCE OF SUPPORT for environmental research with regard to your organisation?

Insignificant	....4....
Minor	....2....
Significant	.....
Important	....1....
Very Important	.....

NOTES (explain as considered necessary)

(Add additional pages if necessary)

3. Townships in remote areas, established for agricultural activities, mining, etc., serve as a nucleus for obtaining information from what would otherwise be a little-known area biologically. The distribution of musuem records often reflects the concentrations of people. How would you describe the significance to your Institution of FLORAL RECORDS obtained from what are essentially "mining towns" (towns that would probably not exist unless there was a central mining operation) over the last 25 years?

Insignificant	3
Minor	1
Significant	2
Important	1
Very Important	

NOTES (explain as considered necessary)

(Add additional pages if necessary)

4. Over the last 25 years, environmental impact assessments have become a routine activity associated with mining exploration, mining, and mineral processing. One possible consequence of EIS's is that information on the distribution and abundance of fossil flora is obtained from areas that are chosen on the basis of geological rather than biological criteria. How would you describe the significance of FOSSIL DISTRIBUTIONAL DATA obtained through EIS's associated with the mining industry?

Insignificant	...../.....
Minor	.....
Significant	.....
Important	.....
Very Important	.....

NOTES (explain as considered necessary)

(Add additional pages if necessary)

5. Over the last 25 years, environmental impact assessments have become a routine activity associated with mining exploration, mining, and mineral processing. One consequence of this is that funds and facilities have been made available to biologists from a variety of organisations so that they can visit and the examine the FOSSILS in target areas which are often remote. How would you describe the significance of this ADDITIONAL SOURCE OF SUPPORT for environmental research with regard to your organisation?

Insignificant	.....
Minor	.....
Significant	.....
Important	.....
Very Important	.....

NOTES (explain as considered necessary)

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6. Townships in remote areas, established for agricultural activities, mining, etc., serve as a nucleus for obtaining information from what would otherwise be a little-known area biologically. The distribution of musuem records often reflects the concentrations of people. How would you describe the significance to your Institution of FOSSIL RECORDS obtained from what are essentially "mining towns" (towns that would probably not exist unless there was a central mining operation) over the last 25 years?

Insignificant	....1.....
Minor	.....
Significant	.....
Important	.....
Very Important	.....

NOTES (explain as considered necessary)

(Add additional pages if necessary)

7. With reference to acquisitions of FLORAL SPECIMENS in your Institution, over the last 25 years, how would you rate the significance, in terms of new information (distribution records, new species, etc.) of specimens acquired directly or indirectly from the following sources. These include consultancies and research projects initiated by those sources, and infrastructural developments associated with those sources. (This analysis excludes internally initiated and funded collecting trips by your own Institution). (See also Question 9):

	High	Medium	Low	Negligible
Amateur Collectors	3	3	1	
Farmers & Graziers		2	1	4
Fisheries Activities				7
Forestry Activities		2	3	1
Mining Activities	1	1	1	4
University Researchers	1	2	3	1
Wildlife Departments	3	2	1	1
Other... staff	2			
Other... other Herbaria				

NOTES .....

(Add additional pages if necessary)

8. With reference to acquisitions of FOSSIL MATERIAL in your Institution, over the last 25 years, how would you rate the significance, in terms of new information (distribution records, new species, etc.) of specimens acquired directly or indirectly from the following sources. These include consultancies and research projects initiated by those sources, and infrastructural developments associated with those sources. (This analysis excludes internally initiated and funded collecting trips by your own Institution). (See also Question 9):

	High	Medium	Low	Negligible
Amateur Collectors				
Farmers & Graziers				
Fisheries Activities				
Forestry Activities				
Mining Activities				
University Researchers	1			
Wildlife Departments				
Other.....				
Other.....				

NOTES .....

(Add additional pages if necessary)

9. With reference to acquisitions of specimens in your Institution, over the last 25 years, what percentage [known precisely (K) or a guesstimate (G)] would have been acquired, directly or indirectly, from mining activities (including consultancies, infrastructure, etc.):

%	Plants	Fossils
0-1	G G G	G
2-5	G G G	.....
6-10	.....	.....
11-20	G	.....
>20	.....	.....

NOTES .....
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(Add additional pages if necessary)