MT KEITH NICKEL PROJECT
TAILINGS STORAGE UPGRADE
CONSULTATIVE ENVIRONMENTAL REVIEW
The Environmental Protection Authority (EPA) invites people to make a submission on this proposal.

The Consultative Environmental Review (CER) proposes the development of an upgraded tailings storage facility at the Mt Keith nickel project, located about 90km south of Wiluna. In accordance with the Environmental Protection Act 1986, Western Mining Corporation Limited has prepared a CER which describes the proposal and its likely effects on the environment. The CER will be available for public review for a period of three weeks, commencing on Wednesday 31 January 1996 and closing on Wednesday 21 February 1996.

Comments from Government agencies and the public will assist the EPA to prepare an assessment report in which it will make recommendations to Government.

Why write a submission?

A submission is a way to provide information, express your opinion and put forward your suggested course of action - including any alternative approach. It is useful if you indicate any suggestions you have to improve the proposal.

All submissions received by the EPA will be acknowledged. Submissions will be treated as public documents unless provided and received in confidence subject to the requirements of the Freedom of Information Act, and may be quoted in full or in part in each report.

Why not join a group?

If you prefer not to write your own comments, it may be worthwhile joining a group or other groups interested in making a submission on similar issues. Joint submissions may help to reduce the workload for an individual or group, as well as increasing the pool of ideas and information. If you form a small group (up to 10 people) please indicate the names of all the participants. If your group is larger, please indicate how many people your submission represents.

Developing a submission

You may agree or disagree with, or comment on, the general issues discussed in the CER or the specific proposals. It helps if you give reasons for your conclusions, supported by relevant data. You may make an important contribution by suggesting ways to make the proposal more environmentally acceptable.

When making comments on specific proposals in the CER:

- clearly state your point of view
- indicate the source of your information if this is applicable
- suggest recommendations, safeguards or alternatives.

Points to keep in mind

By keeping the following points in mind, you will make it easier for your submission to be analysed:

- Attempt to list points so that issues raised are clear. A summary of your submission is helpful.
- Refer each point to the appropriate section, chapter or recommendation in the CER.
- If you discuss different sections of the CER, keep them distinct and separate, so there is no confusion as to which section you are discussing.
- Attach any factual information you may wish to provide and give details of the source. Make sure your information is accurate.

Remember to include:

- your name
- your address
- the date
- whether you want your submission to be confidential.

The closing date for submissions is Wednesday 21 February 1996.

Submissions should be addressed to:

Department of Environmental Protection
Westralia Square
141 St George's Terrace
PERTH WA 6000

Attention: Mr Colin Murray
MT KEITH NICKEL PROJECT

TAILINGS STORAGE UPGRADE

CONSULTATIVE ENVIRONMENTAL REVIEW

Prepared for
Western Mining Corporation Limited
Mt Keith Operations

January 1996

by
Gutteridge Haskins & Davey Pty Ltd
619 Murray Street
West Perth WA 6005
Tel (09) 322 3899
Fax (09) 322 3926

Editorial assistance from
Bowman Bishaw Gorham
1298 Hay Street
West Perth WA 6872
Tel (09) 481 8588
Fax (09) 481 8338
EXECUTIVE SUMMARY

Western Mining Corporation Limited (WMC) proposes to develop an upgraded tailings storage facility (TSF) at the Mt Keith nickel mine, located 90km south of Wiluna in the north-eastern Goldfields of Western Australia.

Mining and processing of nickel ore commenced at Mt Keith in 1994. Two conventional ring dyke type tailings cells have been used to store tailings to date and the operating licence contains approval for two further cells.

Need for the Proposal

Engineering and environmental investigations for a “best practice” storage facility at Mt Keith commenced in 1990 with a feasibility study into centralised thickened discharge disposal. Test work continued during 1992 and a tailings disposal options study was commissioned in 1993.

As a result of these studies, it was decided in 1994 to seek approval for a conventional four-cell paddock storage but to build only two cells immediately and continue investigations into advanced tailings management, such as centralised discharge disposal.

The need to upgrade the tailings storage capacity has become more immediate due to a range of technical factors and revised projections for nickel concentrate production. The primary factors include:

- The initial design life of the current storage cells was based on a tailings output of 6.5Mtpa, whereas output has increased to 8.5Mtpa.

- Further possible increases in nickel production and therefore tailings output are anticipated. While the initial four-cell paddock storage system was designed to cater for 130 Mt of tailings, projected mining and production operations now indicate that a total tailings storage capacity of about 240 Mt is required.

Selection of the Storage Method

The centralised discharge system was selected on the basis of an extensive study of storage options. The study commenced in April 1995 and included recognised specialists in all areas of tailings disposal. In addition, representatives of both the Department of Environmental Protection and Department of Minerals and Energy were members of the study team. Consequently both Departments have been continuously consulted over this ten month period.
The centralised discharge system is considered superior to conventional dam-type tailings storage because:

- the 3% final slope facilitates rehabilitation of the tailings surface;
- the free-draining structure inhibits the formation and persistence of an internal water table, thereby reducing seepage to the underlying groundwater;
- the absence of a water table reduces the likelihood and severity of capillary salt rise at the tailings surface, thereby greatly aiding the establishment of vegetation;
- the system provides greater operational flexibility in terms of the rate of production and deposition of the tailings; and
- the storage is more stable and less susceptible to liquefaction than conventional tailings dams.

**Description of the Storage Facility**

The proposed storage facility will be of the centralised discharge type, comprising a containment embankment 4,600m in diameter and 3m to 5m in height, carrying a ring main distribution pipe which will feed nine vertical risers located within the storage facility.

Tailings slurry will be discharged through the risers and will flow out to form a series of low, overlapping cones with a slope of about 3%. The rate and distribution of tailings placement will be actively managed and optimised to achieve rapid drying, maximum solids density, rapid sealing of the underlying ground surface and minimal ponding of water within the facility. Tailings water and stormwater runoff will be recovered and recycled to the mine plant as process water. When completed, the TSF will form a series of low conical mounds 1,700ha in area and 45m high in the centre with an average slope of 3%.

The centralised discharge tailings storage principle has not previously been employed in Western Australia but has been used successfully in a number of locations elsewhere including Gove (N.T.).

**Identification of Environmental Issues**

The principal environmental issues associated with the construction and operation of the TSF have been identified as:

- removal of approximately 1,800 ha of vegetation and fauna habitat;
- interruption of surface drainage and possible runoff shadowing of areas downslope of the TSF;
• possible seepage of saline water into the underlying groundwater; and

• impacts on the nearby Wanjarri Nature Reserve.

Other issues include dust, noise, the possible presence of Aboriginal heritage sites, effects on the visual landscape and the stability of the completed tailings stockpile.

These issues have been studied by a number of detailed investigations including:

• on-site flora and fauna surveys, habitat and land system mapping;

• geotechnical investigations of tailings stability;

• hydrogeological studies to characterise the underlying groundwater conditions;

• computer modelling of potential saline seepage under a “worst-case scenario”; and

• archaeological and ethnographic studies to search for Aboriginal heritage sites and cultural connections with the project area.

Environmental Impacts and Management

On the basis of the above investigations, the environmental impacts of the proposal are predicted to be minor and readily managed. The potential impacts are discussed below along with environmental management measures proposed by the proponent.

Vegetation and Habitat Removal

The removal of 1,800ha of vegetation and fauna habitat constitutes a substantial area, but this area is insignificant when compared to the very large area of similar habitat which exists in the north-eastern Goldfields. The studies have shown that the land systems, vegetation associations and habitats impacted by the TSF are all common and well represented in surrounding areas, including the Wanjarri Nature Reserve. The proportion of each land system directly impacted by the proposal is limited to less than 0.2% of the total area of each system.

Specific searches for Gazetted rare flora and fauna have failed to find any evidence of their occurrence within the area of direct impact. Nevertheless, WMC has committed itself to carry out detailed surveys for the rare Crest-tailed Marsupial Mouse or mulgara (Dasycercus cristicaudata) prior to construction and the implementation of a relocation programme if any are found.
**Drainage Interruption**

The proposed TSF lies on a broad sheet-wash alluvial plain. The existing diffuse surface drainage patterns will be interrupted by the perimeter wall. Diversion drains will be employed to redirect surface flow from upslope to downslope of the TSF, where it will be released in a diffuse pattern to mimic the existing pattern of drainage. This strategy will minimise adverse impacts on downslope vegetation due to runoff shadowing. The proponent will monitor the health of vegetation and will take appropriate remedial action if necessary.

**Groundwater and Seepage**

The superficial (shallow) aquifer located beneath the TSF site contains subpotable water at a salinity of 700 mg/L to 1,500 mg/L (TDS). The groundwater flows very slowly east towards the Wanjari Nature Reserve. The potential for saline tailings water to seep into the aquifer has been studied by computer modelling assuming “worst-case” conditions including:

- the presence of a permanent water table within the tailings stockpile;
- the presence of permanent ponded water within the stockpile;
- the presence of preferred flow paths through the underlying caprock;
- seepage and runoff water salinity of 70,000 mg/L (not accounting for the lower salinity of ponded stormwater); and
- no dilution within the aquifer by natural recharge and outflow.

The modelling has shown that, under worst-case conditions, the maximum expected rise in groundwater salinity beneath the TSF is 1,070 mg/L, leading to a potential maximum salinity of approximately 1,770 mg/L to 2,570 mg/L TDS. This is unlikely to be environmentally significant because:

- the depth of the aquifer (16 - 18 m) means that it is not accessible to plants or animals;
- the aquifer’s usefulness for stock watering would be unaffected by this increase (cattle can readily drink water at up to 5,000 mg/L TDS and sheep can tolerate up to 6,000 mg/L); and
- the resource has no current beneficial use other than for process water and other subpotable uses at the mine.

The modelling indicated that most of the seepage (up to 450 m³/day) would occur in the first few months of operation, before the
ground surface beneath the TSF becomes sealed by low permeability tailings. By the fifth year of operation, the rate of seepage is predicted to be negligible (1.6 m³/day and decreasing).

Despite the indications of a minor impact, the proponent will actively monitor the salinity of seepage water and underlying groundwater both within and outside the TSF. If excess salinity is detected in the groundwater, existing and possibly new bores located immediately downstream of the storage will be used to recover the saline water for use in processing. By the time the TSF is decommissioned in approximately twenty years, seepage will be almost non-existent and will require no further management.

Impacts on Wanjarri Nature Reserve

The impacts of the project upon Wanjarri Nature Reserve are expected to be negligible. All of the direct impacts of the project will be confined to the TSF site itself, which is 1.8 km from the Nature Reserve at its closest point. Indirect impacts such as runoff shadowing, seepage, dust and noise will be managed so as to minimise their effect, and will in any case be restricted to the near vicinity of the TSF. The proponent will continue its existing involvement in funding and participating in the management of Wanjarri Nature Reserve.

Rehabilitation

When the TSF is full of tailings it will be rehabilitated. Trials will be carried out on the modified surface of the existing tailings cells to test alternative rehabilitation methods.

The probable absence of an internal water table within the completed tailings store will reduce the likelihood and severity of salt rise by capillary action. As a result, the salinity of the tailings surface soil is expected to steadily decrease and applied topsoil will not become saline. This will greatly aid the establishment of vegetation. The rehabilitation will be carried out in line with the final Rehabilitation Plan.

Regulatory Consultation

WMC has consulted with relevant government agencies on this proposal for more than a year, including:

- in April 1995, a Tailings Storage Study Team was established by WMC which included representatives from DEP and DME. The team met every month until December to investigate alternative storage methods, siting, design and the environmental aspects of tailings storage;

- discussions commenced with CALM in December 1994 regarding co-operative management of the nearby Wanjarri Nature Reserve,
leading to a draft Memorandum of Understanding for joint management of the reserve;

- discussions on the proposal have taken place between WMC and officers of the Water and Rivers Commission;

- the Shire of Wiluna and the local Pastoral Station Manager have been provided with summaries of the proposal.

**Conclusions and Commitments**

The proponent believes that the proposed TSF has an acceptably low and manageable level of environmental impact while presenting substantial environmental advantages over conventional tailings dams, including:

- more efficient water usage and less demand on groundwater resources;

- improved stormwater management within the tailings storage;

- a free-draining structure that inhibits the formation and persistence of an internal water table, thereby reducing seepage to the underlying groundwater;

- reduced likelihood and severity of capillary salt rise at the tailings surface, thereby greatly improving the environmental preconditions for successful rehabilitation;

- greater stability and less risk of liquefaction during earthquakes; and

- a final shape that is more in keeping with the existing landforms.

The proponent has made a number of formal and auditable commitments to environmental management of the project. The potential impacts and management measures are summarised in Table 1, and the commitments are summarised in Table 2.
TABLE 1: Summary of issues contained in the Environmental Protection Authority guidelines for the project and their treatment.

<table>
<thead>
<tr>
<th>TOPIC</th>
<th>EPA SPECIFICATION</th>
<th>EXISTING ENVIRONMENT</th>
<th>POTENTIAL FOR IMPACT</th>
<th>PROPOSED MANAGEMENT</th>
<th>OUTCOME</th>
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<tr>
<td>1. Security of remnant vegetation/land systems</td>
<td>Conduct plant, vegetation and land system studies to the requirements of CALM.</td>
<td>Seven land systems exist in the general area of influence of the proposal. All well represented regionally.</td>
<td>All systems in the footprint of the TSF assessed as having low conservation priority.</td>
<td>Minimise vegetation clearing. Rehabilitate progressively.</td>
<td>Minor regional impact</td>
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<td>of region</td>
<td>Three land systems in the footprint of the TSF.</td>
<td>All well represented in Wanjarri. Main impact is removal of vegetation over footprint of TSF.</td>
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<td>Undertake flora and fauna research.</td>
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<td>2. Protect or enhance conservation values of Wanjarri Nature Reserve</td>
<td>Develop and implement conservation strategies to the requirements of CALM and NPNCA</td>
<td>Wanjarri is an &quot;A&quot; Class Nature Reserve located 1.8km south of TSF. The Department of CALM has recommended reclassifying to a Conservation Park to allow for multiple use of the Reserve.</td>
<td>No direct impact. Surface flows will be reinstated. Contaminated groundwater will not impact on Reserve values.</td>
<td>Become involved with co-operative management of Wanjarri.</td>
<td>No impacts</td>
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<td>3. Groundwater resource</td>
<td>Implement best practice to avoid contaminating the groundwater, refer ANZECC guidelines</td>
<td>Three aquifers are present - superficial, palaeochannel and deep fractured rock. Water quality in superficial and palaeochannel is subpotable, with salinity at 700mg/L - 1500mg/L.</td>
<td>Plume of saline groundwater could potentially intrude into superficial aquifer. Salinity of aquifer may approximately double under the TSF. Impact on beneficial uses is negligible.</td>
<td>Design walls and embankments to minimise seepage. Minimise risk of seepage through TSF. Use electromagnetic surveys and monitoring bores to detect plumes. Recover if necessary using production bores</td>
<td>Negligible impact on beneficial uses.</td>
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<td>4. Surface drainage</td>
<td>Ensure no significant changes to existing drainage systems and vegetation/land systems</td>
<td>Flat topography and low relief cause surface flows consisting of stream flows and sheet flows. Drainage in the area is currently from the west. Surface drainage generally flows out of Wanjarri Nature Reserve.</td>
<td>Water starvation downstream due to shadowing effect Soil erosion due to altered surface flow.</td>
<td>Construct stormwater diversion drains to reinstate the natural drainage Monitor vegetation and invertebrate fauna to assess the effects on ecology due to changes in the drainage patterns and remediate if required Monitor soil erosion and remediate if required</td>
<td>Some shift in vegetation distribution downstream due to changes in distribution of flow. Overall effect will be minor. Erosion will be minimised.</td>
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<td>5. Implement an Environmental Management System</td>
<td>Conform with intent and criteria of Interim Australian Standards 14001 &amp; 14004</td>
<td>Operating environmental management plan is in place</td>
<td>N/A</td>
<td>An environmental management system consistent with Interim Australian Standards 14001 and 14004 will be prepared and implemented.</td>
<td>Sound and proper management of facility and environment</td>
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<td>6. Site selection process</td>
<td>Choose most appropriate site on environmental criteria; rehabilitate to agreed landowner specifications.</td>
<td>Relevant factors which influenced site selection include:  - Barr-Smith Ranges  - Wanjari Nature Reserve  - Wiluna - Leinster Road  - Goldfields Gas Pipeline  - Deep tight clays which minimise seepage;  - No Aboriginal heritage implications  - Leases and tenements held by WMC</td>
<td>Poor siting could result in loss of significant areas, and downstream impacts</td>
<td>Select site which takes environmental, conservation and management factors into consideration</td>
<td>No impact on Barr-Smith Ranges, significant areas or restricted habitats.</td>
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<td>7. Plants and animals</td>
<td>Conduct plant and animal studies to the requirements of CALM/NPNCA; develop conservation plans for any rare and priority species.</td>
<td>Habitats represented in the footprint of the TSF are well represented elsewhere, including Wanjari Nature Reserve. No rare or priority species recorded in numerous flora and fauna surveys Typical vegetation is sparse mulga shrublands with wanderrie understorey Vegetation is xerophytic (not dependent on groundwater)</td>
<td>The major impact will be the clearing of plant communities within the footprint of the facility. No impact on rare or priority species</td>
<td>Facility will be fenced to prevent access by large animals Monitoring will be undertaken in the project area for the Mulgar (a rare mammal) before construction. If any are trapped, a suitable translocation programme will be implemented A site assessment will be undertaken in conjunction with CALM for Declared Rare Flora before construction commences. A management programme will be agreed with CALM if any are found. After operations cease, the TSF will be rehabilitated. WMC will establish a long term programme to fund a study into the ecology of Mulgar</td>
<td>Impact will be only on the vegetation and associated fauna in the footprint of the TSF</td>
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| 8. Rehabilitation | Develop process to identify post-mining land use and to define criteria for successful rehabilitation | Land is currently used for pastoral and mining purposes.  
Pastoral leases are held by WMC.  
Substantial areas of the site degraded, with accelerated erosion and poor regeneration. | Tailings will form a gently sloping profile which may be hostile to vegetation and subject to erosion | Topsoil will be stripped from the site before construction and, stockpiled for later rehabilitation  
Rehabilitation trials on Cells 1 and 2 will assess erosion, salt crusting, salinity of run-off and means to establish vegetation | Final landform and vegetation will be structurally and ecologically stable, non-toxic to the environment, and will support land uses consistent with the Mt Keith Environmental Management Programme |
| 9. Ensure integrity of facility to extreme events | Design facility to technical requirements of DME.  
Gentle slopes, low in regional topography.  
TSF lies in seismic zone with very low activity.  
Infrequent storm events cause broad sheet flooding across valley. | Earthquakes have the potential to cause liquefaction and failure  
Floods have the potential to cause erosion. | The storage facility has been designed to comply with the most stringent guidelines from DME  
The structure is inherently safer than conventional tailings dams. | Tailings facility complies with technical requirements of DME.  
Facility will be stable, with a high factor of safety |
TABLE 2: Summary of Environmental Commitments

<table>
<thead>
<tr>
<th>Issue</th>
<th>Objective</th>
<th>Commitments</th>
<th>Timing</th>
<th>Whose requirements</th>
<th>Specification</th>
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<tbody>
<tr>
<td>1. Security of remnant vegetation/land systems of region</td>
<td>Protect the ecological values of affected land systems and associated vegetation, habitats and fauna</td>
<td>Minimise clearing of vegetation and rehabilitate areas no longer required for operations</td>
<td>Pre- and post-construction</td>
<td>DME, DEP</td>
<td>Compliance with tenement conditions</td>
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<td>Contribute to co-ordinated management in north-eastern Goldfields with other land users</td>
<td>Ongoing</td>
<td>CALM, WADA</td>
<td>Consultation ongoing</td>
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<tr>
<td>2. Protect or enhance conservation values of Wanjarri Nature Reserve</td>
<td>Protect the ecological values of remnant affected land systems and areas no longer required for operations</td>
<td>Manage surface drainage and groundwater quality, to minimise impact on Wanjarri Nature Reserve</td>
<td>Ongoing</td>
<td>CALM</td>
<td>Minimal impacts on Wanjarri</td>
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<td>Contribute to management of Wanjarri Nature Reserve, in accordance with existing Memorandum of Understanding with CALM</td>
<td>Ongoing</td>
<td>Signatories of the Memorandum of Understanding</td>
<td>Improved management of Wanjarri Nature Reserve</td>
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<td>3. Groundwater resource</td>
<td>Protect the water quality and long term yield of superficial and palaeochannel aquifers</td>
<td>Implement monitoring programme to detect and monitor saline seepage out of TSF. If seepage is detected, formulate response plan</td>
<td>During and after construction</td>
<td>WRC and DEP</td>
<td>No change to existing and future beneficial uses</td>
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<td>DME guidelines</td>
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<td>4. Surface drainage</td>
<td>Maintain as far as possible the pre-existing flow patterns, and protect downstream vegetation from the effects of saline runoff.</td>
<td>Implement a soil erosion monitoring programme. Should accelerated soil erosion be detected as a result of TSF, implement a remediation programme.</td>
<td>Ongoing</td>
<td>DME (reported in annual environmental report)</td>
<td>Erosion minimised in comparison with control plots</td>
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<td>WRC</td>
<td>Minimal impact on vegetation and soil structure as indicated by vegetation and erosion monitoring</td>
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<td>Implement a vegetation monitoring programme. Should changes in vegetation be detected as a result of the TSF, implement a remediation programme.</td>
<td>Ongoing</td>
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<td>5. Implement an Environmental Management System (EMS) to ensure sound management of TSF and environment</td>
<td>Develop an Environmental Management System (EMS) to ensure sound management of TSF and environment</td>
<td>Identify and implement an EMS. Update existing Environmental Management Programme (EMP) to include matters relevant to the TSF</td>
<td>EMP updated within 12 months. EMS implementation ongoing</td>
<td>In accord with Australian Standards including independent auditing</td>
<td>Compliance with intent of Interim Australian Standards 14001 and 14004</td>
</tr>
<tr>
<td>Issue</td>
<td>Objective</td>
<td>Commitments</td>
<td>Timing</td>
<td>Whose requirements</td>
<td>Specification</td>
</tr>
<tr>
<td>-------</td>
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<tr>
<td>6. Site selection process</td>
<td>Select most appropriate site on environmental criteria</td>
<td>Siting will take into account all environmental aspects including hydrology, hydrogeology and significant features</td>
<td>Preconstruction</td>
<td>No impact on ecologically significant areas or restricted habitats</td>
<td></td>
</tr>
<tr>
<td>7. Plants and animals</td>
<td>Protect rare and priority species</td>
<td>Assess TSF site for Declared Rare Flora and priority listed species</td>
<td>Preconstruction</td>
<td>CALM</td>
<td>Compliance with Conservation and Land Management Act 1984.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Conduct trapping programme over TSF for mulgara. If any are trapped, implement relocation programme</td>
<td>Preconstruction</td>
<td>CALM</td>
<td>Successful relocation of mulgara, if present</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fund and conduct long term research into distribution and ecology of mulgara in north-eastern Goldfields</td>
<td>Ongoing</td>
<td>CALM</td>
<td>Improved understanding of mulgara ecology</td>
</tr>
<tr>
<td>8. Rehabilitation</td>
<td>Provide stable landforms and self-sustaining vegetation cover through progressive and final long term rehabilitation.</td>
<td>Prepare draft rehabilitation programme, updated as required to reflect results of rehabilitation trials and advances in knowledge of rehabilitation techniques. Submit final rehabilitation plan prior to implementation</td>
<td>Draft rehabilitation plan within two years. Updates and trials ongoing.</td>
<td>DEP, CALM and DME</td>
<td>Stable, non-polluting aesthetically acceptable landform.</td>
</tr>
<tr>
<td>9. Ensure integrity of facility to extreme events</td>
<td>Design and construct safe facility</td>
<td>Design and construct TSF in accordance with most stringent geotechnical guidelines</td>
<td>Design stage and during construction</td>
<td>DME</td>
<td>Compliance with DME Guidelines for Tailings Storage Facilities</td>
</tr>
<tr>
<td>10. Other</td>
<td>Avoid disturbance to Aboriginal heritage sites</td>
<td>No Aboriginal heritage sites will be disturbed without permission from the Minister for Aboriginal Affairs. If any previously unrecorded sites are found, all work in immediate vicinity will cease and appropriate procedures adopted</td>
<td>Ongoing</td>
<td>Dept of Aboriginal Affairs</td>
<td>Compliance with Aboriginal Heritage Act 1972.</td>
</tr>
<tr>
<td></td>
<td>Minimise dust</td>
<td>Minimise clearing and stripping and implement dust control strategies during construction. Establish vegetation cover on topsoil piles and perimeter walls.</td>
<td>During construction and ongoing</td>
<td>DEP and DME</td>
<td>Compliance with Environmental Protection Act 1987 Licence conditions, and Mines Safety and Inspection Act</td>
</tr>
</tbody>
</table>

**REGULATORY AUTHORITIES**

- **WADA**: Department of Agriculture
- **CALM**: Department of Conservation and Land Management
- **DME**: Department of Minerals and Energy
- **WRC**: Water and Rivers Commission
- **DEP**: Department of Environmental Protection
4. EXISTING ENVIRONMENT

4.1 Historical and Current Land Use

4.2 Climate
   4.2.1 Rainfall
   4.2.2 Temperature
   4.2.3 Wind
   4.2.4 Evaporation

4.3 Geology

4.4 Landforms, Topography and Soils

4.5 Surface Water

4.6 Groundwater

4.7 Land Systems

4.8 Vegetation and Flora
   4.8.1 Monk Land System
   4.8.2 Bullimore Land System
   4.8.3 Ararak Land System

4.9 Fauna

4.10 Aboriginal Heritage

5. ENVIRONMENTAL IMPACT ASSESSMENT

5.1 Overview

5.2 Impact on Land Systems, Vegetation and Fauna
   5.2.1 Land Systems
   5.2.2 Vegetation and Flora
   5.2.3 Fauna
   5.2.4 Edge and Barrier Effects

5.3 Surface Drainage Interruption
   5.3.1 Run-off Shadowing
   5.3.2 Erosion
   5.3.3 Stormwater Run-off from the TSF

5.4 Impacts on Groundwater
   5.4.1 Rate of Seepage
   5.4.2 Seepage Composition
   5.4.3 Impact on Groundwater Resources

5.5 Impacts on Wanjarri Nature Reserve
   5.5.1 Surface Water
   5.5.2 Groundwater

5.6 Minor Environmental Issues
   5.6.1 Noise
   5.6.2 Dust
   5.6.3 Aboriginal Heritage
   5.6.4 Visual Landscape
   5.6.5 Liquefaction Potential
   5.6.6 Risk Assessment
6. ENVIRONMENTAL MANAGEMENT

6.1 Overview

| 6.1.1 Environmental Management Programme | 45 |

6.2 Land System Management

| 6.2.1 Objective | 46 |
| 6.2.2 Management Strategy | 47 |

6.3 Surface Water Management

| 6.3.1 Objectives | 48 |
| 6.3.2 Management Strategy | 48 |

6.4 Groundwater

| 6.4.1 Objective | 49 |
| 6.4.2 Management Strategy | 50 |

6.5 Management of Impacts on Wanjarri Nature Reserve

| 6.5.1 Objective | 50 |
| 6.5.2 Management Strategy | 51 |

6.6 Management of Minor Impacts

| 6.6.1 Noise | 51 |
| 6.6.2 Dust | 52 |
| 6.6.3 Aboriginal Heritage | 52 |

6.7 Rehabilitation

| 6.7.1 Objectives of Rehabilitation | 52 |
| 6.7.2 Rehabilitation Strategy | 53 |
| 6.7.3 Rehabilitation Trials | 54 |
| 6.7.4 Decommissioning | 55 |

7. SUMMARY OF ENVIRONMENTAL COMMITMENTS

7.1 Basis for Achievement of Commitments

7.2 Summary of Commitments

| 7.2.1 Clearing of Vegetation | 56 |
| 7.2.2 Management in North-Eastern Goldfields | 56 |
| 7.2.3 Management of Wanjarri Nature Reserve | 56 |
| 7.2.4 Groundwater Monitoring | 57 |
| 7.2.5 Monitoring of Drainage Modification Effect on Vegetation | 57 |
| 7.2.6 Monitoring of Soil Erosion | 57 |
| 7.2.7 Stormwater Diversion | 57 |
| 7.2.8 Environmental Management System | 57 |
| 7.2.9 Assessment of Declared Rare Flora | 57 |
| 7.2.10 Pre-construction mulgara Trapping | 58 |
| 7.2.11 Long-term mulgara Research | 58 |
| 7.2.12 Rehabilitation Plan | 58 |
| 7.2.13 Aboriginal Sites | 58 |
| 7.2.14 Dust Control | 58 |

8. REFERENCES

| | 59 |
**LIST OF FIGURES**

<table>
<thead>
<tr>
<th>Figure No</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Location Map</td>
</tr>
<tr>
<td>2</td>
<td>Tenement Boundaries</td>
</tr>
<tr>
<td>3</td>
<td>Oblique Photograph Showing Minesite Layout</td>
</tr>
<tr>
<td>4</td>
<td>Alternative Sites Considered</td>
</tr>
<tr>
<td>5</td>
<td>Isometric View of Tailings after 6 Months Storage (Scale 1:1 (V:H))</td>
</tr>
<tr>
<td>6</td>
<td>Isometric View of Tailings after 16 Years Storage (Scale 1:1 (V:H))</td>
</tr>
<tr>
<td>7</td>
<td>Isometric View of Tailings after 16 Years Storage (Scale 20:1 (V:H))</td>
</tr>
<tr>
<td>8</td>
<td>Embankment Design</td>
</tr>
<tr>
<td>9</td>
<td>Stormwater Diversion System</td>
</tr>
<tr>
<td>10</td>
<td>Annual Rainfall Compared to Average Rainfall</td>
</tr>
<tr>
<td>11</td>
<td>Comparison of Rainfall Data for Wet and Dry Years</td>
</tr>
<tr>
<td>12</td>
<td>Flow Paths and Ponding Areas Throughout the Project Area</td>
</tr>
<tr>
<td>13</td>
<td>Regional Drainage in Relation to Wanjarri Nature Reserve</td>
</tr>
<tr>
<td>14</td>
<td>Regional Drainage in Relation to Barr-Smith Ranges</td>
</tr>
<tr>
<td>15</td>
<td>Hydrogeological Cross-Section</td>
</tr>
<tr>
<td>16</td>
<td>Palaeochannel Route</td>
</tr>
<tr>
<td>17</td>
<td>Land Systems</td>
</tr>
<tr>
<td>18</td>
<td>Land Units</td>
</tr>
<tr>
<td>19</td>
<td>Areas Surveyed for Flora, Fauna and Land Units</td>
</tr>
<tr>
<td>20</td>
<td>Topsoil Stripping and Storage</td>
</tr>
<tr>
<td>21</td>
<td>Rehabilitation Concept</td>
</tr>
</tbody>
</table>

**LIST OF TABLES**

<table>
<thead>
<tr>
<th>Table No</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Summary of issues - Executive Summary</td>
</tr>
<tr>
<td>2</td>
<td>Summary of environmental commitments - Executive Summary</td>
</tr>
<tr>
<td>2.1</td>
<td>Examples of centralised Discharge Tailings Disposal</td>
</tr>
<tr>
<td>4.1</td>
<td>Yeelirrie average rainfall</td>
</tr>
<tr>
<td>5.1</td>
<td>Impact on land systems</td>
</tr>
<tr>
<td>5.2</td>
<td>Comparison with ANZECC Guidelines for groundwater</td>
</tr>
</tbody>
</table>
### LIST OF PLATES

<table>
<thead>
<tr>
<th>Plate No</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DRMS Habitat Unit</td>
</tr>
<tr>
<td>2</td>
<td>HPMS Habitat Unit</td>
</tr>
<tr>
<td>3</td>
<td>SAMU Habitat Unit</td>
</tr>
<tr>
<td>4</td>
<td>WABS Habitat Unit</td>
</tr>
</tbody>
</table>

### LIST OF APPENDICES

<table>
<thead>
<tr>
<th>Appendix</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Tailings and Tailings Water Chemistry</td>
</tr>
<tr>
<td>B</td>
<td>Seepage Assessment and Modelling</td>
</tr>
<tr>
<td>C</td>
<td>Western Mining Corporation Environmental Policy and Mt Keith</td>
</tr>
<tr>
<td></td>
<td>Environmental Responsibilities</td>
</tr>
</tbody>
</table>
1. INTRODUCTION

1.1 Background

1.1.1 The Proponent

The Proponent for this project is Western Mining Corporation (WMC) Mt Keith Nickel Operations. Mt Keith Nickel Operations is wholly owned by WMC.

The address of the proponent is:

Mt Keith Nickel Operations
PMB 1
Leinster Western Australia 6437

1.1.2 Location

The Mt Keith Nickel Project is located within the Shire of Wiluna, at latitude 27° 15' and longitude 120° 35'. The operations are approximately 710 km north-east of Perth and 430 km north of Kalgoorlie. The nearest population centres are Wiluna, 90 km to the north, and Leinster, 90 km to the south (Figure 1).

1.1.3 Land Tenure

The Mt Keith Project is located within two active pastoral stations (Mt Keith and Albion Downs) which are leased and administered by WMC. Approval for the current nickel mining operations within the pastoral leases was granted via mining tenements issued under the Mining Act 1978. The mining operations are encompassed by 10 mining tenements, which are shown in Figure 2.

1.1.4 Current Operations at Mt Keith

The Mt Keith nickel mine is a substantial and long-term nickel project, with a production target of approximately 60,000 tonnes of nickel concentrate per annum. Mining is expected to be conducted over at least a 20 year period.

Current operations are based on open pit mining techniques. Overburden removal and process plant construction commenced at the site in March 1993 and was completed in September 1994. The mine and ore processing plant were commissioned on 29 September 1994.

The Mt Keith operation is licensed to process 9.0 million tonnes of ore per annum (Mtpa). Existing mining and processing infrastructure at the site comprise the following principal components:

- nickel ore open pit;
- two overburden dumps;
• ore processing plant (crushing and grinding, flotation concentrators, concentrate thickening, and filtration);
• Run-of-mine pad (to store mined ore prior to processing);
• process water ponds; and
• two tailings storage cells.

The layout of these facilities is shown in the aerial photograph of the site at Figure 3.

An on-site workforce of approximately 450 people is located at the Mt Keith Village situated 7 km to the south of the minesite.

Full details of the Mt Keith mining operations are provided in the original Notice of Intent (Australian Consolidated Minerals Ltd, 1990) and the Supplementary Report to the Notice of Intent (Nedpac-Kinhill Joint Venture, 1990). Both these documents are available for viewing at the Environmental Protection Authority library.

1.2 Project Scope and Timing

This proposal is for a new tailings storage facility (TSF) at the Mt Keith Operation. The proposal should be read in conjunction with the previously submitted, and approved, proposal documents listed below:

• Mt Keith Nickel Deposit Notice of Intent (Australian Consolidated Minerals, 1990);
• Mt Keith Nickel Deposit Notice of Intent Supplementary Report (Nedpac-Kinhill, 1990);
• Mt Keith Project Tailings Storage Design and Management Report (AGC Woodward-Clyde, 1994a); and
• Mt Keith Tailings Storage Site Selection Investigations (AGC Woodward-Clyde, 1994b).

1.2.1 Project Timing

The tailings deposition schedule requires that the TSF be available for deposition of tailings by November 1996, when the existing Cells 1 and 2 will be full. Construction would commence around April 1995 providing that all necessary government approvals be granted by that time.
1.3 Regulatory Approval Process

1.3.1 Responsible Authorities and Relevant Legislation

The decision making authorities who have an input to the Mt Keith Nickel Mine TSF are outlined below.

- Department of Minerals and Energy (DME)

  The DME controls the activities of extractive industries under the provisions of several Acts including the *Mining Act, 1978*, *Explosives and Dangerous Goods Act, 1961* and the *Mines Safety and Inspection Act, 1995*. It is a condition of the mining lease that before commencement of mining and ore processing, the lessee must submit a written proposal (Notice of Intent - NOI) to the DME for assessment. Once the assessment is processed and referred, a formal agreement to mine may be granted subject to payment of a bond and the setting of operating and environmental conditions. The DME's NOI procedure is the main assessment procedure used for mining projects in most parts of the State (Minerals Environment Liaison Committee, 1994).

- Environmental Protection Authority (EPA)

  The EPA has primary responsibility for environmental protection and regulation, and pollution control in Western Australia through the provisions of the *Environmental Protection Act, 1986*. The EPA routinely issues Works Approvals and Pollution Control Licences for mining operations.

- Water and Rivers Commission (WRC)

  The WRC, under the provisions of the *Rights in Water and Irrigation Act, 1914*, has the authority to issue licences for the extraction and use of groundwater.

- Department of Conservation and Land Management (CALM)

  CALM manages the Wanjarri Nature Reserve, an A Class Reserve located approximately 1.8 km south of the proposed tailings storage. CALM's involvement in this process is related to the assessment and management of potential impacts on Wanjarri. A Draft Management Plan has been written for the Reserve (CALM 1995).

Proponents must also comply with the relevant legislation and regulations administered by other State and Federal Government agencies including:

- *Wildlife Conservation Act, 1950*;
• Conservation and Land Management Act, 1984;
• Bush Fires Act, 1954;
• Aboriginal Heritage Act, 1972 - 1980 (in particular Section 18);
• Native Title Act, 1993;
• Australian Heritage Commission Act, 1975;
• Soil and Land Conservation Act, 1945;
• Agriculture and Related Resources Protection Act, 1976;
• Land Act, 1933; and
• Occupational Health, Safety and Welfare Act, 1984 (as amended).

1.3.2 Regulatory Consultation

WMC has been consulting with relevant government agencies on this proposal for more than a year. These consultations include the following:

• WMC’s Mt Keith Operations staff began discussions with officers from CALM in December 1994, on the issue of the sharing of resources and co-operative management of the nearby Wanjarri Nature Reserve;

• in April 1995, a Tailings Storage Study Team was established by WMC which included representatives from DEP and DME. The team met every month until December to investigate alternative storage methods, siting, design and the environmental aspects of tailings storage;

• in August 1995, a draft Memorandum of Understanding was prepared between WMC and CALM for the joint management of the Wanjarri Nature Reserve;

• discussions on the proposal have taken place between WMC and officers of the Water and Rivers Commission;

• the Shire of Wiluna and the local Pastoral Station Manager have been provided with summaries of the proposal.

1.3.3 Statutory Environmental Approval Process

In certain circumstances, the EPA may require a proposal to be assessed under Part IV of the Environmental Protection Act. One of four levels of assessment may be assigned to a proposal by the EPA. These are:
• Informal Review with Public Advice;
• Consultative Environmental Review (CER);
• Public Environmental Review (PER); and
• Environmental Review and Management Programme (ERMP).

Following a review of the NOI for the current proposal prepared by the proponent and submitted to DME and the EPA, the EPA determined that the proposal should be subjected to formal environmental assessment at the level of Consultative Environmental Review (CER).

The CER will be made available for public review for a period of 3 weeks during which submissions may be made regarding the proposal. At the conclusion of the public comment period the EPA will consider the proposal together with any public submissions. Submissions will be treated as public documents unless specifically marked confidential. The proponent will be asked to comment on any issues which are raised by the public, by way of a summary of issues prepared by the Department of Environmental Protection (DEP) on behalf of the EPA. Where appropriate, the proponent may amend the proposal and/or change the management commitments in response to comments raised during the review period.

When their assessment is completed, the EPA will prepare a report (Bulletin) which will summarise the issues and advise firstly, whether the project is environmentally acceptable and secondly, recommend appropriate conditions. Once released by the Minister for the Environment, anyone can appeal against the recommendations of an EPA assessment report within a two week period of its release.

The project can not proceed without the approval of the Minister for the Environment, who may also advise under what conditions approval is granted. Only the proponent can appeal against Ministerial conditions which, when set, are legally binding for the life of the project.

1.4 Schedule for EPA Assessment Process

The CER will be available for public review for the period 31 January to 21 February 1996. Following the public review period, the provisional agreed timetable (ie subject to third party appeals) for EPA assessment and preparation of the Bulletin is 4 weeks. This timetable will allow the Minister for the Environment to consider granting approval for the project in April 1996.
2. PROJECT JUSTIFICATION AND EVALUATION OF ALTERNATIVES

2.1 Rationale for Proposed New Tailings Storage Facility

Refinements made to operations at the ore processing plant at the Mt Keith mine site have resulted in an increase in tailings output from the initial start-up figure of 6.5 Mtpa in September 1994 to the current 8.5 Mtpa. As a result, the mining operations will produce more tailings over the life of the mine than originally estimated. Subject to approval, further increases in ore throughput are projected, with tailings output expected to reach 15 Mtpa during the 20 year life of the project. Greater tailings storage capacity is therefore required.

In order to provide an appropriate perspective for the proposed tailings storage upgrade, the current approved tailings storage system is briefly described prior to discussing the need for the new facility.

2.1.1 Current Tailings Storage

Currently the tailings are conveyed to, and deposited into, two storage cells located about 4km to the east of the mine. The tailings are contained within constructed embankments which are sequentially raised every 1 - 2 years to provide incremental increases in storage capacity.

Tailings are thickened prior to pumping to the two storage cells and discharged into each cell via outlets around the perimeter embankment. The two storage cells occupy areas of 111 hectares (ha) and 115 ha respectively. They are the first two of an initial design concept for a four cell paddock system to cater for tailings disposal over the projected life of the mine.

Overall, the four cells were expected to achieve storage of 130 Mt of tailings.

2.1.2 Need for Tailings Storage Upgrade

The engineering and environmental investigations for a 'best practice' storage facility at Mt Keith commenced in 1990 with a feasibility study into central thickened discharge disposal. Test work continued during 1992 and a tailings disposal options study was commissioned in 1993. As a result of these studies it was decided in 1994 to submit for assessment and approval a conventional four cell paddock storage facility. However, only two cells were to be built initially, with investigations into other forms of tailings management (such as the central discharge method) to continue.
In addition, the need to upgrade tailings storage capacity and operational flexibility has become more immediate due to a range of technical factors and revised projections for nickel concentrate production. Some of the primary factors are outlined below:

- The initial design life of the current storage cells was based on a tailings output of 6.5 Mtpa, whereas output has increased to 8.5 Mtpa as mentioned previously.

- For technical reasons the tailings are settling and compacting more slowly and are therefore occupying a larger proportion of the available storage volume per tonne of material than anticipated in the initial design.

- The sequential raising of the embankments around each cell will be significantly more expensive than first envisaged, because they will be raised by the ‘downstream lift’ method instead of the ‘upstream lift’ method. An upstream lift is the process by which the embankment of a tailings dam is increased in height by building on top of the existing embankment and the dried compacted tailings adjacent to the embankment. If the tailings are not dry or solid enough to support the weight of the ‘lift’, a downstream or centre-line lift must be adopted. This involves the addition of material both to the top of the existing embankment, and to the outside wall sufficient to support the lift. More material is required for a given height increase, compared with the upstream lift. It is therefore a more costly project.

- Further possible increases in nickel ore production and therefore tailings output are anticipated as mentioned previously. Whilst the initial four cell paddock system was envisaged to cater for 130 Mt total storage capacity, projected mining and production operations now indicate a tailings storage capacity of about 240 Mt is required.

The emergence of the above technical factors hastened a reassessment of tailings management planning. An immediate apparent solution would be to construct a further two storage cells, which have been approved under the original Mt Keith Nickel Project Mining Licence. However, the projected increased production at the mine means that the initial storage design of a four cell paddock system would also need to be substantially increased over time. A total of 8-10 cells could potentially be required, occupying an area of approximately 1300 ha.

In response to the above technical aspects, and in keeping with WMC’s commitment to best practice management, WMC’s Mt Keith Operations made a commitment in April 1995 to expedite the completion of investigations into all proven tailings discharge and storage technologies, with the objective of improving on current tailings storage practices. Whilst the impetus for this investigation
was to resolve the tailings storage issue at Mt Keith, any refinements achieved could be expected to have application elsewhere in WMC's operations.

2.2 Evaluation of Alternatives - Storage Method

2.2.1 Storage Method Selection

In early 1995 a study programme was established to finalise the detailed review of tailings systems and tailings management practices for WMC and Mt Keith in particular. This was prompted by the predicted future requirements in tailings storage capacity at Mt Keith and a belief that tailings management in Western Australia generally could be improved.

The scope of the programme included the following key elements:

- a literature review of available tailings storage and disposal methods;
- determination of the nature of the tailings material, its behaviour and characteristics, and the Mt Keith environs;
- field trials and laboratory testing to achieve the above;
- field trails to test proposed disposal concepts; and
- a review and analysis of the combined data and the design, planning and implementation of a tailings disposal facility for Mt Keith to suit the mine design life.

The literature review of available tailings storage and disposal methods was conducted by Gutteridge Haskins and Davey Pty Ltd (GHD 1995) on behalf of WMC. Various alternatives were examined on the basis of five criteria considered essential for the efficient and safe operation of the Mt Keith tailings storage. These were:

- **practicality** - feasible and constructible;
- **safety** - short and long term stability under static and dynamic loading and major storm events;
- **robustness** - capable of smooth operation with minimal supervision;
- **environmentally acceptable** - whether the storage is environmentally acceptable during operation and after mine closure; and
- **cost effectiveness**.
The review identified three potential methods of tailings deposition which might meet the above criteria. These were co-disposal (disposing of tailings and mining overburden together), a ring dyke structure (such as the existing two cell paddock-type storage), and a thickened and centralised discharge.

Although co-disposal of coarse mining overburden with fine process tailings has a number of theoretical advantages (such as the use of less space to dispose of mining wastes, and facilitation of the rehabilitation process), this method is unsuitable for Mt Keith for two main reasons. Firstly, the method is best suited to using 'hard' rock overburden waste, which has sufficient void volume (i.e., spaces between the rock fragments) to contain the finer tailings particles. The overburden at Mt Keith does not have a high void volume, and also has a relatively high moisture content, thus limiting the amount of tailings that can be co-disposed with the rock. Secondly, unlike the other two disposal methods, co-disposal has not been put into practice on a production scale and more testing and research would be required to determine its viability as a large scale storage option.

The co-disposal theory has other problems associated with it, such as the difficulty in matching the production of tailings and overburden to achieve the optimum mixture for disposal, and the conveying of the mixed material to the disposal site in a safe manner. Co-disposal was therefore discounted as a tailings disposal option at Mt Keith.

Having narrowed the field of disposal options, further investigations and field trials were conducted. These included laboratory testing of tailings to determine their mineralogy (chemical characteristics), rheology (flow characteristics) and settling properties, and field work to measure tailings flow, settling, drying and compacting properties. Full details of the results of these tests and analyses are presented in the GHD report (Gutteridge Haskins and Davey, 1995).

From the study programme it was concluded that centralised thickened discharge of the tailings from multiple discharges (such as the proposed TSF) has significant cost and environmental advantages over conventional upstream raised ring dyke storage.

A brief description of the proposed storage facility is included below in order to identify some of the key benefits in comparison to the existing storage method at Mt Keith. (A more detailed description of the proposal is provided in Section 3.0).

2.2.2 Proposed Tailings Storage Facility

The proposed new storage facility will use a thickened and centralised method of tailings discharge to the storage area. The fundamental differences to the existing cell storage system in operation at Mt Keith are as follows:
• the tailings will be discharged from central 'risers' (vertical, extendable pipes) in comparison to the current perimeter discharge system on the embankment walls;
• the tailings will settle to form a low conical mound around each riser in comparison to the existing 'artificial' stacking method in which the lateral spread of the tailings is contained within high embankments;
• the new storage facility will comprise of nine risers (hence nine low, conical mounds of tailings) which will provide more disposal flexibility for the duration of the mining operations, in comparison with the current method which requires periodic construction of new cells or raising of embankment walls;
• the new facility will essentially be a single circular storage surrounded by a low embankment (once-only construction), and having an area of approximately 1700 ha in comparison to an expanded paddock cell system which would encompass approximately 1300 ha.

The proponent's project team believes this is the best available technology for tailings management at Mt Keith. Experience elsewhere is summarised below.

2.2.3 Comparison with Tailings Storages of Similar Types

Whilst the disposal of tailings using the centralised thickened discharge method is relatively new, there are a number of examples where the technique is utilised successfully and represents current best practice.

The proposed Mt Keith tailings storage upgrade remains unique in WA, however as outlined in Table 2.1, a number of other mining projects use similar disposal methods.
### TABLE 2.1
EXAMPLES OF CENTRALISED DISCHARGE TAILINGS DISPOSAL

<table>
<thead>
<tr>
<th>Type</th>
<th>Locations</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Disposal</td>
<td>Pinjarra</td>
<td>Thickened tailings discharge into conventional storage. Maximises evaporative drying and storage capacity and reduces environmental risk and potential for seepage.</td>
</tr>
<tr>
<td>Central Thickened</td>
<td>Elura</td>
<td>Drilling and testing at Elura demonstrated that a ‘dry’ stack was achieved and therefore no potential for seepage. Oxidation and acid generation potential was also reduced.</td>
</tr>
<tr>
<td>Discharge</td>
<td>PeakGold Bougainville</td>
<td></td>
</tr>
<tr>
<td>Thickened Tailing</td>
<td>Les Mines Selbari, Quebec</td>
<td>Normal tailing behaved like a two phase mixture was thickened to 55 to 70% before discharge via central stack. Resulting cone was amenable to rehabilitation and stable. Method resulted in lower operating cost and larger solids capacity in existing facility.</td>
</tr>
<tr>
<td>Disposal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thickened Tailings</td>
<td>Denison Mines, Ontario</td>
<td>Centralised thickened tailings were deposited to an active conventional tailing storage for uranium mill tailings. The discharge of thickened tailings provided a beach slope of 5% thereby increasing surface run-off, minimising infiltration and providing good surface drainage for future vegetation.</td>
</tr>
<tr>
<td>Disposal</td>
<td>Kidd Creek Bauxite</td>
<td>showed that disposal capacity of an area can be increased substantially. The sloping surface permits quick run-off and allows evaporation to assist the consolidation process, even in a wet environment. Re-vegetation procedures were facilitated by adding fertiliser and seed to last layer of tailings to be deposited.</td>
</tr>
<tr>
<td>Tailings</td>
<td>Tailings, Toronto</td>
<td></td>
</tr>
</tbody>
</table>

### 2.3 Benefits of the Proposal

The environmental benefits of the tailings proposal are outlined below, followed by a summary of the overall benefits of the Mt Keith Nickel Project.

#### 2.3.1 Key Environmental Benefits

The environmental advantages of the thickened, centralised discharge storage facility are considered to represent a substantial improvement over the current system.

It is considered that the principal benefit derives from the fact that tailings water drains more readily from a centralised discharge storage than a ring dyke dam, thereby eliminating the creation of a permanent perched water table within the tailings. A perched water table causes water to seep through the floor of a storage facility, and its absence in the centralised discharge option will therefore significantly reduce the potential for seepage. The absence of a perched water table also reduces waterlogging and leads to less rise of saline water by capillary action and this is expected to facilitate the final rehabilitation works.

Other key benefits are listed as follows:

- more efficient for process water and stormwater recycling, reducing demand on the underlying groundwater supplies;
- improved stormwater management within the storage area, including a reduction in the potential for stormwater contamination via infiltration through the tailings;
- improved settled density of the tailings leading to greater stability and reducing the risk of liquefaction;
- improved landscape character of final 'landform' in comparison to conventional cell storages with high embankments; and
- more amenable to rehabilitation.

2.3.2 Benefits of the Mt Keith Project

The Mt Keith Nickel project is a substantial and long term nickel project in Western Australia, with a production goal of approximately 60,000 tonnes of nickel concentrate per annum.

The Mt Keith tailings upgrade is a one-off project designed to accommodate the present and future tailings disposal requirements of the operation. The proposed tailings upgrade is the result of a $2 million study initiated to ensure the storage will be an example of a responsible development and is compatible with the environmental values of the area, amenable to rehabilitation, and has a reduced potential for seepage. It has also been designed to be easy to manage, efficient in recycling water, safe and compatible with the surrounding topography.

The Mt Keith tailings storage upgrade, designed to cater for the increase in production throughput, will contribute to an increase in the economic benefits of the Mt Keith Nickel Project through:

- the State Government receiving additional revenue in the form of royalties, payroll tax and other charges;
- increased income flow to the Federal Government through tax revenue (personal income tax and corporate tax);
- increased demand for goods and services which will generate income and create opportunities for other Australian business sectors;
- increased employment and the social and financial benefits that flow from that; and
- technological improvements in the art of tailings storage.

Materials used during construction will be sought from Western Australia.
2.4 Evaluation of Alternatives - Site Selection for New Storage Facility

2.4.1 Location Factors

A number of studies have been carried out to identify the preferred location for the TSF (e.g., AGC Woodward-Clyde, 1994). Five general areas were considered (Figure 4). A number of factors were considered when selecting the site, including:

- location relative to present infrastructure;
- adequate area for sufficient storage;
- tenement boundaries;
- foundation conditions with respect to seepage;
- groundwater conditions;
- the presence of seepage pathways;
- surface water conditions;
- topography with respect to initial embankment construction;
- archaeological and ethnographic considerations; and
- potential for future mining of the site.

Within the constraints imposed by the above, a final selection process was undertaken, with the site chosen having the following advantages over others considered:

- it avoids the Barr-Smith Ranges and other sites of environmental significance;
- the topography (gentle slopes) is suitable for the construction of a tailings storage facility;
- it avoids the nearby Wiluna - Leinster Road;
- it is at least 2 km from the Village (to minimise dust at the Village);
- it is at least 2 km from the Goldfields Gas Pipeline (to avoid risk or interference with the Pipeline);
- it has deep tight clays which minimise the potential for seepage.
it is located within land systems (Monk and Bullimore) which are not highly sensitive to disturbance and are well represented in Wanjarri Nature Reserve; and

it avoids sensitive land units and rare flora and fauna habitat types.

A brief discussion indicating why the alternative sites are considered unsuitable, or less suitable than the chosen site, follows.

The known occurrence of significant Aboriginal sites in the Bar-Smith ranges to the west and in the breakaways to the north and north east makes these sites less suitable for waste disposal.

**Western site**

The western site is suitable with regard to its proximity to the western waste dump for construction material.

The site is not suitable due to its undulating topography with steep slopes, incised drainage lines and unsuitable foundation conditions.

**Northern and north eastern sites**

The proximity of the northern and north eastern sites to the process plant was considered advantageous.

However the presence of rock outcropping, breakaways, deeply incised drainage lines, near surface granite and fractured foundation conditions makes these sites unsuitable from the construction and hydrogeological viewpoints.

**Southern site**

The southern site is similar in topography, hydrology, hydrogeology and foundation conditions, to the selected TSF site.

However, the southern site and surrounding area is unsuitable due to the proximity to the Mt Keith Village and infrastructure including the airstrip and potable water borefields.

Location of the TSF within this area would also restrict the potential for expansion of the eastern waste dump, southward. The area is also restricted by tenement holdings and the north western boundary of the Wanjarri Nature Reserve.

**2.4.2 Timing Factors**

Mining is expected to be conducted over a 20 year period to a depth of 300m below ground level. Exploration drilling has confirmed nickel mineralisation to 500m depth and it is anticipated that the actual mine life will be in excess of 20 years (Nedpac-Kinhill Joint Venture, 1990).
The current two storage cells were originally intended to provide sufficient storage to the end of year 10 (2004), for a maximum design embankment height of 20 m. At the current embankment height and rate of tailings generation, the two cells will be ‘full’ by the end of October 1996.

The new facility will cater for tailings storage for the balance of the mine’s lifetime, including possible extended mining beyond the currently projected 20 year period.
3. **PROJECT DESCRIPTION**

3.1 **The Centralised Discharge Storage Concept**

3.1.1 **Overview**

The proposed TSF will consist of a perimeter containment embankment (3 m high on the western side rising to 5 m on the eastern side) carrying a ring main distribution line which will feed nine risers located centrally within the storage. The storage is circular, having an average diameter of 4,600 m, an area of approximately 1,700 ha, and an approximate 12 m to 14 m fall in natural surface elevation from west to east across the storage.

3.1.2 **Deposition Strategy**

The tailings will be deposited mostly from the central risers. Some tailings may also be deposited from the ring main to seal and protect the upstream face of the perimeter wall, and to form an inward sloping beach. The tailings deposited from the central risers will form cone shaped mounds which will grow radially to eventually cover the storage area (Figures 5 - 7).

The formation of shallow beach slopes to cover as much of the natural surface as possible in Year 1 is considered advantageous. This will seal the floor of the storage with low permeability tailings and thereby further reduce the potential for seepage to groundwater. Therefore during operation of the tailings storage, the following average beach slopes are predicted:

- Year 1 - 1.5% to 2.0%;
- Years 2 and 3 - increasing from 2% to 2.5%; and
- Year 4 onwards - 2.5 to 3%

Discharge will be primarily from one central riser and up to eight subordinate risers. This number of risers is required to 'grow' the mounds in a stable and orderly manner. Deposition of the tailings will generally occur from 3 - 4 risers simultaneously. During riser changeover, risers will be flushed to prevent blockage.

3.1.3 **Underdrainage**

The tailings will mostly be pumped to the storage area in a water 'slurry' comprising approximately 45% solids. As the solids settle on the storage mounds, the slurry water (or supernatant water) will be recycled to the processing plant for further tailings transport.

A system of collector trenches and slotted pipe underdrains will be situated over the floor of the storage and used to collect both supernatant water and water expressed during tailings consolidation, and return it to the decant structure. The effectiveness of the drains will diminish with time due to tailings consolidation and subsequent decrease in permeability, at which
time potential seepage is greatly diminished due to the sealing effect of the tailings.

The underdrainage system will also minimise the potential for seepage and assist the consolidation of the tailings.

3.1.4 Supernatant/decant Water

Supernatant water will be collected in a concrete sump and pumped via a pipeline to the existing return water pond, from where it will be reused in the process. The decant system is designed to minimise evaporation and the volume of standing saline water by maintaining the pond over a minimum area. During normal operation, there is no standing water except in the sump itself.

In order to promote supernatant run-off along the shortest route to the decant sump, deposition will be carried out such that the central cone is always higher than the outer cones, and the (outer) western cones are always higher than the eastern cones.

Data describing the quality of decant water is included in Appendix A.

3.1.5 Stormwater Retention

The perimeter embankment over the eastern (or downstream) section of the storage is designed as a water retaining structure, having an upstream impermeable clay zone, a central cut off trench incorporating a seepage interception drain and a downstream blanket drain (Figure 8). The central decant areas of the existing storage cells (Cells 1 and 2) could also be used to temporarily store water, as long as only the central part of each cell is used.

The TSF is designed with sufficient capacity to contain the run-off from a 1 in 100 year, 72 hour storm event without releasing water to the environment. An overflow structure is incorporated to handle a storm event in excess of this. Under such conditions the large dilution provided by natural run-off would reduce salinity to insignificant levels.

Stormwater will be retained in the storage and returned to the plant as required. Stormwater may stand in the storage for up to 6 months given that the volume of water expected from a 1 in 100 year 72 hour storm event would yield an initial ponded water depth of up to 4.5 m. A design freeboard of 0.5 m is provided for this major storm event. The salinity will be lower than normal decant water due to dilution.

3.1.6 Operation and Maintenance

The proposed TSF is designed for minimum maintenance. The storage will be monitored and managed to ensure that it runs correctly. Areas requiring maintenance are:
- internal drains, which will require periodic unblocking to ensure that no water ponding occurs;
- filters within the drainage system, which may become covered with tailings;
- the decant sump, which will require periodic cleaning; and
- the pumping and flushing systems.

Maintenance of perimeter drains will continue after decommissioning until vegetation is sufficiently established to no longer warrant it.

Access ramps will be provided into the body of the storage. It is envisaged that a long reach excavator or backhoe will be retained specifically for maintenance work.

After decommissioning, the stormwater will still be captured and retained within the TSF. Net evaporation at a rate of approximately 3.6 m per year will ensure that the stormwater pond, which will have a maximum depth of 4.5 m after a 1 in 100 year event, is evaporated within a year or two after the storm event.

3.2 Design of External Stormwater Diversion System

3.2.1 Stormwater Management Requirements

Given the large areal extent of the proposed storage facility, particular attention has been devoted to stormwater management peripheral to the site. The facility potentially ‘blocks’ or interrupts the natural flow paths of stormwater drainage to the east of the facility.

In addition, the northern section of the facility is located ‘downstream’ of existing mine infrastructure, notably the two tailings cells, the east waste dump, and the mine pit. Therefore, the stormwater management design also includes upgrading of existing drainage around the waste dumps, plant and pit.

The general philosophy of stormwater management is to ensure diversion of run-off around the northern and southern ends of the tailings facility with the objectives of:

- minimising the ‘blocking’ of natural drainage patterns to protect the downstream biological environment;
- avoiding the flooding of mine facilities, including the airport and Mt Keith Operations Village; and
- minimising erosion and sediment transport due to concentration of run-off in erosion-prone areas.
3.2.2 Design Approach

The stormwater drainage has been designed to cater for storms of 1 in 100 year Average Recurrence Interval (ARI). The drain locations are shown on Figure 9.

Methods for predicting peak discharge rates from catchments, and maximum volumes yielded, are described in Australian Rainfall and Run-off (AR&R) (Institution of Engineers, Australia, 1987). Required capacities of the drainage channels were determined using the Rational Method for the ‘Arid Interior’ as described in AR&R.

In the areas where estimates of run-off volume are more critical than rates of run-off, the AR&R method for predicting total rainfall excess was based on ‘Arid Interior - Eastern Goldfields - loamy soil’.

In recognition of the fact that run-off prediction is not an exact science, a conservative approach has been adopted to drainage design and refinements will be made as further information becomes available.

3.3 Identification of Environmental Issues

Previous sections of this report have described the main elements of the proposed TSF and have also provided comparisons with the existing storage cell method in use at Mt Keith. In addition, the environmental benefits of the new storage method have been highlighted (refer Section 2.3).

The environmental issues which have been addressed during the design of the facility, and which require management attention during construction and operation, are identified below. This list of issues is intended to provide a background perspective to the remainder of the report, for example, the relevance of the various components of the existing environment described in Section 4, and the subsequent impact assessment and management sections.

In broad terms, the environmental issues associated with the new tailings facility are mostly the same as for the current two cell storages approved and in use at Mt Keith. The main difference relates to the increased scale of the proposal; the existing tailings cells occupy an area of almost 230 ha whilst the new facility will encompass an area of about 1,800 ha (including perimeter roads and drains).

However, it must be emphasised that the existing cell storage system would also require substantial enlargement to cater for future tailings output. In the event that this method was retained at Mt Keith, the final storage configuration would involve at least 8 cells encompassing an area of about 1,300 ha, as previously mentioned.
The environmental issues have been grouped according to whether they represent direct effects (at the facility site and due to operations within the site) or indirect effects (in areas peripheral to the storage site).

1. **Summary of Environmental Issues Related to Direct Effects**

- Avoidance of sensitive or high conservation value environments (site selection);
- Loss of flora and fauna (or re-location of fauna) from the 1,800 ha disposal site;
- Integrity of regional vegetation associations and land systems (or land units);
- Potential seepage of tailings slurry water to underlying groundwater systems;
- Blocking of surface drainage patterns and capture of rainfall within the impoundment; and
- Post-mining land use - rehabilitation of site and restoration of landscape.

2. **Issues Related to Indirect or Off-site Effects**

- Changes to surface drainage patterns affecting biological environments in downstream areas of the catchment (drainage ‘shadow’ effects);
- Ensure protection of nearby Wanjarri Nature Reserve (eg potential hydrological changes - surface drainage, groundwater system);
- Potential for noise and dust emissions; and
- Long-term stability of tailings mounds (eg potential for liquefaction and loss of tailings from within the impoundment).
4. EXISTING ENVIRONMENT

4.1 Historical and Current Land Use

Pastoralism has been the predominant land use in the project area since the Mt Keith Station and Albion Downs Stations were established around the turn of the century. Bores established for stockwatering, stock routes, and degraded vegetation feature amongst the landscape changes brought about by grazing over many years.

Following the area’s establishment as a goldfield during the 1890s, mineral exploration has been ongoing. Nickel sulphides were discovered in the region in 1968 by Mr Jim Jones, a local pastoralist. This lead to exploration interest which identified the ore body currently being mined at Mt Keith and other prospective areas, predominantly to the west of the project area.

The mining leases which cover the project area were in the ownership of several companies in association between 1969 and 1988 when the previous owners Australian Consolidated Minerals (ACM) carried out a full feasibility study for a nickel mining operation.

WMC acquired the project from ACM in September 1991, commenced pre-stripping in 1993 and commissioned mining operations in September 1994. The project area now incorporates infrastructure for the nickel mining operation, including road and air transport facilities, and has an on-site work force of 450 people located at the Mt Keith Village 7km south of the mine site.

Nature conservation is the third significant land use in the general project area. The Wanjarri Nature Reserve (A30897), comprising approximately 53,000 ha, is located to the south of the project area. The Reserve is managed by CALM for the purpose of wildlife and landscape conservation, for scientific study, and for preservation of features of archaeological, historic or scientific interest, in accordance with the Wanjarri Nature Reserve Draft Management Plan (CALM 1995).

The Reserve is currently an A Class Nature Reserve for the conservation of flora and fauna, and is vested in the National Parks and Nature Conservation Authority. The Draft Management Plan recommends that the classification of the land be changed to Conservation Park, in order to allow camping, which is illegal but currently occurs, to be carried out legally.

4.2 Climate

4.2.1 Rainfall

The climate of the Mt Keith area is semi-arid with a long term average annual rainfall of approximately 220 mm (Mt Keith average
218 mm, Albion Downs 225 mm, Yakabindie 207 mm). Significant rainfall events are usually associated with thunderstorms or dissipating tropical cyclones between December and April, but rainfall is also received occasionally from northward straying depressions between May and August. Rainfall is historically low and unreliable. Rainfall records for Yeelirrie, located approximately 100 km west of Mt Keith, are shown in Table 4.1.

**TABLE 4.1 - AVERAGE RAINFALL DATA FOR YEELIRRIE (1928-1993)**

<table>
<thead>
<tr>
<th>Month</th>
<th>Average Rainfall (mm)</th>
<th>Monthly Mean</th>
<th>Number of Raindays</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>27.0</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>February</td>
<td>25.5</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>March</td>
<td>30.8</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>April</td>
<td>22.4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>26.4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>June</td>
<td>24.9</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>July</td>
<td>16.6</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>August</td>
<td>13.3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>September</td>
<td>4.6</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>October</td>
<td>8.0</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>November</td>
<td>8.3</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>December</td>
<td>16.4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>226.0</td>
<td>40</td>
<td></td>
</tr>
</tbody>
</table>

The frequency of tropical cyclone dissipation over the area is variable between years, as is the quantity of rainfall delivered by individual rainfall events. Figure 10 shows total annual rainfall compared to the long term average, and Figure 11 compares average monthly rainfall data to monthly data for the year 1950, which was a ‘dry’ year, and 1992 which was a ‘wet’ year. These data highlight the considerable variability of rainfall in this area.

**4.2.2 Temperature**

Daily maximum temperatures frequently exceed 40 °C between November and March. Winter minimum temperatures average 6 °C in July, but sub-zero temperatures (down to about -5 °C) are not uncommon (eg at Yeelirrie). There are quite extreme diurnal temperature ranges in the spring and autumn months.

**4.2.3 Wind**

The predominant winds in the region are from the east and north-east, however, during the spring months (September to November) the winds shift in the afternoon to the west and north-west.

**4.2.4 Evaporation**

High temperatures and low humidity throughout much of the year produce an average yearly pan evaporation rate for the region of 3,800 mm. Average evaporation exceeds average rainfall in all months of the year.
4.3 Geology

The Mt Keith Nickel Project lies within the Murchison province of the Archaean Yilgarn Block. The nickel sulphide ore is found in the north-north-west trending Agnew Wiluna Greenstone Belt which dominates the regional geology. Linear greenstone belts are separated by large areas of granitoid rocks, formed by sequences of metamorphosed sedimentary, volcanic and intrusive rocks. The greenstone belts are tightly folded along north-north-west to north-north-east trending axes, having undergone low to medium grade metamorphism and are displaced by major strike faults.

There is the potential for lower grade mineralisation to occur to the west of the main Mt Keith ore body. To the east, however, the near surface rock, to a depth of at least 500 m, is barren of commercial grades of mineralisation. The greenstone belt continues to the north and south (trending slightly north-north-west and south-south-east) and again there is significant potential for mineralisation and, hence, additional mines.

4.4 Landforms, Topography and Soils

The project area lies within a broad valley flanked to the west, north and north east by low hills and breakaways.

The valley landforms may generally be described as broad stony and gravelly plains with gentle slopes and low relief, at RL 520 to 535 mAH D.

Topographically distinct local features include the Barr-Smith Ranges which are located approximately 10 km to the west and rise steeply to 30 m height above the plain, Mt Keith and associated hills some 8 km to the north, and an area typified by breakaways which can rise to 10 m above the plain, located approximately 3 km to the north-east.

Five typical soil types are recognised in the Mt Keith area. These are:

- shallow stony earth loams on greenstone hills;
- red earthy sands on upland sandplains with red sands on occasional dunes;
- earthy loams and shallow earthy loams overlying red-brown hardpan on undulating terrain; and
- shallow acid or neutral red earths on extensive flat and gently sloping plains.

Additional descriptions of local landforms are given in Section 4.7 which describes the area in terms of the land classification system.
which has been developed for the area by the Western Australian Department of Agriculture.

4.5 Surface Water

As a result of the low annual rainfall (average 220 mm), and the very high annual evaporation (3,800 mm) there is no permanent surface water in the project area.

However, as is typical for semi-arid areas within the inland reach of cyclonic depressions, short periods of intense rainfall, whilst infrequent, are typical. They combine with the flat topography and low relief to cause significant surface water flows comprising both stream flows in identifiable drainage lines, as well as sheet flow and localised short term flooding.

Figure 12 presents a map of flow paths and ponding areas for surface drainage within the area proposed for tailings disposal and its surroundings. This map has been developed from topographic analysis together with vegetation and habitat analysis.

Figures 13 and 14 show surface water drainage paths for the wider locality.

4.6 Groundwater

Three aquifers are known in the project area. These are:

- a shallow unconfined aquifer developed within the alluvial surface sediments, with a thickness of approximately 10m and a water table 14m to 18m depth below ground surface;

- a tertiary semi-confined palaeochannel (ancient river) aquifer which has been identified and evaluated by drilling, previous abstraction experience and electromagnetic survey. The palaeochannel follows a discrete path through the project area and lies 60 to 80 m below the ground surface. It is generally 6 to 8 m thick and 100 to 150 m wide, and has been locally mapped over 25 km of its length and forms the South Lake Way Wellfield. Hydraulic discontinuities where palaeochannel sands form a series of pods, or have high clay content, have been identified within the project area from drilling data;

- a deep fractured rock aquifer confined by low permeability clay sediments which has developed within oxidised granitic sediments.

Figure 15 presents a generalised hydrogeological cross section through the project area whilst Figure 16 maps the location and path of the palaeochannel.

As it is recharged by rainfall infiltration, water quality in the superficial aquifer has relatively low salinity and is classified as
subpotable (below human drinking water standard), having a salinity in the range 700 to 1500 mg/L of total dissolved solids.

Water quality in the palaeochannel aquifer, being locally recharged from the superficial alluvial aquifer, is also regarded as subpotable and has a similar water quality to the superficial aquifer.

Two process bores source their supply from the superficial and palaeochannel resource in the proposed tailings disposal area. These are bores SLW1 and SLW2. These bores are to remain in place to be used for early monitoring and plume recovery, if required, and will be sealed off when no longer required. There are no other users of this aquifer in the close vicinity of the project area.

4.7 Land Systems

Recognising previous research and land system analysis carried out by the Western Australian Department of Agriculture, it is convenient to describe the area based on the land system and land unit classification system which has emerged from that work.

The land systems, land units and habitat units of the North-eastern Goldfields have been described by Pringle et al, (1994), and the sensitivity and conservation of those land systems and land units within a 50km radius of the Mt Keith Operation have been identified by van Vreeswyk (1995).

The following section provides land system and land unit descriptions for an area which includes the proposed tailings disposal site and extends 2km north west and south, and over a 7.5km wide area to the east which follows the course of surface drainage and the palaeochannel.

Figures 17 and 18 show the land systems and land units surrounding the Mt Keith Operation respectively.

Land systems and land units were graded on their sensitivity to disturbance based on their soil susceptibility, pastoral value, protection by stony mantles, run-on (surface water flow) and slope. The conservation value of each land system was assessed based on their association with declared rare and endangered flora, distribution within the North-eastern Goldfields, reservation within the Wanjari Nature Reserve and resource condition.

Monk Land System

This land system consists of very gently inclined wash plains with occasional wanderrie (local grasses) banks in topographically lower areas, and forms around 75 - 80% of the area of ground (‘footprint’) of the proposed TSF. The Monk land system is widespread in the North-eastern Goldfields area. Important local features include:
• Predominantly plain underlain by hardpan unit (PLH - moderate sensitivity to soil erosion due to sheet run-on) supporting mulga shrublands/woodlands habitat unit (HPMS);

• also loamy plain land unit (PLO) supporting wanderrie bank mulga grassy shrublands (WABS) habitat unit;

• minor areas of the narrow drainage line land unit (DRN - high sensitivity to soil erosion by concentrated run-on) with drainage tract mulga shrublands/woodlands habitat unit (DRMS);

• minor areas of sandy bank land unit (BAS - low sensitivity) supporting wanderrie bank mulga grassy shrublands habitat unit (WABS);

• minor areas of vegetation grove on hardpan or granite land unit (GRO - low sensitivity) supporting groved mulga shrublands/woodlands habitat unit (GRMU);

• The eastern tip of this area enters the northern boundary of the Wanjarri Nature Reserve.

• not known to be associated with any declared rare or priority listed plant species;

• represented within the Wanjarri Nature Reserve;

• areas of Monk land system located east and west of proposed TSF are associated with the palaeodrainage.

**Bullimore Land System**

The Bullimore land system consists of extensive gently undulating sandplains with reticulate or parallel dunes, and occupies approximately 15 - 20% of the footprint of the proposed TSF. Important features include:

• widely distributed within the north eastern Goldfields;

• mainly loamy plain land unit (PLO - low sensitivity to erosion) supporting both sandplain hummock grassland with mulga overstorey (SAMU) and mulga wanderrie grassy shrublands (MUWA) habitat units;

• also sand sheet land unit (SSH - low sensitivity to erosion) supporting both sandplain hummock grassland with mulga overstorey (SAMU) and sandplain spinifex hummock grassland (SASP);

• known to support one declared rare flora species, Victoria Desert Smokebush *Conospermum toddi* and one declared rare fauna species the mulgara *Dasycercus cristicaudata*. 
although no survey within the Mt Keith area has ever confirmed their presence, this land system is known to be associated with nine priority listed flora including *Acacia eremophila var. variabilis*, *Calytrix creswelli* and *C. praecipua*, *Dampiera ramosa*, *Desert Wandoo Eucalyptus pimplana*, *Lepidobolus deserti*, *Lambs Tails* *Newcastelia insignis*, *Philotheca tubiflora*, and the Feather Flower *Verticordia interioris* (van Vreeswyk, 1995);

- the majority of these rare and priority flora and fauna species are known to be associated with the deeper sandy soils of the sand sheet unit, none of which lies within the footprint or indeed the study area discussed here.

**Ararak Land System**

This land system consist of level to gently undulating plains with mantles of fine ironstone gravel. It is widely distributed in the North-eastern Goldfields and occupies the remaining 5% (approximately) of the footprint of the project. Important features include:

- plain ironstone gravel land unit (PLL - low sensitivity), supporting lateritic mulga wanderrie grassy shrubland habitat unit (LMWS);
- minor areas of the narrow drainage line land unit (DRN - moderate sensitivity);
- minor areas of hardpan or granite land unit (GRO - low sensitivity) supporting groved mulga shrublands/woodlands habitat unit (GRM)
- significant areas reserved within Wanjarri Nature Reserve;
- not known to be associated with any declared rare or priority listed plant species.

**Desdemona Land System**

This land system is represented at the north east extent of the study area well beyond the footprint of the proposed TSF. It consists of extensive plains with sandy surfaces and very few surface drainage features. Important features include:

- Wide distribution through the North-eastern Goldfields
- associated with the palaeochannel in areas with narrow drainage line land unit (DNR) supporting drainage tract mulga shrublands/woodlands habitat unit (DRMS);
• also loamy plain unit (PLO) supporting mulga wanderrie grassy shrublands habitat unit (MUWA).

Sherwood Land System

The Sherwood system is one of the most common land units in the North-eastern Goldfields. It occurs within the Wanjarri Nature Reserve, and to the north and east of the proposed tailings storage. Important features are:

• some priority plant species are known for this land system, however habitat units which typically support these species do not occur within the study area;

• granite breakaways, and extensive stony granite plains (PLG), low sensitivity to disturbance;

• mulga shrublands and minor halophytic shrublands;

• minor drainage line land unit (DNR) - moderate disturbance sensitivity due to soil erodibility and concentrated surface water flow;

• drainage tract mulga shrublands/woodlands habitat unit (DRMS).

Violet Land System

This land system comprises undulating plains with stony and gravelly mantles and low rises. There are two areas within the study area, but none fall within the footprint of the proposed TSF. Prominent features include the following:

• Three component land units are recognised - low rise land unit (RIL) supporting stony ironstone mixed shrublands habitat unit (SIMS); ironstone gravel land unit (PLL - low sensitivity) with sandplain hummock grassland with mulga overstorey (SAMU); and narrow drainage line land unit (DRN - moderate sensitivity due to soil erosion risk under concentrated surface water flow conditions) with drainage tract mulga shrublands/woodlands habitat unit (DRMS).

• not represented in the Wanjarri Nature Reserve;

• relatively common in the north-eastern goldfields;

• not known to support any declared rare or priority listed plant species

Jundee Land System

This land system consists of level to gently inclined wash plains with mantles of fine ironstone gravel. It is widespread in the North-
eastern Goldfields and, while in the study area, is not in the footprint of the proposed TSF. Important features include the following:

- plain underlain by hardpan land unit (PLH - moderate sensitivity due to soil erosion by sheet flow run-on) with hardpan mulga shrublands/woodlands habitat unit (HPMS);
- minor areas of the narrow drainage line land unit (DRN - moderate susceptibility to disturbance) supporting drainage tract mulga shrublands/woodlands habitat unit (DRMS);
- no known declared rare or priority listed flora

4.8 Vegetation and Flora

Whilst specific surveys of the vegetation of the project area have been undertaken by Dunlop et al (1989), Pringle (1995) and Cockerton (1996) it is convenient to describe the area's vegetation and flora on the basis of the land system categories described in the previous section. In this regards emphasis is now focused on the area directly affected by the footprint for the TSF. Areas covered by these surveys are shown on Figure 19.

4.8.1 Monk Land System

On the Monk land system, the predominant land unit for the project area is a loamy plain supporting mulga wanderrie grassy shrublands (Plate 4). The vegetation has a well developed mulga (Acacia aneura) tall shrub or low tree overstorey, prominent understorey shrubs including Eremophila forestii, E. spectabilis and Ptilotus obovatus, and a well developed wanderrie grass layer. Perennial low shrubs and grasses usually dominate the vegetation. The condition of this habitat on the site is often fair to poor, with accelerated soil erosion and often dead overstorey with patchy regeneration.

The next most common land unit is a drainage tract, supporting drainage tract mulga grassy shrublands/woodlands (Plate 1). This is a moderately close tall shrubland or low woodland of mulga, with a scattered understorey of isolated plants with diverse and abundant annual herbs in good seasons.

Within the drainage tracts are sandy banks, supporting similar vegetation to that described above for the loamy plain. Flanking the drainage tracts are areas of hardpan on granite, supporting groved mulga shrublands/woodlands, with groves of thickly vegetated mulga but poorly developed understorey, and large inter-grove areas with little perennial vegetation. The groves develop along contours, and accumulate water and nutrients disproportionately.

The other land unit in the area is the hardpan land unit which supports a hardpan mulga shrubland/woodland (Plate 2). Vegetation consists of scattered to moderately close mulga tall shrublands and
low woodlands, with often substantial understorey concentrated below individual or clumps of overstorey plants. This is a widespread habitat unit in Australia’s arid shrublands, and occurs as wide flat plains which are subject to sheet flooding.

4.8.2 Bullimore Land System

The only land unit within the storage area which is on the Bullimore land system is a sand sheet unit supporting sandplain spinifex hummock grassland (Plate 3). This has a scattered mulga overstorey above a spinifex (*Triodia basedowii*) dominant hummock grassland understorey.

4.8.3 Ararak Land System

One part of the Ararak land system occurs within the TSF. This is all a gravelly sandy plain, which supports a lateritic mulga wanderrie grassy shrubland. This habitat unit has a scattered mulga overstorey, but is commonly dominated by a low shrub *Eremophila sp.* stratum.

4.9 Fauna

The vertebrate fauna of the North-eastern Goldfields is typically Eremaean. This fauna is abundant and diverse, with 178 bird, 11 amphibian, 93 reptilian, and 36 mammalian species recorded in the North-eastern Goldfields over the last 25 years (Murphy, 1994).

This diversity can be attributed largely to the geographic location of the region, being situated within the semi-arid region of Western Australia, bordering both the more arid environment of the Australian interior and the more temperate regions of the south-west.

As such the fauna of the region consists of elements typical of both these regions in addition to those that are considered endemic to the semi-arid region. The influence of the adjoining climatic and biological regions is clearly indicated in the composition of the various faunal groups with 30% of bird, 73% of amphibian, 34% of reptilian and 40% of native mammalian species occurring at the limit of their current known distribution (Murphy, 1994).

Except for the three macropod species and possibly some species of bat, all non-avian species are generally considered resident. Some 58% of bird species, however, are considered nomadic and are likely to occur in the North-eastern Goldfields region either seasonally or episodically (Murphy, 1994). The majority of these species will only occur in a region following periods of good rainfall when resources become plentiful.

It is unlikely that all species recorded in the North-eastern Goldfields will occur in the immediate areas surrounding the Mount Keith Nickel Operations. In a study conducted as part of the original
Notice of Intent for the Mount Keith Nickel Deposit (Dunlop et al., 1989) a total of 42 birds, 41 reptiles, and 14 mammals were recorded. A more extensive study conducted in the Wanjarri Nature Reserve as part of a biological survey of the North-eastern Goldfields (Hall et al., 1994) recorded a total of 85 birds, 39 reptiles, and 22 mammal species.

Dunlop et al. (1989) described five distinct vegetation associations with characteristic vertebrate assemblages. Of these five assemblages those associated with the denser mulga shrubland and woodland habitats, and the habitats supporting denser hummock grasslands, were found to have more abundant and diverse fauna.

Eleven bird species listed by the Specially Protected Fauna Notice (1994) have been recorded or are likely to occur in the North-eastern Goldfields. Only four of these species are likely to be currently extant in the North-eastern Goldfields and all are nomadic species which may occur episodically in the region (Murphy, 1995). It is therefore unlikely that mining will pose any direct threat to these species.

Only one species of reptile, the Woma python <i>Aspidites ramsayi</i>, potentially occurring in the North-eastern Goldfields is listed by the Specially Protected Fauna Notice (1994). This species has not been recorded in the region for at least two decades and is likely to be uncommon and unlikely to be threatened directly by mining practices (Murphy, 1994).

Two small dasyurid (carnivorous) marsupials are listed by the Specially Protected Fauna Notice (1994). These include the mulgara <i>Dasycercus cristicaudata</i>, and the Long-Tailed Dunnart <i>Sminthopsis longicauda</i>.

The Long-Tailed Dunnart is known only from one recording from the Barr Smith Range to the west of the Mt Keith minesite. The species is thought to be associated with the breakaway land unit. However, it has seldom been recorded and little is known of its biology. Other specimens have been recorded from the Pilbara region and although rare, the species is thought be reasonably widespread.

The mulgara has been recorded from the Wanjarri Nature Reserve to the south of the Mt Keith minesite and is thought to be primarily associated with the sand sheet land units of the Bullimore land system. Mulgara have also been recorded from habitats on lateritic rises supporting sparse hummock grassland understorey with scattered mulga from the Marymia region near Meekatharra. The species’ range is thought to extend across Australia and the ecology of the species is currently being studied in NSW.

The mulgara is the only resident declared rare fauna species that potentially may occur within the project area. A recent ‘walk-over’ survey conducted by a WMC environmental officer and an officer of
CALM did not find any indication of the existence of the mulgara within the project area.

In addition to the regional and local vertebrate fauna studies described above, detailed invertebrate fauna surveys of the project area have been undertaken by Dunlop et al (1989) and Postle (1996). These studies have shown that the area has an abundant and diverse invertebrate fauna assemblage despite disturbance by grazing and drought in some habitats. Their characteristics do not appear to be greatly different from those in other arid and semi-arid zones in Australia.

The results of these studies will be used by WMC as baseline data for downstream monitoring and measuring the success of rehabilitation of the tailings storage facility.

4.10 Aboriginal Heritage

The proposed tailings storage area has been subject to several Aboriginal heritage surveys in recent years (e.g. Veth et al. 1989 & 1990, Moore et al 1991, Murphy et al 1991, McDonald et al 1992, Murphy et al 1992, Prince et al 1994 a - d). An approval under Section 18 of the Aboriginal Heritage Act 1972 - 1980 was provided for a portion of the land covered by the project area in October 1993. A final and conclusive Aboriginal heritage survey of the land was undertaken in January 1996, in consultation with Aboriginal people, with no Aboriginal sites being located on the land.
5. ENVIRONMENTAL IMPACT ASSESSMENT

5.1 Overview

The major environmental issues for the proposal have been identified as:

- the loss of approximately 1800 ha of land systems, vegetation and fauna habitat;

- interruption and redirection of surface drainage, with potential impacts in terms of soil erosion and run-off 'shadowing' of plants downslope of the storage facility;

- seepage of saline tailings water into the superficial groundwater aquifer beneath the facility; and

- potential effects on Wanjarri Nature Reserve.

These major issues are analysed in detail in this section. Other minor issues, including noise, dust, landscape and cultural resources, are also discussed. On the basis of these analyses, management measures have been developed where necessary and are presented in Section 6.

5.2 Impact on Land Systems, Vegetation and Fauna

The TSF will cover a footprint of approximately 1,800 ha (including perimeter access road). Within this area, all of the existing landforms, vegetation and fauna habitats will be lost. This area compares with the approximate 2,000 ha similarly impacted by currently approved operations at Mt Keith including the mine pits, processing plant, infrastructure, waste dumps and existing tailings cells.

5.2.1 Land Systems

The TSF will directly impact the Monk, Bullimore and Ararak land systems, as mapped by van Vreeswyk (1995). In addition, the Desdemona, Sherwood, Jundee and Violet land systems are located within a few kilometres of the TSF and could potentially be impacted upon indirectly.

Table 5.1 shows the areas of each land system directly impacted upon by the TSF footprint, and an analysis of the significance of the impact in terms of the conservation value of the unit, its representation in the north-east Goldfields and in the Wanjarri Nature Reserve.
Table 5.1 Impact on Land Systems

<table>
<thead>
<tr>
<th>Land System</th>
<th>Total Area in NE Goldfields (ha)</th>
<th>Area in Wanjarri Nature Reserve (ha)</th>
<th>% of total in NE Goldfields</th>
<th>Conservaton Priority (van Vreeswyk, 1995)</th>
<th>Area Impacted by TSF Footprint (ha)</th>
<th>% of total in NE Goldfields</th>
<th>Significance of Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monk</td>
<td>816,219</td>
<td>4,305</td>
<td>0.5</td>
<td>Very low</td>
<td>1440</td>
<td>0.18</td>
<td>Very low</td>
</tr>
<tr>
<td>Bullimore</td>
<td>2,401,326</td>
<td>29,919</td>
<td>1.2</td>
<td>Moderate</td>
<td>270</td>
<td>0.01</td>
<td>Negligible</td>
</tr>
<tr>
<td>Ararak</td>
<td>202,141</td>
<td>1,901</td>
<td>9.4</td>
<td>Very low</td>
<td>90</td>
<td>0.04</td>
<td>Negligible</td>
</tr>
</tbody>
</table>

The rationale for the determination of the significance of the impact is discussed below.

The Monk land system has a very low conservation priority, therefore the impact on this land system is of very low regional significance. However, locally the TSF occupies a reasonable proportion of the Monk land system and has some potential for indirect effects. Therefore the overall impact on this land system is low at the local level.

A very small proportion of the Bullimore land system is affected by the TSF, compared with the regional distribution and the area of the Bullimore land system represented in Wanjarri. The Bullimore land system is of moderate conservation priority. For this reason, whilst the impact on the land system is negligible from a regional perspective, the impact at a local level is very low.

The Ararak land system is of very low conservation value, being widespread in the north eastern Goldfields and well represented in Wanjarri. The area of this land system to be disturbed by the TSF is very small. As such, the impact on this land system is negligible on both a regional and local level.

In summary, the land systems to be directly affected by the TSF are all widely distributed, of low to medium conservation value and well represented in Wanjarri Nature Reserve. It is concluded that the impact on the distribution and total area of these land systems will be minor at the regional and local scale.

Potential indirect impacts on land systems related to changes in surface drainage conditions are discussed in Section 5.3.

5.2.2 Vegetation and Flora

The construction of the TSF will result in the loss of plant communities within the footprint of the facility itself.

The majority of the vegetation within the footprint is open mulga woodland/shrubland with a hummock grass understorey, on gentle loamy plains. As noted by Pringle (1995), much of the mulga...
overstorey in this area is dead and regeneration is poor, with accelerated soil erosion. This may be a result of historical overgrazing.

Within the drainage lines the mulga overstorey is more dense and in good condition. Understorey is sparse.

These vegetation communities are well represented in the region and within Wanjarri Nature Reserve. The loss of these communities is therefore not of special significance.

Surveys by Dunlop et al. (1989), Cockerton (1996) and WMC ecologists have found no Declared Rare Flora over the site. The only possible priority listed or declared rare flora species are associated with the sand plain spinifex hummock grasslands within the sand sheet land unit of the Bullimore land system.

No loss of Declared Rare Flora or priority species is expected.

5.2.3 Fauna

The TSF will remove 1,800 ha of fauna habitat and may truncate or cause ‘boundary’ effects on adjoining habitats.

The Bullimore land system is associated with the mulgara *Dasyurus cristicauda*, a Gazetted Rare fauna species. The preferred habitat of the mulgara in Western Australia is sandy flats between low sand dunes, a landform which does not occur in or near the footprint of the TSF. Mulgara have however been sighted in Wanjarri Nature Reserve, in association with the sand sheet unit of Bullimore.

A CALM officer inspected the TSF site in January 1996 and found no indication that the mulgara was present. The likelihood of direct impact on the mulgara is therefore considered to be low.

Other fauna present in the project area are widespread and common. The impact on them will therefore be limited to the removal of 1,800 ha of habitat.

Following decommissioning and rehabilitation, an equivalent area of somewhat different, but nonetheless useful, habitat will be created. In the long term, temporary ponding of stormwater and rainwater within the decommissioned TSF may increase the usefulness of the area for fauna, particularly birds.

5.2.4 Edge and Barrier Effects

Edge effects occur where undisturbed habitat is bordered by a disturbance such as mining, clearing or traffic. Edge effects increase the effective area of disturbance by providing an avenue into the undisturbed area for weeds, predators, vehicles and humans, by fragmenting habitats and blocking fauna movements.
In this case, edge effects will be limited as the TSF will be an inactive, rather than active, boundary. In other words, the TSF will not be a source of weeds, pests or human intrusion. Active disturbance at the boundary will only occur during the construction of the TSF, at which time boundary effects will be managed as described in Section 6.2.

5.3 Surface Drainage Interruption

The TSF will permanently obstruct water surface flows in the existing drainage channels. Diversion drains will divert water around the TSF and release it as diffuse sheet flow on the downslope side. A catchment totalling approximately 18,000ha contributes stormwater to these drains. Some concentration of flow is inevitable in this process. The patterns of surface flow before construction of the TSF are shown on Figure 12.

The identified impacts will include:

- the potential for water starvation of downstream vegetation caused by run-off ‘shadowing’; and

- potentially accelerated soil erosion downstream due to concentration of run-off.

5.3.1 Run-off Shadowing

Vegetation in the drainage lines downstream of the TSF relies on occasional inundation for growth and flowering, between which events it lies essentially dormant. If this periodic inundation ceases the vegetation may suffer stress or die.

Structures such as the TSF may potentially ‘shadow’ downslope areas by obstructing the natural flow of water in shallow drainage lines and sheet wash areas, thereby causing the death of vegetation or changing vegetation distribution. This impact may be minimised by correct dam design and management of the stormwater.

The surface water management strategy outlined in Section 6.3 is designed to re-establish natural flow downstream and avoid such impacts. The distribution of this modified flow is likely to be different from the original flow regime, so some areas of land may potentially become better watered while others receive less water.

Two broad, shallow, braided drainages pass through the proposed location of the TSF. The more northern of these drainage lines is more substantial, and currently receives run on flow which has already been diverted around the existing mine infrastructure upstream, by a series of flood protection and diversion drains.

The southern, less substantial drainage line, receives run on flow from the west and southwest of the proposed TSF site. Some of
this flow has been previously interrupted upstream by the Wiluna-Leinster Road.

The proposed diversion drains will divert flow around the northern and southern sides of the TSF. The drains will release this diverted flow within the same braided drainage lines downstream of the site.

The potential for run on shadowing is considered minimal because the drains will re-instate flow in those drainage lines.

The vegetation type most likely to be affected is mulga woodland nearby the release points, which may be subject to more regular or more substantial inundation.

The only areas which will receive less run on are those contained within the TSF, which will have been cleared during construction.

5.3.2 Erosion

Concentration of run-off will cause increased flow velocities in some drainage channels and may cause localised erosion. Where flow is diverted around the TSF this may also cause erosion of the adjacent soils.

The diversion drains will be designed to achieve a diffuse release of water and so minimise the potential for erosion. The low slopes downstream of the TSF and occasional nature of run-off events will further reduce this potential. This impact is therefore expected to be minor and localised.

5.3.3 Stormwater Run-off from the TSF

Preliminary calculations have indicated that stormwater shed from the surface of the TSF may, through dissolution of salts from the tailings, be too saline to be released to the environment. To avoid this problem, all run-off from storms up to a 1 in 100 year storm event will be retained within the TSF perimeter wall and reclaimed for use in the process plant.

Run-off from a greater than 1 in 100 year storm will overflow via properly constructed overflow structures. This run-off will be of relatively low salinity due to dilution, and will be released into an environment which will already be substantially flooded, resulting in further dilution. There is therefore expected to be no significant impact on the surrounding environment from stormwater run-off from the TSF.

5.4 Impacts on Groundwater

Most tailings water and stormwater in the TSF will be collected by underdrains and directed to sumps from where it will be piped to the process plant as required. However, some water will seep through the base of the tailings and may reach the water table. The aquifers
affected will depend on the rate of seepage and the permeability
distribution within the aquifers. The rate of seepage will depend on:

- the possible occurrence of a water table within the tailings;
- the duration of stormwater ponding;
- the permeability of the tailings and the substrate, including
  preferential flow pathways;
- the sealing effect of the tailings; and
- the distribution and rate of application of the tailings.

5.4.1 Rate of Seepage

Computer modelling of seepage is included at Appendix B. The
modelling was carried out on the basis of a ‘worst case’ scenario,
with assumptions including:

- the occurrence of a permanent water table within the tailings;
- water ponding from a 1 in 100 year storm event; and
- the presence of a preferential seepage pathway directly beneath
  the ponded water.

The maximum seepage rate predicted by the worst case model was
450 kilolitres per day (kL/d) for the first ten months, which reduced
to 5.5 kL/d after one year and 1.6 kL/d after five years. The total
predicted seepage in this worst case over the 20 year operating life
of the facility is 69,000 kL, which equates to less than 1% of the
estimated underlying groundwater resource. The fall in seepage
over time is due to the sealing effect of the tailings on the ground
surface.

Due to the use of worst case assumptions, this is likely to be a
substantial over-estimate. The actual seepage should be
considerably less, given that:

- a water table is not expected to form within the tailings;
- water ponding will be limited in duration and extent;
- much of the potential seepage water will be intercepted by the
  system of collector drains and trenches; and
- air drying and desiccation of the tailings, which will be promoted
  by the scheduling of tailings deposition, will significantly reduce
  the permeability of the base of the TSF.
5.4.2 Seepage Composition

The seepage water will contain salts at a concentration of 50,000 to 80,000 mg/L. Seepage originating from ponded stormwater may be substantially less saline than this. For assessment purposes, a uniform seepage concentration of 70,000 mg/L has been assumed.

In addition to salt, the seepage water will contain elevated concentrations of magnesium (Mg), calcium (Ca), sulphate (SO₄) and boron (B). The full chemistry of the tailings water is shown at Appendix A.

5.4.3 Impact on Groundwater Resources

The superficial and palaeochannel aquifers underlying the TSF are subpotable, with salinities of 700 - 1500 mg/L. Based on hydrogeological studies, the TSF footprint directly overlies a groundwater resource of approximately 8 million kL within the superficial aquifer. The seepage water would form a ‘plume’ of saline water within the superficial aquifer. The degree of mixing with the aquifer water would depend on the time interval and the presence of horizontal layers of varying permeability within the aquifer.

Using the modelled seepage as described above, and allowing for partial depletion of the resource by twenty years of groundwater pumping, it has been calculated that the average salinity of the underlying superficial aquifer could rise by approximately 1,070 mg/L over the 20 year operational life of the TSF.

If a saline plume develops, it is likely to have higher peak salinity than the estimated average value, if it develops along a preferred pathway. It is very difficult to accurately and reliably predict the seepage rate and salinity of a plume along a preferred pathway. However, such plumes are readily identifiable using electromagnetic imaging and bore monitoring methods, where there is a measurable difference between background and plume salinity (conductance) values. As described below and in section 6.4, a groundwater management strategy is proposed to manage the impacts on groundwater resources of saline plumes with average salinity values in excess of 4000 mg/L, with the aim of maintaining the groundwater resource within subpotable limits.

The actual average rise is likely to be significantly less than 1070 mg/L because of:

- the use of worst case assumptions in the seepage modelling;
- dilution of the groundwater by natural recharge; and
- lower salinity of seepage due to dilution by stormwater
A 1,070 mg/L rise in the salinity of the superficial aquifer would have no significant impact on the current value of the groundwater resource for human use or natural ecosystems. This is because:

- the salinity is already too high for human potable uses;
- cattle and sheep can drink water with up to 5000 mg/L and 6000 mg/L respectively, so future pastoral use would be unimpaired; and
- the depth of the superficial groundwater (approximately 16 to 18 m below ground) is too great for trees, other plants or animals to access it. The vegetation in and near the project area is all xerophytic (ie adapted to dry conditions) and therefore not groundwater dependent.

Following the modelled influx of tailings water, the groundwater would continue to meet the Australian and New Zealand Environment and Conservation Council (ANZECC) water quality guidelines for livestock watering. The relevant parameters and their degree of compliance with the Guidelines are summarised in Table 5.2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Background concentration (mg/L)</th>
<th>Seepage concentration (mg/L)</th>
<th>Final concentration after 20 years (mg/L)</th>
<th>ANZECC Guidelines (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salinity (TDS)</td>
<td>700 - 1,400</td>
<td>&lt;70,000</td>
<td>700-2570</td>
<td>&lt;5,000 (cattle)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;6,000 (sheep)</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>20 - 80</td>
<td>2,000</td>
<td>50 - 100</td>
<td>&lt;600</td>
</tr>
<tr>
<td>Boron (B)</td>
<td>?</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>5</td>
</tr>
<tr>
<td>Nitrate (NO₃⁻)</td>
<td>50 - 100</td>
<td>50 - 100</td>
<td>50 - 100</td>
<td>40 (cattle)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>60 (sheep)</td>
</tr>
</tbody>
</table>

1. Guideline not achieved by background water

Measures will be adopted to minimise the formation of a saline plume. These include monitoring to identify such a plume and the use of production bores to recover saline water and return it to the process plant. These management measures are discussed in detail in Section 6.4.

It should be stressed that the occurrence of significant saline seepage into the superficial aquifer, if it occurs at all, will be a very short-term phenomenon, and will essentially have ceased after five years. By the time the TSF is decommissioned after approximately 17 years of operation, the rate of seepage will be so low that the quantity of saline water entering the aquifer will be negligible and will have no measurable effect on the salinity of the groundwater.

Seepage modelling and investigations indicate that seepage potential from this type of storage is lower than traditional paddock storages.
5.5 Impacts on Wanjarri Nature Reserve

Wanjarri Nature Reserve is situated approximately 1.8 km south-east of the TSF. There will be no direct impact on Wanjarri associated with the footprint of the TSF.

Potential impacts on the Reserve arise from its location downstream of the TSF in terms of both surface flows and groundwater. These potential impacts are analysed in the following two sections.

5.5.1 Surface Water

A small proportion of the natural surface drainage from the site of the TSF flows across the northern end of Wanjarri. This area also receives run-off from within Wanjarri itself.

Drainage diverted around the TSF will be released immediately downstream of the facility. Within a short distance, and before it reaches Wanjarri, the flow will have substantially reverted back to its natural pattern. There will therefore be no run-off shadowing effects from the TSF on Wanjarri. Note that whilst the TSF is located 1.8 km from the Nature Reserve at its closest point, the distance between Wanjarri and the TSF along the drainage lines potentially affected is 7 km (refer Figure 12).

5.5.2 Groundwater

Hydrogeological investigations carried out for the project indicate that groundwater in the superficial aquifer moves very slowly from the TSF site towards the Wanjarri Nature Reserve, while in the palaeochannel aquifer a hydraulic discontinuity exists between the TSF and Wanjarri. A saline plume in the superficial aquifer (as discussed in Section 5.4) could therefore travel through the nature Reserve if not appropriately managed.

The superficial and palaeochannel aquifers have no known ecological significance for the vegetation or fauna of Wanjarri Nature Reserve. The vegetation of the Reserve is all xerophytic, and is not groundwater dependent. There are no large eucalypts or similar trees which would rely on groundwater. The absence of permanent surface water (such as soaks) means that animals do not have access to the groundwater and therefore would be unaffected by any change in its quality.

5.6 Minor Environmental Issues

Minor issues are potential impacts of low magnitude or environmental significance. Most are indirect, and include noise, dust, changes to the visual landscape, Aboriginal heritage, and liquefaction potential and risk assessment for the tailings and embankment. These are discussed in the following sections.
5.6.1 Noise

The emission of noise during the construction of the tailings storage will have a minimal impact on the surrounding areas given the existing noise levels from the mine and processing operations, and the remoteness of the operation from human habitation. Noise levels during operation associated with placement of tailings will be low.

5.6.2 Dust

Dust could be generated from unstable surfaces during the initial construction of the storage, during its operation and after decommissioning. The extent of dust generated from unsealed surfaces depends on factors such as the moisture content and particle size of the surface soils. Prevailing winds in the area will deposit most dust that is generated to the south and south-west of the TSF.

Dust is not expected to impact the Wanjarri Nature Reserve.

Apart from its occupational health implications, high levels of dust may have adverse impacts on vegetation through physical damage ('sand-blasting') and smothering. However, localised whirlwinds are a common feature of the semi-arid environment around Mt Keith and the natural vegetation in the area will have evolved adaptive mechanisms for coping with the periodic dusting they receive from these air movements.

Due to the distance of the project from human habitation (70 - 80 km from the nearest private residence at Wiluna), dust nuisance impacts on neighbours will not be a problem.

5.6.3 Aboriginal Heritage

Approval under Section 18 of the Aboriginal Heritage Act 1972 - 1980 has been obtained for a portion of the land covered by the project. No sites have been found elsewhere on this area. There are therefore no archaeological or ethnographic issues that might preclude the development of the land for the purposes of the tailings storage area and associated works.

5.6.4 Visual Landscape

The topography within the perimeter of the tailings storage will change from a gentle, fairly even slope of approximately 0.25%, to a series of overlapping, rounded conical hills about 45 m high, and with a slope of 3%. There are several ranges of similar low hills in the close vicinity, so this shape will be much less visually obtrusive than conventional tailings dams, with their steep sides, flat tops and square corners.
Following rehabilitation, the profile will make the TSF noticeable only at short range. The visual impact of the structure is therefore assessed as very low.

5.6.5 Liquefaction Potential

Due to the shape, size and method of operation of centralised discharge storages, liquefaction during seismic and large rain storm events is perceived to be a potential risk.

The liquefaction potential of the Mt Keith tailings was closely examined by Gordon Geological Consultants (1996) using the empirical approach of Seed et al described by Fell MacGregor & Stapledon (Geotechnical Engineering of Embankment Dams). Input parameters were obtained from a consolidation model for the Mt Keith tailings in conjunction with undrained shear strength values measured both in situ and in laboratory tests.

Mt Keith lies in a seismic zone with very low activity. The parameters considered relevant for this project were:

- peak ground acceleration 0.3 m/sec\(^2\) with a 10% chance of being exceeded in a 50 year period;
- peak ground velocity 30 mm/sec with a 10% chance of being exceeded in a 50 year period;
- peak ground intensity VI MM with a 10% chance of being exceeded in a 50 year period.

The results indicate that, except for very recently deposited tailings (ie up to 24 hours), the Mt Keith tailings show a low susceptibility to liquefaction due to the large proportion of fines.

The analysis did show that at fast rates of rise (ie. 6 m/year to 8 m/year), the underlying tailings may not have sufficient time to consolidate and, therefore, may have the potential to liquefy. Hence, a multi-discharge system has been adopted to restrict the average rate of rise of the storage to 4 m/year in the first year, reducing thereafter to about 1.5 m/year.

As the perimeter embankment will be constructed using cohesive soils, the embankment is not considered to have the potential to liquefy.

5.6.6 Risk Assessment

The proposed storage facility is unique in Western Australia because of its size and proposed tailing disposal methodology. It utilises disposal techniques that have been proven in other parts of the world.

The risk associated with the proposed storage is considered to be very low, and lower than most other kinds of tailings dams. This is
because the proposed storage incorporates numerous safety measures not always incorporated into other tailings dams, such as:

- an outer containment wall that will be approximately 400 m from the expected toe of the tailings mounds;

- the deposition system is automated with features such as safety alarms and automatic riser flushing;

- the dual-deposition-system means that several risers can be used at once to control deposition;

- underdrains will aid consolidation of tailings;

- a downstream water containment dam to act as a buffer dam;

- an extensive seepage control and detection system as outlined later in this report; and

- a management philosophy of minimising contained water.

The Guidelines for risk assessment as outlined by the DME cater generally for ring dyke and embankment storages. However, the design as proposed will comply with the most stringent guidelines (Category 1 Tailings Storage).

Stability analyses using the computer programme SLOPEW were carried out using the phreatic surface predicted by SEEPW. The geotechnical investigation (Gutteridge Haskins and Davey, 1995) found the storage structure to be stable for all conditions of static and dynamic earthquake loading.
6. ENVIRONMENTAL MANAGEMENT

6.1 Overview

Specific management strategies have been formulated to minimise potential impacts and manage the actual impacts of the proposed TSF.

The overall management strategy aims to:

- avoid creating adverse environmental impacts through proper design and operation of the TSF with specific regard to the environment;
- monitor and mitigate the impacts which cannot be avoided;
- monitor and minimise potential downstream and peripheral impacts;
- implement corrective actions to reduce impacts, and undertake remedial action where necessary; and
- monitor and improve the environmental management programme.

The specific management strategies adopted to address the main environmental aspects of the proposal are outlined below.

In addition to the management strategies specific to this proposal, Mt Keith Operations, and Western Mining Corporation Limited as an organisation, have implemented several management tools and systems to assist in the pursuit of best practices. These include:

- Site Environmental Policy;
- Operating Environmental Management Programme;
- workforce education through induction programmes and a regular newsletter; and
- environmental auditing procedures.

Some of these systems are briefly described below.

6.1.1 Environmental Management Programme

The environmental management programme (EMP) was compiled and submitted to the DME in May 1994. The operating EMP is the formal management structure and operational system designed to promote environmental excellence. Some components of the EMP are:
The EMP, and its component systems, will form part of an Environmental Management System (EMS) to be implemented in the near future.

Western Mining Corporation recently commissioned an independent auditing group to review available EMSs for compliance with Interim Australian Standards and suitability to Western Mining Corporation operations.

Of the eleven EMSs reviewed, three were recommended as suitable, and will be trialled before being fully implemented.

In addition to site based environmental management, Mt Keith Operations (MKO) (and other Western Mining Corporation operations) is approaching environmental management from a regional perspective. This is reflected in the Memorandum of Understanding MKO has with the Department of CALM for co-operative management of Wanjarri Nature Reserve, and MKO's involvement in regional research and conservation projects.

Western Mining Corporation also has a system of regular environmental auditing of operations, to ensure environmental management standards are maintained and improved.

6.2 Land System Management

6.2.1 Objective

The objective of land system management is to protect the ecological values of the affected land systems and their associated vegetation, habitats and fauna.

The main impact on land systems is the direct loss of approximately 1,800 ha of land.

The analysis presented in Section 5.2 indicates that the clearing of 1,800 ha is environmentally acceptable, given the wide distribution
of the affected land systems, their representation in Wanjarri Nature Reserve, and the absence of highly ecologically sensitive land within the cleared area. Management will therefore be directed primarily toward restricting clearing and disturbance to within the actual footprint of the TSF and its necessary infrastructure, minimising wider disturbances such as edge effects, and protecting rare or significant flora and fauna species if found within the area of impact.

6.2.2 Management Strategy

Clearing boundaries will be clearly defined and marked before and during construction. All construction workers will be briefed on the need to minimise clearing and off-site disturbance. The use of off-road vehicles away from the construction site will be prohibited.

After construction has finished, all disturbed areas no longer required for operations will be rehabilitated to the satisfaction of the DME.

A perimeter fence will be erected around the top of the embankment to prevent access by large fauna such as kangaroos and stock. The amount of vegetation (and hence fauna habitat) cleared will be restricted to those areas necessary for the construction of the storage facility and associated works.

A monitoring programme will be developed in conjunction with CALM to trap for mulgara over the project area before construction, and if any are trapped, a suitable management and translocation programme will be implemented to the satisfaction of CALM prior to any clearing in affected areas.

WMC will establish a long term programme to fund and conduct research into the distribution and ecology of the mulgara in the North-eastern Goldfields.

A site assessment for Declared Rare Flora species will be undertaken in conjunction with CALM prior to the commencement of construction. In the event that Declared Rare Species are identified within the site, appropriate action will be taken as advised by CALM.

At the end of operations, the TSF will be comprehensively rehabilitated in line with the Rehabilitation Plan and on the basis of the results of rehabilitation trials on the existing tailings cells.

This management strategy will be formalised in the Environmental Management Programme, which will be prepared and implemented in consultation with CALM.
6.3 Surface Water Management

6.3.1 Objectives

The objectives of surface water management are to:

- maintain as far as possible the pre-existing surface flow patterns upstream and downstream of the TSF; and
- protect downstream vegetation from the effects of saline run-off from the TSF.

The environmental values to be protected are:

- vegetation downstream of the TSF (protect from run-off shadowing and saline run-off); and
- soils around and downstream of the TSF (protect from erosion).

Management is aimed at:

- achieving an optimum drainage design which carries upstream run-on efficiently past the dump and restores similar flow patterns on the downstream side; and
- developing a post-decommissioning stormwater drainage design which minimises the salinisation of run-off from the tailings surface and minimises its effects on vegetation.

6.3.2 Management Strategy

Diversion drains will be constructed to carry upstream run-on past the TSF and return it to its original flow pattern on the downstream side. The downstream ends of the diversion drains will incorporate diffuser structures to encourage dissipation of the flows, such as sill drains constructed on the contour.

The diversion drain will be designed as channels with bunds on the tailings side (see Figure 9). The design will be such that small storm events and part of larger events will be released at the end of the diversion channel into the area upslope of the existing main drainage.

In larger events, run-off will overtop the channel to form a sheet flow over the eastern side of the tailings storage area. This will occur in events ranging from 1 in 1 year to 1 in 10 year, depending on the distance from the end point of the channels. The channels will overtop more frequently near the end points, which replicates the natural drainage situation by effectively re-establishing sheet flow. Downslope of the diversion channels, this sheet flow will be redistributed by the topography into patterns similar to the existing flows.
A vegetation and invertebrate monitoring programme will be developed in consultation with CALM to assess the effects on vegetation status of changes to drainage patterns. If net vegetation loss is found to be occurring due to the changes associated with drainage diversion, an assessment will be made and an appropriate programme developed to remediate the impact.

WMC will implement a long term soil erosion monitoring programme downstream of the tailings storage area. Where an increase in soil erosion is found to be occurring, WMC will develop and implement a plan to minimise and manage the erosion.

Studies will be undertaken on the tailings surfaces of Cells 1 and 2 to assess the salinity likely to be found in stormwater run-off from the tailings surfaces. A strategy to dispose of this stormwater following decommissioning of the tailings storage will be developed following these studies. It is anticipated that the salinity of run-off from the tailings will decrease significantly within a few years after decommissioning, due to the depletion of the leachable salt store from within the tailings.

The results of vegetation and erosion monitoring will be reported annually to the DME.

This management strategy will be formalised in the Environmental Management Programme, which will be prepared and implemented to the satisfaction of the DME.

6.4 Groundwater

6.4.1 Objective

The objective of groundwater management is to protect the water quality and long term yield of the superficial and palaeochannel aquifers. The environmental values to be protected are the aquifers' current and potential uses for process water supply, stock watering, ecosystem maintenance and other, presently undefined future beneficial uses.

The issue to be addressed by the management strategy is the potential for a plume of saline water to seep from the tailings storage into the underlying superficial aquifer. If not appropriately managed such a plume would move slowly eastward. The rate of seepage will decrease rapidly as the base becomes sealed by tailings, so the main management effort will be directed towards the first few years of operation. By the time the TSF is decommissioned, the rate of seepage is expected to be so low as to make further management unnecessary.
6.4.2 Management Strategy

The occurrence of saline seepage will be minimised by careful design and operation of the TSF, including:

- walls and embankments designed to be as close to impervious as practical;
- scheduling of the early stages of tailings deposition to achieve the fastest possible sealing of the base of the TSF; and
- operating discharge points, pumps and drains so as to minimise ponding of water within the TSF.

Surveys using electromagnetic imaging techniques, and existing and new monitoring bores within and outside the storage, will monitor the salinity of the underlying groundwater and detect the occurrence of saline plumes. If a significant plume is detected, existing and new production bores that draw from the superficial aquifer will be operated to recover the saline water, which will be recycled to the mine plant as process water. Such action is not expected to be required during the later years of mine life, as indicated in Section 6.4.1.

The rate of abstraction will be adjusted as necessary to prevent saline water migrating outside the near vicinity of the dump or downwards into the palaeochannel aquifer.

Abstraction rates and monitoring results will be reported annually to the DME. An appropriate post-decommissioning strategy will be developed prior to decommissioning.

This management strategy will be formalised in the Environmental Management Programme, which will be prepared and implemented to the satisfaction of the DME.

6.5 Management of Impacts on Wanjarri Nature Reserve

6.5.1 Objective

The objective of this management strategy is to protect the ecological values of Wanjarri Nature Reserve from direct and indirect disturbance. The environmental values to be protected include:

- land systems and land units within the Reserve;
- superficial and palaeochannel groundwater resources;
- vegetation, flora and fauna, particularly rare or threatened species; and
- the public amenity of the Reserve.
The analysis in Section 5.5 indicated that the construction and operation of the TSF will have no significant direct or indirect impacts on the Nature Reserve. This is due to a combination of factors including:

- the selection of a site for the TSF that incorporates a reasonable buffer to the Nature Reserve;
- the low potential for off-site impacts from the proposal; and
- management measures to be put in place to mitigate surface drainage, groundwater quality and other impacts should they occur.

The management strategy for the Reserve is therefore focused on maintaining co-operative arrangements with CALM.

6.5.2 Management Strategy

WMC has entered into a Memorandum of Understanding with CALM to become actively involved in the management of the Wanjarri Nature Reserve.

WMC is committed to active involvement with both CALM and the Department of Agriculture in the development of a regional conservation and multiple land use management strategy for the North-eastern Goldfields, and will continue to devote resources to this effort.

WMC at Mt Keith is currently establishing its own environmental management strategy in conjunction with other WMC operations in the north eastern Goldfields. This involves funding and conducting research and monitoring programmes directed at increasing information on the flora of the region.

6.6 Management of Minor Impacts

Minor impacts such as noise and dust, and issues in relation to Aboriginal heritage will be managed in line with current best practice in the mining industry.

The specific management strategies described below will be formalised in the Environmental Management Programme, which will be prepared and implemented to the satisfaction of the DME.

6.6.1 Noise

No management of this issue is required apart from that related to normal occupational health requirements.

Noise levels generated during the construction and operation of the storage will comply with the neighbourhood Noise Regulations and the Mines Safety and Inspection Act. All personnel in areas subject
to noise from heavy machinery or other sources will be supplied with appropriate protective equipment.

6.6.2 Dust

To reduce the potential for dust generation, clearing and stripping around the minesite will be kept to a practical minimum.

During the construction of the TSF, dust generation will be controlled by standard dust control strategies such as the watering of construction sites. It is proposed to trial the use of proprietary dust suppressing agents, such as Dustex (a calcium lignosulfonate) during the initial startup of the storage, until the tailings have provided a sealing layer over the natural ground surface. Alternatively saline water may be sprayed on the exposed surfaces within the storage, creating a dust-suppressing salt crust.

During tailings deposition the tailings will be kept moist beneath the salt crust that forms as surface moisture evaporates.

Following decommissioning and revegetation of the tailings storage surface, dust generation will be no greater than for the surrounding land. While the vegetation is establishing, selective placement of the waste rock/soil piles (see Section 6.7) will reduce wind velocities over the area. Short-term measures employed to limit dust generation may include the use of non-invasive local grass species to provide surface cover.

6.6.3 Aboriginal Heritage

As there are no known Aboriginal archaeological or ethnographic sites within the area of impact of the TSF, no management of this issue is currently necessary.

If previously undiscovered Aboriginal heritage sites are discovered during clearing or ground preparation for the TSF, work in the immediate vicinity will cease and the Department of Aboriginal Affairs will be notified. If necessary, application for permission to disturb the site will be sought from the Minister for Aboriginal Affairs.

6.7 Rehabilitation

6.7.1 Objectives of Rehabilitation

WMC will aim to provide self-sustaining vegetation cover and stable landforms through progressive rehabilitation of disturbed land and final long-term rehabilitation as a part of decommissioning of the TSF.

The main environmental objectives of rehabilitation are to:

- ensure structural stability and safety to the public;
- minimise off-site impacts by controlling infiltration, sedimentation and related degradation of existing drainages;

- return the storage facility and surrounds to a condition that will support land uses consistent with the Mt Keith Environmental Management Programme and tenement conditions, potentially including fauna habitat, pastoral use, mineral exploration and aesthetic values; and

- employ rehabilitation methods that do not require ongoing maintenance to ensure long-term performance.

It is generally considered that the best way of achieving these objectives in the long-term is to establish stable land forms with self-sustaining vegetation cover consistent with the multiple land use objectives. The main difficulty facing the establishment of such vegetative cover at Mt Keith will be the salinity of the tailings surface.

The tailings storage system described in this document has several advantages for rehabilitation over conventional tailings storage. It is expected that, after drying and consolidation of the tailings, there will be no perched water table, as would be expected in a conventional TSF. Both entrained water and stormwater run-off will be shed to the water storage area in the eastern side of the storage, and depending on the final salinity levels, will be contained and allowed to evaporate.

Due to the absence of a perched water table in the tailings, capillary rise of saline water and the concentration of salts at the surface will be minimised and the salinity of the surface layers will gradually decrease due to leaching by rainwater. Water shedding will also reduce salts from most of the storage area as the salts will be dissolved from the surface crust by stormwater and will collect in the water storage area. This reduction in surface and near-surface salinity will enhance the conditions for vegetation.

### 6.7.2 Rehabilitation Strategy

The top 150 mm of topsoil will be stripped from the storage facility footprint prior to construction. This soil will be stockpiled at the toe of the perimeter wall in a bank not more than 2 m high (Figure 20). This stockpile and the perimeter wall will be revegetated immediately after construction with indigenous lower and middle storey species to maintain biological viability of the topsoil. Revegetation of the perimeter wall will involve the placement of topsoil and seeding or hydromulching of the outer walls, bunds and diversion drains where appropriate. Erosion and dust generation may be controlled by planting a local grass species.

For the surface of the tailings storage, a detailed rehabilitation plan is inappropriate at this time, as rehabilitation will not be undertaken
6.7.4 Decommissioning

Following closure, approximately 75% of the surface of the storage will be rehabilitated. The water storage area and the low area between the tailings mounds will not be rehabilitated as they may be inundated regularly with saline water and would, therefore, be unsuitable for revegetation.

The rehabilitation programme will continue and its success will be monitored after decommissioning until the vegetation has reached a stage where it is self-sustaining and compatible with the surrounding natural vegetation and future beneficial uses. The monitoring and completion criteria for rehabilitation will be in consultation with the DME, DEP and CALM.
7. SUMMARY OF ENVIRONMENTAL COMMITMENTS

7.1 Basis for Achievement of Commitments

Western Mining Corporation Mt Keith Operations (MKO) already has an Environmental Management Programme (EMP) for the Mt Keith Nickel Project, which has been prepared in accordance with its existing licences.

The Mt Keith Environmental Officer is responsible for the day-to-day implementation of the EMP. It is proposed that this EMP will be updated to include the additional management requirements (e.g., objectives, procedures, actions) for the new tailings storage facility.

During the updating process, the specific management practices implicit to each of the commitments will be established, along with such aspects as environmental performance indicators and an acceptable auditing programme. Reporting requirements (e.g., frequency, to whose satisfaction) will also be clearly identified.

In respect to auditing, MKO conducts in-house auditing for the site, and the WMC Corporate Environmental Group undertakes regular internal audits of all WMC projects. Furthermore, WMC is currently undertaking trials of a number of Environmental Management Systems (EMS) with a view to selection and implementation of a comprehensive EMS for its operations.

The Mt Keith EMP, including the proposed EMP update for the new tailings storage facility, will be embraced by the EMS.

7.2 Summary of Commitments

7.2.1 Clearing of Vegetation

Only the minimum area required for construction and operation of the project will be cleared. Once construction is completed, all disturbed areas no longer required for the operation of the facility will be rehabilitated in line with the tenement conditions.

7.2.2 Management in North-Eastern Goldfields

WMC will continue active involvement with both CALM and the Department of Agriculture in the development of a regional conservation and multiple land use management strategy for the North-eastern Goldfields.

7.2.3 Management of Wanjarri Nature Reserve

WMC will be actively involved in the management of Wanjarri Nature Reserve, in accordance with its existing Memorandum of Understanding with CALM.
7.2.4 Groundwater Monitoring

A groundwater monitoring programme will be implemented to detect and monitor seepage of tailings water and stormwater out of the tailings storage. This will include monitoring of the perimeter wall, nested bore monitoring, and monitoring of the water supply bores. If seepage is detected and exceeds ANZECC guidelines for beneficial uses for stock water, an appropriate response plan for seepage management will be formulated.

7.2.5 Monitoring of Drainage Modification Effect on Vegetation

WMC will develop and implement a vegetation monitoring programme in consultation with the Department of CALM. Should changes in vegetation status as a result of the tailings facility be detected, an appropriate programme to remediate the impact will be developed and implemented.

7.2.6 Monitoring of Soil Erosion

WMC will implement a long term soil erosion monitoring programme downstream of the facility. If accelerated soil erosion as a result of the facility is detected, a programme of remedial works will be implemented.

7.2.7 Stormwater Diversion

Stormwater diversion drains will be designed to replicate as closely as possible the natural drainage patterns downstream of the facility. If required, modifications will be made to improve discharge patterns.

7.2.8 Environmental Management System

WMC Mt Keith Operations will identify and implement an Environmental Management System consistent with the intent of Interim Australian Standards 14001 and 14004.

Within one year of the receipt of approval for the proposed TSF from the Minister for the Environment, the existing Mt Keith EMP will be updated to include matters relevant to the operation of the TSF, including:

- stormwater, erosion and drainage monitoring;
- vegetation and fauna monitoring;
- control and monitoring of seepage;
- rehabilitation; and
- final decommissioning of the tailings storage facility.

7.2.9 Assessment of Declared Rare Flora

A site assessment in conjunction with CALM will be undertaken forDeclared Rare Flora and priority species over the footprint of the
TSF, prior to construction, and if required, conservation plans prepared.

7.2.10 Pre-construction mulgara Trapping

A monitoring programme will be developed in conjunction with CALM to trap for mulgara over the project area before construction. If any are trapped, a suitable management and relocation programme will be implemented.

7.2.11 Long-term mulgara Research

WMC will establish a long term programme to fund and conduct research into the distribution and ecology of the mulgara in the North-eastern Goldfields.

7.2.12 Rehabilitation Plan

Within two years of commencement of operations, a draft Rehabilitation Plan will be prepared. This plan will include:

- topsoil management;
- rehabilitation trials on the existing tailings storage Cells 1 & 2;
- establishment of vegetation cover on the tailings surface following decommissioning;
- monitoring of rehabilitation success; and
- completion criteria.

The draft rehabilitation plan will be revised as required, to reflect the results of rehabilitation trials and advances in the state of knowledge of tailings rehabilitation techniques.

A final rehabilitation plan will be submitted to DEP, DME and CALM prior to implementation.

7.2.13 Aboriginal Sites

No Aboriginal sites will be disturbed without permission from the Minister for Aboriginal Affairs. If any previously unrecorded Aboriginal sites are found within the project area, all work in the immediate vicinity will cease. Procedures will be adopted in accordance with the Aboriginal Heritage Act 1972.

7.2.14 Dust Control

Clearing and stripping will be kept to a practical minimum, and dust control strategies implemented such as spraying with water and/or dust control chemicals, as appropriate. Dust will be controlled on topsoil piles and perimeter walls by the establishment of vegetation or rock armouring, as appropriate.
8. REFERENCES


Conservation and Land Management, Dept. of. (1992). Declared Rare and Priority Flora List for Western Australia.


Murphy, A. (1992). Revised Report on Archaeological Investigations - Proposed Borefields, Sandpits Village Site and General Purposes Area, Mt Keith Nickel Project. For Western Mining Ltd - ACM.


Western Australia. Department of Agriculture Western Australia, Technical Bulletin No. 87.


van Vreeswyk, A.M.E. (1995). The sensitivity and conservation value of land in the region of Western Minings' operations in the North-eastern Goldfields, Western Australia: A report to Western Mining Corporation, Department of Agriculture, Western Australia.


FIGURES
**WANJARRI NATURE RESERVE**
A Class Reserve 30897
Conservation of Fauna & Flora

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**WESTERN MINING CORPORATION LIMITED - PROPERTIES DEPARTMENT**

**MT. KEITH AREA**

**SURVEYED BOUNDARIES & COORDS.**

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**Scale 1: 100,000**

**Figure No. 2**

**Plan No.**

Z51
MT. KEITH NICKEL PROJECT

OBLIQUE MINESITE PERSPECTIVE TO SOUTHEAST

SHOWING EXISTING INFRASTRUCTURE AND

PROPOSED TAILINGS STORAGE FACILITY UPGRADE

FIGURE 3
FIGURE 4

MOUNT KEITH PROJECT
GENERAL PLAN
LAYOUT OF TAILINGS STORAGE
SITE OPTIONS

MOUNT KEITH PROJECT
GENERAL PLAN
LAYOUT OF TAILINGS STORAGE
SITE OPTIONS

MOUNT KEITH PROJECT
GENERAL PLAN
LAYOUT OF TAILINGS STORAGE
SITE OPTIONS

MOUNT KEITH PROJECT
GENERAL PLAN
LAYOUT OF TAILINGS STORAGE
SITE OPTIONS

MOUNT KEITH PROJECT
GENERAL PLAN
LAYOUT OF TAILINGS STORAGE
SITE OPTIONS

NORTHERN SITE

WESTERN SITE

SOUTHERN SITE

EASTERN SITE

NORTH EAST SITE
Figure 5  Mt Keith Tailings Storage. Centralised Discharge
Low Level Isometric View. Scale 20:1 (V:H)
6 MONTHS STORAGE
Figure 6  Mt Keith Tailings Storage. Centralised Discharge
Low Level Isometric View. Scale 1:1 (V:H)
16 YEARS STORAGE
Figure 7  Mt Keith Tailings Storage. Centralised Discharge
Low Level Isometric View. Scale 20:1 (V:H)
16 YEARS STORAGE
NEW CREST ACCESS ROAD.
PAVEMENT 100 COMPACTED
THICKNESS OF APPROVED
GRAVEL COMPACTED TO
95% MMDD (TYP)
LOW PERMEABILITY
CLAY ZONE
FENCE AROUND DAM
PERIMETER, REFER DETAIL (TYP)
Silty clayey sand
150 TOPSOIL (TYP)
EXIST. NSL
UPSTREAM
ZONE 1
ZONE 2
ZONE 3
ZONE 5
DOWNSRREAM
2000 MIN.
3000
2000
1.75
CL
VARYING

TYPICAL SECTION THROUGH EMBANKMENT
1:200

WESTERN MINING CORPORATION LTD
MT KEITH TAILINGS STORAGE
TYPICAL SECTION THROUGH EMBANKMENT
FIGURE 8
ANNUAL RAINFALL (1928-1993) AT YEELIRRIE

Fig 10
COMPARISONS OF MONTHLY RAINFALL AT YEELIRRIE

MEAN RAINFALL (1928-1993) 226 mm

1950 - A DRY YEAR 43 mm

1978 - AN 'AVERAGE' YEAR 211 mm

1992 - A WET YEAR 501 mm

Fig 11
DEPTH BELOW SURFACE (m)  

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GENERALISED HYDROGEOLOGICAL CROSS SECTION  

FIGURE 15
Legend to Figure 18

Land Systems

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<td>Waguin</td>
</tr>
<tr>
<td>Win</td>
<td>Windarra</td>
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Land Units

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
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<tbody>
<tr>
<td>BAS</td>
<td>Sandy bank</td>
</tr>
<tr>
<td>DRN</td>
<td>Narrow drainage line</td>
</tr>
<tr>
<td>GRO</td>
<td>Vegetation grove</td>
</tr>
<tr>
<td>PGS</td>
<td>Saline stony plain</td>
</tr>
<tr>
<td>PLG</td>
<td>Stony plain</td>
</tr>
<tr>
<td>PLH</td>
<td>Plain underlain by hardpan</td>
</tr>
<tr>
<td>PLL</td>
<td>Plain with ironstone gravel</td>
</tr>
<tr>
<td>PLO</td>
<td>Loamy plain</td>
</tr>
<tr>
<td>PLU</td>
<td>Gritty - surfaced plain on granite</td>
</tr>
<tr>
<td>RIL</td>
<td>Low rise</td>
</tr>
<tr>
<td>SSH</td>
<td>Sand sheet</td>
</tr>
</tbody>
</table>
DRMS Quadrat 3

No Photograph Taken

DRMS Quadrat 6
SAMU Quadrat 1

SAMU Quadrat 5
APPENDIX A

TAILINGS AND TAILINGS WATER CHEMISTRY
### TABLE A.1 - COMPOSITION OF TAILINGS SOLIDS

<table>
<thead>
<tr>
<th>Element</th>
<th>Total Element Concentration (mg/kg or %)</th>
<th>Average Crustal Abundance * (mg/kg or %)</th>
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<tbody>
<tr>
<td>Ag</td>
<td>&lt;0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Al</td>
<td>0.52%</td>
<td>8.2%</td>
</tr>
<tr>
<td>As</td>
<td>2.5</td>
<td>1.5</td>
</tr>
<tr>
<td>B</td>
<td>100</td>
<td>10</td>
</tr>
<tr>
<td>Ba</td>
<td>8</td>
<td>500</td>
</tr>
<tr>
<td>Bi</td>
<td>0.1</td>
<td>0.048</td>
</tr>
<tr>
<td>Ca</td>
<td>0.26%</td>
<td>4.1%</td>
</tr>
<tr>
<td>Cd</td>
<td>&lt;0.1</td>
<td>0.11</td>
</tr>
<tr>
<td>Co</td>
<td>41</td>
<td>20</td>
</tr>
<tr>
<td>Cr</td>
<td>880</td>
<td>100</td>
</tr>
<tr>
<td>Cu</td>
<td>180</td>
<td>50</td>
</tr>
<tr>
<td>F</td>
<td>50</td>
<td>950</td>
</tr>
<tr>
<td>Fe</td>
<td>4.6%</td>
<td>4.1%</td>
</tr>
<tr>
<td>Hg</td>
<td>&lt;0.01</td>
<td>0.05</td>
</tr>
<tr>
<td>K</td>
<td>0.090%</td>
<td>2.1%</td>
</tr>
<tr>
<td>Mg</td>
<td>24%</td>
<td>2.3%</td>
</tr>
<tr>
<td>Mn</td>
<td>700</td>
<td>950</td>
</tr>
<tr>
<td>Mo</td>
<td>0.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Na</td>
<td>1.1%</td>
<td>2.3%</td>
</tr>
<tr>
<td>Ni</td>
<td>1,600</td>
<td>80</td>
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<tr>
<td>P</td>
<td>&lt;20</td>
<td>1,000</td>
</tr>
<tr>
<td>Pb</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>S</td>
<td>4,800</td>
<td>260</td>
</tr>
<tr>
<td>Sb</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>Se</td>
<td>0.17</td>
<td>0.05</td>
</tr>
<tr>
<td>Sn</td>
<td>1</td>
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<tr>
<td>Sr</td>
<td>9.0</td>
<td>370</td>
</tr>
<tr>
<td>Th</td>
<td>0.3</td>
<td>12</td>
</tr>
<tr>
<td>Ti</td>
<td>&lt;0.2</td>
<td>0.6</td>
</tr>
<tr>
<td>U</td>
<td>0.1</td>
<td>2.4</td>
</tr>
<tr>
<td>V</td>
<td>15</td>
<td>160</td>
</tr>
<tr>
<td>Zn</td>
<td>30</td>
<td>75</td>
</tr>
</tbody>
</table>

### TABLE A.2 - CHEMISTRY OF TAILINGS WATER
(Campbell, 1995)

<table>
<thead>
<tr>
<th>Element/Parameter</th>
<th>Ex-Mill Tailings-Slurry Water (mg/L)</th>
<th>Storage-Decant Water (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>8.9</td>
<td>6.4</td>
</tr>
<tr>
<td>EC (direct)</td>
<td>67,000</td>
<td>72,000</td>
</tr>
<tr>
<td>EC (diluted)</td>
<td>86,000</td>
<td>92,000</td>
</tr>
<tr>
<td>TDS (gravimetric)</td>
<td>47,000</td>
<td>50,000</td>
</tr>
<tr>
<td>Na</td>
<td>15,000</td>
<td>18,000</td>
</tr>
<tr>
<td>K</td>
<td>870</td>
<td>1,000</td>
</tr>
<tr>
<td>Mg</td>
<td>1,600</td>
<td>2,000</td>
</tr>
<tr>
<td>Ca</td>
<td>100</td>
<td>110</td>
</tr>
<tr>
<td>Cl</td>
<td>23,000</td>
<td>25,000</td>
</tr>
<tr>
<td>SO₄₂⁻</td>
<td>8400</td>
<td>9100</td>
</tr>
<tr>
<td>HCO₃</td>
<td>85</td>
<td>85</td>
</tr>
<tr>
<td>CO₃</td>
<td>35</td>
<td>&lt;1</td>
</tr>
<tr>
<td>F</td>
<td>&lt;0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>NO₃⁻</td>
<td>20</td>
<td>13</td>
</tr>
<tr>
<td>Total-SiO₂</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>Reactive-SiO₂</td>
<td>0.6</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Notes: EC = Electrical Conductivity; TDS = Total-Dissolved Solids (Gravimetric Method). EC (direct) represents measurement directly on water samples, whereas EC (diluted) represents measurement on diluted water samples (using deionised water), so that the actually-measured EC is less than 5,000 µS/cm.
APPENDIX B

TAILINGS SEEPAGE ASSESSMENT AND MODELLING
## TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 INTRODUCTION</td>
<td>1-1</td>
</tr>
<tr>
<td>2.0 SEEPAGE MECHANISMS</td>
<td>2-1</td>
</tr>
<tr>
<td>3.0 SEEPAGE MODELLING</td>
<td>3-1</td>
</tr>
<tr>
<td>3.1 EMPIRICAL CALCULATIONS</td>
<td>3-3</td>
</tr>
<tr>
<td>3.2 PC-SEEP COMPUTER MODEL</td>
<td>3-5</td>
</tr>
<tr>
<td>3.2.1 Model Configuration</td>
<td>3-3</td>
</tr>
<tr>
<td>3.2.2 Seepage from Tailings Deposition</td>
<td>3-5</td>
</tr>
<tr>
<td>3.2.3 Tailings Deposition with Preferred Seepage Pathway Through Hardpan</td>
<td>3-7</td>
</tr>
<tr>
<td>3.2.4 Pooling of Stormwater from 1:100 Year Event on Natural Ground Surface</td>
<td>3-7</td>
</tr>
<tr>
<td>3.2.5 Pooling of Stormwater from 1:100 Year Event on Natural Surface Blanketed by Tailings</td>
<td>3-8</td>
</tr>
<tr>
<td>3.3 DISCUSSION OF RESULTS</td>
<td>3-8</td>
</tr>
<tr>
<td>3.3.1 Tailings Deposition with Production Bore Operating</td>
<td>3-8</td>
</tr>
<tr>
<td>3.3.2 Seepage from a Tailings Deposition with Preferred Seepage Pathway Through Hardpan</td>
<td>3-9</td>
</tr>
<tr>
<td>3.3.3 Seepage from a Pond that may Result from a 1:100 Year Storm Event Formed Over the Natural Surface</td>
<td>3-10</td>
</tr>
<tr>
<td>3.3.4 Seepage from a Pond Formed from a 1:100 Year Storm Event on Insitu Tailing Layer</td>
<td>3-11</td>
</tr>
<tr>
<td>3.4 SUMMARY</td>
<td>3-12</td>
</tr>
<tr>
<td>4.0 IMPACT ON GROUNDWATER SALINITY</td>
<td>4-1</td>
</tr>
<tr>
<td>5.0 COMPARISON OF SEEPAGE POTENTIAL - PADDOCK VERSUS CENTRAL DISCHARGE DISPOSAL</td>
<td>5-1</td>
</tr>
<tr>
<td>6.0 SEEPAGE MONITORING AND MANAGEMENT</td>
<td>6-1</td>
</tr>
<tr>
<td>6.1 RESPONSE PLAN</td>
<td>6-2</td>
</tr>
<tr>
<td>7.0 REFERENCES</td>
<td>7-1</td>
</tr>
</tbody>
</table>
Prediction of the impact on the surrounding environment of seepage from the Mt Keith Tailings Storage (conceptual design) has been approached in two stages.

The first stage quantified (using empirical methods) the potential seepage volume, and rate of propagation of seepage, and formulated an understanding of the (unsaturated and saturated) hydraulic regime within the Mt Keith Tailings conceptual design.

The second stage involved modelling the potential seepage using the numerical model PC-SEEP developed by Geo-Slope Pty Ltd. A two-dimensional finite element algorithm is used to solve flow equations through the unsaturated and saturated zones. The model was used to simulate the spatial distribution of tailings leachate as a function of time and predict vertical seepage rates from the tailings deposit.

The assessment of seepage for the Mt Keith Tailings was conducted only for the central discharge conceptual design. An account of the assessment of seepage on the paddock disposal option is provided in reference 3.

The scenarios provided for seepage modelling are “worst case”. In reality and with judicious management of tailings and minimisation of ponded water on tailings area, the potential for seepage is much reduced from that stated in the following.
2.0 SEEPAGE MECHANISMS

Potential seepage from the tailings will occur by gravity drainage whilst they remain saturated, although there are several factors which will contribute to controlling the volume of water seepage. These include:

- low permeability of the air-dried and desiccated tailings;
- low permeability of the compacted tailings;
- spatial distribution of permeabilities - it is probable that the horizontal permeability will be much greater (10 to 100 times) than the vertical permeability (due to the tailings being deposited in layers and chemical precipitation occurring at the surface through evaporative processes);
- capillary action (through a zone of about 4 m) which tends to draw water to the surface, reducing potential vertical drainage to the base of the tailings;
- evaporation and drying parameters (depending on salinity, salt encrustation, hygroscopic effects and bedding thickness);
- water retention capacity of the tailings and total volume of water retained in tailings;
- vertical and horizontal permeability of the tailings foundations and substrata;
- underdrainage;
- interception and cut-off trenches; and
- tailings management.

Of the above, most of the controlling aspects are fixed by the physical parameters of the materials and the design of the tailing storage. Tailings management can be varied as required to maximise drying and compaction of the tailings, which would maximise bleed water recovery and in turn will limit potential seepage. Unfortunately, emphasis by management to achieve one or two of the above could adversely affect the remaining, i.e. to maximise drying and early density increases, the achievable bleed water recovery may be compromised.
There is some speculation as to whether or not a water table would be present at the base of the tailings storage with the conceptual tailings design. Conflicting evidence is given in various papers that the presence or absence of a water table will be dependent on the drying factor and compaction (thus reduction of pore space and resaturation) achieved for the tailings.

Given that the Mt Keith project lies in an arid environment and given the low rate of tailing rise, evaporative drying of the tailings will likely be achieved. However, for modelling purposes, the existence of a perched water table in the tailings has been assumed as a “worst case” scenario. Operational experience will probably demonstrate that the tailings forms a “dry” stack. In this case, the potential for seepage will only occur in areas where permanent ponding may form, although the collector drains should intercept much of this potential seepage. However worst case scenarios have been modelled and results are presented in Section 3 of this report.
3.0 SEEPAGE MODELLING

3.1 EMPIRICAL CALCULATIONS

The perceived worst case scenarios are tabled in this section for set time periods. For this seepage estimation, bleed water is to remain in the storage area and will be available to seep in the first year. Tailings will be discharged at a rate equivalent to 10 million tonnes per annum (MTPa) ore throughput. From twelve months onwards, 15 MTPa ore throughput is assumed.

The percentage of seepage from the tailings used in these estimations is provided in Table 3-1 and is taken from underdrain recordings from field tailing trials data presented on Figure 1.

The formula used to calculate the infiltration for each active tailings layer cycle is:

\[
\text{Rate of infiltration} = \frac{\text{Seepage}}{\text{area of tailings}} \times \text{porosity of substrata}
\]

Where: seepage = (retained water in slurry) - \( [(\text{evaporation} \times \text{pf}) \times (\text{surface area})] \) - collected decant water.

Note: Area of tailings = tailings base area.

\( \text{pf} = \text{evaporation pan factor} \)
TABLE 3-1
WORST CASE SEEPAGE CALCULATION

<table>
<thead>
<tr>
<th>Tailings Layer</th>
<th>Seepage %</th>
<th>Duration (months)</th>
<th>Mode (MTPa ore)</th>
<th>Water to Tailings (kL/d)</th>
<th>Collected Bled (kL/d)</th>
<th>Area of Tailings ($m^2 \times 10^3$)</th>
<th>Water Retained in Tailings (kL/d)</th>
<th>Infiltration Rate (m/d)</th>
<th>Depth of Saturation under Tailings Base (mbgl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 year</td>
<td>12</td>
<td>12</td>
<td>10</td>
<td>31,800</td>
<td>0</td>
<td>5,500</td>
<td>31,800</td>
<td>0.002</td>
<td>3.8</td>
</tr>
<tr>
<td>2 years</td>
<td>8</td>
<td>12</td>
<td>15</td>
<td>47,700</td>
<td>13,000</td>
<td>5,800</td>
<td>34,700</td>
<td>0.0004</td>
<td>4.5</td>
</tr>
<tr>
<td>3 years</td>
<td>4</td>
<td>12</td>
<td>15</td>
<td>47,700</td>
<td>13,000</td>
<td>6,000</td>
<td>34,700</td>
<td>0.0002</td>
<td>4.8</td>
</tr>
<tr>
<td>5 years</td>
<td>2</td>
<td>24</td>
<td>15</td>
<td>47,700</td>
<td>13,000</td>
<td>6,200</td>
<td>34,700</td>
<td>0.0002</td>
<td>5.0</td>
</tr>
<tr>
<td>10 years</td>
<td>2</td>
<td>60</td>
<td>15</td>
<td>47,700</td>
<td>13,000</td>
<td>8,600</td>
<td>34,700</td>
<td>0.0004</td>
<td>5.7</td>
</tr>
<tr>
<td>20 years</td>
<td>2</td>
<td>120</td>
<td>15</td>
<td>47,700</td>
<td>13,000</td>
<td>12,700</td>
<td>34,700</td>
<td>0.0006</td>
<td>6.7</td>
</tr>
</tbody>
</table>

* Please note that evaporation has not been taken into account in these estimates. Additionally, a uniform saturation/infiltration front is assumed. This is unlikely to occur in operation where the saturation will be concentrated at the perimeter of the cones and water flow downwards will be controlled by a combination of vertical relict structures and the primary hydraulic conductivities.
A porosity of 20% was adopted for the above estimation to account for soil moisture and air entrapment. The silty-sands in the underlying sub-strata could potentially have a porosity of 40 to 50%. In addition, if vertical structure does exist, water may bypass dry zones leaving them “unwetted”. In this case, there would be potential for tailings water to reach the water table earlier than predicted via these preferred pathways or macropores. However, the volume involved should be small, and limited by the low permeability and small cross-sectional area of the conduits.

3.2 PC-SEEP COMPUTER MODEL

3.2.1 Model Configuration

The PC-SEEP model is a two-dimensional unsaturated/saturated groundwater flow model. The model is set up in cross-sectional mode using a unit width to compute flow volumes. It was used to predict vertical seepage rates from the tailings deposit at a number of stages during the tailings storage operation (from 3 months to 20 years after commencement of operations).

The geology underlying the tailings deposition area was assumed to be as follows:

- 0-0.5 m Channel Deposits (alluvial, silty sands)
- 0.5-14 m Wiluna Hardpan
- 14-29 m Pisolitic Loam with water table at 18 m
- 29-60 m Sandy Clays

Table 3-2 presents the modelled material parameters.

<table>
<thead>
<tr>
<th>Material</th>
<th>Saturated Hydraulic Conductivity (m/d)</th>
<th>Porosity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tailings</td>
<td>$2.6 \times 10^{-3}$</td>
<td>0.4</td>
</tr>
<tr>
<td>Channel Deposits</td>
<td>5</td>
<td>0.3</td>
</tr>
<tr>
<td>Wiluna Hardpan</td>
<td>Horizontal = 0.35 (vertical $3.5 \times 10^{-3}$)</td>
<td>0.4</td>
</tr>
<tr>
<td>Pisolitic Loam</td>
<td>0.14</td>
<td>0.3</td>
</tr>
<tr>
<td>Sandy Clays</td>
<td>0.14</td>
<td>0.3</td>
</tr>
</tbody>
</table>
Material properties were estimated from field and laboratory investigations by Woodward-Clyde and GHD. At time of reporting, Western Geotechnics were conducting core permeability tests to confirm vertical hydraulic conductivity of the Wiluna Hardpan.

The following assumptions were made in the modelling:

- The floor of the tailings storage was assumed to be flat, although in fact the floor slopes gently from west to east.

- The hydraulic conductivity of the materials does not vary with depth, location or direction, except for the Wiluna Hardpan where the vertical hydraulic conductivity was estimated to be two orders of magnitude less than the horizontal hydraulic conductivity.

The model configuration and runs have evolved as the understanding of the seepage mechanisms and design system become better quantified.

Initially, seepage from the tailings storage was modelled as two discrete systems:

- seepage from the tailings deposits; and
- seepage from a pond in the storage.

The second scenario was modelled in a preliminary manner, as firm details on the design and construction of such a pond was not available.

The subsequent model configurations as presented herein incorporate an initial flux condition to replace an initial head condition at natural surface, as well as recovery from a pumping bore (SLW2), consideration of preferential seepage pathways and ponding resulting from a 1:100 year storm event.

The model setup for each scenario is described below, and the results are discussed in Section 3.3.
3.2.2 Seepage from Tailings Deposition

A model was set up covering 2,800 m (horizontal) by 100 m (vertical). The left lateral boundary (nominally west) was set at the centre of the tailings storage and the right lateral boundary (nominally east) extended 500 m past the perimeter (i.e. giving the Tailings Storage a radius of 2,300 m).

The 100 m thickness allowed for the underlying geology and the successive construction of the tailings risers (maximum central height of 45 m at year 20).

A conservative approach was adopted to model the seepage mechanism, taking into account the proposed method and schedule for depositing tailings in the storage. It is conservatively assumed that a perched water table will develop at an early stage within the tailings storage. For these preliminary runs, the perched water table is simulated by specified head nodes, with the model calculating the seepage rates/volumes.

This scenario was modelled with a production bore operating and with no surface preparation (sealing, lining, etc). Drains have been included at the base of the tailings toe.

For each modelled scenario, six stages of tailings deposition were examined, involving modelled time periods of three months, eight months, one year, five years, ten years and twenty years after commencement of deposition.

For this scenario, it was assumed that for the first 3 months following commencement of deposition, the peripheral rim of tailings will be constructed. (In fact, tailings are discharged from the risers from day 1. However, this does not change model predictions significantly). From 0 to 1 year, the cells representing seepage from ponded water at this location were set as specified heads at natural surface. The lateral extent of these cells is limited to the area above the collector drain at the toe of the rim. During this time, it is assumed that the rim collector drain at the toe of the beach slope will intercept drainage from pondage at this point. (It was assumed that ponding would not occur at any other location due to the gentle slope of the land from west to east). From 1 year to 20 years,
the specified heads at this location were set at 0.5 m above natural surface, assuming a layer of tailings 0.5 m thick is placed by year 1.

From 1 year to 5 years after commencement of deposition, specified head nodes representing the perched water table at the toe of the central tailings cone were set in the model at natural surface. These specified head nodes were then relocated higher in the tailings storage after 5 years and 10 years from the commencement of deposition (to 1.5 and 8.5 m above natural surface respectively), to model the increase in height of the point of conveyance of the central and outside cones (i.e. the potential pondage point).

The system of collector drains that is proposed in the conceptual design was modelled by specifying a 50 m wide drain in the Channel Deposits (0.5 m below natural surface) at the toe of the rim deposition (Drain 1), and at the toe of the central tailings cone (Drain 2). It has been conservatively assumed that the tailings cone geometry above these locations could give rise to permanent ponded water in the tailings storage, and thereby provide the greatest potential seepage rate.

The profile of the tailings at each of the stages was estimated as an average of the cross-section profile through a central riser and two outside risers and the cross-section profile through the central riser only. The central heights of the tailings cones were estimated to the nearest 0.5 m. The radii of the cones were estimated to the nearest 10 m.

A production bore located 50 m east of the tailings storage perimeter was incorporated into the model to simulate the effects of pumping. These simulations are presented in Figure 2. The results where the pump and tailing storage are decommissioned for 30, 40 and 50 years are shown in Figure 3.

The water level at the production bore was decreased with time from 21 m below natural surface at 0 months to 30 m below natural surface at 20 years, to simulate aquifer depletion simultaneously with recharge from the tailings seepage.
3.2.3 Tailings Deposition with Preferred Seepage Pathway Through Hardpan

A 50 m preferential seepage pathway through the Wiluna Hardpan was incorporated into the model for the second scenario to simulate the possibility of a tributary of the palaeochannel daylighting to surface in the vicinity of semi-permanent pond or internal drain. The modelled time periods were as for the tailing deposition scenario described previously and pumping effects of an operating bore 50 m from the toe of the embankment incorporated into the model.

For the simulation the vertical permeability of the Wiluna Hardpan in the area below Drain 2 was increased to 0.035m/d, an order of magnitude greater than the assumed generalised vertical permeability of this unit.

An initial flux condition was applied to simulate ponded water over the natural surface. Thereafter, a specified head condition was applied to simulate water levels for the increasing height of the cones over the modelled time periods as indicated in Section 3.2.2. The result of the transient runs are presented in Figure 4.

3.2.4 Pooling of Stormwater from 1:100 Year Event on Natural Ground Surface

If a 1:100 storm event occurs over the proposed tailing storage design, a pond of collected runoff will form that is approximately 2 to 3 m deep. Given continuing bleed water contribution and the requirement to maintain the process water salinity at above 40,000 mg/L, the surplus water will take 10 months to remove.

This model run was set up as for the normal tailing deposition configuration and incorporated a 600 m wide pool of water simulated by specified flux cells. It was assumed that no surface preparation had been carried out. The specified flux cells were discontinued in the simulation, as the pond is assumed to have been depleted over this timeframe through pumping to the process plant. The transient run results were examined at 10 months, 1 year, 5 years, 10 years and 20 years after commencement of operation and the results are presented at Figure 5.
3.2.5 Pooling of Stormwater from 1:100 Year Event on Natural Surface Blanketed by Tailings

A model configuration was set up as for the previous scenario but with a 0.5 m blanket of tailing over the area of inundation.

These results are presented in Figure 6.

3.3 DISCUSSION OF RESULTS

3.3.1 Tailings Deposition with Production Bore Operating

Table 3-3 presents the modelled seepage rates for the eight stages examined for this case (refer Section 3.2.2). The seepage rates presented are average rates for the time period indicated, and apply to actual areas within the tailings storage. The seepage rates decrease very quickly to very low rates following specification of a tailings blanket, indicating that tailings thickness is an important parameter in the model.

<table>
<thead>
<tr>
<th>Time Period (years)</th>
<th>Average Modelled Seepage Rate (m$^3$/d)</th>
<th>Horizontal Through Channel Deposit</th>
<th>Through Hardpan</th>
<th>Through Drain 1</th>
<th>Through Drain 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-1</td>
<td>NQM</td>
<td>151</td>
<td>NQM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-5</td>
<td>808</td>
<td>3.1</td>
<td>0.0</td>
<td>629</td>
<td></td>
</tr>
<tr>
<td>5-10</td>
<td>0.0</td>
<td>0.9</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>10-20</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>20-30</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>30-40</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>40-50</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

NQM - not quantified by model as the specified head boundary condition at the natural surface applying to this time period results in excessive and unrealistic amounts of water predicted to be reporting to the drain.

Figures 2 and 3 show the predicted water tables for the above scenarios.
The graphical results show that the water table response up until one year following commencement of deposition, is mainly due to the effect of pumping from the production bore, and that there is little water table response to the seepage. Mounding of the water table is evident at 5 years, and decreases until 20 years, under the influence of pumping from the adjacent bore.

Figure 3 shows that once pumping from the production bore and ponding in the tailings has ceased, the water table returns to a horizontal profile over a short timeframe, at a level similar to the initial precommissioning conditions.

In the first year potential horizontal movement of seepage exceeds that of vertical seepage through hardpan. This is well supported by field observation of seepages from the present tailing storage facility where water was contained mainly in the surficial channel deposits leaving underlying hardpan largely 'dry'.

The model simulations indicate that the drains are effective in intercepting seepage where the drains directly underlie seepage sources. It may be concluded that additional thickness of tailings deposition provides benefits in limiting seepage, but at the cost of likely decreased drainage returns, unless the deposition is managed well to maximise runoff rather than seepage/drainage through the tailings.

3.3.2. Seepage from a Tailings Deposition with Preferred Seepage Pathway Through Hardpan

Table 3-4 below presents the predicted seepage rates when ponding occurs directly over an area where a preferential seepage pathway exists for various stages of the tailings storage operation. In this case, the specified head at the natural surface (0-1 years) was replaced with a more realistic specified flux boundary condition, resulting in predictions of lower seepage rates for this time period.
TABLE 3-4
MODELLED SEEPAGE RATES FROM TAILINGS DEPOSITION
WITH PREFERRED SEEPAGE PATHWAY THROUGH WILUNA HARDPAN

<table>
<thead>
<tr>
<th>Time Period (years)</th>
<th>Average Modelled Seepage Rate (m$^3$/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Horizontal Through Channel Deposit</td>
</tr>
<tr>
<td></td>
<td>Through Hardpan</td>
</tr>
<tr>
<td></td>
<td>Through Drain 1</td>
</tr>
<tr>
<td></td>
<td>Through Drain 2</td>
</tr>
<tr>
<td>0-1</td>
<td>131</td>
</tr>
<tr>
<td>1-5</td>
<td>0.0</td>
</tr>
<tr>
<td>5-10</td>
<td>0.0</td>
</tr>
<tr>
<td>10-20</td>
<td>0.0</td>
</tr>
</tbody>
</table>

The predicted water table for each of the above scenarios is shown on Figure 4.

The graphical results of ponding directly over a preferential seepage pathway simulation indicates that no effect would be visible after the first year of operation, however, after 5 years of operation there would be complete saturation to surface along the preferred permeable pathway. After 5 years the seepage contribution lessens due to the thickening of the tailing blanketing and, along with continuing pumping operation, water levels decline as indicated.

3.3.3 Seepage from a Pond that may Result from a 1:100 Year Storm Event Formed Over the Natural Surface

The modelled seepage rates resulting from the simulated runs of ponding over the natural surface from 0 to 10 months are presented in Table 3-5.
TABLE 3-5

MODELLED SEEPAGE RATES FROM A POND FORMED OVER 600 METRES OF NATURAL SURFACE FOR 10 MONTHS

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Average Modelled Seepage Rate (m³/d)</th>
<th>Horizontal Through Sand</th>
<th>Hardpan</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10 months</td>
<td>450</td>
<td>68</td>
<td></td>
</tr>
<tr>
<td>10 months - 1 year</td>
<td>0.0</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>1-5 years</td>
<td>0.0</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>5-10 years</td>
<td>0.0</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>10-20 years</td>
<td>0.0</td>
<td>0.0</td>
<td></td>
</tr>
</tbody>
</table>

The graphical results of pond seepage indicate a rapid rise of the water table underneath the ponded area over the first 10 months. Upon removal of the pond boundary condition, the water level declines slowly in response to pumping and isostatic adjustment of the groundwater levels which leads to a general subdued rise over the modelled area.

3.3.4 Seepage from a Pond Formed from a 1:100 Year Storm Event on Insitu Tailing Layer

The modelled seepage rates resulting from the simulated runs of ponding over a tailings blanket for a 10 month period are presented in Table 3-6.

TABLE 3-6

MODELLED SEEPAGE RATES FROM A POND FORMED OVER 600 METRES OF TAILING BLANKET FOR 10 MONTHS

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Average Modelled Seepage Rate (m³/d)</th>
<th>Horizontal Through Sand</th>
<th>Through Hardpan</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 10 months</td>
<td>130</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>10 months - 1 year</td>
<td>0.0</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>1-5 years</td>
<td>0.0</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>5-10 years</td>
<td>0.0</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>10-20 years</td>
<td>0.0</td>
<td>0.0</td>
<td></td>
</tr>
</tbody>
</table>
The graphical results of pond seepage indicate a rapid wetting of the underlying substrata for the initial 10 months, however, the transient unsaturated condition between the wetting front and water table does not result in a saturated flow condition. The resulting flux through unsaturated flow causes groundwater mounding in the area immediately below the ponded area for the ensuing 20 years; however, this is reduced by ongoing pumping, resulting in a similar end point to the simulation described in Section 3.3.3.

3.4 SUMMARY

Four seepage scenarios were examined for the Mt Keith Tailings Storage using the PC-SEEP model:

- seepage from tailings deposition in conjunction with production bore operating;
- seepage from tailings deposition as above with a preferential seepage pathway through the Wiluna Hardpan directly underlying ponded water;
- seepage from a pond formed as a result of a 1:100 year storm event and overlying the natural surface; and
- seepage from a pond formed as a result of a 1:100 year storm event and overlying a tailings blanket.

The geological layers boundary condition and parameters used for the above scenarios were identical apart from the preferred pathway simulation.

Installed drainage is predicted to be only effective where it directly underlies the seepage boundary condition. Pumping of the production bore restricts groundwater level rises generally and can be effective in reducing mounding of the groundwater table, depending on the actual conditions simulated.

The greatest predicted impact on water table levels occurs as a result of seepage from ponding due to a 1:100 year event, or the effect of preferred pathways.
Predicted seepage rates reduce considerably once tailings are deposited, and/or ponding is no longer assumed to occur on the natural surface, and/or ponding is restricted to small areas between the cones.

It is iterated that in practice, management practices will ensure that no permanent ponding will occur on the natural or tailings surface, that the impact on the groundwater is greater if the vertical permeability of the Wiluna Hardpan is higher, however the rate of seepage reduces to $5.5 \text{ m}^3/\text{d}$ after 1 year once a tailings blanket is lain down, then to $1.6 \text{ m}^3/\text{d}$ after 5 years. It is concluded then that variation in vertical permeability of the Wiluna Hardpan may allow rapid migration of seepage to the groundwater in the early years of tailing deposition only.

If a smaller CDD option as proposed were to be adopted then the potential seepage contribution from storm events would be less, and given that tailings deposition is concentrated into a smaller area, the benefit of reducing seepage by covering with a tailings layer will be effected sooner.
4.0 IMPACT ON GROUNDWATER SALINITY

A subpotable water resource exists under the proposed tailings storage which in part is utilised as a water supply for downstream processing purposes. The water quality is generally 1,000 to 1,300 mg/L total dissolved solids (TDS).

If we assume the water resources that directly underlie the proposed tailings storage area are the most likely to receive seepage during the 20 year design life, then the potential resources that are subjected to salinity increases through seepage may be estimated. Approximately 4,350 ML may be affected, assuming volume of 8,000 ML underlying the tailings (area of tailings x 10 m saturated thickness x 5% groundwater storage factor) less 20 year pumping of 3,650 ML.

Model simulations indicate the seepage contribution to groundwater may be as little as 33 ML to as much as 69 ML (combining operational seepages with ponding events) for the 20 year design life.

Therefore at the end of the 20 year design life, the potential bulk salinity increase above the 1,200 mg/L average initial conditions may be around 1070 mg/L, based on 4,350 ML at 1,200 mg/L, and 69 ML at 70,000 mg/L. Please note that the potential salinity levels in a pond resulting from a storm event have not been quantified at this stage.

Please note that the above estimation assumes a diffuse salinity contribution to the groundwater. The potential salinity distribution (horizontally and vertically) cannot be quantified by this mass balance approach which does not account for concentration of seepage to the groundwater through either preferred pathways or density driven mechanisms. These effects could result in the temporary formation of discrete ‘pockets’ of high salinity water initially, with these becoming diluted through diffusion and convection processes in time.
Notwithstanding the modelling results for both systems, seepage from the thickened tailing disposal system (conceptual design) is less likely to impact on the environment than a paddock style tailings disposal system where a central decant pond provides a permanent, hydraulic head and a flux source giving a driving mechanism for seepage.

Potential seepage rates for the Mt Keith paddock tailing deposition facility were modelled in 1994 as part of the storage and management design (Woodward-Clyde, 1994). To provide a design where potential seepage was minimised from the paddock tailing system, it was necessary to model a number of scenarios for a 1,000 x 1,000 m square paddock including systems of underdrainage, lining and foundation treatments. The modelling results indicated that for seepage to be minimised from a paddock style tailings disposal facility the following would be required:

- a 200 x 200 m HDPE liner be installed under the central decant area where permanent ponding was expected (this was later modified to a 400 x 400 m HDPE liner).
- underdrainage positioned at 20 m spacings within the central area over the HDPE liner; and
- the floor of the paddock be treated by either in situ compaction and treatment to reduce foundation permeability and clay line areas of the floor not amenable to conditioning measures.

The above measures were incorporated into the tailings design with an attendant high capital cost. Operational experience over the first year indicated these measures have been effective in that no rise in the groundwater levels or salinity have been observed by the monitoring system. However, there have been a number of surficial seepages migrating under the tailings embankment along relict alluvial channel deposits. An
allowance for these preferred seepage pathways was not included in the original 1994 modelling, and the causes for observed seepage include:

- rapid rise of tailings pile which exceeds design criteria;

- water contribution from recent extreme storm events to decant ponds leaving them at higher levels for longer periods and occupying larger areas than the design criteria;

- no internal drainage in the confining tailings embankments;

- saturated backfill in the unlined decant pipeline trench outside the tailings perimeter; and

- anisotropic permeability in the Wiluna Hardpan, where the horizontal permeability is greater than the vertical permeability.

The above factors have been accounted for in the proposed CDD design, and appropriate features included in the seepage model.

Notwithstanding the modelling results for both systems, seepage potentials for the central thickened tailing deposit (conceptual design) should be reduced given the following assumptions:

- no permanent ponds are planned to be formed over the storage;

- the main potential source of seepage (ponded water from rainfall or runoff from the cones) will not be concentrated in any one area for lengthy periods of time;

- the decant pumping area will be fully lined and maintained at minimum water levels;

- the hydraulic head which could develop in the tailings cone is unlikely to be substantial;
insitu surface trenches and drains are designed to intercept a large proportion of seepage, noting that much of the early seepage movement will occur laterally in the top 0.5 m of soil (preferred pathways);

unlined drains occupy a very small portion of the total surface area;

the embankment is a water retaining structure, incorporating a cut off key trench with frontal key trench and toe blanket drains.

In addition, recordings of water drainage return during field trials (see Figure 1) demonstrated that potential for seepage reduces with each successive tailings layer. For the trial where 50% slurry density input was deposited, no return water from underdrains was recorded in response to deposition of a third layer over two earlier layers that have been allowed to dry and desiccate.

For the 45% slurry density output the percentage return of inputted water had reduced to 4% from the third deposited layer. The graphical trend indicated the percentage return was likely to reduce with successive deposited layers.
Whilst all practical measures are to be incorporated into design and management to prevent seepage from discharged tailings, a monitoring system to provide early warning of seepage and a response and management plan to address potential seepage is still required. This is important with respect to:

- WMC's policy of Duty of Care to the Environment;
- Government regulatory requirements;
- avoiding contamination of groundwater resources which may impair future beneficial users; and
- avoiding impact upon local vegetation.

Monitoring of seepage of the central thickened discharge tailing disposal should incorporate two components. Firstly, an investigation programme is required to specifically investigate the perimeter of the tailing impoundment in order to:

- identify geological conditions which may control the rate and direction of leachate migration;
- identify preferential seepage pathways with respect to location and depth;
- put in place a monitor system comprising EM survey and nested monitor bores; and
- provide baseline data for later comparative analysis.

The second component is to conduct a programme where ongoing assessment and confirmation of the potential for seepage may be made. This would involve the installation of up to 20 sets of nested shallow monitor bores within the tailings area, sealed against surface water infiltration and monitored to check the presence and rate of seepage infiltration during operation. Use of data gathered during this programme would enable the model calibration to be refined, and the model would then provide a reliable analytical and management tool where prediction and quantification of seepage potential could be estimated.
The same approach to monitoring of seepage should be adopted for the smaller proposed CDD (Option 2) and provides an opportunity to optimise design and management systems for the final larger CDD option.

The monitoring requirements include:

- the water level of each monitor bore be recorded on a monthly basis;
- electrical conductivity of water samples from each monitor bore be recorded on a monthly basis;
- a full chemical analysis be conducted on water samples every six months from each monitor bore; and
- a six monthly repeat EM survey be conducted along an established grid.

An appropriate response plan for seepage management would then be formulated, incorporating refinements in tailings management and design.

It is envisaged that such a response plan would take the following form.

6.1 RESPONSE PLAN

The recommended approach is to investigate the extent of leakage as soon as it is detected and then to design a site-specific system to maximise the efficiency of recovery.

The response plan has a sequential list of actions to be taken, as listed below:

1. If seepage is detected via monitor bore, repeat the sampling to confirm results.

2. Investigate the extent of the seepage by:
   (i) EM survey;
   (ii) drilling and installation of monitor bores; and
   (iii) installation and testing a trial recovery bore.

3. Evaluate results and design a recovery system.
4. Install a recovery system.

5. Operate the system, with monitoring and a regular review of results.

6. Amend the recovery system as appropriate, i.e. more bores or alternative methods.

This approach should minimise the capital cost of installing the recovery system and should maximise the effectiveness of recovery. The plan is described in greater detail below.

Repeat the Monitor Bore Sampling to Confirm Results

It is important to repeat the sampling of monitor bores which have apparently detected seepage as soon as practicable after the results have become available. This is both to confirm the reliability of the results before initiating further site work, and to determine whether the concentrations of leachate are increasing rapidly or not.

Investigate the Extent of the Leachate Plume

EM Survey

An EM Survey is a cost-effective method of mapping the extent of leachate plumes. In addition, the intensity of the EM anomaly can give qualitative information as to the conductance and depth of the plume. Apparent resistivity profiles derived from the EM data may supply information as to the nature and depth of the plume and direction of migration.

Drilling and Installation of Monitor Bores

The EM survey would be used to help determine where to install additional monitor bores, which would be required to:

- establish monitor locations beyond the initial spread of the contaminant plume; and
- monitor the recovery programme within the area of the plume.
Install and Test a Trial Recovery-Production Bore

The results of the EM survey and monitor bore programme would be used to locate a trial recovery bore which would be used to assess the hydraulic conditions at the site. It would aim to demonstrate where hydraulic continuity does and does not exist and it would be intended that this bore be used as part (or all) of the recovery system.

Evaluate Results to Design a Containment and Recovery System

The results of investigations would be used to recommend additional recovery measures in the event that the single test production bore was not sufficient. Various options exist, including:

- strategically-located, additional low yield bores, probably situated to the east and west of the first recovery bore, i.e. across the strike of the main fracture system;
- interception drains and large sumps, if the plume were extremely shallow and located within weathered, i.e. weak, material;
- large diameter, shallow well(s), with pumping controlled by a float switch; and/or
- construction of a cut-off slurry-wall, or similar.

Install Recovery System

The final recovery system would then be completed by construction of additional recovery wells or sumps, if one bore were insufficient. Additional monitoring bores would also be constructed if necessary. The importance of careful and thorough monitoring of a recovery operation cannot be over-estimated.

Operate System

The recovery system operation programme would include:

- pumping to discharge into the tailings decant outfall pond; and
• closely monitoring water levels and quality in the monitor bores to demonstrate the prevention of further spread and, later, progressive contraction of the plume.

Adjust the Recovery System as Appropriate

The results of monitoring would be regularly reviewed with respect to the effectiveness of plume control. If appropriate, the system would be extended to improve recovery and eventually, it might be progressively shut down as recovery reaches its practical limit.

In the event of a major leak, resulting in a leachate plume that persists and is difficult to control by means of interception and recovery wells, it may be necessary to consider measures to seal the source of the leak.
M.P.A. Williams. "Peak Gold Mine Cobar, NSW. A Case History".


MT, KEITH TAILINGS FIELD TRIALS
UNDERDRAINAGE RETURN AS A PERCENTAGE OF TOTAL INPUTTED WATER

Woodward-Clyde

<table>
<thead>
<tr>
<th>DATE</th>
<th>REV</th>
<th>DESCRIPTION</th>
<th>CHK'D</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/12/95</td>
<td>A</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX C

WESTERN MINING CORPORATION
ENVIRONMENTAL POLICY
AND
MT KEITH OPERATIONS
ENVIRONMENTAL RESPONSIBILITIES
The Company is committed to achieving compatibility between economic development and the maintenance of the environment. It therefore seeks to ensure that, throughout all phases of its activities, WMC personnel and contractors give proper consideration to the care of the flora, fauna, air, land and water, and to the community health and heritage which may be affected by these activities.

To fulfill this commitment, the Company will observe all environmental laws and, consistent with the principles of sustainable development, will:

**Progressively establish and maintain** company-wide environmental standards for our operations throughout the world.

**Integrate environmental factors** into planning and operational decisions and processes.

**Assess the potential environmental effects** of our activities, and regularly monitor and audit our environmental performance.

**Continually improve** our environmental performance, including reducing the effect of emissions, developing opportunities for recycling, and more efficiently using energy, water and other resources.

**Rehabilitate the environment** affected by our activities.

**Conserve important populations** of flora and fauna that may be affected by our activities.

**Promote environmental awareness** among Company personnel and contractors to increase understanding of environmental matters.

HM Morgan

*Chief Executive Officer*

*October 1995*
Mount Keith Operations
Environmental Responsibilities

This booklet describes the environment at Mount Keith in Western Australia, and indicates the environmental responsibilities of individuals involved in the development and operation of Western Mining's Mount Keith Nickel Operations (MKO). At MKO we take our responsibility to the environment very seriously and any disregard of these responsibilities may result in dismissal.

It is essential that all MKO employees and contractors clearly understand the nature of their obligations, and that they are sufficiently well informed to be able to play their part in the proper protection of the environment.

As well as a desire to conduct its operations as a responsible corporate citizen, MKO has an obligation to the Western Australian Government, and the community in general, to protect the environment within the areas under its control. There are also legal requirements set down by legislation.

MKO environmental staff are available to provide you with further information, advice and assistance.
The Mount Keith project area is located in the mulga woodlands of the semi-arid East-Murchison region of Western Australia with high summer temperatures, low rainfall and generally poor quality soils. Like so much of arid and semi-arid Australia, the area is generally sensitive to disturbance. The area has been used for sheep grazing since the 1920s and destocking of the project area will assist in the regeneration of the region’s flora.

**Vegetation**

The lower plains are typically covered with grasses and low mulga woodland. Much of this vegetation has been heavily grazed and is in poor condition. The breakaways support a variety of plant species such as *Acacia*, *Eucalyptus*, *Cassia*, *Eremophila* and *Callitris*.

In addition the *Cue Grevillea* is known to occur in the area. This plant grows up to two metres high and has leaves up to four centimetres long that curve downwards, and tiny pink-white flowers. The Department of Conservation and Land Management (CALM) have advised that the *Cue Grevillea* is protected by law. A fine of up to $10,000 per plant may be imposed for damage or removal of any part of the plant.

**Fauna**

Even though the vegetation in the project area is seriously degraded, the fauna present includes 23 species of mammals, 76 species of reptiles, 7 species of frogs and up to 150 species of birds. Despite the presence of pastoral stock and feral rabbits and foxes, the wildlife is quite diverse.

**Aboriginal Sites**

There are two types of Aboriginal sites: archaeological and anthropological.

Archaeological sites are evidence of past occupation by Aboriginals. They include engraving sites, quarries, stone artefacts and rock paintings.

Anthropological sites are concerned with the relationships of Aboriginal people with the land. They include initiation and ceremonial sites, and can indicate tribal boundaries.

Should you visit a site of either Aboriginal or European heritage significance, you should leave it undisturbed so that others may have the opportunity to enjoy it.

**Climate**

Summers are hot, with average January temperatures in the high 30s and winters exhibiting a milder range of temperatures from around 18°C to close to zero. Rainfall averages 220mm annually, and may result from either summer thunderstorm activity or from winter depressions. Summer cyclones can cause sporadic heavy rainfall of up to 90mm, contributing to an erratic annual range of 80 to 550mm.

**Terrain**

The majority of the area consists of a topsoil sand plain, overlying a hard lateritic layer. Below this lies an extensively weathered zone consisting of alluvium, clays and weathered bedrock. Any relief is provided by wind-blown sand dunes or rocky outcrops. The latter can be either ridged hills (up to 45m) or, more commonly table-topped ridges (up to 50m) which are laterite capped and bounded by low undercut cliffs known locally as “breakaways”.

**Typical breakaway country**
INDIVIDUAL RESPONSIBILITIES

The rules applying to your responsibility for environmental protection are simple and sensible. In general, the environment should be disturbed as little as possible and care should be taken at all times.

Terrain

You can prevent surface damage and soil erosion by avoiding areas which are not designated roadways or tracks. Off-road travel within the project area is not permitted. Outside the project area, it must be avoided unless absolutely necessary. In wet weather, travel on unmade tracks must be limited so as to avoid making wheel ruts that encourage erosion.

Vegetation

All vegetation in the area is very important as it protects soil from wind and water erosion. This aspect is particularly important, and MKO policy is to retain existing trees and vegetation to the maximum extent possible. Avoid unnecessary removal of trees, shrubs, grasses and dead wood. Once exposed, topsoil is readily removed by the wind.

Fauna

MKO is committed to protecting all wildlife. The hunting and trapping of animals within the project area is not permitted. Firearms are banned. Venomous snakes can be a serious problem especially near buildings. Accumulated rubbish attracts mice which in turn tends to attract venomous snakes.

You can assist our biological studies by reporting any unusual fauna sightings to the environmental officer. Please include the following:-

- Description (size, colour, distinctive markings)
- Date and time
- Location
- Description of the animals activity.

Aboriginal Sites

Aboriginal sites must not be disturbed. If you are in doubt about the existence of a site, advice should be sought from the environmental officer. In the meantime, the site must be left alone.

Work Practices

Dump all refuse materials in designated areas. This includes rubbish, unused concrete, oils and saline water. If you see materials of this nature you should take them to a designated area or report the matter to the environmental officer.

Should you be involved in an accident, or an incident that causes any pollution, no matter how small, you should report the matter immediately. Prompt action can be taken to limit any affects of the pollution, and plans can be made to ensure that similar incidents do not recur. Examples would include burst pipelines and oil or fuel spills.

At MKO we wish to be constantly improving our work practices, and monitoring our activities, so that we minimise any
environmental impact. If you have an idea on how we can improve, we would like to hear from you. An 'Environmental Ideas Sheet' is available to record your suggestions, or simply talk to one of the environmental staff about your proposal.

Relations with Pastoralists

Land surrounding the Mount Keith project area is used by pastoralists for grazing sheep. Considerable effort has been made to develop and maintain good relations with these people.

MKO expects all individuals to help maintain good relations by observing certain regulations. Fences must not be damaged and gates must be left as found, which is normally shut; stock must not be interfered with in any way; domestic dogs and cats are banned from the project area; water in dams or other water sources must not be polluted in any way.

Off Site Activities

You may prefer to spend your recreation time in the surrounding region, away from the township of Leinster and the camps.

Seek permission from pastoralists before entering their properties. If you plan to travel off-site, the pastoralists' contact names and numbers are readily available from the environmental staff. When off-site you are requested to respect pastoralists' property. Shallow pits should be dug for containment of camp fires. Take care to extinguish and bury fires before leaving a camp site, and take your litter away with you. Avoid unnecessary excursions away from established roads and tracks.

Special care should be taken in the Wanjarri Nature Reserve to the south of the project area. Information on the Reserve and conservation matters in the area is available from CALM, (090) 212 677, or from your environmental officer.

Outback Safety

Travelling through the Outback can be hazardous for those who are inexperienced or unprepared. If you are contemplating long journeys through arid country, you should be aware of the dangers of Outback travel, as well as the techniques for survival.

Snakes

Large venomous snakes, particularly the Mulga and Western Brown, inhabit the project area. Scorpions, spiders and centipedes are also frequently seen. You should become aware of the dangers snakes and spiders represent. Leave all snakes alone.

If someone is bitten, you should apply a broad firm bandage around the limb and bitten area. Keep the limb still by using a splint. Do not cut or wash the bite. Do not apply a tourniquet. Do not move the victim unnecessarily. Transfer the patient to the First Aid centre as soon as possible.

Recommended reading is “Stay Alive - a Handbook of Survival” by Maurice Dunleavy published by the Australian Government Printing Services.