OLYMPIC DAM EXPANSION PROJECT

1
volume

WMC (Olympic Dam Corporation) Pty Ltd

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ENVIRONMENTAL IMPACT STATEMENT

KINHILL

WMC (Olympic Dam Corporation) Pty Ltd

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ENVIRONMENTAL IMPACT STATEMENT

Prepared for

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Cover photo:

An aerial photo montage within the Olympic Dam Special Mining Lease, reproduced in metallic copper ink. The view shows the dunes and swales typical of the area in which the project is located.


OLYMPIC DAM
MINE AND
PROCESSING PLANT
OLYMPIC DAM
VILLAGE
ROXBY DOWNS
N
0
2 km
Photo date: 4-10-95

FOREWORD

Through this Environmental Impact Statement (EIS), WMC is seeking approvals from the Commonwealth and South Australian governments to expand the Olympic Dam mine and processing plant.

To assist government to assess our project, this EIS also provides the community with the opportunity to comment on WMC's plans to further develop the major orebody at Olympic Dam as a world-class mining and processing operation.

The ability for people outside the Company to express views about our plans is very important.

WMC intends to commit $1.48 billion to this expansion, the largest single capital investment in its sixty-four year history. The expansion is also one of the largest development projects being proposed in Australia at this time, and as such, we encourage community interest in our plans.

WMC is making this commitment recognising that Olympic Dam faces strong competition from other world producers of its major commodity—copper. To ensure the long-term viability of Olympic Dam, we must ensure that the design of the expansion adopts leading edge technology to be competitive in the world market.

At the same time, it is important for the community to be confident that pursuing economic development, job creation and export growth through the expansion is compatible with maintenance of the environment. This is the foundation of WMC's Environment Policy.

We appreciate your interest in Olympic Dam and welcome any comments you may wish to make about this EIS.

P. M. Bowman

PEARCE BOWMAN
Executive General Manager
Copper Uranium Division
WMC Limited

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SUMMARY

WMC Limited (WMC) proposes to undertake a two-phase expansion of production at its Olympic Dam operations in northern South Australia. The first phase of the expansion will initially increase the production rate from the current 85,000 t/a copper and associated products to the already approved rate of 150,000 t/a. Construction for this initial step has already commenced. Subject to the necessary approvals, the first phase of the expansion will enable copper production to be increased to a nominal rate of 200,000 t/a. The second phase of the expansion, which is subject to WMC Board approval, would further increase production to 350,000 t/a.

This environmental impact statement (EIS) considers both phases of the Expansion Project above the already approved rate of 150,000 t/a to 200,000 t/a and then 350,000 t/a copper.

The operations at Olympic Dam are based on one of the world's largest polymetallic orebodies, with known mineral reserves of 11.4 Mt of copper, 0.34 Mt of uranium (as uranium oxide), 400 t of gold and 2,790 t silver.

At a nominal copper production rate of 200,000 t/a, the corresponding rate of production for associated products would average approximately 4,630 t/a uranium oxide, 2,050 kg/a gold and 23,000 kg/a silver. However, owing to the variability in the ore grade, the peak production rates in any year could be up to 210,000 t/a copper, 5,000 t/a uranium oxide, 2,110 kg/a gold and 28,350 kg/a silver.

In the second expansion phase to a nominal production rate of 350,000 t/a copper, the corresponding production rate for associated products would average approximately 7,730 t/a uranium oxide, 3,630 kg/a gold and 49,600 kg/a silver.

Following completion of the first phase of the expansion, surplus smelting capacity could be used to produce copper from imported copper concentrates or other ores. If both the new and existing smelters were fully utilised, the overall copper production after the year 2000 would be up to 285,000 t/a.

The major issues raised by this proposal to expand Olympic Dam operations relate to:

- the sustainable supply of water
- the containment of tailings
- the management of radiation exposures.

In the proposed expansion, the mining method and metallurgical processes would remain essentially unchanged, and are thus well understood. The expansion also offers the opportunity to incorporate recent advances in technology and productivity that would lead to improved environmental performance, waste minimisation, energy and water conservation, and better occupational health and safety standards.

The Olympic Dam Expansion Project EIS demonstrates how all of the environmental, social and pollution control issues for the proposed two-phase expansion would be managed.

1 PROJECT BACKGROUND

WMC began exploring South Australia for copper deposits in 1961. In 1972, a review of historical geological data combined with various geological models led WMC geologists to focus on the region to the west of Lake Torrens. Large-scale surveys indicated a number of coincident gravity and magnetic anomalies, suggesting that the Olympic Dam area warranted further exploration, and in 1977 WMC's Chairman reported to the Annual General Meeting that drilling had outlined a large prospective ore position.

Because of the likely size of the project, WMC sought partners to assist with its development, resulting in the formation of a joint venture with the BP Group in July 1979. In May 1980, the decision was made to sink an exploration shaft (the Whenan Shaft) to a depth of approximately 500 m. Feasibility studies into the metallurgical processing were conducted, and preliminary design work was undertaken. Environmental baseline studies began later that year.

Production at Olympic Dam commenced in 1988 at a rate of 45,000 t/a of refined copper and associated products. Between 1989 and 1995, the production rate was increased to the present levels in two optimisation programmes, ultimately raising the ore mining rate to 3 Mt/a and the copper production rate to 85,000 t/a.

In 1993, WMC acquired full ownership of Olympic Dam. The facilities are now operated by WMC (Olympic Dam Corporation) Pty Ltd, a wholly owned subsidiary of WMC Limited.

The regulatory framework and approvals process

The operations at Olympic Dam are regulated by the *Roxby Downs (Indenture Ratification) Act 1982*, which was ratified by the South Australian Parliament in June 1982 and amended in 1996. The original Indenture applied to the development of an operation recovering up to 150,000 t/a copper and associated products. The amended Indenture provides for the development of an operation recovering up to 350,000 t/a copper and associated products.

Environmental assessment at Olympic Dam has been comprehensive from the project's inception. It began with the preparation of the Draft EIS and Supplement which was based on a mining and processing operation capable of producing 150,000 t/a of refined copper and associated products. The project as defined in these documents was assessed and approved by the South Australian and Commonwealth governments in 1983.

The environmental management and assessment process since that time has included licence approvals, a waste management plan, environmental monitoring programmes updated every three years, and annual environmental and radiation monitoring reports. Also required have been an environmental review of the existing operations, and detailed environmental and Aboriginal heritage assessments for the progressive development of water and power supply infrastructure.

In addition, WMC has provided the State Government with Project Notices setting out details of all operational changes, and has complied since project commencement with all applicable Acts, Regulations and codes of practice.

For the proposed Expansion Project, the environmental impact assessment process entails:

- preparation of an EIS according to guidelines approved by both the State and Commonwealth governments;
- submission of comments by the public and by government departments;
- preparation of a response (or 'Supplement') document by WMC;
- review of all documents by both governments, leading to a decision on whether the Expansion Project will be allowed to proceed and, if so, under what conditions.

Structure of this summary

The structure of this summary parallels the structure of the EIS, which was shaped by two key considerations: the need to describe the scale and physical characteristics of the Expansion Project in the most effective way, and the need to examine those environmental factors that have been identified in the EIS guidelines and by WMC's environmental consultants as being the most relevant in assessing the effects of the proposal.

2 EXISTING OPERATIONS

The existing operations at Olympic Dam comprise an underground mine, mineral processing plant and associated infrastructure located within the Special Mining Lease area of approximately 29,000 ha. WMC has systems in place—covering environmental as well as occupational health and safety procedures—for managing all these facilities. In December 1996, the Olympic Dam operations employed 449 people in mining activities and 514 people in mineral processing.

Mining and processing

Access to the mine is through the vertical Whenan and Robinson shafts and the inclined service tunnel. Since mining commenced in 1988, more than 100 km of underground development has taken place, producing 17 Mt of mined ore.

The ore minerals consist mainly of fine-grained copper sulphide, uranium, gold, silver and rare earths, located beneath some 350 m of unmineralised sedimentary rocks. The primary extraction method is a variant of sublevel (underground) open stoping, in which blocks of mineralised ore are systematically blasted and the ore recovered for crushing below ground. The crushed ore is then hoisted up one of the shafts to the surface stockpile.

Following extraction, stopes are backfilled with a cemented aggregate of crushed mullock (waste rock), deslimed mill tailings, cement and pulverised fuel ash. Twenty-one mine-to-surface airways are used to ventilate the underground workings.

Above ground, the processing facilities (collectively referred to as the metallurgical plant) comprise a copper concentrator (including a grinding mill), hydrometallurgical plant, copper smelter, sulphuric acid plant, copper refinery, and gold and silver refinery. The plant currently produces 85,000 t/a copper, 1,500 t/a uranium oxide, 850 kg/a gold and 13,000 kg/a silver.

Copper is recovered primarily by flotation of copper sulphide from a slurry of finely crushed ore, after which the copper concentrate is smelted to produce blister copper, and is converted by electrorefining to high purity copper. Wastes generated during electrorefining are treated to recover gold and silver. After treatment by flotation, the finely crushed ore is leached with sulphuric acid to dissolve the uranium and any remaining copper. The leach liquor is then processed in the solvent extraction plant to separate the residual copper and the uranium streams. This residual copper is recovered by electrowinning, and the uranium is converted to yellowcake and then calcined to produce uranium oxide.

The mine and processing operations produce a series of waste streams which are managed in separate dedicated facilities. These include a storage facility for the tailings solids, evaporation ponds for tailings liquor, a disposal pond for mine drainage water, a recycling centre and solids landfill, and sewage treatment facilities. The plant has been designed so that any spillage of ore, concentrate or process slurries can be readily returned to the process circuit. The plant also includes comprehensive air pollution control equipment, and air emissions and noise are monitored and kept within statutory requirements.

Existing infrastructure

Electrical power is supplied by a 132 kV transmission line to Olympic Dam via Pimba from the Port Augusta power station. With the current demand reaching 40 MW average load, the transmission line is approaching capacity.

Water is supplied from two borefields which abstract water from the Great Artesian Basin. The total water use is about 15 ML/d, of which some 1.6 ML/d is used by the township.

Roxby Downs and the Olympic Dam operations are accessed by sealed bitumen road from the Stuart Highway, and by a regular air passenger service from Adelaide.

The workforce is accommodated in the Roxby Downs township and at the village. The township was established in 1988 and houses the plant workforce and government and service industry employees. The Olympic Dam Village is located about 5 km south of the process plant, and 9 km north of the town, and comprises the construction workforce camps, the industrial area and the airport.

At present, some 2,500 people live in the township and approximately 200 people at the village. The township has been developed in accordance with the parameters set out in the Indenture, and has a very well developed infrastructure. The town's population enjoys a high level of community amenities and has a very positive attitude towards involvement in community activities.

Environmental management

An environmental management and monitoring plan has been formulated covering all Olympic Dam operations, to ensure that the requirements of WMC's Environment Policy and the legally required management obligations are fulfilled. The current plan consolidates and updates the previous environmental monitoring programme and waste management plan, and covers the period from 1 March 1996 to 28 February 1999. Annual environmental management reports are made available to the public by Mines and Energy South Australia, and copies are held by the State Library of South Australia.

All aspects of the Olympic Dam operations are regulated by comprehensive occupational health and safety procedures, with a major focus on radiation safety. At the commencement of operations in 1988, WMC initiated stringent radiation safety practices to protect all personnel and the environment. The results of monitoring programmes have shown that radiation exposure levels to employees, members of the public and the environment have been maintained well within statutory limits and international guidelines. WMC has also implemented formal programmes that continually seek to improve the safety of the workplace.

WMC is continuing a consultation programme with the Roxby Downs community, local pastoralists, Aboriginal groups and other community groups, in order to consult with and inform them about the operation's activities. Ethnographic and archaeological sites are identified in consultation with the Aboriginal community, and recorded and managed.

3 DESCRIPTION OF THE PROPOSED EXPANSION

The first phase of the proposed Expansion Project would increase copper production to the already approved rate of 150,000 t/a by the year 1999, with a further increase, if approved, to 200,000 t/a to be achieved by the year 2000. However, an accelerated construction programme is being implemented and these production rates may be achieved at earlier dates.

The WMC Board has made no formal decision on implementation of the possible second phase expansion to a copper production rate of 350,000 t/a. However, for the purposes of hydrogeological and economic modelling, it has been assumed in this EIS that the second phase would be operational in the year 2010, and construction would start in the year 2008.

In planning for both phases of the Expansion Project, it has been assumed that ore would be supplied exclusively by the mine. However, there may be times when feed for copper production may be supplemented by ore imported from other mines in South Australia, or by copper concentrates imported from other mines in Australia or overseas. The use of imported copper concentrate or ore would be largely determined by economics and by the availability of surplus capacity in the metallurgical plant. The importation and treatment of ores or concentrates for the recovery of uranium is not proposed.

Geology and mineralisation of the deposit

The Olympic Dam deposit, located in the Stuart Shelf geological province in the far north of South Australia, lies beneath approximately 350 m of barren, flat-lying sedimentary rocks within a formation known as the Olympic Dam Breccia Complex (breccias consist of rock fragments cemented by finer material). The core of the complex comprises barren quartz–haematite breccias, flanked to the west and east by a broad zone containing abundant haematite-rich breccias intermingled with altered granite breccias. The known copper–uranium mineralisation occurs within these zones.

The mineralisation of the deposit can be broadly categorised as follows:

- copper–uranium (with some gold and silver) ore: This ore comprises most of the resource, and is primarily contained within haematite breccias;
- gold ore: This ore type generally occurs as small zones hosted by either granite-rich or haematite-rich breccias. There are some rare, but significant, extremely high-grade concentrations of free gold, especially around the margins of the quartz–haematite core.

Proved and probable total ore reserves as at 30 June 1996 are 73 Mt and 496 Mt respectively, yielding an average of 2% copper, 0.6 kg/t uranium oxide, 0.7 g/t gold and 4.9 g/t silver.

Mining

In most respects, mining operations for the Expansion Project would remain unaltered. The most significant changes proposed to achieve the target production rates are the construction of a new vertical haulage shaft and the replacement of diesel trucks by an automated electric rail system for ore haulage underground.

A coarse ore blending stockpile would be installed on the surface to achieve a more consistent ore grade at the metallurgical plant. This blending stockpile would allow mining to proceed in the most efficient manner by maximising the productive use of mining equipment. It would also optimise the recovery of metal from ore in the processing plant by minimising grade variations.

For the processing plant to achieve a sustained production rate of 200,000 t/a copper, the mine would need to supply 8.7–9.2 Mt/a of ore, depending on the grade of ore processed. At least thirty stopes would need to be operated in any one year for this rate of production. At any one time, the number of stopes in operation would vary from an average of thirteen to about twenty-three.

In the proposed expansion, the main ore haulage level would be established approximately 740 m below ground level. The new vertical shaft, referred to as the No. 3 shaft, would be sunk from the surface to minimise interference with other operations. Underground development associated with the No. 3 shaft would include a new crusher station and ore handling system.

The ventilation system for the proposed expansion would be similar to that currently in use, with approximately one new ventilation shaft being installed each year. A new backfill system would be designed to maximise the use of deslimed tailings in addition to using other backfill material from an expanded quarry. Expanded mine services would include additional pumping facilities, water supply, power, communications and control equipment, workshops, explosives magazine, and amenities.

Mineral processing

The principal modifications to the metallurgical plant for a nominal capacity of 200,000 t/a refined copper would include the following:

- a new ore stockpile, a new autogenous mill and additional flotation cells added to the copper concentrator section of the plant;
- expansion of the hydrometallurgical plant, including expansion of the tailings leach area and expansion of the copper–uranium solvent extraction area;
- construction of a new smelter complex with a nominal capacity of 180,000 t/a copper, and an associated acid plant of capacity 1,640 t/d sulphuric acid;
- expansion of the copper refinery to a nominal capacity of 179,000 t/a electrorefined copper, and 23,750 t/a electrowon copper;
- construction of a new gold and silver refinery;
- relocation and expansion of buildings, laboratories and site services.

The modifications to the tailings retention system for the expansion to 200,000 t/a, assuming the current paddock system for tailings disposal is continued, would include the construction of another two tailings storage cells of 100 ha each, increasing the overall storage area to 390 ha. Another lined four-cell evaporation pond of 50 ha, to increase the overall evaporation pond area to 118 ha, would also be provided. Discussion of an alternative tailings storage system—central thickened discharge—is provided in Section 8. The mine water disposal pond would be relocated and enlarged to 30 ha.

Modifications for the possible second phase expansion to 350,000 t/a would include:

- further expansion of the copper concentrator and hydrometallurgical sections of the plant
- construction of a new copper matte smelter and associated acid plant
- duplication of the copper refinery.

Modifications to the tailings retention system for this phase, based on the paddock method, would include provision of a further three tailings storage cells of 110 ha each, increasing the overall storage area to 720 ha.

4 WATER MANAGEMENT

Future rates of water abstraction from the Great Artesian Basin, including amounts required for expansion up to a copper production rate of 350,000 t/a, will be maintained within the requirements of the special water licences that apply to the borefields.

At present, of the approximately 425 ML/d of water flowing into the South Australian sector of the Great Artesian Basin, pastoral use is estimated to be 132 ML/d; mound spring flows—66 ML/d; flows associated with gas and oil production—22 ML/d; Olympic Dam and Roxby

Downs use—15 ML/d; and vertical leakage—190 ML/d. As part of the Expansion Project, Olympic Dam water use is expected to increase to 34 ML/d for 200,000 t/a copper production, and then to 42 ML/d for 350,000 t/a.

The cost of water at Olympic Dam is high owing to the extensive infrastructure required to source the water and the cost of treatment to achieve potable water quality. At a copper production rate of 200,000 t/a, the cost of process and potable water at Olympic Dam would be some 1.8 and 2.7 times greater, respectively, than the cost of potable water to Adelaide consumers.

The high cost has been an incentive for WMC to design the plant to be water efficient and to investigate and implement water use minimisation programmes. Since the first full year of production, process and potable water use at Olympic Dam has reduced from 2.10 kL per tonne of ore milled to the current rate of 1.57 kL per tonne. A further reduction to 1.24 kL per tonne is planned as part of the expansion to a copper production rate of 200,000 t/a.

Numerical modelling of the future borefield operation, over a planning period of twenty years to the year 2016, was undertaken using an updated hydrogeological model and recently acquired data to assess compliance with requirements of the special water licences. The modelling was also used to update predictions on the effects of borefield operation on mound springs and pastoral bores.

The results of the numerical modelling show that the drawdown limits of the special water licences over the twenty-year planning period would continue to be met. The predicted reductions in flows from current levels would be less than 16.5% for all mound springs and less than 2% for those springs that are considered to be ecologically significant. An increase in flow is predicted at a number of mound springs near Borefield A, with these springs having shown the greatest flow reduction from the previous Borefield A operations.

The numerical modelling also shows that the pastoral bores closest to the WMC borefields would be most affected by reductions in aquifer pressure. Two pastoral bores currently having low artesian pressure are predicted to cease flowing. However, water would continue to be available at these and all other existing pastoral bores, and current flow rates could, if necessary, be maintained by pumping. Arrangements in this regard would be in accordance with the Indenture, which contains provisions for the maintenance of existing pastoral water supplies.

Options exist for the provision of water supplies beyond the twenty-year planning horizon adopted for this EIS. These options include the continued use of the existing borefields together with the development of further water conservation measures. In addition, it is expected that estimates of the obtainable long-term water supply will increase. Such increases could result from the use in future modelling of additional measured data to replace assumptions made previously. The current modelling uses precautionary principles in the selection of assumptions, thereby resulting in conservatively low estimates of the available long-term supply.

The development of a borefield further into the Great Artesian Basin may also be necessary to meet long-term water supply needs. If required, this borefield would be the subject of further environmental evaluation. Although research indicates that water outflows from the basin currently equal inflows, it is considered feasible that the basin could be further developed by providing strategically positioned bores which harvest groundwater that would otherwise be lost to evaporation via vertical leakage from the aquifer.

Groundwater below the Olympic Dam site generally occurs at a depth of 50 m, is highly saline (with total dissolved solids in the range 20,000–40,000 mg/L) and contains detectable levels of naturally occurring metals including uranium and radium. Owing to its salinity, this groundwater is not currently used as a water supply, with the exception of some minor use for dust suppression and drilling at the operations.

The direction of regional groundwater flows was reviewed as part of this EIS. While not totally conclusive, this review indicated that groundwater under Olympic Dam flows to the north-east and then probably to the east, to the saline aquifers under the northern end of Lake Torrens.

The impact of the underground mining operations at Olympic Dam on the regional aquifer is substantial but localised, with little if any effect distinguishable beyond a distance of approximately 5–10 km. However, this localised aquifer drawdown does dominate the groundwater regime of the mine area, with groundwater flowing towards the mine from all adjacent areas, including the area beneath the tailings retention system.

Due to the slow rate of regional groundwater flow, water levels would be expected to take a long time, perhaps centuries, after the cessation of mining to recover to a point where the pre-mining groundwater flow system was re-established.

Seepage to groundwater is known to occur from the mine water disposal pond, which receives groundwater that drains into the mine. This seepage, however, essentially constitutes natural groundwater. Seepage also occurred previously from the tailings storage facility and associated evaporation ponds, but the design and operation of these has been changed substantially in recent years to ensure seepage is minimised. Investigations into this seepage have concluded that it has had no adverse impact on the environment or the health of employees or members of the public. In addition, groundwater monitoring around the area indicates that the new measures are successfully meeting their objective of minimising seepage.

As part of the Expansion Project, the tailings retention system would be expanded, with the design of the new facilities incorporating features to ensure seepage continues to be minimised. The extensive groundwater monitoring system in this area would also be extended. In addition, the mine water disposal pond would be relocated so that seepage from this facility would not interfere with groundwater monitoring near the tailings retention system.

Stormwater management for the expanded project would continue to use the same approach as the existing plant and would include the provision of impervious bunding around process equipment, enabling spillages, wash water and stormwater to be collected and returned for use as process water.

5 LAND USE

Although its viability has always been dependent on the region's erratic rainfall, pastoralism remains the most extensive land use in the region. Mining activities are also undertaken and these include Olympic Dam (copper, uranium, gold and silver); Coober Pedy and Andamooka (opal); Mt Gunson (copper); and intensive minerals exploration in the wider area.

Other land uses include defence-related activities at Woomera; tourism, particularly in the Lake Eyre and mound springs areas; and conservation parks. Settlements are dispersed, with Roxby Downs being one of only two major regional centres in South Australia north of Port Augusta, the other being Coober Pedy.

Pastoralists in the region have benefited from the existing operation which has brought improved access to town facilities and potentially more reliable stockwater supplies via the Olympic Dam water supply pipelines.

Additional stock and fauna losses may result from increased vehicle traffic between Olympic Dam and Woomera, particularly during the construction period. In the operational phase there would be an increased risk to stock and pastoral property from the larger population.

There would be no direct impacts from the proposed expansion on other land uses or features of European heritage value in the region.

6 ABORIGINAL CULTURE AND RELATIONSHIPS

There are currently three registered claimant Applications for a Native Title Determination over the Olympic Dam Project Area, which comprises the Special Mining Lease and Municipal Lease areas. There are also several other applications over all or part of the borefields and pipeline and power line corridors.

WMC has contributed to, and continues to participate in, statutory conferences and meetings convened by the National Native Title Tribunal. In accordance with its Indigenous Peoples Policy, WMC is committed to the continued protection of sites of Aboriginal heritage significance, and has appointed community relations officers who are responsible for ongoing consultation with Aboriginal groups in all of WMC's Australian operations areas, including Olympic Dam.

Aboriginal heritage studies and consultation with Aboriginal groups have been ongoing since the 1983 EIS, and have produced considerable additional information about the archaeological and ethnographic aspects of Aboriginal heritage in the Project Area, the borefields, the pipeline and power line corridors, and the Stuart Shelf Exploration Area. For development in these areas, a strategy of site avoidance has been adopted for all ethnographic sites and, where possible, archaeological sites.

Owing to the ubiquitous nature of the archaeological record in the Olympic Dam Project Area, avoidance of archaeological sites is not always feasible. Prior to any new development, Aboriginal people are consulted and surveys undertaken with consulting archaeologists and anthropologists. A sign-off procedure is part of the surveys. Measures for the protection of sites during construction are included in project-specific environmental codes of practice.

In addition to fulfilling its obligations for Aboriginal heritage assessments, WMC is also active in general support of broader Aboriginal cultural processes. The company has funded and provided logistic support to a recent women's ceremony near Roxby Downs; supported an archaeological site excavation and surface artefact collection by the Royal Geographical Society of South Australia and the Andamooka Land Council; initiated discussions with Aboriginal groups in relation to community development programmes; and developed strategies to facilitate greater employment opportunities for Aboriginal people.

7 BIOLOGICAL ENVIRONMENT

WMC's Environment Policy establishes the company's corporate commitment to the National Strategy for Ecologically Sustainable Development. WMC has effective environmental management programmes for all its operations, and has implemented a government-approved comprehensive environmental management and monitoring programme (EMMP) at Olympic Dam. In addition, WMC staff undertake a wide range of biological research programmes beyond the EMMP or legislative requirements, and this has led to a better understanding of regional biodiversity and conservation issues.

Flora

The vegetation of the Project Area and region is characterised by low density arid zone vegetation that has been degraded for over a century by past land use and introduced herbivores, particularly the European rabbit. Within the Project Area, this type of degradation has slowed since the more recent removal of domestic stock and the release in 1996 of Rabbit Calicivirus Disease.

The Project Area and region are dominated by three vegetation communities that occur repeatedly and are associated with the two major landform types: dunefields and stony tablelands. There are no species recorded in the Project Area or region that are classified as rare or endangered under Australian or South Australian legislation.

The dunefields are generally dominated by Acacia woodland and tall shrubland vegetation on the dune ridges, merging into low chenopod shrubland vegetation in the dune swales. The Project Area contains relatively large areas of white cypress pine and western myall communities that are biologically important and poorly preserved elsewhere in formal conservation areas. The impact of the proposed expansion on these vegetation communities is expected to be negligible.

Vegetation associated with water drainage occurs where water collects in swales between some dunes. These areas are generally dominated by swamp cane-grass (sometimes with lignum), chenopod low shrubland and short perennial grasses.

The vegetation present in areas of stony tableland is dominated by low chenopod shrubland. Other significant vegetation communities associated with areas of stony tableland, such as bladder saltbush/stalked Ixiolaena low shrubland and cane-grass tussock grassland, are not expected to be affected during the proposed expansion. There are no plant species recorded in the Project Area or region that are classified as threatened under Australian or South Australian legislation.

In comparison with many other settled areas in Australia, relatively few introduced plants are present. The majority of the sixty-three introduced species recorded are annuals and do not pose a threat to native vegetation. In the past, three proclaimed pest plant species have been recorded in the Project Area and twelve in the region. The activities by WMC have not increased the number or distribution of proclaimed introduced plant species in the region, and the proposed Expansion Project is expected to have a minimal effect in this respect.

Past land clearing in the Project Area as a result of mining and associated activities has been minimal (approximately 3.5% of the total area) although there have been adverse impacts to some small areas of vegetation due to some air emissions and activities such as off-road driving. However, these impacts have been mitigated through environmental management actions and community education.

Predicted impacts of the proposed Expansion Project include clearance of some dunefield vegetation communities, particularly tall shrubland and low chenopod shrubland. Land clearance is expected to be between 632 ha and 1,082 ha for the 200,000 t/a expansion, and between 1,008 ha and 1,628 ha for the 350,000 t/a expansion. However, vegetation and communities of habitat and local conservation significance will be preserved wherever possible (for example, in reserves in the municipal expansion area).

WMC has developed and implemented effective vegetation retention and rehabilitation programmes during past development phases at both the operations area and township. Strategies that retain vegetation and promote rehabilitation will be part of the EMMP and the environmental code of practice for the Expansion Project.

Fauna

Species of particular conservation significance in the region and the Project Area include five mammal species, twenty-one bird species and five reptile species. The plains rat, plains-wanderer and possibly the woma python (if additional animals are found) are of conservation significance either nationally or internationally. It should be noted that most vertebrate species are naturally low in abundance in this arid environment.

Large mammals such as kangaroos have benefited from the removal of domestic stock and the provision of fresh water and increased food resources. Eighteen bird species have also benefited from the project as it has increased their water and food supply and nesting sites. Past and current activities associated with mining in the region have not had an adverse impact on small mammal populations in the Project Area.

All vertebrate species recorded before the 1983 EIS are still present. Detailed research programmes by WMC have expanded knowledge of the distribution, abundance and ecology of these and an additional number of species.

Some loss and modification of habitats as a result of the proposed expansion is unavoidable. However, the habitats expected to be changed are not essential to the survival of any animal species, and the total modified area is anticipated to increase from approximately 3.5% to less than 10% of the total Project Area. Since the Project Area comprises less than 2% of the dominant environmental association of the region, the overall disturbance to the association is expected to be about 0.2%. Any adverse impacts to animals are expected to be localised and short-term while animals shift to alternative habitats.

To guard against potential impacts to animals, WMC has implemented various management procedures. These include fencing evaporation ponds and using deterrents to keep animals, particularly birds, away from the evaporation and tailings retention ponds.

WMC will continue to monitor the presence and abundance of native and introduced animals and, in addition, will continue to control the abundance of the rabbit, cat and fox, as part of the EMMP. Control of these introduced species will continue to have a positive impact on the abundance and diversity of native animal species in the Project Area.

Mound springs

The artesian (mound) springs present along the margins of the Great Artesian Basin, including those located in the region of Borefields A and B, are important habitats for endemic and relict plant and animal species, especially macroinvertebrate groups. The springs and their habitats are important scientifically, historically and culturally.

Degradation of the mound springs has been occurring since European settlement, and has been exacerbated by the uncontrolled use of artesian water and the continued use of the mound springs habitat by introduced animals.

Plant species of conservation significance that are present in mound springs include salt pipewort, twigrush, cutting grass and sea rush. Animal species of conservation significance are also present, notably the fish species Dalhousie goby and Dalhousie hardyhead; the endemic macroinvertebrate groups hydrobiids, ostracods, amphipods and isopods; and probably a number of biogeographically significant spider species. Each of these taxa relies on the habitat provided by mound springs for its survival.

The taxonomy and ecology of the invertebrates endemic to the mound springs are of great interest to numerous researchers. Of particular interest is the isolation of endemic invertebrate populations from each other, and the genetic variation and species divergence that have occurred and are continuing to occur as a result of this isolation. WMC personnel are currently involved in research of this type.

Recently, water abstraction by WMC has been identified as the probable cause of an adverse habitat change at the Bopeechee and Hermit Springs spring groups. This impact has been remedied by the reinjection of water adjacent to these spring groups and a reduction since November 1996 in water abstraction in Borefield A from 15 ML/d to 6 ML/d.

The majority (up to about 85%) of water required for the proposed expansion will be abstracted from Borefield B, with the abstraction rate from Borefield A remaining at 6 ML/d. This scenario, as predicted by groundwater modelling to the year 2016, is expected to have a significant, positive impact on water discharge rates and the ecology of mound springs in the vicinity of Borefield A. Minor to moderate negative impacts to mound springs are expected as a result of pumping from Borefield B. The greatest impact is predicted to occur to springs within the Wangianna spring group. This spring group is composed of several spring vents, the largest of which has been highly modified for pastoral use. The springs in this group lack plant species of conservation significance and have only small populations of endemic mound springs fauna.

WMC will continue monitoring mound springs water flow rates, vegetation and endemic invertebrate populations as part of the EMMP. The company is also in the process of conducting additional sole and collaborative research on significant mound springs plant and animal species and is considering further research options to assist in the understanding and management of the mound springs.

8 TAILINGS MANAGEMENT

The principal components of the existing tailings retention system at Olympic Dam are:

- a 'paddock method' tailings storage facility, comprising three storage cells of approximately 190 ha total area, tailings distribution pipelines contained within a bunded pipeline corridor and decant facilities for supernatant tailings liquor;
- two liquor evaporation ponds, each divided into four cells with a combined evaporative area of 68 ha, which are used to dispose of supernatant tailings liquor and excess acidic process liquor by evaporation;
- a mine water disposal pond used for the disposal of groundwater that drains into the mine, partly by evaporation and partly by seepage.

In the current operation, some of the tailings from the metallurgical plant are treated to remove the sand fraction for use as mine backfill. The remaining fine fraction and the remainder of the tailings are thickened and pumped to the tailings storage facility via two above-ground pipelines. The pipeline route is bunded for the entire length, with transverse bunds at regular intervals to contain any spillage.

Other minor waste streams from processing are also directed to the tailings retention system. Excess acidic liquor resulting from tailings thickening passes to the liquor evaporation ponds, as does supernatant liquor decanted from the tailings storage facility.

The present tailings production rate varies depending on the quantity of ore milled and whether or not the sand plant is in operation. The amount of tailings expected to be delivered to the tailings storage cells during 1996–97 is approximately 2.7 Mt. About 4% of the tailings produced is presently used as mine backfill, with an objective of the Expansion Project being to increase this proportion to approximately 20%. On this basis, the rate of tailings delivery would increase to about 6.6 Mt/a at 200,000 t/a copper production and 12.5 Mt/a at 350,000 t/a copper.

The operation of the tailings retention system was changed in 1994 and 1995 to its present arrangement following the discovery of a localised elevation in the water table, which was attributed to seepage from the system. The results of all investigations concluded that the seepage had no adverse impact on the environment or on the health of employees or members of the public. This conclusion was supported by the findings of the Environment, Resources and Development Committee of the Parliament of South Australia.

Management and monitoring systems

Management and monitoring systems for the existing tailings retention system are well established and would be extended to meet the needs of the Expansion Project. Management of the system involves the collection and assessment of operational data, and planning for future development of the tailings system. It also involves operational staff checking the system several times a day, and making adjustments where necessary.

The operational data collected are used in liquor balance calculations to identify any apparent loss of liquor before the loss begins to have any environmental effects. The existing groundwater monitoring system would also be extended to cover the expanded facilities.

For the Expansion Project, two tailings storage options are being considered. One is to continue the existing paddock method, constructing additional similar cells. The other is to adopt a new tailings storage method for the site, which would involve further thickening of the tailings slurry and discharging it from elevated outlets to form a final tailings profile resembling a series of intersecting flattened cones. The feasibility of using the new central thickened discharge method on the Olympic Dam tailings is the subject of current pilot trials.

Among other important design criteria, the design of the expanded tailings facilities for both options would include measures to ensure that seepage is minimised. Features of the design to minimise seepage would include:

- site preparation to provide a low permeability floor lining;
- use of perimeter embankments that incorporate a low permeability clay zone;
- deposition of the tailings in thin layers, allowing the tailings to dry and consolidate prior to the deposition of subsequent layers;
- use of decant structures to remove supernatant liquor for disposal by evaporation in lined ponds.

Hydrology

The expanded facility would be designed to handle run-off from extreme rainfall events. The paddock method currently used would achieve this by storing the run-off on the tailings surface, allowing removal by the decant facilities for use in the process or disposal by evaporation. The central thickened discharge method would require the provision of stormwater ponds, sized to store the run-off resulting from a 1-in-100-year average return interval storm.

As discussed above, the focus of the design and future operation of the expanded tailings retention system would be to minimise seepage. It is relevant, however, to assess the likely impacts if seepage were to occur. In this regard, monitoring results and other test work conducted on the existing facilities provide a sound basis for making predictions.

The Andamooka Limestone which underlies the entire site, including the tailings storage system, has been shown by experience to offer both advantages and disadvantages as a foundation. The obvious disadvantage is the limestone's inherent permeability, requiring the proposed floor preparation and lining systems to minimise seepage. However, the limestone has the ability to neutralise acidic liquors and to remove metals (including radionuclides) from solution, thereby providing a natural safeguard to minimise pollution.

Another safeguard for the control of groundwater pollution is the presence of the cone of groundwater depression associated with the underground mining operation. This dominates the local groundwater regime, resulting in groundwater flow within about 5–10 km towards the mine. As discussed in Section 4, this effect would continue to develop as the mine expands and is expected to persist for a long time, perhaps centuries, after the cessation of mining.

Tailings radiation control

The tailings at Olympic Dam contain approximately 80% of the radioactivity associated with the original ore. The operation and final rehabilitation of the tailings storage facility would therefore be determined by the need to ensure that doses to people from the radiation remaining in the tailings are as low as reasonably achievable and less than levels considered acceptable.

Measurements of radon and radon decay products in air near the tailings storage facility during operations have shown that natural ventilation is sufficient to disperse and dilute radon and radon decay products to very low levels within quite short distances.

Similarly, dust monitoring has shown that the tailings storage facility is not a major dust emission source. This is because the smooth, flat, even grain size and moist surface of the tailings limit the processes that could lead to dust lift-off. Although the potential for dust increases during mechanical working of the tailings, particularly during successive lifts of the storage cell walls, water sprays are effective in limiting dust release.

A final rehabilitation plan for the tailings storage facility is subject to ongoing trials. However, preliminary calculations indicate that provision of 1 m of cover over the tailings surface, overlain by rock armour, would be sufficient to achieve an acceptable reduction in the long-term release of radon.

9 AIR QUALITY AND NOISE

Air quality

Airborne process emissions at Olympic Dam include sulphur dioxide, sulphur trioxide and sulphuric acid mist, oxides of nitrogen, hydrogen fluoride, carbon monoxide, carbon dioxide, particulate matter and dust. The principal sources of gaseous emissions are the acid plant, the copper smelter and fuel burning equipment. Process particulate emissions arise mainly from the smelter. Dust is also produced in plant operations, quarrying and traffic movements.

Meteorology, including wind patterns and thermal structure, is the major factor governing the transport and dispersion of airborne emissions. Weather information has been recorded for several years at weather stations near the Olympic Dam operations, and the data collected have been used to predict the impact of the emissions from the proposed Expansion Project. Results from dispersion modelling studies and assessment of gaseous emission controls for individual process units indicate that the Expansion Project will conform to existing and anticipated national and State air quality goals and emission limits.

Dust arises mainly from the handling and storage of process chemicals in stockpiles, from quarry operations and from unsealed roads. Dust control measures currently include the use of covered and underfeed conveyors, water sprays and road wetting. The control equipment and techniques already in use on the site have kept occupational concentrations below levels recommended and these measures would continue to be employed for the Expansion Project. Environmental dust levels outside the Special Mining Lease are well within State and national guideline figures.

Noise

The expanded operations would involve the addition of a new range of operating machinery, and hence new noise sources. The existing plant operations were used as a baseline in the assessment of potential noise impacts from the proposed expansion on residents of Roxby Downs township and the Olympic Dam Village. Predicted noise levels, including maximum operating sound power, were calculated for each phase of development. These predicted levels were then compared with environmental requirements.

It was calculated that noise levels for the Expansion Project would remain generally less than 62 dBA at the security fence, with a maximum of 67 dBA, following possible future expansion to 350,000 t/a copper production. Predicted noise levels at the Olympic Dam Village, adjacent to the Special Mining Lease boundary, would be up to 34 dBA. These levels are below the criterion limit of 70 dBA for an industrial zone. The predicted noise levels at Roxby Downs and Olympic Dam Village would increase by 1–2 dBA, but would be some 5–10 dBA below the existing minimum background noise levels in Roxby Downs and would therefore not be audible at most times.

Within the operations area, occupational noise levels would continue to be at sufficient levels in some areas to require control measures. The contracts for new equipment would include noise specifications to limit occupational noise exposure as much as practicable. Other occupational control measures, which include hearing protection equipment, noise monitoring, signage and employee training, would continue.

10 RADIATION

Radiation is associated with the mining, processing and disposal of wastes from the Olympic Dam operation.

In making predictions about the likely impacts of the proposed Expansion Project, there is a wealth of data available from the previous operation upon which to draw. The radiation studies conducted for this EIS have also made use of the most recent recommendations by national and international expert bodies charged with researching scientific evidence relating radiation exposure to health effects. Where data from years past have been used, the radiation exposures have been recalculated in order to provide a consistent method of comparing recent and past exposures.

The occupational and environmental radiation data that have been generated during the operation of the current mining, processing and waste disposal facilities at Olympic Dam have been analysed and used to determine the impacts of operating the facilities at the current copper production rate of 85,000 t/a. Where it has been possible to identify causal links between production and radiation levels, the relationships have been used to predict the likely impacts associated with copper production rates of 200,000 t/a and 350,000 t/a.

Individual radiation exposures to underground mining personnel are unlikely to be greatly changed by an increase in production rates, the reason being that the ventilation system, local ventilation control and mining methods would remain largely unchanged, and these are the three factors that have the greatest influence on the exposure rate. The analyses of past data show a relatively constant rate of exposure from year to year. The effects of the proposed automated electric train haulage system on radiation exposure would be the subject of investigations once the system was operational. However, it is likely that any effect would be to reduce individual exposures.

Proposals for the expanded surface facilities are largely extensions of existing facilities and methods. The major exceptions are that a new smelter and a new calciner will be constructed. Analysis identified the existing smelter as the source of the greatest individual radiation exposures. The design of the new smelter incorporates features to reduce the radiation doses, and hence reduce these exposures.

The analyses of past exposures in the metallurgical treatment plant show a relatively unchanging annual rate. Predictions based on the monitoring of current exposure rates show that future exposures would be maintained well within currently recommended limits.

As part of Olympic Dam's monitoring programme, pathways along which radionuclides travel following release into the environment have been examined to determine the geographical extent of dispersion. In general, radionuclides attributable to operations can be found at distances up to 5 km from the site. Beyond this they are difficult to distinguish from background radiation. As a consequence, radiation doses to the public are unlikely to significantly change following the Expansion Project and are expected to remain at only a small proportion of international radiation standards.

11 PROJECT INFRASTRUCTURE AND TOWN DEVELOPMENT

Water supply

Water is drawn from Borefield A and Borefield B in the south-west of the Great Artesian Basin, and pumped via buried pipelines to Olympic Dam. Borefield A was approved in the 1983 EIS, and Borefield B was approved in November 1995 following further hydrogeological and environmental assessments.

Borefield B is being developed in two stages. The initial stage, for which commissioning commenced in November 1996, involved the installation of three production bores (only one of which is currently in operation), seven observation bores, approximately 110 km of buried pipeline to connect with the existing Borefield A (M1) pipeline, and a forward pump station. Stage 2 will include the construction of an additional pipeline to Olympic Dam beside the M1 pipeline, connection of the other two production bores, and the decommissioning of an existing pump station.

The Borefield B pipeline route was selected after consideration of environmental constraints, engineering requirements and cost optimisation factors. All work was confined to a disturbance corridor of minimum practicable width within an overall easement of 100 m. Particular care was taken to avoid and protect sites that were significant in terms of flora and fauna habitat and Aboriginal heritage.

A specific environmental code of practice was prepared for the construction of Stage 1. All aspects of the work were subject to environmental clearance and assessment of work methods before commencement. Compliance with the code of practice was regularly audited, and monitoring has continued to assess the environmental effects of construction. A similar process will be implemented for Stage 2.

Electricity supply

Electricity is currently supplied to Olympic Dam via a 132 kV transmission line from the Davenport substation at Port Augusta. A new 275 kV transmission line, which had been foreshadowed in the 1983 EIS, is presently being constructed. The new line will parallel the existing line for most of its length with minor deviations near Port Augusta, to comply with the revised Port Augusta Development Plan, and east of Woomera to avoid an area of Aboriginal heritage significance.

The corridor for the dual lines will be approximately 130 m wide (an increase of 30 m over that originally predicted), providing a separation of 80–90 m between the two lines. With the exception of those areas where the new transmission line deviates from the existing easement, the present service road will be used for construction and line maintenance. Disturbance will be confined to the new transmission tower sites, and to some limited vegetation clearance in order to maintain statutory conductor clearances.

For the possible expansion phase to 350,000 t/a copper, the existing 132 kV line is proposed to be replaced with a second 275 kV line (in addition to the one presently under construction) in order to ensure security of power supply. This additional new line would follow the same alignment as the existing 132 kV line, apart from the two minor deviations for the 275 kV line under construction. Any additional environmental disturbance caused by construction of the additional 275 kV line would be minimal.

As with Borefield B, a specific environmental code of practice has been prepared for the transmission line under construction. The code of practice will be updated prior to the construction of the future additional 275 kV line.

Other infrastructure

The existing road network is suitable for the Expansion Project, during both construction and operation. No additional roads would be required, other than minor roads in the plant area and in Roxby Downs township. The construction of a railway line to Olympic Dam is not included in the current proposal, although it is a future option. It would be subject to separate technical and economic review.

The products from Olympic Dam would continue to be exported through Port Adelaide. Should the option of importation of copper concentrates be pursued, the port facilities at Whyalla, Port Pirie or Port Adelaide could be used for this purpose. The possible importation of copper concentrates through Whyalla would require an upgrade of the wharf facilities and infrastructure.

Olympic Dam is serviced by a licensed all-weather airport, capable of handling turboprop and small jet aircraft. During the construction period, additional flight services may be needed. The use of larger aircraft would require an upgrade of the runway and terminal facilities; a decision to increase capacity in this way has not yet been made.

Olympic Dam is connected by optical fibre cable with the national telephone grid. Telecommunications planning provides for an increase to the capacity of the existing service in response to project demands. Telstra has recently installed a digital mobile telephone service to cover the operations and Roxby Downs township.

Township development

The first phase of the Expansion Project requires the provision of up to 130 new dwellings for the increased permanent workforce, and the development of two self-contained construction villages with a combined capacity of 1,200 people and provision for expansion to 1,600. The South Australian Government has announced funding for the construction of a medical centre in Roxby Downs, which is expected to be opened in early 1998.

Town planning provides for an additional 200 residential allotments if required, increased open space, pedestrian and cycle pathways, and additional recreation facilities, particularly for teenagers. A new caravan park is also proposed. The town planning also provides for future development of the town to the south, for the possible future second phase of the Expansion Project.

Water supply, sewerage and sewage treatment infrastructure and electricity services would be expanded or replaced as appropriate.

In the conceptual design for the township expansion, particular attention has been paid to the effects of climate, the preservation of vegetation and sand dunes, and the avoidance of Aboriginal heritage sites.

12 SOCIAL ENVIRONMENT

The principal feature of the social environment for the Olympic Dam operations personnel is the town of Roxby Downs, which was established in 1986 to accommodate Olympic Dam personnel, their families, and the associated commercial and community facilities.

The Roxby Downs Statistical Local Area, which includes the town of Roxby Downs and the Olympic Dam Village, is markedly different in its social characteristics from the surrounding

Northern Statistical Division and South Australia as a whole. Population and employment have been declining in the Northern Statistical Division while increasing in the Roxby Downs Statistical Local Area. The population of the latter is younger and better educated, has a higher income and rate of employment, and is characterised by predominantly two-parent families and far fewer single-parent families.

The fundamental social effect of the Expansion Project would be an increase in the number of permanent jobs that are likely to be generated locally. This increase derives from both direct and indirect employment—'direct' referring to employment on the project site and 'indirect' to the non-project workforce employed by the public and private sectors in supporting the project, its workforce and the town.

It is estimated that the direct operational workforce at Olympic Dam will need to increase from 895 to 1,076 by the year 2000. This increase of 181 persons is predicted to consist of 159 new jobs in the mine (120 staff and 39 contractors) and 22 in the process plant (11 each of staff and contractors).

It is also estimated that in 1996 there were between 269 and 358 persons in the indirect operational workforce and that this is likely to increase to between 323 and 430 by the year 2000. This would represent the generation of between 54 and 72 new positions in the indirect operational workforce.

It is expected that an average direct employment of 1,300 construction personnel including management will be required on site, over a two-year period, to expand the mining and processing facilities to enable production to reach 200,000 t/a copper by the year 2000. In addition, between 200 and 300 personnel are likely to be required on a short-term basis from January to April 1998.

It is further estimated that between 130 and 260 indirect jobs based at Olympic Dam will be required to support the two-year construction workforce of 1,300. It is expected that most of these additional indirect jobs will be casual and filled by existing residents of Roxby Downs and Andamooka.

A model was developed for estimating the likely size and social characteristics of the increased population of Roxby Downs resulting from the increased direct and indirect local workforce. From this model, the 1996 population of Roxby Downs of 2,500 is estimated to increase to 3,100 by the year 2000 and to 4,500 by the year 2010.

An assessment was made of the implications of the increased population for the town and its services, including housing, child care and education, community health and medical services, community welfare and support services, recreation and cultural facilities, policing and emergency services, and retail and commercial facilities. The results of the assessment showed that the increase in population resulting from the expansion to 200,000 t/a copper production would have a minimal impact on existing services and facilities.

As part of the EIS process, consultations were held with the communities of upper Spencer Gulf, Roxby Downs and Andamooka. The municipal councils and economic development boards of Whyalla, Port Augusta and Port Pirie expressed a generally positive view of current Olympic Dam operations and of the proposed expansion, which are seen as a source of economic and social benefits to local communities.

In the main, the residents of Roxby Downs liked living there, referring to the town as 'an oasis in the desert'. Residents generally had a high level of satisfaction but were keen to see a range of specific improvements in the design and functioning of the town. These views have been taken into account by WMC in designing the southern expansion of Roxby Downs.

Overall, apart from reservations about the influx of the construction workforce, the proposed expansion is viewed positively by Roxby Downs residents, with potential benefits including the creation of employment opportunities, with associated social and economic benefits, and a sufficient increase in the population of Roxby Downs to enable a viable expansion of commercial facilities as well as to justify an expansion of community services.

13 ECONOMIC IMPACTS

The impacts on the South Australian and Australian economies of increasing production at Olympic Dam were modelled using a computable general equilibrium (CGE) model which provided estimates of changes in employment, gross state product (GSP) and gross national product (GNP) and a number of other economic indicators.

Two phases of expansion were modelled, the first being expansion to production of 200,000 t/a copper, and the second phase being possible future expansion to a production rate of 350,000 t/a. Each phase consists of a construction period and an operational period, modelled separately.

The construction periods, commencing respectively in the years 1997 and 2008, are relatively short term, generate activity and employment in the construction and service sectors of the economy, and require imports of equipment.

The operational phases, commencing respectively in the years 2000 and 2010, generate employment in mining and processing, and produce metals for domestic use and export. The 'base case' for modelling the expansion to 200,000 t/a is production in 1996–97 of 85,000 t/a, and the base case for expansion to 350,000 t/a is production in 2006–07 of 200,000 t/a. The results reported are changes from the base case for a 'typical year' of construction or operation.

Construction for the first phase of expansion to 200,000 t/a is planned to last for two and a half years. Direct employment at Olympic Dam is estimated at 1,300 jobs. Total employment generated in South Australia is estimated at between 1,750 and 2,500 jobs, with up to 3,000 additional jobs in Australia. (This was the only phase for which employment in the rest of Australia was estimated; all subsequent estimates are the 'low estimate' of employment generation.) It is predicted that the GSP for South Australia would increase by between 0.4% ($120 million) and 0.5% ($150 million), with a negligible increase in GDP.

The operational phase of expansion to 200,000 t/a is expected to employ directly up to 181 people additional to the base case. Total additional employment in South Australia is estimated at 1,100. It is predicted that the South Australian GSP would increase by 0.4% ($115 million) and the GDP would increase by 0.1% ($340 million). Annual royalty payments to the South Australian Government are expected to increase by $12 million, depending on metal prices.

The future possible expansion to 350,000 t/a has been modelled on the basis of a construction phase that would last for two and a quarter years. The construction workforce is estimated to be 1,100 people and total employment in South Australia is estimated at 1,240. The GSP for South Australia is predicted to increase by 0.3% ($87 million) with no change in the GDP.

The employment generated in the operational phase of expansion from 200,000 t/a to 350,000 t/a is predicted to be up to 510 additional jobs at Olympic Dam and a total of

1,190 additional jobs in South Australia. The GSP is expected to increase by almost 0.5% ($135 million) and the GDP by 0.1% ($468 million). The South Australian Government is expected to collect $17 million in royalties each year.

The CGE model was used to estimate impacts of the expansion on other sectors of the economy in investment and output from mining and processing. A minor contraction in some sectors is predicted, particularly in agriculture (and mining during the construction phases) owing to price and exchange rate effects. In all cases, these would be offset in South Australia by the Olympic Dam project and GSP increases. National effects are negligible; however, these contractions lead to slight decreases in GSP in other States, in some of the phases modelled.

A slight increase in the consumer price index is estimated, and this flows through to a need for increased borrowings by the Commonwealth Government to make indexed welfare and other payments. In the construction periods there are short-term negative effects on the balance of trade owing to the importation of equipment. In the operational phases, the impact on the national balance of trade is positive, and predicted to be $96 million annually for 200,000 t/a copper and $124 million annually for 350,000 t/a.

The impacts of the Expansion Project on the South Australian economy would be positive in terms of employment created, revenue raised by the State and contributions to the GSP. Production at a future possible rate of 350,000 t/a would support an additional 2,290 jobs in South Australia, compared with the base case in 1996–97. The estimated increase in GSP of more than 0.5% when operations are at 350,000 t/a is significant in terms of the State's annual total increase in GSP, which has ranged between 1.0% and 5.7% since the beginning of the 1990s.

14 REHABILITATION AND DECOMMISSIONING

Olympic Dam has an existing rehabilitation programme to reinstate and revegetate disturbed areas using local indigenous plant species and ensure the long-term viability of rehabilitated areas. Achieving these objectives involves progressively rehabilitating areas disturbed by operational activities and conducting a monitoring programme to assess the effectiveness of rehabilitation, and modifying the programme if needed.

Before land disturbance or construction can begin, a signed environmental clearance form must be obtained from the Environmental Superintendent. The clearance sets conditions that minimise the impact of disturbance and thereby facilitate rehabilitation. All areas disturbed in any significant, adverse way by the Expansion Project would be rehabilitated according to the existing rehabilitation methods and monitored to ensure the completion criteria are met before finalisation of the project.

Rehabilitation planning begins before areas are disturbed and is an integral part of the existing clearance procedure. The existing rehabilitation programme uses passive methods for small areas, which essentially involve leaving them to regenerate naturally, and active methods for larger areas, which require earthworks as well as additional sources of locally collected seed.

Successful rehabilitation programmes undertaken since 1984 include those on drill pad sites, disused access roads and tracks, borrow pits and, most recently, the Borefield B pipeline corridor. Further development of rehabilitation procedures and the continued application of environmental codes of practice will ensure that standards of rehabilitation are either maintained or improved.

The decommissioning of the areas managed by WMC would be to a best practice standard, with rehabilitation success measured by the development of a self-sustaining state in rehabilitated areas compared with undisturbed communities. Final rehabilitation procedures and completion criteria would be included in a decommissioning plan that would be submitted to the South Australian Government for approval prior to implementation. Due to the acidic nature of the tailings, the type and extent of rehabilitation for the tailings storage cells will be determined by the results obtained from ongoing rehabilitation trials.

The rehabilitation procedures and completion criteria contained within the plan would generally focus on such parameters as vegetation species composition, vegetation density, vegetation cover, likely fauna species composition and abundance, water quality, erosion rates, visual quality and land capability.

15 MANAGEMENT AND MONITORING—ENVIRONMENT AND WORKPLACE

Environmental management at Olympic Dam is guided by the EMMP. In addition, the site's Statement of Environmental Commitment requires all employees and contractors to be responsible for implementing environmental management guidelines. Specific personnel, however, are responsible for monitoring, auditing and reporting environmental performance as well as providing specific environmental advice to management, other employees and contractors.

There are environmental management and monitoring programmes undertaken at Olympic Dam covering meteorology, waste management, hydrogeology, airborne emissions, environmental radiation, vegetation, rehabilitation, fauna, borefields (including the mound springs), and community consultation and heritage issues. Reviews of the management and monitoring activities are provided to regulatory authorities in quarterly and annual reports.

In addition to the statutory requirements placed on WMC, employees are undertaking research programmes in the Olympic Dam area and the surrounding environs which are increasing knowledge of the region's environment to an exceptionally high level.

Environmental management during construction of the Expansion Project would be guided by an environmental code of practice. This code describes the procedures to be followed to minimise environmental impacts and the monitoring and audit process that would be undertaken to verify compliance. The environmental code of practice would be incorporated into construction contracts and issued to all contractors and new personnel as part of the site induction process.

Olympic Dam also has in place a workplace hazard management system, which would continue to be used. A review of existing workplace hazards has been undertaken to provide information for the design of the Expansion Project.

Following the Expansion Project, Olympic Dam would continue to use and store minor quantities of hazardous chemicals. The small inventories of these chemicals, together with established safety procedures and the remoteness of the site, would result in negligible off-site individual and societal risk.

The safeguards that would be adopted for the construction and operation of the Expansion Project are important elements of the proposed overall environmental management. The following table summarises these safeguards together with outcomes that have been predicted based on experience with the existing facilities.

Summary of environmental safeguards

Issue	Environmental safeguard	Predicted outcome
Erosion	Environmental clearance would be required prior to constructing any new works. Progressive rehabilitation would be undertaken.	Experience has shown erosion is controlled effectively by safeguards.
Vegetation disturbance	Environmental clearance would be required prior to constructing any new works. Progressive rehabilitation would be undertaken.	The Expansion Project would result in further clearing for the construction of new facilities. Some amelioration would be provided by progressive rehabilitation. Experience has shown safeguards to be effective in minimising clearance.
Bushfires and other fires	Natural safeguard is provided by characteristics of regional vegetation. Further protection is provided by roads and tracks and the site fire-fighting service.	Bushfires are not expected from site activities. There is a high level of confidence in the site fire-fighting service's ability to contain and control fires.
Changes to groundwater	Design of the tailings storage facilities and evaporation ponds has been based on ensuring seepage is minimal. As a further safety factor, the tailings retention system is also located within the cone of groundwater depression caused by dewatering of mining operations. The existing extensive groundwater monitoring system would be extended to include the new facilities.	Changes in groundwater systems under the Special Mining Lease would be dominated by dewatering of mining operations and the associated mine water disposal pond. No significant or detrimental change in groundwater quality is expected.
Air pollution	Expanded facilities would incorporate additional air cleaning equipment and higher discharge stacks. Improved ventilation of work areas would also be provided.	There would be overall improvement in ambient and workplace air quality.
Water pollution	Processing areas would be sealed and bunded to enable spillages to be collected and returned to the process.	No pollution of surface or groundwater is expected.
Exposure to radiation	A comprehensive range of safeguards is already in place. These include management of working conditions (ventilation), limitation of access, use of protective clothing and equipment, and monitoring.	No significant increases are expected in individual or combined exposure levels. Exposure levels would remain well within current guidelines. There would be a probable reduction in maximum exposure resulting from optimised smelter design.
Pollution from solid and liquid waste	Solid and liquid wastes with potential to pollute would be managed in the tailings retention system.	No significant or detrimental pollution is expected.
Noise	Noise emission limits would be specified in equipment supply contracts. Access would be controlled and hearing protection equipment provided, where required. Workplace noise monitoring would be undertaken.	No noise impacts to residential areas are expected owing to distance from site.
Economics	Expansion Project policy is to use South Australian services and labour as far as reasonably practicable, taking into account technical, quality and delivery considerations.	Olympic Dam would continue to be a significant contributor to the State economy. It would provide both short-term and long-term additional employment and revenue for governments.
Social, recreation and community considerations	Additional housing would be provided at Roxby Downs for the increased operational workforce. Construction personnel would be provided with accommodation and recreation facilities at Olympic Dam Village to minimise the need to interact with Roxby Downs. Arrangements for the provision of social infrastructure at Roxby Downs are contained in the Indenture.	Residents of Roxby Downs would continue to enjoy the benefits of high household incomes and the use of excellent social and recreational facilities.

Summary of environmental safeguards (continued)

Issue	Environmental safeguard	Predicted outcome
Renewable resources (water usage)	Agreed limits on drawdown of potentiometric heads are incorporated into special water licences. Potentiometric heads would continue to be monitored in the borefields region.	Drawdown of potentiometric heads would remain within the agreed limits.
Mound springs	Agreed drawdown limits are set out in special water licences. Ongoing monitoring would be conducted in the EMMP. Enhanced monitoring of Davenport and Welcome spring groups would be undertaken.	Significant positive impact for most mound springs in Borefield A region. Minor to moderate adverse impact on some mound springs in the vicinity of Borefield B (for example, the biologically insignificant Wangianna spring group).
Surface traffic	Transport arrangements during construction would be developed in consultation with relevant authorities.	Some disruption of traffic is inevitable owing to the use of off-site fabrication and hence oversized loads. These loads would have the necessary escorts and provide frequent passing opportunities for other traffic.
Greenhouse gas emissions	WMC has committed to joining the Greenhouse Challenge. An engineer specialising in life cycle analysis has been employed to focus on energy and water use minimisation. Regular energy audits of the site have commenced.	The energy use per unit of production is expected to reduce.
Heritage sites and values	The operations are conducted in accordance with the WMC Indigenous Peoples Policy. Consulting archaeologists and anthropologists consult with the Aboriginal people prior to any construction activities. A Community Liaison Officer is responsible for ongoing consultation with the Aboriginal people.	Disturbance of ethnographic sites would be avoided and disturbances of archaeological sites minimised. Experience with the Borefield B pipeline and the 275 kV transmission line show disturbance of sites of significance can be avoided by careful design and route selection.
Biological diversity	Ongoing monitoring is conducted in accordance with the EMMP.	No reduction in biological diversity of the region is expected. Monitoring and research undertaken by WMC staff and consultants are providing valuable knowledge of the regional environment. WMC also actively controls feral animals and has voluntarily removed stock from previously overgrazed areas.
Design for environmental protection	Environmental design criteria are established prior to commencement of design. Preliminary designs are also reviewed by site staff with responsibility for environmental management prior to finalisation. A signed environmental clearance form is required prior to commencement of construction.	The plant and infrastructure design avoids environmentally sensitive areas wherever practicable. Construction activities are based on facilitation of rehabilitation and are also responsive to previous environmental management experience.
Employee and contractor education	Environmental codes of practice are incorporated into construction contracts. Formal inductions occur for all new employees and contractors on the site, covering safety, environmental issues and radiation management.	There is a thorough understanding of site requirements by all employees and contractors.

CHAPTER 1

PROJECT OBJECTIVES AND BACKGROUND

CHAPTER 1

PROJECT OBJECTIVES AND BACKGROUND

This chapter provides the background to the Olympic Dam Project, including information on WMC Limited, the existing operations at Olympic Dam and the proposed Expansion Project. The history of development, the approvals process and project timing are also discussed. The chapter includes a discussion of the world's copper and uranium markets, and the consequences of not proceeding with the project. It concludes with an outline of the scope and structure of the remainder of the report.

1.1 PROJECT BACKGROUND

1.1.1 Company profile

WMC Limited (WMC) is one of Australia's largest mining companies. Its main business is the discovery, development and processing of mineral resources.

Established in 1933, WMC is managed and predominantly owned by Australians. During the 1980s it extended its activities to overseas countries, in keeping with its strategy of becoming an internationally oriented resource-based enterprise.

In addition to being a major world nickel producer and one of Australia's largest gold producers, WMC holds extensive interests in copper and uranium. It also has a major shareholding in Alcoa World Alumina and Chemicals (AWA), the world's largest producer of bauxite, alumina and alumina-based chemicals, and a major Australian producer of aluminium.

Hi-Fert, a company wholly owned by WMC, is a major supplier of fertiliser products in Australia, with a network of over 190 agents. WMC is presently developing a world-scale fertiliser plant based on a large phosphate rock deposit at Phosphate Hill, near Mount Isa in Queensland. WMC also produces talc for processing and sale in Japan and Europe.

WMC's overseas activities include mineral exploration in North and South America, Africa and the Philippines, and evaluation of processing opportunities in Eastern Europe and elsewhere.

At 30 June 1996 WMC had equity accounted assets of $6,982 million with parent shareholders' equity of $4,168 million. WMC's sales revenue in 1995–96 was $2,350 million. If its 40% interest in AWA were to be included, this figure would rise to $3,864 million. WMC has approximately 92,000 shareholders and 7,225 employees, including contractors. Over 2,500 employees hold an interest in WMC through the Employee Share Option Plan.

Key policy commitments

WMC is committed to achieving compatibility between economic development, safety and health, the maintenance of the environment, and relationships with Indigenous peoples throughout all phases of its activities. It seeks to ensure that its personnel and contractors give proper consideration to safety and health matters, to the care of flora, fauna, air, land and water, and to community health and heritage issues which may be affected by these activities.

WMC has therefore developed three key policies (reproduced in Appendix A) which are fundamental to all WMC operations worldwide: the Safety and Health Policy, the Environment Policy and the Indigenous Peoples Policy.

The prime objective of the Safety and Health Policy is to develop the culture and processes that will ensure the safety and health of all WMC employees, contractors and customers as well as the communities associated with its worldwide operations.

The Environment Policy states that WMC will observe all environmental laws and undertake its activities in a manner consistent with the principles of sustainable development. The key points of the policy in relation to this EIS are the commitments to:

- integrate environmental factors into project planning
- assess and monitor the potential environmental effects of company activities
- develop opportunities for efficiently using energy, water and other resources
- conserve important populations of flora and fauna
- rehabilitate the environment affected by company activities.

The Indigenous Peoples Policy sets out WMC's commitment to developing relationships of mutual understanding and respect with the Indigenous peoples of the areas in which it operates or proposes to operate.

Specific to WMC (Olympic Dam Operations) Pty Ltd is a Statement of Environmental Commitment, to ensure that all employees clearly understand their environmental responsibilities. The Statement of Environmental Commitment is reproduced in Appendix A.

WMC is also a signatory to the Australian Minerals Industry Code for Environmental Management (Appendix A), which sets out obligations for environmental management, consultation, publication of annual environmental reports and environmental auditing. In regard to environmental reporting, WMC published its first Environment Progress Report for the year 1994–95, in 1996 (WMC Limited 1996a).

1.1.2 Existing operations at Olympic Dam

The operations at Olympic Dam are located some 580 km by road north-north-west of Adelaide in South Australia (Figure 1.1) and are wholly owned and operated by WMC (Olympic Dam Corporation) Pty Ltd, a wholly owned subsidiary of WMC Limited. Olympic Dam has been in production since August 1988 and currently processes approximately 3 Mt/a of ore, for the recovery of some 85,000 t/a of refined copper, 1,500 t/a of uranium oxide, 850 kg/a (30,000 oz/a) of gold and 13,000 kg/a (460,000 oz/a) of silver.

The operations at Olympic Dam are based on one of the largest polymetallic orebodies in the world, containing one of the world's largest known copper resources, the world's largest known uranium resource and world-class gold and silver resources. Table 1.1 summarises the known Olympic Dam mineral reserves.

Table 1.1 Ore reserves at Olympic Dam

Ore type	Ore reserve[1] (Mt)	Copper	Uranium[2]	Gold	Silver
Copper–uranium	569	2.0%	0.6 kg/t	0.7 g/t	4.9 g/t
Gold	0.3	0.7%	0.2 kg/t	4.9 g/t	1.0 g/t
TOTAL METAL		**11.4 Mt**	**0.34 Mt**	**400 t**	**2,790 t**

1 *Proved and probable.*
2 *As uranium oxide (U_3O_8).*
Source: WMC 1996b and internal WMC reports.

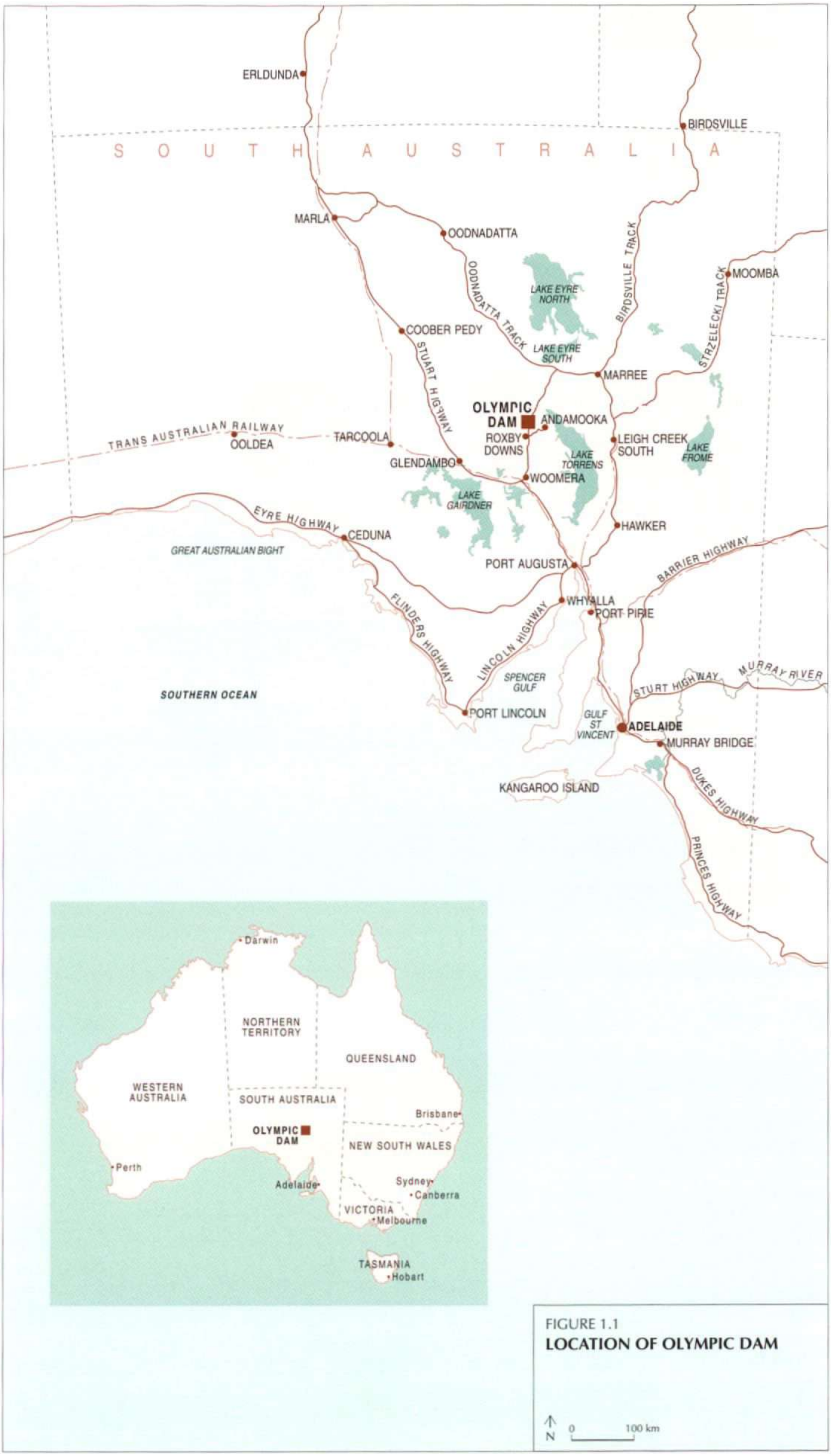

FIGURE 1.1
LOCATION OF OLYMPIC DAM

Olympic Dam is unique, as a copper mine, in the size of the resource and in its association with other economic minerals.

The layout of the existing mining and mineral processing facilities is shown in Figure 1.2. These facilities, described further in Chapter 2, include the following components:

- an underground mining operation;
- mineral processing and metal production facilities including grinding, flotation, leaching, solvent extraction, smelting, copper electrowinning and electrorefining, uranium oxide calcining and packaging, and gold and silver refining;
- facilities for production of process chemicals, including sulphuric acid and oxygen;
- waste disposal facilities, including structures for the storage of tailings and the evaporation of wastewaters.

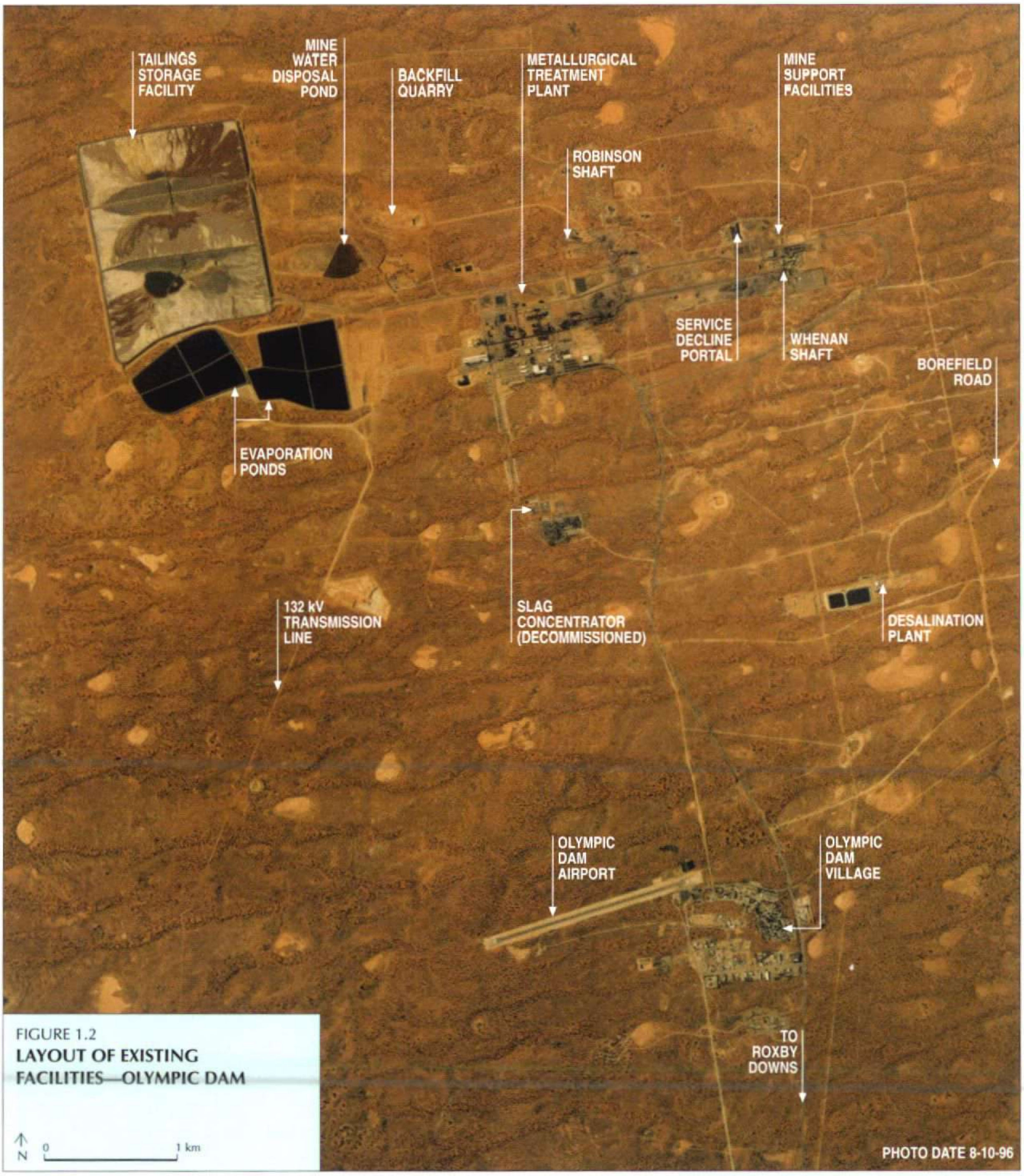

FIGURE 1.2
LAYOUT OF EXISTING FACILITIES—OLYMPIC DAM

The existing infrastructure includes two borefields with associated pipelines and monitoring bores, a water treatment plant, power lines and distribution systems, roadways, an airport, village accommodation and a townsite. The existing infrastructure is described further in Chapter 11.

WMC (Olympic Dam Corporation) Pty Ltd employs some 963 persons on site, including contractors, and a further fifty-one in Adelaide. Table 1.2 provides a breakdown of the activities undertaken by this workforce.

Table 1.2 Workforce associated with Olympic Dam—December 1996

Activity	Staff	Contract	Total
OLYMPIC DAM			
Mining	286	163	449
Processing	378	136	514
Subtotal	**664**	**299**	**963**
ADELAIDE AND MELBOURNE			
Copper Uranium Division	51[1]		51
Olympic Dam Expansion Group	30	238	268
TOTAL	**745**	**537**	**1,282**

1 *Includes contract staff.*

The Olympic Dam operation provides a major contribution to the South Australian and national economies. Table 1.3 summarises this annual contribution for 1995–96.

Table 1.3 Olympic Dam's annual contribution to the State and national economies—1995–96

Item	Annual expenditure/revenue
REVENUE	
Total annual sales	$389.2 million
Annual exports	$269.1 million
EXPENDITURE[1]	
Salaries and wages	$46.8 million
Environmental care[2]	$3.2 million
TAXES	
State royalties	$10.6 million
State payroll tax	$2.9 million
WorkCover	$1.6 million
Commonwealth PAYE tax	$15.1 million
Other taxes (State and Commonwealth)	$3.5 million

1 *Does not include goods and services, depreciation, amortisation, non-cash provisions and contractors.*

2 *Radiation, Environment, Safety and Quality Department costs only. Does not include capital or operating costs of environmental management facilities.*

As of February 1996, the South Australian Government had received $45 million in royalties since the beginning of production at Olympic Dam in 1988. This compares with the Government's $40 million capital investment in infrastructure support during the initial establishment of the project. Future State royalty income will be received without much further capital expenditure by Government. To date, the total capital expenditure at the operations has exceeded $1.1 billion.

1.1.3 The proposed expansion

The following provides a brief summary of the scope of the proposed Expansion Project. A detailed description is contained in Chapter 3. It should be noted that actual production rates for the Expansion Project will vary according to the ore grade and the availability of equipment. Hence the rates used below to indicate the levels of ore and metal production are nominal.

The Expansion Project would be developed in two phases. The first phase involves expansion to the already approved rate of 150,000 t/a copper by the year 1999, increasing, if approved, to 200,000 t/a copper by the year 2000. Construction of the facilities for a production rate of 150,000 t/a copper commenced in January 1997. It should be noted that WMC is presently implementing an accelerated construction and mine development programme, which is expected to bring forward these completion dates.

The possible future second phase would be additional expansion, including construction of a matte smelter, to achieve a total production capacity of 350,000 t/a copper. In this EIS, it is assumed for water abstraction and economic modelling purposes that this production rate would be achieved by the year 2010; however, the WMC Board has made no formal decision in this regard at the present time.

The initial increase to 150,000 t/a copper plus associated products corresponds to an ore-mining rate of 6.5 Mt/a. The corresponding rate for associated products would average approximately 3,420 t/a uranium oxide, 1,640 kg/a (57,800 oz/a) gold and 18,000 kg/a (640,000 oz/a) silver. On completion of the first expansion phase, and subject to environmental approvals being obtained, the nominal copper production rate would be 200,000 t/a, with a mining rate of 9.0 Mt/a ore. The corresponding rate for associated products would average approximately 4,630 t/a uranium oxide, 2,050 kg/a (72,300 oz/a) gold and 23,000 kg/a (810,000 oz/a) silver. However, because of variations in the ore grade, both mining and production rates would fluctuate somewhat: the peak mining rate would be up to approximately 9.25 Mt/a ore, with the peak production rates expected to be approximately 210,000 t/a copper, 5,000 t/a uranium oxide, 2,110 kg/a (74,500 oz/a) gold and 28,350 kg/a (1,000,000 oz/a) silver.

If the construction of the second expansion phase were to be approved by the WMC Board, the nominal mining rate would be approximately 17.0 Mt/a of ore, with a production rate of 350,000 t/a copper. The corresponding rate for associated products would average approximately 7,730 t/a uranium oxide, 3,630 kg/a (128,000 oz/a) gold and 49,600 kg/a (1,750,000 oz/a) silver.

Following completion of the first phase of the expansion, surplus smelting capacity could be used to produce copper from imported concentrates and other South Australian ores during periods when the smelting capacity exceeded the supply of ore available from the mine. If both the new and existing smelter were fully utilised, the overall copper production after the year 2000 would be up to 285,000 t/a.

To achieve the 285,000 t/a rate, some additional refinery equipment not included in the first phase would need to be installed. In the second expansion phase, a new smelter would be built and the existing smelter closed down. Because most of the copper concentrate would contain gold and silver as impurities, production of these precious metals would increase during this interim stage. However, there would be no increase in uranium oxide production.

Table 1.4 compares the scope of the Expansion Project with existing operations and with those that have already received government approval. Production rates may be amended in the detailed design phase to take into account such factors as economic justification, design feasibility, new technology, reliability, maintainability, safety and the environment.

Under the proposed expansion, the mining and mineral processing methods would remain essentially the same except that improvements since project inception in technology, energy and water efficiency, and pollution control would be incorporated into the design. The new metallurgical plant would be designed so that any spillages of ore, concentrate or process slurries could be readily returned to the process cycle, as for the existing metallurgical plant.

Underground open stoping would continue to be the principal mining method employed, with an increase in the number of stopes from an average of thirteen to about twenty-three. Rock used to refill the stopes after ore removal would continue to be a mixture of deslimed mill tailings and mullock or quarry rock, and cement and pulverised fuel ash.

Additional processing facilities would initially include a further autogenous mill, a second tailings leach module and a new blister copper smelting furnace with an associated acid plant and oxygen plants, as well as an expansion of the refinery. Additional tailings, liquor and mine water disposal facilities, and electrical and water supply infrastructure would be provided.

At Roxby Downs, additional housing would be provided, including company houses and units, non-company houses and single persons' quarters (village accommodation). A second caravan park would be built, and water, electricity supply and sewerage services would also be upgraded.

Table 1.4 Expansion Project production rates

Mineral	Existing operations	Approved operations[1]	Expansion Project		
			First phase	After first phase	Second phase
COPPER					
From Olympic Dam ore[2]	85,000 t/a	150,000 t/a	200,000 t/a	200,000 t/a	350,000 t/a
	(3.0 Mt/a ore)	(6.5 Mt/a ore)	(9.0 Mt/a ore)	(9.0 Mt/a ore)[3]	(17.0 Mt/a ore)
From imported concentrates/other ores	–	–	–	85,000 t/a	–
Nominal copper production rate			**200,000 t/a**	**285,000 t/a**	**350,000 t/a**
ASSOCIATED PRODUCTS					
Uranium oxide[2]	1,500 t/a	3,420 t/a[5]	4,630 t/a	4,630 t/a	7,730 t/a
Gold[4]	850 kg/a	1,640 kg/a[5]	2,050 kg/a	2,920 t/a[6]	3,630 kg/a
Silver[4]	13,000 kg/a	18,000 kg/a[5]	23,000 kg/a	32,800 t/a[6]	49,600 kg/a

1 *1983 EIS. Approval is based on copper production rate.*
2 *Nominal values. Quantity varies depending on copper–uranium grade in ore processed.*
3 *Olympic Dam ore. Other South Australian ores may supplement this figure.*
4 *Nominal values. Quantity varies depending on gold–silver grade in ore and concentrates processed.*
5 *Expected production rates. 1983 EIS indicative production rates were 3,000 t/a uranium oxide, 3,400 kg/a gold and 23,000 kg/a silver.*
6 *Assumes imported concentrate gold–silver grade is similar to Olympic Dam concentrate.*

1.2 HISTORY OF DEVELOPMENT AT OLYMPIC DAM

1961 to 1975

WMC began exploring South Australia for copper deposits in 1961. In 1972, a review of historical geological data combined with various geological models led WMC geologists to focus on the region to the west of Lake Torrens (Figure 1.1). Large-scale surveys indicated a number of coincident gravity and magnetic anomalies, suggesting that the Olympic Dam area warranted further exploration.

An Exploration Licence was granted over that area in May 1975, and by July the first drill hole, RD1, had intersected low-grade copper mineralisation (approximately 1%) 353 m below the surface. Subsequent analysis showed that the mineralisation also contained minor amounts of uranium and gold.

1976 to 1979

By 1976, eight diamond drill holes had been completed, a number that increased to thirteen by the end of 1977. WMC's Chairman reported to the 1977 Annual General Meeting that drilling had outlined a large prospective ore position and that, because of the likely size of the project, WMC was considering a joint venture for project development at that time.

Discussions with interested companies resulted in the formation of a joint venture with the BP Group, announced on 27 July 1979. In conjunction with the signing of the Joint Venture Agreement, WMC transferred its ownership in the project to Roxby Mining Corporation Pty Ltd, a wholly owned subsidiary of WMC. Ownership of the project was as follows: Roxby Mining Corporation Pty Ltd, whose name was later changed to WMC (Olympic Dam Corporation) Pty Ltd, 51%; and two companies in the BP Group, namely BP Australia Limited, 36.5%, and BP Petroleum Development Limited (a company incorporated in the United Kingdom), 12.5%.

In late 1979, permanent single persons' quarters were established at Olympic Dam, and eight diamond drills were operating by the end of the year. While exploration continued, the Joint Venturers began to carry out metallurgical testing and other work necessary to evaluate the project.

1980 to 1983

In May 1980, the decision was made to sink an exploration shaft (the Whenan Shaft) to a depth of approximately 500 m. During that year three additional diamond drills were put into operation, engineering facilities associated with the exploration shaft were constructed, work on the shaft commenced, and the village was expanded by the addition of housing and caravan park accommodation.

Feasibility studies into the metallurgical processing were conducted, and preliminary design work undertaken. Environmental baseline studies were commenced in late 1980 and have been continuous since that time.

The Indenture Agreement between the Joint Venturers and the South Australian Government, setting out the relationship of the parties, was ratified by the South Australian Parliament in June 1982. The principal matters with which the Indenture was concerned were:

- the obligations of the State Government and the Joint Venturers, and conditions relating to the development;
- security of tenure for the Joint Venturers, and access to services;
- the amount of royalties payable by the Joint Venturers.

The Joint Venturers prepared a draft EIS for the Olympic Dam Project, which was published on 14 October 1982 (Kinhill – Stearns Roger 1982). The Draft EIS was based on a mining and processing operation capable of producing 150,000 t/a of copper plus associated products. The Draft EIS was made available for public comment for a period of six weeks.

In April 1983, the Joint Venturers responded to the comments received from the public and from various Commonwealth and State government departments in the Supplement to the Draft EIS. The Draft EIS, the Supplement and supporting documentation were assessed by the Department of Home Affairs and Environment (Commonwealth Government) and the Department of Environment and Planning (State Government).

Ministerial approval for the project was received on 28 June 1983 from the State Government and on 10 August 1983 from the Commonwealth Government.

1984 to 1988

A pilot plant began operating in 1984 to assess metallurgical factors for the processing of Olympic Dam ore. This was followed by further feasibility studies, and detailed design and construction activities. Production at Olympic Dam commenced in 1988 at a rate of 45,000 t/a of copper plus associated products.

1989 to 1995

Between 1989 and 1995, the production rate at Olympic Dam was increased to the present levels in two optimisation programmes:

- The first optimisation of the operation was completed in 1992. This involved increasing ore treatment capacity from 1.5 Mt/a to 2.2 Mt/a by optimising the operation of existing plant and installing further equipment, including an extra ball mill and additional cells in the refinery. This resulted in a production rate of 66,000 t/a of copper plus associated products.
- The second optimisation of the operation was completed in 1995. This involved increasing ore treatment capacity to 3.0 Mt/a by installing new plant, including a new autogenous mill, two countercurrent decantation thickeners and additional cells in the refinery. This resulted in a production rate of 85,000 t/a of copper plus associated products.

In 1993, WMC acquired full ownership of Olympic Dam. The facilities are now operated by WMC (Olympic Dam Corporation) Pty Ltd, a wholly owned subsidiary of WMC Limited.

On 20 October 1995, the Commonwealth Minister for Primary Industries and Energy, under the *Environment Protection (Impact of Proposals) Act 1974*, designated WMC as the proponent in relation to future decisions to grant export approvals from Olympic Dam under Regulation 11 of the Customs (Prohibited Exports) Regulations.

The South Australian Minister for Mines and Energy, in response to this designation, submitted a proposal for a State-run environmental review that would comprise two interrelated elements:

- assessment of a new borefield development then under way (Kinhill Engineers 1995);
- an environmental review of Olympic Dam operations (WMC—Olympic Dam Corporation 1995), to evaluate the variations to design and operation of the project as implemented from those proposed in the Final EIS approved in 1983, and the developments required to take production up to the approved level of 150,000 t/a of copper plus associated products. In addition, the environmental review would evaluate seepage of liquid from the tailings retention system and its impact, and would include future options for expanding the system.

The Commonwealth Minister for the Environment, Sport and Territories stated that if this environmental review was completed in full under the South Australian legislation, no further review process by the Commonwealth would be necessary to meet the objectives of the *Environment Protection (Impact of Proposals) Act 1974*.

The review of the borefield development and the environmental review were conducted with public input. Both procedures were advertised nationally and locally, and public comment sought. Following the borefield review, a Special Water Licence was issued to WMC by the State Government in November 1995.

The environmental review of the Olympic Dam operations was produced in November 1995. Following assessment of this review, completed in January 1996 (Department of Housing and Urban Development 1996), the Commonwealth and State governments confirmed in early 1996 the approvals obtained in 1983.

1996 to the present

WMC has continued to evaluate the feasibility of expanding production at Olympic Dam, culminating in studies for expansion of the facilities to a production capacity of 200,000 t/a of copper and associated products.

In July 1996, the WMC Board authorised proceeding with the detailed design of an expansion to 200,000 t/a of copper and associated products, and the conceptual design of further expansion to 350,000 t/a. Further optimisation studies in the second half of 1996 have produced the Expansion Project plan detailed in this EIS.

In October 1996, an agreement was made between WMC and the State Government on WMC's and the State's obligations for expansion at Olympic Dam to 350,000 t/a copper and associated products. These obligations were incorporated into the *Roxby Downs (Indenture Ratification) (Amendment of Indenture) Amendment Act 1996.* The Amendment Act was passed by the State Parliament in December 1996.

1.3 THE APPROVALS PROCESS

1.3.1 Regulatory framework

This section describes the legislative, regulatory and policy framework in which the operations at Olympic Dam have been working to date, and which would apply to the proposed expansion.

The Olympic Dam and Stuart Shelf Indenture

The legal framework setting out the relationship between the South Australian Government (the State) and the Joint Venturers for project development and operation was established by the State Parliament through the *Roxby Downs (Indenture Ratification) Act 1982* and updated by the *Roxby Downs (Indenture Ratification) (Amendment of Indenture) Amendment Act 1996.* These Acts ratified and amended the Olympic Dam and Stuart Shelf Indenture, hereafter referred to as the Indenture.

The original Indenture provided for the development of an operation recovering up to 150,000 t/a of copper and associated products. The Amendment provides for the increase of this limit to 350,000 t/a of copper and associated products. The environmental approval processes associated with the existing plant and the Expansion Project are described below.

Environmental impact assessments

The Olympic Dam Project has been subjected to a comprehensive environmental assessment process from its inception. This has included environmental impact assessment for the currently approved operations, licence approval processes, the preparation of a waste management plan and the preparation every three years of environmental management programmes. Also required have been the assessment of the borefield development and the environmental review described in Section 1.2.

The Draft EIS (Kinhill – Stearns Roger 1982) and the Supplement (Kinhill Stearns 1983) together with the State Assessment Report (Department of Environment and Planning 1983) and the Commonwealth Government Assessment report (Department of Home Affairs and Environment 1983) comprised the Final EIS for the currently approved operations. These documents are referred to collectively hereafter as the 1983 EIS.

The 1983 State and Commonwealth government approvals permit the mining and processing at Olympic Dam of approximately 6.5 Mt/a of ore, for the recovery of 150,000 t/a of copper plus associated products (which at the time were expected to be approximately 3,000 t/a uranium oxide, 3,400 kg/a gold and 23,000 kg/a silver). As discussed in Section 1.2, these approvals were confirmed in early 1996 by both governments in an environmental review.

The approval of the 1983 EIS by the State Minister for Mines and Energy obliged the operators to:

- advise the Minister of any changes of environmental significance to the project concepts as described in the 1983 EIS;
- comply with all commitments and undertakings set out in the 1983 EIS.

Following this approval, the project underwent a series of further field, technical and environmental studies which formed the basis for commitment to the project by the Joint Venturers. The 1983 EIS provided assessment of a conceptual design, including in some instances an evaluation of options for mining and processing operations. This was necessary because the design could not be finalised until:

- the completion of pilot plant trials, which determined the optimal processing methodology and options for disposal of tailings, which took place during 1984;
- the sinking of the exploration shaft, which determined the mining methodology.

In the original development and in the expansions to date, the mining and metallurgical processes have followed the principles outlined in the 1983 EIS. In the proposed expansion, the mining and metallurgical processes would remain essentially unchanged, other than to incorporate improvements in technology and productivity since project inception. The environmental management and pollution control issues for the proposed expansion are thus well understood. The opportunity would also be taken to incorporate measures for improved environmental performance, waste minimisation, energy and water conservation, and occupational health and safety.

The Commonwealth and State governments have both determined that any expansion of production beyond that approved under the 1983 EIS (150,000 t/a copper plus associated products) will require the preparation of a new EIS. The purpose of this EIS is to fully describe the proposed Olympic Dam Expansion Project as part of the approvals process. The assessment procedure for the EIS is outlined in Section 1.3.2.

Other government requirements

As required by the Indenture, the State Government was provided with Project Notices that included full details of final design. Throughout the project, WMC has held discussions with the State authorities on all Project Notice design changes, including expansions and any variations from the 1983 EIS. The use of Project Notices has proved to be an effective method for informing the State Government of changes to the design of the initial plant and details of the two optimisation programmes in 1992 and 1995.

The process of issuing Project Notices will continue to be followed for future plant expansions in accordance with the Indenture. There continues to be provision for consultation with the Commonwealth Government through the tripartite Olympic Dam Consultative Committee, comprising representatives from the State and Commonwealth governments and WMC.

The governments and WMC are currently discussing new terms of reference and procedures for meetings of the committee.

Environmental and radiation management programmes

In regard to ongoing environmental management, Clause 11 of the Indenture requires that a programme for the protection, management and rehabilitation (if appropriate) of the environment, including arrangements for monitoring and studying sample areas in order to ascertain the effectiveness of such a programme, shall be submitted to the Minister for Mines and Energy every three years.

In addition, the Indenture requires compliance with the Commonwealth codes of practice concerning mining and milling of radioactive ores, which specify measures for the control of radiation exposure, waste management and dose assessment for members of the public. The Indenture also requires compliance with any codes, standards or recommendations as may be issued from time to time by the International Commission on Radiological Protection or the International Atomic Energy Agency.

The current programmes are set out in the Environmental Management and Monitoring Plan 1996 prepared by WMC (Olympic Dam Corporation) Pty Ltd. Under the terms of the Indenture and the requirements set by the State, quarterly and annual reports are produced. The Environmental Management and Monitoring Plans and the annual reports are made available to the public.

Water and power

In accordance with special water licences granted under the Indenture, water for the project is drawn from Borefields A and B which abstract water from the Great Artesian Basin. Borefield A was assessed in detail in the 1983 EIS and provided the original water supplies for the project. Approval in principle was granted in the 1983 EIS process for Borefield B to provide an ongoing supply of water to both Olympic Dam and the Roxby Downs township.

Borefield B was subject to a further environmental assessment (Kinhill Engineers 1995), a public consultation process (in 1995), and government assessment (Department of Housing and Urban Development 1995). All approvals were obtained, and commissioning of Borefield B commenced in November 1996.

Hydrogeological modelling of the borefields operation over a twenty-year planning horizon has shown that the agreed limits on aquifer pressure drawdown in the current licences are not exceeded at water abstraction rates sufficient for a production rate of 200,000 t/a copper and up to 285,000 t/a copper using supplementary imported concentrates (Section 1.1.3).

With the implementation of further water use minimisation programmes, the special water licences should also allow sufficient water abstraction for production of 350,000 t/a copper over the last six years of the planning horizon to 2016. By this time the planning for a further twenty years, to 2036, would be complete. As part of this longer term planning, WMC is developing plans for another borefield which would be subject to separate public consultation and government assessment should the establishment of such a borefield become necessary.

Power is currently supplied to the operations by a 132 kV transmission line from Port Augusta. The 1983 EIS provided approval in principle for the construction of a second line carrying 275 kV power from Port Augusta, subject to Aboriginal heritage studies and the investigation of route alternatives.

The alignment of the 275 kV power line (which is presently under construction) includes two minor deviations from the route previously approved. One minor deviation is near Port Augusta and has resulted from changes to the Port Augusta Development Plan in 1986. The other minor deviation is near Woomera and has resulted from a route change to minimise potential impact on Aboriginal heritage sites. The required studies were completed early in 1997, and construction of the new power line is expected to be completed by January 1998.

For the possible future second expansion phase to 350,000 t/a copper, it is proposed that the existing 132 kV line be replaced with a second 275 kV line. This additional line would follow the same alignment as the existing 132 kV line, and would include the two minor route deviations described above.

Legislation and codes of practice

In addition to the conditions laid down in the Indenture, WMC is obliged to comply with relevant State and Commonwealth legislation and codes of practice. Table 1.5 lists relevant State and Commonwealth Acts and codes of practice relating to environmental issues, while Table 1.6 provides a similar list relating to occupational health and safety and hazard management issues. Of the State legislation listed in Table 1.5, the *Development Act 1993*, the *Environment Protection Act 1993*, the *Mining Act 1971* and the *Water Resources Act 1990* are applicable to the extent that they are not inconsistent with the Indenture.

The most significant environmental licences held by the project are under the State *Environment Protection Act 1993* and the *Radiation Protection and Control Act 1982*.

Table 1.5 Relevant legislation and codes of practice—environmental issues

State legislation	Commonwealth legislation	Codes of practice
Aboriginal Heritage Act 1979	*Aboriginal and Torres Strait Islander Commission Act 1989*	Australian Code for the Transport of Dangerous Goods by Road and Rail 1992
Aboriginal Heritage Act 1988	*Aboriginal and Torres Strait Islander Heritage Protection Act 1984*	Code of Practice on the Management of Radioactive Wastes from the Mining and Milling of Radioactive Ores 1982
Controlled Substances Act 1984	*Aboriginal Sacred Sites Act 1989*	Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores 1987
Country Fires Act 1989	*Atomic Energy Act 1953*	Code of Practice for the Safe Transport of Radioactive Substances 1990
Dangerous Substances Act 1979 and Regulations	*Australian Heritage Commission Act 1975*	
Development Act 1993	*Customs (Prohibited Exports) Act 1901*	
Environment Protection Act 1993 and Regulations	*Customs Tariff (Uranium Concentrate Export Duty) Act 1980*	
Explosives Act 1936	*Endangered Species Protection Act 1992*	
Heritage Act 1993	*Environment Protection (Impact of Proposals) Act 1974*	
Mines and Works Inspection Act 1920 and Regulations	*Environment Protection (Nuclear Codes) Act 1978*	
Mining Act 1971 and Regulations	*Industrial Chemicals (Notification and Assessment) Act 1989*	
National Environment Protection Council (South Australia) Act 1995	*National Parks and Wildlife Conservation Act 1975*	
National Parks and Wildlife Act 1972	*Native Title Act 1993*	
Native Vegetation Act 1991	*Nuclear Non-Proliferation (Safeguards) Act 1987*	
Pastoral Land Management and Conservation Act 1989	*World Heritage Properties Conservation Act 1983*	
Planning Act 1982		
Public and Environmental Health Act 1987		
Radiation Protection and Control Act 1982 and Regulations		
Roxby Downs (Indenture Ratification) Act 1982 and *Roxby Downs (Indenture Ratification) (Amendment of Indenture) Amendment Act 1996*		
Soil Conservation and Land Care Act 1989		
Water Resources Act 1990		
Wilderness Protection Act 1992		

Table 1.6 Relevant legislation and codes of practice—occupational health and safety and hazard management

State legislation	Commonwealth legislation	Codes of practice
OCCUPATIONAL HEALTH AND SAFETY		
Controlled Substances Act 1984 *Dangerous Substances Act 1979* and Regulations *Environment Protection Act 1993* and Regulations *Explosives Act 1936* and Regulations *Mines and Works Inspection Act 1920* and Regulations *Occupational Health, Safety and Welfare Act 1986* and consolidated Regulations *Radiation Protection and Control Act 1982* and Regulations	*Environment Protection (Nuclear Codes) Act 1978* *Occupational Health and Safety Act 1995* *Industrial Chemicals (Notification and Assessment) Act 1989*	Adopted National Exposure Standards for Atmospheric Contaminants in the Occupational Environment (NOHSC 1991) Australian Code for the Transport of Dangerous Goods by Road and Rail 1992 Code of Practice on the Management of Radioactive Wastes from the Mining and Milling of Radioactive Ores 1982 Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores 1987 Code of Practice for the Safe Use of Radiation Gauges (NHMRC 1983) Guidance Note for the Labelling of Workplace Substances (NOHSC 1991) Guidance Note for the Storage of Chemicals (NOHSC 1990) Standard for the Control of Major Hazard Facilities (NOHSC 1995) (Draft) Standard for the Control of Workplace Hazardous Substances (NOHSC 1994) National Standard for Limiting Occupational Exposure to Ionising Radiation 1995 Standard for Plant (NOHSC 1995)
HAZARD MANAGEMENT		
Occupational Health, Safety and Welfare Act 1986 *Dangerous Substances Act 1979* *Environment Protection Act 1993*	*Occupational Health and Safety (Commonwealth Employment) Act 1991*	Draft National Code of Practice for the Control of Major Hazard Facilities 1995

1.3.2 The environmental impact assessment procedure

The environmental impact assessment procedure for the Expansion Project is shown diagrammatically in Figure 1.3. It should be noted that under the State environmental assessment procedure, an EIS is followed by a Response document after receipt of submissions. Under the Commonwealth environmental assessment procedure, the initial document would be referred to as a Draft EIS, and would be followed by a Supplement after receipt of submissions.

It has been agreed by the State and Commonwealth governments that the procedure in Figure 1.3 will satisfy the legislative requirements and administrative procedures of both. Assessment of this EIS, of public and government department submissions, and of the Response/Supplement will be led by the State Government.

A draft set of guidelines for this EIS was advertised for public comment on 9 November 1996. The draft guidelines remained open for public comment for a period of four weeks. The finalised guidelines, issued jointly by the State and Commonwealth governments, incorporate changes resulting from the assessment of public comments and are contained in Appendix B for reference.

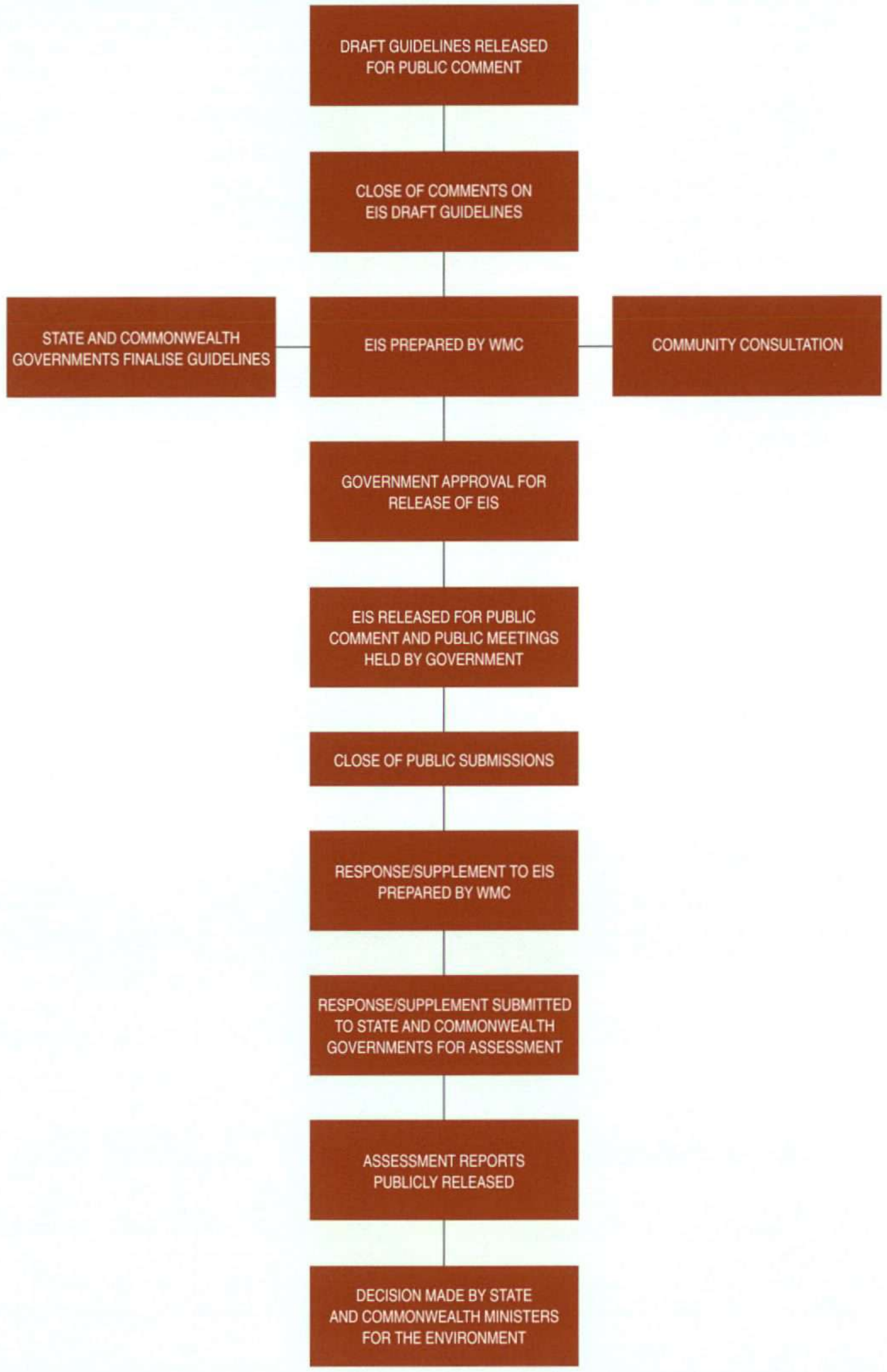

FIGURE 1.3
ENVIRONMENTAL IMPACT ASSESSMENT PROCEDURE FOR THE OLYMPIC DAM EXPANSION PROJECT

The EIS is available for comment by the public and by government departments and agencies for a period of eight weeks. During this time members of the public are invited to forward comments on any aspect of the proposal to either the State or Commonwealth governments as advertised. All comments will be forwarded to WMC. WMC's responses to comments received will be contained in a Response/Supplement to the EIS.

Following publication of the EIS and Response/Supplement, the relevant State and Commonwealth government departments and agencies will assess the documents and publish the results in assessment reports. The EIS, Response/Supplement and the assessment reports will be considered by the respective State and Commonwealth government ministers to determine whether the Expansion Project will be allowed to proceed and, if so, under what conditions.

1.4 PRODUCTS AND MARKETS

The Expansion Project is based on analysis of the markets available for Olympic Dam's key products, copper and uranium oxide. The value of these products and their role in world markets are discussed below.

1.4.1 Value of production

At a production rate of 200,000 t/a copper, the annual value of production at Olympic Dam—including the 4,630 t/a uranium oxide, 2,050 kg/a gold and 23,000 kg/a silver—would be approximately $650 million (December 1996 prices).

At a production rate of 350,000 t/a of copper, the Olympic Dam Project would rank among the largest copper producers in the world. At this production rate, the annual value of production—including the 7,730 t/a uranium oxide, 3,630 kg/a gold and 49,600 kg/a silver—would be approximately $1,128 million (December 1996 prices). The breakdown of these figures is shown in Table 1.7.

Table 1.7 Annual value of Olympic Dam Project production—December 1996 prices

Commodity	Value[1]	200,000 t/a copper ($ million)	350,000 t/a copper ($ million)
Copper	$2,250/t	450	788
Uranium oxide	$35/kg	162	271
Gold	$16,200/kg	33	59
Silver	$210/kg	5	10
TOTAL		**650**	**1,128**

1 *Values are approximate, based on December 1996 prices, and are subject to market forces.*

1.4.2 Copper: Use and markets

Copper has many useful attributes. It is the most efficient non-precious metal conductor of electricity, it has excellent thermal conductivity, is resistant to corrosion, is strong yet readily workable and can be readily recycled. World data on the end uses of copper are not available. However, an indication of the major markets is given from US statistics shown in Table 1.8.

In the construction industry, copper's uses include electrical building wire, water tubing and roofing. It is also used as a heat exchanger in air-conditioners and refrigeration units.

Copper wire is used for telephone lines and in electrical motors, generators and transformers. In motor vehicles, it distributes electricity around the vehicle and is used as winding wire in the small motors serving accessories such as electric windows, electric locking controls and air-conditioners. Growth in copper wire consumption has kept pace with the growing number of faxes, computers and other devices found in homes and businesses.

Table 1.8 Copper consumption by end use—USA 1993

Use	Per cent
Construction	42
Electrical and electronic products	24
Industrial machinery and equipment	13
Transport equipment	12
Consumer and general products	9
TOTAL	**100**

As an electrical conductor, copper competes with aluminium which has captured some market share, particularly in very high voltage overhead lines where aluminium has a weight advantage. However, copper remains the conductor of choice in the high volume building wire sector.

Copper is also a component of brass and bronze and other alloys. It plays a minor part in the production of coinage, is a supplement in human diets, and is present in fertilisers and a variety of chemicals. Environmental and commercial pressures to conserve energy are likely to increase copper use. Electrical losses are reduced when thicker wire is used in building circuits, when heavier copper windings are used in motors, and when copper is substituted for aluminium in motor windings.

Copper recycling is a substantial industry because it makes economic sense to recycle. Copper has a high value and can be readily remelted or refined. Most copper applications have very long lives; for example, building wire frequently lasts many decades.

Figure 1.4 shows historical trends in consumption. World consumption of refined copper was approximately 12 Mt in 1995. In addition, about 3.5 Mt of scrap copper were directly remelted. Consumption of copper is expected to show sound long-term growth, underpinned by rapid economic growth in Asia and the ubiquitous role of electricity in modern life.

The copper market is essentially a world market. Copper is easily stored and transported, quality differences among major producers are small, and tariff barriers are low and falling. Major producers of copper metal are the United States, Chile, Japan (from imported concentrate), Russia and China. Major consumers are the Western European nations, Japan, China and other Asian nations, and the United States.

1.4.3 Uranium: Use and markets

Uranium is a relatively common element, about as abundant as tin and about one thousand times more abundant than gold. Its industrial use is mainly confined to the production of electricity in nuclear power stations, although other important applications include the production of radioisotopes used extensively in medical, industrial and scientific research.

Naturally occurring uranium contains three separate isotopes. One isotope (uranium-235) has the unique property of being able to undergo controlled nuclear fission, releasing very large amounts of energy. This energy, released in a nuclear power reactor, provides the heat for steam raising and the production of electricity by turbo-generators. Conventional thermal power stations use mainly coal or hydrocarbon fuels to provide this heat.

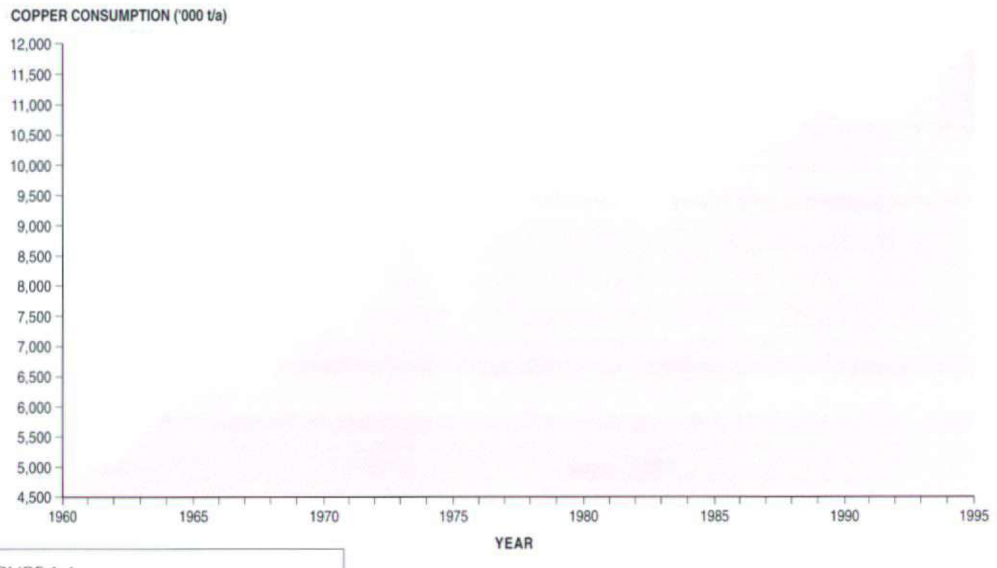

FIGURE 1.4
HISTORICAL TRENDS IN WORLD COPPER CONSUMPTION

Source: World Metal Statistics Quarterly Summary reports

Naturally occurring uranium contains approximately 0.7% of the uranium-235 isotope. Most nuclear power reactors which are currently in operation or in the planning stages require uranium fuels enriched to about 3% uranium-235. Most uranium oxide is chemically refined and processed into uranium hexafluoride (UF_6) at a conversion plant, and then further upgraded in an enrichment plant by isotopic separation. The enriched UF_6 is sent to a fuel fabrication plant where the fuel assemblies (which form the core of the nuclear power reactor) are manufactured.

None of these activities are presently carried out in Australia, and the conversion and enrichment facilities in other countries are adequate to meet current and foreseeable demand.

Uranium supply and demand

At the end of September 1996, there were 436 reactors in operation worldwide (343.5 GW capacity) with another thirty-two (25.3 GW capacity) under construction. The leading nuclear nations are shown in Table 1.9.

The current demand for uranium amounts to around 64,492 t/a of uranium, which is equivalent to 76,051 t/a of uranium oxide in the form U_3O_8. According to forecasts produced by the Uranium Institute (1996a), nuclear generating capacity and reactor requirements are expected to grow steadily, and thus uranium demand is also expected to grow steadily. The nuclear generating capacity forecast, together with uranium demand and the equivalent uranium oxide production required, is shown in Table 1.10.

Most uranium is produced as uranium oxide concentrate, in the form U_3O_8. The major uranium-producing countries in 1995 are listed in Table 1.11, together with their production of uranium oxide as U_3O_8 and equivalent uranium.

According to the Uranium Institute (1996b), the production capacity of uranium mines in 1995 was 46,530 t/a of uranium (54,870 t/a of U_3O_8); however, the worldwide primary production of uranium in 1995 was only 33,275 t/a uranium (39,239 t of U_3O_8) which was about 55% of total reactor requirements. The capacity of existing mines is forecast to fall to about 39,000 t/a of uranium oxide by the year 2001, as existing deposits are depleted.

Table 1.9 Worldwide nuclear power generating capacity—major countries (September 1996)

Country	Generating capacity (GW)	Percentage of total electricity production
United States	99.1	22.5%
France	60.2	76.1%
Japan	40.9	33.4%
Germany	21.0	29.1%
Russia	19.2	11.8%
Canada	14.8	17.3%
Ukraine	12.9	37.8%
United Kingdom	11.9	25.0%
Sweden	9.9	46.6%
South Korea	9.1	36.1%
Spain	7.0	34.1%
Belgium	5.5	55.5%
Taiwan	4.9	26.8%
Worldwide	343.5	17.0%

Source: Uranium Institute 1996a, 1996b.

Table 1.10 Projected worldwide nuclear generating capacity

Year	Reactor requirements		Nuclear generating capacity (GW)
	Tonnes U	Equivalent in tonnes U_3O_8	
1996	64,066	75,550	343.5
1997	64,492	76,051	349.6
2000	66,596	78,533	361.9
2005	72,160	85,094	374.6
2010	74,775	88,178	401.0
2015	75,635	89,192	410.8

Source: Uranium Institute 1996b.

Table 1.11 Major uranium-producing countries—1995

Country	Production	
	Tonnes U_3O_8	Equivalent in tonnes U
Canada	12,400	10,515
Australia	4,377	3,712
Niger	3,502	2,970
United States	2,783	2,360
Russia	2,653	2,250
Namibia	2,367	2,007
Worldwide	39,239	33,275

Source: Uranium Institute 1996a.

New production from major Australian and Canadian facilities is expected to commence from around 1998–99, which should raise production capacity to around 67,300 t/a of uranium oxide in the year 2000. Assuming a capacity utilisation factor of 75%, this should generate production of around 50,500 t/a uranium oxide in the year 2000.

The Uranium Institute forecasts that primary production will increase to around 51,300 t/a uranium oxide in the year 2002 (assuming a capacity utilisation factor of 75%), and will remain around this level until 2010 and beyond, well below reactor requirements.

The shortfall in supply will be filled from various sources including commercial and military inventories and reprocessed spent nuclear fuel. Figure 1.5 depicts the reference case developed by the Uranium Institute (1996b) to show the likely supply shortfall over the next twenty years.

1.5 CONSEQUENCES OF NOT PROCEEDING WITH THE PROJECT

If the Expansion Project did not proceed, there would be some consequences (benefits and disbenefits) for metal markets (in particular, copper and uranium), for the South Australian and national economies, and for the environment. These are discussed below.

1.5.1 The copper market

Olympic Dam's approved production rate of 150,000 t/a of copper represents about 1.25% of current world consumption of refined copper.

Although at a possible future production rate of 350,000 t/a copper the Expansion Project would be a large individual producer, this output would still only represent about 2.9% of current world consumption of refined copper. There are a number of other large projects at varying stages of development throughout the world, many situated in developing countries.

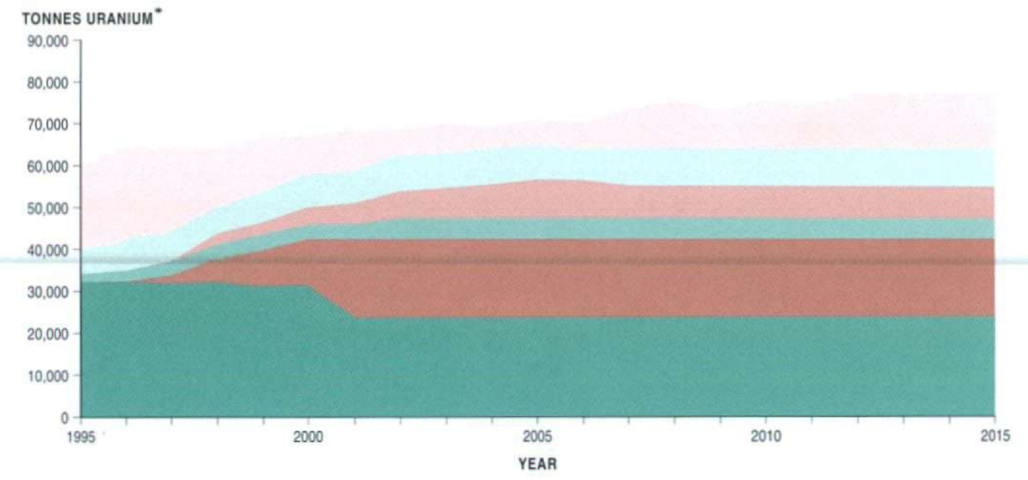

FIGURE 1.5
FORECAST URANIUM SUPPLY AND DEMAND

Source: Uranium Institute 1996b

Copper production foregone at Olympic Dam would therefore be replaced by the expansion of existing projects elsewhere, or by the development of new ones.

There are no known alternative copper projects in South Australia, and very few projects within Australia, that could even partially replace the proposed additional copper production at Olympic Dam. Replacement production would therefore be substantially sourced overseas, and the benefits of development lost to this country.

1.5.2 The uranium market

At the proposed production rate of 7,730 t/a uranium for the possible future second phase of expansion, Olympic Dam would represent about 20% of present world production. As with copper, there are a number of alternative projects awaiting development, particularly in Canada and other parts of Australia. If additional uranium were not produced at Olympic Dam, uranium demand would be met by increased output from existing projects elsewhere, or by the development of new projects.

Australia has new alternative sources of uranium as a consequence of changes in Commonwealth Government policy, which had previously prevented the establishment of new uranium mines. The additional Olympic Dam uranium could therefore be partly replaced by an increase in production in existing uranium mines or by the development of new mines elsewhere in the country. However, a significant proportion of the replacement production could occur in overseas countries, and the benefits of development would accrue there.

1.5.3 The State and national economies

The estimated benefits for the South Australian and national economies from the first phase of the Expansion Project, to production of 200,000 t/a copper, are substantial and include:

- the creation of between 1,750 and 2,500 new jobs in South Australia during the construction phase, including direct jobs at Olympic Dam and indirect jobs in the State, and up to an additional 3,000 jobs in other parts of Australia;
- an increase in the gross state product of South Australia of between 0.4% ($120 million) and 0.5% ($150 million) per annum during the construction phase;
- the creation of around 1,100 new permanent jobs in South Australia during production, including 191 direct jobs at Olympic Dam and Adelaide and indirect jobs in the State;
- an increase in the gross state product of South Australia of just less than 0.4% ($115 million) per annum during production, and an increase in the gross domestic product of Australia of 0.1% ($340 million);
- an increase in receipts by the State of South Australia of around $12 million per annum in royalties from the project during production;
- increased tax revenue for the State of South Australia and the Commonwealth from payroll, corporate, sales and personal taxes;
- an increase in annual revenue from the sale of copper, uranium oxide, gold and silver of around $320 million, and a positive annual impact on Australia's balance of trade of $96 million during production.

The additional benefits for the South Australian and national economies estimated to flow from the possible future second phase of the Expansion Project, to production of 350,000 t/a copper, are also substantial and include:

- the creation of around 1,240 new jobs in South Australia during the construction phase including direct jobs at Olympic Dam and indirect jobs in the State;
- an increase in the gross state product of South Australia of around 0.3% per annum ($87 million) during the construction phase;

- the creation of around 1,190 new permanent jobs in South Australia during production, including 510 direct jobs at Olympic Dam and Adelaide;
- an increase in the gross state product of South Australia of around 0.5% ($138 million) per annum during production, and an increase in gross domestic product of Australia of 0.1% ($468 million);
- an increase in receipts by the State of South Australia of around $17 million per annum in royalties from the project during production;
- increased tax revenue for the State of South Australia and the Commonwealth from payroll, corporate, sales and personal taxes;
- an increase in annual revenue from the sale of copper, uranium oxide, gold and silver of around $400 million and a positive annual impact on Australia's balance of trade of $124 million.

Should the Olympic Dam Expansion Project not proceed, these benefits could be lost to the South Australian economy, because there are no known alternative developments with the same potential for investment in South Australia, particularly in a long-term context. In the short to medium term, the Australian economy would lose the window of opportunity to export a valuable resource into world markets.

1.5.4 Environmental benefits of not proceeding

All projects result in some disturbance to the environment. It is the role of project planners, developers and regulators to ensure that no significant environmental impacts occur, and that the residual impacts are managed so that the benefits of project development outweigh the effects of the disturbances.

As this project involves the expansion of existing facilities, the potential for environmental disturbance is less than for a project in an undisturbed area. Nevertheless, there would be some environmental benefits, both real and perceived, associated with not proceeding with the Expansion Project, and these are outlined below. These benefits should be considered against the significant economic benefits accruing from the project.

Any real or perceived environmental benefits of not proceeding also need to be considered in the context of the extensive studies undertaken by Olympic Dam's environmental staff and by consultants engaged by WMC, which have contributed significantly to the understanding both of the local environment and of similar arid environments elsewhere in Australia.

Clearing of vegetation

Unlike new project developments, a decision not to proceed with the Expansion Project would not reduce the expected level of disturbance to the natural environment at the end of the mine's life.

Firstly, as described in Chapter 3, the additional mining and processing facilities required for the Expansion Project would be mainly located within areas already cleared for the existing facilities. Secondly, additional clearing of the natural environment occurs at present on an as-needed basis for the progressive development of the tailings retention system and the quarry, which provides essential backfill material; this would continue. The Expansion Project would require a similar ultimate amount of clearing for these facilities, but this clearing would occur at a faster rate over a correspondingly shorter mine life.

A minor amount of clearing required for the township expansion could be avoided if the Expansion Project did not proceed. However, the township development needed to support the mine expansion is contained within an area already approved for development in the 1983 EIS.

Great Artesian Basin

The annual abstraction water requirements for both Olympic Dam and Roxby Downs, sourced from borefields abstracting from the Great Artesian Basin, would increase as a consequence of the Expansion Project. At this time it is envisaged that the project's water requirements would be met by the existing borefields (A and B) operated under existing licence provisions.

However, should this not be the case, an additional borefield may need to be developed. If such a borefield is required in the future it would be subject to a separate environmental impact assessment.

The benefits to the Great Artesian Basin of not proceeding with the project are therefore as follows:

- a reduction in the localised drawdown of the aquifer in the vicinity of the existing borefields (Section 4.5);
- a diminution of the possibility of a further borefield needing to be developed in the future.

The operations at Olympic Dam have made significant progress towards water conservation, and efforts will continue to be expended in this area in the future. In the first full year of production in 1989–90, the operations (excluding the township) consumed a total of 2.10 kL of water sourced from the Great Artesian Basin per tonne of ore processed. In 1995–96, this water consumption had reduced to 1.57 kL per tonne of ore processed, and it is expected that a further reduction to 1.24 kL per tonne of ore processed will be achieved by the time the production rate of 200,000 t/a of copper is achieved. Water conservation measures and issues are discussed further in Chapter 4.

The present rate of abstraction and natural discharge from the South Australian portion of the Great Artesian Basin is estimated to be equivalent to the rate of recharge at 425 ML/d (Sibenaler 1996). This includes 190 ML/d percolated upward as vertical leakage, 132 ML/d from flowing bores mainly associated with the pastoral industry, 66 ML/d natural discharge from mound springs, 22 ML/d abstracted as part of the Cooper Basin operations and 15 ML/d abstracted for the Olympic Dam operations.

Further development of the Great Artesian Basin as a water resource is believed to be possible in South Australia through the use of strategically placed bores that would 'harvest' water that would normally be lost by vertical leakage to surface evaporation. At a production rate of 200,000 t/a copper, the Olympic Dam abstraction rate would be 34 ML/d. As noted in Section 1.3.1, the current special water licences should also be sufficient for the production of 350,000 t/a copper over the last six years of the twenty-year planning horizon to 2016. By that date the planning for a further twenty years, to 2036, would be complete.

Water abstraction from the Great Artesian Basin is reducing regionally as a result of the State Government's programme to rehabilitate old, uncontrolled pastoral bores and plug others that are no longer required. Since 1977, Mines and Energy South Australia, which is implementing the programme, has repaired or plugged 192 bores, potentially saving an estimated 105 ML/d that was previously wasted (Sampson 1996). This quantity is some three times the estimated abstraction rate required to support an annual production rate of 200,000 t/a copper at Olympic Dam.

Lake Eyre Basin

The Commonwealth Government has considered whether the Lake Eyre Basin has natural heritage values of World Heritage quality. At the present time, World Heritage listing of the area is not being pursued by the Commonwealth. Olympic Dam is located some 50 km outside the Lake Eyre Basin, while Borefield A and Borefield B are located within it.

On the basis that the mine will continue to remain operational, proceeding with the Expansion Project will not affect the maintenance of the natural heritage values of the Lake Eyre Basin.

275 kV transmission lines

The Olympic Dam mine currently sources its power requirements from a 132 kV transmission line from Port Augusta. This transmission line is approaching capacity supplying the existing operations and a new 275 kV transmission line from the site to Port Augusta is under construction. Any further development at the mine up to the currently approved production rate of 150,000 t/a of copper plus associated products would still have required construction of the new line, even if expansion above 150,000 t/a of copper did not occur.

As noted in Section 1.3.1, for the second expansion phase to 350,000 t/a copper, the existing 132 kV line is proposed to be replaced with a second 275 kV line (in addition to the one presently under construction). This additional line would follow the same alignment as the existing 132 kV line, apart from the two minor deviations for the 275 kV line under construction. Any additional environmental disturbance caused by construction of the additional 275 kV line would be minimal.

Tailings management

Amongst other considerations, the tailings storage facilities at Olympic Dam are designed to minimise seepage to the underlying soils. Future tailings storage facilities will also be designed to ensure minimal seepage. Experience has shown that the risk of seepage is greatest when new facilities become operational, that is, before the tailings beaches have been fully established.

Future operations at Olympic Dam require the progressive establishment of additional tailings storage facilities as existing facilities reach capacity. Overall, the Expansion Project would require the development of a similar amount of tailings storage facilities, but these would be developed at an increased rate (including an initial expansion of the existing facilities) over a correspondingly shorter mine life. Therefore, when considered over the longer term, a decision not to proceed with the Expansion Project would not affect the overall volume of tailings storage, and thus not reduce the risk of seepage occurring from the tailings storage facilities.

1.6 SCOPE AND STRUCTURE OF THE REPORT

1.6.1 Scope

The scope of this EIS covers the environmental implications of the Olympic Dam Expansion Project, in response to the EIS guidelines (Appendix B) issued by the State and Commonwealth governments.

The EIS does not revisit the issues covered in the 1983 EIS, the Borefield B report (Kinhill Engineers 1995) and the environmental review (WMC—Olympic Dam Corporation 1995). It also does not include issues associated with the nuclear fuel cycle or policy issues associated with uranium mining, which are excluded from the scope as set out in the guidelines.

1.6.2 Structure

Two key considerations have shaped the structure of this EIS: the need to describe the scale and physical characteristics of the Olympic Dam Expansion Project in the most effective way, and the need to examine those environmental factors that have been identified in the EIS guidelines and by WMC's consultants as being the most relevant in assessing the environmental effects of the proposal.

Major elements of the project have been broadly categorised as follows:

- additional facilities (including infrastructure) required for mining, processing and tailings disposal;
- effluents and emissions arising from the above, with particular reference to the movement of radioactive material through the mining and processing stages;
- supporting services, with particular reference to water use and the management of water resources;
- impacts on the terrestrial environment;
- accommodation of the workforce;
- social and economic aspects, including creation of employment opportunities.

The existing operations at Olympic Dam are described in Chapter 2. The physical elements of the Expansion Project are described in Chapter 3. Subsequent chapters (Chapters 4 to 15) describe the effects of the Expansion Project on the existing environment, with environmental aspects grouped according to their relationship to major elements of the project (Table 1.12).

The individual chapters discuss the present environment, the potential impact of the Expansion Project, and the proposed environmental controls, management systems and procedures. Where appropriate, the assessment method is also described.

Table 1.12 Report structure

Major project element	Environmental considerations	Chapter
Project description	• Existing operations—general • Future operations—general	2 3
Water management	• Water use • Hydrogeology	4 4
Surface development	• Land use • Aboriginal heritage • Terrestrial environment • Rehabilitation and decommissioning	5 6 7 14
Effluents and emissions	• Tailings storage • Air emissions • Noise • Radiation	8 9 9 10
Infrastructure development	• Power supply • Solid/liquid waste disposal • Other infrastructure	11 11 11
Community and economic development	• Social effects • Town design • Economic effects	12 12 13
Environmental and safety management	• Management plan • Emergency response • Contingency planning • Monitoring programme	15 15 15 15

Appendix A presents the WMC policy and other commitments relevant to the Expansion Project. Appendix B presents the EIS guidelines as finalised by the State and Commonwealth governments. Of necessity, this document contains a significant number of technical terms. As these may not be familiar to readers, a glossary has been included as Appendix C. Technical abbreviations used in the document are contained in Appendix D, while references are brought together as Appendix E, categorised by the chapter in which they occur. The agencies consulted during preparation of this document are listed in Appendix F. Appendix G lists members of the EIS study team. The technical appendices relating to specific chapters (H–M) are separately bound in Volume 2.

CHAPTER 2

EXISTING OPERATIONS AND ENVIRONMENTAL MANAGEMENT

CHAPTER 2

EXISTING OPERATIONS AND ENVIRONMENTAL MANAGEMENT

This chapter describes the existing operations at Olympic Dam. The discussion covers the mining operations, mineral processing facilities, infrastructure, waste management, environmental management systems, occupational health and safety procedures, and the township. Experience gained from the existing operations would be used to operate and manage the expanded project.

2.1 MINING

Mining commenced at Olympic Dam in 1988. Since that time, in excess of 100 km of underground development has been completed and 17 Mt of ore mined. The mine workings extend from 350 m to 700 m below the surface, and cover an area of 1 km by 3 km, about the size of the Adelaide central business district. In December 1996, 286 people were directly employed in mining activities, and a further 163 maintenance, mining and other contractors were also employed.

The proposed expansion would not involve any significant change in the primary mining method. The most significant changes proposed are in the area of access and materials handling.

2.1.1 Geology

The ore deposit is located within the basement rocks of the Stuart Shelf geological province. This province is located in the mid-north of South Australia, in the region to the west of Lake Torrens (as shown in Figure 1.1).

The ore minerals, which are mainly fine-grained copper sulphide minerals, uranium minerals, gold, silver and rare earth minerals, occur in a magnetic hydrothermal breccia complex underneath 350 m of unmineralised sedimentary rocks. The ore occurs in a number of distinct ore zones, which determine the mine access and layout. The geology of the region and of the deposit is described in detail in Section 3.2.

2.1.2 Access

Access to the mine is provided by two vertical shafts—the Whenan Shaft and the Robinson Shaft—and a service decline, an inclined tunnel that provides access to the mine for vehicles (as shown in Figure 1.2). All ore and mullock (waste rock) are hoisted to the surface through the Whenan and Robinson shafts.

The service decline and the main development headings (tunnels for mining access) are 6 m wide by 4.8 m high, permitting access by conventional vehicles, including trucks and personnel carriers, as well as the front end loaders and off-highway trucks used for mining. The maximum gradient for the decline and other headings is 1 in 9.

2.1.3 Development

Working faces where any horizontal underground development is being advanced are known as development headings. The headings are drilled out with jumbo drill machines, and on completion are referred to as drives. Types of drives include drill drives, tramming drives and haulage drives (Figure 2.1).

Blastholes are charged with ammonium nitrate/fuel oil mixture (ANFO) and initiated with shock tube detonators. Explosive charging is facilitated by the use of a fully self-contained charging vehicle, complete with ANFO loader, hose reel, crane and basket, and air compressor. The average heading advance for each blast is 3.8 m.

The broken rock is loaded by conventional 4 m^3 capacity front end loaders into 30 t capacity off-highway trucks for haulage to the underground crusher. After removal of the rock from the development headings, the walls and back (roof) are secured using 2.4 m long rockbolts. Additional support, such as grid mesh and shotcrete, is used as required.

2.1.4 Production

The primary extraction method is a variant of sublevel open stoping, as shown in Figure 2.1. In this method, the orebody is divided into a series of transverse blocks called stopes, the width of which depends on such factors as geological structures, mineralisation, backfill and extraction level geometry. A maximum width of 35 m applies for transverse stopes. Stopes run the full width of the orebody and are usually between 60 m and 180 m high. A typical stope may contain 300,000 t of ore. At the bottom of the stope, a system of drawpoints is developed for extraction of the ore by front end loaders. The bottom of the stope itself is tapered to facilitate this process.

Drill drives are driven on the stope centre line at 40 m vertical intervals, and blastholes drilled in vertical rings as shown in Figure 2.1. The blastholes are charged with ANFO which is then detonated with shock tube detonators. A maximum of 80,000 t of ore is fired in each stope blast.

A slot is opened up for the full height and width of the block at one end of the stope, and vertical rings of blastholes are then fired a few rings at a time into this void. The rock falls to the bottom of the stope and is extracted through the drawpoints. Blasting and extraction continue in vertical slices until the stope is completely empty. Before blasting commences, the crown pillar (the rock that constitutes the roof of the stope) is supported with 15 m long cable bolts to ensure the stability of nearby openings and to prevent dilution of the ore from falls of waste rock.

After final extraction of the primary stopes is complete, the voids are backfilled with cemented aggregate fill (CAF). CAF consists of crushed mullock (waste rock) or rock obtained from a surface quarry and deslimed mill tailings with the addition of Portland cement and pulverised fuel ash. Dune sand is sometimes substituted for mill tailings if insufficient mill tailings are available. Backfill is introduced directly into the stope from the surface through 300 mm diameter boreholes.

Only when a stope has been filled and the backfill given time to solidify are the adjacent stopes mined. The secondary stopes (stopes where no further mining is to occur) are filled with uncemented development mullock or quarry rock. Quarry rock is obtained as required from a conventional surface dolomite quarry located to the north of the metallurgical plant (Figure 1.2). Mullock, when available, is used in preference to quarry rock for stope backfill.

2.1.5 Ore and mullock handling

There are two separate sets of existing ore and mullock handling facilities: those associated with the Whenan Shaft, and those associated with the Robinson Shaft. The Robinson Shaft is a 5.3 m diameter circular concrete shaft 580 m deep, and is used for hoisting development rock and mullock. The Whenan Shaft is a six-compartment rectangular (6.3 m x 3.5 m) shaft 500 m deep, and is used for hoisting ore.

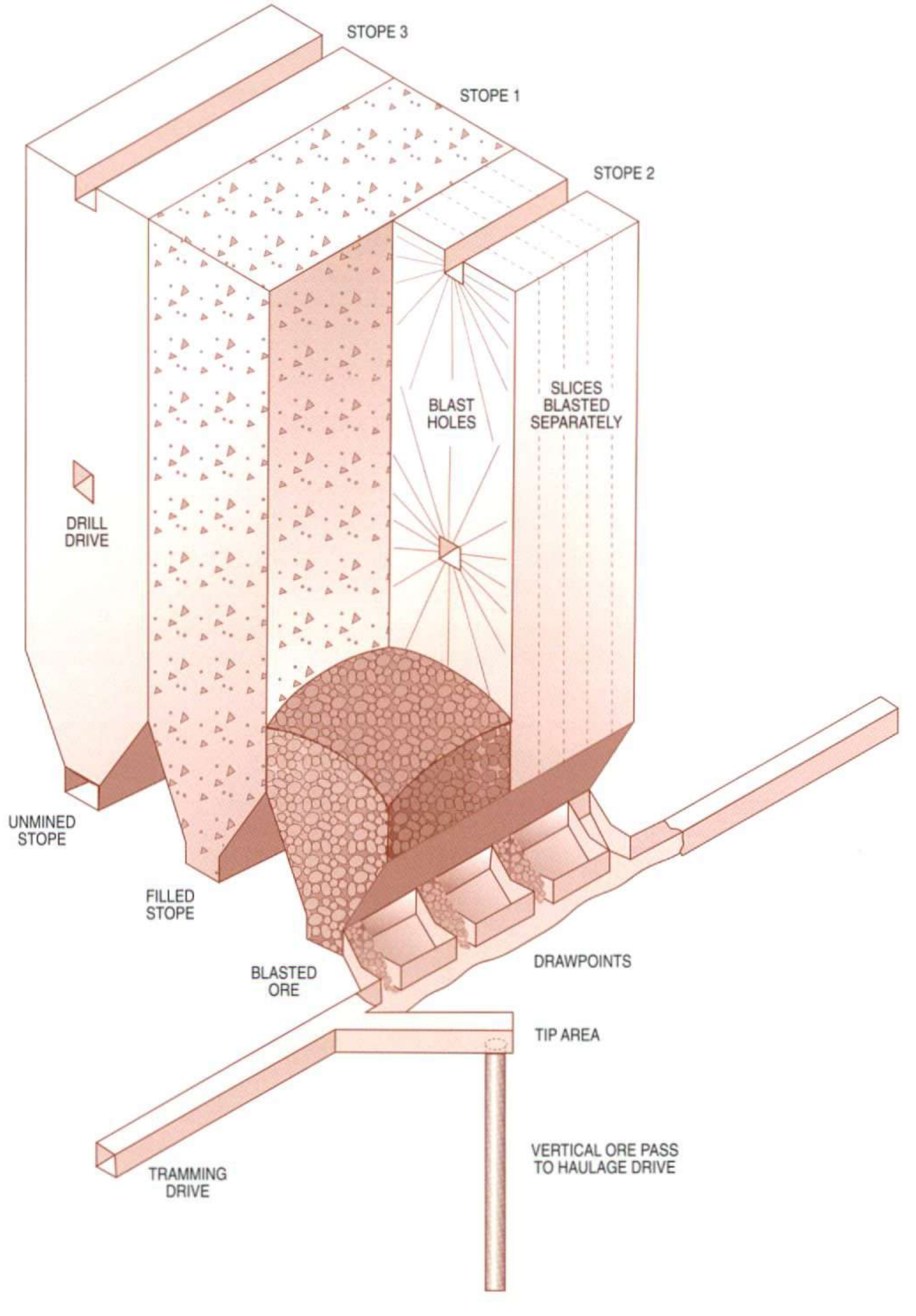

FIGURE 2.1
SUBLEVEL OPEN STOPING

Ore from the stopes is loaded by front end loaders into 30 t trucks, which carry the ore to a tip area, where two ore passes are located. The drawpoints where the front end loaders operate are equipped with water sprays for dust suppression, as are the ore tip areas. Ore must pass through a grizzly (a heavy grid designed to screen large rocks) before entering the ore passes. Large rocks collected by the grizzly are broken with a rock breaker. Ore then gravitates to the bottom of the pass where plate feeders carry the ore to a single 550 t/h jaw crusher, where it is reduced in size to less than 200 mm. The crushed ore then passes to a vibrating feeder which delivers it on to a belt conveyor, where an electromagnet is used to remove any steel material.

The crushed ore is then fed on to the main underground conveyor, which carries it 460 m up an incline of 1 in 6 to crushed ore bins adjacent to the Whenan Shaft. The ore is conveyed from the crushed ore bins by a belt conveyor and loaded into 9.25 t capacity bottom-discharge skips for hoisting to the surface. The Whenan Shaft hoisting capacity is 480 t/h. The hoisting system is monitored remotely and operates automatically. On reaching the surface, the ore is conveyed to the process plant stockpiles.

An isometric diagram of the Whenan Shaft ore handling system is included as Figure 2.2, and a simplified flowsheet of the system included as Figure 2.3.

At the Robinson Shaft, the facilities are similar to but simpler than those described above for the Whenan Shaft. Mullock is delivered by 30 t truck and tipped directly onto an apron feeder to a 400 t/h jaw crusher. The crushed mullock then passes directly to a 1,500 t crushed mullock bin. Crushed mullock then passes through a bin feeder to a conveyor, and then to 7 t capacity skips for hoisting to the surface. The hoisting capacity is 400 t/h. On reaching the surface, the crushed mullock is carried by truck to the backfill plant or to the mullock stockpile.

2.1.6 Ventilation

The ventilation system is required to remove contaminants from the mine air, principally heat (from the surrounding rock and from mining equipment), mobile vehicle diesel exhausts, blasting fumes, dust and radiation products.

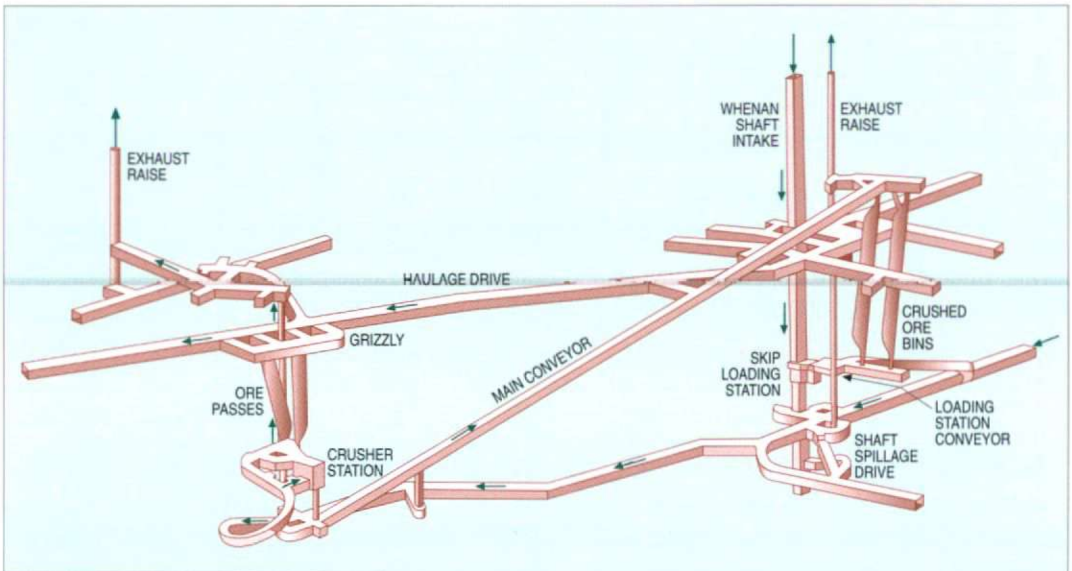

FIGURE 2.2
ISOMETRIC DIAGRAM OF WHENAN SHAFT ORE HANDLING AND VENTILATION SYSTEM

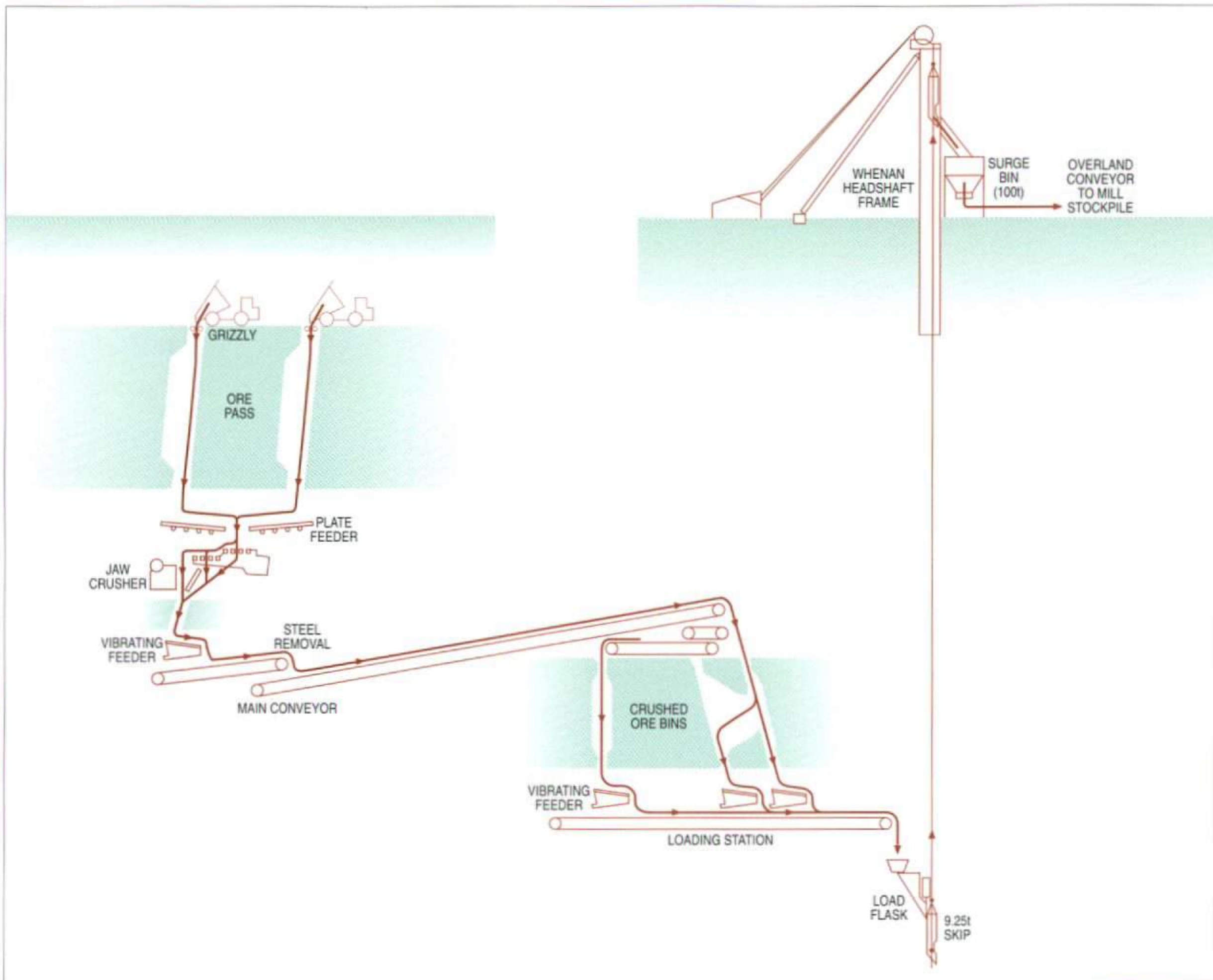

FIGURE 2.3
WHENAN SHAFT MATERIALS FLOWSHEET

Development drives are frequently developed to a length of up to 500 m before through flow is established. During this period, adequate ventilation (25 m^3/s) is achieved by use of 90 kW fans forcing air through ventilation tubing to the face of the development heading. There are twenty-one airways connecting the underground workings to the surface. Eighteen of these are ventilation shafts (or raises) from 2.4 m to 4.5 m in diameter, and the Whenan and Robinson shafts and the service decline make up the total. Depending on their location, air flows either into an intake raise (downcast) or out of an exhaust raise (upcast) through these openings. The total air ventilation rate through the mine as of 30 June 1996 was 1,500 m^3/s at 2,000 Pa negative pressure. Figure 2.2 shows the ventilation arrangement at the main crusher station and the Whenan Shaft.

Stoping areas are designed so that all accesses are located on the intake (i.e. fresh air) side, and the main intakes and exhaust are as close as practical to the stopes. The stopes are under negative pressure, with air being drawn in through the drawpoints (when open) and drill sublevels and exhausted through main vent returns on the top drill sublevel. The flow of air through the stopes is controlled by the use of regulators in the breakthroughs to the exhaust raises.

A comprehensive radiation exposure management programme has been implemented to assess radiation levels throughout the mine and to monitor personnel exposures. A computerised system is used to log individual employee work location, hours in location and other information, including use of airstream filter helmets. Detail on the monitoring programme is provided in Chapter 10.

2.1.7 Maintenance

All routine maintenance of heavy mobile equipment is carried out in an underground workshop equipped with overhead cranes. A drive-through service bay is equipped with a fast fuel system and pressurised oil and grease dispensing facilities. Major repairs and component rebuilds are carried out in the surface workshops or off site in Adelaide or other centres. Other equipment is maintained regularly, and repairs are carried out *in situ* or in the underground or surface workshops, as appropriate.

Non-destructive testing of winder ropes is conducted every three months, and a sample is taken every six months for testing to failure.

2.1.8 Mine services

Potable water is supplied to the mine through a pipeline in the Whenan Shaft and several boreholes located in the stoping areas. Pressure reducers are used to control pressure at the workings. Compressed air is likewise reticulated through the working areas. Air and water pipelines are extended as required. Recycled mine (saline) groundwater is used for drilling and dust suppression.

The total volume of water pumped from the mine is approximately 3.2 ML/d. This water arises from seepage from an aquifer intersected by the decline, Whenan Shaft and surrounding raise bores. Small electric or compressed air pumps are used to transfer mine water to local settling sumps located underground, and electric plunger pumps then lift the water to the surface to the main mine water dams.

Electrical energy is supplied to underground substations within the mine at 11 kV through cables in boreholes. This is transformed to 440 V or 1,000 V for reticulation throughout the workings to supply fans, pumps and jumbo drills. Armoured cable is used for all underground reticulation.

Nearly all supplies and consumables are delivered underground through the decline in conventional highway trucks. Mining personnel are transported underground in the Whenan Shaft service cage lift, which is also used for delivery of maintenance spares.

2.1.9 Mine planning

Orebody modelling is carried out using commercially available software that permits interactive design and editing. Stope outlines are drawn and edited on the screen and stope reserves, including loss and dilution factors, are calculated directly.

Blasthole rings and cable bolt patterns are designed using in-house software on personal computers. Data from the stope design system are imported directly and used as the basis for blasting and support design. The graphical output includes all the necessary information on borehole depth, inclination and blasting data. Scheduling of development and stoping is also computerised. Surveying is also highly automated, with extensive use being made of control stations and data loggers. Survey data are transferred electronically to the mine planning programmes.

2.2 MINERAL PROCESSING FACILITIES

The layout of the existing mineral processing facilities (referred to generally as the metallurgical plant) is shown in Figure 2.4. Figure 2.5 shows a simplified process flowsheet for the existing metallurgical plant.

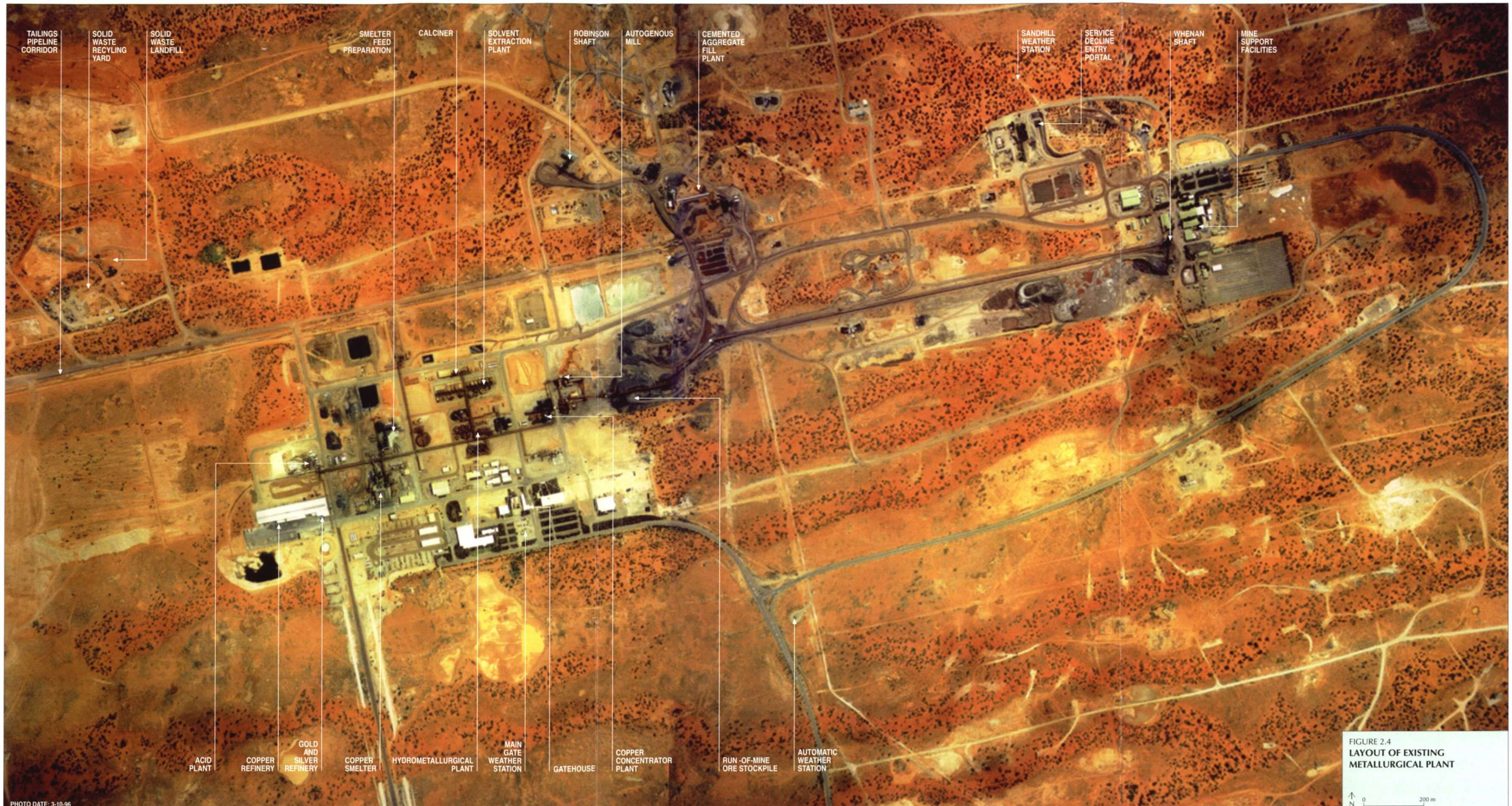

FIGURE 2.4
LAYOUT OF EXISTING METALLURGICAL PLANT

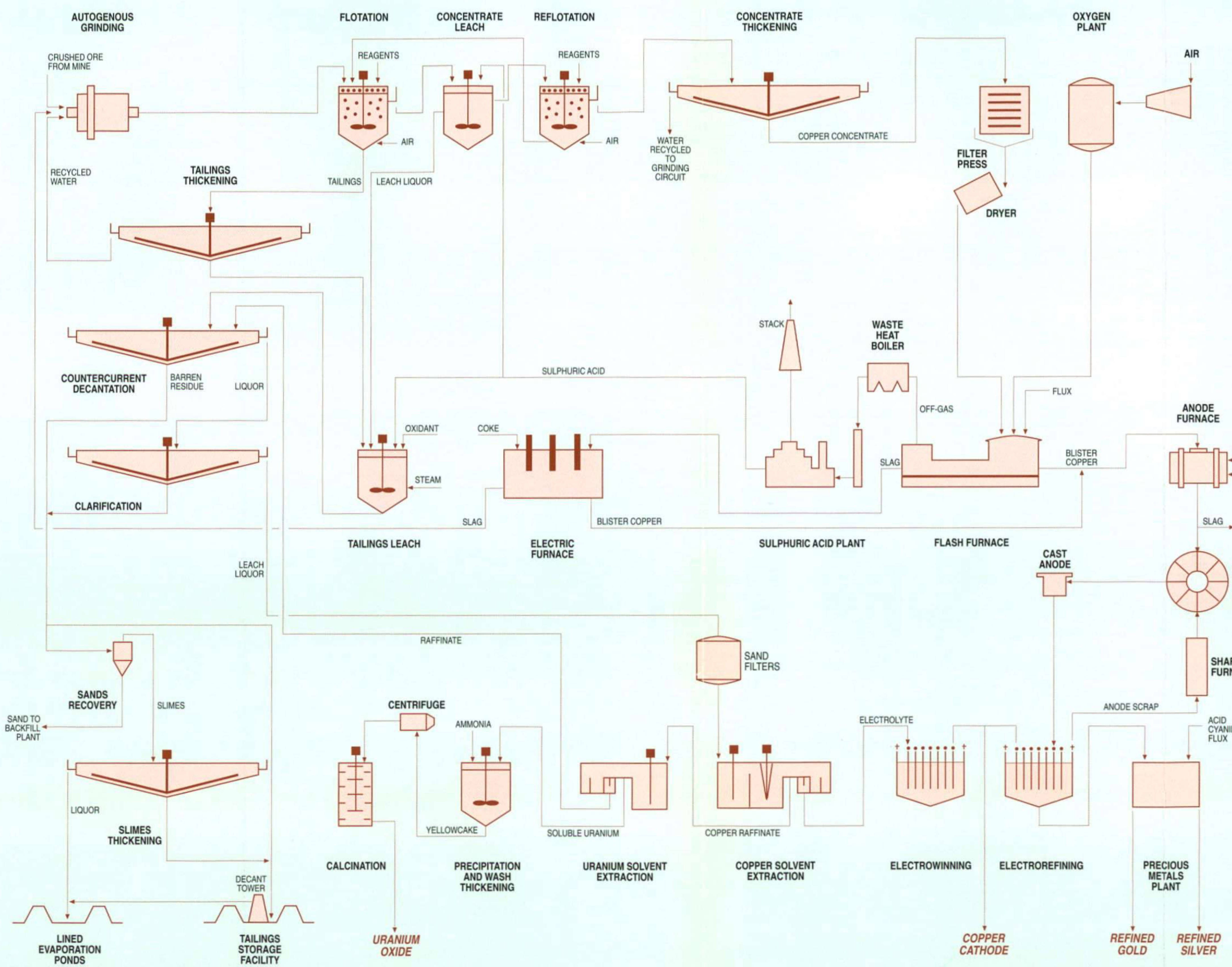

FIGURE 2.5
SIMPLIFIED PROCESS FLOW DIAGRAM - EXISTING PLANT

The mine ore is processed to produce 99.99% purity cathode copper, 98.5% purity uranium oxide, and refined gold and silver of 99.99% purity. The ratio of copper and uranium in the ore varies, and thus production levels vary within limits. The present cathode copper production is at the operation's current full capacity of 85,000 t/a. Uranium oxide production is currently 1,500 t/a, while gold production is 850 kg/a and silver production is 13,000 kg/a. However, the plant's available capacity is more than 1,800 t/a of uranium oxide.

In December 1996, 378 people were directly employed in mineral processing activities, and a further 136 contractors were also employed.

The metallurgical plant has been designed so that any spillages of ore, concentrate or process slurries can be readily returned to the process circuit. The metallurgical plant consists of a grinding mill, copper concentrator, hydrometallurgical plant, copper smelter and sulphuric acid plant, copper refinery and precious metal recovery facilities, all of which are described further in the following sections. Waste management and control of emissions are described in Section 2.4. Raw materials and product handling and transport are described in Section 3.6, together with the discussion for the Expanded Project.

2.2.1 Copper concentrator

Ore is reclaimed from the stockpile and ground in a comminution circuit which consists of a 34 foot (10.4 m) diameter autogenous grinding mill (Figure 2.6), and a pebble crusher operated so that 80% of the product, a finely ground slurry, would pass through a 75 μm screen.

The slurry is pumped to the flotation plant where it is mixed with reagents in a series of agitated and aerated tanks in which the copper sulphide particles attach themselves to bubbles and are floated to the surface (Figure 2.7).

This copper sulphide concentrate also contains the bulk of the gold and silver that is recovered from the ore. The non-sulphide particles, which do not float and are discharged from the bottom of the tanks as flotation tailings, contain most of the uranium bearing minerals.

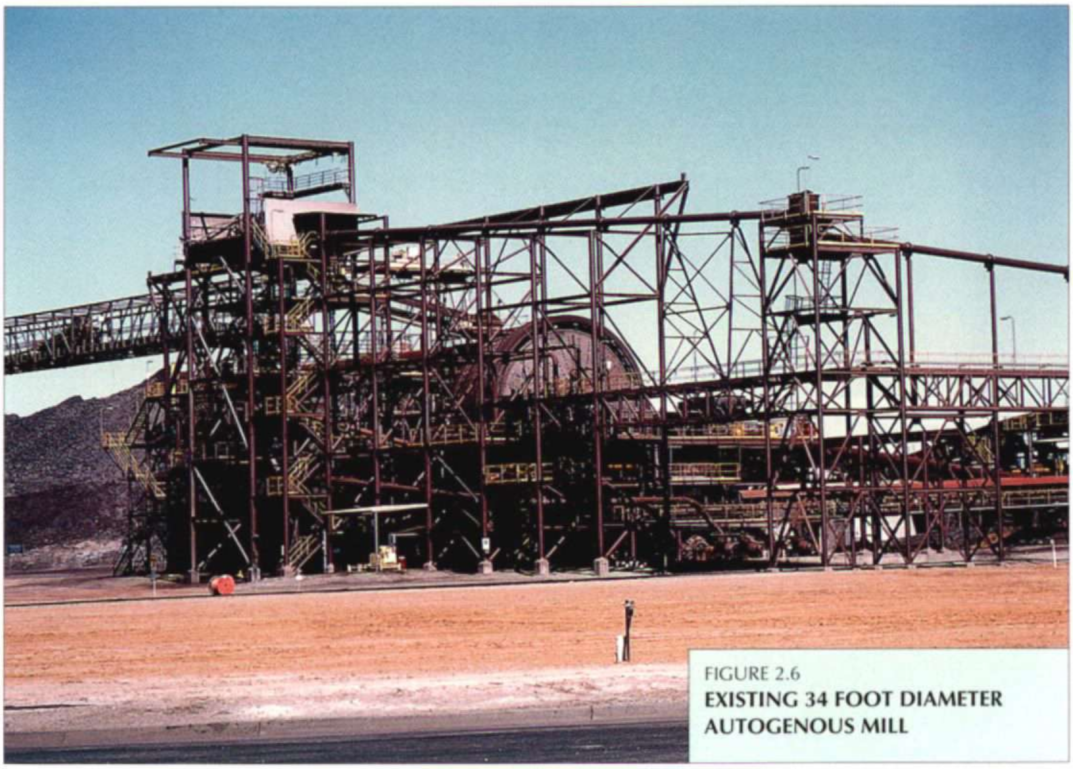

FIGURE 2.6
EXISTING 34 FOOT DIAMETER AUTOGENOUS MILL

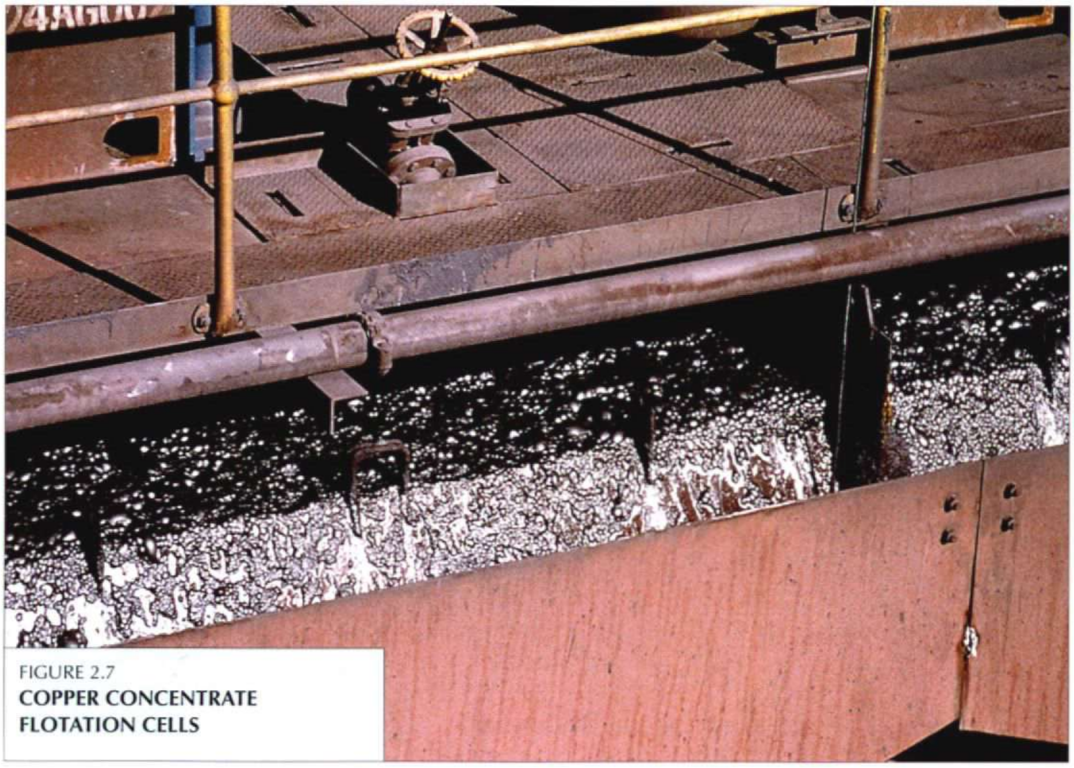

FIGURE 2.7
COPPER CONCENTRATE FLOTATION CELLS

2.2.2 Hydrometallurgical plant

The copper concentrate and flotation tailings are sent separately from the copper concentrator to the hydrometallurgical plant, which has two functions—to clean and upgrade the copper concentrate before it is sent to the smelter area, and to extract the uranium from the tailings and process it into saleable uranium oxide.

The copper concentrate is leached with sulphuric acid to dissolve as much as possible of any contained uranium. The leached concentrate is then refloated to produce the final copper concentrate. This flotation step rejects waste material liberated during the acid leach and produces a copper concentrate that contains about 55% copper. The copper concentrate is then thickened, filtered, dried and transferred to the copper smelter for further processing as described in Section 2.2.3. The uranium-rich liquor produced in the acid leach is mixed with the other uranium leach liquors, and further processed to recover uranium as described below.

The flotation tailings are leached separately in an acid liquor containing an oxidant. The slurry is heated to 60°C by injection with steam. This leaching process extracts uranium and residual copper from the flotation tailings. The leached residue is washed and the liquor separated in a continuous countercurrent decantation (CCD) circuit which has eight high-rate thickeners connected in a combined series/parallel arrangement.

Part of the final tailings residue from the CCD circuit is deslimed through clusters of hydrocyclones to separate the coarse sand, which is used for mine backfill. The slimes (fine) fraction of the tailings is thickened and then pumped, together with the remainder of the tailings residue, to the tailings storage facility (Section 2.4.1).

The leach liquor is clarified and pumped through three sand filters to remove fine suspended solids prior to pumping to the solvent extraction plants. The copper solvent extraction plant recovers the soluble copper from the clean leach liquor. The soluble copper is concentrated into an electrolyte which is pumped to the refinery for the production of electrowon copper, as described in Section 2.2.4.

After the copper has been recovered from the leach liquor, the copper raffinate is processed in the uranium solvent extraction plant. The soluble uranium is extracted and concentrated

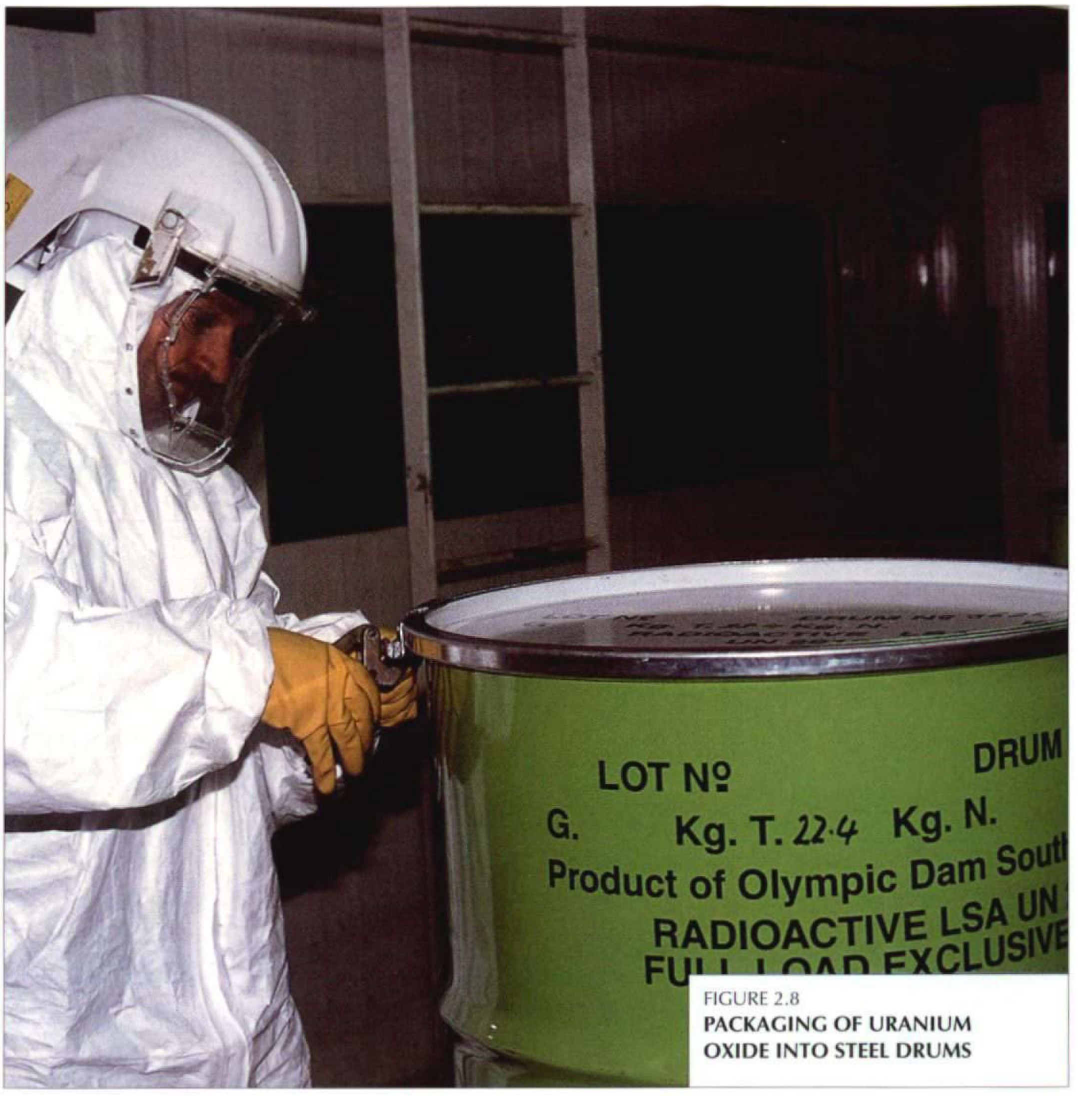

FIGURE 2.8
PACKAGING OF URANIUM OXIDE INTO STEEL DRUMS

into a purified solution of ammonium sulphate. This solution is treated with ammonia to precipitate ammonium diuranate, which is commonly referred to as yellowcake. The yellowcake is washed and centrifuged, and then calcined in an oil-fired furnace to produce uranium oxide. Raffinate passes back to the CCD circuit.

Uranium oxide is a granular material, and is dark green in colour, although colloquially (and incorrectly) it is sometimes referred to as yellowcake. Uranium oxide (as U_3O_8) is the final product and is packed into 205 L drums (Figure 2.8) and transported in standard 2 m x 2 m x 6 m containers for shipment overseas.

2.2.3 Copper smelter

In the copper smelter (Figure 2.9), copper concentrates are smelted to produce copper anodes using direct-to-blister copper smelting technology licensed to the Finnish company Outokumpu Oy.

The copper concentrate from the hydrometallurgical plant is dried at the feed preparation area, then mixed with silica flux (sand) and recycled dust from the waste heat boiler and dust collectors. This mixture is fed into the reaction shaft of the flash smelter, together with 80–90% oxygen-enriched air. The fine concentrate reacts or flashes instantaneously in an exothermic (heat releasing) reaction, at 1,250°C. Copper and slag droplets fall to the hearth of the furnace where two separate layers form: blister copper and slag containing iron, silica and approximately 20% copper as oxide.

FIGURE 2.9
EXISTING COPPER SMELTER

The slag and blister copper are removed periodically by tapping the furnace (Figure 2.10).

The molten slag is tapped into an electric furnace for recovery of the oxidised copper. Three submerged carbon electrodes supply heat to the furnace. The slag reacts with a layer of coke to produce both blister copper and a slag containing 3–5% copper, which is recycled to the grinding circuit (Section 2.2.1).

The molten blister copper from the flash furnace and electric furnace is tapped into one of two anode furnaces for further purification by fire refining. This comprises an oxidation phase (by injection of oxygen) to remove sulphur, followed by a reduction phase (by

FIGURE 2.10
TAPPING COPPER

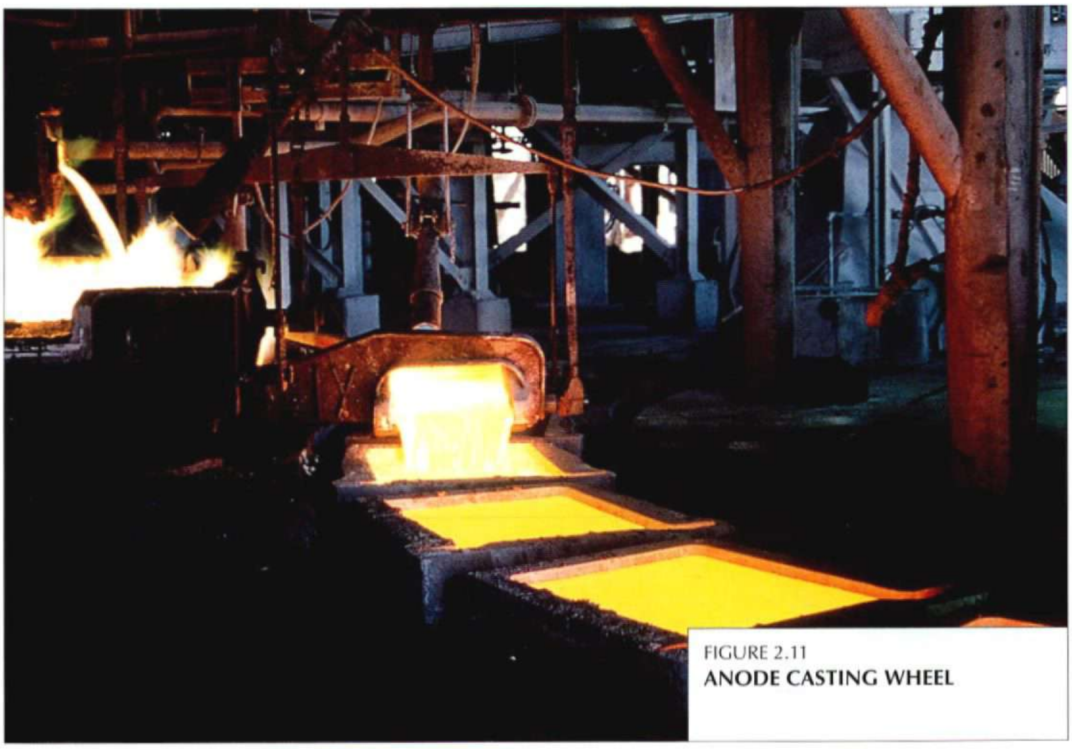

FIGURE 2.11
ANODE CASTING WHEEL

injection of LPG) to remove excess oxygen. After removal of the sulphur and oxygen, the copper, now at about 99.6% purity, is cast into copper anodes on a revolving casting wheel (Figure 2.11). Anodes are also cast from the shaft furnace, a furnace that melts clean refinery scrap and other scrap copper. The impurities in anode copper include the gold and silver contained in the feed concentrate.

Oxygen plants (Figure 2.12) produce oxygen for the flash smelting reaction. A waste heat boiler recovers heat generated from the flash smelting reactions. Steam produced from the boilers is utilised in the hydrometallurgical plant and the refinery.

FIGURE 2.12
EXISTING OXYGEN PLANT

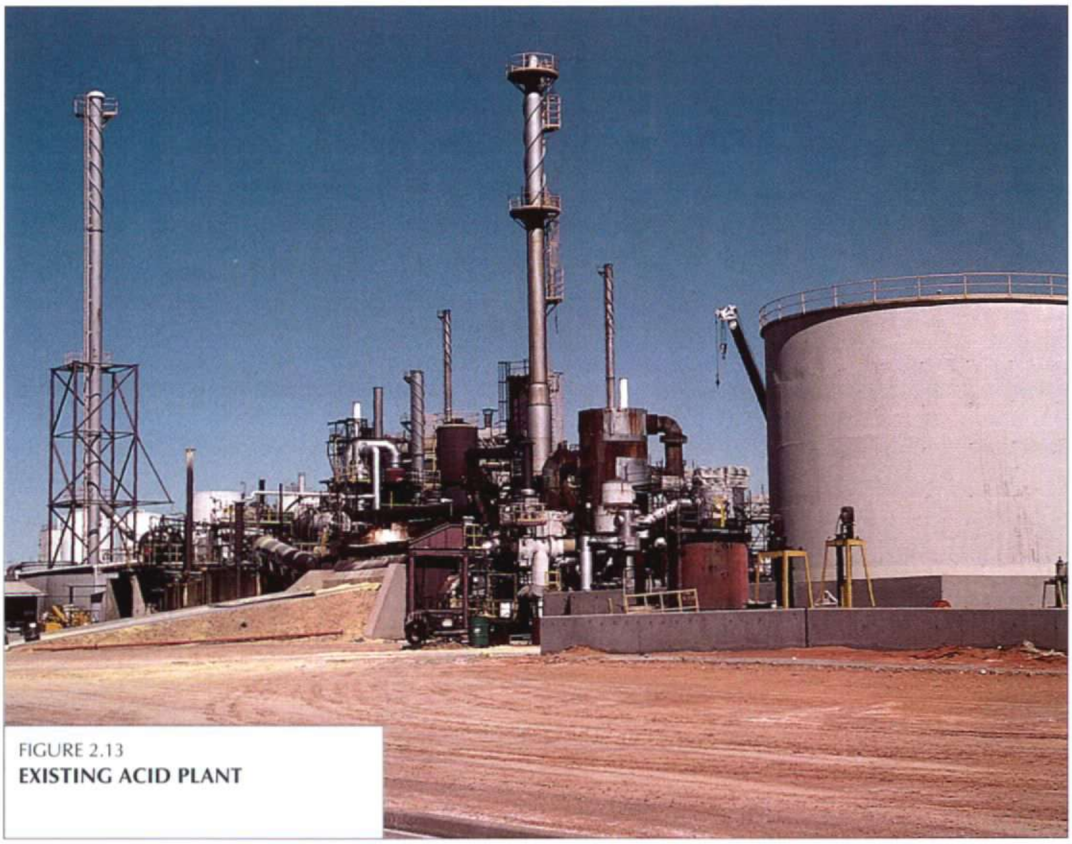

FIGURE 2.13
EXISTING ACID PLANT

In the flash smelting reaction, the sulphur fraction of the copper sulphide is oxidised to produce sulphur dioxide (SO_2) gas, which passes to a 400 t/d acid plant (Figure 2.13) where it is converted to sulphuric acid. The smelter off-gas supplies about 70% of the sulphuric acid required by the operations. The remainder of the acid requirements are met by burning molten sulphur in the sulphuric acid plant and converting it to sulphuric acid, and by purchasing acid.

2.2.4 Copper refinery

Copper anodes produced by the copper smelter are transported to the electrorefinery where they are loaded into plastic-lined and acid-resistant concrete cells (Figure 2.14). Next to each anode is a stainless steel mother plate or cathode. After the cells have been filled with a dilute sulphuric acid – copper sulphate electrolyte, a direct electrical current (27,000 amps)

FIGURE 2.14
ELECTROREFINERY

is passed through each cell, travelling from the anode through the electrolyte to the cathode. The copper dissolves at the anode and is redeposited on the cathode, while impurities either dissolve in the electrolyte or fall to the bottom of the cell. In this way, the anode copper is refined to high purity (99.99%) cathode copper.

After each seven-day cycle, the cathode mother plates are removed from the cells, the copper stripped off as copper cathode sheets and the mother plates returned to the cells. The copper sheets are then sampled and bundled for shipment and sale (Figure 2.15). After three seven-day cycles, the remnant copper anodes (16% of original weight) are removed from the cells, washed and returned to the smelter for melting. The shaft furnace or the anode furnaces are used to melt this scrap and recast it into anodes.

Most of the copper is produced by the electrorefining process. However, about 10% is recovered by electrowinning from the solution generated in the copper solvent extraction area of the hydrometallurgical plant (Section 2.2.2). In the electrowinning cells, lead anodes are used and the copper deposited on the mother cathodes is recovered from the electrolyte.

Control of the electrolyte impurities in the electrorefining tankhouse is achieved by returning a proportion of the electrolyte bleed to the copper concentrate leach circuit in the hydrometallurgical plant.

Acid mist is generated mainly in the electrowinning section of the tankhouse; emissions in the electrorefining section are quite minor and require no treatment other than by natural ventilation. The generation of electrowinning acid mist is controlled by a combination of physical suppression by the use of floating plastic beads on the surface of the electrolyte in the cells and a controlled dosage of a chemical surfactant (foaming agent).

The tankhouse walls and roofs are provided with ventilators to promote air flow, and personal monitoring and static samples are used to confirm that levels of acid mist within the tankhouse meet occupational health standards. Owing to its proximity to both the acid plant and the smelter, the refinery is fitted with sulphur dioxide alarms to alert personnel in the event of a sulphur dioxide leak emergency.

FIGURE 2.15
BUNDLED COPPER CATHODES

2.2.5 Gold and silver refinery

During the electrorefining process, anode slimes are generated by impurities in the anode falling to the bottom of the cells. The anode slimes contain most of the gold and silver present from the original feed ore. This gold and silver is recovered in the gold and silver refinery. A simplified flowsheet for the refining of gold and silver is shown in Figure 2.16.

The initial treatment involves copper removal, after which anode slimes are neutralised and treated with sodium cyanide to solubilise gold and silver. The slimes residue is then filtered off and passed to the tailings storage facility for impoundment.

A zinc precipitation step recovers gold and silver in solution as a solid precipitate. The barren cyanide solution arising in the zinc precipitation filter is neutralised with ferrous sulphate prior to disposal in the tailings retention system. The addition of ferrous sulphate prevents the formation of hydrogen cyanide when the barren cyanide solution is combined with the acidic tailings. The zinc precipitate is acidified with sulphuric acid and oxidants, namely hydrogen peroxide and sodium nitrate, to solubilise the zinc and remaining impurities. The off-gases that are evolved in this process are ducted to a caustic soda scrubber system to minimise nitrogen oxide emissions.

The gold–silver precipitate is filtered and smelted in a rotary furnace to produce combined gold–silver (doré) anodes. Furnace gases are scrubbed to maintain particulate emission levels below statutory limits. Effluent discharge from the scrubber is also directed to the tailings retention system.

The doré metal is cast into anodes which are placed into silver refining cells to recover silver by electrolysis as cathode. Emissions that arise during the preparation of silver electrolyte are ducted to the scrubbing system used for the zinc precipitate acidification gases. The silver cathode is smelted and cast as silver bullion.

Gold recovered from the silver refining cells as a gold mud is filtered and washed with acid prior to being cast into gold anode. The gold anodes are placed into gold refining cells which recover pure gold by electrolysis as cathode. The gold cathode is smelted and cast as gold bullion.

2.3 INFRASTRUCTURE

2.3.1 Energy

Electrical power is supplied to Olympic Dam by a 132 kV transmission line from Pimba, off the 132 kV transmission line from the Port Augusta power station to Woomera. The transmission line to Woomera was originally constructed in the early 1950s and then extended to supply the requirements of Olympic Dam for the initial project in 1986. As part of the original project infrastructure, two major 132 kV switchyards were constructed: one near Pimba, several kilometres from Woomera, where the transmission line extension originates, and the other at Olympic Dam, where it terminates. Two 132/11 kV 27/33 MVA main power transformers at the Olympic Dam 132 kV switchyard reduce the voltage to 11 kV for general plant distribution.

The electrical power demand at Olympic Dam is presently of the order of 40 MW average load (44 MW peak load). At this loading, the capacity of the 132 kV transmission line supply to Olympic Dam and Woomera is approaching its limit. A new 275 kV transmission line is presently under construction, and is expected to be completed in January 1998. Further information on the new 275 kV transmission line is provided in Sections 3.9 and 11.2.

On-site power generation is generally reserved for emergency purposes and consists of 2 x 2,400 kW diesel alternator sets at the metallurgical plant and 3 x 800 kW diesel alternator

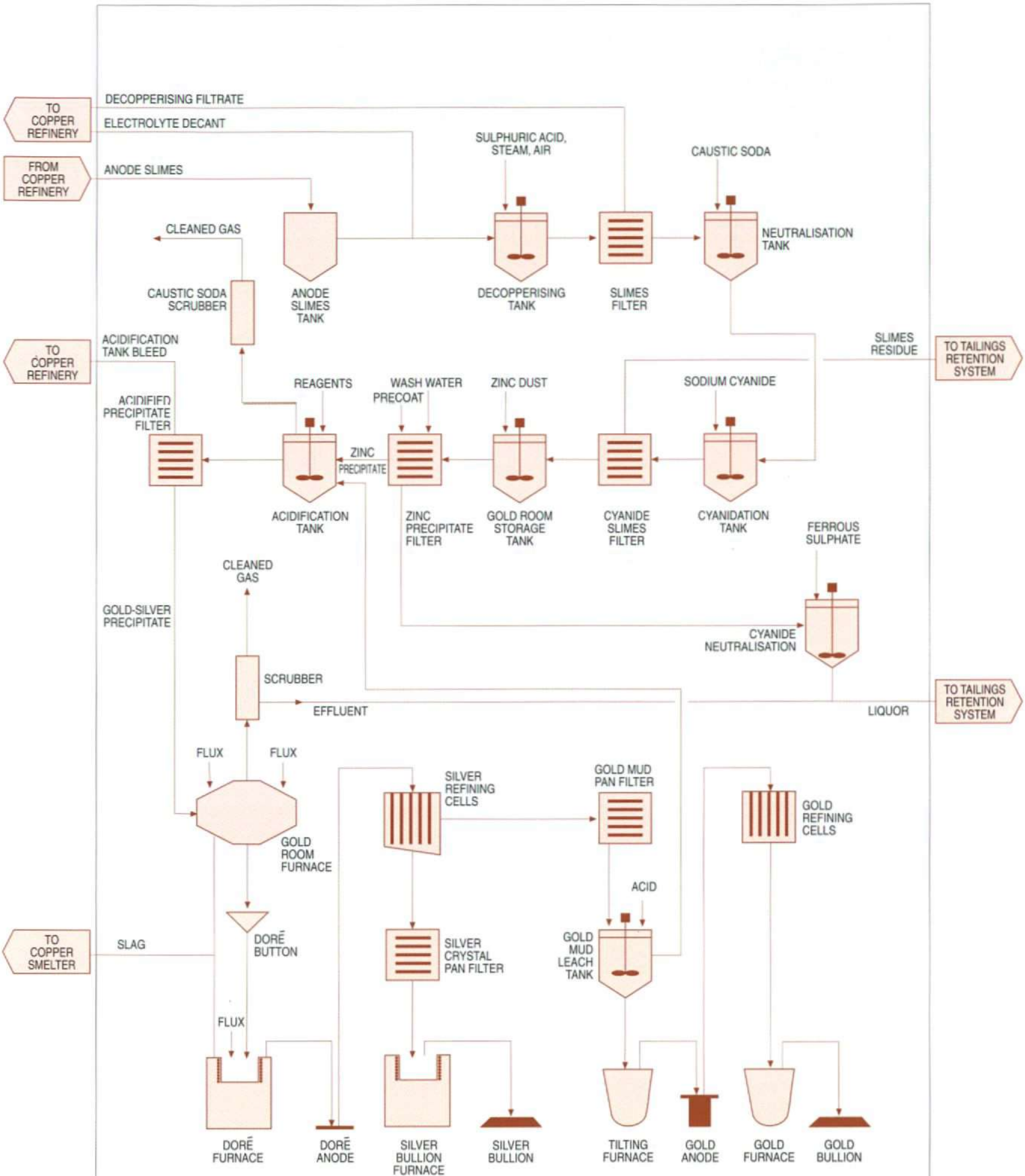

FIGURE 2.16
GOLD AND SILVER REFINING SIMPLIFIED FLOW DIAGRAM - EXISTING

sets at Whenan Shaft. The 2,400 kW diesel alternator sets at the metallurgical plant are also occasionally run while starting large 11 kV drives such as mill motors.

Forms of energy other than electrical power are also consumed at the current operations. These include the energy released from the copper concentrates when they are oxidised in the flash smelter and from the burning of elemental sulphur in the acid plant. Other forms of energy include diesel and petrol for vehicles; LPG in the anode furnaces; diesel in the flash smelting furnace, anode furnaces, auxiliary boilers, yellowcake calciner and mine site vehicles; and coke in the electric furnace. Table 2.1 summarises the current site energy consumption.

WMC has sent a letter of intent to the Commonwealth Government to sign on to the Greenhouse Challenge programme. This applies to all WMC facilities, including the Olympic Dam operations. The next available time for signing on is October 1997. To this end, data collection has commenced to establish WMC's baseline emissions, and a team has been assembled at Olympic Dam to propose, evaluate and implement energy reduction projects.

Table 2.1 Current site energy use

Energy type	Annual consumption[1] (GJ)
Electrical power	1,165,931
Diesel/fuel oil	753,394
Petrol	7,398
LPG	405,034
Coke	58,077
Copper concentrate oxidation	330,000
Sulphur	55,387

1 *Based upon actual use for 1995–96.*

An energy savings review of Olympic Dam was conducted in April–May 1995 by independent energy consultants. A number of the recommendations from this review are currently being progressed, with significant savings in electrical energy predicted. The consultants are presently conducting a further review of the Olympic Dam operation, including the Expansion Project, results of which are pending.

The current Expansion Project will include a life cycle assessment for all major equipment items. This assessment will examine equipment usage over a twenty-year operational time frame, and will focus on minimising the use of water and energy in the expanded plant. The life cycle assessment work will have a key influence on WMC's participation in the Greenhouse Challenge programme.

2.3.2 Water supply

Water supply to the operations is from two borefields (A and B) which are located some 100 km and 200 km respectively north-east of Olympic Dam. These borefields and associated pipelines and pump stations are described in Section 4.1.

The water usage at Olympic Dam and Roxby Downs is presently about 15.0 ML/d, comprising 10.5 ML/d for process use and 4.5 ML/d of treated water of potable quality. Some 1.6 ML/d of the potable quality water was used in Roxby Downs township.

With the implementation of better practices, water usage has reduced from 2.10 kL/t of ore processed in 1989–90 (the first full year of production) to 1.57 kL/t of ore processed in 1995–96. These figures include both process and potable water used at the mine and metallurgical plant. Investigations are continuing in order to identify further opportunities for water conservation. Ultimately the limiting factor in terms of process water recycling is the build-up of chloride, which affects metal recoveries in the hydrometallurgical plant.

In regard to potable water use, a committee has been formed to promote water conservation by the workforce and the local community, through such measures as encouraging arid zone native gardens. Treated sewage effluent is also used for watering community sports grounds and the golf course.

2.3.3 Access and telecommunications

Access to the Olympic Dam operations is via a sealed bitumen road of a minimum sealed width of 7 m. The operations are located some 14 km north of Roxby Downs. The access road to Roxby Downs and the operations links with the Stuart Highway some 85 km south of Roxby Downs (Figure 1.1). The road to Andamooka is also sealed.

The Olympic Dam mine is also serviced by an airport capable of handling turboprop and small jet aircraft. Kendall Airways operates a regular passenger service to this airport from Adelaide.

Telstra has recently installed a digital mobile phone network to serve Roxby Downs, Olympic Dam and nearby areas. The Olympic Dam operations have direct electronic and telecommunications links to WMC offices in Adelaide and elsewhere.

2.4 WASTE MANAGEMENT

2.4.1 Solid and liquid wastes

The mining and processing operations produce a series of waste streams which are managed in separate dedicated facilities as described below.

Tailings retention system

The primary waste stream from the operation is the tailings from the metallurgical processing of ore. Tailings are essentially the finely ground residue of the ore remaining after as much as possible of the copper, uranium, gold and silver components have been recovered. The tailings contain residual quantities of uranium-238 (^{238}U) and the principal radioactive isotopes in its decay chain (Figure 2.17). The overall radioactivity in the tailings is approximately 80% of the radioactivity of the original ore. The extraction of uranium by leaching renders tailings slurry acidic, with a pH of 1–2.

The tailings, which contain approximately equal proportions of solids and water by weight, are dewatered and retained in the tailings retention system. The principal components of the tailings retention system are the tailings storage facility, where tailings are stored, and the tailings liquor evaporation ponds. These are described separately below, and in more detail in Chapter 8.

The current tailings retention system has recently been upgraded following the detection of seepage from this facility. The seepage was publicly announced by WMC in February 1994, and a full description of the seepage event and the implementation of the upgraded facilities, including an improved groundwater monitoring programme, has been publicly documented (WMC—Olympic Dam Corporation 1995). Further discussion is provided in Chapter 8.

The seepage event was the subject of an inquiry by the Environment, Resources and Development Committee of the Parliament of South Australia (South Australia, Parliament 1996). The committee found that the changes 'have been undertaken with commendable zeal and that they appear to represent an appropriate response to the leakage which will minimise the likelihood of future problems provided the new system is properly constructed, monitored and managed'. It also reported that 'on the basis of current evidence, there have been no harmful effects to employees, the local community or the environment arising out of the leakage from the tailings retention system at Olympic Dam and that it is highly unlikely that any such harmful effects will emerge in the future'.

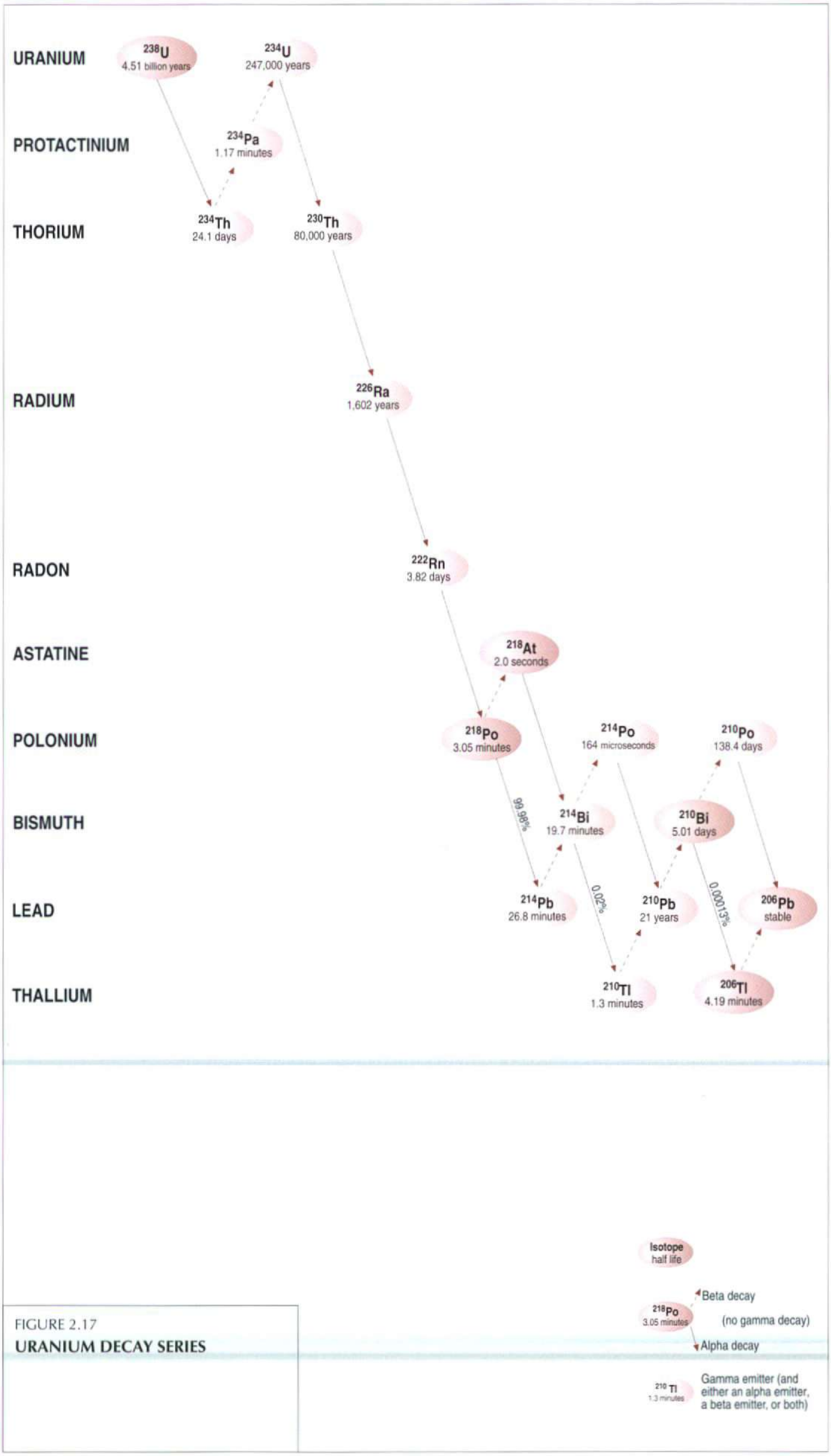

FIGURE 2.17
URANIUM DECAY SERIES

Tailings storage facility

Part of the tailings stream is hydrocycloned in a sands recovery plant to separate the coarse (or sand) fraction for use in mine backfill, while the fine fraction (or slimes) is thickened in the slimes thickener circuit (as shown in Figure 2.5). Not all the coarse material in the tailings is able to be utilised for mine backfill, and thus only that proportion of the tailings necessary is hydrocycloned. The underflow of the slimes thickener is combined with the remaining portion of the tailings that have not been hydrocycloned, and then pumped to the tailings storage facility. The slimes thickener overflow is pumped to the evaporation ponds.

There are three tailings storage cells of total area 190 ha (as shown in Figure 1.2). The tailings, which currently leave the metallurgical plant slimes thickener at a rate of approximately 2.7 Mt/a (of solids), are deposited using the subaerial deposition method. This involves placing the tailings in thin layers (approximately 100 mm thick) and allowing each layer to dry before the next layer is added. This method is ideally suited to the climate at Olympic Dam, where evaporation rates are approximately 14–18 times rainfall. To ensure an even deposition, the tailings are released progressively around the perimeter of each cell through a series of outlets from a main distribution pipe. Deposition of tailings at any time takes place over a length of approximately 200 m.

The solids settle out of the slurry to form beaches, with liquor flowing to the low point in each cell. Cracks that form as each layer dries and consolidates are filled with new tailings in the next deposition release.

The cycle of progressive deposition around all cells in sequence takes several weeks. Excess liquor that has not evaporated flows to the low points in the tailings cells, forming supernatant liquor ponds. This liquor is removed from the pond by decant systems and flows via a pipeline to the evaporation ponds.

Tailings liquor evaporation ponds

The tailings liquor evaporation ponds accept liquor from the decant systems of the tailings storage facility, slimes thickener overflow, and wash water resulting from the washing of acid from the mine backfill material. Following concentration by natural evaporation, the residual liquor is pumped back to the tailings mixing tank and combined with fresh tailings. The tailings from this tank are then pumped to the tailings storage facility.

The evaporation ponds have been constructed with a composite liner with an expected overall permeability of not more than 10^{-9}m/s, which comprises:

- a synthetic liner composed of a nominally 1.5 mm thickness, high-density polyethylene (HDPE) membrane;
- a compacted clay liner of a minimum of 300 mm in thickness, characterised by a low permeability of 5×10^{-7} m/s, immediately underneath the synthetic liner.

The evaporation ponds have recently been fitted with a bird control system developed on site. The system, used at night, comprises a rotating light that operates intermittently, mounted on a small pontoon. The system takes advantage of water birds' aversion to a moving intermittent beam of light shining on them, to deter them from frequenting the ponds. The system has been successful in diverting birds to other ponds in the area where they can come to no harm.

Mine water disposal pond

Naturally saline groundwater (total dissolved solids of about 20,000–40,000 mg/L) enters the underground mine workings principally by infiltration through the raise bores and mine workings (e.g. shafts, tunnels). This water is used in mining operations and other sections of the operation, including the mine backfill plant, drilling, and for dust suppression. During times of construction almost all of the mine water is consumed.

Any remaining mine water that cannot be used in the operation is discharged to the mine water disposal pond. This mine water, apart from its high salinity, has very low levels of contaminants, and is of similar quality to the natural groundwater. This is discussed further in Section 4.6.

The existing mine water disposal pond is located to the east of the tailings storage facility (as shown in Figure 1.2), is 15 ha in area and currently receives approximately 3.2 ML/d of mine water.

It should be noted that the mine water disposal pond is a natural unlined claypan, and therefore much of the mine water is lost by seepage. This seepage is considered to have a low potential for environmental impact, as the minewater is of similar quality to natural groundwater in the area. The seepage lies within a cone of depression in the natural groundwater level caused by dewatering of the underground mine (described in Section 4.6), and is thus self-impounding.

Solids landfill

All wastes produced on site are disposed of in an on-site landfill area, after reclaimable material has been recovered. Waste generated on site is defined as radioactively contaminated and cannot be removed from the site without specific approval from the statutory Radiation Safety Officer on site.

Wastes include tyres, paper, packaging, drums, approved chemicals and substances, concrete, and domestic type wastes (e.g. food scraps). An active programme has been established to minimise the waste going to landfill and to recover, reuse or recycle, where possible. Scrap material that has been recovered is cleaned and undergoes a formal clearance procedure prior to being removed from the site.

Sewage treatment

Sewage from the mine and processing plant area is treated in an on-site treatment system, which comprises primary treatment and an evaporation pond. At present some of the effluent is being reused for revegetation purposes; however, as part of the focus on water conservation, its potential total use is being re-examined.

The civil administration of Roxby Downs is responsible for management of effluent from the town sewerage system. This system provides primary treatment and lagooning, and the recovered effluent is used for irrigating the community golf course and other grassed recreational areas.

Stormwater run-off

Stormwater collected in the bunded parts of the metallurgical plant is presently recovered when practicable by pumping it into the process water system. Stormwater run-off from other impervious areas within the plant is currently directed to unlined sumps and allowed to infiltrate and evaporate. Collection and use of stormwater is undertaken following major rain events, although this has been infrequent owing to the low level of rainfall in the region.

2.4.2 Airborne emissions

Airborne emissions from the operation include salt, fugitive dust, and process particulate and gaseous emissions from a variety of sources including unsealed roads, stockpiles, materials movement, mine ventilation, process stacks, and tailings storage. All control equipment is designed to meet State emissions standards and national emissions guidelines. Control equipment is also subject to works approval by the South Australian Environment Protection Authority (EPA) under the *Environment Protection Act 1993*, and the operations hold a prescribed activity licence issued under that Act. The EPA licence, which is a public document, outlines conditions of operation, emission limits and exemptions.

Salt spray

Salt spray emissions originate from the local aquifer and are brought to the surface entrained in the mine ventilation raise bore airstreams. Salt spray emissions have been shown in the past to impact adversely on the local vegetation if the emission volumes are significant (WMC—Olympic Dam Operations 1994, WMC—Olympic Dam Operations 1995). Over recent years the salt release into the environment has been controlled by redirecting the ventilation airstream flows into collection pits, which collect a large proportion of the total salt emission (Figure 2.18). This has been demonstrated to prevent vegetation damage, and to allow previously damaged areas to recover.

Fugitive dust

Fugitive dust emissions originate from unsealed roads, mine ventilation, stockpiles, materials movement, process stacks, and tailings storage. Several management strategies have been employed to reduce dust emissions and, hence, dust impact. These strategies include wetting of materials, collecting dust by improved environmental engineering, and improved process control.

The controls stated in the 1983 EIS assumed that the ore might be dusty. In practice, owing to the dampness of the ore, dustiness is not generally a problem. The main overland conveyor from the mine and the stockpile reclaim conveyors are all covered. Water sprays are used when necessary for tipping of ore or mullock onto the main stockpiles. However, this is unnecessary most of the time because the material is damp.

Dust emissions from the sulphur stockpile are controlled by using side tipping trucks for restocking. This results in minimal dusting at this point.

Process emissions

Process emissions originate from the processing of ores and other materials within the metallurgical plant. The process emissions that are monitored are particulates (including heavy metals); the acid gases—sulphur dioxide (SO_2), sulphur trioxide (SO_3) and sulphuric

FIGURE 2.18
RAISE BORE FAN AND SALT SPRAY EMISSION CONTROL

acid mist; nitrogen oxides; lead-210 (^{210}Pb); and polonium-210 (^{210}Po). The principal acid gas stack sources include the acid plant and the two anode furnace stacks. Other potential sources of acid gases, and also particulates, include fugitive emissions from the smelter roof ventilation, blister tapping, slag tapping and the electric furnace as well as the use of emergency vent stacks when operational difficulties are encountered.

The original electric furnace design included a fabric filter. However, this unit has proven to be unsuitable owing to the occasional high temperatures experienced in the off-gas. A scrubber system is being installed as an alternative control measure. The University of Adelaide has also completed research work on a preconditioning chamber, and this chamber is to be included in the new design. The new equipment is expected to be operational by mid-1997.

Dust from the uranium oxide bin and packaging area is collected by a high-efficiency venturi scrubber. This avoids the need for dry handling of collected material. Scrubber effluent is returned to the solvent extraction plant.

The off-gases that are generated in the gold refinery processes (Section 2.2.5) are ducted to a caustic soda scrubber to minimise nitrogen oxide emissions.

The gases produced in the flash furnace, which contain SO_2 and SO_3, are controlled by passing the gases to a sulphuric acid plant. The gases first pass through a waste heat boiler and electrostatic precipitator, and are then ducted to the humidifier and mist precipitators at the acid plant where the gas is cleansed of dust. The SO_2 then undergoes conversion to SO_3 as it passes through a catalyst bed. Following conversion, the gases pass through a series of absorption towers to remove the SO_3 component, prior to release to the atmosphere via the acid plant stack.

The conversion performance of the acid plant is closely monitored. The acid plant typically requires relatively frequent cleaning of the catalyst to ensure that the standards are met. Air emissions from the plant are designed to meet the EPA standards of 100 mg/m^3 SO_3 and total acid gases from sulphuric acid plants of 3.0 g/m^3 (as SO_3 equivalent) during normal operations. The EPA licence includes an exemption to these standards for up to five hours during start-up. Measured acid gas emissions indicate levels of up to about 1.4 g/m^3 during normal operation. In January 1994 and August 1995, algorithms were added to the plant process control system to provide operators with a direct indication of acid plant emissions.

The anode furnaces undergo a cyclical operation (Section 2.2.3). The oxidation and reduction phases are characterised by elevated emissions of particulate matter and heavy metals. Emissions of particulates, heavy metals and also ^{210}Po (which can build up by the recycling of collected dust) are controlled by ventilation to a fabric filter. The EPA licence provides for exemptions from emission standards during abnormal plant conditions for up to 20 minutes during reduction and 30 minutes during oxidation.

The smelter design and installation includes local ventilation to collect emissions emitted during tapping of molten metal and slag. The effectiveness of the ventilation system is monitored through occupational airborne contaminant monitoring. A programme is in place to upgrade the ventilation system in order to improve occupational hygiene conditions, and to reduce temperatures in the workplace.

The plant monitoring programme includes regular stack measurement of particulate and SO_2 levels, two meteorological stations, four sites at which total suspended particulates are monitored, and an SO_2 monitoring station.

On 1 February 1996 WMC submitted an Environment Improvement Programme, as required in the State EPA licence, which presented a programme for improvement of air emissions control for the three areas for which exemptions are currently held. As described above, this programme is well under way for the electric furnace, acid plant and anode furnaces.

Noise

Noise emissions emanate from various sources throughout the site, with the major noise sources being associated with the ore handling and crushing facilities (autogenous mill and ball mills), the anode furnaces and the flash furnace.

Results of noise surveys throughout the operations have been used to limit noise exposure levels for employees to less than statutory limits. This is achieved by restricting access to those areas of the plant where hearing protection is required. These areas are also provided with signage indicating that hearing protection must be worn in these areas. Hearing protection is made available to all employees and visitors to the operations.

Noise exposure monitoring of employees is a component of the overall occupational health monitoring programme undertaken at the operations.

Noise emissions at the site are not sufficient for these to be audible above background levels at the nearest residences (Olympic Dam Village), which are located some 5 km from the plant site.

2.5 ENVIRONMENTAL MANAGEMENT SYSTEMS

2.5.1 Staffing and responsibilities

WMC maintains a Radiation, Environment, Safety and Quality Department to administer the environmental management and monitoring programme formulated for the operations (Figure 2.19). This department currently has forty-six staff, comprising the department manager and secretary, seventeen in the environmental group, thirteen in radiation, eleven in occupational health and safety, and three in quality management.

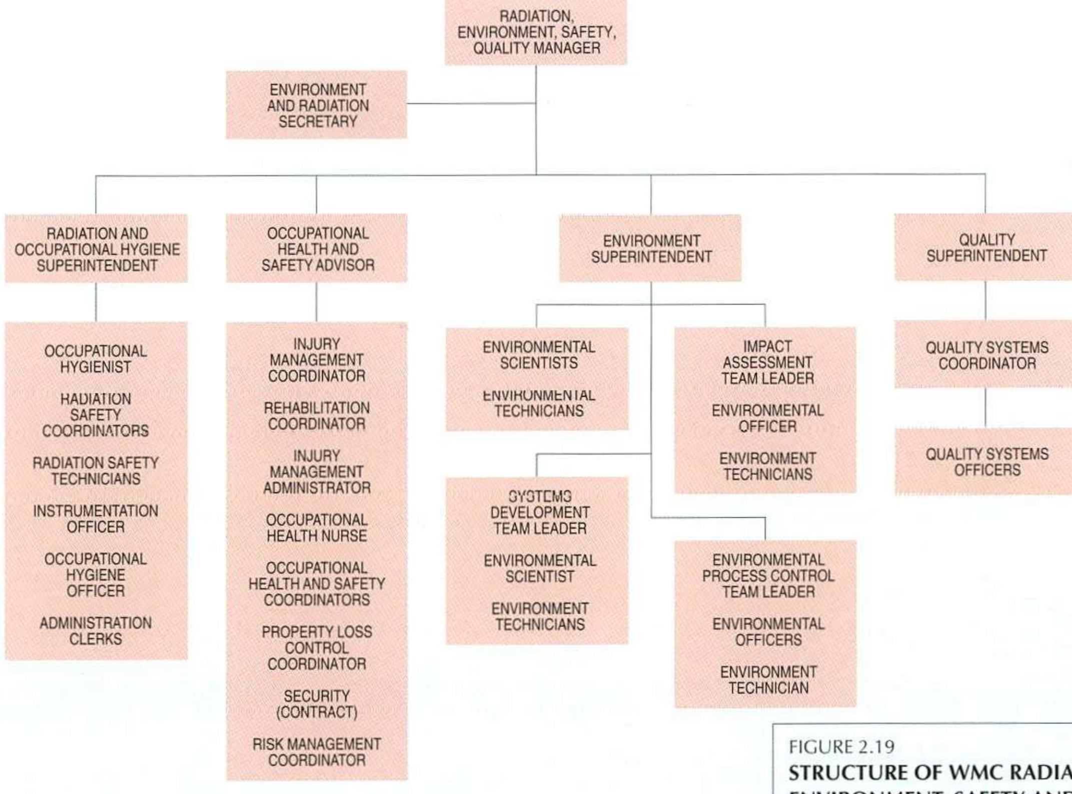

FIGURE 2.19
STRUCTURE OF WMC RADIATION, ENVIRONMENT, SAFETY AND QUALITY DEPARTMENT

One of the primary roles of the department is to ensure that the requirements of the WMC Environment Policy and the legally required environmental management obligations are fulfilled for the whole operation.

This is achieved by:

- setting high standards of environmental protection and management;
- satisfying the requirements of the Indenture;
- complying with the Commonwealth codes of practice on radiation protection in the mining and milling of radioactive ores and the management of radioactive wastes;
- managing, monitoring and protecting the environment, and reporting to the State quarterly and annually as required under Clause 11 of the Indenture and the special water licences.

The two major areas monitored are the natural environment and environmental radiation. Monitoring of the natural environment involves assessment of meteorology, vegetation, mine site rehabilitation, fauna, terrain analysis, soil salinity, hydrogeology and the borefields.

Environmental radiation monitoring is undertaken in all areas. Vegetation, soil, dust, farm animals and atmospheric and water samples are monitored for radionuclides. A laboratory capable of low-level radioactivity determinations is maintained to carry out analyses. The laboratory is located away from the mine and metallurgical plant, near the Olympic Dam Village.

2.5.2 Previous management programmes

Up to the end of February 1996, environmental management had been guided by the implementation of two plans, the Environmental Management Programme (EMP), and the Waste Management Programme.

Clause 11 of the Indenture requires that every three years a programme for the protection, management and rehabilitation (if appropriate) of the environment, including arrangements for monitoring and studying sample areas in order to ascertain the effectiveness of such a programme, shall be submitted to the Minister for Mines and Energy. Until early 1996, WMC was operating under its third three-year EMP, which covered the period from 1 March 1993 to 29 February 1996. The annual EMP reports submitted to the State have been made available to the public since 1991.

The Waste Management Programme is required under the Code of Practice on the Management of Radioactive Wastes from the Mining and Milling of Radioactive Ores 1982 (AGPS 1982). The Code of Practice also addresses control of radiation exposure and dose assessment for members of the public.

2.5.3 Current management programme

In 1995 discussions took place between WMC and the State Government regarding replacement of the then current EMP and the Waste Management Programme system with a consolidated and updated Environmental Management and Monitoring Plan (EMMP).

The EMMP covers the period 1 March 1996 to 28 February 1999. The relevant documents are the EMMP (WMC—Olympic Dam Corporation 1996a), and a justification document (WMC—Olympic Dam Corporation 1996b). The aims of the EMMP are to:

- establish a single coordinated management system that ensures environment and radiation impacts are minimised;
- establish and maintain audit systems on management and monitoring systems;
- establish and maintain monitoring programmes to determine the impact of the operation, including operational emissions, on the surrounding environments;

- determine the radiation doses received by specific members of the public groups from the operation;
- identify, assess and reduce the potential for possible environmental emergencies and worst case situations;
- describe reporting systems and systems for consultation with government;
- comply with the WMC Environment Policy and the Olympic Dam Statement of Environmental Commitment (Appendix A).

It is also intended to develop environmental management systems consistent with certification to the standards in the ISO 14000 series for environmental management at the operations. The EMMP is described in greater detail in Chapter 15.

Reports on the EMMP will continue to be made to the State quarterly and annually, as described in Section 2.5.1. The annual EMMP and environmental monitoring reports will continue to be available to the public. Brochures are also issued annually summarising the occupational and environmental radiation monitoring results.

2.5.4 Rehabilitation

The objectives of the disturbed land rehabilitation programme are to:

- rehabilitate areas disturbed by operation-related activities once they are no longer required for operational activities;
- monitor the effectiveness of the rehabilitation programme.

Rehabilitation undertaken on the site uses both passive and active methods. Passive methods are used in small areas of disturbance, where nearby plants provide some shelter and seed for the area being rehabilitated. Active methods are used where the rehabilitation area is quite large and needs to have an additional source of seed and, in some cases, protection from wind erosion.

Disturbed sites throughout the operations area that require rehabilitation in the short term include drill pads, roadways, access tracks, embankments, quarries, borrow pits, the tailings retention system walls, and other areas where vegetation has been removed and which are not being, or expected to be, used further for operational activities.

Rehabilitation criteria are established in the EMMP. This states that rehabilitation is deemed to be complete when 80% of the total cover of perennials calculated from control sites in the relevant association is achieved. Rehabilitation sites to be deemed complete must also have 80% of the cover provided by the dominant perennial species surrounding the disturbed area in the equivalent landform type. When criteria are met the sites are removed from the annual rehabilitation monitoring programme. However, a subset of rehabilitated sites is monitored every three years to ensure that the vegetation does not regress to a more disturbed state.

Although the rehabilitation monitoring programme was designed to monitor the progress of drill pads and other small areas, it can be applied to larger rehabilitation areas by using multiple monitoring points within the single area. The rehabilitation programme is described in greater detail in Chapter 14.

2.5.5 Consultation programme

WMC recognises that a general framework for consultation with all community groups is essential. The objectives of the community consultation programme undertaken by WMC are to:

- maintain and improve the relationship WMC has with the Roxby Downs and Olympic Dam Village communities, local pastoralists, Aboriginal groups and other community groups;

- ensure that all local groups potentially affected by the operation's activities have been adequately consulted.

WMC believes that consultation maximises the information available to the community and the company prior to a decision-making phase, thereby ensuring that decisions affecting different groups are based on the maximum available information. The resultant activities will, therefore, minimise any adverse impact on third-party interests. WMC recognises that there are some groups of people that require specific mechanisms for consultation. These include Aboriginal groups, pastoralists and local community members.

Any work that is to occur on adjacent pastoral properties is brought to the attention of the relevant pastoralists by way of written communication and direct discussion. All local pastoralists regularly receive copies of the divisional bulletin, which provides updates on development, construction and other activities. Pastoralists are periodically invited to the site for an operations update involving site tours and formal presentations. Contact with pastoralists is frequent and relatively informal, with environmental personnel and project-specific personnel being involved.

The Roxby Downs Advisory Committee was formed as a mechanism for consultation between the community, the town administrator and WMC. However, it is understood that the committee has not met since early 1996. Wider community issues were raised at these meetings, including development and environmental issues. On an individual level, members of WMC's Radiation, Environment, Safety and Quality Department are actively involved in local community groups, such as the Tidy Towns Committee. When larger issues arise, town meetings are organised to give community members the opportunity to understand and discuss these issues.

Significant developments undergo public review by way of publication of environmental management documents for the development (e.g. the EIS). Recently the Borefield B Supplementary Environmental Study (Kinhill Engineers 1995) and the Environmental Review (WMC—Olympic Dam Corporation 1995) were made available for public review.

Professionals employed at the operations regularly publish technical papers, which undergo peer review, and attendance at relevant conferences is supported. This process allows for feedback to the operation from peers in other communities.

A Public Affairs Adviser and a Community Relations Officer are based in Adelaide and report to the Manager, Corporate Affairs. The Public Affairs Adviser works closely with the Radiation, Environment, Safety and Quality Department at Olympic Dam in providing information to the wider community. The Community Relations Officer consults frequently in the Olympic Dam region with Aboriginal, pastoral and other communities.

Further community consultation is proposed as part of an extension of new arrangements for meetings of the Olympic Dam Environment Consultative Committee comprising representatives of WMC and the Commonwealth and State governments.

2.5.6 Aboriginal heritage

WMC continues to monitor and manage those ethnographic and archaeological sites specified in the 1983 EIS, in accordance with the recommendations in those reports and in Hiscock (1985), and sites identified in subsequent heritage surveys.

Consultation has been, and continues to be, undertaken with all Aboriginal groups with a recognised interest in areas affected by the operations in accordance with the WMC Indigenous Peoples Policy (contained in Appendix A). Specific issues relating to Aboriginal heritage are considered in Chapter 6.

2.5.7 Management systems during construction activities

The management systems implemented during construction activities at WMC, as agreed with government, are described in the EMMP. In particular, the EMMP describes the issue of an environmental and workplace design criteria document for any new development or activity. The EMMP also provides that before any undisturbed land is used, an Environmental Clearance must be obtained from the Environment Superintendent.

2.6 OCCUPATIONAL HEALTH AND SAFETY

2.6.1 Management of exposure to radiation

The mining and processing of ore that contains uranium and its decay products (as shown in Figure 2.17) may result in release of radionuclides to the environment. The major release paths into the environment for these radionuclides are through mine ventilation shafts, dust lift-off from stockpiles and process materials movement systems, stack emissions, and dust lift-off from the tailings retention system.

The radionuclides released are those in the uranium decay series (Figure 2.17). Radon-222 (^{222}Rn) is a gas that occurs naturally in the atmosphere. This natural global occurrence of ^{222}Rn results in measurable activities of ^{222}Rn and its decay products ^{210}Pb and ^{210}Po in the region. As the other radionuclides in the ^{238}U decay chain are also naturally occurring there is also a background activity caused by these radionuclides. The airborne activities of ^{238}U, ^{230}Th and ^{226}Ra, however, are considerably lower than those from ^{222}Rn and decay products ^{210}Pb and ^{210}Po.

Owing to the natural occurrence of these radionuclides, WMC measures the radiation in the operational areas as well as in control areas. This enables an assessment of the operationally elevated radiation in the environment surrounding the operation to be made by subtracting the naturally occurring radiation measured at control sites. Radiation measurements are made from sampling or measuring activities in pathway materials to biological groups.

The operations at WMC are undertaken in accordance with an environmental radiation management programme, which has the following objectives:

- minimise the emission of radioactive materials to the atmosphere and local environment by implementing sound engineering and management principles;
- monitor any elevated levels of radiation in the environment surrounding the operation;
- minimise and assess the radiation exposure of critical groups, as defined in relevant codes (discussed in Chapter 10).

There are two primary objectives to the environmental radiation monitoring programmes undertaken at the operations. These are to:

- provide information for critical group dose assessment;
- monitor the effectiveness of operational control mechanisms.

The monitoring programmes required to fulfil these objectives are complementary.

The principal control techniques used to limit exposure of the public to elevated levels of radioactive materials from the operation are as follows:

- Access to supervised areas around the metallurgical plant and surface facilities associated with the underground mine is controlled. Control measures include a perimeter fence approximately 2.3m high with public access through two security gatehouses only, and signs on the entrance and boundaries of supervised areas, with access to authorised persons only.

- The buffer zone established around the operational areas by the Special Mining Lease boundary excludes grazing and residential development.
- There is a formal review mechanism of all new plant and equipment which ensures that occupational health and safety, and environmental and environmental radiation issues are addressed in the design stage.
- Use is made of pollution control mechanisms, including stack scrubbing equipment, which are constantly operated and monitored. This equipment undergoes preventive maintenance programmes and any failure is addressed immediately.
- No equipment is permitted to leave the site without a formal radioactive contamination check and cleaning, if necessary.
- The siting of the Olympic Dam Village and Roxby Downs township some 5 km and 14 km south respectively of the operational areas maintains a significant distance between the residential areas and the operation.

Since commencement of operations at Olympic Dam, radiation exposures to employees, members of the public and the environment have been maintained well within all statutory limits and international guidelines. A summary of these results is published annually in an information brochure, and detailed results are provided to government. All commitments made in the 1983 EIS relating to occupational and environmental radiation have been complied with. Radiation issues are discussed further in Chapter 10.

2.6.2 Health and safety

Formal programmes are implemented to continually improve the safety of the workplace provided to employees and contractors. As is common industry practice, the effectiveness of these programmes is monitored by the collection of statistics on the frequency rates per million hours worked of lost time and medically treated injuries. Table 2.2 shows that there has been a significant improvement in employee safety, as measured by these statistics, over the last two financial years. These improvements are in keeping with improvements in the overall WMC Group.

Improvements in the safety of the operations have followed a strong emphasis by management on safety awareness. This emphasis continues in site safety programmes based on WMC's safety and health objectives, involving:

- strengthening the implementation of safety and health systems;
- increasing the line management and workforce involvement in safety and health improvement;
- development and implementation of comprehensive safety and health systems auditing;
- defining and holding line management accountable for effectiveness of safety and health systems.

Table 2.2 Frequency of injuries at Olympic Dam operations (per million hours worked)

Financial year	Lost time injury frequency rate		Medically treated injury frequency rate	
	Olympic Dam	WMC Group	Olympic Dam	WMC Group
1994–95	7.5	10.9	104.9	45.4
1995–96	6.3	10.6	43.9	27.7

Source: WMC Limited 1996.

2.7 TOWNSHIP AND VILLAGE

2.7.1 Roxby Downs township

The township of Roxby Downs (Figure 2.20) was established in 1988 to accommodate the plant workforce and associated government and service industry workers. At present the population of the town is about 2,500, and the Olympic Dam Village houses approximately 200 additional personnel.

The township currently contains some 700 houses and flats as well as a caravan park. A further 101 residential lots have recently been developed to meet current demand. The single persons' quarters, located in the township, provide accommodation in the form of 335 single-room units.

The town is served by a range of recreational facilities including:

- a swimming pool
- a multi-purpose indoor recreation complex
- four combined tennis and netball courts

FIGURE 2.20
LAYOUT OF EXISTING FACILITIES AT ROXBY DOWNS

- a main oval and adjacent grassed area
- a school oval
- various playgrounds
- a bowling green
- a golf course.

Separate areas outside the town have been developed for other activities, including motor sports and a horse riding/pony club.

Roxby Downs is also served by the following government non-recreational facilities:

- area school
- TAFE college
- library
- police station
- government office complex and medical centre
- day care and child minding centre
- town hall.

The township has been developed in accordance with the parameters set out in the Indenture, which specifies the relative responsibilities of the State Government and WMC.

The majority of housing in Roxby Downs has been provided by WMC, the remainder being provided by private and government developers. Much of WMC-provided housing is being purchased through the company's home purchase scheme, which is currently under review.

The municipal authority currently operates at a deficit, which is shared by the State Government and WMC. The only significant deficiency in the existing public infrastructure is the lack of a comprehensive medical facility. At the time of writing this EIS, the State Government was in the process of commissioning construction of a medical facility. The medical facility is expected to be opened in early 1998.

Generally, the township of Roxby Downs is in a very positive stage of community development, with a high level of involvement in community activities, especially sporting and recreational activities, and voluntary efforts to develop or enhance facilities. Social issues at Roxby Downs are discussed in Chapter 12. Turnover rates of staff at the operations are relatively low, and there is a low rate of industrial disputation.

2.7.2 Olympic Dam Village

The Olympic Dam Village is located approximately 5 km south of the process plant and 9 km north of the Roxby Downs township. Olympic Dam Village comprises:

- Construction Camp 1
- Construction Camp 2
- industrial area
- caravan park
- airport.

The Olympic Dam camps are used intermittently to accommodate construction personnel working at Olympic Dam operations.

Recreational facilities provided at the camps include:

- swimming pool
- squash courts
- tennis courts
- mess facilities.

The Olympic Dam Village facilities are to undergo significant refurbishment and improvement for the Expansion Project. This is described in greater detail in Section 11.7.

CHAPTER 3

DESCRIPTION OF THE EXPANSION PROJECT

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DESCRIPTION OF THE EXPANSION PROJECT

This chapter describes the proposed expansion of Olympic Dam to an initial nominal production rate of 200,000 t/a copper, and possible later expansion to 350,000 t/a copper. The mining methodology and metallurgical operations are described, as well as the associated infrastructure facilities. Mine ventilation, the control and management of effluents, emissions and wastes are also discussed. Other topics covered are materials handling and transport, the possible importation of concentrates, the use of other copper ore, the construction phase, and the various mining and processing alternatives that have been considered.

3.1 PROJECT SCOPE

The Olympic Dam Expansion Project would be developed in two phases. The first phase would be expansion from the current production rate of 85,000 t/a of refined copper to the approved capacity of 150,000 t/a by the year 1999, with a nominal production rate of 200,000 t/a to be achieved by the year 2000. The possible future second phase would be further expansion to a total production capacity of 350,000 t/a in the longer term.

The size and timing of the possible future expansion to 350,000 t/a of refined copper would be dependent on a number of factors including product prices, operating costs and changes in processing technology. No formal decision on the possible future expansion to 350,000 t/a copper has been taken by the WMC Board at this time. However, in this EIS it has been assumed for water abstraction and economic modelling purposes that this production rate would be achieved by the year 2010.

Both phases of the expansion—200,000 t/a and the possible future 350,000 t/a of copper—are based on the processing plant feedstock being supplied exclusively by the mine. However, there may be times when ore from mine production may be supplemented by ore imported from other mines in South Australia, or by copper concentrates imported from other mines in Australia or overseas.

The use of imported copper concentrate or ore would be largely determined by economics and the availability of surplus capacity in the metallurgical plant. It is not proposed to import and treat ores or concentrates for the recovery of uranium.

3.2 GEOLOGY

The Olympic Dam deposit, which includes economic quantities of copper, uranium, gold and silver, is a syngenetic orebody hosted by a high-level hydrothermal breccia complex (Western Mining Corporation 1993). Since the commencement of mining operations at Olympic Dam, the predicted geology of the orebody has been more precisely defined. The following sections consider the revised geological model of the ore deposit, and discuss both the regional geology and the geology of the deposit.

3.2.1 Regional geology

The Olympic Dam deposit is located in the Stuart Shelf geological province, which is located to the west of Lake Torrens (Figure 3.1). In this province, incomplete sequences of flat-lying,

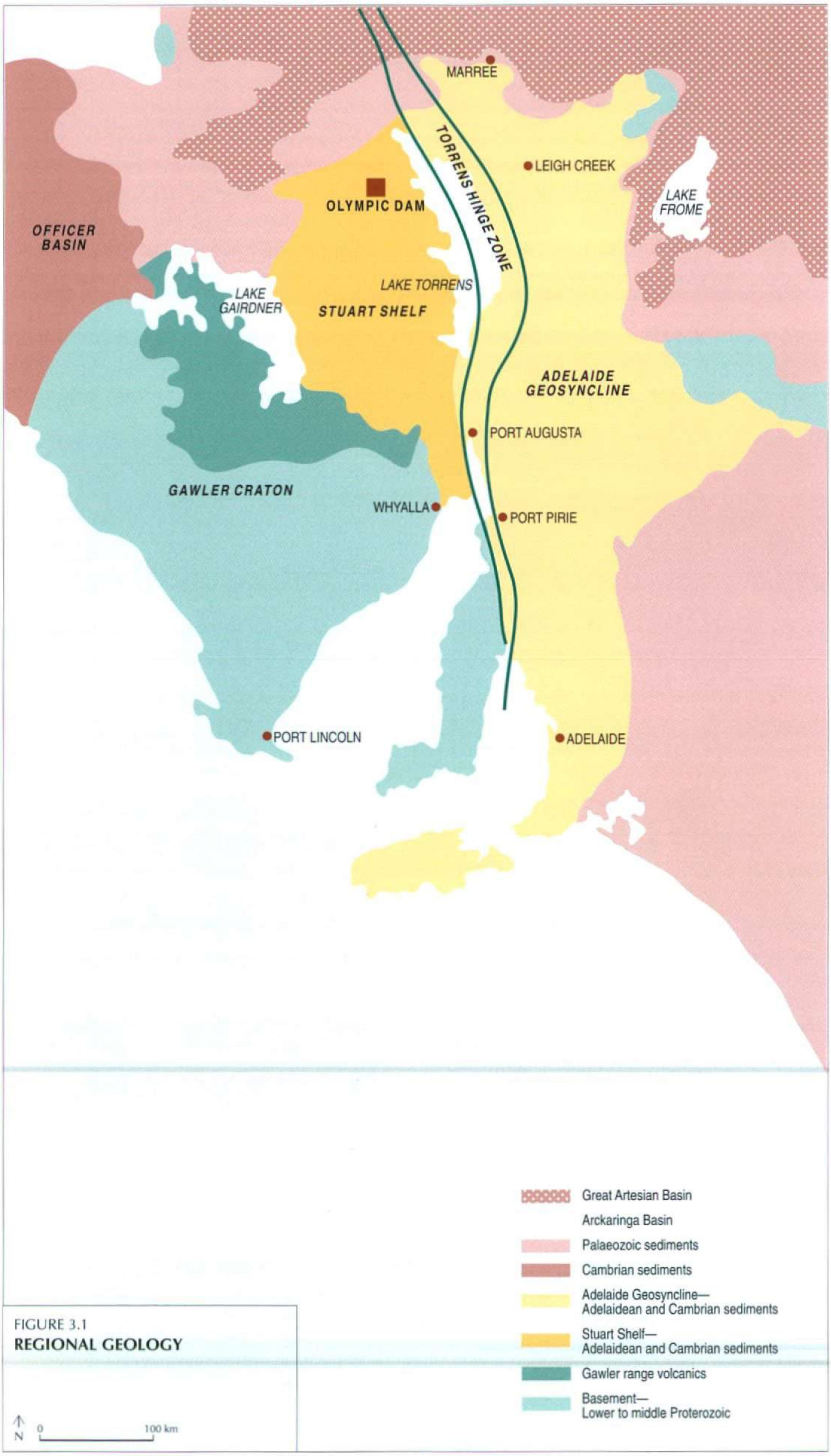


FIGURE 3.1
REGIONAL GEOLOGY

undeformed Proterozoic and Palaeozoic (Cambrian) marine sediments related to the Adelaide Geosyncline unconformably overlie the north-eastern part of the Precambrian Gawler Craton (Western Mining Corporation 1993).

The north–south trending Torrens Hinge Zone forms the eastern and north-eastern boundary of both the Stuart Shelf and the Gawler Craton. To the east of the Torrens Hinge Zone lies the Adelaide Geosyncline where the sedimentary sequence is substantially thicker and variably deformed. The northern extension of the shelf is overlain by Late Palaeozoic and Mesozoic sediments of the Arckaringa and Great Artesian basins. Figure 3.2 is a cross-section through the northern Stuart Shelf showing the sedimentary sequences in the Olympic Dam area.

3.2.2 Geology of the deposit

The stratigraphy, structure and mineralisation of the Olympic Dam deposit are described below.

Stratigraphy

The Olympic Dam deposit lies beneath approximately 350 m of barren, flat-lying sedimentary rocks. The deposit is hosted by the haematite-rich Olympic Dam Breccia Complex which occurs entirely within Roxby Downs Granite. The Roxby Downs Granite is a pink to red syeno-granite that rises to a peak, the apex of which is centred on the haematite-rich core of the Olympic Dam Breccia Complex.

This complex is an extensive breccia system containing a wide variety of hydrothermal, pyroclastic, cataclastic and epiclastic breccia types (Figure 3.3). The core of the complex comprises barren quartz–haematite breccias, with localised dyke swarms and diatreme systems. The quartz–haematite core is flanked to the west and east by a broad zone containing abundant haematite-rich breccias intermingled with altered granite breccias. The known copper–uranium mineralisation occurs within these zones.

Individual breccia zones are typically tabular to lenticular in shape and are elongate in a west-north-west or north-west orientation (Western Mining Corporation 1993). In total,

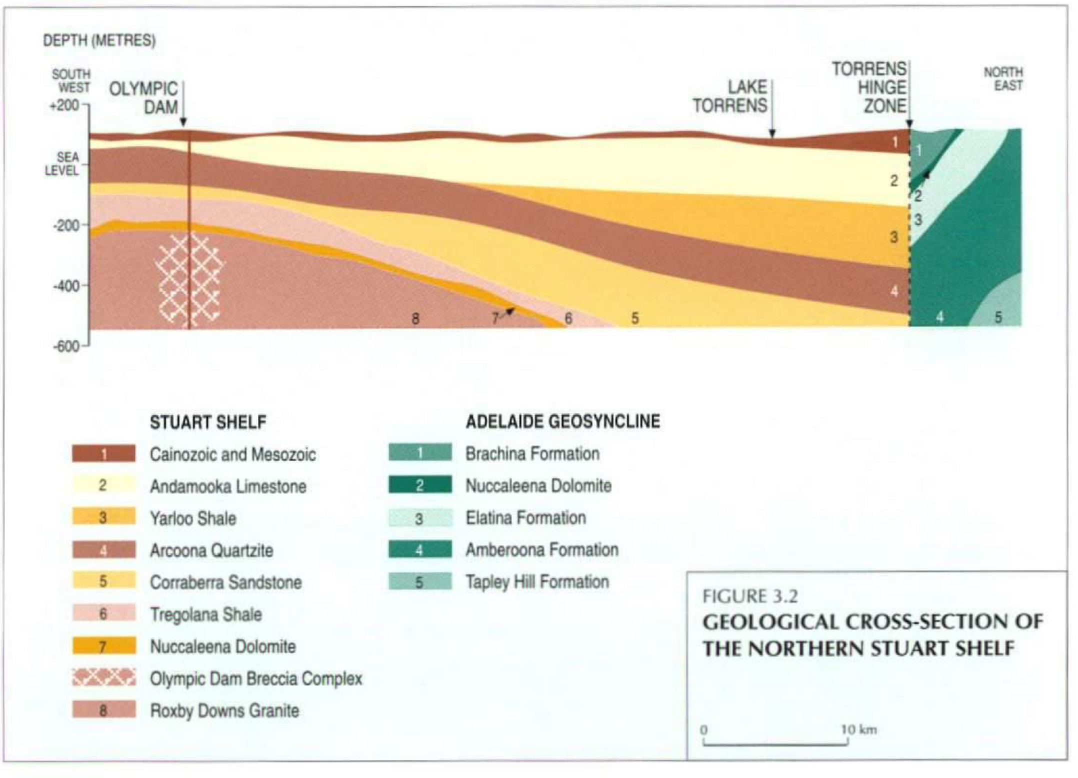


FIGURE 3.2
GEOLOGICAL CROSS-SECTION OF THE NORTHERN STUART SHELF

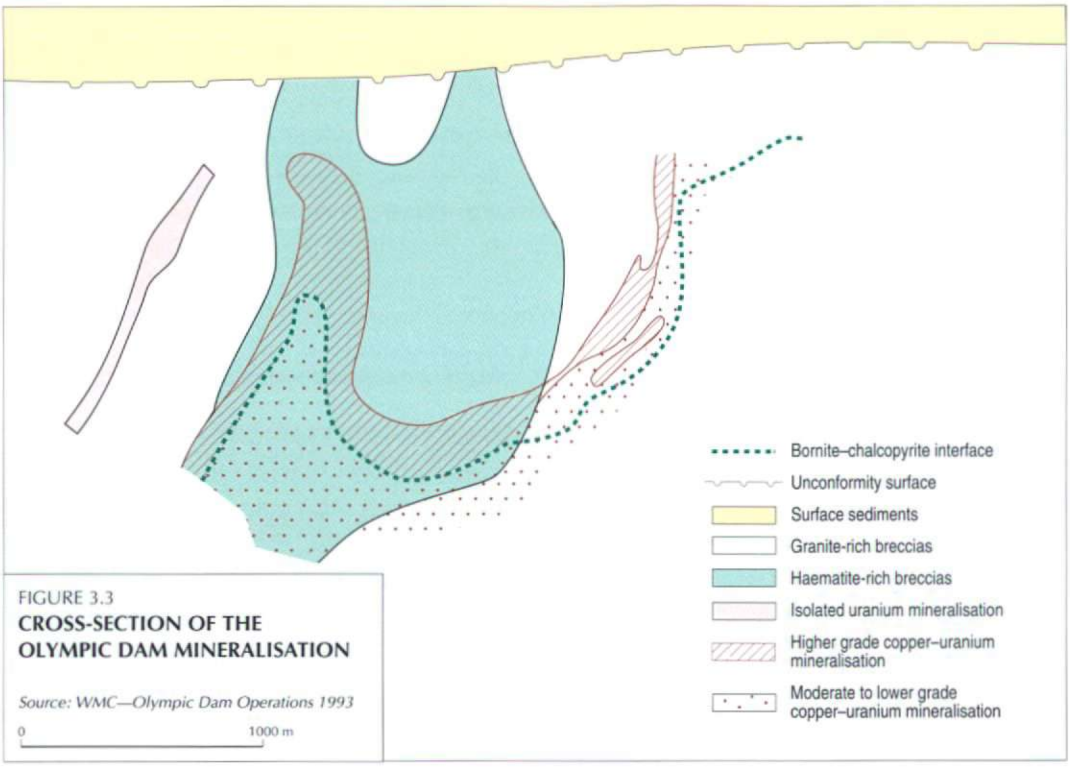


FIGURE 3.3
CROSS-SECTION OF THE OLYMPIC DAM MINERALISATION

Source: WMC—Olympic Dam Operations 1993

haematite-rich breccia bodies occupy an area of approximately 3 x 3.5 km. Depths to the basement increase to 500 m within several kilometres of the site, and to greater than 1,000 m at other, more distant, localities. The contact between the basement and the overlying cover sediments is nearly flat-lying with gentle undulations.

Structure

The early WMC geological models interpreted the Olympic Dam deposit as being a large, fault-bounded, sediment-filled trough, or graben structure, and considered that mineralisation occurred as strata-bound and transgressive bodies within this structure. The model has evolved into one that now views the deposit as a large diatreme that probably vented at the surface, resulting in the deposit's steep orientation.

Mineralisation

Mineralisation of the deposit can be broadly categorised as follows:

- copper–uranium (with some gold and silver) ore: This ore comprises most of the resource, and is primarily contained within haematitic breccias;
- gold ore: This ore type generally occurs as small zones hosted by either granite-rich or haematite-rich breccias. There are some rare, but significant, extremely high-grade concentrations of free gold, especially around the margins of the quartz–haematite core.

The principal copper–uranium mineralisation is generally confined to individual elongate haematite-rich breccia zones. The deposit consists of a large number of individual ore zones distributed throughout the breccia complex. Copper mineralisation typically consists of fine to medium-grained disseminated sulphides. The principal copper sulphides are chalcopyrite, bornite and chalcocite. Zonation of the mineralisation also occurs, ranging from the rare but significant native copper to chalcocite, bornite, chalcopyrite and pyrite at depth.

Uranium mineralisation is broadly associated with copper mineralisation. Most of the uranium within the deposit occurs as pitchblende, with minor amounts of coffinite and brannerite.

The creation of the breccia complex at Olympic Dam appears to have been driven by magmatic and seismic hydrothermal activity. Faulting, brecciation, alteration, dyke injection, diatreme formation and mineralisation were independent and multiphase. Brecciation occurred within a near-surface eruptive volcanic event owing to superheating of surface and subsurface water. Mineral compositions, ore textures and thermodynamic data suggest that fluids ascending from depth and descending (near-surface) fluids have been integral to the mechanics of mineral precipitation (Western Mining Corporation 1996).

Economically viable mineralisation occurs almost entirely within, but is not confined to, the Olympic Dam Breccia Complex haematitic hydrothermal breccias. The reserves of the two ore types are presented in Table 1.1.

3.3 MINING

This section describes the proposed changes to the mining operation that are necessary to achieve the expanded production targets. The most significant of these are the construction of a new vertical haulage shaft and the replacement of diesel trucks by automated electric rail for haulage underground.

3.3.1 Resources and ore reserves

The early inferred resource estimate in 1982 was recalculated by WMC in 1993 following significant changes in the geological understanding and modelling of the Olympic Dam deposit. Categories of inferred and indicated resource and probable and proven reserve formed the bases of the calculations, the results complying fully with the Australian Code for Reporting of Identified Mineral Resources and Ore Reserves issued by the Joint Ore Reserves Committee of the Australasian Institute of Mining and Metallurgy, the Australian Institute of Geoscientists and the Minerals Council of Australia (Joint Ore Reserves Committee 1996). The outline of the inferred resource is shown in Figure 3.4.

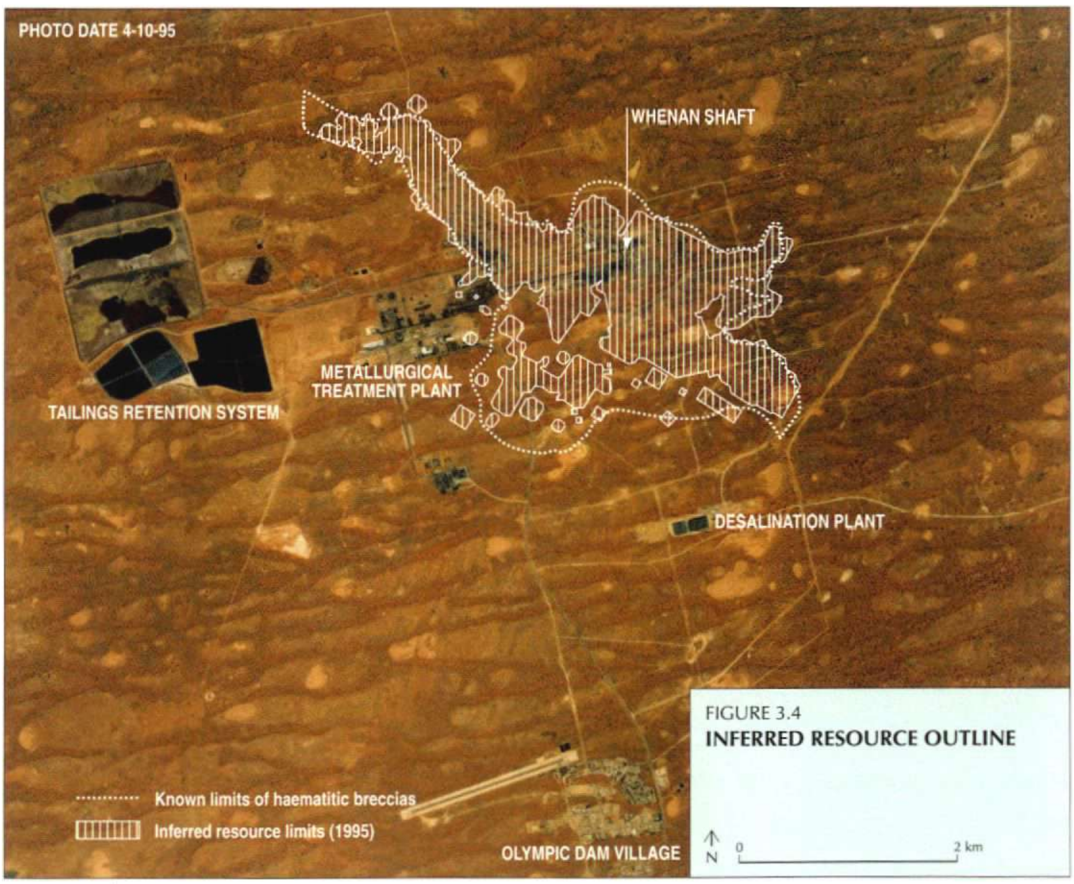


FIGURE 3.4
INFERRED RESOURCE OUTLINE

The procedures used to estimate stope reserves for preparation of the production schedule at Olympic Dam involve an assumption of 8% dilution for new stope design. Dilution relates to the amount of waste rock that unavoidably contaminates the ore. An extraction factor of 95% is currently applied to all stopes. This has been increased to 99% for future extraction following reconciliations of production statistics from completed stopes.

The mine schedule is based on the extraction of 'proved plus probable reserves' of copper–uranium ore, modified from earlier figures to allow for ore mined to date, changed loss and dilution parameters as given above, and a changed cut-off grade. The amounts of copper–uranium ore in each category as at 30 June 1996 are shown in Table 3.1. The gold ore reserves (totalling 300,000 t) are listed in Table 1.1.

Table 3.1 Mineable copper–uranium ore reserves at 30 June 1996

Ore category	Tonnes of ore ('000s)	Copper (%)	Uranium oxide (kg/t)	Gold (g/t)	Silver (g/t)
Proved	73,000	2.5	0.8	0.5	4.3
Probable	496,000	2.0	0.6	0.7	5.0
TOTAL	**569,000**	**2.0**	**0.6**	**0.7**	**4.9**

The copper grades of the ore available for mining decrease with time. In order to maintain refined copper production at 200,000 t/a, it would be necessary to mine higher tonnages of ore in some years. This is further discussed in Section 3.3.4.

3.3.2 Grade control

A coarse ore blending stockpile would be installed on the surface to achieve a more consistent ore grade at the metallurgical plant. Currently, ore is extracted from stopes underground in a manner intended to provide an even grade of ore on a daily basis. However, this is often difficult to achieve because the grades within stopes vary widely, and the logical mining sequence does not always provide the required average grades.

The surface blending stockpile would allow mining to proceed in the most efficient manner, maximising the use of mining equipment and minimising the waste incurred by frequent changes of extraction location. It would also permit optimum recovery of metal from ore in the processing plant by minimising grade variations.

3.3.3 Geotechnical review

Stability of the mine workings is critical to the success of the project. A review of past geotechnical work has been conducted, and the most significant finding is that in situ maximum principal stresses may approach 30–50% of the intact rock strength in the vicinity of the extraction and haulage levels. At these stress levels, problems such as stress-induced spalling and rock bursts could be expected.

Ore passes and intake shafts would be located in such a way as to minimise the induced stresses and their effects. This procedure would place the ore passes in relatively unstressed ground. It is also planned to increase the level of rock mechanics monitoring and investigation activities in order to obtain a better knowledge of rock fabric parameters and in situ stresses, as well as gauge any implications for safety management.

3.3.4 Ore production schedule

The ore production schedule is driven by the objective of achieving a sustained production rate of 200,000 t/a refined copper metal in the first phase of the expansion, at a copper to sulphur ratio that would provide the most effective operation of the smelter. This would necessitate mining between 8.7 Mt/a and 9.2 Mt/a depending on the grade of ore processed.

The proposed production schedule for the fifteen years from 1996–97 is shown in Table 3.2. It should be noted that WMC is implementing an accelerated construction and mine development programme, which is expected to shorten the time to achieve a production rate of 9.0 Mt/a ore.

Table 3.2 Production schedule from 1996–97

Year		Total ore production ('000s t)	Copper (%)	Uranium oxide (kg/t)	Gold (g/t)	Silver (g/t)	Copper recovered[1] ('000s t)
1	1996–97	3,197	2.96	0.87	0.43	5.88	88
2	1997–98	3,336	2.83	0.74	0.46	5.68	88
3	1998–99	5,041	2.56	0.77	0.46	5.16	120
4	1999–00	8,028	2.46	0.71	0.44	4.76	185
5	2000–01	8,712	2.56	0.74	0.42	4.33	209
6	2001–02	9,012	2.45	0.69	0.42	3.91	207
7	2002–03	9,171	2.36	0.77	0.41	3.69	202
8	2003–04	9,015	2.43	0.73	0.38	3.53	205
9	2004–05	9,182	2.35	0.69	0.37	3.51	202
10	2005–06	9,234	2.35	0.71	0.41	3.80	203
11	2006–07	9,199	2.38	0.72	0.41	4.65	205
12	2007–08	9,115	2.39	0.72	0.42	4.81	204
13	2008–09	9,227	2.43	0.72	0.39	4.94	210
14	2009–10	9,090	2.43	0.71	0.41	5.29	207

1 *Excludes copper from imported concentrate.*

In order to achieve the planned mining rate of 8.7 Mt/a by 2000–01, it would be necessary to develop approximately 28 km/a of underground openings during the three-year mine expansion programme. This figure is expected to increase for the accelerated mine development programme. After this initial period, the development requirement would be approximately 17 km/a.

During the expansion period, the additional ore made available by the development of these underground openings would bring the total production to levels above the capacity of the processing plant. Because the grade of the ore won from development would be lower and more variable than that of the material extracted from the stopes, stope production would be maintained, with excess ore being stockpiled on the surface until treatment capacity was available.

Given the high variability of the grade within stopes, a large number of stopes must be in production at any one time to achieve an overall ore grade as consistent as possible. The schedule calls for at least thirty stopes to be operated in any year when production reaches a nominal 9.0 Mt/a. The number of stopes in operation at any one time would vary from an average of thirteen to about twenty-three.

3.3.5 Access

As noted in Section 2.1, access to the mine from the surface is currently provided by the Whenan and Robinson shafts and a service decline. In addition, there are eighteen ventilation shafts.

The service decline extends to 420 m below the surface. It was constructed principally to facilitate movement of mobile equipment and other large pieces of machinery into and out of the mine, but is also used for transporting people and supplies, and occasionally for hauling development ore and mullock.

The Whenan Shaft is a vertical, six-compartment, rectangular shaft, 6.3 m by 3.5 m and 500 m deep. It is currently being used for hoisting ore and for transporting personnel into and out of the mine. There are no plans to augment the capacity of the Whenan Shaft.

The Robinson Shaft is a vertical concrete-lined shaft 5.3 m in diameter and 580 m deep, used mainly for hoisting mullock. The hoisting capacity and utilisation of the Robinson Shaft have been enhanced recently by installing a crusher station and upgrading the winder capacity to 400 t/h.

In the proposed expansion, the main ore haulage level would be established at RL –640 m AHD (Australian Height Datum), which is approximately 740 m below ground level. A new shaft, referred to as No. 3 shaft, would be sunk from the surface to minimise interference with other underground operations. Underground development associated with the No. 3 shaft would include a new crusher station and ore handling system. These areas would be accessed from the service decline, which would extend to the bottom of No. 3 shaft.

No. 3 shaft would be 7 m in diameter, concrete lined, and equipped with an automated winder and 35 t capacity skips. This new shaft would be designed specifically for ore hoisting and would not, as a general rule, be used for transport of personnel. However, it would provide another ventilation pathway and could also be used for emergency egress.

3.3.6 Mining method

Although consideration was given to other mining methods, the current method of sublevel open stoping has proven to be very effective, and there are, at this stage, no plans to make any significant changes. Among the alternative mining methods considered were vertical crater retreat and sublevel caving, which are discussed in Section 3.12.

The current mining method is described in Section 2.1 and illustrated in Figure 2.2. In the expanded operation, the full depth of the ore zone would be extracted in one vertical pass. Drill drives would be excavated at 60 m intervals in new areas, compared with the current 40 m intervals.

The size of the sublevel open stopes would range from 300,000 t to 600,000 t. As a general rule, no more than 50,000 t/month would be mined from any one stope.

3.3.7 Mine materials handling and hoisting

The key to successful expansion to a nominal 9 Mt/a would be the installation of an effective and efficient materials handling and rock hoisting system, comprising the following:

- the transport of ore from stopes and mullock from development headings to loading areas underground;
- the reduction in the size of rock on the grizzlies to facilitate subsequent handling;
- the crushing of rock to facilitate hoisting it to the surface;
- the transport of ore and waste from underground to the surface;
- the movement of personnel and materials to and from the surface.

Figure 3.5 provides a schematic diagram of the proposed ore handling system.

Ore from stopes would be carried from the drawpoints on the extraction levels to ore passes by load-haul-dump units. The ore passes would be fitted with grizzlies, and mobile rockbreakers would be used to break oversized rock. Ore passes would be located within each stoping area.

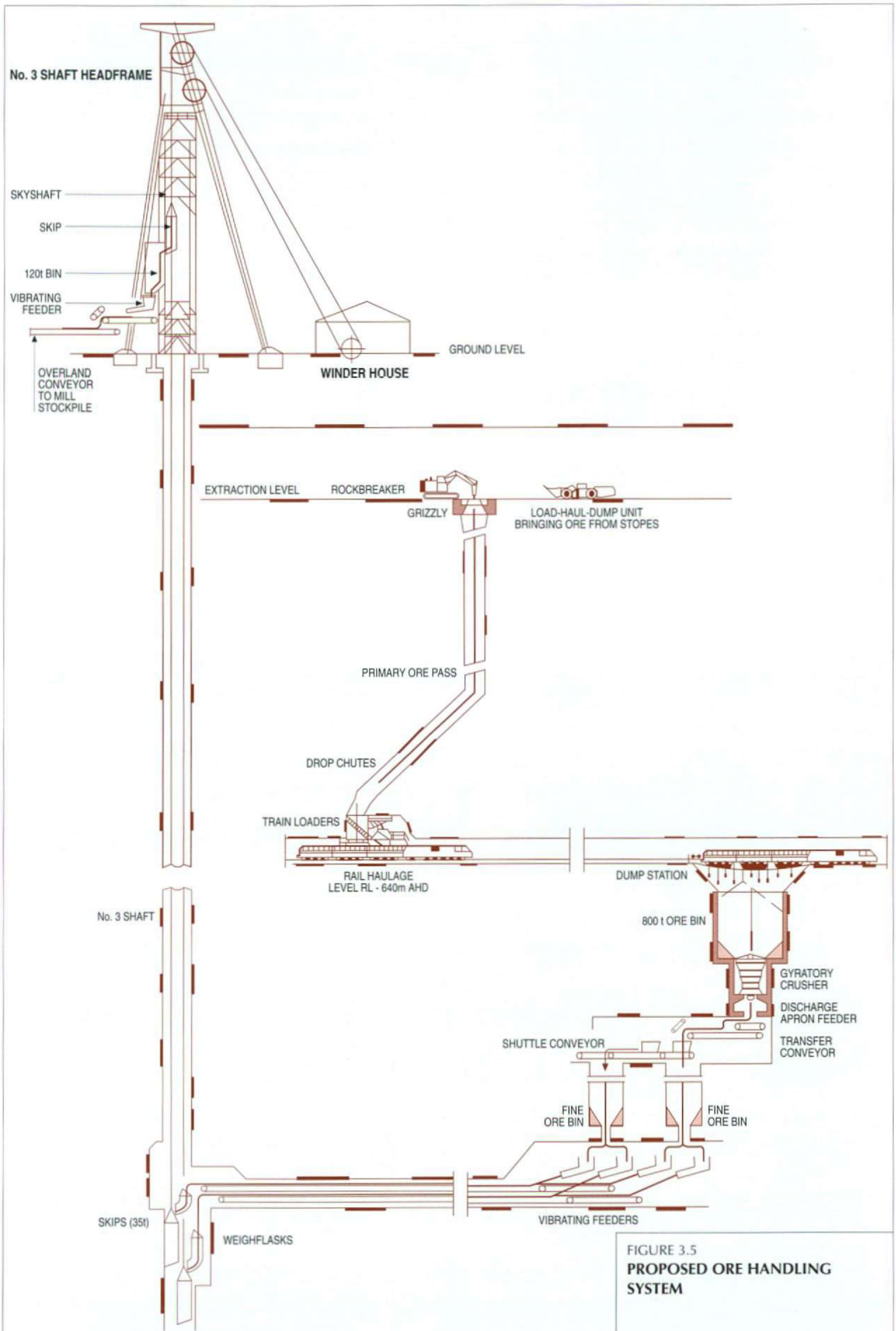


FIGURE 3.5
PROPOSED ORE HANDLING SYSTEM

From the ore passes, ore would be remotely loaded on to one or two automated electric trains and transported to the dump station above the crusher. The ore would be reduced in size by a gyratory crusher and transferred to one of two crushed ore storage bins excavated out of the rock. Ore would then be transported by belt conveyor to the No. 3 shaft, where it would be loaded into skips for hoisting to the surface. At the surface, the ore would be discharged into a 120 t bin and then fed by a vibrating feeder to an overland conveyor leading to the mill stockpile.

Development mullock would either be trucked to the Robinson Shaft or dumped in empty stopes where no further adjacent mining is to occur. During the mine expansion phase, any excess mullock not able to be hoisted or dumped in empty stopes would be trucked up the service decline to the surface. The Whenan Shaft would be used as a supplementary ore hoist, and for personnel and materials transport.

Extraction level operations

Twenty new grizzlies would be constructed at various locations throughout the extraction levels. These grizzlies would feed a system of primary ore passes, each 3 m in diameter. In order to control dust and air flow, each grizzly would be equipped with a door, which would be closed when the grizzly was not in use.

Load-haul-dump vehicles or dump trucks would carry run-of-mine ore from the nearby drawpoints to the grizzlies. Oversized rock would be broken on the grizzlies by one of two roving mobile rockbreakers. All passes would deliver ore to the train loading stations on the main ore haulage level at RL –640 m AHD.

Rail loading and haulage

Ore would gravitate from the extraction level grizzlies down a series of ore passes to nine train loading stations, located in chambers mined at the bottom of each of the primary ore passes on the main ore haulage level at RL –640 m AHD. The layout of the rail haulage level is shown in Figure 3.6.

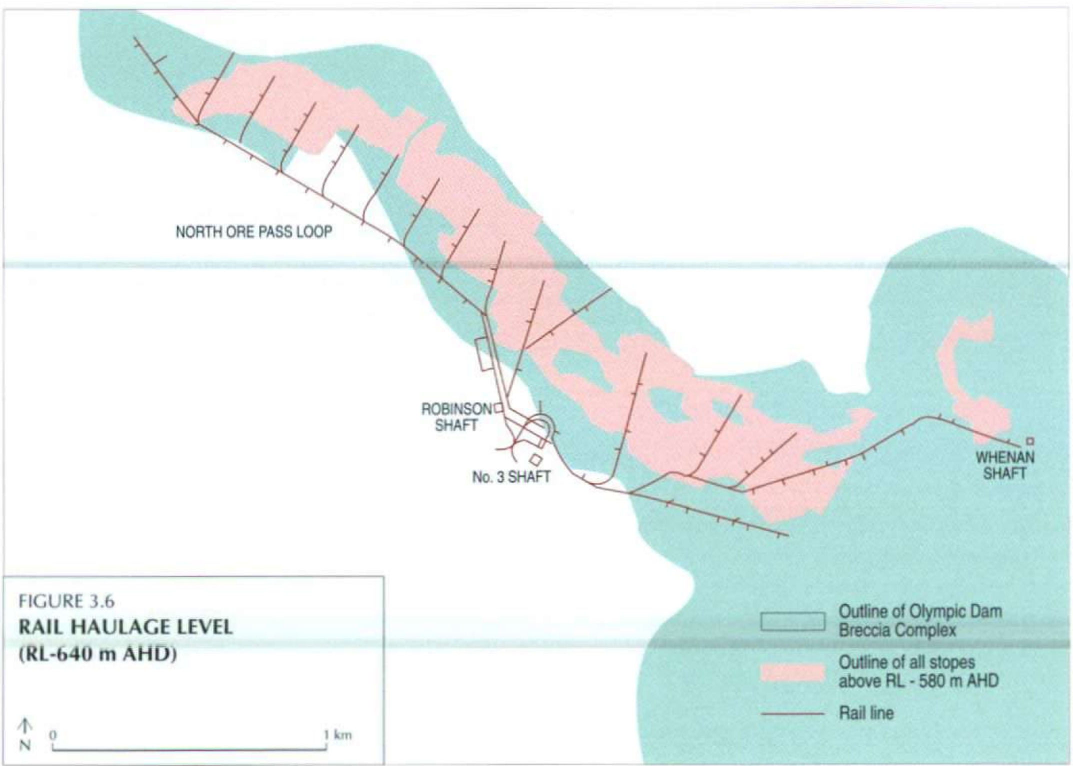


FIGURE 3.6
RAIL HAULAGE LEVEL (RL-640 m AHD)

Trains would be loaded through in-line drop chutes of a type commonly used in mining operations. These allow ore to be drawn from the ore passes and fed into the train ore cars in a controlled manner. Level controls in the ore pass above each train loader would prevent the ore pass from emptying completely, thereby avoiding damage to the equipment below from falling rock.

Two trains would be used to haul ore from the north and south sections of the mine to the primary crusher adjacent to the No. 3 shaft. As the trains moved through the dump station, the bottom-dump rail cars would discharge their load into a coarse ore bin of 800 t capacity located over the crusher station. Each train would consist of two 28 t electric locomotives and twenty-two 20 t bottom-dump wagons.

The use of electric trains would have a significant beneficial effect on ventilation and cooling requirements. The train haulage system would be automated and controlled from a central control room.

Crushing station

The ore would be crushed underground to provide material of a suitable size for hoisting and feeding to the autogenous mills in the processing plant.

The crushing station has been designed to accept material that has passed through the extraction level grizzlies, although occasional breaking of oversize rocks in the crusher by one of the mobile rockbreakers may be necessary. Allowance has been made for the future installation of a fixed rockbreaker at the crusher, if warranted. The crusher would be a gyratory unit capable of accepting a feed size of up to 1,100 mm, and would crush to a nominal size of 150 mm. The peak capacity of the crusher would be 2,200 t/h, which is adequate to handle peaks in delivery from train haulage.

A fully reinforced concrete crusher substructure would be provided, complete with clear access, laydown areas, maintenance areas and overhead cranes. Water sprays would be used to suppress dust generated in the crusher feed area, and an extraction system would control dust emissions from beneath the crushing chamber.

Ore from the crusher would fall on to an apron feeder, which would transfer the ore to conveyors for transport to a fine ore bin located below and to one side of the crusher station. A self-cleaning magnet positioned over the head end of the transfer conveyor would remove steel material. The fine ore bin would have a capacity of 3,750 t, equivalent to three hours' hoisting. An ultrasonic level detector would prevent both overfilling and complete emptying of the bin.

Loading and hoisting

The loading station would deliver ore to the No. 3 shaft hoisting system at a design capacity of 1,250 t/h. The loading station would consist of a twin feeder/conveyor arrangement delivering directly into 35 t capacity weigh flasks, from which the ore would be discharged into 35 t capacity skips for hauling to the surface. The loading station would be fully automatic in operation. The hoisting system would use a ground-mounted, four-cable friction winder.

3.3.8 Ventilation

The primary purposes of a ventilation system are to remove diesel fumes, heat, dust and radiation products. The ventilation system for the proposed expansion would be similar to that currently in use. Ventilation shafts would be installed as the underground workings were expanded, and the service decline and the three shafts would act as air inlets to the mine. Figure 2.2 shows the current ventilation arrangements adjacent to the Whenan Shaft.

Air would be drawn through the mine by fans fitted to some of the ventilation shafts. Volumetric air flows would be calculated to ensure conformity with health and safety requirements, as is the current practice. Fans and ventilation tubing would be used in development headings to complement the primary ventilation system.

Design criteria

The design of the ventilation system must take into account the following factors:

- the presence of radon emitting material
- high virgin rock temperatures
- high ambient air temperatures
- a high degree of mechanisation.

The following criteria are, and would continue to be, used for design of the ventilation system:

- minimum air velocity in transport and personnel access roadways—0.5 m/s
- minimum air velocity in haulage routes—1 m/s
- minimum air velocity in development ends—0.5 m/s
- minimum volume of air provided to development faces—25 m^3/s
- maximum air velocity in intake airways where employees travel—6 m/s
- maximum air velocity in service shafts—10 m/s
- maximum air velocity in shafts with rope guided skips—10 m/s
- maximum air residence time after contact with ore and before reaching exhaust airway—15 min.
- minimum air cooling power—135 W/m^2
- total volume of air passing through mine per million tonnes per year—300 m^3/s.

These criteria are based on the requirements to provide sufficient air to dilute the concentrations of fumes and radiation products to acceptable levels and then remove them from the mine, and to remove the heat emanating from the rock and from other sources to maintain working temperatures at acceptable levels. The ventilation system is also used to remove dust directly from dust generating areas such as ore passes. Air cooling power (W/m^2) is a function of temperature and humidity.

Primary ventilation system

The primary ventilation system for the expansion would involve a series of exhaust shafts fitted with fans drawing air out of the mine, as is used in the existing mine. Currently, air is drawn into the mine through the service and haulage shafts, the decline and some of the intake shafts. Its passage through the mine is determined by the location of these shafts, and the flow is controlled as necessary by adding or removing fans, by changing the direction of flow, and by using regulators in the workings.

In the proposed expansion, the Whenan Shaft, the service decline, the Robinson Shaft and the new No. 3 shaft would be maintained as air intakes. Approximately one new ventilation shaft would be required each year. Detailed network simulation of the ventilation system would be undertaken on an ongoing basis when development layouts and specific ventilation requirements for each area are defined more precisely, as is current practice. The main purpose of such an analysis is to determine fan pressure requirements.

The ventilation system design for the proposed expansion is based on the use of 4.5 m, 5.0 m and 6.0 m diameter ventilation shafts, with ventilation rates of 290 m^3/s, 350 m^3/s and 500 m^3/s respectively at an air velocity of 18 m/s. Production scheduling is based on sublevel open stopes within designated mine areas with a length along the orebody of about 500 m. In most of these areas, it is proposed to install a series of intake shafts on one side of the ore zone (with an access ramp), and a series of exhaust shafts on the opposite side. This guideline has been varied in areas where the access is centrally located.

All fans would be centrifugal fans because of their ability to withstand the difficulties caused by moist, salt-laden air. Salt build-up remains a problem on ductwork and fan impellers. Despite the increase in mine air flow and the construction of larger diameter shafts, the more efficient axial flow fans have not been considered because of the difficulty in maintaining impeller balance.

Approximately ten ore passes would deliver ore from production levels to the haulage level. Dust can be generated as the ore enters, passes through and leaves the ore pass. In addition to using water suppression sprays to reduce dust generation, the design developed for the expanded operation makes allowance for an exhaust ventilation shaft adjacent to every one or two ore passes. Each ventilation shaft would be operated under forced ventilation to capture fugitive dust as closely as possible to its source and exhaust it on one of the stoping levels away from the main access.

At the conclusion of stoping in any mine area, the area would be maintained under negative pressure to allow a nominal air flow to leak into and through it to prevent the build-up of radiation decay products.

Secondary ventilation system

In order to achieve and maintain the proposed level of production, it would be necessary to develop some 28 km/a of underground openings up to years 2000–01, although this could increase for the accelerated mine development programme described in Section 3.3.4. After this initial period, the development requirement would be about 17 km/a.

Nearly all of these openings would be developed as 'dead ends', which would require forced ventilation to remove blasting fumes and dust, diesel fumes, radiation products and heat from the rock and from machinery. For ventilation of development headings, an air volume of 25 m^3/s per heading has been allocated based on operational experience of the existing mine, with up to four headings in each mine area.

The most common system of secondary ventilation in mines involves using a fan to force air from a primarily ventilated area through a rigid or flexible tube to the area requiring ventilation. This is the system currently in use and proposed for all future operations.

Spot coolers may be used to reduce temperatures in areas where people are working and where ventilation air rates are inadequate to provide acceptable working temperatures. The increased depth of operations proposed would mean a significant increase in virgin rock temperature, which is expected to be about 50°C at the RL –580 m AHD extraction level.

Cooling would be provided as necessary in development areas via movable skid-mounted air-cooled water chillers installed in suitable excavations well away from the working face. Chilled water would be pumped in flexible hoses from each chiller to a bulk air cooler located at the intake to the fan ventilating the heading. The chilled water cools the air as it enters the fan, and is then recirculated back to the chiller. The hot air from the chiller would be exhausted to the surface.

3.3.9 Backfill operations

After all of the ore has been extracted from a stope, it is backfilled with rock or other suitable material. The fill provides support for mined-out areas and allows total extraction of wide orebodies that cannot be mined as a single stable stope. Emptied stopes are filled with either development mullock or cemented aggregate fill (CAF), as described in Section 2.1.

The proposed backfill system is designed to maximise the use of deslimed mill tailings, which otherwise would have to be disposed of on the surface. The amount of mill tailings able to be returned to the mine is limited by the strength requirements of the CAF, as only the coarsest material can be used. The achievable utilisation figure has been found to be approximately 20%, and this figure has been used in development planning. The proposed backfill system is similar to that currently in use, and would consist of:

- mullock from development headings placed by load-haul-dump units directly into empty stopes;
- a surface quarry to provide rock to supplement the supply of mullock from years 2001–02 to 2010–11 and a crushing and screening plant for sizing rock from the quarry;
- mullock storage bins located at Robinson Shaft and Whenan Shaft, and a stockpile for hoisted development mullock to feed the crushing and screening plant in the years of major mine expansion from 1996–97 and 2000–01;
- diesel trucks to haul mullock on the surface from the shaft mullock bins, mullock stockpile or quarry, and to haul mixed fill from the fill mixing plant to the surface-to-stope backfill holes;
- a CAF mixing plant to prepare backfill material, with associated crushing and screening plant, deslimed tailings storage and binder storage;
- a modified bulldozer to build barricades in drawpoints and drill drives to retain fill inside the stope.

Backfill quarry

A backfill quarry is presently used to service the existing operations, and would continue to operate in the expanded operations. The quarry is located approximately 1 km north of the northern boundary of the tailings storage area, in an area where the dolomitic Andamooka Limestone is close to the surface. The products from the quarry have several uses, including:

- rock for backfilling of mined out areas
- road surfacing material
- armouring for erosion control on tailings pond embankments
- rock cover for decommissioning of tailings areas
- concrete aggregates for a range of construction uses.

The quarry is and would continue to be operated by contractors. Currently, overburden is removed by bulldozers, scrapers or front end loaders; the mining benches are drilled and blasted; and the broken rock loaded by front end loaders into trucks for transport to the crushing and screening plant, where products are manufactured according to demand. The quarry is located some 15 km from the township. At this distance, the noise and dust from blasting have not proven to be a nuisance or a hazard.

Operations at the quarry would continue as in the past to satisfy the requirements of the expansion. At a nominal production rate of 9 Mt/a of ore from the main mine, the required quantity of rock from the backfill quarry for use in the CAF as backfill would be approximately 4.5 Mt/a. Adequate reserves for the foreseeable future exist within the area currently set aside for quarrying.

3.3.10 Mine services

The underground services have been identified and sized on the basis of mine development requirements for the initial expansion phase, and for sustained production at a nominal rate of 9 Mt/a of ore.

The services comprise:

- secondary ventilation systems including associated axial flow fans;
- spot cooling units to provide localised cooling for personnel;
- a mine water drainage and dewatering system;
- a saline mine water reticulation system;
- a potable water supply system;
- an 11 kV electrical supply and reticulation at 1 kV and 415 V;
- communications for personnel (radios and telephones), and equipment monitoring and control systems;
- workshop facilities for equipment servicing and maintenance underground;
- an explosives magazine;
- crib rooms, toilets, first aid stations, offices and other amenities.

The secondary ventilation and spot cooling units have been described in Section 3.3. The other services are described below.

Mine dewatering

A new main mine dewatering pump station has recently been commissioned. It has provision to increase the primary pump sets from three to five to meet future pumping requirements.

For the expansion, mine water would continue to be collected and pumped to the surface from strategically located pump stations. The quantity of mine water collected would increase from the present 3.2 ML/d to up to 7.3 ML/d. The expected quality of the mine water would be 20,000–40,000 mg/L of total dissolved solids.

Suspended solids would be removed in settling ponds, allowing the water to be used for reticulation back to the mine and for dust suppression. Excess mine water would be pumped to a new 30 ha mine water disposal pond (Section 3.8.3).

Should the whole mine dewatering system be inoperative for some reason, such as a power failure, the decline to the bottom of the No. 3 shaft and the shaft itself could be used for emergency water storage up to the loading station level. This would provide up to three days' storage.

Water supply and reticulation

For reticulation of the saline mine water, the mine would be divided into four reticulation zones, each with two dedicated water supply lines from the surface. This would ensure that the pressure was controlled between 100 m and 150 m head. The estimated maximum water usage per zone is approximately 15 L/s. The water would be delivered at a volume and pressure suitable for use in drilling machines, for generating foam for fire fighting and for dust suppression. A facility for filling water trucks would be provided in each mine zone.

A separate reticulation system would be provided for potable water. This system would be an extension of the existing mine potable water supply.

Mine power supply system

The main 11 kV power supply would be from main switchboards located at the Whenan Shaft, the Robinson Shaft and No. 3 shaft.

The power supply underground would be provided from the surface distribution system by new 11 kV power supply cables in dedicated drill holes. Armoured cable installed in each dedicated drill hole would connect to movable skid-mounted transformer substations underground. Five new power supply droppers are planned.

Electrical power would be provided to the crusher, loading station, automated rail haulage system, rock breakers, small and large pump stations, ventilation and cooling systems, lighting and mining equipment. The reticulation voltage to the main underground equipment in the mining areas would be 1,000 V and 415 V.

Communications, control and monitoring systems

A new mining operations control centre in the Whenan Shaft area would be used to oversee operation of ore production from the stopes, the automated rail haulage system, the crushing station, the loading station and the hoisting system. The control centre would use a series of closed circuit television cameras, fibre optic cable links, programmable logic controllers and a personal computer-based system control and data acquisition (SCADA) system. All critical services would be monitored and controlled by the SCADA system.

Personnel communications for surface and underground areas would be by radio and telephone. Telephone communications would be extended into the new development by up to forty extensions off the PABX line interface module in the administration building.

A mine-wide radio system using dedicated channels would be established for control and monitoring of equipment items underground that were not part of the fixed infrastructure. For surface radio coverage, the system would use the existing Whenan Shaft repeater, which would be extended if required.

Workshop, fuel and lubricant supply systems

A workshop would be established on the main haulage RL –640 m AHD level to service the haulage trains and other equipment. Additional workshops would also be provided to accommodate the underground mobile plant fleet. A new fuelling and lubricant supply system and tanks would be established in the vicinity of Robinson Shaft.

Underground explosives magazine

The existing explosives magazine complex would be retained and extended to provide sufficient storage for the increased quantities of ammonium nitrate/fuel oil (ANFO) mixture, high explosives and detonators. An additional sump would be developed as a storage for molten ANFO should a fire occur in the magazine.

Amenities

Two crib rooms (lunchrooms), similar to the existing facilities, would be provided adjacent to the Whenan Shaft at RL –320 m AHD. Other amenities, including first aid stations and underground offices, would also be provided.

Sewage from the underground toilets would be treated underground by a two-stage digestion process, the first being anaerobic and the second aerobic with chlorination. The resulting odourless and sterilised effluent would be pumped to the surface by the existing pump station located at RL –420 m AHD for further treatment and disposal.

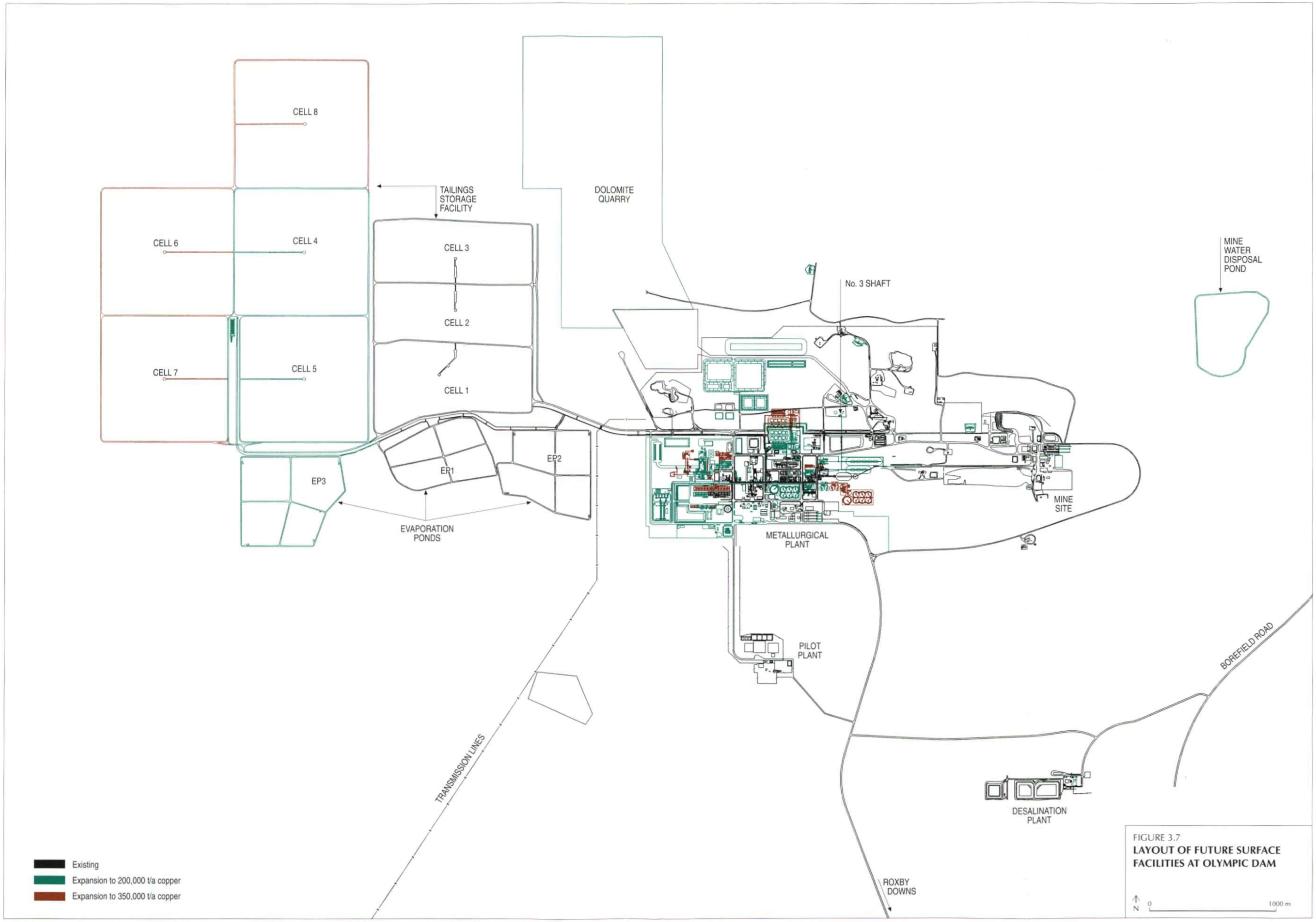


FIGURE 3.7
LAYOUT OF FUTURE SURFACE FACILITIES AT OLYMPIC DAM

3.4 LAYOUT OF SURFACE FACILITIES

3.4.1 200,000 t/a development

The layout of surface facilities at the plant site necessary to produce 200,000 t/a of refined copper is shown in Figure 3.7.

The main surface manifestation of the changes to the underground mining operations described in Section 3.3 would include the following:

- a head frame and winder facility associated with the new No. 3 shaft;
- an expanded dolomite quarry for the production of mine backfill material;
- an expanded batching plant for the production of structural mine backfill from mullock, quarried dolomite and tailings;
- additional ventilation shafts and corresponding fan installations for mine ventilation;
- main service corridors for power, mine water and potable water supply, and communications;
- surface settling ponds for the mine water, for subsequent reclamation and use both underground and on the surface for dust suppression.

The metallurgical treatment plant layout necessary to produce 200,000 t/a of copper is shown in Figure 3.8. This layout would include the placement of new facilities as infill between existing plant and some expansion of the metallurgical plant complex to the west.

The principal modifications to the metallurgical plant layout for a nominal capacity of 200,000 t/a refined copper (described further in Section 3.5) would include the following:

- a new ore stockpile located to the south-east of the existing stockpile;
- a new autogenous mill and additional flotation cells added to the copper concentrator section of the plant;
- expansion of the tailings leach area by the provision of additional countercurrent decantation (CCD) thickeners, a clarifier and two high compression tailings thickeners, and expansion of the copper–uranium solvent extraction area;
- construction of a new smelter complex with a nominal capacity of 180,000 t/a copper and associated acid plant of capacity 1,640 t/d of 98% sulphuric acid;
- revamp and expansion of the oxygen plant facilities, to a total capacity of 565 t/a;
- expansion of the copper refinery to a nominal capacity of 179,000 t/a electrorefined copper and 23,750 t/a electrowon copper;
- construction of a new gold and silver refinery;
- relocation and expansion of buildings and laboratories for technical services and administration;
- modifications to site services, including roadways, laydown areas, stormwater management and electrical distribution systems.

The modifications to the tailings retention system to accommodate a nominal production rate of 200,000 t/a of copper, shown in Figure 3.7, include the following:

- initial construction of another two cells of area 100 ha each, increasing the overall storage area to 390 ha, and progressive filling of these with tailings;
- construction of another lined four-cell evaporation pond of 50 ha, to increase the overall evaporation pond area to 118 ha, if the current paddock system for tailings disposal is continued;

- relocation and enlargement of the mine water disposal pond to 30 ha.

The above modifications, and an alternative option of tailings deposition using the central thickened discharge system, are described further in Chapter 8.

3.4.2 Possible 350,000 t/a development

The layout of surface facilities at the plant site necessary for the possible future production of 350,000 t/a of copper is shown in Figure 3.7. The metallurgical treatment plant layout necessary to produce 350,000 t/a of copper is also shown in Figure 3.8. The principal modifications to the 200,000 t/a plant include the following:

- additional grinding facilities;
- additional flotation cells;
- additional clarifiers and tailings thickeners;
- additional CCD thickeners;
- expansion of the copper–uranium solvent extraction area;
- duplication of the electrowinning/electrorefining complex;
- duplication of the copper smelter feed preparation area;
- construction of a third smelter and associated acid plant;
- duplication of the anode furnaces and anode casting wheel associated with the new 200,000 t/a smelter.

The modifications to the 200,000 t/a tailings retention system to accommodate a production rate of 350,000 t/a of copper, shown in Figure 3.7, would include the provision of a further three tailings storage cells of 110 ha each, increasing the overall storage area to 720 ha.

The above modifications, and an alternative option of tailings deposition using the central thickened discharge system, are described further in Chapter 8.

3.5 ORE PROCESSING

Section 2.2 described the metallurgical treatment process and facilities currently used at Olympic Dam. The proposed treatment process to be used in the expanded operations is based upon continued use of the current processing technology with some improvements. This section describes the technology and equipment proposed. The alternative technologies for mineral processing considered in earlier studies are discussed in Section 3.12.

3.5.1 Copper concentrator

The copper concentrator involves the reclamation of ore from stockpiles for grinding, and the separation of copper concentrates by flotation. Improvements that would be incorporated in the expanded plant include the use of a blending stockpile and ore reclamation system to blend run-of-mine ore, thereby producing a more consistent mill feed (in terms of copper grade) than is currently the case. A schematic process flowsheet is given in Figure 3.9.

Coarse ore stockpile

Two parallel coarse ore stockpiles would be provided as part of the Expansion Project. The stockpiles would have a capacity of approximately 140,000 t of ore, comprising 86,000 t on one stockpile and 54,000 t on the other.

The operation of the coarse ore stockpiles would involve the following:

- receival of run-of-mine ore by overland conveyor;

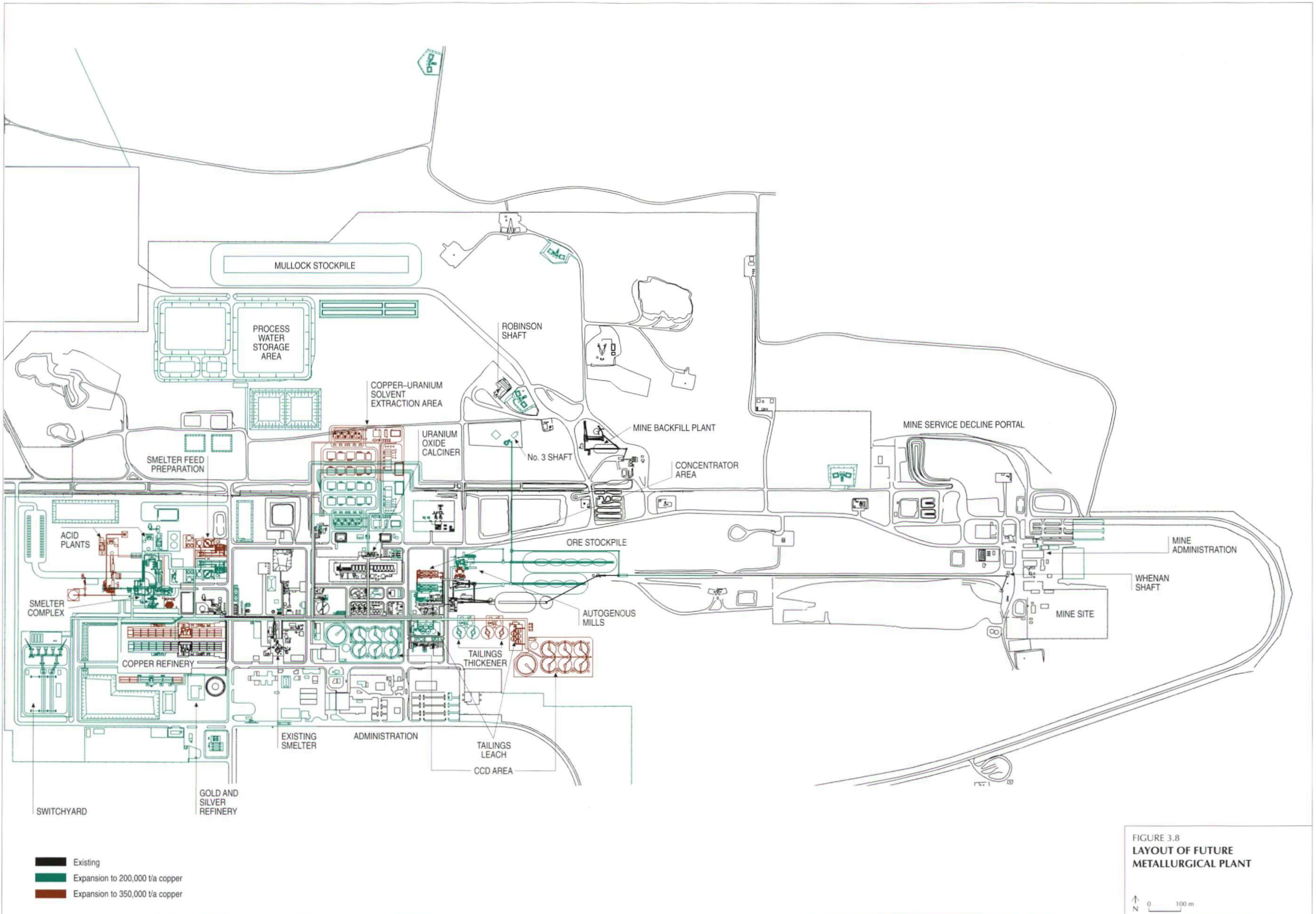


FIGURE 3.8
LAYOUT OF FUTURE METALLURGICAL PLANT

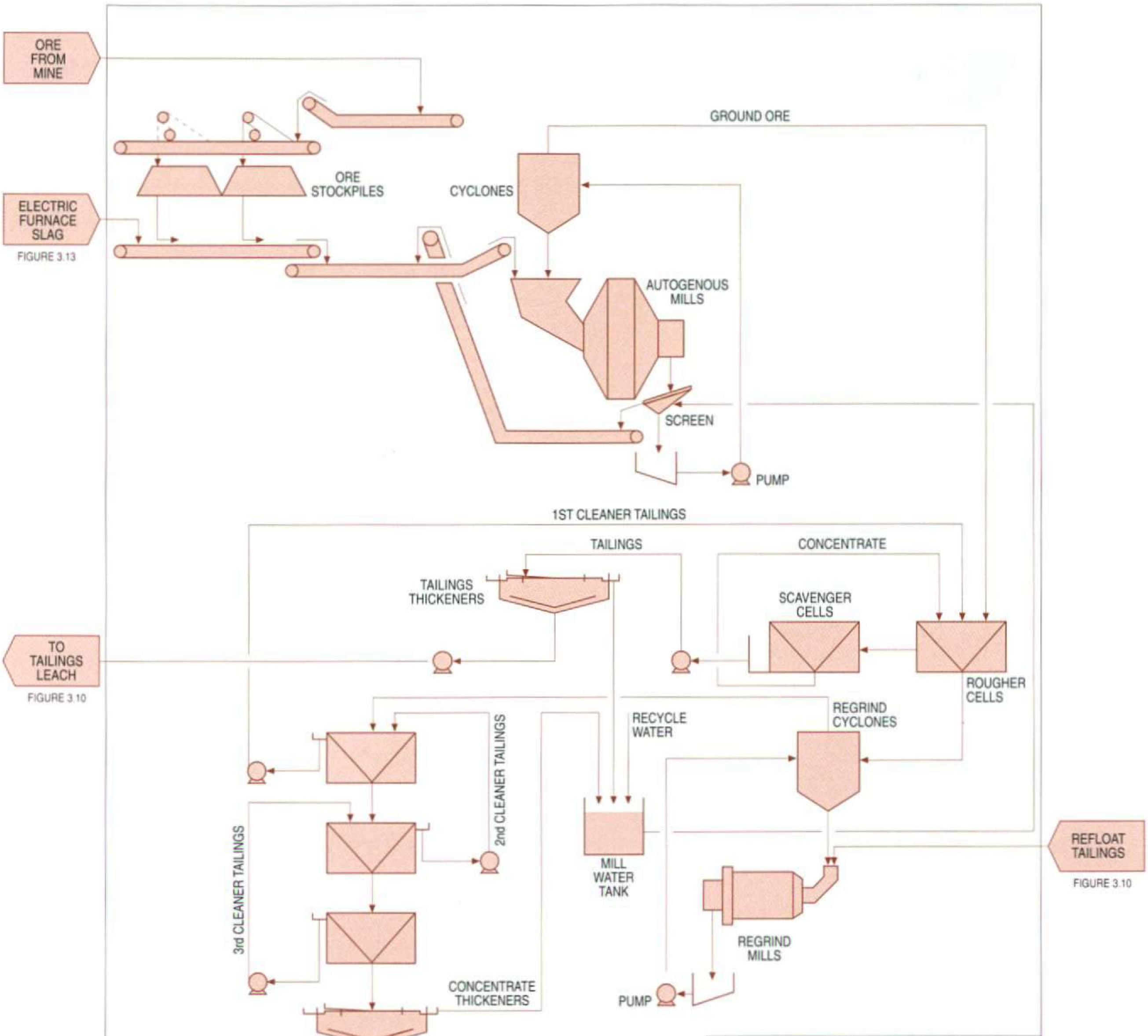


FIGURE 3.9
COPPER CONCENTRATOR (INCLUDING ORE GRINDING MILL) SCHEMATIC FLOWSHEET

- distribution of the run-of-mine ore to the stockpiles by a travelling stacker conveyor;
- recovery of ore from the stockpile by gravity to apron feeders underneath, and delivery by conveyor to the grinding circuit.

Grinding

Ore grinding would continue to be provided by autogenous mills. Each autogenous mill operates in closed circuit with screens and cyclones.

For the expansion to 200,000 t/a of copper, the existing 34 foot (10.4 m) diameter autogenous mill would be operated in parallel with a new 38 foot (11.6 m) diameter autogenous mill. The capacities of these mills are 415 t/h and 660 t/h respectively. Expansion to 350,000 t/a of copper would involve the installation of another mill of similar size.

Flotation

The separation of copper concentrates from the ore would continue to be provided by a flotation circuit, which involves the following:

- initial separation in flotation cells containing rougher and scavenger cells;
- regrinding of the coarse fraction of the concentrate;
- progressive cleaning of the concentrate by further treatment in flotation cells;
- thickening of the concentrate and tailings, and recovery of water for return to the grinding circuit.

The Expansion Project would involve the provision of additional flotation (rougher/scavenger and cleaner) cells and thickeners. The expansion to 200,000 t/a of copper would involve the duty of the existing tailings thickeners being changed to concentrate thickeners and two new tailings thickeners being constructed. These new thickeners would operate at a high solids density, thus reducing the overall use of process water. Expansion to 350,000 t/a of copper would involve the installation of further flotation cells and thickeners.

3.5.2 Hydrometallurgical plant

The hydrometallurgical plant has two functions:

- to clean and upgrade the copper concentrate before it is delivered to the smelter
- to extract uranium and any remaining copper from the flotation tailings.

The operation of the expanded hydrometallurgical and solvent extraction plant would be similar to the existing plant. An improvement proposed for incorporation in the expanded hydrometallurgical plant would be the use of pulsed column technology for uranium extraction. Pulsed column technology is currently being trialled at the existing plant. The use of pulsed column technology results in improved phase separation and reduced loss of organics. The schematic flowsheet for the hydrometallurgical plant is shown in Figure 3.10.

Concentrate leach

In concentrate leaching, the copper concentrate is leached with sulphuric acid to dissolve any contained uranium. The concentrate is thickened, filtered and neutralised prior to being refloated to reject waste material liberated during the acid leach. In the expanded plant, the final leached copper concentrate would then be sent to new smelting facilities via the feed preparation circuit, as described in Section 3.5.3.

The uranium-rich liquor produced in the acid leach is combined with other uranium leach liquors and further processed to recover uranium as described below. The tailings from the reflotation cells are returned to the concentrator for further processing.

For the expanded concentrate leach plant, the existing tailings leaching tanks and thickeners from the existing CCD circuit would be refurbished and retrofitted for the new duty. The expanded plant would also require additional minor tanks and pumps.

Copper and uranium solvent extraction and uranium production

The extraction of copper and uranium from the flotation tailings involves the leaching of uranium and any remaining copper with hot acid and oxidant (chlorate). The leach liquor is then separated from the tailings in a continuous CCD circuit.

The solids that have been washed thoroughly to remove the dissolved metals are pumped to the tailings retention system. Prior to disposal, the sand portion of some of the tailings is separated out by hydrocyclones to produce a product suitable for use in CAF for placement underground in mined-out stopes (Section 3.3).

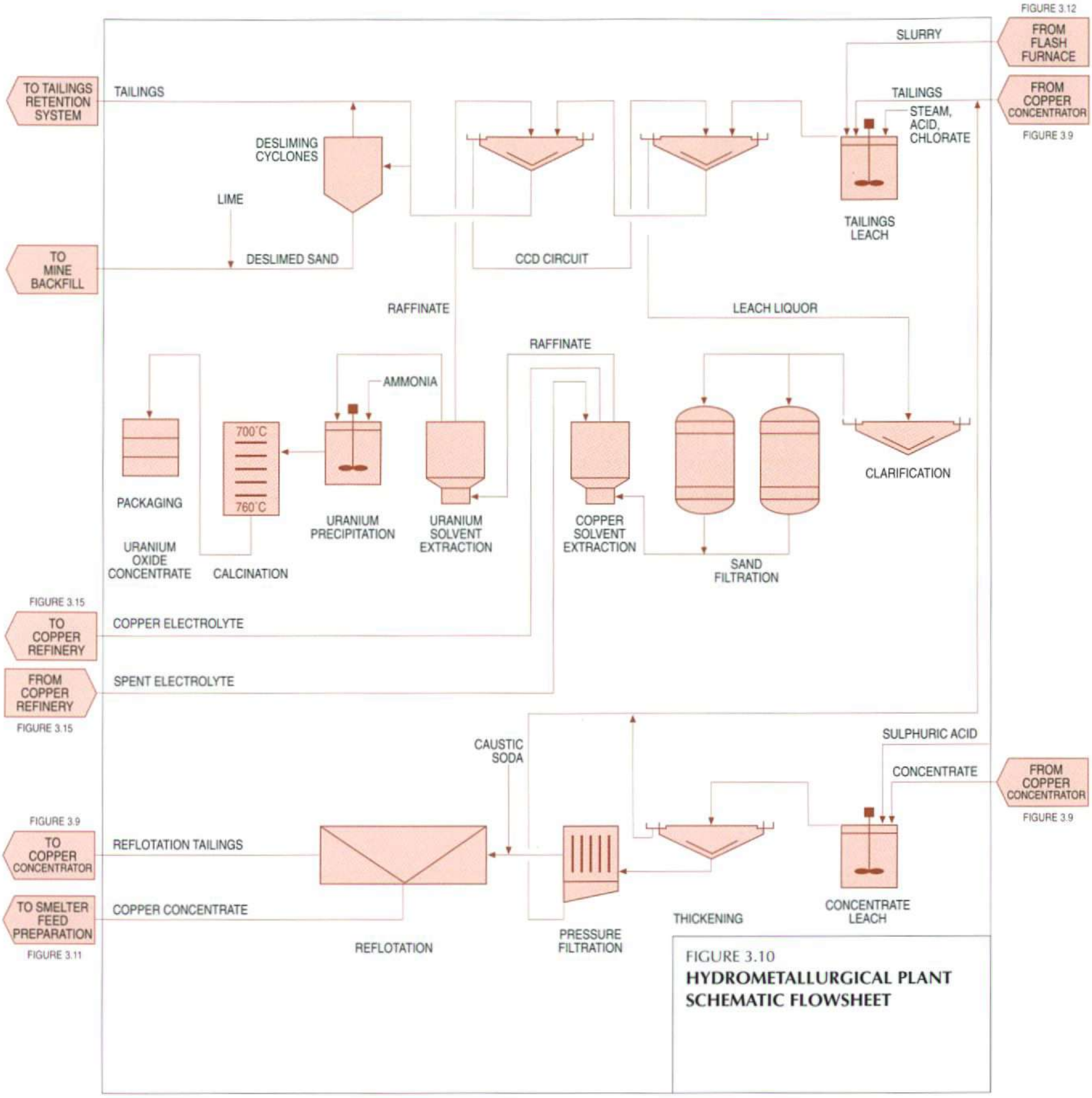


FIGURE 3.10
HYDROMETALLURGICAL PLANT SCHEMATIC FLOWSHEET

Clarification of the leach liquor takes place in a clarifier and sand filter prior to further treatment in copper and uranium solvent extraction circuits.

From the copper solvent extraction circuits, the concentrated copper solutions are delivered to the electrowinning circuit (Section 3.5.6), which is included in the copper refinery. The spent electrolyte is then returned from the copper refinery for reuse. The upgraded solution from the uranium solvent extraction is treated with ammonia to precipitate ammonium diuranate, commonly referred to as yellowcake. The yellowcake is calcined to produce uranium oxide concentrate (as U_3O_8), and then packaged for delivery.

The expanded facilities for production of 200,000 t/a of copper would include:

- additional agitated leach tanks;
- additional CCD thickeners and associated tanks and pipework;
- additional clarification plant, which would operate in parallel to existing plant;

- new copper solvent extraction plant (operating in parallel to existing plant), comprising mixer-settler plant constructed of HDPE-lined concrete;
- new uranium solvent extraction plant (operating in parallel to existing plant), comprising 17 m high fibreglass columns using pulsed column technology. Uranium scrubbing and stripping would be conducted in mixer-settler tanks constructed of HDPE-lined concrete;
- additional precipitation tanks and an additional centrifuge, operated in parallel with existing plant;
- upgrading of the existing desliming cyclones and a new sand delivery line to the cemented aggregate fill plant for use as mine backfill;
- additional reagents storage;
- a new calciner similar to, and operating in parallel with, the existing installation. The existing packaging plant would continue to be used for packaging uranium oxide concentrate.

The calciner would be a vertical multi-hearth type with rotating arms that move the concentrate from level to level. The unit would be diesel fired, and operate at 700–760°C. The uranium oxide concentrate would discharge to a trommel and then to a 20 t storage bin. Off-gases would be scrubbed in a high energy venturi scrubber.

The further expansion to 350,000 t/a would involve the installation of similar additional copper–uranium solvent extraction equipment, and a further calciner and packaging plant.

3.5.3 Copper smelter

Direct-to-blister copper smelter technology (licensed to the Finnish company Outokumpu Oy) would continue to be the means of producing copper metal (blister copper) from copper concentrates for the 200,000 t/a copper expansion. This phase of the expansion would involve the construction of a new direct-to-blister smelter to replace the existing smelter. The capacity of the new smelter would be 180,000 t/a blister copper. (The balance to 200,000 t/a refined copper would be via electrowinning from copper electrolyte produced in the hydrometallurgical plant.)

If the plant is expanded to 350,000 t/a, the function of the new smelter would change in that it would be used to produce blister copper by converting copper matte produced in a new flash smelter.

The new flash smelter would incorporate improvements in:

- the collection of sulphur dioxide from the process
- the conversion to sulphuric acid and the efficiency of sulphur dioxide control
- ventilation around the smelter and other furnaces.

The existing smelter would be placed on cold stand-by, but could be utilised if it was decided to increase overall copper production at Olympic Dam on an interim basis, using imported copper concentrates or other South Australian copper ores (Section 3.7).

Smelter feed preparation

The copper concentrate from the hydrometallurgical plant would continue to be prepared by thickening, pressure filtration and drying, as shown in Figure 3.11. The expanded facilities would be similar to the existing facilities but on a much larger scale. For expansion to 200,000 t/a of copper, this would involve the installation of two large filters and two new dryers. Expansion to 350,000 t/a of copper would involve the installation of similar additional equipment.

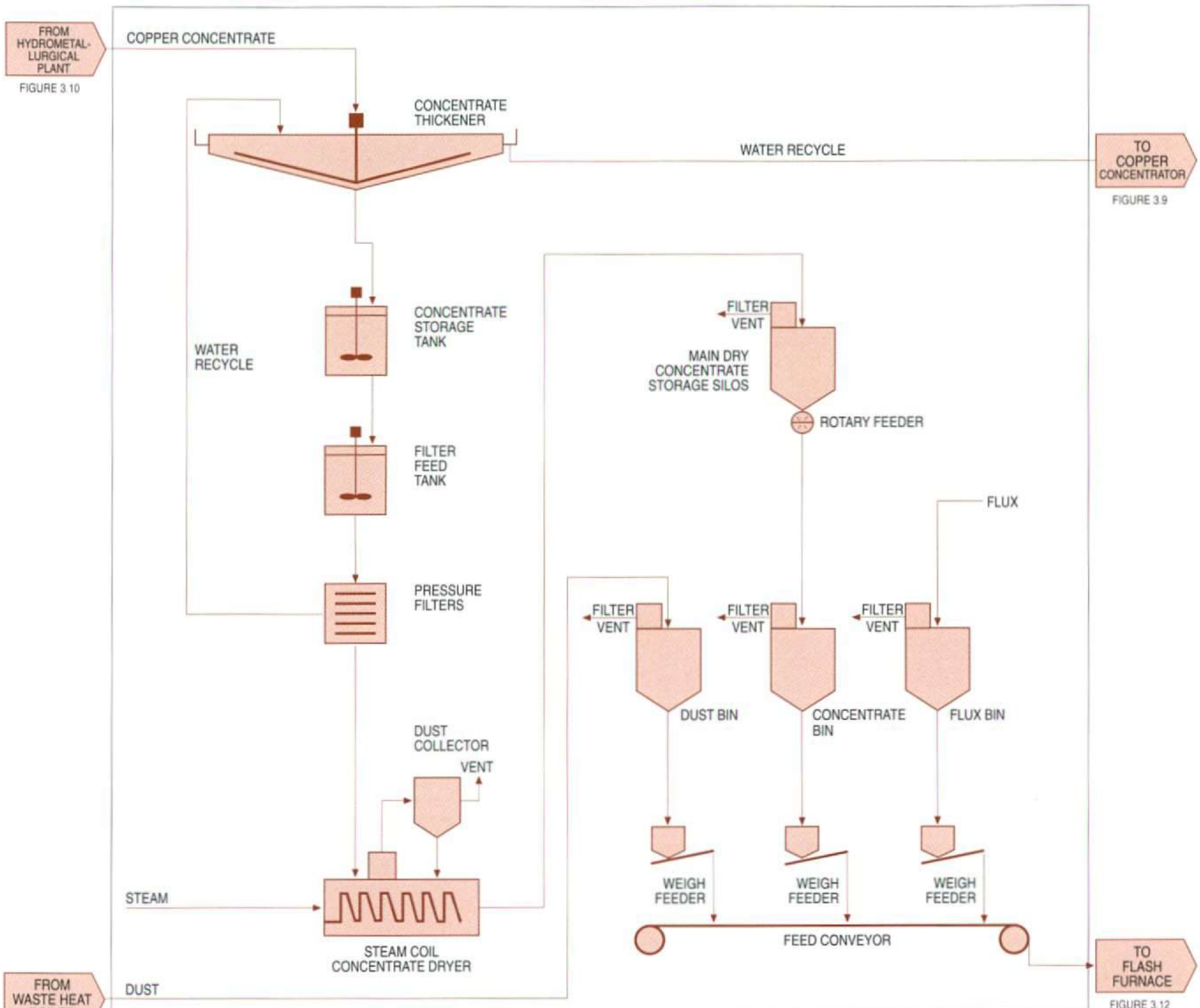


FIGURE 3.11
COPPER SMELTER FEED PREPARATION SCHEMATIC FLOWSHEET

Flash smelter

In the flash smelter, copper concentrate is fed into the smelter reaction shaft together with oxygen enriched air and silica flux (sand). The fine concentrates react, or 'flash', instantaneously to form copper and slag droplets and furnace gases containing sulphur dioxide. The blister copper and slag droplets fall to the furnace hearth and form two distinct layers that allow their periodic removal—the blister copper to two anode furnaces operated in parallel, and the slag to an electric furnace for the further recovery of blister copper.

The flash furnace gases are directed via the waste heat boiler and electrostatic precipitator to an acid plant where the sulphur dioxide is converted into sulphuric acid for use in the hydrometallurgical plant. Figure 3.12 shows the schematic flowsheet for the flash furnace and gas handling system, comprising:

- a waste heat boiler for the recovery of heat to be used elsewhere in the plant as steam, and associated facilities for the recovery of dust, for return to the process;
- an electrostatic precipitator for the recovery of dust, for return to the process.

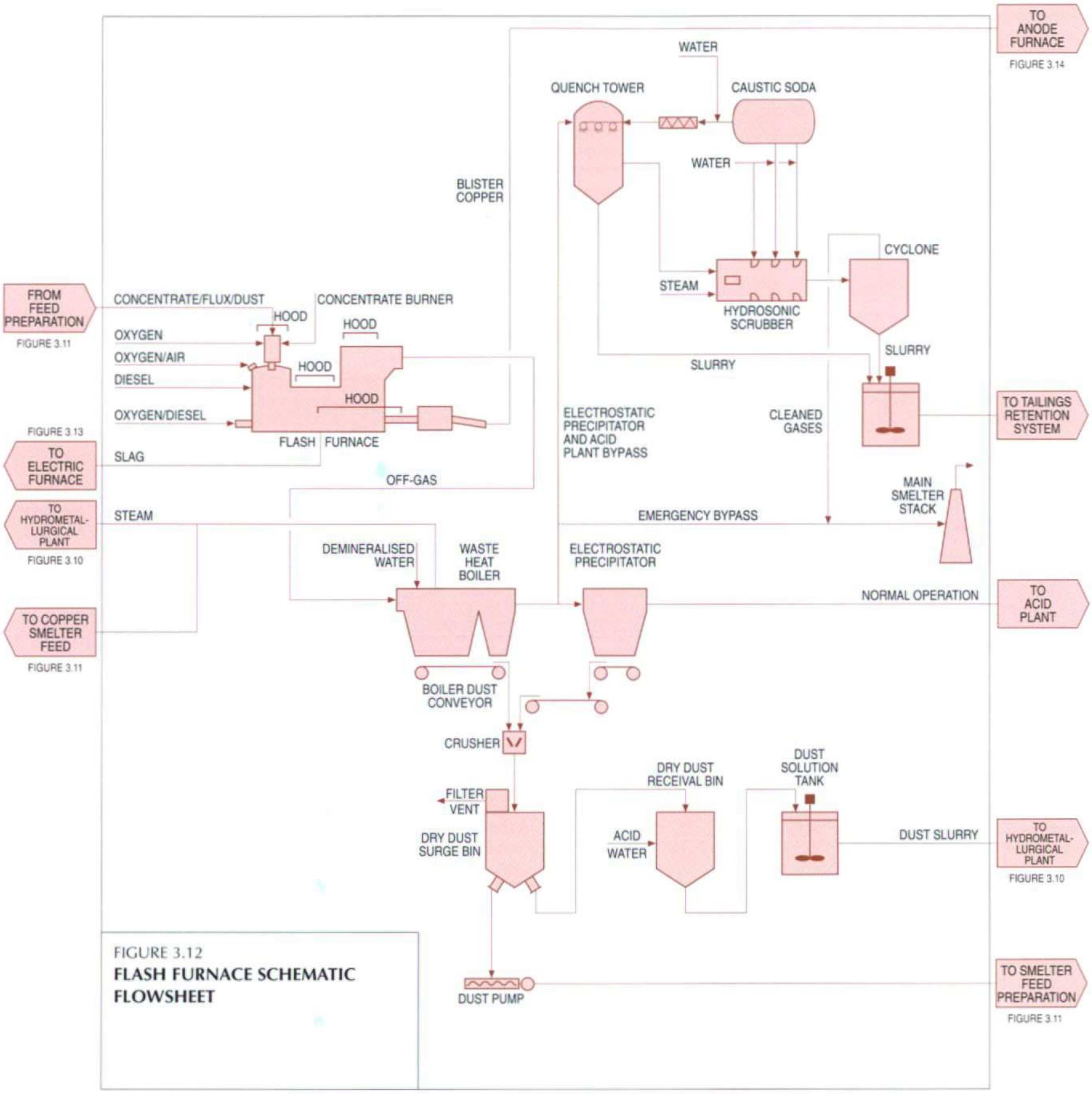


FIGURE 3.12
FLASH FURNACE SCHEMATIC FLOWSHEET

Dust from the flash furnace operation is primarily a result of incompletely reacted concentrate passing into the off-gas treatment system. The amount of dust generated by Olympic Dam's concentrate mixture is high, owing to the fine consistency of the feed. This has resulted in considerable costs associated with dust handling, maintenance and system shut-downs in the existing smelter. Minimising this dust generation is a high priority in the design of the new flash furnace. The intention is to design the concentrate burner and the furnace's internal gas velocities to minimise dust generation.

Flash smelter dust handling

Dust would be recovered from the flash furnace gases in the waste heat boiler and in an electrostatic precipitator. The chemical constituency of the oxidised dust collected in the waste heat boiler would be approximately 35–45% copper, 20–27% iron, 5–8% silica, less than 1% sulphur, and minor amounts of zinc, lead, bismuth, arsenic, alumina and lime.

Gases exiting the waste heat boiler would be at a temperature of approximately 350°C and would be laden with dust that would not settle in the boiler. This dust, as well as the condensed metals, would be collected in an electrostatic precipitator. The chemical constituency of dust collected by the precipitator would be approximately 25–40% copper, 5–15% iron, 15–25% sulphur and 5–15% silica.

The waste heat boiler dust would be mixed with electrostatic precipitator dust in the dry dust surge bin, where it would be diverted in approximately equal proportions to either the dust bleed or the dust pump. Overall, 7–8 t/h of dust would be collected in the waste heat boiler and electrostatic precipitator. In the dust bleed, dust would be mixed with acid and water and pumped to the hydrometallurgical plant for copper recovery and the removal of metal impurities. The dust pump would send the dust to the dry dust day bin from which the dust would be metered into the feed to the concentrate burner.

Bypass gas handling system

A bypass for the flash furnace gases would be provided to permit periodic inspection of the electrostatic precipitator and to handle certain conditions of acid plant shut-down. At these times, the flash furnace concentrate burner would be shut down, resulting in a rapid fall in particulate loadings in the off-gases. Sulphur dioxide concentrations, however, would persist at elevated levels for a short time.

A typical sulphur dioxide decay profile has been developed using data from existing operations. These indicate that the initial sulphur dioxide concentration would remain at around 30% volume for approximately fifteen minutes, drop to 10% volume in about the next ten minutes and then decay to a steady level of less than 1% volume within a further thirty minutes. A gas treatment system would control sulphur dioxide and particulate emissions to atmosphere during operation of the electrostatic precipitator bypass.

The operational frequency of the electrostatic precipitator bypass is expected to be once every one to two weeks, and total bypass time is expected to be approximately 100 hours per year. The gas treatment system for the electrostatic precipitator bypass would comprise the following:

- a deluge spray quench tower to cool and saturate the flash furnace off-gases. Caustic soda solution would be injected to provide a first stage of particulate and sulphur dioxide removal;
- a hydrosonic scrubber comprising a steam ejector using steam from the flash furnace waste heat boiler would provide the motive power for the scrubber. Water would be injected directly in the first stage of the scrubber, followed by two further injection stages of water dosed with caustic soda. The scrubber would provide a high degree of particulate and sulphur dioxide removal;
- a cyclone demister for removal of water droplets from the gases prior to their release to the atmosphere via the main smelter's scrubbed gases stack.

An emergency bypass for the flash furnace gases would also be provided for use when the electrostatic precipitator and acid plant bypass was unavailable. Use of the emergency bypass would be rare and is estimated to total less than eight hours per year. During operation, the emergency bypass would direct the hot flash furnace gases to the main smelter stack.

Flash smelter expansion staging

The plant expansion to 200,000 t/a of copper would involve installation of a new flash smelter of 180,000 t/a capacity together with an associated gas handling system. A new acid plant and oxygen plant would also be installed.

The expansion to 350,000 t/a of copper would involve the installation of a new flash smelter that would treat all the copper concentrates produced by hydrometallurgical plant into copper matte containing 62–68% copper. The copper matte would then be recovered, granulated, ground and fed into the 180,000 t/a flash smelter, which would operate as a flash converter to produce blister copper. Upgrades to the acid and oxygen plants would also be required. Metallurgical assessment has indicated that the 180,000 t/a flash smelter would have adequate gas handling capacity to meet flash converting requirements for the production of 350,000 t/a of copper when fed with a 68% copper matte.

Electric furnace

Slag produced by the flash smelter would continue to be treated in an electric furnace to recover copper. A new electric furnace of 11.5 m internal diameter would be provided as part of the expansion to 200,000 t/a of copper. A schematic flowsheet depicting the operation of the electric furnace and associated gas handling equipment is provided in Figure 3.13.

The electric furnace receives molten slag from the flash furnace and is then charged with coke and reverts (cooled slag from the flash furnace). Within the electric furnace, the blister copper and molten slag separate into layers, allowing periodic removal. The blister copper is sent to the anode furnaces for further processing, while the slag is cooled, broken up and returned to the grinding circuit of the concentrator.

In two important aspects, the slag cleaning operation undertaken in the existing electric furnace at Olympic Dam is unlike any other slag cleaning operation in the copper industry. Firstly, the slag from the flash furnace is very high in copper, a considerable part of which is copper oxide. Secondly, the presence of radioactive isotopes of lead (^{210}Pb) and polonium (^{210}Po) prevents lowering of the copper content in the electric furnace slag to less than 4%,

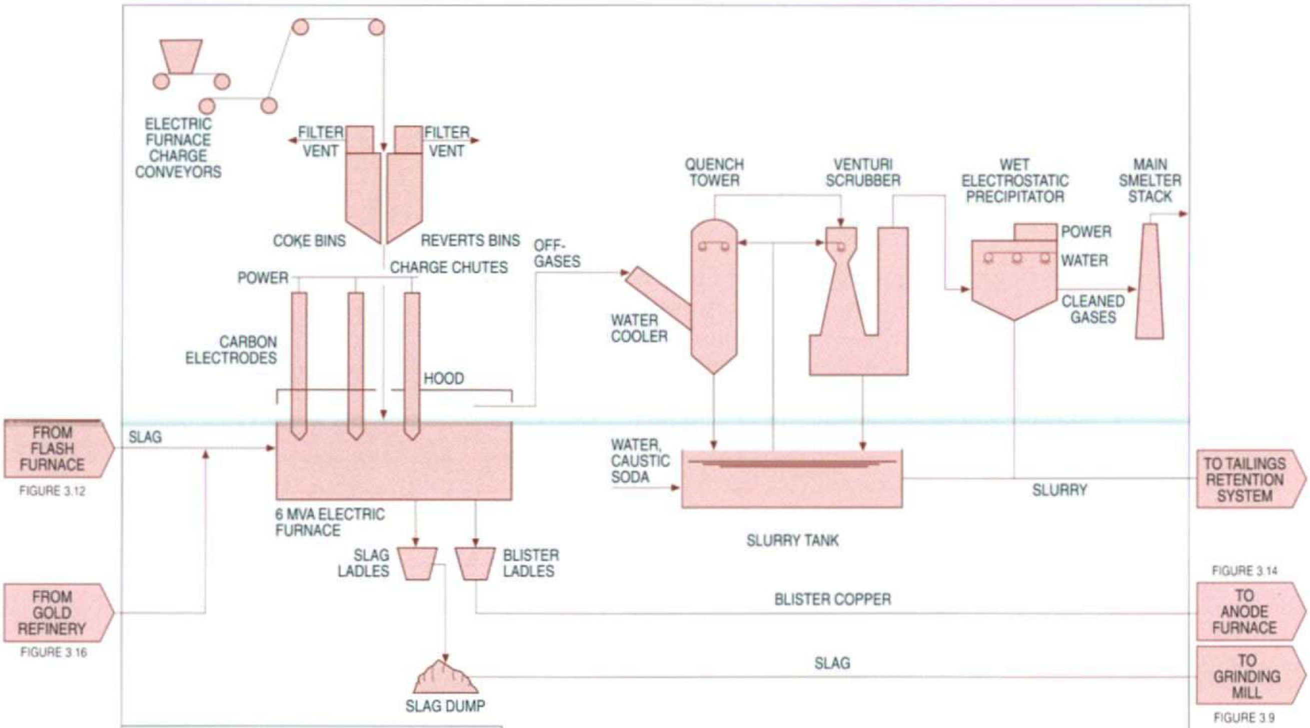


FIGURE 3.13
ELECTRIC FURNACE SCHEMATIC FLOWSHEET

as unacceptable levels of these components would otherwise appear in the blister copper. These radioactive isotopes are more easily controlled by treating the discard slag from the electric furnace by slow cooling and flotation of the copper. The radioactive components then follow the tailings and join the main mill tailings in the tailings retention system. The same approach would be adopted for the new electric furnace.

For the expansion, the electric furnace off-gases would leave the furnace fully combusted and would then be treated in a gas cleaning system which would comprise the following equipment:

- a quench tower incorporating a caustic injection system
- a venturi scrubber with further injection of caustic
- a wet electrostatic precipitator.

On leaving the wet electrostatic precipitator, the gases would have less than 75 mg/Nm^3 (dry) of particulates (mg/Nm^3 (dry) being a measure of gas volume) as well as heavy metal concentrations that would be within State standards and national guidelines. The gases would then pass to the main smelter stack via an induced draft fan.

The slurry collected from the gas cleaning system would be neutralised with caustic soda, thickened and then discharged into the tailings retention system.

For the expansion to 350,000 t/a copper using the copper matte/converter smelting system, the electric furnace may become redundant and be removed to make room for a granulator. However, should the control of radionuclides require a two-stage slag treatment operation similar to that for the existing direct-to-blister process, the 11.5 m diameter electric furnace would be more than adequate for the treatment of flash converter slag.

Anode furnaces and casting wheels

The refining of blister copper from the flash and electric furnaces would continue to be done in anode furnaces. For the expansion to 200,000 t/a, two new anode furnaces and a new anode casting wheel would be installed. Expansion to 350,000 t/a would involve a further two anode furnaces and another anode casting wheel.

Pyrometallurgical refining within anode furnaces is currently undertaken in batches involving:

- an oxidation phase, wherein the molten copper is injected with air in order to liberate the remaining sulphur;
- a reduction phase using liquefied petroleum gas (LPG) to remove oxygen.

Pyrometallurgical refined copper is then tapped to the anode casting wheel. The cast anodes are washed, weighed and delivered to the copper refinery. A schematic flowsheet of the anode furnace and casting wheel operation is provided in Figure 3.14.

The gas cleaning system for the anode furnaces would incorporate diversion of gases generated in the oxidation and blister copper filling stages to the acid plant.

In this process, off-gases from each anode furnace would pass through a hood and after-burner duct. During the reduction stage, combustion of unburnt gases would take place, with the exhaust temperature controlled to approximately 1,000°C. During other stages of the furnace cycle, the off-gas temperatures would be lower. The after-burner duct would discharge to a spray water quench tower, which would cool and condition the gases before they passed to a venturi scrubber. The quench tower would cool the gases to approximately 78°C, and remove coarse particulate matter. Quenched gases would then pass directly to a wet electrostatic precipitator, for fine particulate removal.

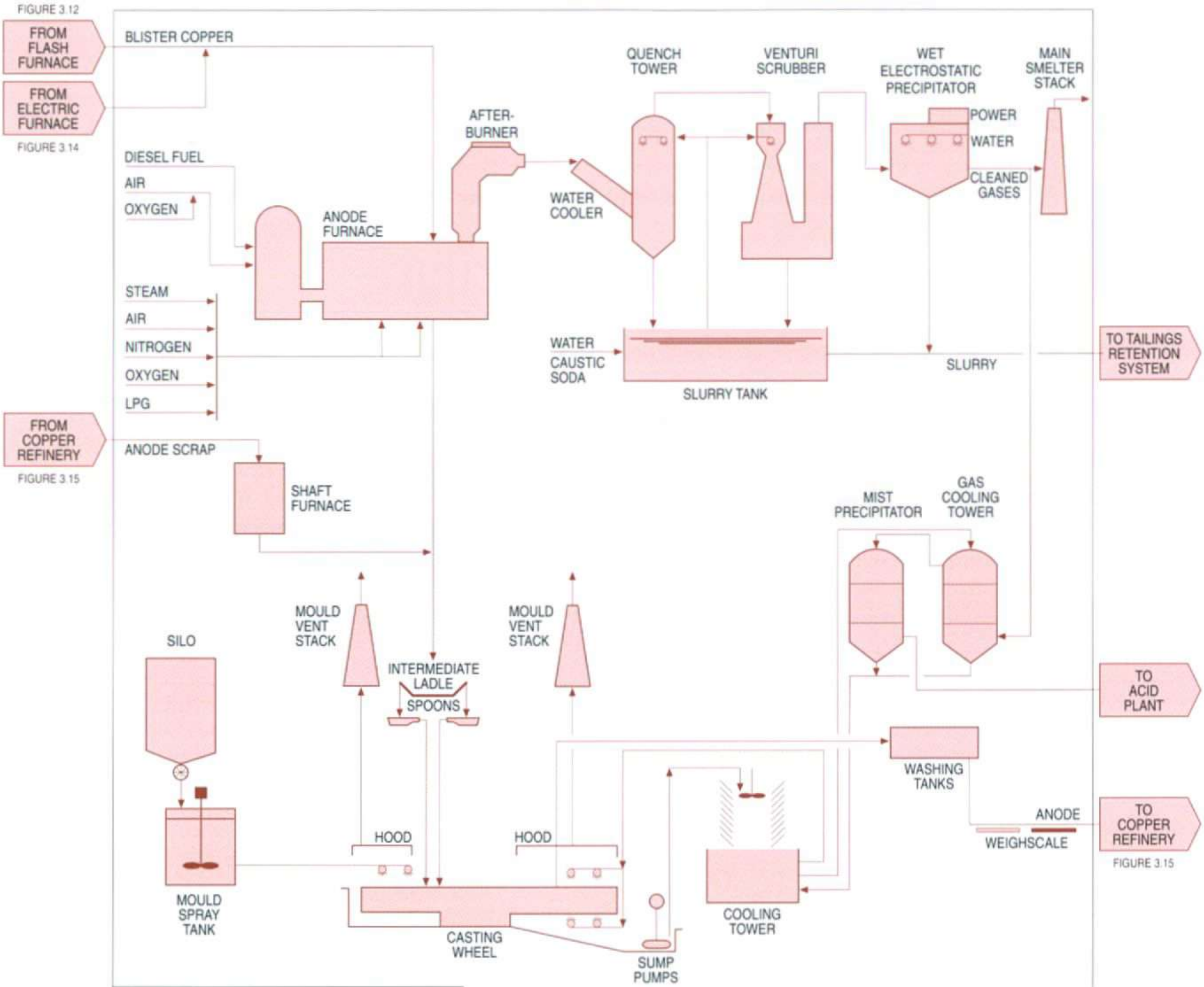


FIGURE 3.14
ANODE FURNACE AND CASTING WHEEL SCHEMATIC FLOWSHEET

During the reduction, casting and holding stages, where there would be no significant sulphur dioxide levels, the cleaned gases would discharge to the main smelter stack in conjunction with other smelter dry gases. During the oxidation and blister copper filling stages, the gases leaving the wet electrostatic precipitator would be diverted to the acid plant via a gas cooler/radial flow scrubber, a first-stage mist precipitator and a second-stage mist precipitator. This treatment would deliver optically clear gases at less than 25 mg/Nm^3 (dry) particulate and 40°C to the acid plant.

Flash furnace and electric furnace ventilation

Ventilation air for the new flash furnace and electric furnace would be drawn from the roof, tapholes and launders on the electric furnace and from the reaction shaft, uptake shaft, tapholes and launders on the flash furnace. The separate air flows would be ducted to the main smelter stack. Pollutant discharge limits for the ventilation air would be set at less than 75 mg/Nm^3 (dry) of particulates and 700 mg/Nm^3 (dry) of sulphur dioxide. Heavy metal emissions would be within the State standards and national guidelines.

Main smelter stack system

The main smelter stack would be a double flue arrangement 90 m high, supported by an external steel framework. One flue would be fibre-reinforced plastic, to be used for scrubbed smelter gases and ventilation gases. The other flue would be steel and would serve the acid plant.

The smelter stack design has been subject to extensive dispersion modelling to assess the adequacy of the proposed height. This is discussed further in Chapter 9.

3.5.4 Acid plant

A new acid plant would be installed for the expansion to 200,000 t/a copper. This acid plant would receive metallurgical gases continuously from flash smelting furnace operation and produce sulphuric acid. The nominal design capacity for the acid plant from flash furnace gases would be 1,415 t/d of 98% sulphuric acid.

The acid plant would also continuously burn sufficient sulphur to produce between 100 t/d and 900 t/d of sulphuric acid. This production would be in addition to that produced from metallurgical gas. At the minimum sulphur burning rate and the maximum flash furnace rate, the continuous capacity of the acid plant would be 1,515 t/d. When treating anode furnace oxidation gases in addition to flash furnace gas, the capacity of the acid plant would increase by up to 110 t/d. When treating anode furnace copper blister filling gases, the capacity of the plant would increase by up to 15 t/d.

The sulphuric acid plant would be a double catalysis/double absorption design to ensure efficient conversion of sulphur dioxide to sulphur trioxide, and efficient absorption of the latter. The plant would be equipped with mist eliminators and would use gas monitors on the stacks to continuously review plant performance. The plant would be equipped with a preheat system to enable the plant to rapidly reach optimum sulphur dioxide conversion efficiency during start-up.

The oxidation section of the acid plant would be designed for a maximum total flow rate of 130,000 dry Nm^3/h, comprising gases from the new flash furnace and anode furnaces, and gases from the combustion of sulphur and dilution air. The acid plant stack would be 90 m high and would be part of the main smelter stack system described in Section 3.5.3.

The gas leaving the acid plant would be optically clear and contain not more than 2 kg of sulphur dioxide per tonne of 100% sulphuric acid and 0.075 kg sulphur trioxide per tonne of 100% sulphuric acid, in conformance with the national emission guidelines. Stack emissions would also not exceed the State emission standards of 3,000 mg/m^3 of acid gases expressed as sulphur trioxide and 100 mg/m^3 acid mist expressed as sulphur trioxide.

A production rate of 350,000 t/a copper would require duplication of the new acid plant.

3.5.5 Oxygen plant facilities

The existing oxygen plant facilities have a total capacity of 154 t/d and comprise four separate oxygen plants that collectively produce the total oxygen requirements for the existing metallurgical plant. These oxygen plants comprise the following:

- a 115 t/d cryogenic oxygen plant that houses its own air compressors and produces low-pressure oxygen;
- a 17 t/d cryogenic oxygen plant that does not house its own air compressors and draws on plant air produced by the existing compressor plant;
- two 11 t/d pressure swing absorption (PSA) oxygen plants owned by BOC Gases of Canada and contracted to WMC to provide low-pressure oxygen.

New oxygen plant facilities rated at a total of 450 t/d would be installed in proximity to, and to the west of, the new smelter facility location for expansion to 200,000 t/a of copper. This equipment could be installed in two or three stages. On completion of commissioning, the new oxygen plant facilities, the two existing 11 t/d PSA plants and the 17 t/d cryogenic oxygen plant would be decommissioned. The 115 t/d plant would remain in operation in its present location, giving a total oxygen plant capacity of 565 t/a.

After the expansion, there would be a small demand for high-pressure nitrogen, which is a by-product of the oxygen plant. This nitrogen would be required at the two new anode furnaces for the injection of inert gas through the anode furnace tuyeres and for the pneumatic transport of concentrates. A secondary need for nitrogen would be for fire fighting requirements at the new and existing dry concentrate silos.

Expansion to 350,000 t/a of copper would require the installation of further similar oxygen production plant.

3.5.6 Copper refinery

High purity copper cathode (99.99% pure) would continue to be produced by the electrorefining of copper anodes and electrowinning from copper electrolyte produced in the hydrometallurgical plant. In the existing plant, both of these processes are conducted in the same refinery building. Following the expansion, the two processes would be undertaken in separate buildings.

Figure 3.15 provides a schematic flowsheet for the future operation of the copper refinery. The processes involved are described further below.

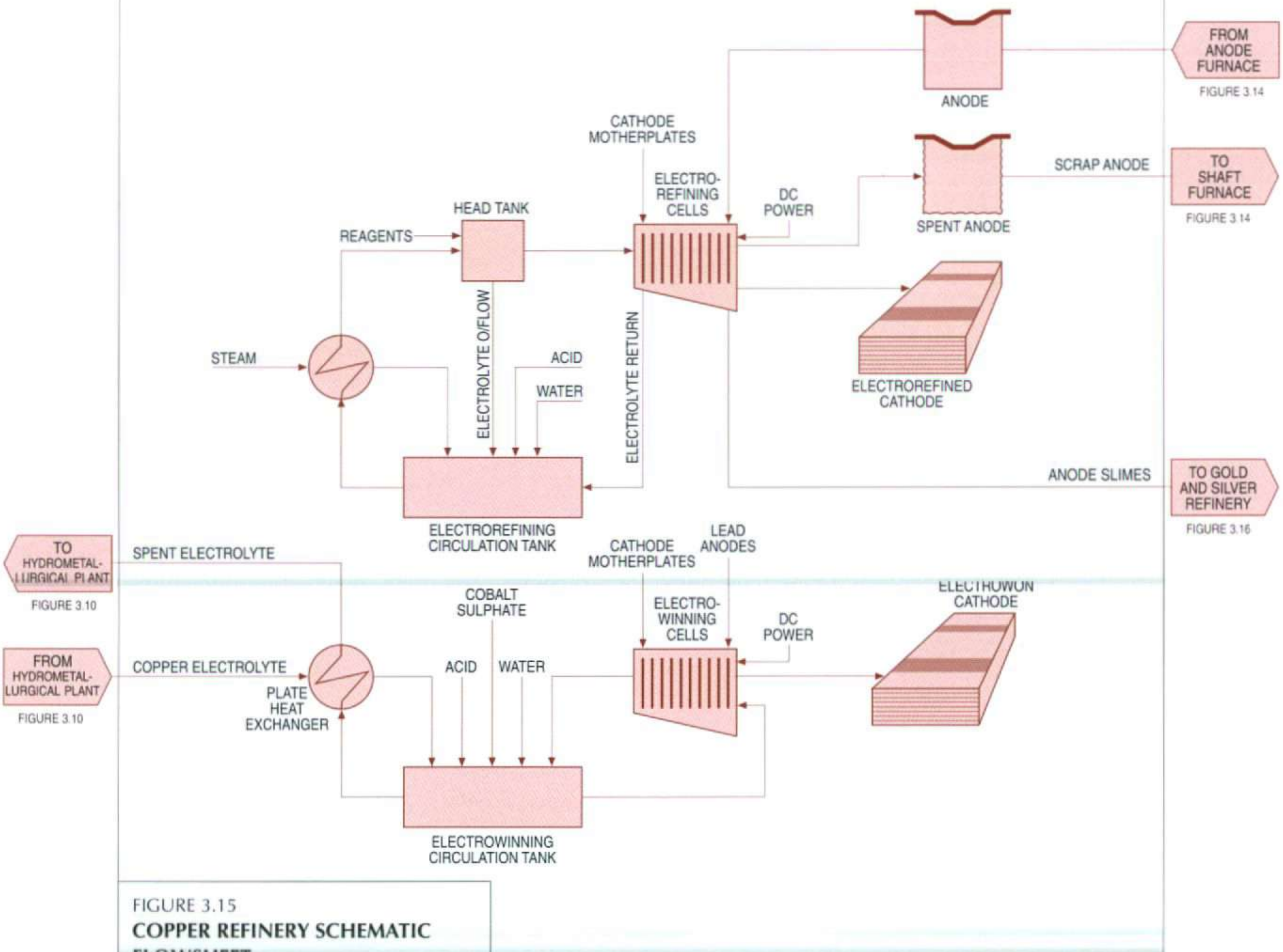


FIGURE 3.15
COPPER REFINERY SCHEMATIC FLOWSHEET

Electrorefining

For the expansion to 200,000 t/a copper, the capacity of the copper refinery would be increased to 179,000 t/a electrorefined copper. The existing total production stripping system would be retained. In this process, stainless steel permanent cathodes act as motherplates for cathode production, and an automatic stripping machine separates the copper cathode from the motherplate. The copper cathode is then weighed, bundled and strapped for shipment.

Anodes and anode scrap would be transported using a heavy-duty trolley system. Anodes would be individually weighed and rejected if outside a predetermined weight range at the smelter prior to transport to the refinery. A new 22 t overhead electric crane would be used to load prepacked bundles of anodes into the cells, and to unload scrap anodes and cathodes for stripping.

Most of the existing cells are of the lined concrete type. The new cells would be constructed from polymer concrete, similar to those installed in recent plant optimisations. The electrolytic cells would contain the anodes and stainless steel motherplates as cathodes. Copper from the anodes would be deposited on the motherplate by passing DC current through an acidic copper sulphate solution.

The electrolyte solution would be circulated through the cells by two circulation systems, each servicing half of the cells. Each of the two circuits would have dedicated heat exchangers to maintain electrolyte at 62°C, and head tanks where reagents were added to control the quality of the deposit.

During the twenty-one day refining cycle, the anodes would dissolve and three crops of cathodes would be harvested on the sixth, thirteenth and twenty-first days. The cathodes deposited on the motherplates would be washed, stripped, stacked, weighed, and bundled ready for shipment in an automated cathode washing and stripping machine. At the end of an anode cycle, the anode scrap would be washed and stacked in an automated anode scrap washing machine and transported by the trolley system back to the smelter for remelting.

Insoluble impurities in the anodes (including mould wash, precious metals and fine copper powder) which settle as slimes to the bottom of the cells would be pumped to the gold and silver refinery after each complete anode cycle. All deslimed solutions would be returned to the circuit via filters, which would also filter, as a side stream, a volume equal to 20% of the circulating solution. The electrolyte copper strength and soluble impurities such as arsenic and nickel would be controlled by bleeding spent electrolyte back to the hydrometallurgical leach circuit. Bismuth would be recovered by treating an electrolyte bleed stream in a small ion exchange plant.

Electrowinning

The electrowinning cells, with a capacity of 23,750 t/a of electrowon copper, would be housed in a separate building north of the existing refinery. All cells would be of polymer concrete construction and located at ground level.

In the electrowinning process, clean strong electrolyte is pumped from the hydrometallurgical plant solvent extraction area to the electrowinning circulation systems. Spent electrolyte is returned to the solvent extraction plant. The incoming strong electrolyte is heated with steam in a plate heat exchanger that maintains the circulating electrolyte temperature at 40°C.

The electrowinning cells contain insoluble lead anodes and stainless steel permanent cathode motherplates. In the cells, the electrolysis process reduces copper in the solution and deposits it as metal on the cathodes. Oxygen is released at the lead anodes. The copper-depleted electrolyte returns to the circulation tank, where part of the flow is removed and mixed with the incoming strong electrolyte to make the cell feed. Make-up sulphuric acid is also added to the spent compartment of the circulation tank.

A bleed stream is used to control iron and other impurities in the electrolyte, this stream being removed after the addition of make-up water. The bleed is pumped to the concentrate leach area in the hydrometallurgical plant, where the acid is consumed in the leach reactions.

An acid mist is generated by the liberation of oxygen produced at the anodes. This mist is controlled by adding polyethylene beads to the cells, which float on the electrolyte surface, and by using a foam additive that fills the interstices in the bead layer. Recent trials with an improved foam at the existing electrowinning cells have demonstrated improved control of acid mist.

The new copper refinery design provides for automated copper stripping using permanent stainless steel cathodes. In this operation, an overhead bridge crane (relocated from the existing electrorefinery) transports cathode plates to and from an automatic cathode stripping facility. Cathodes are harvested on a seven-day cycle from the cells.

At the stripping machine, the cells are placed on a conveyor and automatically taken through a spray wash booth. Following washing, the copper cathode sides are stripped by flexing and collected in stacks. The cathodes are then weighed, sampled and banded for shipment on the discharge conveyor, and removed and stacked by forklift truck.

The new copper refinery building would be open-sided to cell walkway level to allow natural ventilation. The building would be designed to allow the future installation of cross-flow ventilation fans, if improved acid mist extraction was found to be necessary.

3.5.7 Gold and silver refinery

The new gold and silver refinery would recover these metals from slimes deposited in the electrorefinery cells, in a process very similar to that in use in the existing plant. The existing refinery would be closed down.

The process involves treatment of the slimes with cyanide to dissolve the gold and silver followed by precipitation of these metals with zinc. Two stages of electrolytic cells recover the silver and gold as pure products, which are then individually smelted into bullion.

Figure 3.16 shows the schematic flowsheet for the refining of gold and silver from anode slimes. In the process, the anode slimes, containing precious metals and residual radionuclides, are washed from the electrolytic cells during the anode replacement cycle into collection tanks and pumped to the slimes treatment plant where they are filtered to remove the bulk of the contained electrolyte. The electrolyte is in turn filtered and returned to the copper refinery.

After filtering, the slimes are leached to remove the contained copper prior to being neutralised and then subjected to intensive cyanidation, which dissolves the contained gold and silver. The cyanided residue is reslurried and pumped to the tailings retention system for disposal, and the waste cyanide solutions are treated with ferrous sulphate prior to disposal, to ensure cyanide in solution is not passed to the tailings retention system. The gold and silver-bearing cyanide solution is pumped into the gold room for further processing.

The precious metal bearing cyanide solution is treated in a zinc precipitation step to precipitate the gold and silver. This precipitate is leached to remove residual zinc, copper and selenium. The acidified precipitate is dried in a rotary kiln, combined with fluxes and smelted in the rotary gold room furnace to form doré metal, which is cast as a round ingot known as a 'button'.

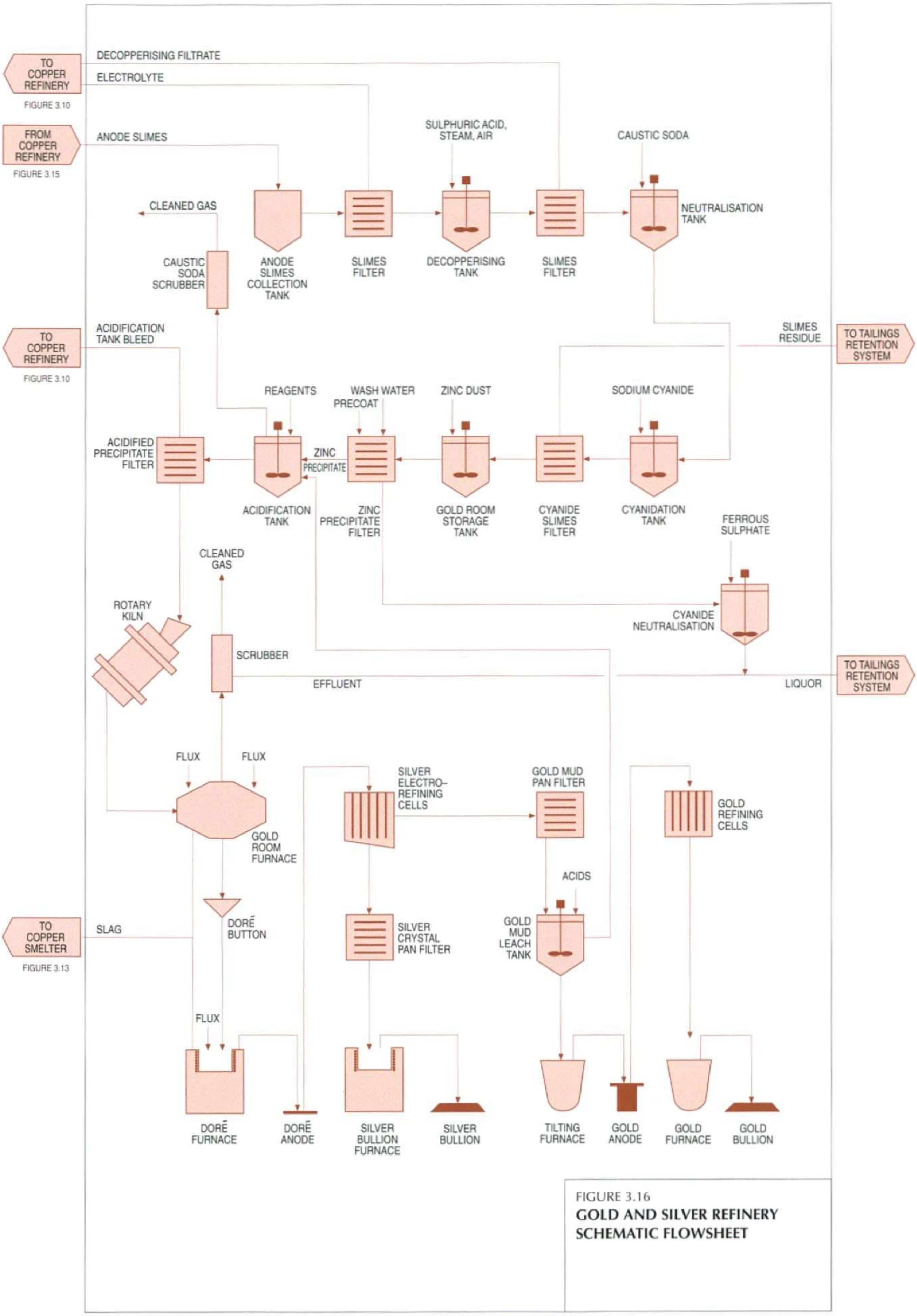


FIGURE 3.16
GOLD AND SILVER REFINERY SCHEMATIC FLOWSHEET

The doré buttons are remelted in an induction doré furnace and cast to form doré anodes to feed the silver electrorefining cells. The silver crystals deposited on the cathodes are collected, washed and remelted in a separate induction furnace to produce silver bullion.

The gold in the doré anodes forms a slime (or mud) in the silver electrorefining cells which is collected, leached to remove residual silver, and melted to form gold anodes. The anodes are refined in gold refining cells, where gold is deposited on titanium cathode motherplates. The gold is stripped, melted and cast again into gold anodes.

These anodes are then refined again in another set of refining cells to produce gold cathode deposits on titanium motherplates. This double refining eliminates any radionuclide contamination of the gold product. The gold deposits are stripped from the titanium motherplate and melted to produce 99.99% refined gold bullion.

The air pollution controls for the new gold and silver refinery would be similar to the existing gold and silver refinery, described in Section 2.2. Nitrogen oxides produced in the acidification tank would be scrubbed in a caustic soda scrubber system, and particulates arising in the rotary furnace would be scrubbed in a venturi scrubber.

3.6 MATERIALS HANDLING AND TRANSPORT

3.6.1 Raw materials

Ore derived from on-site mining would continue to be the principal raw material handled on site, as described in Section 3.1. In addition, on-site process plant would continue to be used as the principal source of sulphuric acid and oxygen used in the metallurgical process and in the smelter.

Other raw materials, including chemicals used in the metallurgical process, would continue to be sourced off site from established suppliers and transported to the site by road. Table 3.3 summarises the chemical use for the existing and expanded project.

It can be seen from Table 3.3 that the transport of dolomite and nitrogen would be introduced to the site following the Expansion Project while the transport of acid and lime would cease. Dolomite and nitrogen are routinely transported safely throughout Australia.

The safe packaging and transport of chemicals to Olympic Dam is ultimately the responsibility of suppliers and transport companies. However, WMC would require them to undertake these activities in accordance with relevant legislation and codes of practice (Tables 1.5 and 1.6).

On-site storage of chemicals would be undertaken in dedicated storage areas designed, constructed and operated in accordance with relevant legislation and codes of practice (Tables 1.5 and 1.6). In particular this would include, but not be restricted to:

- inventory control
- restriction of access
- separation according to hazard classification
- provision of impervious surfaces and bunding as appropriate
- maintenance of a database of material safety data sheets.

Site safety, emergency response capabilities and contingency planning issues are discussed further in Chapter 15.

Table 3.3 Annual site chemical use[1]

Chemical	Existing plant (1995–96)	Expanded Project copper production	
		200,000 t/a	350,000 t/a
Acid from site (t)	91,455	444,967[2]	810,446
Acid from off site (t)	53,822	0	0
Alcohol (t)	24	43	130
Amine (kL)	63	86	260
Ammonia (t)	1,546	4,509	7,504
Borax (t)	35	81	179
Caustic soda—liquid (kL)	1,036	3,875	6,933
Caustic soda (t)	26	67	112
Coagulant (t)	1,021	1,929	3,453
Cobalt sulphate (t)	5	15	28
Cyanide (t)	71	187	310
Dolomite (t)	0	19,320	85,168[3]
Ferrous sulphate (t)	74	207	344
Flocculant (t)	473	863	1,545
Frother (kL)	115	420	752
Hydrogen peroxide (kL)	92	215	476
Kerosene (kL)	1,978	3,505	11,482
Lime (t)	2,077	0	0
Silica (t)	18	42	54
Nitric acid (kL)	19	45	99
Nitrogen (t)	0	16,443	29,514
Oxime (t)	94	164	598
Oxygen (t)	61,004	114,017	183,001
Soda ash (t)	227	624	1,097
Sodium chlorate (t)	5,380	13,653	24,434
Sodium nitrate (t)	14	31	70
Sulphur (t)	3,231	52,543	90,657
Wax (t)	16	33	56
Xanthate (t)	241	667	1,193
Zinc dust (t)	29	67	148

1 *Excludes fuels which are given in Table 3.7.*
2 *Includes acid from burning sulphur.*
3 *Includes provision for treatment of acidic liquor for minimisation of water use.*

3.6.2 Products

The products that would continue to be produced at Olympic Dam are:

- copper cathode
- uranium oxide concentrate
- refined gold
- refined silver.

All of the above are currently transported from the site by road, an arrangement that would continue following the expansion. The particular handling and transport requirements for each of the products are discussed below.

Copper

Copper product from Olympic Dam would continue to be in the form of copper cathode sheets. These sheets are currently bundled into packs weighing approximately 3–3.5 t and stored in an open area prior to transport. They are then loaded by forklift on to trucks for transport from the site.

The copper cathode sheets do not have any particular transport requirements. Currently, use is made of empty supply trucks leaving the site to backload this product, and this practice would continue following the Expansion Project.

Uranium oxide

All uranium oxide produced at Olympic Dam would continue to be exported through Port Adelaide. Presently, shipping occurs about three times a year. This would increase to about six to eight times a year following the 200,000 t/a of copper expansion. The current shipping arrangements are as follows:

- The uranium oxide is packaged into 205 L steel drums (Figure 2.8) specially marked with an identification of the contents, a serial number, the contained weight and the origin of the product.
- The loaded steel drums are stored within a designated warehouse on site.
- When a shipment is due and the ship has arrived at Port Adelaide, the entire shipment of steel drums is loaded by forklift truck into 2 m x 2 m x 6 m shipping containers, which are then loaded on trucks.
- The trucks carrying the entire shipment are assembled into a convoy to travel to Port Adelaide under escort, with the convoy including empty containers and equipment necessary to recover any spillage in the unlikely event that this occurs.
- The shipping containers are loaded directly on to the awaiting ship.

The arrangements outlined above have been used successfully, without incident, since production began at Olympic Dam in 1988. Any changes to these arrangements would be subject to review and approval by regulatory authorities.

Gold and silver

Gold and silver bullion is currently stored under secure conditions within the gold room prior to armoured and escorted transport to Adelaide. These arrangements would continue for the Expansion Project.

3.7 IMPORTATION OF COPPER CONCENTRATES OR OTHER ORES

Two opportunities would exist after the Expansion Project for the purchase and treatment of imported copper concentrates or other South Australian copper ore to supplement Olympic Dam production. These opportunities are:

- use of surplus capacity in the new upgraded concentrator and smelter in the early years of their operation, while mine output is being increased, by supplementing either the new smelter with imported copper concentrate or the upgraded concentrator and new smelter with other South Australian copper ore;
- use of the existing smelter, which would otherwise be shut down, to smelt concentrate produced on site, thereby providing additional capacity in the new smelter for treatment of imported concentrates.

Imported copper concentrates or other ore would be blended with mine concentrates or ore and used as feed for the upgraded concentrator and/or new smelter as appropriate. Continued use of the existing smelter would be based on the use of concentrates derived from ore mined at Olympic Dam.

A preliminary review of western world producers of copper concentrates has indicated a number that do not have their own smelting operations and have copper concentrates potentially suitable for further processing at Olympic Dam. The quantity, if any, of imported copper concentrates or other South Australian copper ore that would be processed at Olympic Dam would be dependent upon economic factors and the availability and suitability of these materials. Table 3.4 summarises the desirable characteristics of concentrates for blending with Olympic Dam concentrates.

At the assumed copper grade of 35%, the maximum quantity of concentrates able to be treated would peak at 236,000 t/a at Year 13, which corresponds to a peak additional cathode copper production of 79,940 t/a. In practice, any importation rates are expected to be considerably lower than this figure.

Table 3.4 Desirable characteristics of imported copper concentrates

Factor	Preferred range
Grade	Greater than 35% copper
Copper to sulphur ratio	Greater than 1.2 to 1
Particle size	Less than 75 µm
Impurities	Low levels of arsenic, tin, bismuth, mercury, iron, selenium and tellurium

The options for transport for imported copper concentrate involve either shipment to Whyalla and transportation by truck to Olympic Dam, or shipment to Port Pirie or Adelaide followed by transportation by rail to Pimba or Port Augusta and then truck to Olympic Dam. It is expected that Australian copper concentrate or other South Australian copper ore would be delivered by surface transport direct to Olympic Dam.

The Whyalla wharf facilities can receive shiploads of up to 20,000 t of concentrate with a nominal moisture content of 8%. Ships would be unloaded using either a stockbridge and clam shell unloader or ships' cranes with grabs, loading into trucks via a hopper. Refurbishment of the existing bulk wharf at Whyalla would be required, including:

- a new concrete deck;
- a new hopper designed to overlay the ship in order to capture any spillage from the loading operation;
- a new concentrate storage shed of 20,000 t capacity.

The Adelaide wharf facilities can receive shiploads of up to 10,000 t of concentrate, and the Port Pirie wharf facilities can receive shiploads of up to 15,000 t of concentrate. Ships' cranes with grabs would be used for unloading concentrate. A new concentrate storage shed would be required at Adelaide, whereas storage facilities are already available at Port Pirie.

At the moisture content received, dust emissions would not be expected to be a problem. Additional dust controls would be provided as required, including water suppression sprays and the enclosure of transfer points and conveyors.

Side-tipping trucks would fill from the road hopper and transport the concentrate to the storage shed. Each truck load would be weighed on a weighbridge and sampled prior to tipping on to the stockpile.

The concentrate would then be reclaimed by front end loader into 75 t side-tipping road trains for delivery to Olympic Dam. The maximum copper concentrate import rate of 236,000 t/a would require approximately sixty truck movements per week to Olympic Dam. However, as noted above, any importation rates would be expected to be considerably lower than this figure.

At Olympic Dam, the concentrates would be transferred to a storage shed, reclaimed by front end loader and placed into a hopper feeding a concentrate conveyor which would deliver the material to a steam coil concentrate dryer. The dry concentrates would be pneumatically transferred to storage bins before being blended with Olympic Dam concentrates, for supply to the new flash smelter.

Additional copper refinery capacity, in the form of additional electrolytic cells, would be provided to match the increased copper anode production.

3.8 EFFLUENTS AND EMISSIONS

3.8.1 Tailings containment

The tailings from the metallurgical processing of ore would continue to be managed in the tailings retention system. The additional rate of tailings throughput would, however, require additional cells to be developed in this system. Table 3.5 shows the rates of tailing production and the areas required using the traditional paddock disposal method.

It is noted that the additional tailings throughput would affect only the operational area needed at any time to evaporate the additional tailings liquor and not the final tailings volume. Hence, the final area of tailings at the completion of mining would be determined by the quantity and depth of tailings deposited and not by the tailings deposition rate.

Table 3.5 Tailings production and area requirements—paddock disposal method

Copper production (t/a)	Mining rate (Mt/a)	Tailings production (Mt/a)	Tailings operational area[1] (ha)
85,000 (existing)	3.0	2.7	190
200,000	9.0	6.6	390
350,000	17.0	12.5	720

1 *For initial production rates.*

The following provides a brief description of the development of the tailings retention system under the two deposition methods being considered: the traditional paddock method, as currently used at Olympic Dam, and the central thickened discharge system, which is a potential alternative. Greater detail is provided in Chapter 8.

Paddock method

The initial phase of expansion to 200,000 t/a copper would involve the construction of an additional two tailings cells, each 100 ha in area. These cells would be adjacent to the existing tailings containment cells (Figure 3.7). Expansion to 350,000 t/a copper would involve the construction of an additional three cells of area 110 ha each. The new and existing cells would be operated as a combined facility.

All new embankments would be constructed from the local swale and sand dune materials or from reclaimed tailings (subject to the success of trials currently being undertaken). As with the existing facility, the initial embankments would be constructed to a height of 10 m. As additional storage capacity was required, the embankments would be raised using reclaimed tailings or locally sourced dune and swale materials in increments up to 5 m high to achieve a total height of 30 m.

The tailings would be discharged into the containment cells using the subaerial deposition method. This means that tailings would be deposited in thin layers in each cell on a cyclical basis, with the cycle times varied according to seasonal fluctuations, to enable the moisture content of each deposited layer to be reduced to a predetermined level. At this level, the tailings would be partially saturated, dense and of high strength, and would retain sufficient moisture to limit radon emission.

Supernatant liquor would separate from the tailings during the deposition cycle and for a few days after deposition has stopped, as the tailings settle. The supernatant liquor and all rainfall on the storage surface would be directed to structures located centrally in the tailings containment cells, which would decant the liquor for collection and pumping to the evaporation ponds. These ponds would have synthetic and clay liners.

When the final height of tailings was achieved, a new set of cells would be constructed adjacent to the completed cells. This process would be repeated for the life of the mine.

Decommissioning and rehabilitation of the tailings storage facility would be undertaken progressively as the cells reached their final height. This would involve covering the tailings surface with earth and rock armour as described in Chapters 8 and 14.

Central thickened discharge method

The central thickened discharge method of tailings deposition involves the discharge of thickened tailings from one or more towers located within the tailings retention area and the collection of supernatant liquor and rainfall from the perimeter embankment. Prior to discharge, the tailings are passed through a thickener in order to remove part of the tailings liquor for return to the process plant or for disposal by evaporation.

The outer embankment would be approximately circular about the discharge towers and would initially be constructed to a height of 2–4 m using materials removed from within the storage area. The height of the discharge towers would be 30–35 m above natural ground level, and the deposited tailings would form cone-shaped beaches around the towers. Supernatant liquor and rainfall runoff would be recovered by a system of open drains, and pumps operating at the outer embankment. A pipeline around the perimeter of the outer embankment would convey the collected supernatant liquor back to the process plant or to the evaporation ponds.

The potential advantages of the central thickened discharge method over the paddock method include the following:

- Improved dewatering of tailings is possible prior to discharge, thereby increasing opportunities for water recycling.
- There is greater operational flexibility in terms of accommodating varying rates of tailings production.
- The system holds a greater volume of contained tailings for any given embankment height.

The disadvantages of the central thickened discharge system, compared with the paddock method, are:

- A greater land area may be required to store a given volume of tailings.
- Lined drains and other structures are required over the whole area to collect and drain supernatant liquor.

The central thickened discharge method is currently undergoing trial on site, using Olympic Dam tailings (Section 8.6.3). These trials will identify any technical difficulties associated with handling the thickened tailings and the feasibility of the method in general. If the method proves feasible, it would be considered as an alternative to the paddock method.

3.8.2 Solid waste

Solid wastes arising from the mine site—including tyres, paper, packaging, timber pallets, drums, concrete and domestic wastes (e.g. food scraps)—would continue to require disposal following the Expansion Project. All waste generated on site is defined as radioactively contaminated and cannot be removed without the specific approval of WMC's statutory Radiation Safety Officer.

The existing programmes established to reduce the quantity of waste going to the on-site landfill would be maintained. These programmes include the sorting of waste and the recovery, reuse or recycling of waste where possible.

The Roxby Downs township operates a landfill for disposal of collected domestic refuse. This landfill would continue to be operated following the Expansion Project. Waste minimisation practices currently undertaken at the landfill include the segregation of garden wastes (e.g. tree loppings) and processing of these by the Community Tidy Towns team for use as garden mulch. Proceeds from donations for the mulch go to the Royal Flying Doctor Service.

The existing landfill operations do suffer from some wind scattering of lighter refuse, principally plastic bags. Changed management measures, including modified tipping layouts and daily covering with sand, are currently being investigated to control this problem.

Solid waste management is discussed in greater detail in Section 11.5.

3.8.3 Wastewater

For the expanded project, sources of wastewater would continue to be:

- process wastewater, site laboratory wastes and equipment washdown
- saline groundwater seepage into the underground mine
- stormwater runoff from roofs and paved areas
- sewage from the mine, plant, workshops and offices
- sewage from the Roxby Downs township and the Olympic Dam Village.

Process wastewater disposal

Wherever possible, all process wastewater is currently recycled within the process plant to recover valuable mineral constituents and reduce water consumption. As described further in Chapter 4, the cost of providing water at Olympic Dam is high, resulting in an economic incentive to minimise water use. Measures that have been investigated in earlier feasibility studies to further reduce water use are discussed in Section 3.12.

The principal constraint to water reuse in the process plant is the build-up of dissolved salts, especially chlorides, which affect the metallurgical treatment process. Process water that is no longer suitable is pumped to the tailings retention system together with the tailings. A portion of the process wastewater evaporates on the tailings beaches, as described above, with the remainder (together with collected rainfall) decanted from the tailings supernatant pond for disposal by evaporation in lined evaporation ponds.

The Expansion Project would require the construction of a third four-cell evaporation pond of 50 ha if the paddock method is used for tailings storage. The location of this additional evaporation pond is shown in Figure 3.7. This additional evaporation pond would not be required if the central thickened discharge tailings storage system is adopted.

Mine water

Groundwater that infiltrates into the underground mine workings and mine water used for drilling would continue to be collected in sumps and pumped to the surface mine water settling ponds. The water would then be reclaimed for reuse underground in the drilling machines, and for dust suppression in the mine and process plant and on the unsealed haul roads. The regional groundwater is highly saline, having a quality of 20,000–40,000 mg/L of total dissolved solids, and hence is not suitable for process or potable water use.

Currently, the amount of groundwater collected exceeds the mine's requirements. Excess mine water is pumped to the mine water disposal pond, where it partly infiltrates the ground and partly evaporates. The location of the existing mine water disposal pond is adjacent to the tailings retention system, and within the cone of groundwater depression (Section 4.7) surrounding the mine.

The expanded mine workings would result in a greater inflow of groundwater and consequently a greater quantity of excess water requiring disposal. A new 30 ha mine water disposal pond would be constructed to the north-east of the Whenan Shaft (Figure 3.7). The location of the new facility takes the following into consideration:

- The existing location affects the groundwater monitoring undertaken for the tailings retention system, whereas the new location provides sufficient distance between the two facilities to avoid this interference.
- The new location allows the facility to be expanded as necessary to dispose of the greater quantity of collected groundwater.

The new mine water disposal pond would consist of an embankment of 3 m in height constructed of locally available material. Little or no treatment of the pond base would be provided, as infiltration is considered to be an effective and environmentally benign method of disposal.

Stormwater runoff

Stormwater collected in the bunded parts of the metallurgical plant is presently recovered by pumping it into the process water system. This practice would continue in the expanded plant.

Stormwater runoff from other impervious areas within the plant is currently directed to unlined sumps and allowed to infiltrate and evaporate. Collection and use of this water is undertaken following major rain events, although this has been infrequent owing to the low level of rainfall in the region. The expanded plant would continue to use this method of disposing of stormwater runoff.

Sewage

Sewage from the mine, plant, workshops and offices is currently collected, subjected to primary treatment and evaporated. Sewage from remote locations is treated and disposed of locally in septic tanks.

The operations sewage collection and treatment system would be upgraded for the Expansion Project to cater for new site layouts and an additional workforce. The upgraded facilities would make provision for reuse of this water, either for landscape watering or for process water.

The sewage collected from the Roxby Downs township is given primary treatment followed by further treatment in lagoons, and is then used for irrigation of the golf course, ovals and other grassed recreational areas. The demand for treated effluent for this purpose currently exceeds the quantities available, a situation that is expected to continue after the Expansion Project.

The Olympic Dam Village area currently has three sets of sewage lagoons, one located adjacent to the airport, and the other two adjacent to the industrial area.

The lagoons adjacent to the airport would be retained but would be used only for emergency, because of concerns about attracting birds. The lagoons adjacent to the Lavricks light industrial site would remain unchanged, while those adjacent to the industrial area would be used to service the revamped Olympic Dam Village area, except those parts of the village already served by the industrial area lagoons.

It is planned to provide a sewage treatment plant in conjunction with the existing lagoons which are adjacent to the industrial area, to provide additional treated effluent. This effluent would be available for landscape watering.

3.8.4 Emissions to air

Emissions to air following the Expansion Project would generally be similar to the existing plant but at a higher rate owing to the increased processing rate. However, for sulphur dioxide, the use of improved emission control technology would result in a reduction in emissions.

A range of control equipment would be used to ensure that emissions remained within the State standards and national guidelines. These control systems, which would include fabric filters, venturi scrubbers and electrostatic precipitators, are described in Section 3.5. Fugitive emissions would be controlled by enclosing equipment, and by using water suppression sprays and fabric filter collectors.

A comprehensive discussion of air emissions, including emission inventories and dispersion modelling, is provided in Chapter 9.

WMC has made a commitment to participate in the Greenhouse Challenge programme. Work is currently progressing within all divisions of the company to allow an agreement to be signed with the Commonwealth Government in the second half of 1997. The main thrust of this programme is to reduce the consumption of energy in WMC's operations, thus reducing the emission of gases with global warming potential, including carbon dioxide, methane and nitrogen oxides.

The Copper Uranium Division of WMC has determined its greenhouse gas emission inventory, and is currently developing action plans for the reduction of energy consumption at Olympic Dam. Particular attention is being paid to the Expansion Project, with the aim of designing for energy efficiency at the earliest stage of the project.

The predicted effectiveness of action plans for energy consumption reduction is demonstrated by the expected carbon dioxide emission rates given in Table 3.6. These rates, which include carbon dioxide emissions associated with generation of electricity used on site, show a reduction in emission rates per tonne of ore milled of about 15% following expansion to 200,000 t/a copper, and a further reduction of 18% following expansion to 350,000 t/a.

Table 3.6 Inventory of carbon dioxide emissions[1]

Copper production (t)	Ore milled (Mt)	Carbon dioxide emissions	
		Total (t)	Per tonne ore milled (t/t)
83,050	3.0	398,023	0.13
200,000	9.0	975,280	0.11
350,000	17.0	1,494,584	0.09

1 *Includes carbon dioxide associated with generation of electricity used on site.*

3.8.5 Noise sources

The principal noise sources associated with the Expansion Project would be:

- ventilation fans, conveyor belt drives, head frames and ore handling
- grinding mills and motors in the concentrator and hydrometallurgical treatment plant
- smelter operation, including blowers and burners
- quarry operations and the backfill plant
- traffic.

Specifications for all new equipment would include requirements relating to noise control. The generally applicable noise level for plant is 83 dBA at 1 m on a twelve-hour basis. This is equivalent to 85 dBA for eight-hour exposure.

The goal for noise exposure of operators is 80 dBA or less, and this criterion is used as a design figure. Where these noise levels are not achievable, hearing protection must be used. Areas above 83 dBA would be signposted.

Owing to the distance of the operation from the Special Mining Lease boundary, environmental noise levels at the boundary would be well within accepted criteria. Noise is discussed further in Section 9.5.

3.8.6 Heat

Heat emissions would arise from all areas of the expanded plant where energy is consumed. This includes chemical energy liberated in the smelter by the oxidation of copper concentrates. Table 3.7 summarises the energy use of the existing and expanded operations.

Table 3.7 Site energy use (GJ/a)

Energy type	Existing (1995–96)	Copper production rate	
		200,000 t/a	350,000 t/a
Electricity	1,165,931	2,960,926	4,443,500
Diesel/fuel oil	753,394	1,207,299	1,801,591
Petrol	7,398	7,414	7,732
LPG	405,034	1,157,667	1,763,418
Coke	58,077	237,086	614,672
Concentrates	330,000	929,263	1,667,922
Sulphur	55,387	646,273	1,115,086

3.9 PROJECT INFRASTRUCTURE

The following sections summarise the infrastructure requirements of the expanded project. Greater detail is provided in Chapter 11.

Power supply

The power supply for the project expansion to 150,000 t/a copper would be based on electricity supplied from the State grid via an existing 132 kV transmission line and a 275 kV transmission line from Port Augusta currently under construction. The latter was approved in principle in the 1983 EIS, subject to Aboriginal heritage investigations and consideration of potential alternative routes. Construction of the 275 kV transmission line is expected to be completed in January 1998.

These studies were undertaken, and the line is being constructed incorporating minor deviations in the route as identified in subsequent route surveys and consultations with Aboriginal groups and landowners. All aspects of the transmission line were approved by the State Government prior to commencement of construction. Environmental management issues during construction are discussed in Section 11.2.

The existing 132 kV transmission line and the 275 kV line currently under construction will be adequate for production of 200,000 t/a copper, and for 285,000 t/a copper using imported concentrates. Additional transmission capacity would be provided for the possible future expansion to 350,000 t/a copper production, to ensure security of the power supply. This would involve the provision of a second 275 kV line by decommissioning the existing 132 kV transmission line and replacing it with a new 275 kV transmission line paralleling the 275 kV line presently under construction.

Water supply

Water supply for the existing and expanded project would continue to be based on water extraction from the Great Artesian Basin. There would be some expansion of the reverse osmosis desalination plant that currently supplies potable water to the Roxby Downs township, Olympic Dam Village and the plant site.

The approvals process used to obtain the special water licences is described in Section 1.3. Water supply infrastructure requirements for the Expansion Project are described in greater detail in Chapters 4 and 11.

Other infrastructure

The expanded project would use the existing roads, airfield and communications infrastructure without any further upgrading of these facilities. The current extent of landscaping and fencing would also be maintained.

There is no specific aspect of the Expansion Project that would require an expansion or modification of the health and safety services provided at Olympic Dam. However, the health and safety of employees are constantly monitored, and ongoing improvement programmes would be continued.

3.10 TOWNSHIP

The township of Roxby Downs and the village at Olympic Dam would be modified and expanded in association with the Expansion Project. The scope of these changes is described briefly below and in greater detail in Chapter 11.

3.10.1 Expansion to 200,000 t/a copper

The first phase expansion to 200,000 t/a copper production would result in up to an estimated 181 additional full-time employees and contractors at the operations and up to 72 further indirect employment opportunities at Roxby Downs. This would require the staged development of up to 253 additional allotments to the south of the existing township. The Roxby Downs township was recently expanded to the east by the creation of 101 additional residential blocks. This development was required to satisfy existing demand not associated with the Expansion Project.

Additional changes to Roxby Downs township and Olympic Dam Village that would occur as part of the expansion include:

- closure of the caravan park at Olympic Dam Village;
- establishment of a new caravan park at Roxby Downs;

- expansion of the existing single persons' quarters at Roxby Downs;
- construction of a medical facility at Roxby Downs by the State Government, in accordance with the amendments to the Indenture;
- upgrade of the existing construction camp facilities at the existing Construction Camp 1 and Camp 2 sites.

3.10.2 Expansion to 350,000 t/a copper

Expansion to a production rate of 350,000 t/a copper is estimated to result in up to an additional 506 full-time employees and contractors at the operations. On the basis of the 200,000 t/a expansion, it is expected that a further township expansion to the south, involving approximately 700 residential lots, would be required to house this workforce.

3.11 CONSTRUCTION

Construction would involve the progressive development of the underground mining operations and the installation of additional processing facilities on the surface. Figure 3.17 shows the construction schedule as approved by the WMC Board, and the mine production schedule for development up to a production rate of 200,000 t/a copper. This figure shows that processing capacity at this level would be achieved by March 1999. At the same time, the mine production would only be about 6.5 Mt/a, supporting a production rate of about 150,000 t/a copper.

Full production at 200,000 t/a copper is planned to be achieved by the year 2000 following a construction period of two and a half years. However, WMC is implementing an accelerated construction programme which should shorten the construction period to less than two years. The timing of potential further expansion to 350,000 t/a copper would be determined after further study of markets for the products and production costs for the expanded operations.

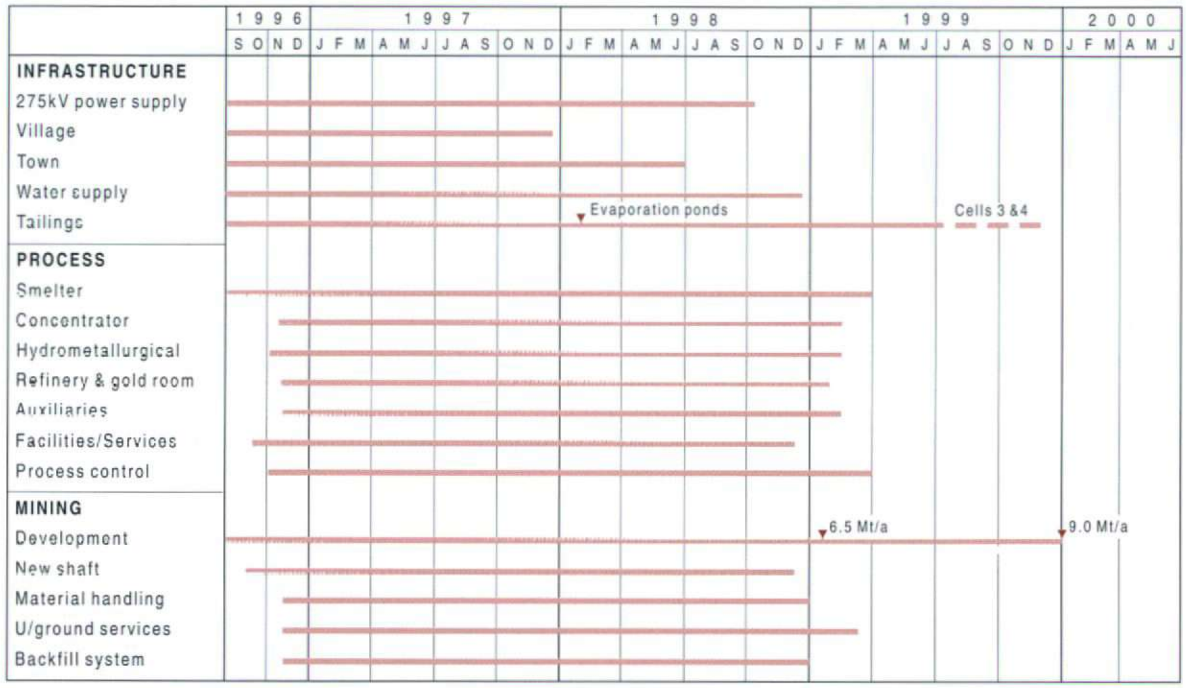
The WMC Board has made no formal decision on the possible future expansion to 350,000 t/a copper. However, in this EIS it has been assumed for water abstraction and economic modelling purposes that 350,000 t/a copper production would be achieved in 2010. This programme, if adopted, would require construction to commence in 2008.

The construction strategy for both phases of expansion would involve the maximum possible use of prefabrication off site. Two or three suitable locations would be identified to carry out this work, which would include total fit-out and testing prior to transporting the prefabrication units to site. Locations with sufficient infrastructure and workforce skills to undertake prefabrication include Adelaide, Whyalla and Port Augusta.

All construction materials would be transported to the site by road. The construction strategy of prefabricating as much as possible off site would necessitate some transport to site of oversize loads. The size of these loads would be restricted in order to avoid having to clear vegetation or remove infrastructure along the transport route. Each oversize load would also be subject to conditions specified in all the permits and escort provisions required by the relevant authorities.

The policy for the Expansion Project is that South Australian services and labour would be utilised as far as is reasonable and economically practicable. Technical and quality considerations, and the ability to deliver on time and within a tight project schedule, would also be taken into account.

The envisaged site construction workforce numbers for expansion to 200,000 t/a copper would involve a peak site workforce requirement of approximately 1,200 construction personnel and 100 construction management staff.



Note: Original schedule as approved by WMC Board. An accelerated construction programme is being implemented, which is expected to shorten the overall construction times.

FIGURE 3.17
CONSTRUCTION SCHEDULE FOR DEVELOPMENT TO 200,000 t/a COPPER

Apart from locally based contractors, all construction personnel would be accommodated in Olympic Dam Villages 1 and 2. The villages would be located at the sites of the existing Construction Camps 1 and 2. The expanded and revamped villages would include recreational facilities and a limited range of shopping facilities for the convenience of the construction workforce. In addition, preference would be given to fly in/fly out arrangements for contractors in order to minimise the amount of recreational time on site.

All construction personnel would receive an induction into the site requirements prior to starting work on site. The induction would include site procedures on the following:

- environmental management;
- protection of sites of Aboriginal heritage;
- radiation exposure management;
- behaviour in relation to local communities and pastoralists;
- other issues relating to occupational health and safety, particularly issues pertaining to construction adjacent to operational plant.

Construction personnel found to be knowingly in breach of site procedures would be immediately dismissed from the site.

All construction materials, with the exception of soil used for earthworks, would be sourced off site from established suppliers with sufficient capacity to meet the project requirements. Wherever possible, earthworks on site would be designed to balance cut and fill requirements, thereby minimising the need to dispose of surplus soil. Existing procedures that control ground disturbance and clearing (Section 2.5) would be applied to construction activities for the Expansion Project.

Up-to-date Australian Standards would be used for design and construction of the Expansion Project, including provisions for structural stability under seismic conditions. Where Australian Standards do not exist, the appropriate international or industry standard would be adopted.

The generation of construction wastes would be minimised by removal of unused building materials off site for use elsewhere. Construction wastes that cannot be recycled would be disposed of in existing landfills at Olympic Dam and Roxby Downs (Section 11.5).

The effects of dust, vibration and noise generated by construction activities would be mitigated by:

- watering of disturbed areas and unsealed roads to control dust;
- providing restrictions on the maximum noise levels of each item of construction equipment in construction contracts;
- restricting activities that may cause noticeable vibration off site to normal working hours.

Visual and aesthetic impacts of the construction activities, and of the completed facilities, would be mitigated by the presence of the existing plant.

3.12 ALTERNATIVES CONSIDERED

The 1983 EIS considered practical alternatives for the following areas of project development:

- mining methods
- metallurgical process routes, with an option to extract copper only
- tailings disposal methods
- water supply sources
- power generation
- town sites.

Since publication of the 1983 EIS, project development has proceeded as described in Chapter 1, and many of the previous alternatives are even less practical now owing to the investment made in existing facilities. The remaining practical alternatives considered in the feasibility studies for the Expansion Project are described below.

3.12.1 Mining methods

The principal alternative mining methods considered were vertical crater retreat and sublevel caving. Vertical crater retreat mining involves the firing of point charges in vertical or near vertical boreholes to remove a series of horizontal slices from the back of the stope. This method has the advantage of requiring the minimum development for drill access, but was rejected because of the difficulty of removing radon from stope sills (bottom access openings). It is also inclined to cause increased ore loss and dilution.

Sublevel caving involves the creation of an opening that is too big to support itself, and that caves in a controlled manner. The caving is controlled by the rate at which broken ore is withdrawn from the bottom of the stope. In the right circumstances, sublevel caving is one of the least expensive of underground mining methods, but was rejected in this case because the strength of the Olympic Dam ore would make control of caving difficult.

3.12.2 Metallurgical processes

During the life of the project, detailed reviews of alternative metallurgical processes have been undertaken. The principal alternative processes considered for the Expansion Project were:

- pressure leaching of ore
- roasting, leaching and electrowinning of concentrate
- concentrate leaching.

These are discussed briefly below.

Pressure leaching

Pressure leaching involves the use of autoclaves operated at high temperature (220°C), high pressure and acid conditions. These aggressive process conditions present engineering difficulties, although the process is being used elsewhere for the recovery of gold, and has been developed for nickel laterite ores.

The advantage of pressure leaching is that there are no smelter emissions. However, the disadvantages include higher water use, lower utilisation of inherent energy because of the generation of low grade heat, and higher energy consumption in the refinery, which would be totally by electrowinning rather than mainly by electrorefining. The technology is also not sufficiently proven at present for application to copper extraction from Olympic Dam ore.

Roasting, leaching and electrowinning

The roasting, leaching and electrowinning process involves the roasting of copper concentrates to remove sulphur, and leaching to prepare a copper solution for copper recovery by electrowinning. The mineralogy of Olympic Dam concentrates presents some difficulties in the control of the roasting process.

The roast/leach/electrowin process would not have any significant advantages for Olympic Dam. The roasting section would generate sulphur oxides and dust, requiring air pollution control systems not dissimilar to that for the proposed smelter system. The recovery of refined copper by electrowinning would have a higher energy demand than smelting and electrorefining.

Concentrate leaching

A number of concentrate leaching processes were considered. In these processes, concentrates are subjected to hydrometallurgical treatment, for extraction and recovery of copper. WMC has participated in research work into these processes. At present these processes show some promise, but the commercial risks for a large project such as Olympic Dam are unacceptable to WMC.

The concentrate leach processes have the advantage of avoiding the need for a smelter or roaster, with their attendant air emission control systems. The disadvantages are a significantly higher water use, the need for extensive water treatment facilities, and the generation of sludge streams that are more difficult to handle than the stable slags from a smelter.

Preferred process

The conclusion of the review was that the known concentrator/smelter/hydrometallurgical process as used in the existing Olympic Dam plant would be the most suitable for the Expansion Project, and that alternative processes would include an unacceptable level of technical and commercial risk. The environmental and radiation management requirements for the existing process are also very well understood.

However, WMC continues to review new developments in mineral processing, and funds research as considered appropriate into new and improved technology. One such current project is the funding of work by the Australian Nuclear Science and Technology Organisation (ANSTO) into means of reducing ^{210}Po emissions in the smelter by improving extractions in the hydrometallurgical plant.

3.12.3 Tailings management

An alternative does exist for the management of tailings involving the deposition by central thickened discharge. This option, discussed in greater detail in Chapter 8, is currently undergoing trial on site, using Olympic Dam tailings. Pending the results of these trials, the proposed tailings management method for the Expansion Project is expansion of the existing facilities using the paddock method. If the central thickened discharge method proves feasible, it would be considered as an alternative to the paddock method.

3.12.4 Acid liquor recycle

The possibility of installing an acid liquor recycle plant was examined in detail in feasibility studies for the Expansion Project. The neutralisation of the acid liquor was proposed to be achieved by the use of calcined dolomite. The quantity of water treated was proposed to be 2.8 ML/d, and the potential water saving identified was 2.4 ML/d.

The detailed review indicated potential engineering problems in the handling and disposal of the gypsum that would be formed, and potential problems with increased chlorides and other contaminants in the recycled water which could adversely affect performance of the metallurgical plant. It was concluded that the acid liquor recycle proposal was not feasible at this time.

Alternative means of obtaining water savings would be investigated further in the detailed design stage. The main measure proposed is the adoption of high solids density thickeners in the hydrometallurgical plant. The latter reduces the overall quantity of process liquor in circulation, thus reducing the overall process water use. Other potential measures for water savings would also be investigated further.

3.12.5 Power generation

An alternative method of power generation, using on-site turbines fuelled by natural gas from the Cooper Basin, was considered in feasibility studies for the Expansion Project. The studies concluded that this option was not economic when compared to the chosen alternative of 100–130 MW of power supplied from Port Augusta via a 275 kV transmission line. In addition, there could be significant delays involved with route selection and the resolution of environmental issues associated with construction of a gas pipeline to the plant site.

This alternative will, however, be subject to re-examination in future should the economics of current arrangements change significantly. If this option is proposed in future, it would be subject to a separate environmental impact assessment process.

CHAPTER 4

WATER MANAGEMENT

CHAPTER 4

WATER MANAGEMENT

This chapter discusses the issues relating to water management for the Expansion Project. In particular, the project's future water requirements are examined, including the effects on the Great Artesian Basin, which would continue to be the principal source of water for future operations. The chapter also discusses the effects of the Expansion Project on the groundwater within aquifers underneath the Special Mining Lease.

4.1 EXISTING WATER SUPPLY SYSTEM

4.1.1 Water sources and infrastructure

Water for potable and process uses at the Olympic Dam operations and the Roxby Downs township is sourced from two borefields—Borefield A and Borefield B (Figure 4.1)—which are operated under special water licences issued under the Indenture. Approvals are in place for the continued operation of Borefields A and B. Future rates of abstraction from the borefields will be maintained within the requirements of the special water licences.

Both borefields abstract water from the Great Artesian Basin aquifer, which is described further in Section 4.2. In addition to these borefields, the Olympic Dam operations are also able to source saline water from:

- dewatering of the underground mine workings;
- a borefield adjacent to the mine facilities established in the early years of mine development.

Borefield A and Borefield B would continue to be the source of potable and process water for Olympic Dam and Roxby Downs following the Expansion Project. The existing water sources and associated infrastructure are described below.

Borefield A

Borefield A comprises nine production bores and nineteen observation bores. The locations of these bores, the pipeline system and the pump stations are shown in Figure 4.2. This figure also shows the boundary of the Designated Area, which is used to define agreed limits on drawdown of aquifer pressure under the Borefield A Special Water Licence. The Special Water Licence is described further in Section 4.2.

The abstraction history of Borefield A is given in Table 4.1. Between 1982 and 1987, six production bores (the southern and central bores) were constructed, flowing under artesian pressure to a central transfer pump station (PS1A). The bores were equipped with pumps in 1987. In 1992 three additional production bores (the northern bores) were installed at the southern shore of Lake Eyre South.

The current abstraction rate from Borefield A has been reduced following commencement of the commissioning of Borefield B in November 1996, and is at present approximately 5–6 ML/d.

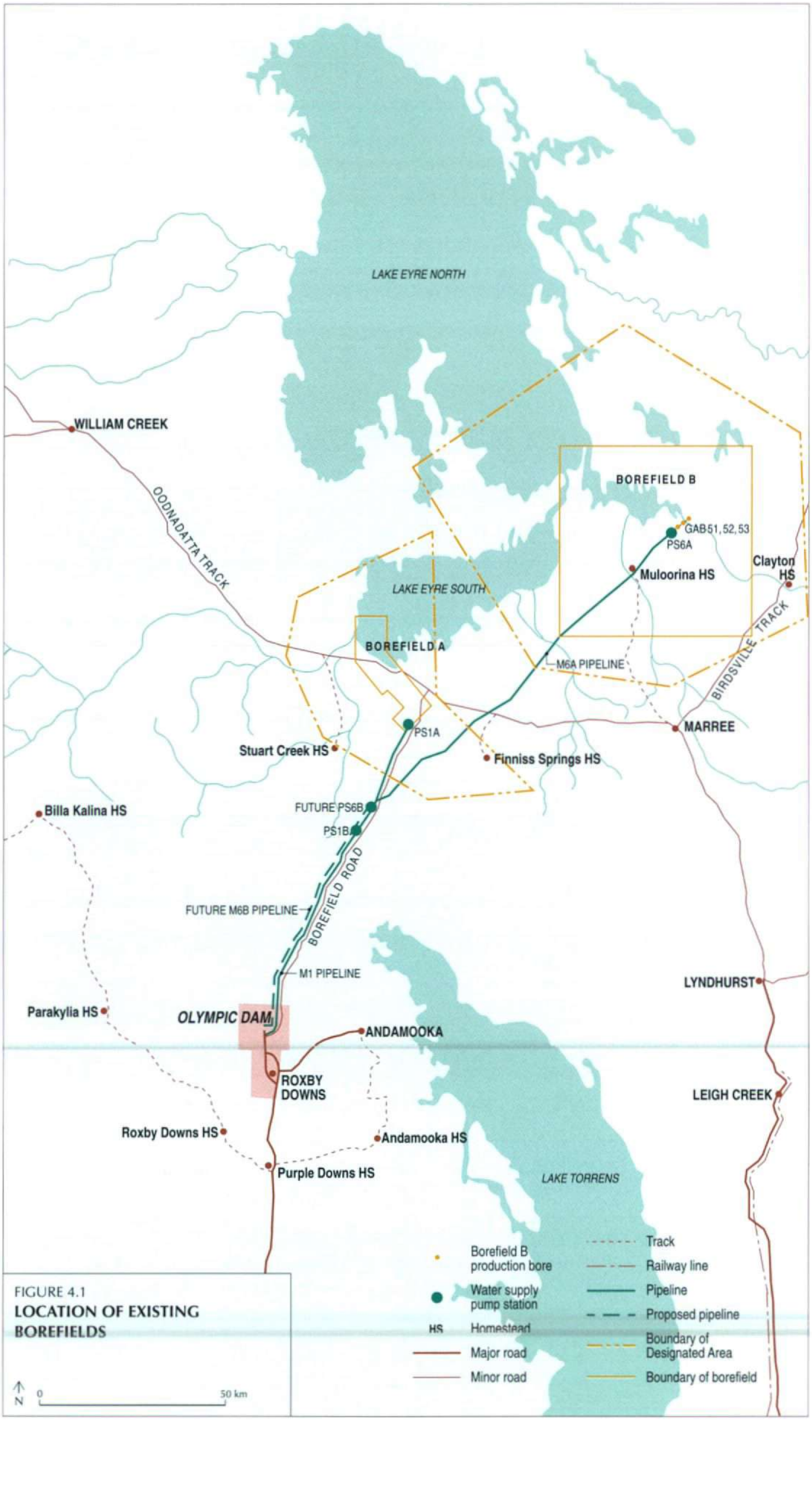


FIGURE 4.1
LOCATION OF EXISTING BOREFIELDS

FIGURE 4.2
BOREFIELD A LAYOUT

Borefield A infrastructure includes a pipeline system that transfers water from the bores to the main pump station (PS1A) located near GAB6. A single main pipeline, designated M1, conveys water from PS1A at Borefield A to Olympic Dam, a distance of approximately 107 km. The M1 pipeline system incorporates two main pump stations:

- PS1A—located at the start of the pipeline at Borefield A, adjacent to bore GAB6
- PS1B—located part way along the pipeline, approximately 34.5 km from PS1A.

The section of the M1 pipeline from PS1A to the booster pump station, PS1B, is designated M1A, and the section from PS1B to Olympic Dam is designated M1B.

Table 4.1 Summary of abstraction history of Borefield A

Period	Average abstraction rates (ML/d)			
	Southern bores GAB6, 15, 16	Central bores GAB12, 14, 18	Northern bores GAB30, 31, 32	**Total**
1983–86	1.30	0	0	**1.30**
1986–87	2.30	0	0	**2.30**
1987–88	2.34	2.08	0	**4.42**
1988–89	4.27	4.56	0	**8.83**
1989–90	5.68	4.30	0	**9.98**
1990–91	6.25	4.39	0	**10.64**
1991–92	5.67	4.39	1.57	**11.63**
1992–93	5.60	3.98	3.01	**12.59**
1993–94	4.50	3.14	4.46	**12.10**
1994–95	4.72	4.37	4.43	**13.52**
1995–96	4.67	5.40	4.92	**14.99**

GAB = Great Artesian Basin.

Borefield B

Borefield B (Figure 4.3) is being developed in two stages. Stage 1 of Borefield B has been constructed, and comprises three production bores (GAB51, GAB52 and GAB53) installed to depths of 700–800 m and approximately 5 km apart. Figure 4.3 also shows the locations of the observation bores that have also been constructed and which are used for monitoring changes in aquifer pressure.

Each production bore is expected to have an average yield of about 11.0 ML/d. So far, only GAB51 has been connected and brought into service. This bore supplies water under artesian pressure to pump station PS6A, which is located adjacent to the bore and is equipped with a single diesel-powered pump.

The main pipeline from Borefield B, designated M6A, is approximately 113.5 km long. It commences at pump station PS6A and presently terminates at its junction with the M1 pipeline, approximately 80 km from Olympic Dam. The abstraction rate from Borefield B since commencement of commissioning in November 1996 has been approximately 9–10 ML/d.

Stage 2 of the Borefield B development will see GAB52 and GAB53 connected and brought into service, together with the construction of pipeline M6B to Olympic Dam and a new pump station (PS6B) at the junction of the M1 and M6A pipelines.

Mine dewatering

Groundwater drains into the mine through various mine openings (the ventilation shafts, the Whenan Shaft, the Robinson Shaft and the service decline) where they pass through the aquifers in the surrounding rocks. Air pumps are used to direct water away from the service decline headings, and small submersible pumps are used to move water from collection and settling sumps to main dams.

Three main pump stations are established in the mine, each capable of pumping water directly to the surface. The first installation, comprising two pumps, is located 420 m below ground level (RL –320 m AHD when converted to the reduced level of Australian Height Datum) adjacent to the Whenan Shaft. A secondary emergency pump station with one pump is located to the west of the shaft at approximately 450 m below ground level (RL –350 m AHD), and is designed to store and pump overflow water from the first

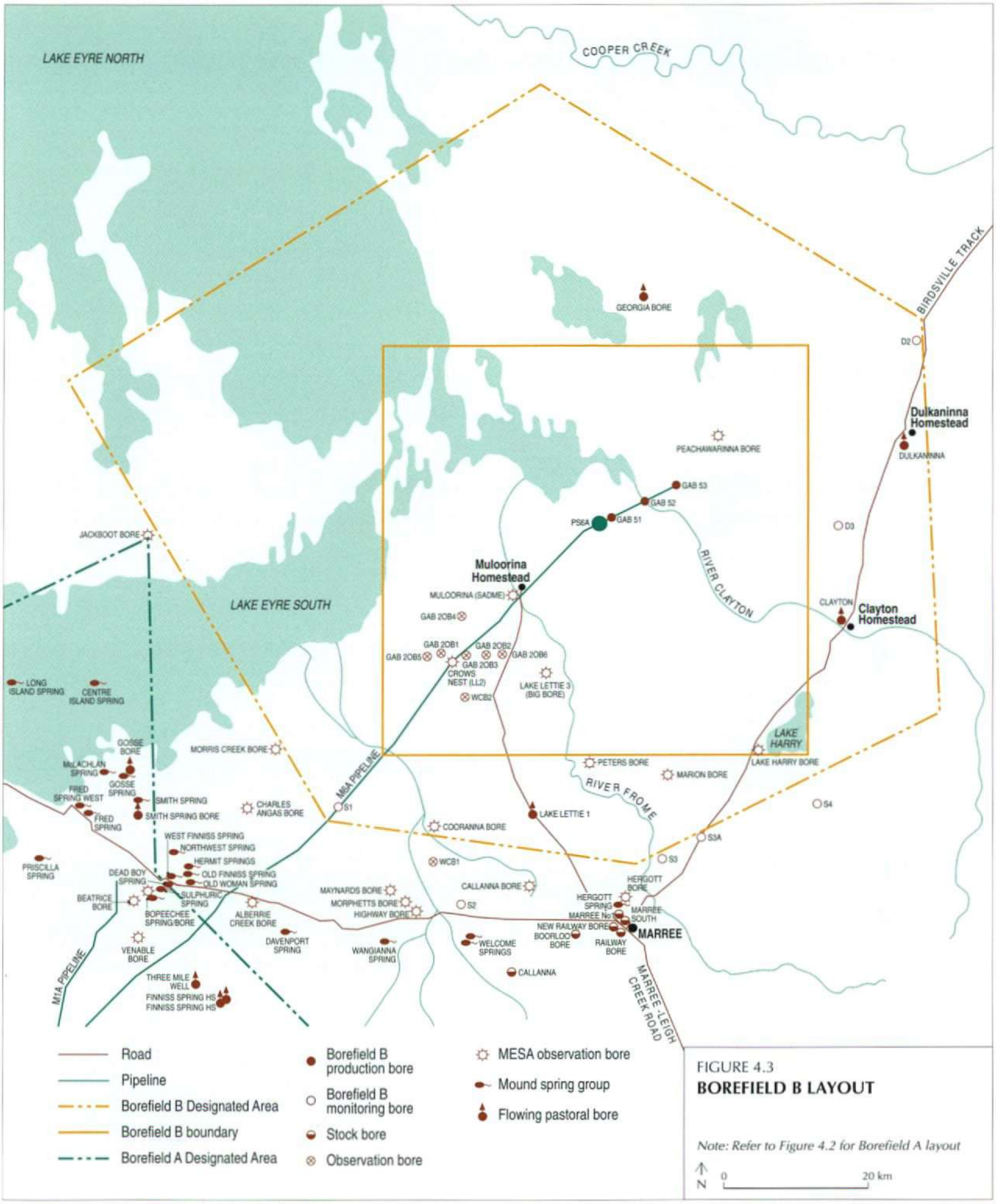


FIGURE 4.3
BOREFIELD B LAYOUT

Note: Refer to Figure 4.2 for Borefield A layout

pump station as required. A third installation, with two pumps, is located 500 m below ground level (RL –400 m AHD).

Owing to its high salinity (total dissolved solids of about 20,000–40,000 mg/L), the collected mine water has limited use, except in underground drilling and for dust suppression on roads and within the plant and mine. The remainder of the mine water is pumped to the mine water disposal pond, currently located adjacent to the tailings storage facility. The current rate of disposal is approximately 3.2 ML/d.

A new mine water disposal pond located north-east of the Whenan Shaft is to be constructed in late 1997.

Saline water borefield

Four production bores in the area south of the Whenan Shaft were drilled, tested and equipped in late 1988 as a supply of saline water. These bores have a total capacity of approximately 2 ML/d.

In recent years, because of the surplus of saline water from mine dewatering, only limited use has been made of the saline water borefield on site. Recent abstractions have been intermittent, with the average rates in the range 0.09–0.30 ML/d.

4.1.2 Water use

The current total water use from Borefield A and Borefield B is approximately 15 ML/d. This water use is shown schematically in Figure 4.4.

Potable water is produced in the desalination plant using reverse osmosis technology. This water meets the guidelines for potable water set out by the Agriculture and Resource

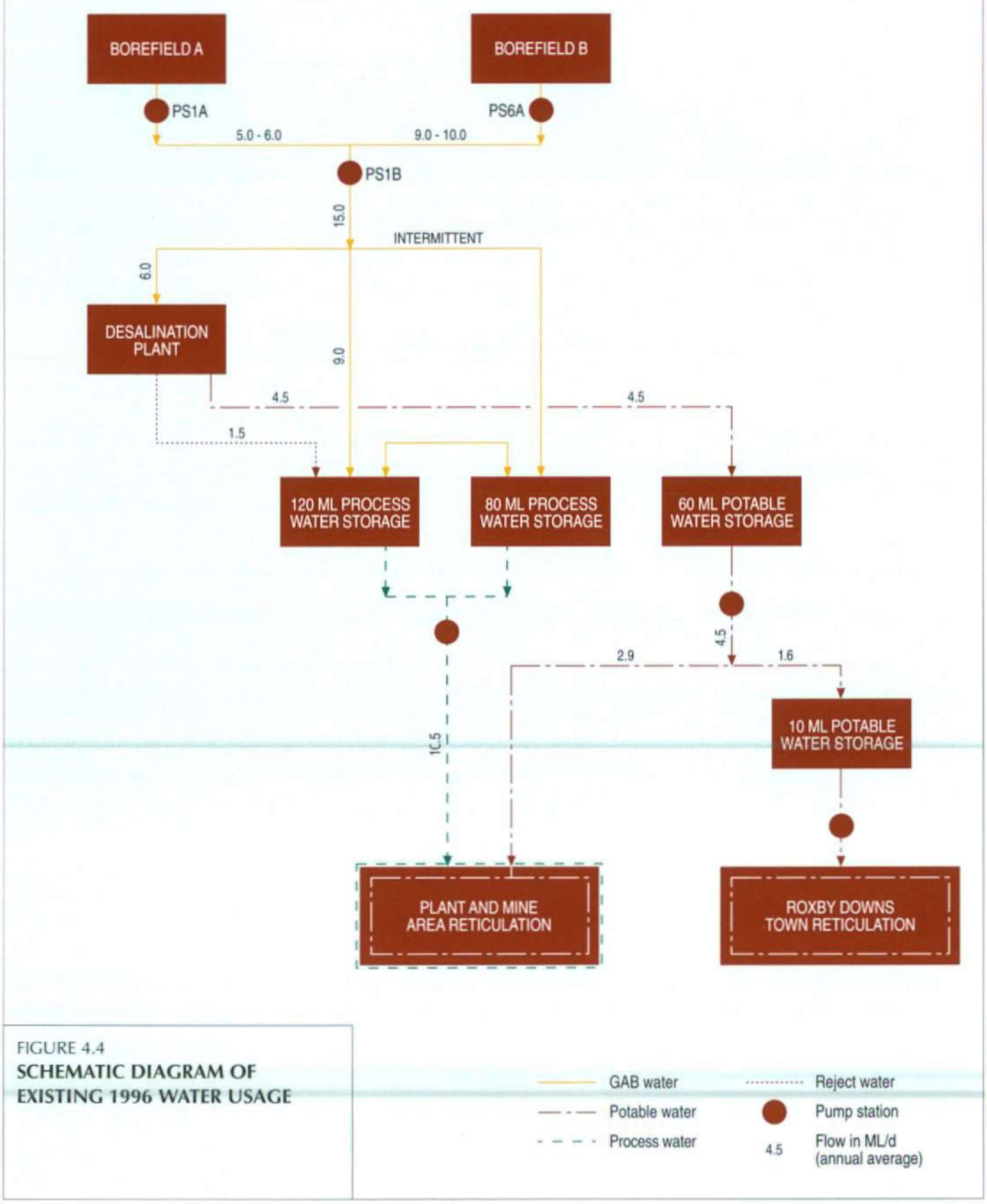


FIGURE 4.4
SCHEMATIC DIAGRAM OF EXISTING 1996 WATER USAGE

Management Council of Australia and New Zealand (National Health and Medical Research Council, and the Agriculture and Resource Management Council of Australia and New Zealand 1996) and the World Health Organization. In Figure 4.4, 'Roxby Downs town reticulation' refers to water consumed in the town of Roxby Downs and the Olympic Dam Village for domestic purposes; 'plant and mine area reticulation' consists of separate potable and process water systems. Potable water is supplied to the mine, metallurgical plant and central services areas for use in ablution and other employee facilities and in processing where desalinated water is required.

Process water is used in the metallurgical plant for processing purposes. It comprises raw water supplied from Borefields A and B and water of high salinity discharged from the desalination plant. Process water represents about 70% of the water consumed by the project. After use, this water is discharged to the tailings storage facility and evaporation ponds, as described in Chapter 8.

4.1.3 Water cost

The cost of supplying water to the operations at Olympic Dam is high in comparison with the charges levied by water utilities providing water for industrial and domestic uses to urban centres in Australia. This comparison reflects the high costs associated with installing and operating an extensive water supply scheme in a remote and arid location.

Because the water extracted from Borefields A and B is not of acceptable quality for potable use, part of the supply must undergo further treatment to attain this standard, which incurs greater capital and operating costs.

The calculation of the unit cost of water for Olympic Dam operations has been based on the cost of developing Borefield B to meet a production rate of up to 200,000 t/a copper. The results are given in Table 4.2.

Table 4.2 Water costs at Olympic Dam[1]

Cost component	Process water ($/kL)	Potable water ($/kL)
Capital cost[2]	1.25	1.62
Operating cost	0.36	0.78
TOTAL	**1.61**	**2.40**

1 *Based on development and water use for 200,000 t/a copper production.*
2 *Amortised over twenty years with a nominal 10% interest on capital.*

As a comparison with the cost of water at Olympic Dam, domestic consumers of water at Roxby Downs are charged $0.88/kL, which is based on Adelaide water pricing. The cost of process water at Olympic Dam is thus nearly twice that of Adelaide water, and the cost of potable water is nearly three times that of Adelaide water.

During the course of preparing this EIS it became evident, through media reporting, that some people believed that WMC obtained water cost-free from the Great Artesian Basin, and should therefore pay some form of royalty or water charge. Contrary to this belief, water is obtained for Olympic Dam at significant cost, particularly in comparison with domestic consumers elsewhere in South Australia.

Domestic consumers in cities and regional centres are levied water charges because the infrastructure necessary to source, treat and distribute potable quality water is provided by government or water utilities. The infrastructure provided may include dams, borefields, treatment plants and distribution pipework. The water charges levied to these consumers are to meet the cost of capital investment in infrastructure, the costs associated with its operation and a financial return on the investment.

At Olympic Dam, the cost of the water supply infrastructure and its ongoing operation has been and still is funded directly and totally by WMC. The expenditure by WMC is considerable, totalling approximately $100 million to date. The high cost of supplying water to Olympic Dam provides a strong incentive for implementation of water minimisation programmes.

4.1.4 Minimisation of water use

Water minimisation programmes continue to be implemented at the Olympic Dam site and at the Roxby Downs township. The programmes implemented to date and their effectiveness are described below.

Olympic Dam

The approach adopted to reduce water consumption at the Olympic Dam operations has involved:

- developing work practices to become more water-efficient;
- substituting lower quality recycled water where practicable;
- modifying metallurgical processes to reduce water consumption or increase water recovery. These modifications have been largely undertaken as part of the two optimisation programmes completed in 1992 and 1995 (as described in Section 1.2).

Water use at Olympic Dam is reported as a function of the tonnage of ore milled. Figure 4.5 shows the historical water consumption per tonne of ore milled, demonstrating that water consumption has reduced from 2.10 kL/t (annual average from July to June) in 1989–90 (the first full year of production) to 1.57 kL/t in 1995–96. The water consumption figures include both process and potable water used at the mine and metallurgical plant.

The reduction in water consumption has occurred in two phases, the first being a consistent decline culminating in 1993 with a period of reasonably consistent water use of about 1.64 kL/t. A second reduction in 1995–96 followed a period of elevated water use during the commissioning period of new plant.

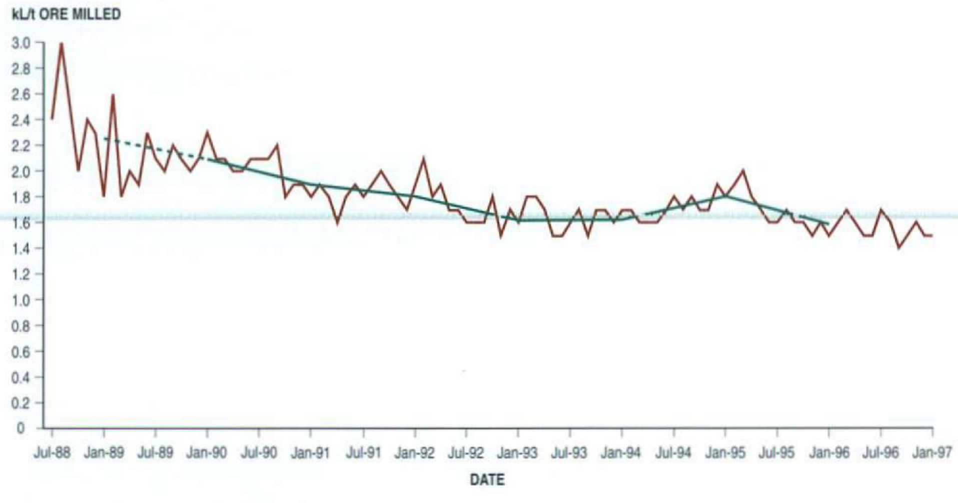


FIGURE 4.5
HISTORICAL RATE OF WATER CONSUMPTION PER TONNE OF ORE MILLED AT OLYMPIC DAM

Roxby Downs

The approach adopted to reduce water consumption at the township of Roxby Downs has involved:

- reusing treated sewage effluent for watering sports fields and the golf course;
- introducing educational programmes for the town residents that stress the need for water conservation and the means by which this can be achieved;
- encouraging residents to establish gardens with low water requirements, in particular by using native plant species.

Water use at Roxby Downs is reported as a function of the number of residents. Figure 4.6 shows the monthly and annual water consumption per resident at Roxby Downs and the Olympic Dam Village since July 1987, demonstrating that this consumption varies significantly with seasonal changes, with the peak water consumption per person in summer being approximately 2.5 times the minimum in winter. Figure 4.6 also demonstrates the effectiveness of water minimisation programmes after 1993, which have offset the previously increasing trend in water use.

4.1.5 Constraints to further water recycling

Owing to the high cost of supply, the processing facilities at Olympic Dam were designed and built, and are being operated, to be efficient in the use of water. However, the continuous reuse of process water results in the build-up of salts (particularly chlorides) and other contaminants, which originate either from the initial water source or from the ore or process chemicals used. Eventually the concentrations of some salts and other contaminants become so high that they have detrimental effects on process efficiency.

Table 4.3 summarises the current constraints on increased reuse of process water.

WMC will continue to research and develop methods to reduce consumption and to encourage water conservation through educational programmes for employees and other Roxby Downs residents.

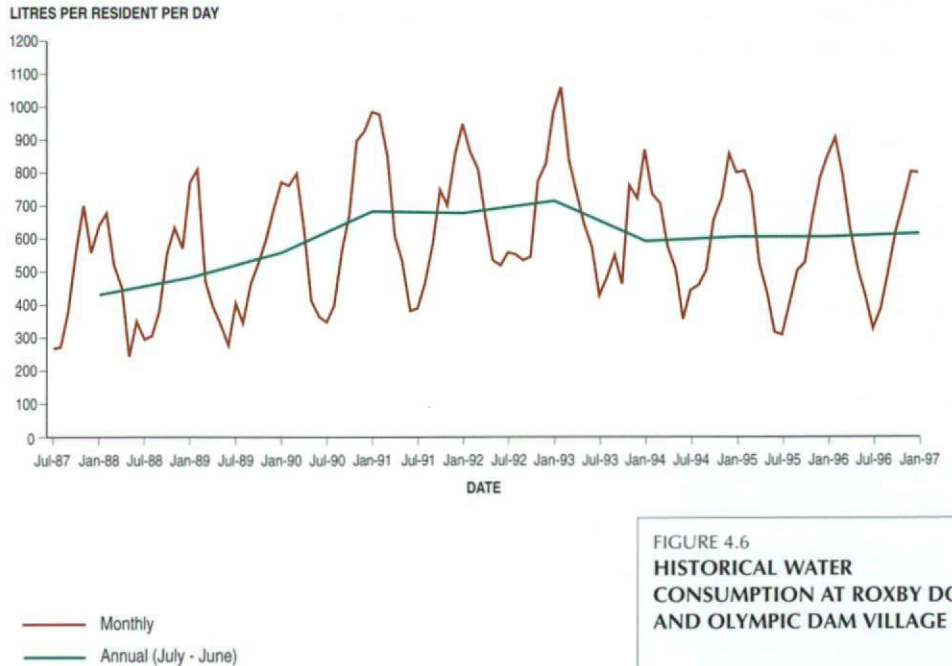


FIGURE 4.6
HISTORICAL WATER CONSUMPTION AT ROXBY DOWNS AND OLYMPIC DAM VILLAGE

Table 4.3 Current constraints on increased reuse of process water

Contaminant	Source	Constraint
Chlorides and total dissolved solids	Process water, ore, process chemicals	Build-up of chloride ions in process water interferes with uranium extraction in the solvent extraction plant
Acids	Sulphuric acid used for leaching uranium and residual copper from the concentrate tailings stream	Acidic water cannot be recycled to the concentrator
Organics	Solvents from solvent extraction plants, domestic wastewater	Organics in recycled water interfere with the flotation process in the concentrator, and may also damage rubber linings on process equipment
Calcium and iron	Ore, process water	Fouling of process equipment results from precipitation and build-up of calcium compounds, largely as calcium sulphate (gypsum), and of iron compounds, largely as jarosite-type complexes, downstream of the leaching operation

4.2 GREAT ARTESIAN BASIN

4.2.1 General description

The Great Artesian Basin (Figure 4.7) underlies approximately 1.7 million km^2 of central Australia (approximately one-fifth of the total land mass of mainland Australia) across Queensland, New South Wales, South Australia and the Northern Territory (Habermehl 1980). Approximately 350,000 km^2 of the basin lies in South Australia (approximately one-third of the area of the State). The total water storage of the Great Artesian Basin is estimated to be 8,700 million ML (Sibenaler 1996).

The Great Artesian Basin is a groundwater basin comprising quartzose sandstones and confining beds of marine mudstone and siltstone of Triassic, Jurassic and Cretaceous age. Groundwater is present in aquifers at depths ranging from a few metres to more than 2,000 m below the surface (Australian Bureau of Agricultural and Resource Economics et al. 1996). An example of an artesian basin in cross-section is given in Figure 4.8.

The basin is asymmetrical in shape, elongated north-east to south-west and tilted down towards the south-west. Tertiary uplift along the eastern margin and subsidence along the western margin and core have caused this asymmetry and the resultant dominant south-west flow of groundwater.

The main aquifer in South Australia associated with the Great Artesian Basin occurs within the Eromanga Basin and comprises sand, silt and gravel of the Algebuckina Sandstone and Cadna-owie Formation. The latter is overlain by Bulldog Shale, forming a semi confining bed. The Algebuckina Sandstone aquifer is a leaky confined aquifer, with pressure maintained by rainfall recharge in areas of outcrop primarily associated with the Great Dividing Range in Queensland, although minor recharge occurs around the southern and western margins.

In the north of South Australia, the aquifer thickens markedly, reaching in excess of 750 m where it is underlain by the generally fine-grained Poolowanna Beds and Simpson Desert basin sediments. In the north-east of South Australia, the low permeability Cooper Basin sediments underlie the aquifer sequence, which is split by the fine-grained Birkhead Formation into the upper Mooga Formation and lower Hutton Formation.

Groundwater flow rates through the Great Artesian Basin have been reported as 1–5 m/a; hence water movement through the sandstone aquifers is extremely slow. Artesian water has been dated at ages of almost 2 million years for the oldest water in the south-western part of the basin (Sibenaler 1996).

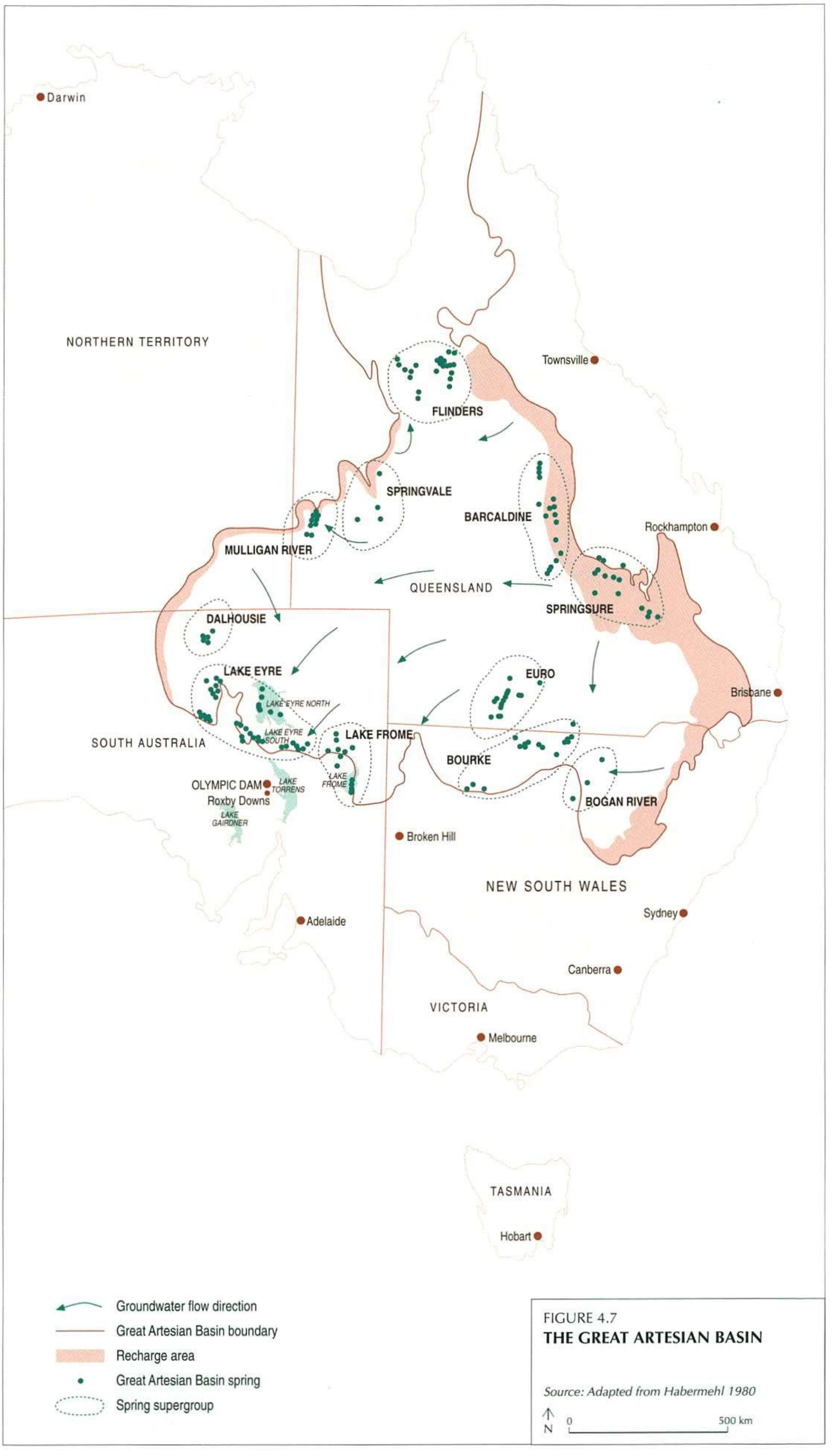


FIGURE 4.7
THE GREAT ARTESIAN BASIN

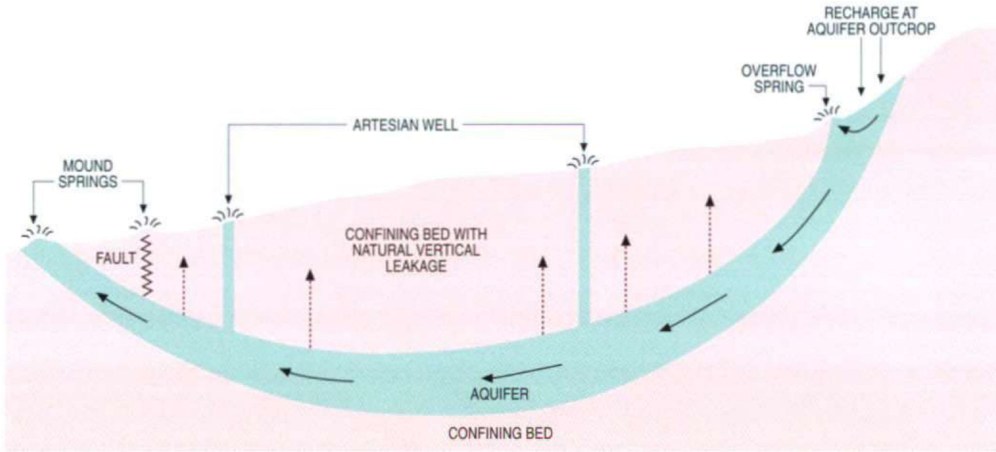


FIGURE 4.8
EXAMPLE OF AN ARTESIAN BASIN

Groundwater discharges naturally through artesian springs (often referred to as mound springs), and through subsurface flows (vertical leakage) into other strata and then to areas of direct evaporation. Mound springs occur where the aquifer outcrops (e.g. Welcome and Davenport spring groups, near Marree) or where major geological structures such as faults have connected the aquifer to the surface (e.g. Dalhousie Springs in northern South Australia).

Figure 4.7 shows the location of major mound spring groups associated with the Great Artesian Basin. Section 7.4 provides detailed information on the ecology associated with the mound springs.

Recharge and discharge rates for the entire Great Artesian Basin are currently close to equilibrium, and are estimated to be in the range of 2,630–2,930 ML/d (R. Habermehl, Australian Geological Survey Organisation, Canberra, pers. comm., January 1997). The discharge rate comprises (approximately):

- 1,200–1,500 ML/d from flowing bores
- 1,300 ML/d vertical leakage
- 130 ML/d natural discharge from mound springs.

The Australian Geological Survey Organisation is currently working on a new computer modelling study to refine and enhance the calculation of recharge into and discharge out of the Great Artesian Basin.

The recharge and discharge rates for the South Australian portion of the Great Artesian Basin are presently estimated to be in equilibrium, equivalent to a rate of 425 ML/d (Sibenaler 1996). The current discharges include:

- 190 ML/d vertical leakage to surface evaporation;
- 132 ML/d from flowing bores, mainly associated with the pastoral industry;
- 66 ML/d through natural discharge from mound springs, including 54 ML/d from Dalhousie Springs;

- 22 ML/d as part of oil and gas abstraction at the Cooper Basin operations;
- 15 ML/d abstracted for the Olympic Dam operations.

Further sustainable development of the Great Artesian Basin as a water resource is believed to be possible in South Australia through the use of strategically placed bores that 'harvest' water that would normally be lost by vertical leakage to surface evaporation. The development of the existing WMC borefields is a practical application of this theory. These borefields were located with the assistance of mathematical modelling of the Great Artesian Basin aquifer, taking into consideration vertical leakage, spring flows and abstractions by other users.

4.2.2 Water quality and temperature

Water quality varies markedly throughout the Great Artesian Basin, with the concentration of total dissolved solids (salinity) generally in the range of 1,000–5,000 mg/L. Little of the water is of potable or near potable quality, which has an upper limit for salinity of 1,000 mg/L. Water quality in the Algebuckina Sandstone is generally of lower salinity, with the concentration of total dissolved solids in the range of 500–1,500 mg/L.

Water within the Great Artesian Basin typically occurs as one of two types:

- bicarbonate-rich waters in most of the basin
- highly corrosive waters containing sulphates found on the western margin.

Groundwater temperatures are highly variable throughout, ranging between 30°C in the shallower areas and 100°C in the deeper sections (Sibenaler 1996).

4.2.3 Groundwater use

Artesian water was first discovered in the Great Artesian Basin in 1878 in a shallow, flowing bore south-west of Bourke. Many shallow bores were soon drilled, initially near springs at the margin of the basin west of Lake Eyre (Habermehl 1980). Droughts and low water supplies led to the drilling of many deep bores in South Australia from 1887 onwards.

With drilling and geological investigations indicating the presence of artesian water nearly everywhere in the arid interior, it was possible to define the extent of artesian conditions before the end of the nineteenth century (Habermehl 1980). By 1915, over 1,500 flowing artesian bores had been drilled throughout the basin. Since then, artesian pressure and water discharge rates have declined and the number of bores has increased.

The groundwater resources of the Great Artesian Basin support an extensive pastoral industry as well as mining developments, regional centres and the naturally occurring mound springs. It has been estimated that there are now 3,000 artesian bores over the entire basin (Sibenaler 1996). In South Australia there are approximately 220 artesian bores (excluding those of the Cooper Basin and Olympic Dam operations) flowing at a rate of approximately 132 ML/day (Sampson 1996).

It is estimated that less than 10% of this water is currently used effectively by the pastoral industry owing to the poor condition of older bores that cannot be shut off as a result of deterioration in the pipework and valves, and to the use of open drains to provide water to livestock (Sibenaler 1996). The water management measures being undertaken by the State and Territory governments, described in Section 4.2.4, have been developed to use water more effectively in future.

4.2.4 Water management

The management of water abstraction from the Great Artesian Basin is the responsibility of the governments of South Australia, Queensland, New South Wales and the Northern

Territory, all of which have ongoing bore rehabilitation and management programmes. By rehabilitating and managing bores, the waste of groundwater is being reduced and pressure is being maintained or restored to the aquifer. The current programmes generally employ three methods of mitigating flow loss, these being:

- abandonment—bores are backfilled with cement;
- rehabilitation—bores are relined and new bore-head equipment fixed;
- replacement—when rehabilitation is not practicable, a replacement bore is drilled generally adjacent to the original, which is then abandoned.

South Australia

For the past twenty years, the South Australian Department of Mines and Energy (MESA) has operated the Bore Rehabilitation Programme in the South Australian section of the Great Artesian Basin to assist with the management of uncontrolled water flow. Since commencement of this programme in 1977, 192 bores have been rehabilitated, with a consequent water saving of approximately 105 ML/d. An additional twelve bores still require extensive rehabilitation, and fifteen to twenty require minor work, which is expected to result in a further estimated water saving of 20 ML/d (Sampson 1996).

To complement the bore rehabilitation programme and further reduce water loss, there is a programme of installing pipework and watering points in place of the open drains that have been used extensively in the past to distribute water over pastoral properties.

Queensland

The Queensland Department of Natural Resources is currently undertaking a programme of bore rehabilitation named the 'Great Artesian Basin Rehabilitation Project', together with a complementary programme, 'Bore Drain Replacement Project', which is aimed at rehabilitating bore drains and pipework. In 1989, when the bore rehabilitation programme commenced, 750 of the 2,300 working artesian bores in the Queensland portion of the Great Artesian Basin did not have any means of flow control. In addition, much of the water discharged into bore drains and was lost through evaporation and infiltration.

Since the inception of the Queensland programmes, approximately 220 bores have been rehabilitated, with a water saving to date of 32,000 ML (an average saving since 1989 of 12 ML/d); 260 km of bore drains have been replaced, and 433 km of pipework covering 140,960 ha of land have been installed (T. Bean, Queensland Department of Natural Resources, pers. comm., December 1996).

New South Wales

The New South Wales Department of Water Resources, together with the Department of Conservation and Land Management, is currently undertaking a bore rehabilitation programme named 'Cap and Pipe the Bores'. Of the estimated 1,200 artesian bores in the New South Wales portion of the Great Artesian Basin, 600 have ceased flowing, 375 have unrestricted flow and 150 have piped distribution systems. Bore assessments commenced during 1995–96 and have been followed by bore rehabilitation and pipework installation, allowing an estimated water saving of 295 ML for the period 1995–96, or 0.8 ML/d (L. Branch, NSW Department of Land and Water Conservation, pers. comm., October 1996).

Northern Territory

The Northern Territory Department of Lands, Planning and Environment is currently establishing a programme to rehabilitate two of the three free-flowing bores in the Northern

Territory portion of the Great Artesian Basin. Rehabilitation of these bores should result in a water saving of approximately 10 ML/d. Rehabilitation of the third free-flowing bore is being considered at present (I. Mathews, NT Department of Lands, Planning and Environment, pers. comm., January 1997).

The discharge from the remaining forty to sixty pastoral bores that abstract groundwater from the Northern Territory portion of the Great Artesian Basin is regulated, and rehabilitation of these bores is not being considered.

4.2.5 Existing abstraction licences held by WMC

The legal framework for the development and operation of Olympic Dam is established by the Indenture between the company and the South Australian Government (Section 1.3). The Indenture provides for the issue of special water licences that enable WMC to abstract groundwater from the borefields up to agreed maximum drawdown levels at the boundaries of the designated areas. The agreement is between the company and the Minister for Mines and Energy.

Special water licences apply to the operation of Borefields A and B. The criteria outlined in these licences are discussed below.

Borefield A

The Special Water Licence for Borefield A contains agreed limits to the drawdown in aquifer pressure within the Designated Area (as shown in Figure 4.1). The term 'drawdown' refers to the reduction in water table or potentiometric head from a defined initial head or existing condition over a specified time interval. The agreed limits for Borefield A are:

- drawdown at the boundary of the Designated Area between observation bores GAB8 and HH2 shall not exceed 4 m;
- drawdown at the boundary of the Designated Area, as measured at Jackboot Bore, shall not exceed 5 m.

The Special Water Licence for Borefield A requires WMC to manage borefield operations in such as way as to prevent adverse effects on mound springs of the Hermit Hill spring complex, The Bubbler and other springs in the Blanche Cup spring complex. It also requires WMC to monitor water pressures in strategically located observation bores and to monitor spring flows on a monthly basis.

Borefield B

The Special Water Licence for Borefield B contains agreed limits to the drawdown of aquifer pressure at the five corner locations of the Designated Area to a maximum of 5 m. The licence also contains requirements for the regular monitoring of aquifer pressure in strategically located observation bores.

The agreed limits in the Special Water Licence for Borefield B were based upon the results of mathematical modelling presented in the supplementary environmental studies for the Borefield B development (Kinhill Engineers 1995). This mathematical modelling predicted the drawdown in aquifer pressure resulting from an abstraction rate of 42 ML/d from both Borefield A and Borefield B over a period of twenty years.

4.2.6 Predicted and observed effects of water abstraction by WMC

The following section discusses previous predictions of the effects of water abstraction by WMC and actual recorded impacts.

The 1983 EIS

The 1983 EIS provided details of the proposed borefield abstraction rates and the predicted impacts on the Great Artesian Basin. In the EIS, it was reported that five bores would be constructed at Borefield A, with four operating at any one time to achieve an abstraction rate of 6 ML/d. It also provided some preliminary observations on the development of Borefield B, although abstraction from Borefield B was not contemplated at that time.

The 1983 EIS did, however, state that Borefield B would be developed to meet the future needs of production, which was expected to be up to 33 ML/d for a production rate of 150,000 t/a copper and associated products. The development of Borefield B has been the subject of further detailed studies and reporting (Kinhill Engineers 1995).

Predictions about the impact on the Great Artesian Basin of the development of Borefield A were made using a groundwater model. These predictions, reported in the 1983 EIS, stated that mound spring discharges along the southern margin of the Great Artesian Basin would be reduced by 100% in the case of Priscilla, and up to 10–33% for others, with effects more marked in close proximity to the borefields and less marked further afield. In addition, localised impacts on discharge rates were predicted at existing bores, particularly Venable Bore in Borefield A and Crows Nest Bore in Borefield B, which were both predicted to experience a 100% reduction in artesian flow. Water quality was not expected to be measurably affected by the development of the borefields.

Kinhill Stearns 1984 and Kinhill Engineers 1995

Using the GABROX model, a report by Kinhill Stearns in 1984 made predictions concerning the impact of further development of Borefield A on the discharge rates from mound springs of the Lake Eyre South region.

The predictions were made for two development scenarios (restricted and extended) and for two assumptions regarding the permeability of the ridge between the north-eastern and south-western sub-basins (impermeable and semi-permeable). These predictions were reviewed by Kinhill Engineers a decade later (Kinhill Engineers 1995), and comparisons made with flow measurements to 1994. The results of this review for the extended borefield, which most closely resembles the actual borefield development, are shown in Table 4.4.

Table 4.4 Reduction in mound spring discharges—predicted (1984) versus actual (1994) results

Spring complex	Spring group (spring number)	Predicted discharge reduction for extended borefield (%)		Actual flow reduction (%)
		Impermeable[1]	Semi-permeable[1]	
Hermit Hill	Beatrice (HBS004)	100	100	40
	Bopeechee (HBO004)	<2	20	43
	Hermit (HHS170)	<1	<1	36
	Old Finniss (HOF096)	<2	<2	Marginal increase
	Venable Bore (HVS001)	100	100	100 (extinct May 1990)
Wangianna	Davenport (WDS001)	<1	< 1	Virtually 0
Lake Eyre	Emerald (LES001)	3	3	Virtually 0
	Fred (LFE001)	6	17	50
	Priscilla (LPS001)	75	60	100 (extinct late 1990)

1 *Refers to the assumed hydraulic properties of the ridge between the north-eastern and south-western sub-basins.*
Source: Adapted from Kinhill Engineers 1995.

Kinhill Engineers (1995) noted that flow from Bopeechee Bore also showed a marked reduction over a similar time period. A prediction for the flow reduction from this bore was not made in 1984.

In general, Kinhill Engineers (1995) stated that the estimates of reduction in mound spring discharge made in 1984, compared with observed flow reductions since 1984, were shown to be reasonable, given that:

- a generalised model for the pumping area was assumed, with the pumping area assumed for Borefield A not accurately reflecting the bore configuration subsequently in place from 1992 onwards;
- the uncertainty in the hydraulic parameters for the model has since been greatly reduced (GABROX92 and, subsequently, the 1995 model);
- data for springs with very low flow rates sometimes contain erroneous values owing to measurement difficulties.

Impacts on mound spring discharges resulting from the development of Borefield B were predicted by Kinhill Engineers (1995) following further groundwater modelling. These predictions were made using the GAB95 (previously GABROX95) groundwater model, which updated the original GABROX model by incorporating the increased level of understanding of the Great Artesian Basin's hydrogeology gained from production bore records and monitoring bore data.

Kinhill Engineers (1995) predicted that, in comparison with flows in November 1994, discharge rates at mound springs within the Bopeechee spring group would decline a further 10–15%, the Welcome and Hergott spring groups would decline 10–15%, and the Hermit Springs and Davenport spring groups would decline up to 10–15% following combined extraction from Borefields A and B.

To mitigate the further impacts on mound springs within the Bopeechee spring group, WMC implemented a reinjection strategy to increase groundwater pressure in the north-eastern sub-basin and thereby increase discharge rates at this spring group. Full details of this strategy are given in Western Mining Corporation (1995) and a summary is provided in Section 4.2.7 of this report.

Current potentiometric heads

Figure 4.9 gives the current (1996) contours representing the potentiometric heads throughout the southern portion of the Great Artesian Basin. The potentiometric heads represent the water pressure within the major aquifers in the Great Artesian Basin. The 1996 potentiometric heads were used as the baseline for the mathematical modelling undertaken for this EIS (Section 4.5). The 1996 heads include the observed effects of the Borefield A operation since 1983. Borefield B has not been in operation long enough to affect the contours.

4.2.7 Current mitigation measures undertaken by WMC

Declining artesian flow from springs HBO004 and HHS170 prompted WMC to initiate an aquifer injection programme using groundwater from Borefield A to partially restore pressure in the vicinity of these springs. Since October 1995, groundwater from production bore GAB6 has been reinjected into the aquifer at monitoring bore GAB20 (Figure 4.2). The initial rate of reinjection was 2 L/s (173 kL/d), which was increased to 4.6 L/s (400 kL/d) in June 1996.

Assessment of the effectiveness of the reinjection programme after November 1996 has been complicated by the reduction in abstraction from Borefield A to 5–6 ML/d following the commencement of commissioning of Borefield B.

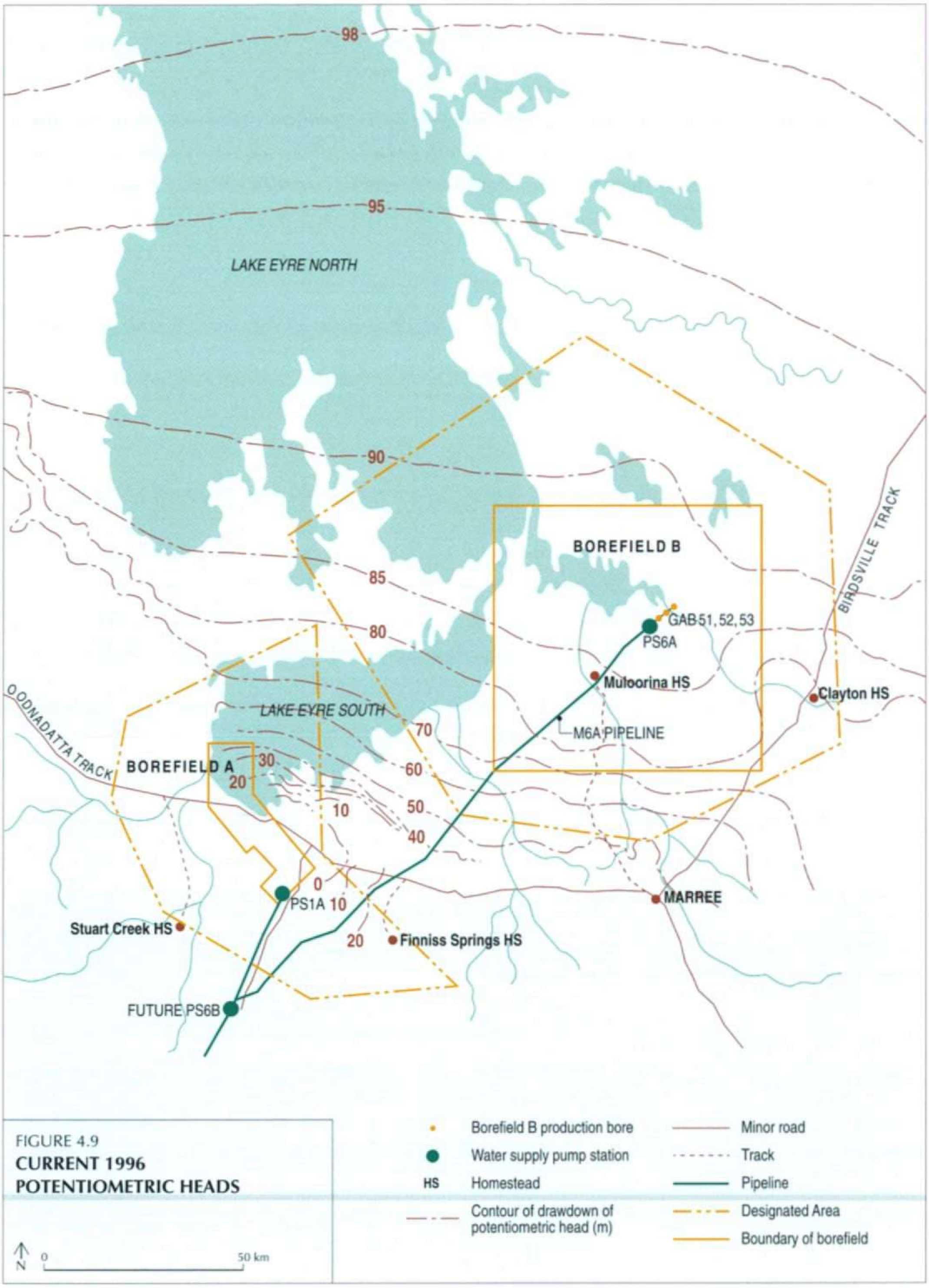


FIGURE 4.9
CURRENT 1996 POTENTIOMETRIC HEADS

Between November 1995 and June 1996, potentiometric heads in monitoring bores GAB7, GAB8, GAB19 and HH2 continued to decrease by 0.3 m, 0.41 m, 0.41 m and 0.2 m respectively. Since June 1996, heads in these bores have increased by 0.92 m, 0.92 m, 1.43 m and 0.41 m respectively to their present levels, indicating that the increased reinjection programme, combined with a decrease in abstraction from Borefield A, has been effective in partially restoring aquifer pressure.

Flows from springs HBO004 and HHS170 continue to be monitored during the ongoing aquifer reinjection programme. However, unlike water levels measured in bores, flows from springs are difficult to measure accurately and are also known to vary naturally over both short (daily) and long (seasonal) periods. Therefore, while the spring flow monitoring results presented below show an initial stabilisation and then an increase in flows, the monitoring period to date has been too short to allow conclusive results to be drawn.

The flows from spring HBO004 fluctuated around 0.22 L/s until March 1996 when the flows recovered, reaching a maximum rate of 0.39 L/s in August 1996. The flow rate at the end of June 1996 was 0.34 L/s, marginally above the rate of 0.32 L/s in June the preceding year. The flow then increased for the next six months until it reached a high of 0.66 L/s in January 1997.

The flow rate recorded at spring HHS170 in June 1995 (five months prior to reinjection at GAB20) was 0.47 L/s. Following the injection of water at GAB20, the flow rate from the spring continued to decline to its lowest reported flow of 0.15 L/s in January 1996. The flow rate then began to increase, reaching 0.42 L/s in July 1996. Between July 1996 and January 1997 the flow from HHS170 declined to 0.21 L/s, slightly higher than at the same time the previous year.

4.3 WATER SUPPLY STRATEGY FOR 200,000 t/a COPPER PRODUCTION

Water requirements

The water requirements of the project following the proposed expansion to 200,000 t/a copper production have been estimated by water balance calculations to be about 33.4 ML/d. This water requirement would be sourced from the existing borefields, and would be in addition to the comparatively minor use of saline water (for underground drilling and dust suppression) obtained from dewatering the underground mine operations and the saline water borefield.

The predicted site water balance is shown in Figure 4.10. When the domestic water supply to the Roxby Downs township and Olympic Dam Village (2.6 ML/d) is excluded, the water balance shows a total site water use (potable and process) of approximately 30.8 ML/d. A site water use of 30.8 ML/d equates to a rate of 1.24 kL/t of ore milled, a reduction of

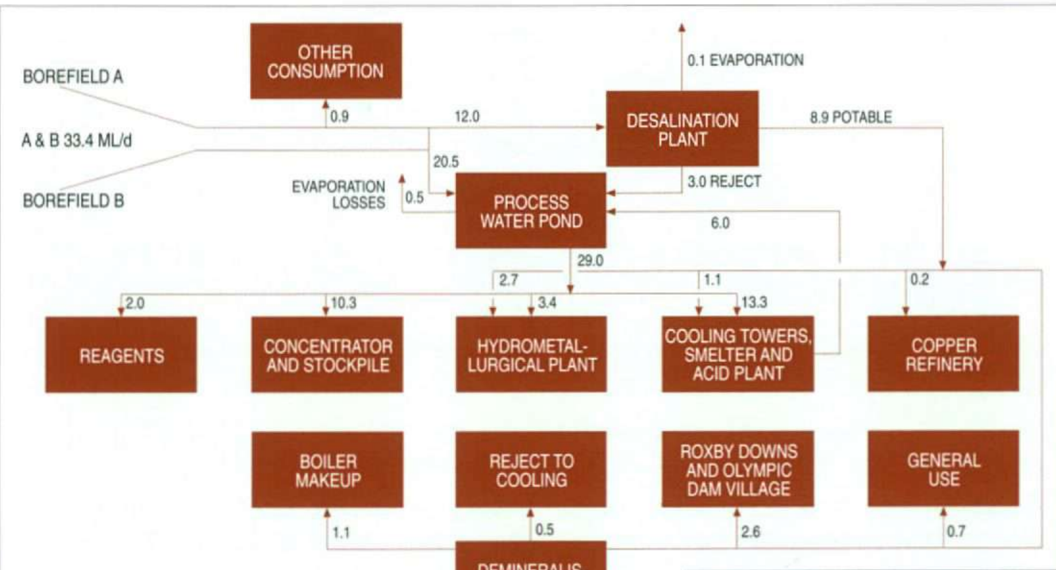


FIGURE 4.10
WATER BALANCE FOR 200,000 t/a COPPER PRODUCTION

Note: All flows in ML/d

approximately 21% from the 1995–96 rate of site water use of 1.57 kL/t of ore milled. Most of the reduction in the rate of water use would be achieved by the installation of high-compression thickeners in the copper concentrator section of the metallurgical treatment plant. These thickeners would allow an increased recovery of process water for recycling.

Also shown in the site water balance is an overall consumption of 8.4 ML/d (13.3 ML/d process water plus 1.1 ML/d potable water less 6.0 ML/d recycled water) in the cooling towers, smelter and acid plant. A significant portion of this water would be used in wet scrubbing systems (Section 3.8) associated with the new smelter. The wet scrubbing systems would be introduced to the site as part of the expansion to provide improved levels of gas cleaning and a reduction in air emissions from the processing plant. However, this water use partially offsets other efficiencies in water use incorporated in the Expansion Project.

Infrastructure requirements

The infrastructure required to meet the water needs of the project at a production rate of 200,000 t/a copper is described in Section 11.1 and summarised below:

- connection of all three production bores in Borefield B to the M6A pipeline at the existing pump station PS6A (Figure 4.1);
- decommissioning of pump station PS1B and construction of a new pump station, PS6B (Figure 4.1);
- construction of a new pipeline, M6B, from pump station PS6B to Olympic Dam (Figure 4.1);
- expansion of water treatment facilities, including water storages.

This infrastructure was discussed in an earlier report (Kinhill Engineers 1995) and has been assessed and approved by the South Australian Government.

Management of water resources

The strategy for the development of future water resources assumes management of abstractions from the existing borefields to mitigate potential adverse effects on the environment and other water users. The monitoring of the borefields is a condition of the special water licences, and WMC has implemented a comprehensive monitoring programme to meet this requirement. This ongoing monitoring will ensure that the information necessary for management of the resource is available when required. The monitoring results are submitted to the State Government annually as part of WMC's environmental management and monitoring programme (Chapter 15).

4.4 WATER SUPPLY STRATEGY FOR 350,000 t/a COPPER PRODUCTION

At the completion of the proposed expansion to 200,000 t/a copper production, the water supply infrastructure to Borefields A and B would have a combined capacity of about 42 ML/d. This capacity, which also equates to the abstraction rate used to define the Designated Area for Borefield B (Kinhill Engineers 1995), would exceed the project requirement of 33.4 ML/d.

Planning for the possible future expansion to a copper production rate of 350,000 t/a is not sufficiently advanced at present to allow water balances to be calculated. However, this planning recognises that the further development of water treatment and recycling facilities at Olympic Dam may be an economic alternative to upgrading infrastructure to Borefield A and B or establishing another borefield. The current water supply strategy therefore assumes that sufficient water treatment and recycling facilities would be provided in future to enable the water use at a copper production rate of 350,000 t/a to be accommodated within the infrastructure capacity of 42 ML/d.

As part of longer term planning, WMC is also considering plans for another borefield that may be required in future. This borefield would be subject to separate public consultation and government assessment should its establishment become necessary.

For water abstraction modelling purposes, this EIS assumes that expansion to 350,000 t/a copper production would occur in 2010. Table 4.5 shows the borefield extraction schedule used for the groundwater modelling described in more detail in the sections following.

Table 4.5 Borefield extraction schedule used for groundwater modelling (ML/d)

Period	Borefield A	Borefield B	**Total**
1996–1998	6	11	**17**
1998–1999	6	14	**20**
1999–2010	6	28	**34**
2010–2011	6	33	**39**
2011–2016	6	36	**42**

4.5 PREDICTED IMPACTS OF FUTURE USE OF THE EXISTING BOREFIELDS

4.5.1 Groundwater model—ODEX1

Predictions of potentiometric heads within the major aquifer of the Great Artesian Basin for future operation of the existing borefields have been undertaken using a new groundwater model known as ODEX1 (WMC Resources 1997).

ODEX1 supersedes the mathematical groundwater models GABROX and GAB95. The new model has been developed principally for modelling the impacts of groundwater abstraction associated with the Expansion Project. This model uses new data arising from recent drilling programmes and geophysical work associated with the development of Borefield B, and from the re-evaluation of piezometric measurements. ODEX1 has deliberately been used with conservative assumptions and probably overestimates drawdown, particularly in the deeper parts of the Great Artesian Basin.

ODEX1 takes into account all current users of the Great Artesian Basin in the vicinity of the borefields—pastoral bores, Cooper Basin operations, WMC Borefields A and B—as well as natural discharges (e.g. mound springs) and vertical leakage.

The current 8.5 ML/d discharge from Georgia Bore, situated 30 km north of Borefield B (Figure 4.3), is not controlled. The modelling has assumed that future flows from this bore will be regulated to rates consistent with pastoral purposes.

As with previous groundwater models, ODEX1 predicts changes with time to potentiometric heads according to selected borefield development scenarios. For the purposes of this EIS, artesian flows from mound springs and pastoral bores are assumed to be directly proportional to the difference between the potentiometric head and the ground surface. When the potentiometric head is predicted to be below the ground surface, artesian flows are assumed to cease.

4.5.2 Predicted impacts on potentiometric heads to the year 2016

The modelling results presented in this EIS are for all abstractions and discharges from the Great Artesian Basin, including the WMC borefields.

If required, the ODEX1 model would be available in future to predict the levels of drawdown attributable to WMC so that these levels could be assessed against the requirements of the special water licences.

Drawdown due to total discharge

Using the 1996 potentiometric heads as starting conditions, and noting that Borefield A commenced production in 1983 and Borefield B in 1996, ODEX1 was used to simulate the drawdown to year 2016. The scenario modelled included flows from mound springs, existing and new pastoral bores, the Cooper Basin operations, WMC bores and vertical leakage.

The MESA Bore Rehabilitation Programme (Section 4.2), which resulted in a period of pressure recovery from 1986, is predicted to have a negligible incremental impact from 1996 onward as the aquifer regains equilibrium.

Results are shown in Figure 4.11. Hydrographs for the model cells located close to each of the corners of the Special Water Licence Designated Area (P1 to P5, D2) are shown in Figure 4.12, and predicted drawdowns by 2016 are tabulated in Table 4.6.

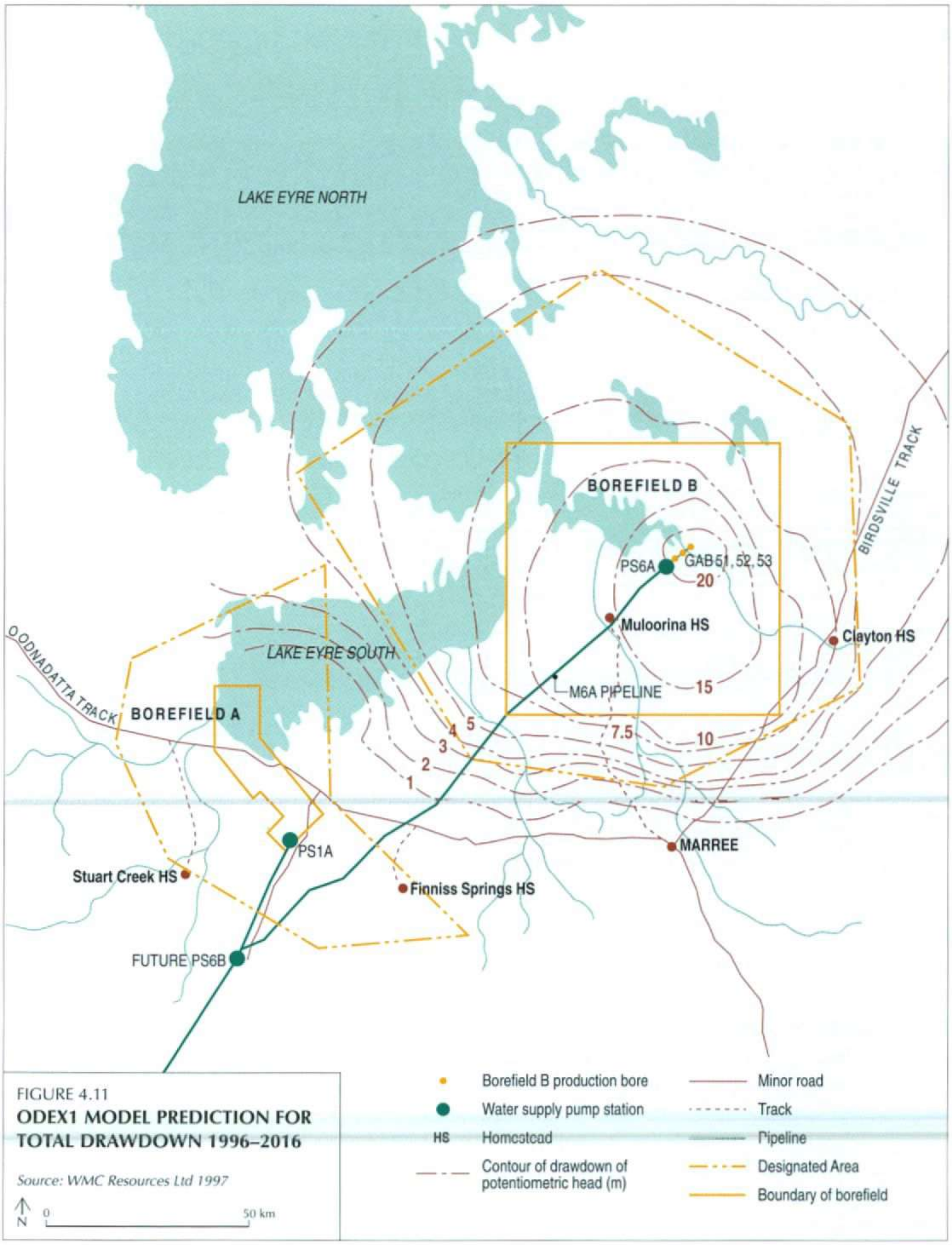


FIGURE 4.11
ODEX1 MODEL PREDICTION FOR TOTAL DRAWDOWN 1996–2016

Source: WMC Resources Ltd 1997

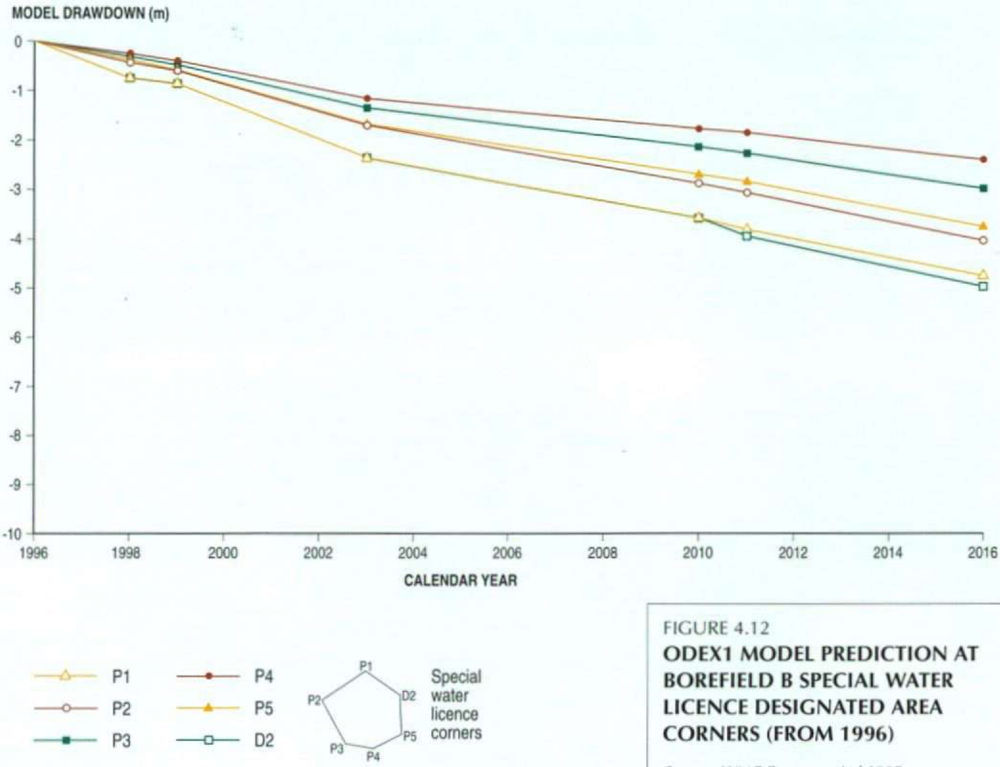


FIGURE 4.12

ODEX1 MODEL PREDICTION AT BOREFIELD B SPECIAL WATER LICENCE DESIGNATED AREA CORNERS (FROM 1996)

Source: WMC Resources Ltd 1997

Data in Table 4.6 are expressed to two decimal places. However, this should not be taken to imply that the second decimal place indicates a highly accurate calculation, which is beyond the limits of the model's predictive capacity. The calculation to two decimal places shows that there is compliance of the predicted values with the agreed drawdown limit of 5 m.

Table 4.6 Predicted drawdown of potentiometric heads at corners of the Borefield B Designated Area—2016[1]

Site	Predicted drawdown (m)
P1	4.86
P2	4.17
P3	3.10
P4	2.52
P5	3.91
D2	4.97

1 *Scenario modelled includes abstractions by other users.*
Source: WMC Resources 1997.

4.5.3 Predicted impacts on mound spring flows

The maintenance of flow at key mound spring groups is a major environmental issue (Section 7.4). Although the ODEX1 model was developed to assess the broader water resource management issues resulting from Borefield B development, it is possible to draw some conclusions about impacts of regional drawdown on major spring groups.

Figure 4.13 shows predicted drawdown of potentiometric heads in the area containing the most ecologically sensitive springs.

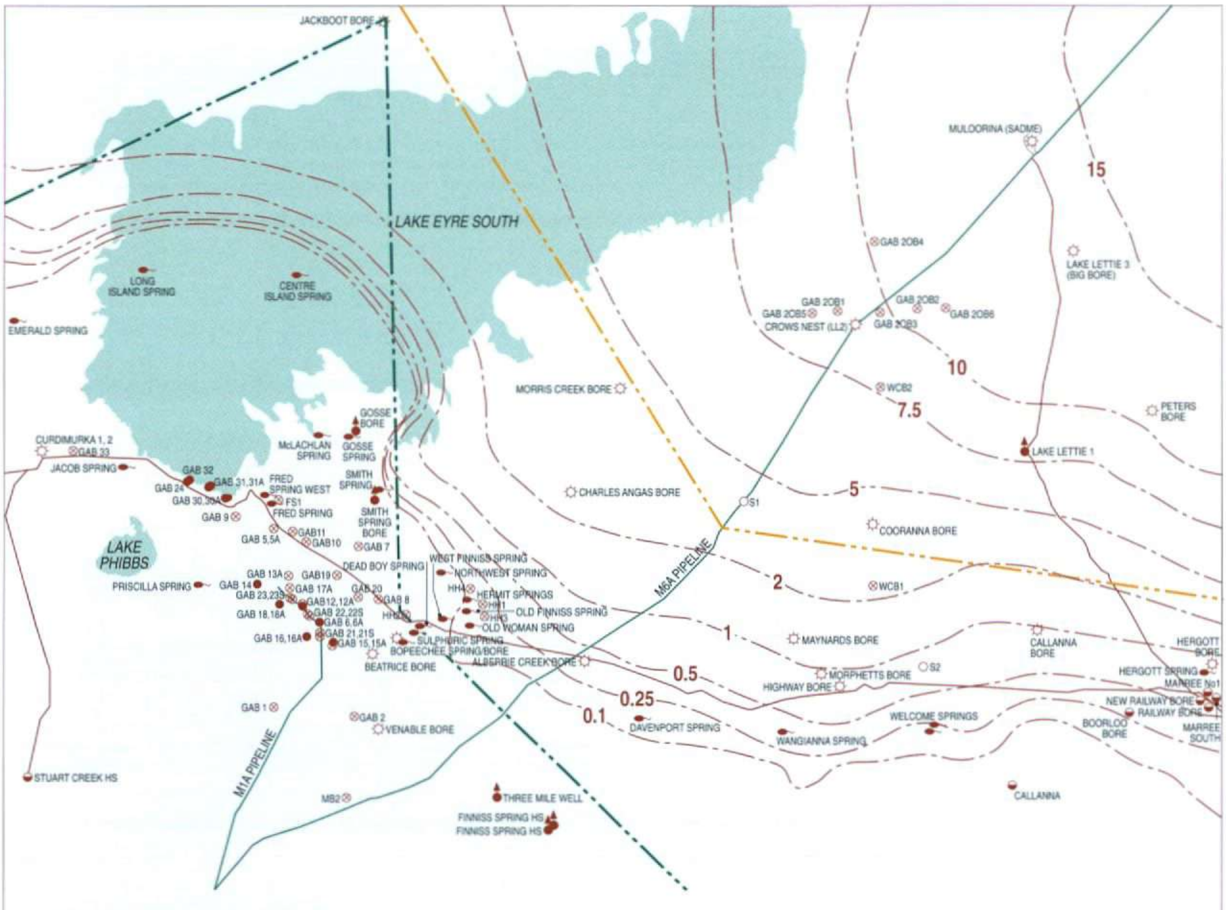


FIGURE 4.13
PREDICTED DRAWDOWN OF POTENTIOMETRIC HEADS— 1996–2016
Source: WMC Resources Limited 1997
Note: Contours in metres
N 0 10 km

It can be seen that, along the line from Marree to Hermit Hill, the predicted drawdown at spring sites is generally less than 0.25 m, which is only a small proportion of the available artesian head, suggesting a minimal impact on springs in that area. Drawdown at springs in the Borefield A area is greater, with most of this drawdown having already occurred since operation of Borefield A commenced in 1983.

The model simulates groundwater discharge from springs by assuming that flows from springs are in direct proportion to the difference between aquifer pressure and ground level.

In practice, it is known that spring flow rate is much more variable than aquifer pressure owing to a number of factors that cannot be considered in a groundwater flow model (and that do not relate to the operation of WMC's borefields). These factors include (but are not restricted to):

- diurnal atmospheric pressure variations (barometric effects)
- evaporation rates
- changes in composition and abundance of vegetation species
- grazing and damage by cattle and horses.

The springs have been grouped into hydrogeological zones on the basis of similarity of expected responses to abstraction from the borefields. A summary of the groundwater model predictions is provided in Table 4.7.

Table 4.7 Predicted changes to mound spring flows—1996–2016

Hydrogeological zone and spring group	Predicted change in flow, 1996–2016[1]	Comments
BOREFIELD A ZONE		
Beatrice	100%	Expected to remain stable after flow increase.
Fred	n/f	Significant increase in aquifer pressure predicted; resumption of flows likely.
Venable	n/f	Significant increase in aquifer pressure expected; resumption of flows likely.
Priscilla[2]	n/f	Significant increase in aquifer pressure expected; resumption of flows likely.
Jacob[2]	–	Major increase in flow expected.
NORTH-EASTERN SUB-BASIN		
Bopeechee	2% increase	Up to 17% increase in flow in 1997 and 1998, followed by a gradual decline in flow, resulting in an overall small increase of 2%[3].
Sulphuric	Less than 1% decline	Up to 13% increase in flow in 1997 and 1998, followed by a gradual decline in flow, resulting in an overall decline of less than 1%.
Dead Boy	–	Located within 1 km of Sulphuric spring group, therefore expected to behave similarly.
West Finniss	1% decline	Up to 5% increase in flow in 1997 and 1998, followed by a gradual decline in flow, resulting in an overall decline of 1%.
WESTERN LAKE EYRE SOUTH GROUP		
Centre Island	0.5% increase	Up to 6% increase in flow in 1998 and 1999, followed by a gradual decline in flow, resulting in an overall small increase of 0.5%.
Emerald	2% increase	Up to 6% increase in flow in 1998 and 1999, followed by a gradual decline in flow, resulting in an overall small increase of 2%.
Long Island	1.5% decline	Up to 3% increase in flow in 1998 and 1999, followed by a gradual decline in flow, resulting in an overall decline of 1.5%.
Gosse	3% increase	Up to 5.5% increase in flow in 1998 and 1999, followed by a gradual decline in flow, resulting in an overall increase of 3%.
McLachlan	12.5% increase	Large increase in flow in 1998 and 1999 (up to 18%), followed by a gradual decline in flow, resulting in an overall increase of 12.5%.
SOUTHERN MARGIN EASTERN ZONE		
Davenport	3% decline	Potential slow, steady decline for all springs in this zone.
Wangianna	16.5% decline	
Welcome	4.5% decline	
Hergott	6% decline	
SOUTHERN MARGIN WESTERN ZONE		
Smith	1.8% decline	Large increase in flow from 1997 to 1999, followed by a decline in flow to 2016.
Hermit Springs	0.8% decline	Steady decline for all springs in this zone except for Smith.
Old Finniss	1% decline	
Old Woman	0.5% decline	
CURDIMURKA–STRANGWAYS ZONE		
Horse[2]	–	Minimal impacts expected.
Anna[2]	–	Minimal impacts expected.
Blanche Cup[2]	–	Minimal impacts expected.
Strangways[2]	–	Minimal impacts expected.

1 *Values are approximate.*
2 *Spring groups outside the ODEX1 domain.*
3 *Current flow rate has been enhanced by reinjection programme.*
– *No prediction made.*
n/f No flow in 1996.

Borefield A zone

Borefield A zone includes the following spring groups:

- Beatrice
- Fred
- Venable
- Priscilla—outside model domain
- Jacob—outside model domain.

Springs close to Borefield A have suffered considerable loss in potentiometric head over the past few years. The planned reduction in discharge from Borefield A to a steady 6 ML/d is predicted to produce pressure recovery of up to 20 m. In general, a major increase in spring flow rate from groups within this zone is expected.

North-eastern sub-basin

The north-eastern sub-basin includes the following spring groups:

- Bopeechee
- Sulphuric
- West Finniss
- Dead Boy.

Springs in the north-eastern sub-basin are expected to respond to the reduction in discharge from Borefield A in the manner illustrated in Figure 4.14. Flow rate recovery is predicted for 1997 and 1998, followed by a gradual decline to around 1996 flow rates by 2016 owing to the combined effects of the two borefields. Dead Boy spring group is expected to behave similarly to West Finniss and Sulphuric.

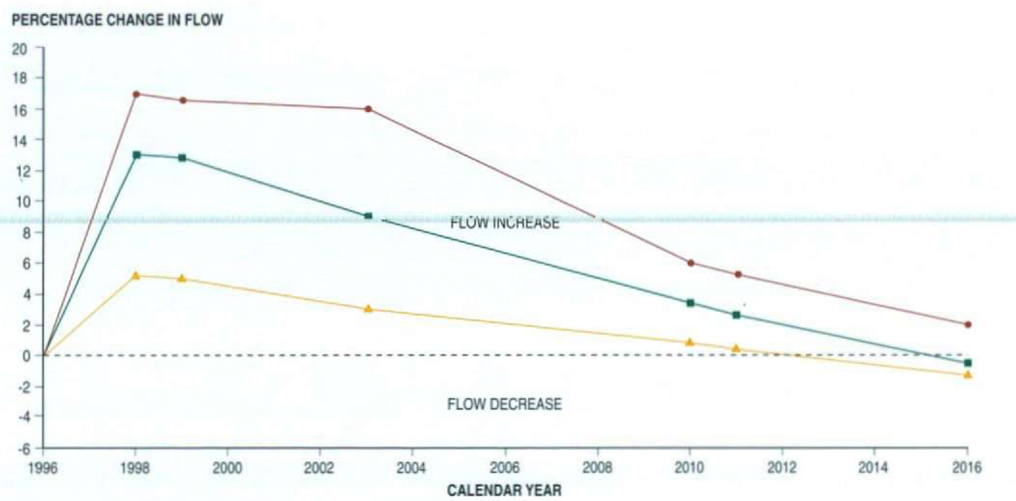


FIGURE 4.14
NORTH-EASTERN SUB-BASIN MOUND SPRINGS: CHANGE IN FLOW FROM 1996 RATE PREDICTED BY ODEX1 MODEL

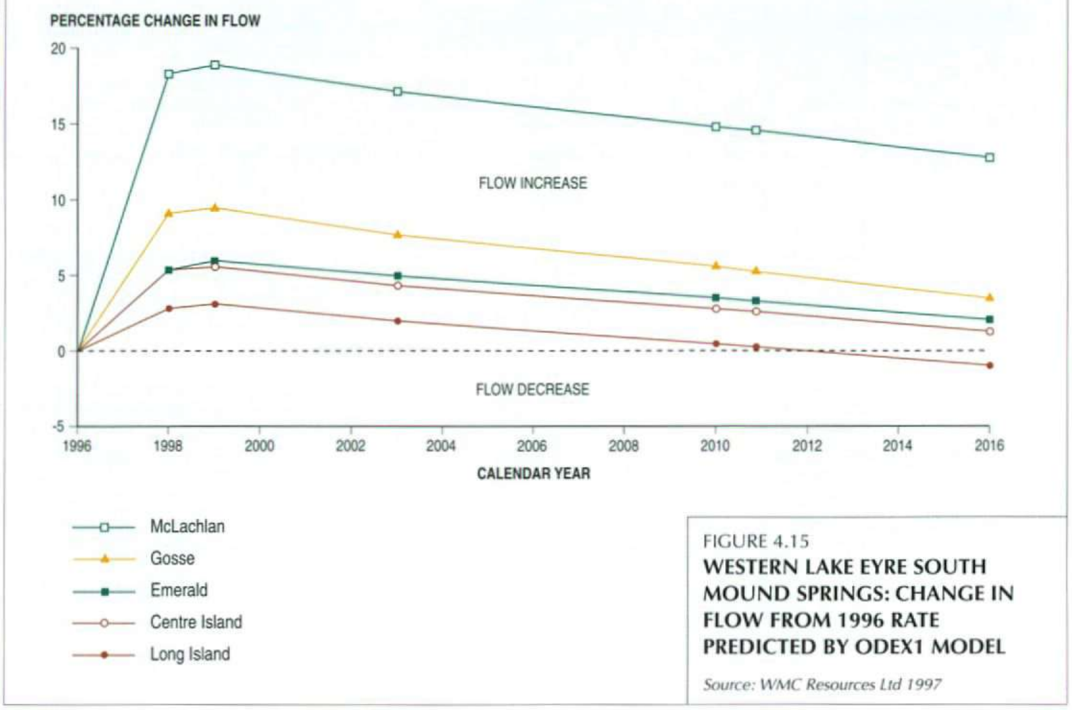


FIGURE 4.15
WESTERN LAKE EYRE SOUTH MOUND SPRINGS: CHANGE IN FLOW FROM 1996 RATE PREDICTED BY ODEX1 MODEL

Source: WMC Resources Ltd 1997

Western Lake Eyre South group

Spring groups in the Western Lake Eyre South group zone include:

- McLachlan
- Gosse
- Emerald
- Centre Island
- Long Island.

Springs in this zone are predicted to respond in a similar fashion to those in the north-eastern sub-basin. Figure 4.15 shows that McLachlan Spring, which is nearest to Borefield A, will benefit the most from the reduction in discharge, but is predicted to show a gradual decline as Borefield B drawdown develops.

Southern margin eastern zone

The predicted impact on flows from the spring groups in the southern margin eastern zone is shown in Figure 4.16. It includes the following spring groups:

- Davenport
- Welcome
- Hergott
- Wangianna.

The area to the east of Bopeechee is protected from the influence of Borefield A by the Hermit Springs basement high. It is also predicted that the springs would be buffered from major impacts of Borefield B by the leaky nature of the Bulldog Shale between them and the borefield.

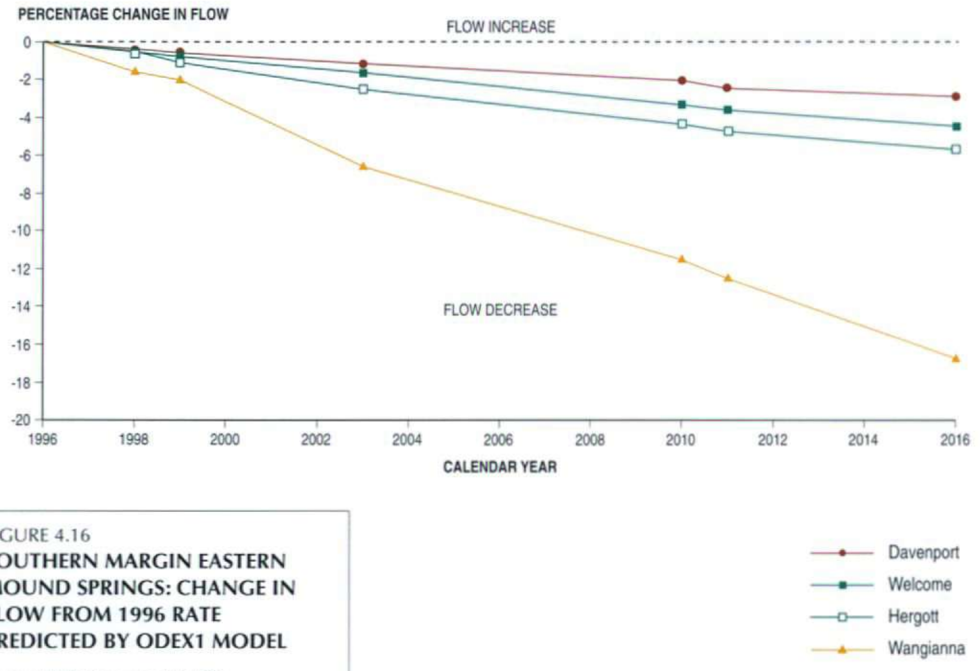


FIGURE 4.16
SOUTHERN MARGIN EASTERN MOUND SPRINGS: CHANGE IN FLOW FROM 1996 RATE PREDICTED BY ODEX1 MODEL

Source: WMC Resources Ltd 1997

Southern margin western zone

Spring groups in the southern margin western zone include:

- Smith
- Old Woman
- Hermit Springs
- Old Finniss.

This zone contains the ecologically sensitive Hermit Springs spring group. Figure 4.17 shows the predicted change in flow rates. Smith spring group is predicted to behave similarly to the Western Lake Eyre South group, as it is more exposed to Borefield A effects and lacks the buffering effect of the poorly developed aquifer and leaky Bulldog Shale that exists north-east of the Hermit Springs group, where changes in flow due to WMC abstraction are predicted to be very small.

It should be noted that changes of the magnitude predicted for Hermit Springs, Old Finniss and Old Woman spring groups are too small to be detected with confidence using currently available measurement methods.

Curdimurka–Strangways zone

The Curdimurka–Strangways zone includes the following spring groups:

- Horse
- Anna
- Blanche Cup
- Strangways.

All these spring groups lie outside the current model domain. The leaky nature of the Bulldog Shale in the area, the springs' considerable distance from Borefield B, and what is believed to be poor aquifer development are expected to minimise changes in flow. Monitoring would continue at these springs to check this prediction.

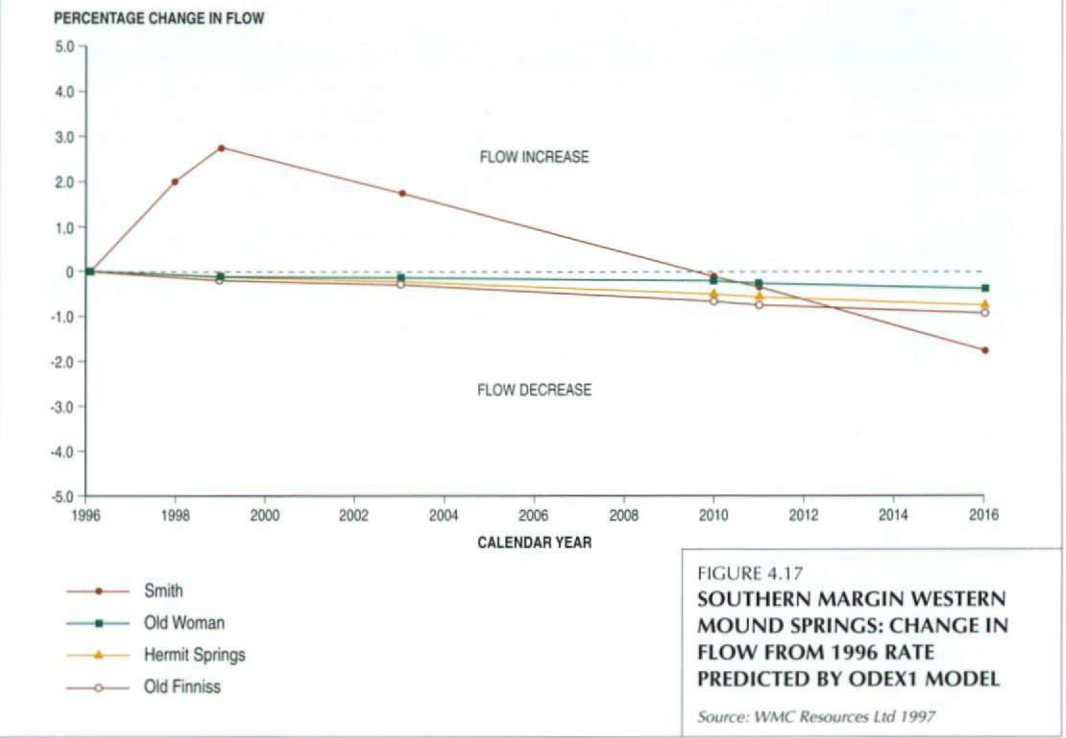


FIGURE 4.17
SOUTHERN MARGIN WESTERN MOUND SPRINGS: CHANGE IN FLOW FROM 1996 RATE PREDICTED BY ODEX1 MODEL

Source: WMC Resources Ltd 1997

4.5.4 Predicted impacts on pastoral bores

Pastoral bores were modelled as constant discharge bores on the assumption that pastoralists would maintain their current flow rates by adjusting flow regulating valves at the well-head to compensate for any reduction in pressure (with the exception of Georgia Bore).

Predicted impacts on the available pressure (head) at pastoral bores are presented in Table 4.8, which shows that those bores in close proximity to Borefield B are clearly the most affected.

Table 4.8 Predicted impacts on pastoral bores—1996–2016

Bore	Measured pressure		Simulated pressure loss from 1996–2016 (kPa)	Reduction in pressure above ground level 1996–2016 (%)
	Date	Pressure above ground level (kPa)		
David	16.04.85	1	4	100
Clark	20.04.85	3	3	100
Callanna	10.08.94	36	8	22
Cooranna	04.08.94	61	35	57
Maynard	10.08.94	40	14	35
Peter	21.08.94	304	105	35
Clayton	22.08.94	313	95	30
Tarkaninna No. 2	22.08.94	246	63	26
Clayton No. 2	21.08.94	354	95	27
Marion	21.08.94	284	135	48
Hergott Spring	10.08.94	62	5	8
Lake Harry	21.08.94	432	137	32
Morphetts	14.11.90	93	9	10
Muloorina	14.09.85	810	144	18
Peachawarinna (Kelly)	11.09.93	779	117	15

Table 4.8 Predicted impacts on pastoral bores—1996–2016 (continued)

Bore	Measured pressure		Simulated pressure loss from 1996–2016 (kPa)	Reduction in pressure above ground level 1996–2016 (%)
	Date	Pressure above ground level (kPa)		
Crows Nest	30.10.90	662	87	13
Nickotime	23.08.94	150	16	11
Morris Creek	21.11.94	567	34	6
Yarra Hill	02.08.94	250	15	6
Dulkaninna No. 2	17.02.88	620	59	10
Jackboot	22.03.94	632	40	6
Charles Angas	21.11.94	456	27	6
Chapalanna	23.08.94	359	19	6
Frome Creek	01.01.66	241	11	5
Lake Billy No. 2	15.05.91	125	10	8
Clayton Dam	23.08.94	135	6	4
Cooryaninna[1] No. 2	22.08.94	661	30	9
Prices No. 2	11.08.94	610	25	4
Alberrie Creek	31.07.85	105	4	4
Cannuwaukaninna	22.08.94	888	42	5
New Kopperamanna	01.10.77	965	36	4

1 *Also called Cooryanna.*
Source: WMC Resources 1997.

The predicted reductions in pressure would result in proportionally reduced flow rates from freely flowing bores. Water would continue to be available at all sites and current rates could, if necessary, be maintained by pumping.

The Indenture provides that pastoralists shall continue to have the right to use groundwater for the proper development and management of the existing use of the lands occupied by them. These rights can only be restricted or terminated by the State if WMC makes alternative supplies available or agrees on an appropriate level of compensation. WMC is in negotiation with pastoralists to formalise arrangements in written agreements.

Although pumping from deep pastoral bores has not been the general practice in the South Australian part of the Great Artesian Basin, a recent paper by Hillier (1996) foreshadows the introduction of pumping from deep pastoral bores where economic considerations permit

4.5.5 Future development of groundwater resources

Modelling of drawdown presented throughout this EIS is based on a twenty-year horizon to the year 2016 for several reasons, including:

- the Designated Area boundary that is the subject of the Special Water Licence for Borefield B was based on modelling for twenty years;
- WMC cannot predict with any degree of certainty what other users may abstract from the Great Artesian Basin over a longer time period, nor can it exercise any control over this. Therefore, a management strategy prepared by government will be essential in determining what drawdown limitation is achievable, given the current and possible future abstractions by pastoralists, Cooper Basin operations, and other resource developments not yet contemplated.

The Special Water Licence seeks to control water abstraction not by volume constraints but by a restriction on drawdown of potentiometric head at the boundary of the Designated Area.

With the operational experience of Borefield B, it is expected that the estimated long-term water supply obtainable under the agreed drawdown restrictions of the special water licences would increase. This increase in estimated yield would result from the use of more data and fewer assumptions in the modelling. The current modelling uses precautionary principles in the selection of assumptions, thereby resulting in lower estimates of available long-term supply.

These factors, combined with further water use minimisation measures expected to be implemented in the future, support the current belief that the existing borefields would be sufficient to meet the project needs beyond the twenty-year planning period.

Under the simulated scenario, the agreed limits of the Special Water Licence are complied with up to the year 2016. If the model predictions are verified in practice, and WMC wishes to continue to extract water from the Great Artesian Basin beyond the year 2016, or at a higher rate than 42 ML/d, it will be necessary to either:

- review impacts other than simple drawdown at the Designated Area;
- seek a further borefield site, probably nearer to the deeper, more productive centre of the basin in South Australia.

The development of a new overall management strategy for the Great Artesian Basin, foreshadowed by Hillier (1996), may have a considerable influence on the decision to follow either of the directions indicated above.

Further hydrogeological information will be acquired from Borefield B production bores and monitoring bores over the next few years, and these data will enable ODEX1 to be refined to improve the accuracy of modelling predictions. Similarly, hydrogeological investigations will be carried out to identify a suitable area and model an additional borefield if this proves to be necessary.

In this context, it is important to note that there is no doubt that a suitable location for another borefield could be found to the north-east of Borefield B, where aquifer thickness is up to 700 m. Such a borefield could be strategically located to harvest water that would otherwise be lost by vertical leakage from the aquifer, resulting in project demands being met with manageable impacts on other users and the mound springs.

4.6 HYDROGEOLOGY AT OLYMPIC DAM

This section presents and discusses an interpretation of the regional and local groundwater flow system at Olympic Dam in the context of its relationship with mine activities. Figure 4.18 provides a locality plan for the region considered.

4.6.1 Regional hydrogeology

The geology in the Olympic Dam area comprises Quaternary surficial sediments overlying Palaeozoic and Proterozoic rocks, which include limestone, quartzite, sandstone and shale, all overlying mafic breccias of the underlying basement complex that hosts the mineralisation. The surface terrain on the Special Mining Lease area is dominated by longitudinal east–west trending sand dunes with interdunal corridors, drainage depressions and low stony tablelands. The orebody and the mine development occur at a depth of 350 m in the basement complex. The local and regional geology are described in Section 3.2.

The Olympic Dam mine is developed beneath a regional aquifer system that occurs in the sedimentary rocks of the Stuart Shelf. The regional stratigraphy is summarised in Table 4.9.

Table 4.9 Summary of regional stratigraphy[1]

Age	Unit description	Approximate thicknesses in the region of Olympic Dam (m)	Comments
Quaternary	Undifferentiated clayey sands, dunefields, playa and drainage deposits	0–10	Extensive across entire area but extremely variable.
Cambrian	Yarrawurta Shale	0–90	Overlies Andamooka Limestone north of Olympic Dam.
	Andamooka Limestone: Indurated limestones of various character. Variably dolomitic and cavernous	0–200	Variable sedimentary sequence in time and location; includes thin shale beds and siltstone.
Neoproterozoic	Yarloo Shale: Laminated shale	0–50	Sporadic in occurrence between Andamooka Limestone and Arcoona Quartzite at Olympic Dam; thicker near the Torrens Hinge Zone.
	Arcoona Quartzite: Quartzite with numerous shale interbeds in its upper part	150–200	Upper section conspicuously interbedded with shales; lower section pale and more massive.
	Corraberra Sandstone: Sandstone, micaceous with shaly interbeds	30	Indurated where observed in Olympic Dam decline.
	Tregolana Shale: Laminated shale	150–300	Dark, strong rock where observed in Olympic Dam decline.
Mesoproterozoic	Basement: Diverse igneous and metamorphic rocks including Olympic Dam breccia sequence	not applicable	Host to the Olympic Dam deposit and other orebodies.

1 *Simplified for the purposes of discussing the regional hydrogeology; for example, omitting remnant Mesozoic rocks at Andamooka. Refer also to Figures 3.1 and 3.2.*

Andamooka Limestone

The Quaternary surface sediments are generally up to 10 m thick and are underlain by the Andamooka Limestone, which is a pale dolomitic limestone generally extending to depths of 40–60 m at Olympic Dam. It is deepest and thickest (166 m) to the north-east of Olympic Dam (Cowley 1990). The limestone exhibits karstic features (dolines, sink-holes, caverns etc.), and there are some minor occurrences of perched aquifers within the Andamooka Limestone, where its base is higher in elevation than the regional water table in the Arcoona Quartzite. These perched zones are believed to be of limited dimensions and may, in some instances, drain completely between major rain events.

Groundwater has been observed within the basal 5–10 m of the Andamooka Limestone during exploration drilling near the mine. To the south and west of Olympic Dam, there is limited pastoral and domestic use of water in the Andamooka Limestone via shallow bores. To the north and east, few, if any, bores penetrate the aquifer.

The Andamooka Limestone is restricted in its distribution within the larger Stuart Shelf area, and overlies deeper aquifer zones within the quartzites and sandstones of the Arcoona Quartzite and Corraberra Sandstone, which are described below. In general, it might be expected to have a higher transmissivity than the quartzites.

The occurrence of Andamooka Limestone is reasonably well known from published data (Figure 4.18). The base of the formation dips to the north and north-east, falling below the water table in the Olympic Dam area. Its base is at ground level near Coorlay Lagoon, and the

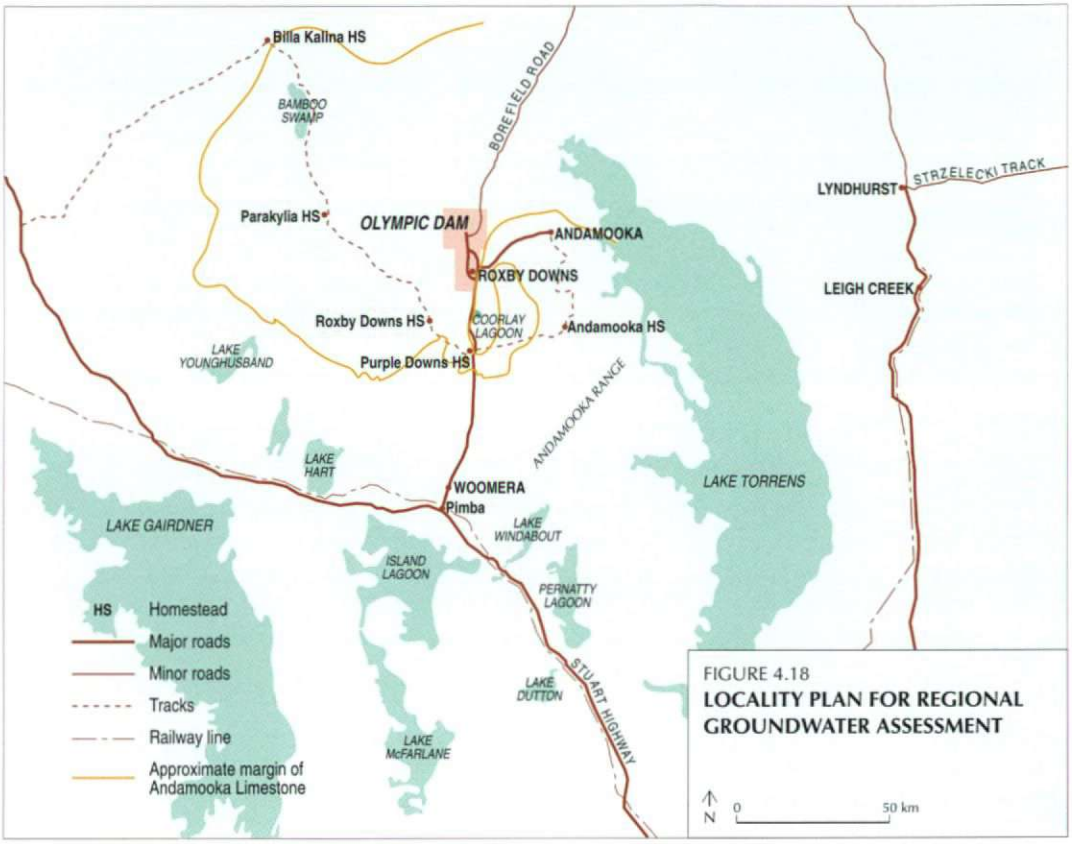


FIGURE 4.18
LOCALITY PLAN FOR REGIONAL GROUNDWATER ASSESSMENT

formation is thickest towards the north-eastern end of its area of occurrence. Its greatest saturated thickness, and therefore perhaps its greatest transmissivity, may occur near the northern end of Lake Torrens.

The distribution of groundwater within the Andamooka Limestone is limited mostly to areas where its base occurs below the regional water table, generally in the area north of Olympic Dam and near the northern end of Lake Torrens. There is some evidence of perched aquifers, which are not understood in detail but may be important locally (e.g. at the mine site). The perched aquifers may be caused by the irregular occurrence of the Yarloo Shale Formation below the Andamooka Limestone, as well as the shale interbeds of the upper Arcoona Quartzite.

Corraberra Sandstone/Arcoona Quartzite

Corraberra Sandstone/Arcoona Quartzite formations are a sequence of fractured and variably indurated sandstones and quartzites, with conspicuous and numerous shale interbeds near the top of the Arcoona Quartzite. The quartzite is fractured rock with measured permeability ranging from 1 x 10^{-3} m/d to 1 m/d. The upper section of the Arcoona Quartzite is considered to be less permeable than the basal section, and is believed to restrict groundwater movement from the Andamooka Limestone.

Static water levels are generally less than 50 m below ground level, with the main zones of permeability occurring at a depth of approximately 160–200 m below ground level at the mine site (Kinhill – Stearns Roger 1982).

The mean salinity (total dissolved solids) of the Arcoona Quartzite is in the range 20,000–40,000 mg/L. The chemical composition of groundwater in the Arcoona Quartzite is generally uniform throughout the region, with the water containing sodium chloride and high concentrations of sulphate (5,000 mg/L), as well as detectable levels of naturally occurring uranium and radium.

Drilling data from WMC at Olympic Dam suggest that groundwater yields are encountered in both formations, with possibly higher yields deeper in the sequence (i.e. in or near the Corraberra Sandstone). This is supported by observations in the Olympic Dam decline. The Corraberra Sandstone and Arcoona Quartzite appear to form a hydraulically continuous aquifer across the Stuart Shelf.

Tregolana Shale

It can be reasonably assumed that the active groundwater flow system does not extend deeper than the top of the Tregolana Shale, the hydraulic conductivity of which appears to be extremely low.

Basement complex

The Olympic Dam Breccia Complex has very little primary porosity, and where faults have been intersected there appears to be little permeability (WMC—Olympic Dam Operations 1993). Although the potentiometric head in the breccia appears to be similar to that in the Arcoona Quartzite, groundwater transmissivities are at least several orders of magnitude lower than in the Arcoona Quartzite, as the breccia complex has a lower permeability. Inflows to the mine from this source occur occasionally, but are reportedly small and, in general, dry up in a few days.

The breccia complex groundwater is similar to that of the Arcoona Quartzite, except that the upper band salinity is higher at 95,000 mg/L and naturally occurring levels of heavy metals such as lead and zinc are higher. The breccia complex groundwater also contains detectable amounts of naturally occurring uranium and radium.

Aspects of geomorphology relevant to regional hydrogeology

The modern landscape is mainly one of low relief, dominated by dunefields, low tablelands and a system of playas, small salt lakes and a few large salt lakes. Dunefields have developed in areas of lower topography, leaving the elevated areas (which are generally underlain by Arcoona Quartzite and Mesozoic remnants) relatively free of dunes. Most of the Andamooka Limestone is overlain by dunes. Within the dunefield swales there are many claypans, vegetated ephemeral swamps, and dolines at some localities.

The tablelands are represented by the large area of the Arcoona Plateau between Woomera and Coorlay Lagoon and the Andamooka Range (Figure 4.18). The Arcoona Plateau forms a surface divide between the catchments of the major terminal lakes (Lake Torrens and Lake Hart – Lake Gairdner). The Andamooka Range forms a surface divide that extends along the west side of Lake Torrens, which separates surface drainage into the west side of Lake Torrens from the set of terminal lake systems in the area underlain by the Andamooka Limestone.

The playas and small salt lakes are believed to be deflation features caused by wind erosion, with the depth of erosion limited by the position of the water table at the time of their formation (Johns 1968a). Deflation can only persist to the depth of the water table since the wind cannot move moist sediments. Those that appear to have been deflated to the water table are located in a group to the south of Olympic Dam, outside the area of the Andamooka Limestone, with Coorlay Lagoon the most northerly. These features may be used to guide the development of the water table contour plan, since they can be regarded as providing an upper limit to the nearby water table elevation.

The surface drainage appears to reflect the underlying geology. Unlike all the surrounding catchments in areas of Arcoona Quartzite, which have well-developed drainage systems with stream channels tens of kilometres in length, the entire area of the Andamooka Limestone is characterised by small catchments that drain to ephemeral terminal lakes of various sizes.

The Stuart Shelf sedimentary rocks lie almost flat over distances of at least 100 km and have remained virtually undisturbed since their deposition. This geological structure and the low relief of the area (maximum elevation differences of 100 m over an area 100 km by 150 km) produce a region where the formation boundaries are almost parallel to the ground surface over large distances. The dominant hydraulic gradients are therefore expected to be more or less horizontal, with vertical components only expected near discharges; that is, near the main salt lakes or in the mine area where seepage and vent raise effects have induced vertical gradients.

The regional groundwater system drains towards the major salt lakes in the region; that is, towards Lake Torrens for the area within about 30 km of Olympic Dam. South-west of Olympic Dam, some groundwater flow is expected towards Lake Hart and Lake Gairdner, which implies that there would be groundwater divides, perhaps in the Woomera area where there is a surface drainage divide. Similarly, a groundwater divide is postulated between the Olympic Dam area and Lake Eyre (and the Great Artesian Basin).

Analyses of groundwater samples taken from boreholes in Lake Torrens are reported by Johns (1968b). Salinities vary, with maximum values greater than 100,000 mg/L total dissolved solids, and are dominated by sodium and chloride ions. The high concentration of dissolved solids is derived from groundwater from both sides of the lake being concentrated by evaporation, and is consistent with the lake being the sink for Stuart Shelf groundwater.

Water table contours and inferred regional groundwater flow system

Figure 4.19 presents an interpretation of the regional water table contours, supported by the following data:

- investigation reports, interpretations and measurements of the groundwater level at and near the mine site;
- groundwater and geological data from publications and various records of MESA;
- topographic data, including heights of the beds of some of the salt lakes, which control the maximum elevations of the water table in some areas.

Although groundwater levels from the regional bore survey are derived from a variety of sources (bores of various depths and WMC exploration holes), they were converted to AHD using survey data or estimated surface elevations from topographic maps, plotted and contoured as a single data set (Table 4.10 and Figure 4.19). The assumptions inherent in this approach are that:

- any vertical head gradients are very small;
- density effects are not sufficiently large to change the overall pattern of heads if there were sufficient data to allow for them;
- there is a single, continuous, regional flow system rather than a compartmentalised system, with apparent gradients indicated by the widely spaced data points.

These assumptions are believed to be reasonable.

The data were hand-contoured for the area south of Bamboo Swamp. The hand-contouring was considered an appropriate approach to develop a regional contour plan given the irregular distribution of the sparse data and the objective of producing a generalised interpretation of the flow system.

In addition to the observed water level data, the data points in the map were set at about RL 35 m AHD along the western shoreline of Lake Torrens. This value was adopted from height data from the published maps of the area, which gave values in the range RL 32–38 m AHD for the lake surface and features within or adjacent to the lake. The implicit assumption in setting this level for the water table along the edge of the lake is that the water table is close to the bed level of the lake. One WMC bore near the lake has a water level at RL 32 m AHD, supporting this approach.

Table 4.10 Estimated groundwater levels in the vicinity of Olympic Dam

MESA ref. no.	Depth to groundwater (m)	Surface elevation (m AHD, estimated)	Groundwater elevation (m AHD)
6137–40	36.6	100+	65
6236–89	43.9	105	61
6236–52	8.5	85	76
6236–10	17.7	95	78
6136–7	10	105	95
6236–40	42.7	135	92
6336–12	0.3	50	50
6337–2, 41	22–24	90	65
6336–20	4	90	84
6336–35	15	110	95
6336–24	73	120	47
6336–3	22	110	88
6336–28	68	170	102
6236–62	6.5	95	88
6337–11	4	50+	46
6235–5	15	120	105
6235–66	24	130	105
6235–9	17	120	103
WMC BDL 1[1]	15.71	66	50
WMC BDL 3[1]	0	32	32
WMC PD 2[1]	62.45	116	54
WMC SGD 2[1]	21.42	89	68
WMC SGD 3[1]	65.38	110	45
WMC WRD 3[1]	33.6	88.9	55

1 *WMC regional monitoring bore; levels recorded in November 1995.*

The contours have been drawn using Arcoona Quartzite water level data for the mine area, rather than the higher levels from piezometers in the Andamooka Limestone, which reflect the results of surface seepages.

The water table contours for the Stuart Shelf presented in Figure 4.19 show:

- interpreted contours
- groundwater flowlines inferred from the contours
- the approximate extent of the Andamooka Limestone
- the approximate positions of the main drainage divides.

The main features of the water table contours are:

- a general similarity to the regional topography, including a groundwater divide parallel to the western shore of Lake Torrens, roughly coincident with the position of the surface water divide;
- gradients to the north and north-east, from water table elevations exceeding RL 100 m AHD in the Woomera area to water table elevations in the range RL 40–50 m AHD west of the north end of Lake Torrens;
- inferred gradients to the east towards Lake Torrens;
- the main flow path through Olympic Dam developed to the north from the Woomera area;

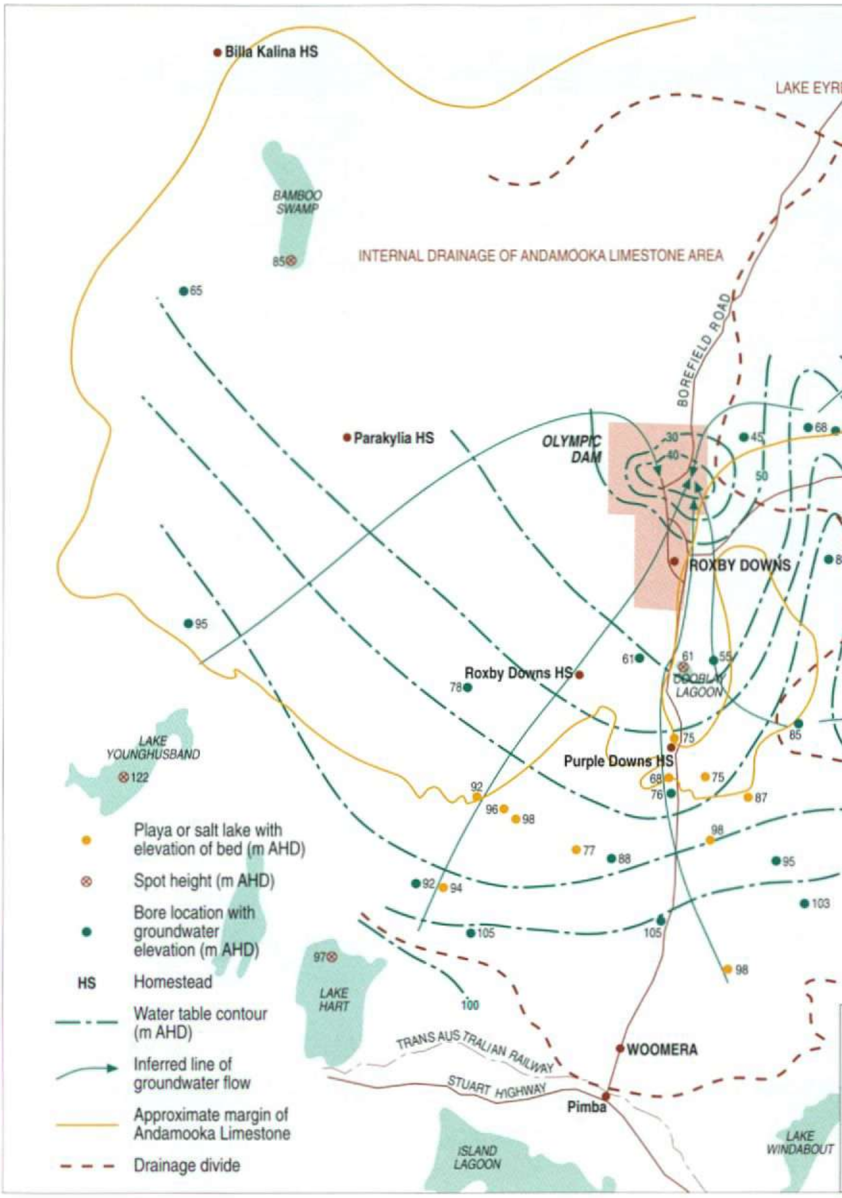


FIGURE 4.19
REGIONAL HYDROGEOLOGY—STUART SHELF WATER TABLE CONTOURS

- a localised impact of the Olympic Dam mine;
- probable flow towards the northern end of Lake Torrens from the west and south-west through the Andamooka Limestone (an interpretation limited by lack of data in this area).

Regional groundwater flow system

The contours show a northerly trending trough extending through Coorlay Lagoon and Olympic Dam, with a groundwater divide separating this northerly flow path from another north-easterly flow path directed towards Lake Torrens. The inferred divide is based on sufficient data to be confident that it exists. However, there are few data points in the area to the north-east of Olympic Dam and west of Lake Torrens, and it is not known whether the divide ceases or persists (either extending further north or swinging to the east to form an east–west divide between Lake Torrens and Lake Eyre).

Groundwater levels in the west of the Stuart Shelf broadly show a gradient towards the east, more or less parallel to the northern boundary of the Andamooka Limestone and towards the northern end of Lake Torrens. The groundwater levels measured in the west and north-west are higher by tens of metres than those immediately north of Olympic Dam, which appears to preclude the northerly flow path from swinging to the west.

The possibilities for the extension of the flow path through Olympic Dam are that it:

- extends northwards, with evaporative discharge south of the Great Artesian Basin;
- swings to the east around the nose of the groundwater divide and discharges groundwater into the northern end of Lake Torrens.

The distribution of the Andamooka Limestone, which is likely to have enhanced hydraulic conductivity due to karstic features, lends support to the latter possibility. The limestone has its greatest thickness around the northern end of Lake Torrens, and the hydraulic gradients are lowest in the area around and north of Olympic Dam. This would allow the relatively more transmissive Andamooka Limestone to collect and channel the groundwater flow from the south and west to discharge at the northern end of Lake Torrens.

The impact of mine drainage at Olympic Dam is substantial but localised, with tens of metres of drawdown near the mine but little, if any, effect distinguishable beyond a distance of 5–10 km. The mine impact can be seen in Figure 4.19.

This contour plan and its interpretation differ from that presented in the 1983 EIS because a larger area has been considered, allowing a clearer picture to emerge of the regional flow system in the light of greater hydrogeological understanding of the region.

4.6.2 Groundwater monitoring

The operations at Olympic Dam include an extensive groundwater monitoring network. This network includes bores strategically located to monitor the effect of the operations on the Andamooka Limestone and Arcoona Quartzite aquifers within the Special Mining Lease area and regional groundwater outside that area.

The monitoring bore network is described below, generally in chronological order of development. The locations of the monitoring bores are shown in Figure 4.20.

Pre-1994 monitoring bores

A network of old exploration boreholes, which are numbered with an RD (Roxby Downs) prefix, has been used for groundwater monitoring since 1981 to record the progressive drainage of the Andamooka Limestone and Arcoona Quartzite aquifers. Most of these bores are open hole (i.e. uncased) and intersect both the Andamooka Limestone and Arcoona Quartzite aquifers. This results in a direct hydraulic connection between two aquifer systems that would otherwise have a low degree of hydraulic connection. The RD exploration boreholes are monitored for water level on a quarterly basis.

Monitoring bores installed between 1994 and 1996

During January 1994, a monitoring bore drilling, testing and sampling programme was developed, initially around the tailings retention system, to further define the nature of the water table in the Andamooka Limestone and Arcoona Quartzite aquifers. Drilling commenced in late February 1994, and between March 1994 and February 1995 forty new, aquifer-specific, groundwater monitoring bores were installed.

Thirty-four of the groundwater monitoring boreholes were installed within a 1 km radius of the tailings retention system. Thirty boreholes were constructed to monitor groundwater in the Andamooka Limestone aquifer, and four others to monitor groundwater in the Arcoona Quartzite aquifer.

Two boreholes were installed at each of three locations at least 7.5 km from the Whenan Shaft to act as regional groundwater monitoring bores for the Andamooka Limestone and Arcoona Quartzite aquifers at each location.

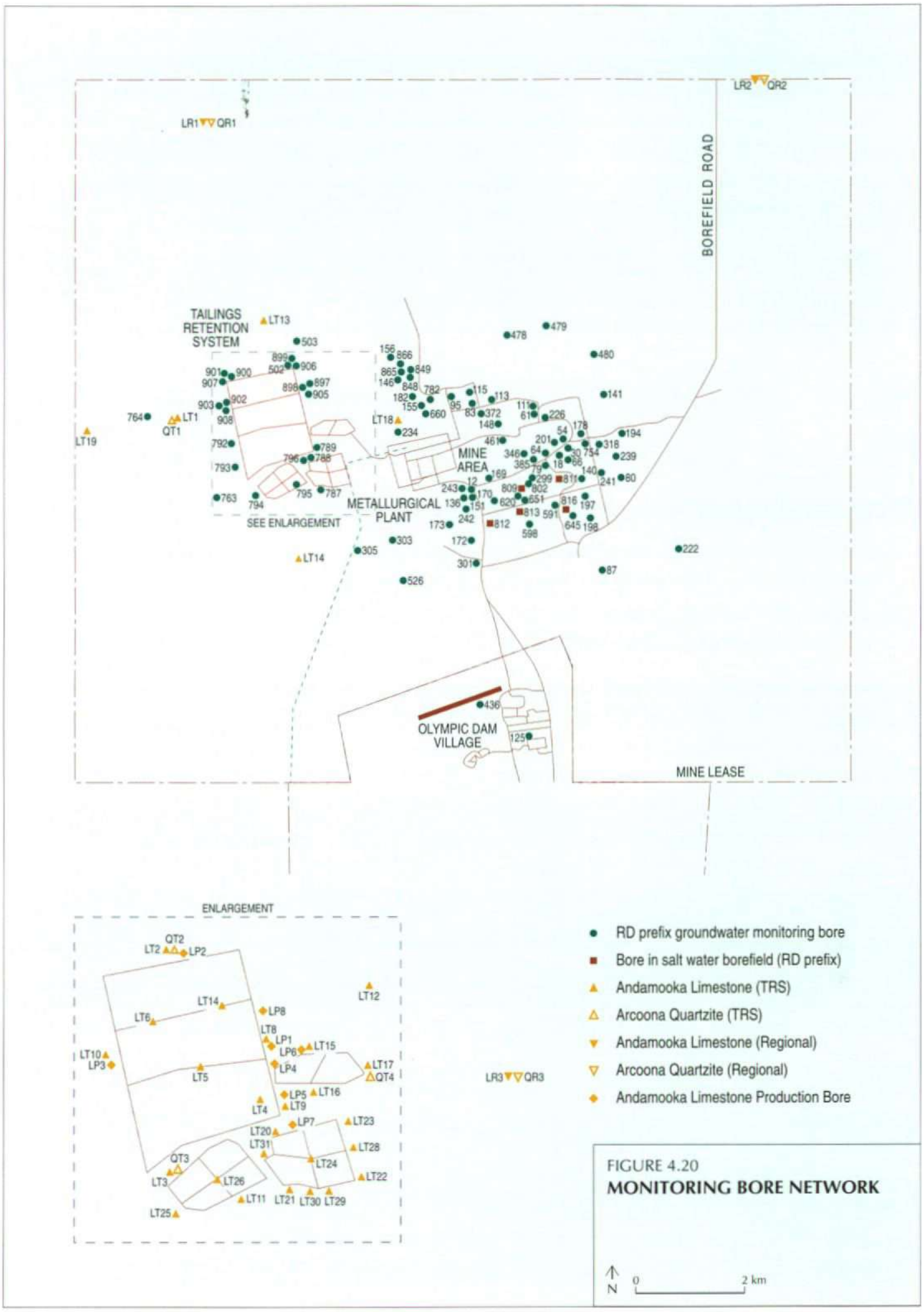


FIGURE 4.20
MONITORING BORE NETWORK

These boreholes have not been given the RD prefix, to differentiate them from the exploration boreholes. Their prefixes refer to the following:

- LT—Limestone aquifer in the tailings retention system area: LT1–LT31 (LT26 has been sited but not installed);
- QT—Quartzite aquifer in the tailings retention system area: QT1–QT4;
- LR—Limestone aquifer; regional: LR1–LR3;
- QR—Quartzite aquifer; regional: QR1–QR3.

Production bore network for tailings retention system groundwater

As a measure for recovering groundwater from below the tailings retention system, three production bores (LP1–LP3) were installed around the system and pump-tested during late 1994. A further five production bores (LP4–LP8) were installed along the eastern boundary of the tailings retention system during February 1995. Pumping from these bores has not occurred to date.

4.6.3 Site activities that influence groundwater systems

The site activities that would influence the groundwater systems are:

- drainage into the underground mining operations
- operation of the tailings retention system
- operation of the saline water borefield.

These site activities are described further below.

Dewatering of underground mining operations

The underground mining operations (shafts, service decline and ventilation raises) intersect the Andamooka Limestone and Arcoona Quartzite aquifers. As a consequence, groundwater from these aquifers drains into the mining operations where it is collected and directed by a series of sumps, pump stations and pipelines to the surface facilities.

The water collected is highly saline and of limited use, with a portion being used in the mine for drilling and on site (surface and underground) for dust suppression. The remainder is disposed of in the mine water disposal pond located adjacent to the tailings storage facility (Figure 4.21).

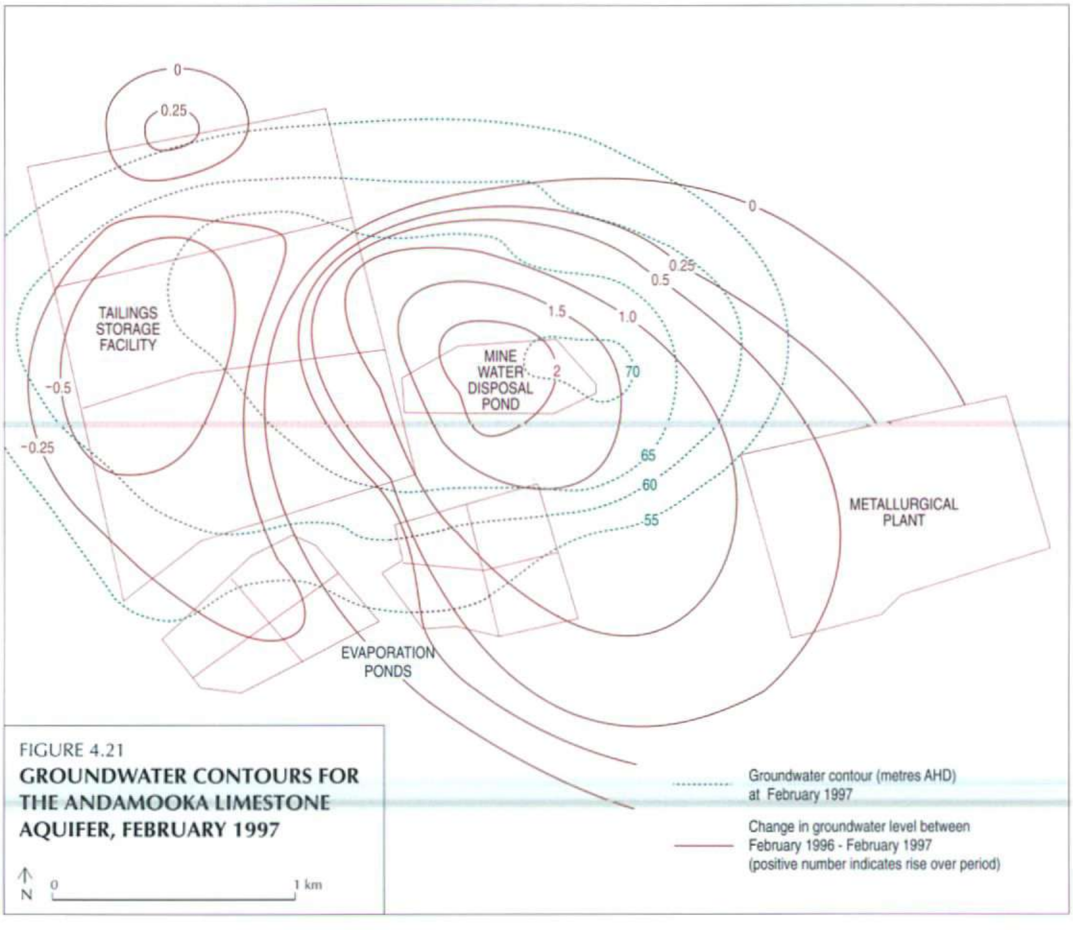


FIGURE 4.21
GROUNDWATER CONTOURS FOR THE ANDAMOOKA LIMESTONE AQUIFER, FEBRUARY 1997

For the Expansion Project, the method of collecting drainage waters from the aquifers would be similar to the existing method but on a larger scale owing to the increased scale of the mining operations.

When ore production (currently 3.0 Mt/a) exceeds 4.0 Mt/a, two additional pumps with a combined capacity of 100 L/s would be installed. As much mine water as possible would be drained by gravity to a pump station 420 m below ground level (approximately RL –320 m AHD), which would be used to pump collected water to the surface for use in dust suppression or disposal in the mine water disposal pond. All other mine water would be drained to a pump station at 620 m below ground level (approximately RL –520 m AHD) or pumped by an auxiliary pump station in each ore pass to a screening chamber at the 360 m level.

Each mine area is expected to have an auxiliary pump station at approximately 400 m below ground level (approximately RL –300 m AHD) and a secondary pump station at the 620 m level. All secondary pump stations in the mine would be identical, each complete with its own sump.

Should the whole mine dewatering system be inoperative for some reason, such as power failure, the decline to the bottom of No. 3 shaft and the shaft itself are intended to be used for emergency water storage up to the loading station level. At the expected drainage flow rate of 7.3 ML/d, this would provide approximately three days' storage.

Operation of the tailings retention system

The tailings retention system consists of the tailings storage facility, the mine water disposal pond and the evaporation ponds. Seepage to groundwater is known to occur from the mine water disposal pond and, previously, from the tailings storage facility. As described in Section 8.1, the operation of the tailings storage facility has changed substantially in recent years in order to ensure minimum seepage from this facility. Groundwater monitoring around the area indicates that the new measures are successfully meeting this objective.

As part of the Expansion Project, the tailings retention system would be modified as follows:

- The mine water disposal pond would be relocated to a new site north-east of the Whenan Shaft (as shown in Figure 3.7) and increased in size from 15 ha to 30 ha to cater for the increased rate of groundwater recovery from the mining operations. The new site has been selected so that seepage would remain within the area of groundwater drawdown caused by the dewatering of mining activities, described further below, and sufficiently distant from the tailings storage facility so as not to interfere with groundwater monitoring at that location.
- The tailings storage facility would be expanded, as described in Chapter 8. As also described, the design of the expanded facilities would be largely driven by seepage minimisation considerations.
- A new evaporation pond would be built that would incorporate a composite (synthetic and clay) lining system as used for the existing evaporation ponds. No measurable seepage would therefore be expected from these facilities.

4.6.4 Local impacts on the Andamooka Limestone aquifer

Figure 4.21 shows the groundwater level contours for the Andamooka Limestone aquifer developed from February 1997 water level monitoring data. The significant feature of the groundwater contour map is a groundwater mound beneath the tailings retention system. Groundwater levels presently extend to a maximum level of about RL 70 m AHD (approximately 30 m below ground level) in Bore LT17 at the eastern end of the mine water disposal pond.

Figure 4.21 also illustrates the current trend in groundwater levels under the tailings retention system by showing changes in water level in the Andamooka Limestone aquifer between February 1996 and February 1997. Decreases in water levels of less than 1 m have been evident in LT-prefixed bores in the central areas of the tailings retention system. These decreases are interpreted as indicating the effectiveness of the changed operating system for the tailings retention system in reducing seepage from the tailings storage facility.

Figure 4.21 shows that the greatest water level increase has occurred underneath the mine water disposal pond, suggesting that this pond is a significant contributor to the groundwater mound currently observed below the tailings retention system.

Groundwater in the mound beneath the tailings retention system area is expected to migrate towards the cone of depression centred on the Whenan Shaft. The cone of depression dominates the groundwater regime of the mine area. Monitoring has identified that this groundwater has dissolved radionuclide levels that are similar to or less than naturally occurring groundwater.

The radionuclide levels would therefore not cause any occupational health problems in the mine dewatering operations.

Following completion of the Expansion Project, the groundwater levels in the Andamooka Limestone aquifer are expected to change as follows:

- Around the Special Mining Lease area there would be a continued general decrease in levels, centred on the Whenan Shaft, owing to the continued dewatering of underground mining activities. This effect would continue to dominate the groundwater regime of the mine area.
- Groundwater levels would decrease underneath the existing tailings retention system, predominantly as a result of the relocation of the mine water disposal pond but also because of the new operational procedures for the tailings storage facility.
- A groundwater mound would develop underneath the new mine water disposal pond. With time, this water would also migrate to the underground mine workings, essentially resulting in recycling of naturally occurring groundwater in the mine area.

4.6.5 Local impacts on the Arcoona Quartzite aquifer

Figure 4.22 provides a groundwater contour plan of water levels as at October 1996 in the Arcoona Quartzite derived from water level information from monitoring bores QT1–QT4 and QR1–QR3. The plan also includes data from the RD exploration bores in the central mine area. This figure shows the extent of a groundwater cone of depression that has formed in the Arcoona Quartzite aquifer.

The asymmetry of the cone of depression appears to indicate recharge to the Arcoona Quartzite aquifer from the Andamooka Limestone aquifer in the vicinity of the south-western corner of the tailings retention system. Drainage between the aquifers could possibly be occurring through old exploration bores in the tailings retention system area, such as RD234, RD788 and RD787, but evidence of this is not conclusive.

The groundwater contours suggest that flow in the Arcoona Quartzite, including that under the tailings retention system, is towards the centre of the cone of depression from all directions.

Following the proposed expansion, the groundwater levels in the Arcoona Quartzite are expected to continue to decline as a result of continued dewatering of underground mine operations.

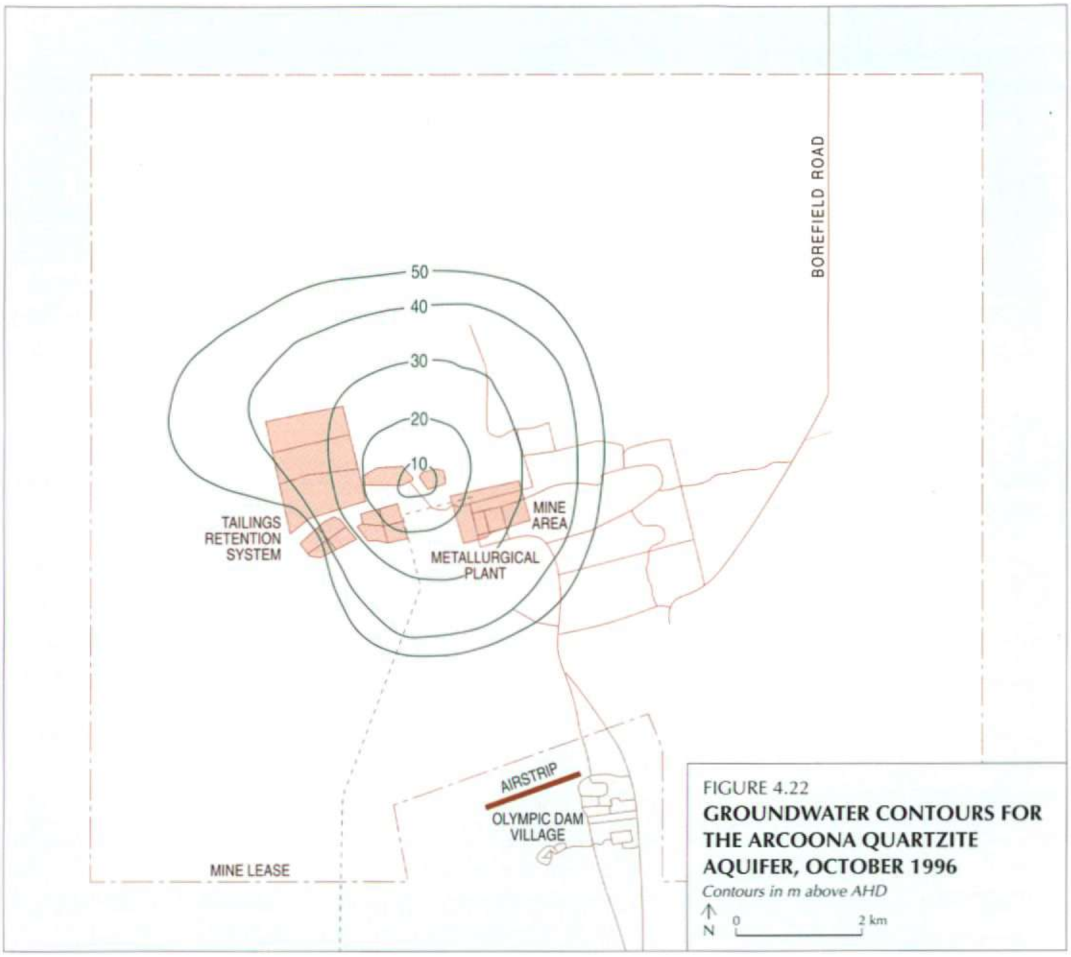


FIGURE 4.22
GROUNDWATER CONTOURS FOR THE ARCOONA QUARTZITE AQUIFER, OCTOBER 1996
Contours in m above AHD

After the cessation of mining, water levels would be expected to take a long time, perhaps centuries, to recover to a point where the pre-mining groundwater flow system re-established itself. The information available strongly suggests that this flow would be directed towards the saline aquifer beneath Lake Torrens.

4.6.6 Impacts on regional groundwater systems

To date, water levels in the regional groundwater monitoring bores have not shown any significant changes that can be attributed to activities at Olympic Dam. The regional water table contours (Figure 4.19) suggest that the cone of depression at the mine site is small when considered at the scale of the Stuart Shelf. It nevertheless appears to be intersecting a significant proportion of the flow through the regional aquifer system, which is probably consistent with the current high rates of mine inflow (estimated at 3.2 ML/d), which could be a substantial proportion of the regional flow given the low gradients and low rates of groundwater recharge.

In future, the groundwater system at Olympic Dam would continue to exhibit a net loss of water through the evaporation of mine drainage water from the mine water disposal pond and the use of water for dust suppression, which also evaporates. Therefore, during the mine life, the cone of groundwater depression in the Arcoona Quartzite aquifer would continue to develop until the rate of groundwater flow towards the mine, from all directions, equalled the rate of water loss. Following the Expansion Project, the rate of mine inflow is expected to increase to about 7.3 ML/d.

Regional groundwater in the Arcoona Quartzite is highly saline and is not used locally as a water supply. It is also too deep to affect surface vegetation. Therefore, the site activities should not result in the regional groundwater being altered in either level or quality such as to harm the environment.

The current belief is that the groundwater flow from the mine area is directed towards Lake Torrens, and flow towards Lake Eyre and the Great Artesian Basin is considered unlikely. In general, a groundwater divide is expected between two large and widely separated areas of groundwater discharge such as Lake Torrens and Lake Eyre, particularly since the Andamooka Limestone aquifer does not extend far to the north beyond Lake Torrens.

4.7 STORMWATER MANAGEMENT

Stormwater management for the Expansion Project would continue to use the same approach as the existing plant. This would involve:

- provision of additional capacity in water-retaining structures, such as the tailings retention system and evaporation ponds, so that direct rainfall can be contained;
- provision of impervious bunding around process equipment, enabling spillages, wash water and stormwater to be collected and returned for use as process water;
- direction of stormwater from other impervious (sealed) areas of the plant to unlined sumps, where it would be allowed to infiltrate and evaporate;
- direction of stormwater from other (unsealed) areas to amenity plantings or retention basins via open drains, where it would infiltrate and evaporate.

Previous experience at the site has indicated that regional rainfall is insufficient in quantity and too erratic to warrant permanent facilities for collection of stormwater to augment water supplies. However, as is current practice, temporary pumping facilities would be used following large rainfall events to recover stormwater for use as process water.

The area proposed for expansion of the tailings retention system is characterised by local drainage patterns and does not serve any regional drainage function. Hence the diversion of stormwater is not required for these facilities, although rock erosion protection would continue to be provided to the outer containment bunds.

CHAPTER 5

LAND USE

CHAPTER 5 LAND USE

This chapter describes the present land use of the region surrounding the Olympic Dam operations. The potential land use impacts predicted in the 1983 EIS are presented and compared with those that have actually occurred since the commencement of mine operations, as a basis for identifying any additional or changed impacts that could arise following the proposed expansion. The chapter concludes with a discussion of the projected long-term use of the Project Area.

5.1 EUROPEAN HISTORY

Early exploration of this region in the mid to late 1800s by Eyre, Stuart, Babbage, Warburton and Giles is well known and has been widely documented. This early exploration led to an expansion of pastoralism in the area following favourable reports of the area's grazing potential.

The mound springs along the south-western margin of the Great Artesian Basin (as shown in Figure 4.7) were influential in this expansion, particularly in the areas providing access for stock to these sources of permanent water. The overland telegraph line, the old bullock track and the Marree – Alice Springs railway line also passed through the mound springs area.

Most of the pastoral leases to the north-west of Port Augusta were taken up during the 1860s and 1870s, with pastoral activity reaching its peak in the late 1880s. Since that time, lease ownership and boundaries have changed many times, generally reflecting changes to economic viability, the effects of droughts or the relocation of transportation facilities. The history of Roxby Downs Station as discussed in the 1983 EIS is typical of that of many present-day stations in the north-west pastoral district.

Pastoralism remains the most extensive land use in the region.

5.2 CURRENT LAND USE

The current regional land uses shown in Figure 5.1 include:

- pastoralism
- mining
- defence (Woomera)
- tourism and recreation
- conservation areas.

The factors that influence regional development are considered in Section 5.4. Land use impacts and mitigation measures are described in Section 5.5.

5.2.1 Pastoralism

Current pastoral land use and land tenure patterns have evolved since settlement of the region in the late 1800s, and are based on cattle grazing north of the Dog Fence, with sheep and/or cattle grazing to the south. The tenure of the various properties is held under

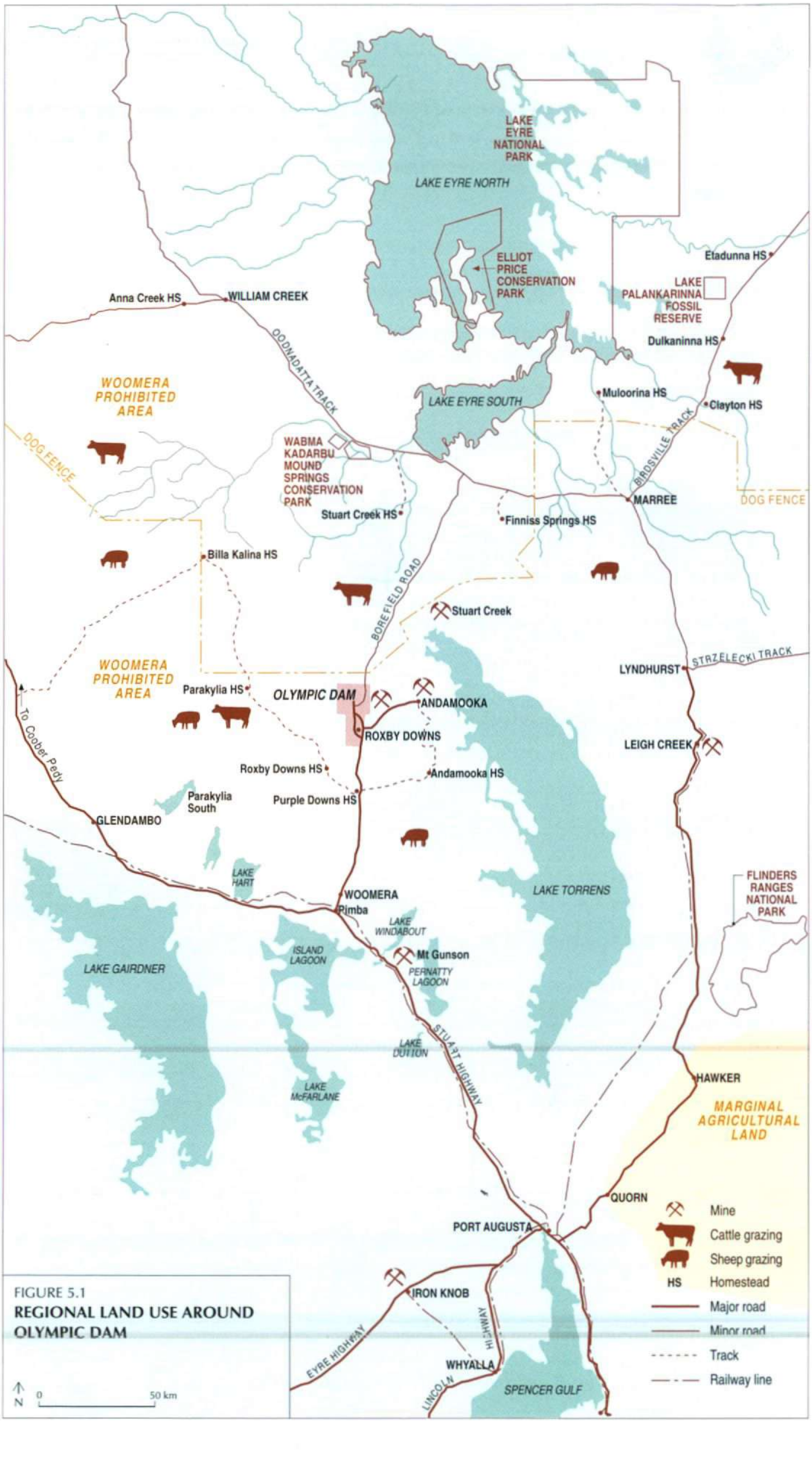


FIGURE 5.1
REGIONAL LAND USE AROUND OLYMPIC DAM

renewable leases regulated under the *Pastoral Land Management and Conservation Act 1989* (SA), in which lessees are granted the right to occupy the area of land specified in the lease and to use it for livestock grazing.

Allied to this Act is the *Soil Conservation and Land Care Act 1989* (SA), which provides for the conservation and rehabilitation of lands within South Australia, in part through the establishment of local soil conservation boards.

Olympic Dam is located within the Kingoonya Soil Conservation District, an area of 65,800 km^2 encompassing twenty-two pastoral leases. The Roxby Downs Town Administrator is represented on the Kingoonya Soil Conservation Board by a senior member of WMC's environmental staff who has been active in the formulation of the District Plan.

There are seven pastoral leases (Figure 5.2) in the immediate vicinity of Olympic Dam, six of which are located in the Kingoonya Soil Conservation District:

- Roxby Downs
- Parakylia South
- Purple Downs
- Andamooka
- Parakylia
- Billa Kalina

The seventh, Stuart Creek, is located within the Marla–Oodnadatta Soil Conservation District.

The total area of these seven stations is approximately 23,000 km^2. Parakylia presently runs both sheep and cattle, and Purple Downs formerly ran cattle but is currently destocked. Roxby Downs and Parakylia South are also currently destocked, but both have run sheep in the past. In recent years, Andamooka has grazed cattle rather than sheep, and this change is considered to be due in part to the presence of an increasing number of dingoes inside the

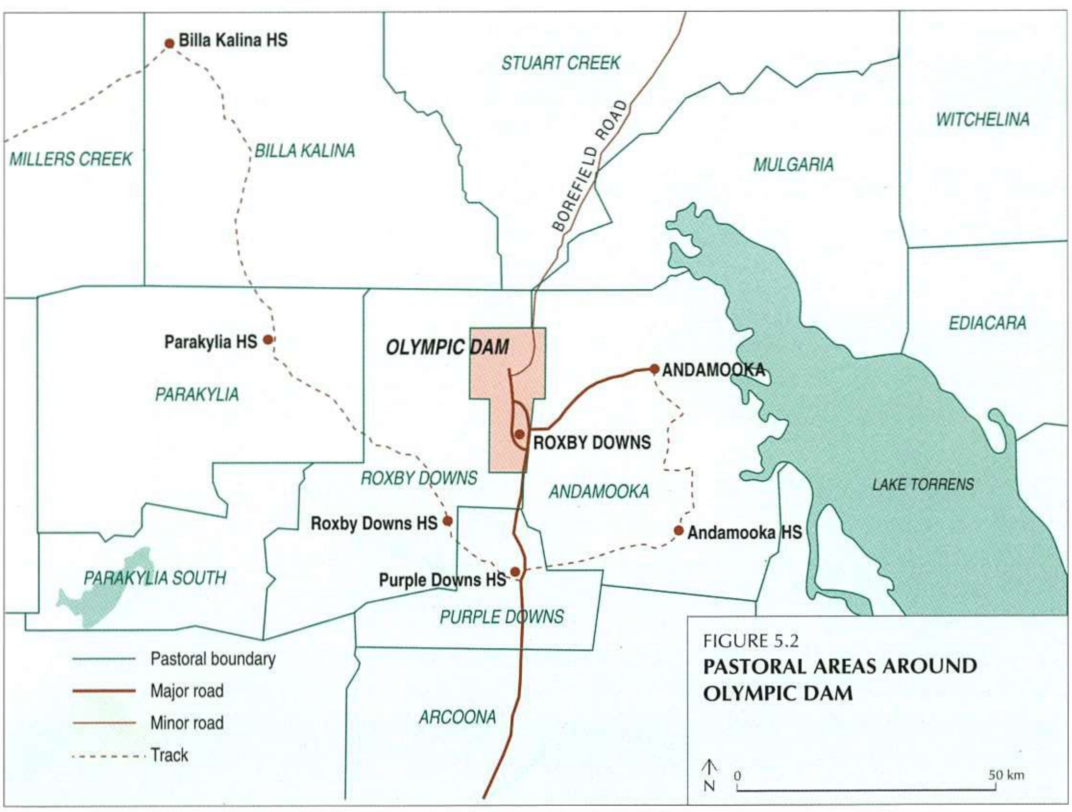


FIGURE 5.2
PASTORAL AREAS AROUND OLYMPIC DAM

Dog Fence (Badman 1995). Billa Kalina and Stuart Creek stations are situated north of the Dog Fence and run cattle exclusively. The Roxby Downs, Parakylia South, Purple Downs and Andamooka pastoral leases are all held by WMC.

The area in the vicinity of Olympic Dam is recognised as being the most productive within the area covered by the Kingoonya Soil Conservation Board (L. Yelland, Pastoral Management Branch, South Australian Department of Environment and Natural Resources (DENR), pers. comm., October 1996). Comparative data of stocking rates for five of the above pastoral leases are presented in Table 5.1. Data for Stuart Creek are reported by the Pastoral Management Branch of DENR as being combined with those for Anna Creek and The Peake stations, and cannot be differentiated. Stocking rates are presented as dry sheep equivalents, a term that refers to the feed requirements of a non-lactating ewe without lamb.

Table 5.1 Comparative data of stocking rates (in dry sheep equivalents) on stations adjacent to Olympic Dam

Item	Pastoral lease				
	Roxby Downs[1]	Purple Downs[1]	Andamooka	Parakylia	Billa Kalina[2]
Area (km^2)	2,813	751	2,359	2,353	5,076
Maximum stock numbers under lease agreement	28,000	9,000	18,700	24,000	20,000[3]
Rated stock numbers (defined by ecological conditions)	21,600	5,783	14,626	18,118	16,000[3]
10-year average stocking level	16,251	6,157	10,661	16,499	19,695[3]
20-year average stocking level	17,675	6,569	11,278	15,887	17,205[3]
Dry sheep equivalent per km^2 (20-year average)	6.28	8.74	4.78	6.75	3.38[3]

1 *Currently destocked. Figures are from data collected prior to destocking.*

2 *Billa Kalina is located north of the Dog Fence and is exclusively a cattle grazing property.*

3 *Conversion of cattle numbers to dry sheep equivalents is 1:5 (Pastoral Management Branch, pers. comm., October 1996).*

Source: J. Chappell, Pastoral Management Branch, Department of Environment and Natural Resources, pers. comm., October 1996.

Under the provisions of the *Pastoral Land Management and Conservation Act 1989*, the Pastoral Board has a duty to assess the condition of leased land. This assessment must include a review of the land's capacity to carry stock, with the resulting report presented to the lessee. The lessee has a duty:

- to manage the pastoral enterprise with land management practices that prevent degradation;
- to endeavour to improve the condition of the land.

Roxby Downs, Purple Downs and Parakylia South pastoral leases were completely destocked in October 1996 soon after being acquired by WMC, following discussion with the Pastoral Management Branch of DENR. This destocking was necessitated by previous overstocking of the land, which led to degradation of the dune tops through wind erosion and dune movement (J. Chappell, Pastoral Management Branch, Department of Environment and Natural Resources, pers. comm., October 1996). The condition of the pastoral leases is being monitored by the Pastoral Management Branch, and any restocking would follow consultation with DENR.

The carrying capacity of a pastoral lease in the area is determined by a combination of such factors as soil quality and conditions, recent rainfall, the quantity and quality of available stock feed, and the location of watering points. In the vicinity of Olympic Dam, stock have traditionally relied on dams which store the surface run-off resulting from the region's erratic rainfall. These small dams are excavated at the lowest points of some of the larger closed catchments, with local clay used to seal the base. Drainage channels leading to the dams are often created to increase run-off. During heavy rain the dams accumulate water and may even fill; however, the region's high evaporation rate and low variable rainfall make them an unreliable water supply. In the vicinity of Olympic Dam, dams are approximately 12 km apart. Claypans, some of which have previously held water for six to eight months following heavy rainfall events, provide an additional source of stockwater.

Stockwater is also provided by WMC to five pastoral properties from the M1 pipeline connecting Borefield A with Olympic Dam. The Borefield B pipeline incorporates potential stockwater takeoffs to service the properties it traverses, as well as adjacent properties. Monitoring bores for both borefields are also a source of stockwater. In total, eight pastoral properties could be serviced from the Borefield B pipeline and monitoring bores.

Rabbit Calicivirus Disease is believed to have spread throughout the area in the vicinity of Olympic Dam in late 1996. WMC environmental management staff at Olympic Dam have found that a significant reduction in rabbit numbers has occurred recently in the area.

The Dog Fence extends generally east–west through the arid zone of South Australia, and provides a barrier to the migration of dingoes into the sheep grazing areas south of the fence. Contractors employed by regional boards undertake regular patrols and maintain the fence. The Dog Fence crosses the Borefield Road approximately 5 km north of the Olympic Dam Special Mining Lease.

5.2.2 Mining

Olympic Dam is located in the Stuart Shelf (Figure 3.1), which is a region of significant mineralisation. In recent years there has been an intensification of mineral exploration of the Gawler Craton – Stuart Shelf region, much of which can be attributed to the South Australian Exploration Initiative. Large-scale aeromagnetic surveys of the State have led to ongoing exploration projects and the discovery of several important gold, coal and iron prospects. It is envisaged that exploration of the region will continue to increase. There are currently more than twenty exploration leases in the immediate vicinity of Olympic Dam (Figure 5.3). Mineral exploration and production in South Australia are regulated by the *Mining Act 1971* (SA) and Regulations.

Copper and uranium

Copper has been mined near Mount Gunson (Figure 5.3), approximately 110 km south-east of Olympic Dam, since 1898. Further copper reserves were discovered nearby in 1973. Although Mount Gunson no longer produces copper concentrates for smelting, production of relatively small quantities of copper-based fertiliser additives continues. Copper was also mined around the turn of the century in the Willouran Ranges, south of Marree, and near Finniss Springs.

The Olympic Dam copper and uranium deposit was discovered by WMC in 1975. The deposit also contains recoverable amounts of gold, silver and rare earth oxides, although the last are currently not being recovered. The mine, commissioned in 1988 to extract and process the deposit, is one of the most significant mining operations in the northern region of South Australia, and is a significant contributor to the State's economy. WMC also maintains an active, ongoing mineral exploration programme in the region.

Coal and iron

Significant coal resources exist within northern South Australia. Of these, the deposit at Leigh Creek has been mined by ETSA Corporation for many years.

An estimated ten billion tonnes of sub-bituminous coal have been discovered by Meekatharra Minerals near Oodnadatta (shown in Figure 1.1) in the Arckaringa Basin. Iron ore deposits have also been discovered in close proximity.

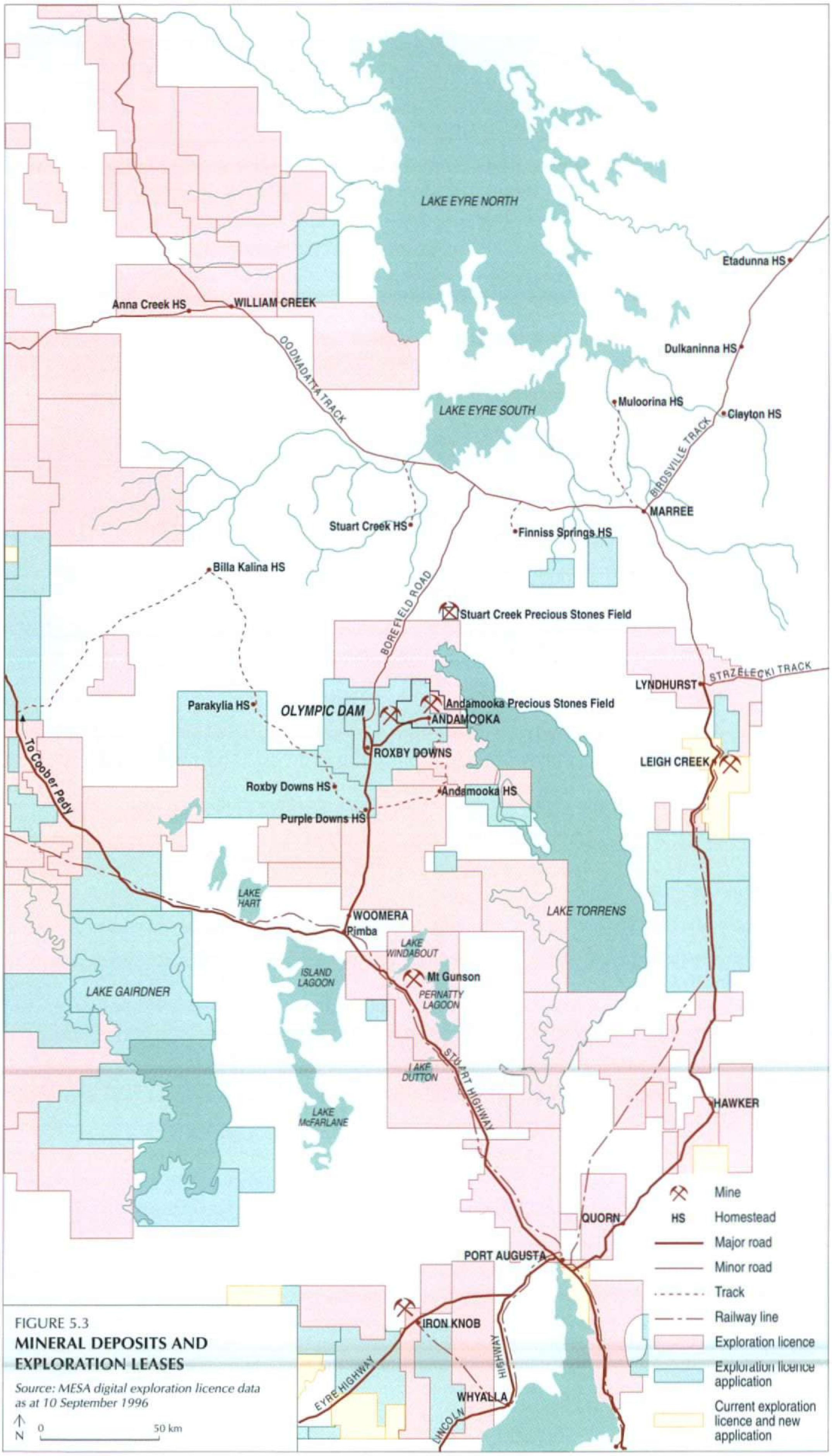


FIGURE 5.3
MINERAL DEPOSITS AND EXPLORATION LEASES

Source: MESA digital exploration licence data as at 10 September 1996

The extensive reserves of iron ore in the Middleback Ranges (west of Whyalla) have been mined by BHP for many years. Railway lines from Iron Knob and Iron Baron transport the ore to BHP's steelworks and iron ore pellet plant at Whyalla.

Gold and silver

Gold and silver are currently extracted from WMC's Olympic Dam mine in conjunction with the mining of copper. The general region including the Gawler Craton and Stuart Shelf (Figure 3.1) has recently been described as Australia's potential next major gold province. Increasing mineral exploration in the region has led to the discovery of further gold deposits, such as the significant finds in exploration drill holes in the Tarcoola region.

Precious stones

Coober Pedy (shown in Figure 1.1), some 250 km north-west of Olympic Dam, has extensive opal resources, discovered in 1915. Mining became established after the First World War, and expanded after major new finds in 1946.

The extensive opal resources at Andamooka, east of Roxby Downs, were discovered in 1930, and deposits were first mined in 1933 (Kinhill – Stearns Roger 1982). More recently, the Mintabie region 30 km west of Marla (also shown in Figure 1.1) has been established as the third major opal mining area in South Australia. Opal is also mined at the smaller Stuart Creek Precious Stones Field, located within the Mulgaria pastoral lease.

Some 80% of world opal production comes from South Australia.

Oil and gas

Oil and gas are produced at Moomba in the Cooper Basin (shown in Figure 1.1) in the far north-east of South Australia, a distance of approximately 400 km from Olympic Dam. The Cooper Basin is one of Australia's principal oil and gas fields. The major facilities are at Moomba, and are operated by Santos Limited.

The Moomba–Adelaide gas pipeline was completed in 1969, and the Moomba–Sydney gas pipeline in 1976. In 1981 a petroleum liquids project was developed and a pipeline was built to a new petroleum liquids plant at Port Bonython, near Whyalla.

Minor deposits

Copper, uranium, iron ore, coal, oil and gas, and precious stones form the core of mining operations in northern South Australia. There are a number of other, smaller mineral deposits which have been worked in the Olympic Dam region. These include barite on the floor of Pernatty Lagoon, manganese in the same location, barite in the Flinders Ranges, and white and grey laminated clays extracted for ceramic purposes at Woocalla, also near Pernatty Lagoon (Kinhill – Stearns Roger 1982).

There is a small sand-mining undertaking on Purple Downs Station, and a small-scale stone quarry on Andamooka pastoral lease (Kingoonya Soil Conservation Board 1996). Neither is currently in operation. Small quarries are also operated intermittently for road and railway construction and maintenance by government agencies and others.

5.2.3 Defence (Woomera)

Woomera, approximately 80 km south of Olympic Dam, was originally established as part of a joint British and Australian long-range missile development project. An extensive Prohibited Area was designated around Woomera in 1946. The extent of the Prohibited Area has since been reduced following modifications to the range function. The present boundary of the Prohibited Area in the vicinity of Olympic Dam is shown in Figure 5.1.

The township is now primarily used as a residential base for the Joint Defence Facility, Nurrungar, located approximately 20 km to the south. From a peak of approximately 4,000 people in 1974, Woomera's population has declined to approximately 1,250. The participation of the United States of America in the Nurrungar facility is declining, and current expectations include closure of Woomera's operations around the year 2000 (D. Kenny, Defence Support Centre, Woomera, pers. comm., October 1996). Alternative uses of the Woomera range are being examined by the Department of Defence and the Commonwealth Government.

Tourism is actively encouraged to compensate for the effect of the decrease in population on the town's local economy (D. Kenny, Defence Support Centre, Woomera, pers. comm., October 1996). Examples of rockets, aircraft and weapons, and information relating to the history and operations of the range are displayed in the Missile Park and Heritage Centre, and a caravan park and hotel provide accommodation and services for tourists and visitors. The facilities for recreation and entertainment at Woomera, including the ten-pin bowling alley, cinema and restaurants, are also used by Roxby Downs residents.

5.2.4 Tourism and recreation

Tourism is a recognised land use in the region, with inherent constraints of distance, remoteness and climatic extremes. Although road conditions in remote areas can affect access by conventional vehicles, the region has been identified in the Flinders Ranges and Outback Tourism Development Strategy (South Australian Tourism Commission 1996) as an area of potential growth.

Regional tourism peaks between March and November, with many visitors in transit between South Australia, Queensland and the Northern Territory, via either the Birdsville or Oodnadatta tracks. Some visitors also tour the region over a prolonged period, either independently or as part of an organised tour.

Principal tourist attractions of the region (Figure 5.4) include:

- the mound springs, in particular Blanche Cup, Coward Springs and The Bubbler in the Wabma Kadarbu Mound Springs Conservation Park;
- Lake Eyre;
- general features of the desert environment;
- sites of scenic, geological or heritage significance;
- the mining towns of Coober Pedy (shown in Figure 1.1), Andamooka and Roxby Downs;
- the township of Woomera.

There are also a number of well-attended social and sporting events organised in the region, such as the:

- biennial Curdimurka Ball
- Glendambo annual bachelor and spinster ball
- Glendambo races and gymkhana
- Roxby Downs horse races, annual cup and gymkhana
- Roxby Downs annual 'Boogie in the Bush'
- Marree camel and horse races
- Andamooka annual White Dam Walk
- Andamooka annual Opal Festival

FIGURE 5.4
ENVIRONMENTAL, HERITAGE AND RECREATIONAL FEATURES

A further benefit that has occurred is the increased awareness of conservation and water use issues in the region.

Potentially negative impacts predicted in the 1983 EIS included:

- division and loss of land
- vehicle–stock accidents
- other hazards to stock
- vandalism.

Concern has been expressed by the regional pastoralists regarding the possible drawdown effects of extracting groundwater from the Great Artesian Basin at Borefield B. All the above potential impacts, both positive and negative, are discussed below.

Access to facilities

Roxby Downs is one of the two largest regional centres in South Australia north of Port Augusta, the other being Coober Pedy. As predicted in the 1983 EIS, the establishment of Roxby Downs has provided regional pastoralists with the convenience of ready access to a wider range of commercial, service and educational facilities than was previously available. The flow-on effect of increased population following the Expansion Project would provide opportunities for further commercial development.

The South Australian Government has announced funding for the construction of a medical facility at Roxby Downs, which will significantly improve medical services in the region.

Stockwater supply

The region falls within South Australia's arid zone, where rainfall is erratic and well below evaporation rates. Pastoralism is dependent on the supply of stockwater of a quality and quantity that can sustain life and promote animal development.

Clauses 13 (13a) and (13b) of the Indenture provide for the supply to third parties of water from the Olympic Dam mine water supply infrastructure. The quantities and locations of these water supplies are subject to negotiation between WMC and the third parties. There are currently ten water takeoff points from the M1 pipeline to Borefield A, supplying stockwater to permanent water points on five pastoral leases. The estimated supply is 5 ML/a (Department of Housing and Urban Development 1996b).

There are water takeoff points on the M6A pipeline from Borefield B that could be made available to third-party users. The Department of Transport has also planned a water takeoff from the M6A pipeline near the Oodnadatta Track. The quantities and locations of any takeoff points would be subject to negotiation between WMC and third parties, as occurred with the agreements for the Borefield A pipeline.

Improved transportation

As a result of the establishment or upgrading of regional roads, such as the Borefield Road, pastoralists have benefited from improved road transportation and access. Following the sealing of the Roxby Downs – Andamooka road, miners, pastoralists, tourists and service industries have also benefited from the improved transport infrastructure that followed establishment of the Olympic Dam mine and Roxby Downs township.

There are no changes expected in the level of benefit to pastoralists in the region in relation to improved road access, as the proposed Expansion Project does not involve any major road construction or improvement. General considerations relating to transportation are discussed in Section 11.3.

Conservation and water use awareness

Since the 1983 EIS, WMC has undertaken extensive ecological survey work and monitoring of pastoral bores and mound springs. WMC staff as well as consultants working for WMC visit the area frequently. Officers of the SA Department of Mines and Energy (MESA) hydrogeological group and DENR also periodically visit the area.

As a result of these visits, and because of increased interest in conservation and water use by the pastoralists themselves, the awareness of these issues in the pastoral community is very high. This awareness has led to pastoralists improving stock control around the mound springs, giving assistance to WMC and others in research activities and helping MESA in its bore capping programme.

Division and loss of land

One of the major impacts predicted with the establishment of the Olympic Dam mine and Roxby Downs township in the early to mid-1980s was the loss of land and production from the Roxby Downs pastoral lease. As compensation for the conversion of approximately 10% of the area of Roxby Downs pastoral lease for the Special Mining Lease and Municipal Lease, arrangements were made for WMC to provide a similar land area from the Purple Downs pastoral lease. Subsequently, the Roxby Downs, Purple Downs and Parakylia South pastoral leases were also acquired by WMC, and destocked to mitigate past management practices which had led to land degradation. As discussed in Section 5.2.1, any restocking would follow consultation with DENR.

The division and loss of land is no longer an issue as WMC now holds the leases to all of the stations in the immediate vicinity that could be affected by the Expansion Project. In due course some extension of the boundaries of the Special Mining Lease area would be necessary as part of the expansion, and this extension would be applied for in the appropriate manner.

Vehicle–stock accidents

North of Port Augusta, as in most remote areas of Australia, many sections of transportation corridors are unfenced, with inevitable risk of death and injury to stock grazing on roadside paddocks and table drains.

The risk of stock mortality is highest on the Borefield Road within the boundaries of Stuart Creek pastoral lease. Stock watering points taken off the M1 pipeline are close to the roadway, as are disused gravel pits that hold water following rain. Towards evening, cattle move away from these water supplies and cross or walk along the roadway, thereby increasing the risk of vehicle–stock accidents. Options for mitigation of this risk are currently being discussed with the pastoral lessees, and may involve the erection of additional hazard signs in the vicinity of these watering points to alert drivers to the presence of cattle.

With the proposed expansion, the mortality rate of stock and native fauna on other roads may rise as a result of the increase in heavy vehicle transportation of mine products and service inputs. WMC includes driver awareness and education in its employee induction and ongoing occupational health and safety programmes.

Hazards to stock and vandalism

Prior to initial approval of the 1983 EIS, regional pastoralists expressed several concerns during the public consultation process relating to the exposure of stock to the increased population of the area, including the potential dangers if shooters and town dogs had unrestricted access to leases. Vandalism of stock watering points and the consequences of interference with gate-regulated stock control were also issues of concern. The incidence of fire was also predicted to increase following destocking of the mine area and the introduction of mine and township revegetation programmes.

These concerns have essentially been alleviated by WMC's recent purchase and destocking of Roxby Downs pastoral lease. The level of impact on other pastoral leases is not reported by pastoralists to have been significant.

WMC management has made a concerted effort to mitigate impacts on adjacent pastoral leases by establishing codes of practice, by promoting a responsible environmental ethic during employee and contractor inductions, and through education. WMC does not permit the possession of guns within the Special Mining Lease.

The incidence of fire does not appear to have increased as predicted in the 1983 EIS. It is recognised that fires can only occur in the years following exceptional rainfall events, when there is sufficient vegetation to sustain a fire (Kingoonya Soil Conservation Board 1996). Most fires in the region are started by lightning strikes and, occasionally, by unextinguished camp fires close to Roxby Downs. Experience to date has shown that these fires are rapidly contained. The effects of reduced grazing of emergent plants by sheep or cattle following destocking, and by rabbits following the introduction of Rabbit Calicivirus Disease, are expected to be offset by a commensurate increase in grazing by kangaroos, with no net change in fire risk from this cause.

Unauthorised use of motorcycles and off-road four-wheel drive vehicles in areas surrounding the town and on neighbouring pastoral properties has caused some loss of vegetation and subsequent erosion. Mitigation measures that have been implemented to date include the establishment of a moto-cross circuit near the Roxby Downs township.

A further mitigation measure involving establishment of a dedicated area for the use of off-road vehicles, encouraging the use of this area and deterring the use of other, more sensitive areas, is currently being considered. Regular local newspaper items and other forms of publicity highlight the environmental issues associated with off-road driving.

Groundwater drawdown effect

As part of the consultation process for the establishment of Borefield B, regional pastoralists expressed concern about the potential impact of drawdown on their water supplies.

The Indenture provides that pastoralists shall continue to have the right to use groundwater for the proper development and management of the existing use of the lands occupied by them.

These rights can only be restricted or terminated by the State if WMC makes alternative supplies available or agrees on an appropriate level of compensation. WMC is in negotiation with pastoralists to formalise arrangements in written agreements.

5.5.3 Mining

There is considerable distance between the few major mining operations in the region. The closest significant mining activity to Roxby Downs is opal mining at Andamooka. The interests of the mining community in the Andamooka Precious Stones Field are protected against the implications of a Special Mining Lease (such as that held by WMC) being granted in the Andamooka region by Clauses 19 (12) and 20 (10) of the Indenture. These clauses protect the rights of the town's present and future opal miners to prospect and mine opals to a depth not exceeding 50 m below the surface.

5.5.4 Tourism and recreation

There are no recognised areas of scenic or recreational attraction in the immediate vicinity of the Olympic Dam mine that may be affected by the proposed Expansion Project (Flinders Ranges and Outback South Australia Tourism Inc. 1996). However, there are unofficial picnic areas, camping areas and off-road vehicle tracks and circuits in the vicinity of Roxby

Downs township that have been affected by uncontrolled use in the past, resulting in soil erosion and degradation of flora (F. Badman, WMC, pers. comm., November 1996). It is expected that, in the absence of mitigation, the proposed increase in the population of Roxby Downs township would proportionally increase impacts on these areas.

WMC has recognised the need to mitigate present and future recreational use impacts. Mitigation strategies currently under review include:

- dedicating a site for use by recreational off-road vehicles;
- promoting and managing visits to selected picnic spots and camping grounds (Hore-Lacy 1994).

The proposed expansion and future operations of the Olympic Dam mine and Roxby Downs township will continue to be a positive influence on regional tourist and recreation industries. The Olympic Dam mine has become a tourist destination in its own right with some 5,000 visitors annually undertaking surface tours of the mine. The fuel, food and accommodation services in the town ensure that Roxby Downs continues to attract visitors to the town and to the region.

The establishment of the Borefield Road has shortened the travel time between Port Augusta and the mound springs by completing a transport corridor linking Port Augusta, Woomera, Roxby Downs and the Oodnadatta Track. It is expected that Roxby Downs may play an increasing role in developing the tourist industry for the region, and that this position would be enhanced by the increased population, services and accommodation expected to accompany the Expansion Project.

A secondary consequence of increasing visitors to the region is a possibility of detrimental impacts associated with uncontrolled access to sensitive areas, particularly the mound springs. The management of these impacts would be a matter for government.

5.5.5 Weapons testing and research

It is not expected that the expansion of the Olympic Dam mining and processing operations would have any direct impact on the current or future operations of the weapons research facility and testing range, as both the mine and Roxby Downs township are outside the Prohibited Area. However, Woomera may benefit from any increase in tourism to the region, as discussed above.

As noted in Section 5.2.3, the recreation and entertainment facilities at Woomera are used by Roxby Downs residents, as are the shops and hospital. This is expected to continue.

5.5.6 European heritage

The Expansion Project would not involve any disturbance of land within national parks and wildlife reserves or to the sites of geological significance, sites listed on the Register of the National Estate and the South Australian Heritage Register. Similarly, there would not be any disturbance by the Expansion Project to items of historical interest associated with European exploration and settlement of the region.

5.6 LONG-TERM LAND USE

WMC, through its Expansion Project, has declared its intent to operate Olympic Dam for at least twenty years beyond completion of the initial expansion phase. While marginal decreases are expected in the quality of ore extracted over this period, the orebody is considered to be large enough to sustain production for a period well in excess of this. The detailed rehabilitation requirements for the mine are presented in Chapter 14.

WMC plans to restock both the Roxby Downs and Parakylia South pastoral leases once they have sufficiently regenerated, following consultation with the Pastoral Management Branch of DENR. Management of the restocked stations may either be undertaken by WMC or be contracted to a third party. WMC intends to continue to operate Andamooka as a productive pastoral lease.

The township of Roxby Downs is a purpose-built, mining support town. It is expected that, unless alternative uses for the municipality are encouraged to sustain the township when the mine and processing plant operations cease, the township would decrease in size and may cease to be a major regional service centre.

CHAPTER 6

ABORIGINAL CULTURE AND RELATIONSHIPS

traditions of Aboriginal people. It was predicted in the 1983 EIS that archaeological sites would be found throughout the area, particularly in sand dunes near claypans or other water sources, or near sources of raw materials.

As a result of the archaeological survey work conducted for the 1983 EIS, 437 archaeological sites were recorded within the project area. Of these, 287 archaeological sites were recorded within the current Olympic Dam Special Mining Lease and the Municipal Lease, fifty-three were recorded in the Borefields area, and ninety-seven in other nearby areas.

The archaeological sites recorded in the Olympic Dam region included surface scatters of stone artefacts such as campsites, knapping floors, quarries and stone arrangements. The distribution of archaeological sites across the landscape was correlated with detailed mapping of landform types and geological regimes to produce a predictive model of archaeological sites located throughout the Olympic Dam Project Area.

The ethnographic information presented in the 1983 EIS was predominantly based on the desktop research of existing Aboriginal site records held by the Heritage Conservation Branch of the Department of Environment and Planning, and of anthropological, linguistic, sociological and ethno-historic sources. The following matters affected the extent of ethnographic information available at the time:

- Much of the research for the 1983 EIS indicated that the Project Area was located within Kuyani territory near the boundary with Kokotha territory. (Further work which began during the preparation of the 1983 EIS and which was completed after its approval caused a revision of this assessment, as explained below in Section 6.3.)
- Negotiations with Kokotha people, represented by the Kokotha People's Committee (KPC), did not result in agreement on arrangements for the confidentiality of cultural information.
- On the basis of preliminary surveys by the Aboriginal and Historic Relics Preservation Unit (now DoSAA), WMC was advised that, to the best of the Unit's knowledge, the Olympic Dam Project Area did not contain significant Aboriginal sites. Subsequent to the 1983 EIS, the Kokotha people provided ethnographic information and WMC took action to protect recorded sites.

Further Aboriginal heritage studies and consultation with Aboriginal groups since the 1983 EIS have produced considerable additional information about the archaeological and ethnographic aspects of the Aboriginal heritage of the Olympic Dam region, and an overview of this is presented below.

6.3 ABORIGINAL HERITAGE MANAGEMENT SINCE 1983

6.3.1 Project Area

Since the 1983 EIS approval for the Olympic Dam Project, WMC has continued to take a proactive approach to Aboriginal heritage within the Olympic Dam region. As a result of the 1983 EIS, nine archaeological sites were identified for their special scientific value. A programme of detailed archaeological recording and salvage work was undertaken on these sites (Hiscock 1985).

In 1983, the then Joint Venturers funded an ethnographic survey with the cooperation of the KPC. This survey resulted in eighteen Aboriginal ethnographic sites being located and recorded both within and adjacent to the Olympic Dam Project Area (Hagen and Martin 1983). This report contained recommendations for protecting these Aboriginal sites, following which WMC established a heritage programme to monitor the sites.

The above report also indicated that the Olympic Dam Project Area was located within the eastern part of Kokotha territory (Hagen and Martin 1983). Berndt (1983) independently assessed and concurred with this finding. The findings of Hagen and Martin (1983) and Berndt (1983) are consistent with the earlier fieldwork of Tindale (1974). Davis and Prescott (1992) drew similar conclusions. However, it should be noted that Berndt in a 1985 review concluded that, prior to the mid-1800s, the area as far west as Coondambo and to near Mount Eba had been Kuyani territory (L. Hercus, pers. comm., April 1997).

As a further commitment to the protection of Aboriginal heritage, WMC signed an agreement with the Andamooka Land Council (ALC) in 1994. The ALC represents a group of Kokotha Aboriginal people who claim primary traditional affiliations with the land on which the Olympic Dam Project Area is located, both through descent and through knowledge of the Aboriginal law for the region.

The agreement between WMC and the ALC provides for additional Aboriginal ethnographic and archaeological site survey programmes in the Olympic Dam Project Area to be conducted as required. This relationship, however, does not exclude other Aboriginal people or groups who may maintain a cultural heritage interest in the Olympic Dam region.

Between September 1994 and June 1995, four separate Aboriginal heritage surveys were conducted in the Olympic Dam Project Area in conjunction with the ALC. These included an ethnographic survey in September 1994, and archaeological and ethnographic surveys in December 1994, March 1995 and June 1995. As a result of these surveys, an additional twenty-three ethnographic sites, two Dreaming Tracks and 124 archaeological sites were recorded.

WMC respects Aboriginal concerns regarding the confidentiality of cultural information and conducts all ethnographic surveys using, at the request of the ALC, a Work Area Clearance procedure, which involves notification to the ALC of the need for survey work, the survey and consultation, sign-off and reporting. In this type of survey the Aboriginal consultants do not disclose cultural information pertaining specifically to sites of significance, but merely advise WMC about the presence of an area of significance. It is WMC's policy to avoid all ethnographic sites and to avoid disturbing archaeological sites whenever possible.

6.3.2 Borefields region

Pipeline corridor and borefields

Aboriginal heritage surveys were undertaken in the late 1980s and early 1990s as part of the environmental studies for the extension of Borefield A, and for the Borefield B corridor (WMC—Olympic Dam Operations 1991, 1992). At that time it was proposed to site Borefield B in the vicinity of Crows Nest Bore. However, following this initial environmental assessment work, Borefield B was relocated to its present location north-east of Muloorina Homestead (Figure 11.1).

Initial studies identified a number of ethnographic sites in the Borefield B region, all of which were avoided by the pipeline corridor to Crows Nest Bore. In addition to the fifty-three archaeological sites identified in the Borefields area in the 1983 EIS, thirteen additional sites were identified in the Borefield A extension survey work, and eighteen sites were identified along the Borefield B corridor to Crows Nest Bore.

Following the decision to relocate Borefield B to north-east of Muloorina Homestead, further Aboriginal heritage studies were undertaken. These are described in the Borefield B Supplementary Environmental Studies report (Kinhill Engineers 1995a). This report was subject to public consultation, and was advertised locally and nationally in September 1995.

The additional surveys showed no sites of ethnographic significance within the pipeline corridor north of Crows Nest Bore. The corridor had already been moved to avoid the principal ethnographic site in the area. Four archaeological sites were located, and the corridor was also realigned to avoid these sites. Overall, a total of eighty-eight archaeological sites have been recorded in the Borefields area.

A specific Environmental Code of Practice was prepared for the Borefield B construction works (Kinhill Engineers 1995b). The code is described in greater detail in Section 11.1. Archaeological sites and environmentally sensitive sites were protected by temporary fencing and signage during construction.

Mound springs

The archaeological and ethnographic significance of the arc of artesian mound springs that extends from the northern end of the Flinders Ranges through the southern edge of Lake Eyre to north-west of Oodnadatta has been examined by Lampert and Hughes (1985) and Hercus and Sutton (1985). Both studies demonstrated the close correlation between Aboriginal sites and their environmental settings; three factors—proximity to drinking water, to raw materials for making stone artefacts, and to sand for camping on—either singly or in combination appear to have most strongly influenced the nature and distribution of sites within the area. Certain mound springs, as reliable sources of drinkable water, would have been major foci for past Aboriginal occupation. The water resources of the mound springs were similarly a focus for European settlement, especially for pastoralism, transport and communications.

Lampert and Hughes (1985) made the assessment that, of some thirty identified mound spring archaeological sites, about two-thirds were of major significance. They concluded that, as a suite, these sites were a regionally important archaeological resource which reflected the prehistoric use of the localised, permanent occurrences of drinkable water at the mound springs. However, there had been considerable degradation of the sites from past trampling and grazing by stock, and destruction from the direct effects of construction of road and pastoral infrastructure. Archaeological sites accessible from adjacent public roads had also been stripped of artefact material, presumably by artefact collectors and/or tourists.

Mound spring ethnographic sites have specific significance to the current traditions of Aboriginal people in the region. The sites are predominantly mythological or ceremonial in nature, and are almost universally associated with the water resources of the springs. Hercus and Sutton (1985), in conjunction with Aboriginal informants, recorded twenty-nine such sites between Marree and Curdimurka, which form part of a number of Dreaming Tracks in the region. Initiations and ceremonies relating to these Dreamings, in which some Aboriginal people alive today have participated, have been performed on many occasions. As a result, they have traditional responsibility for the protection and maintenance of the ethnographic values of the sites and localities. Out of respect for their wishes and traditions, the sites and their particular significances are not identified here.

A review of the Register of the National Estate indicates that the Bidalina Aboriginal site near Coward Springs is the only site with specific Aboriginal values associated with the mound springs that is listed in the Register (D. Heap, Australian Heritage Commission, pers. comm., November 1996).

The proposed expansion at Olympic Dam does not involve any physical disturbance of the mound springs, hence their present archaeological values would not be affected. In addition, the management of Borefield B, which is over 100 km from the mound springs, will ensure that WMC's operations do not significantly alter spring flows, thereby mitigating any adverse effect on their ethnographic significance.

6.3.3 275 kV transmission line

The 275 kV transmission line was approved in the 1983 EIS on an in-principle basis, subject to additional heritage studies and assessment of route alternatives. Ethnographic studies on the transmission line route commenced in late 1992, and further studies were undertaken in early 1994, 1996 and 1997.

These studies showed an area of significance south-east of Woomera, along the route proposed in the 1983 EIS. Further studies were undertaken in 1996 to resolve this issue, and these studies are described further in Section 6.4.

6.4 EXPANSION PROJECT ABORIGINAL HERITAGE SURVEYS

6.4.1 Project Area

Four separate Aboriginal heritage surveys have been conducted on both the Municipal Lease and the Special Mining Lease since the beginning of 1996. These surveys have all focused on proposed works areas associated with the Olympic Dam Expansion Project.

The conduct of the archaeological and ethnographic components of these surveys was consistent with the approach developed during the previous Aboriginal heritage surveys with the ALC. These surveys occurred in January–March, July (twice) and October 1996 and are briefly summarised below.

- ***January–March 1996: Municipal Lease and Special Mining Lease Survey***

  This survey was conducted over two site visits, and examined proposed works areas located within both the Special Mining Lease and the Municipal Lease. The archaeological assessment examined two survey areas, totalling approximately 2.5 km^2. The ethnographic assessment examined seventeen proposed works areas, totalling approximately 9.5 km^2. One ethnographic site was recorded on the Special Mining Lease and no archaeological sites were located (Anthropos Australis in prep.).

- ***July 1996: Special Mining Lease Survey***

  This survey consisted of an archaeological field inspection of thirteen proposed works areas located within the Special Mining Lease. An anthropologist was present throughout the survey to record any ethnographic concerns relating to the proposed works areas. One ethnographic site and thirty-eight archaeological sites were located and recorded within the Special Mining Lease (Archae-Aus 1996a).

- ***July 1996: Municipal Lease Survey***

  This consisted of an ethnographic and archaeological survey of eleven proposed works areas totalling approximately 3 km^2 and located within the Municipal Lease. No ethnographic sites were located and three archaeological sites were located and recorded in one of the proposed works areas (Archae-Aus 1996b).

- ***October 1996: Special Mining Lease and Municipal Lease Survey***

  This consisted of an ethnographic and archaeological survey of eleven proposed works areas located within the Special Mining Lease and the Municipal Lease. During the survey, one ethnographic site was located within the Municipal Lease, thirty-eight archaeological sites were located and recorded within the Special Mining Lease and ten archaeological sites were located and recorded within the Municipal Lease (Archae-Aus in prep.).

As a result of the above four surveys, a total of two ethnographic sites and seventy-six archaeological sites were recorded on the Special Mining Lease and one ethnographic site and thirteen archaeological sites were recorded on the Municipal Lease.

6.7.3 Community development

WMC has initiated discussions with Aboriginal groups in relation to community development programmes. The programmes as currently envisaged could incorporate the following aspects for which WMC would undertake to provide financial or other support to assist the participating groups' attainment of their community-driven aspirations:

- Administrative support:
  - progressing the aims of Aboriginal groups and their relationships with WMC
  - establishing administrative structures.
- Education:
  - establishing scholarships, bursaries and employment traineeships
  - facilitating the retention of traditional culture and laws.
- Employment:
  - arranging subcontracts with principal site contractors.
- Enterprise development:
  - developing appropriate business enterprise and employment schemes
  - establishing structures to encourage joint venture partnerships
  - providing assistance to maximise the potential of existing Aboriginal enterprises.

6.7.4 Aboriginal employment

No known Aboriginal people from groups having a traditional association with the Special Mining Lease or Municipal Lease areas currently live in Roxby Downs, or lived in the area at the time the project was first developed. Individual members of these groups currently reside in Port Augusta, Whyalla, Coober Pedy, Mutijulu, Adelaide and other areas within and outside South Australia.

None of those Aboriginal groups consulted have indicated a desire to live in Roxby Downs for the purpose of gaining employment. Given this situation and the fact that the non-core mining functions are undertaken by contractors or as private commercial undertakings, the strategies to provide greater Aboriginal employment opportunities will include, but not be limited to:

- contractual arrangements to encourage the employment of Aboriginal people
- assistance for the expansion of existing Aboriginal-owned enterprises
- facilitation of new enterprises and joint venture partnerships.

Many of the towns surrounding the Olympic Dam Project Area are faced with shrinking economies resulting from the winding down of railway and manufacturing industries, as well as the seasonal and market influences on the pastoral industry. Under these regional influences, it would be difficult to create new employment opportunities for a particular Aboriginal group whose members are widely scattered and whose traditional values differ from those of the mainstream population. Nonetheless, WMC has undertaken to continue to address the issues through appropriate, proactive consultation strategies directed at providing greater self-reliance for Aboriginal groups.

CHAPTER 7

BIOLOGICAL ENVIRONMENT

CHAPTER 7

BIOLOGICAL ENVIRONMENT

This chapter reviews the existing biological environment in the region and the Project Area, and provides an analysis of the past and predicted project impacts. The chapter includes a brief review of ecologically sustainable development and biological diversity; an assessment of the flora and fauna of the region and in the Project Area, including a review of predicted impacts and mitigation; and an examination of the mound springs in the region.

Throughout Chapter 7 the following areas are discussed:

- the Project Area, which includes all of the land within the Special Mining Lease and the Municipal Lease;
- the region, which comprises the land within a distance of approximately 16 km from the south, east and west boundaries of the Project Area and approximately 6 km north of the Project Area boundary.

The region identified above encompasses all of WMC's flora and fauna monitoring sites as defined in the company's environmental management and monitoring plan (EMMP) (WMC—Olympic Dam Corporation 1996a), and lies almost completely within the Moondiepitchnie environmental association (Appendix H).

Infrastructure items have been developed by WMC outside this region, including Borefield A and Borefield B, north-east of the Project Area, and the power transmission lines, south and south-east of the Project Area.

The environmental impact of these developments has been previously assessed by other studies and, in general, this information will not be discussed in this chapter. However, the mound springs adjacent to the borefields are reviewed in detail (Section 7.4).

7.1 ECOLOGICALLY SUSTAINABLE DEVELOPMENT AND BIOLOGICAL DIVERSITY

This section provides a brief review of WMC's commitment to ecologically sustainable development (ESD) and biological diversity (biodiversity) in the region and the Project Area.

7.1.1 Ecologically sustainable development

The National Strategy for Ecologically Sustainable Development was endorsed by the Council of Australian Governments in December 1992.

The principal objectives of ESD are to:

- enhance individual and community well-being and welfare by following a path of economic development that safeguards the welfare of future generations;
- provide for equity within and among generations;
- conserve biological diversity and maintain essential ecological processes and life-support systems.

The principles of ESD are being incorporated in various government and private sector programmes, including WMC's environmental management commitments. These principles are a foundation for improved environmental management, and include factors such as environmental liability and due diligence and the requirement for best practice environmental management.

Environmental due diligence requires the application of best practice environmental management, including the preparation, implementation and monitoring of such documents as an environmental management programme. WMC has demonstrated its commitment to due diligence requirements, and has established a detailed EMMP for its operations at Olympic Dam (Chapter 15).

7.1.2 Biodiversity

Conservation of biodiversity is a foundation of ESD and one of the three principal objectives of the National Strategy for Ecologically Sustainable Development. The International Convention on Biological Diversity, ratified by Australia in June 1993, provides a global mechanism to allow for the conservation and sustainable use of biodiversity for the benefit of present and future generations (Biodiversity Group 1994). Within Australia, the National Strategy for the Conservation of Australia's Biological Diversity (Department of the Environment, Sport and Territories 1996a) aims to bridge the gap between current activities and the effective identification, conservation and management of Australia's indigenous biological diversity.

The National Strategy considers biological diversity at three levels; namely, genetic diversity, species diversity and ecosystem diversity. The strategy contains six target areas:

- conservation of biological diversity across Australia
- integrating biological diversity, conservation and natural resources management
- managing threatening processes
- improving knowledge and understanding of biodiversity
- involving the community
- Australia's international role.

7.1.3 WMC commitment

WMC is fully committed to establishing effective management of environmental issues, consistent with the principles of sustainable development.

WMC makes continuous improvements to environmental management in the areas it manages by applying information gained from monitoring programmes, scientific research and regular management reviews. Olympic Dam complies with WMC's Environment Policy and relevant State and Commonwealth legislation as a minimum environmental standard.

In addition to operational monitoring, WMC staff are undertaking numerous research programmes that reach beyond statutory requirements applicable to Olympic Dam. The findings of this research are increasing knowledge of regional biodiversity and assisting with effective ESD in the region. These additional research programmes are summarised in Chapter 15.

The EMMP approach adopts elements of environmental management systems designed to improve environmental performance and achieve ESD. WMC is proceeding towards implementation of an environmental management system consistent with the principles of the International Standards Organisation's ISO 14000 series. The current Olympic Dam EMMP represents a major revision of the previous environmental monitoring programme, and has been upgraded to include elements of the ISO 14000 system. Future Olympic Dam EMMPs will be consistent with the principles of the ISO 14000 series.

7.2 FLORA

This section discusses the terrestrial vegetation present in the region and the Project Area, the conservation status of the vegetation communities and individual species, introduced flora, past impacts, potential impacts of the proposed expansion and their mitigation, and monitoring programmes. Information on terrestrial vegetation for the wider region and the Project Area provided in Kinhill – Stearns Roger (1982) remains a relevant and accurate baseline. While a summary of this information is provided in Appendix I, this section focuses on a detailed review of the impacts of WMC's operations in the Project Area.

As indicated at the start of this chapter, developments such as Borefield A, Borefield B and the 275 kV transmission line have been previously assessed for environmental impact through development-specific surveys and reports, and have State and Commonwealth government approval, or approval in principle, to proceed subject to certain conditions. Therefore these developments will not be considered in this section.

WMC is fully committed to effective management of terrestrial vegetation in the Project Area, as indicated in the company's Environment Policy and the Olympic Dam Statement of Environmental Commitment (both in Appendix A of this EIS).

Legislation potentially relevant to WMC in relation to vegetation communities and species includes:

- *Endangered Species Protection Act 1992* (Cwlth)
- *National Parks and Wildlife Act 1972* (SA)
- *Native Vegetation Act 1991* (SA).

International, Commonwealth and State agreements, policies and strategies potentially relevant to WMC in relation to vegetation communities and species include the:

- Convention on Biological Diversity and the National Strategy for the Conservation of Australia's Biological Diversity (Department of the Environment, Sport and Territories 1996a);
- National Conservation Strategy for Australia;
- National Strategy for the Conservation of Australian Species and Communities Threatened with Extinction (Endangered Species Advisory Committee 1992);
- National Strategy for Rangeland Management;
- National Weeds Strategy (draft);
- Wetlands Policy of the Commonwealth Government of Australia (1997);
- Draft Threatened Species Strategy for South Australia (Department of Environment and Natural Resources 1993).

7.2.1 Regional vegetation

As discussed in Kinhill – Stearns Roger (1982), the region is dominated by a few recurring vegetation communities, especially those associated with the dune sands and the clay-based soils of the swales, and smaller areas of vegetation typical of local drainage areas and stony tablelands. The large drainage areas north, south and east of the Project Area, and large expanses of stony tableland to the east, have structurally and floristically different vegetation communities to the dunes. The dominant vegetation communities are generally associated with the dunefields, and these have been described in detail in Kinhill – Stearns Roger (1982). A summary of these vegetation communities is provided in Appendix I.

7.2.2 Project Area vegetation

The Project Area, like the region, is dominated by dunefields with small areas of stony tableland and localised drainage areas (e.g. swamps and claypans). Some sections of the vegetation communities present in this area are subject to greater disturbance than the region and surrounding areas, including mine and metallurgical plant emissions, visitor and vehicle impact, and firewood collection. Additional information about the plant species present in the vegetation communities is provided in Appendix I.

Dunefield vegetation

Dune spacing occurs as a continuum from low to high density with three different dunefield types present in the Project Area: those with widely spaced dunes, those with medium density dunes, and those with high density dunes. In the northern and north-western sections of the Project Area, the landform is dominated by widely spaced dunes with some small areas of medium density dunes. The vegetation communities that dominate this area are mulga woodland/sandhill wattle tall open shrubland or mulga woodland on the dune ridges and slopes, and bladder saltbush/low bluebush low open shrubland in the swales.

The north-eastern section of the Project Area is generally dominated by medium and high density dunefields, with mulga woodland or mulga woodland/sandhill wattle tall open shrubland on the dunes, and bladder saltbush/low bluebush low open shrubland in the swales. Communities of white cypress pine woodland are also present in small areas within this section.

The central section of the Project Area has areas of all three dunefield types. Vegetation communities present are mulga woodland or mulga woodland/sandhill wattle tall open shrubland on the dunes, with bladder saltbush/low bluebush low open shrubland in the swales. Areas of white cypress pine woodland are also present.

The southern section of the Project Area has both high and medium density dunefields. The vegetation communities present are mulga woodland and western myall woodland, with or without bladder saltbush/low bluebush low open shrubland in the swales, and areas of white cypress pine woodland.

There is generally a marked contrast in the species composition and vegetation dynamics of the dunes and the often gibber-coated clays of the swales. Groundcover vegetation on dunes tends to be ephemeral, apart from the tall shrubs, whereas the largely treeless saltbush/bluebush cover of swales is perennial with much less variation in cover.

Drainage area vegetation

The Project Area contains some small areas of temporary wetland including claypans, particularly in the northern and eastern sections. The frequently inundated areas tend to be swampy and can be bare or dominated by swamp cane-grass, sometimes in association with lignum, while the groundcover is dominated by short perennial grasses. Cottonbush shrubland often dominates the margins of these swamp cane-grass/lignum swamp areas. Those areas less frequently inundated are dominated by cottonbush low open shrubland, with lignum sometimes present in the lower lying areas, while bladder saltbush and poverty-bush (*Sclerolaena divaricata)* are present on higher ground. In addition there are two small drainage areas in the north-west of the Project Area that contain tea-tree *(Melaleuca pauperiflora*). There are also some unvegetated, open areas (claypans) among those areas not frequently inundated.

Stony tableland vegetation

The small areas of stony tableland are dominated by bladder saltbush low open shrubland, with some areas that may have degraded to grassland due to overgrazing, and other permanent areas of grassland. Other vegetation associated with this community includes groundcover species, including *Sclerolaena* spp., *Frankenia serpyllifolia,* stalked Ixiolaena *(Ixiolaena leptolepis)* and ray grass (*Sporobolus actinocladus).* There is an absence of trees and tall shrubs.

7.2.3 Conservation status of vegetation communities and species

Some vegetation communities in the region contain plant associations that are poorly conserved in the region or South Australia. These include:

- bladder saltbush/stalked Ixiolaena low shrubland association, which occurs within the bladder saltbush low open shrubland present on the stony tableland east of the Roxby Downs township;
- swamp cane-grass tussock grassland association, which occurs within the swampy drainage areas that are frequently inundated. This association generally includes lignum and short perennial grasses;
- western myall low woodland association, which is present within the sandhill mulga woodland, sandhill wattle tall open shrubland or mulga woodland on the dune ridges and dune footslopes of moderately to widely spaced dunes;
- white cypress pine woodland association, which is dispersed within the mulga woodland on the dune ridges and slopes of some high-density dunes.

Bladder saltbush/stalked Ixiolaena low shrubland and cane-grass tussock grassland associations are classified as Priority 12 vegetation associations (Neagle 1995). According to this reference, these associations are poorly conserved or not conserved interstate, or only occur in South Australia. Cane-grass tussock grasslands are well represented in Innamincka Regional Reserve and Witjira National Park. The western myall low woodland association is classified as a Priority 14 vegetation association in Neagle (1995). Priority 14 associations are not conserved or poorly conserved in South Australia, but there are similar association categories that are reasonably conserved in South Australia.

There are no species recorded in the region or the Project Area that are protected under the *Endangered Species Protection Act 1992* (Cwlth) or the *National Parks and Wildlife Act 1972* (SA). There are six species considered to be regionally significant, these being bullock bush *(Alectryon oleifolius* subsp. *canescens),* emubush *(Eremophila longifolia),* quondong *(Santalum acuminatum),* native apricot *(Pittosporum phylliraeoides),* Sturt pea *(Swainsona formosa)* and sandalwood *(Santalum spicatum).* The first five species were formerly protected under the South Australian *National Parks and Wildlife Act 1972* prior to its amendment in 1991. They are not currently protected under this Act, or under any other Act. However, sandalwood is listed as rare under this Act.

Bullock bush is common throughout the Project Area; however, regeneration of this species by seedlings or, more commonly, suckering has been impeded by grazing stock and rabbits. The destocking of Roxby Downs Station in October 1995, and the current decline in rabbit numbers, presumably due to the introduction of Rabbit Calicivirus Disease into the region, may assist in the regeneration success of this species.

Emubush is relatively uncommon in the region, with a few occurrences dispersed through the dunefields (Fatchen 1980; J. Read, WMC, pers. comm., December 1996). This species has shown evidence of successful regeneration in the past in the Project Area; however, grazing by rabbits has reduced regeneration success in some areas.

Quondong is uncommon in the region and the Project Area, and when present is usually associated with western myall communities and Andamooka Limestone (Fatchen 1980; Kinhill – Stearns Roger 1982).

Native apricot is also uncommon in the Project Area and is most commonly associated with tableland creeks, solution cavities and some dams. Grazing of juveniles of this species has been severe in the past and the regeneration success of the species has been limited. As noted for bullock bush, reduced grazing of this species by stock and rabbits may assist its regeneration.

While Sturt pea has been recorded at very few of WMC's vegetation monitoring sites in the Project Area, following good rainfall this species is widespread and common in the Project Area and the region (J. Read, WMC, pers. comm., December 1996). This species is often very reduced in frequency as a result of grazing.

Sandalwood is also protected under the *Sandalwood Act 1930* (SA). This species is rare in the region and has only been found at one site in the Project Area.

7.2.4 Introduced plant species and plant pathogens

This section discusses the presence, range and abundance of introduced plant species and plant pathogens in the region and the Project Area. Introduced plants are defined as those species that have been introduced to an area, either intentionally or unintentionally, where they have a detrimental impact on the natural environment of that area. The term is inclusive of all plant life forms and habits (e.g. ephemerals, annuals and perennials), and has been used in preference to other terms with more limited definitions and applications. This section discusses two types of introduced plants:

- proclaimed plant species as defined under the South Australian *Animal and Plant Control (Agricultural Protection and Other Purposes) Act 1986;*
- introduced exotic species.

More detailed information regarding introduced plants is included in Appendix I.

Department of the Environment, Sport and Territories (1996b) and Humphries et al. (1991) report that Australia's arid zone has the lowest species density of environmentally threatening, introduced and noxious plants in the nation. None of the species identified as such in the above two references is present in the Project Area or the region. However, some of the species present are degrading or threatening key habitats and communities.

No information is available on the presence or distribution of plant pathogens in the region or the Project Area. However, there is no indication that dieback of native vegetation caused by cinnamon fungus *(Phytophthora cinnamomi)* occurs in the region or the Project Area.

Legislation and policy

There is no specific Commonwealth legislation pertaining to noxious plants or the control of pest plants. However, the South Australian *Animal and Plant Control (Agricultural Protection and Other Purposes) Act 1986* provides legislative control for eight classes (and a number of subdivisions under each class) of proclaimed plant species in South Australia. The eight classes comprise:

- Class 1—aquatic and terrestrial plants that require State-wide destruction (e.g. elodea, khaki weed);
- Class 2—agricultural weeds that require State-wide destruction (e.g. three-corner jack);
- Class 3—agricultural weeds that require limited control in the State (e.g. horehound);
- Class 4—non-agricultural weeds that require State-wide control (e.g. boneseed);
- Class 5—non-agricultural weeds that require limited control in the State (e.g. olive);

- Class 6—terrestrial plants that require destruction in soil extraction areas only (e.g. bindweed);
- Class 7—agricultural weeds that require very limited control in the State (e.g. slender thistle);
- Class 8—terrestrial plants that are reportable (e.g. galvanised burr).

Within the Project Area, WMC is responsible for the control of South Australian proclaimed plants as listed in the South Australian Act.

The Commonwealth *Quarantine Act 1908* aims to control the entry of known and potentially harmful plant species into Australia. The Act may be relevant to WMC if it imports materials from other countries (e.g. contaminated lumber or other packaging materials used by overseas suppliers). The Act is currently being reviewed as part of the Commonwealth Government's environment programme.

Schedule 3 of the Commonwealth *Endangered Species Protection Act 1992* lists dieback of native vegetation by cinnamon fungus as a key threatening process. Under this Act, a threat abatement plan for the management and control of cinnamon fungus may be developed in the future (Australian Nature Conservation Agency 1996a).

Infestation by introduced exotic plants is a major form of land degradation in Australia (Department of the Environment, Sport and Territories 1996a, 1996b), and a number of Commonwealth and State collaborative programmes have been established to assist in the control of such plants. A draft National Weeds Strategy has been prepared, with recommendations from this strategy being released in 1995.

Australia's pest species programmes, including policies, control and implementation strategies and programmes, are currently being reviewed as part of the Invasive Species Programme. This review will result in further development of the National Weeds Strategy, a revised draft of which is due in 1997 (K. Colgan, Biodiversity Group, Environment Australia, pers. comm., September 1996).

WMC's Environment Policy includes commitments to rehabilitation of the environment affected by the company's activities. Control of proclaimed plant species forms a component of the rehabilitation commitment.

Monitoring the presence and abundance of proclaimed and introduced plants is included in the existing vegetation monitoring programme in the Project Area (Section 7.2.7). A formal proclaimed plant species eradication programme is not required within the Project Area owing to the low incidence of these species; however, eradication of proclaimed species is undertaken as necessary (Z. Bowen, WMC, pers. comm., November 1996). Other introduced plant species do not persist in the region or are confined to small areas in the Project Area.

Regional introduced plant species

Badman (1995) provides a major review of introduced and proclaimed plant species in the region, and this reference forms the basis of the discussion in this section.

Owing to the lack or irregularity of regional plant studies prior to 1960 it is difficult to determine the precise history of species colonisation, spread and distribution in the region. However, most introduced species presently in the region have been recorded there for more than fifty years (Kingoonya Soil Conservation Board 1996).

A number of introduced species are of potential concern owing to particular characteristics that enable them to colonise and spread in the region and northern South Australia. These species are listed in Table I.3 in Appendix I. More than 80% of these species are annuals and ephemerals with short lifespans and high reproductive rates that spread readily into available ecological niches. Table I.4 in Appendix I provides a list of all regional introduced species recorded by WMC as part of its vegetation monitoring programme.

Conditions that assist the colonisation and spread of introduced plant species in the region include:

- water and nutrient availability;
- intensive or extended history of disturbance, especially by grazing and vehicles;
- soil disturbance through such activities as road and track construction, tourism, and some types of oil and mineral exploration, and by pest animals;
- fire.

Although not a proclaimed species, long-fruited wild turnip *(Brassica tournefortii)* is considered to be an introduced species of particular concern in the region, especially in sandy areas where it can outcompete indigenous winter and spring annuals (Kingoonya Soil Conservation Board 1996). However, summer rainfall often promotes the growth of native grasses that limit the establishment of this and other introduced species by occupying most of the available niches (e.g. as is currently occurring in the Project Area and region due to the well-above-average rainfall during February 1997).

No non-vascular introduced plants have been recorded in the region or the Project Area.

Introduced and proclaimed plant species in the Project Area

Between 1987 and 1996, sixty-three introduced species were found in the Project Area and region. These species are listed in Table I.4 in Appendix I. Of the introduced species present in the Special Mining Lease and Municipal Lease areas and the region monitored by WMC, 90% are annuals and ephemerals. The remaining 10% of species are made up of short-lived perennials and biennials (9%) and long-lived perennials (1%). Most of the introduced species were present before mining activities commenced. Many continue to survive but the new introductions are generally restricted to damp areas around the town and mine buildings (Badman 1995). In addition, those introduced species restricted to the developed areas within the Municipal Lease are not spreading to the adjacent region and pastoral lands.

WMC monitoring data indicate that there have been three proclaimed plant species recorded in the Project Area between 1987 and 1996. These species are listed in Table 7.1.

Table 7.1 South Australian proclaimed plant species recorded in the Project Area

Family	Species Name	Common name	Proclaimed plant species classification[1]	Current status
Cactaceae	*Opuntia vulgaris*	Prickly pear	Class 1—terrestrial plant requiring State-wide destruction	Recorded once only; not present
Zygophyllaceae	*Tribulus terrestris* (introduced form of species)	Caltrop	Class 2—introduced form only; agricultural weed requiring State-wide destruction	Indigenous form of species present; introduced form has never been found in the Project Area or region
Boraginaceae	*Echium plantagineum*	Salvation jane	Class 3—agricultural weed requiring control in limited areas	Occasional

1 *Under South Australian* Animal and Plant Control (Agricultural Protection and Other Purposes) Act 1986.

Source: Parsons and Cuthbertson 1992; P. Allen, Animal and Plant Control Commission, pers. comm., November 1996.

Five species of introduced plants recorded or present in the Project Area are considered to be potentially damaging. These species are listed in Table 7.2.

Fatchen and Associates (1991) reported that there had not been an increase in the number or distribution of introduced species in the Project Area since vegetation monitoring began in 1981. Following the initial major development phase at the site in the mid-1980s and ongoing developments in the 1990s, very few introduced species have been established in the area through operational activities. Japanese millet *(Echinochloa utilis)* is one such species (Badman 1995), but this is not an invasive species and remains confined to very small areas.

Apart from an occasional plant of salvation jane (also known as Patersons curse), there are no proclaimed species known to occur in the Project Area or the region. Athel pine *(Tamarix aphylla)* has been planted as a salt-tolerant horticultural plant in some of the developed sections of the Project Area; however, it is now being removed and replaced with indigenous tree species.

Table 7.2 Important introduced plants recorded in the Project Area

Family[1]	Species name	Common name	Pest plant classification[2]	Current status
Cruciferae (Brassicaceae)	*Carrichtera annua*	Wards weed	Category 1—very serious threat	Recorded twice only
	Brassica tournefortii	Long-fruited wild turnip	Category 2—serious threat	Present throughout the Project Area
Compositae (Asteraceae)	*Gazania linearis*	Gazania	Category 3—potential threat	Present only in area around Roxby Downs
Gramineae (Poaceae)	*Pennisetum clandestinum*	Kikuyu grass	Category 3—potential threat	Present only in area around Roxby Downs
Liliaceae	*Asphodelus fistulosus*	Onion weed	Category 2—serious threat	Recorded only in Roxby Downs

1 *Alternative family classification in brackets.*
2 *Humphries et al. 1991.*

Within the Special Mining Lease and Municipal Lease areas, the presence and percentage cover of introduced species varied widely in the period May 1986 to May 1994. However, there was a marked decline overall in the presence and percentage cover of introduced species in the area. The variations experienced during this period have been attributed to:

- construction events, particularly that of Roxby Downs (where there was an overall decrease in vegetation cover) in the mid to late 1980s;
- high rainfall events, particularly in 1989;
- rabbit population fluctuations.

Figure 7.1 compares the total introduced plant species cover in the Project Area (over all soil types) with that in adjacent pastoral land, and Figure 7.2 shows the changes in the overall vegetation cover and total introduced plant species cover in the Project Area. The cover of introduced species, which was relatively high in wet periods up to 1989, reduced after 1989 with increased growth of native species. Drought conditions subsequent to 1989 have prevented an increase in introduced plant cover.

Potential impacts and mitigation

None of Australia's worst introduced plant species, as reported in Department of the Environment, Sport and Territories (1996b) and Humphries et al. (1991), is present in the Project Area. Badman (1995) and Fatchen and Associates (1991) provide detailed information indicating that development of Olympic Dam and its associated infrastructure since 1980 has had minimal effect on the presence and spread of introduced plant species

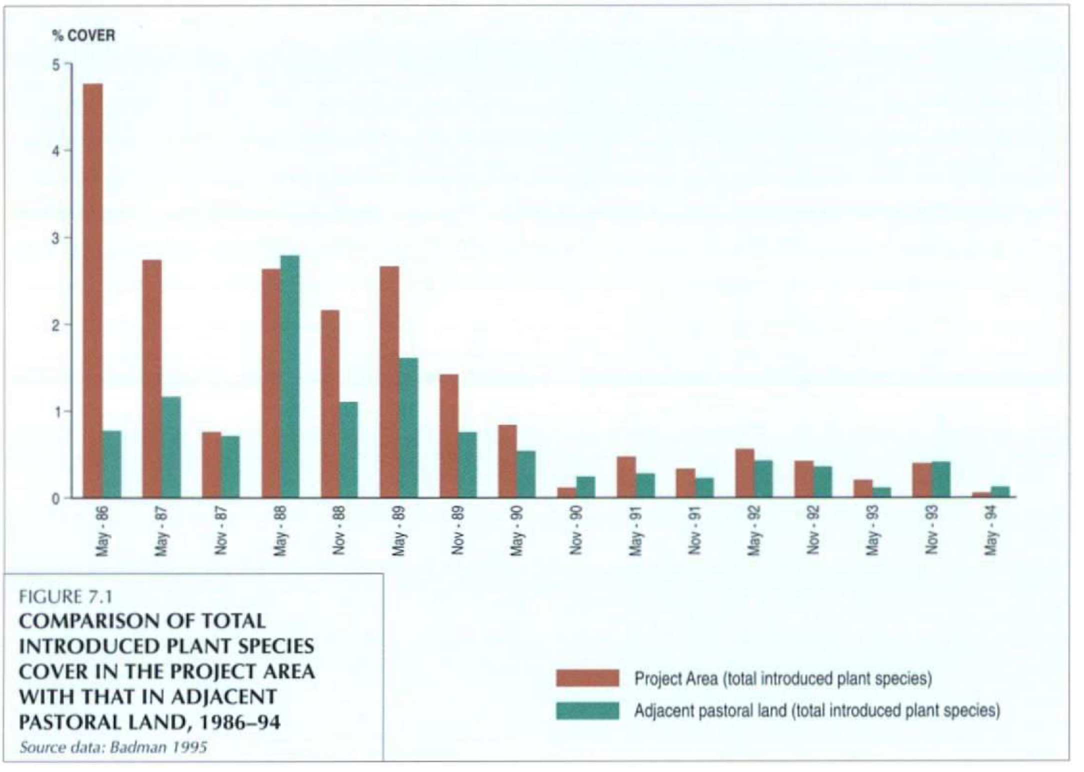


FIGURE 7.1
COMPARISON OF TOTAL INTRODUCED PLANT SPECIES COVER IN THE PROJECT AREA WITH THAT IN ADJACENT PASTORAL LAND, 1986–94
Source data: Badman 1995

in the Project Area and the region. Consequently, potential and actual adverse impacts from the Expansion Project would be expected to be minimal.

Preventing the introduction of new proclaimed plant species and controlling any significant proclaimed plant outbreaks during the early stages of establishment are the two most important management principles used as the basis of introduced plant management in the Project Area. Management actions include cleaning of earthmoving equipment, removal of domestic stock, rehabilitation of disturbed areas and regular monitoring.

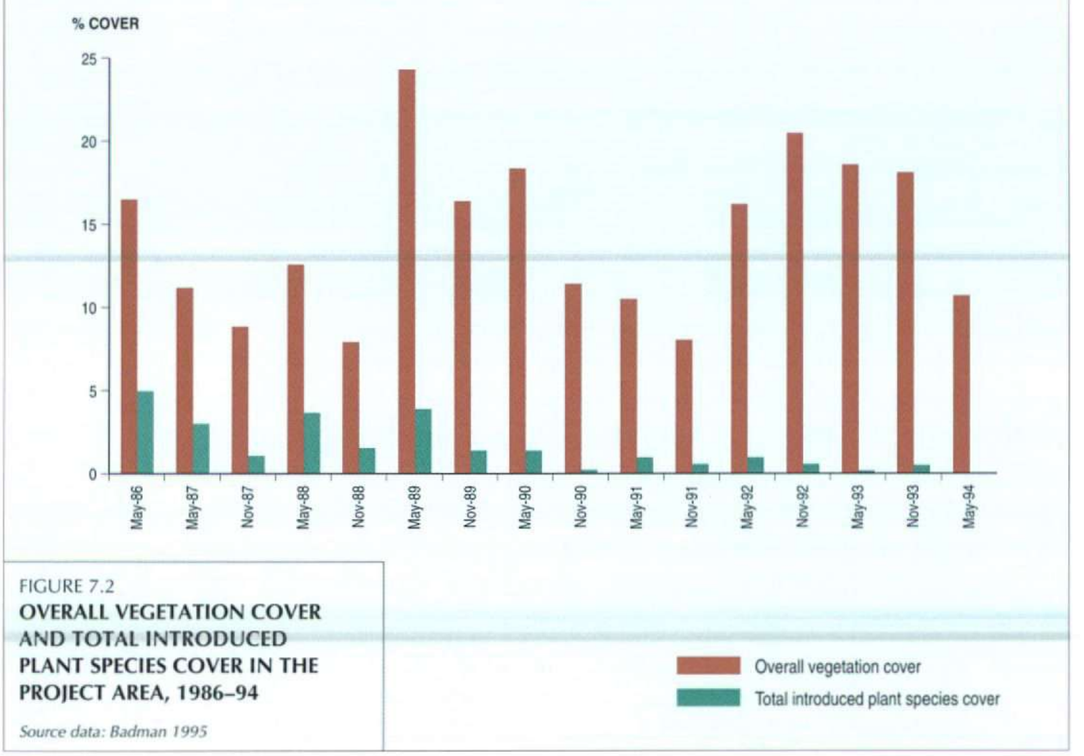


FIGURE 7.2
OVERALL VEGETATION COVER AND TOTAL INTRODUCED PLANT SPECIES COVER IN THE PROJECT AREA, 1986–94
Source data: Badman 1995

Based on past monitoring data and observations, the spread of some existing introduced species (such as long-fruited wild turnip and, more rarely, salvation jane) would be expected to coincide with vegetation clearance and the construction of new infrastructure. This spread would be short-term (one to three years depending on rainfall), following disturbance to the soil surface and reduced competition by native vegetation. Rehabilitation of these areas followed by recolonisation by native vegetation species would reduce the incidence and spread of introduced plant species in the medium to long term.

Monitoring

With the proposed expansion, monitoring of introduced and proclaimed plant species would continue and would be expanded to include assessment of all new disturbance areas. Reporting of the presence, abundance and control of these species would be included in the Olympic Dam EMMP annual report. Control of proclaimed plant species would continue to be conducted in accordance with the legislation and policies of the South Australian Animal and Plant Control Commission. The relevant sections of this programme involve:

- observation of ground-level photopoints;
- assessment and recording of the presence and percentage cover of individual species in vegetation monitoring quadrats;
- opportunistic assessment and recording of the presence of South Australian proclaimed weed species and new introduced plant species in the region and the Project Area;
- immediate investigation of large trees and areas of vegetation, particularly in amenity plantings, that were apparently healthy and, for no obvious reason, wilt and/or die, to determine if dieback caused by cinnamon fungus is responsible.

7.2.5 Terrestrial vegetation—assessment of impacts from the existing operations and current mitigation measures

A total of 138 plant species were recorded in the Study Area in 1982. Of these species, over 80% were present in areas assessed during the vegetation monitoring programme. An additional fifty-five species have been identified during the vegetation monitoring programme (i.e. since 1982). Ephemeral and annual species of the daisy family form the greater proportion of these additional species.

During the operating life of the Olympic Dam mine, vegetation of the Project Area and the adjacent region has exhibited variations in cover and health attributable to a range of variables, such as seasonal conditions, grazing pressure and impacts of mine development and operation. Impacts have been identified from an analysis of data from WMC's extensive database, which comprises 13,000 records for eleven years of monitoring. Any trends have been compared with change maps derived from remote sensing and geographical information system (GIS) analysis of time series aerial photographs of the Project Area. Current mitigation measures are examined and recommendations are made to minimise post-expansion impacts.

Vegetation influences

WMC's vegetation monitoring programme is comprehensive and involves annual surveys of sites in four areas of influence including control sites, namely:

- Area 0—pastoral lease areas subject to domestic grazing and beyond development area boundaries;
- Area 1—within Special Mining Lease or Municipal Lease boundaries but out of development or exploration areas. This area includes land grazed until early 1987;

- Area 2—within Special Mining Lease boundaries, in or near exploration and development areas;
- Area 3—in Municipal Lease development areas, including Roxby Downs township and Olympic Dam Village.

Figures 7.3a and 7.3b summarise variations to vegetation cover across these four influence zones. The Project Area incorporates Areas 1, 2, and 3. Area 1 is an ungrazed control area without the disturbance influences of mine operations and emissions, or domestic stock grazing.

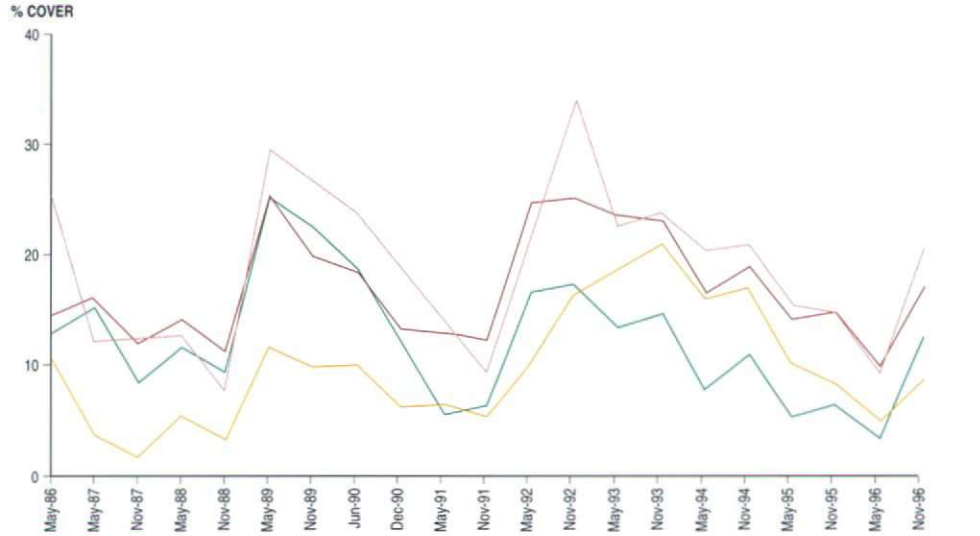


FIGURE 7.3a
VARIATIONS IN MEDIAN TOTAL VEGETATION COVER ACROSS INFLUENCE ZONES—CLAY, 1986–96

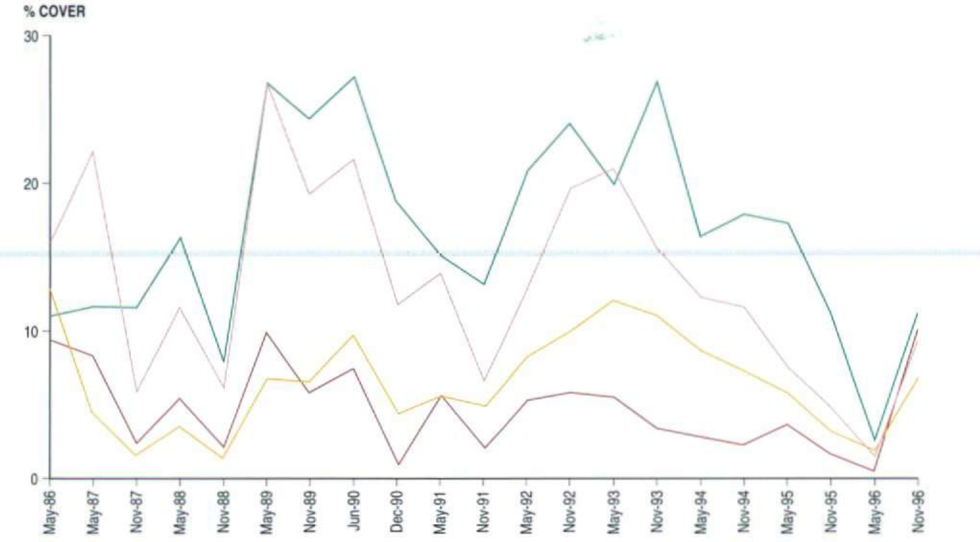


FIGURE 7.3b
VARIATIONS IN MEDIAN TOTAL VEGETATION COVER ACROSS INFLUENCE ZONES—SAND, 1986–96

A substantial initial decrease in perennial plant cover within Area 2 was recorded during the mid to late 1980s. However, a decrease of this magnitude is not supported by aerial photography analysis of the Special Mining Lease, and consequently has been attributed to inconsistent survey methods used prior to 1987. Since 1989, vegetation in all influence zones has exhibited variations of a similar magnitude and shown similar responses to above-average rainfall events recorded throughout 1989 and in 1992. Within Area 2, vegetative cover has stabilised at a level consistently equal to or greater than Area 1.

Project-related impacts

Olympic Dam mining operations have reduced vegetation cover in the Project Area through the direct impacts of land clearance, construction and off-road driving, and through the indirect impacts of increased sand mobility and erosion, salt deposition, gaseous emissions and dust particle deposition. Figures 7.3a and 7.3b present variations in vegetation cover experienced in Area 2.

The most noticeable decrease appears to be in cover of narrow-leaved hopbush in the vicinity of raise bores (subsurface mine ventilation structures). The decline shown in Figure 7.3 arose through loss of vegetation cover monitored near a raise bore, and was due to salt deposition. This is discussed in detail later in this section. Variations in cover of all other species relate primarily to rainfall events.

Land clearance and construction

Approximately 10 km^2 (3.5%) of the area within the Project Area for which aerial photography is available have been significantly changed by the construction of roads, tailings retention facilities, evaporation ponds, process plant and associated infrastructure. Table 7.3 summarises the degree of land clearance and vegetation change detected by aerial photography analysis during aggregated time periods.

Table 7.3 Change mapping statistics for areas covered by aerial photography

Degree of change	1978–84		1984–90		1990–95		1984–95	
	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
Significant change in cover	1.9	0.9	6.5	2.7	4.7	1.4	10.0	3.5
Little or no change in cover	n.r.	n.r.	175.9	72.9	179.7	51.4	76.4	32.0
Change in cover of annual plants	n.r.	n.r.	59.0	24.4	164.7	47.2	154.5	64.5
Photo coverage	245.0		241.4		349.1		240.9	

n.r. Not recorded from aerial photography.

Summing areas or percentages for the periods 1978–84, 1984–90 and 1990–95 produces totals that are greater than those estimated from a single change map for the period 1978–95. This is due to some areas being disturbed between 1984 and 1990, and again between 1990 and 1995. The overall change statistics for the period 1978–95 (9.9 km^2, or 3.5% of the area covered by aerial photography) are considered to accurately represent the area that has been significantly changed.

Figure 7.4 identifies areas within the Project Area that have experienced identifiable changes in vegetation during the period 1984–95.

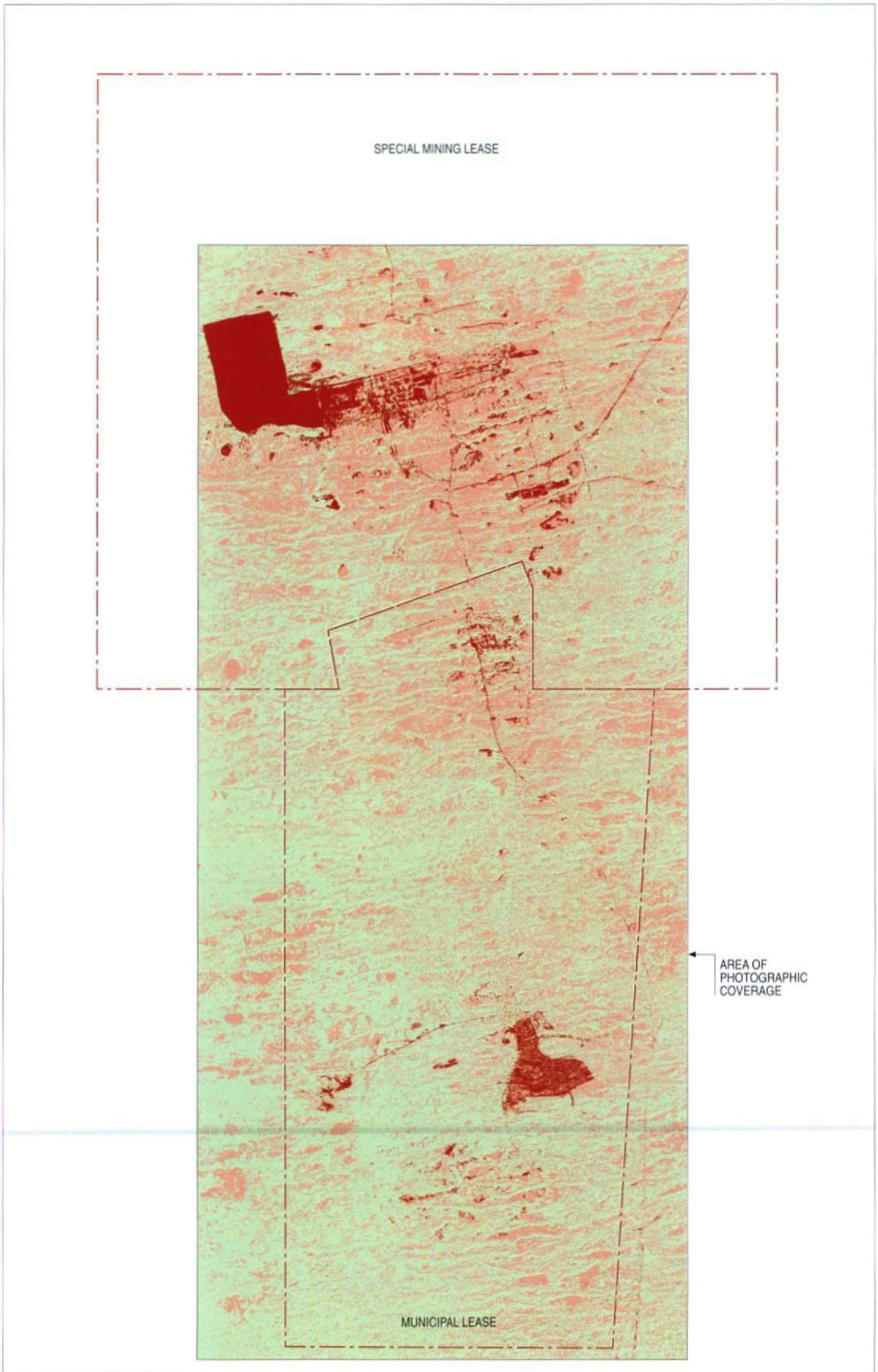


FIGURE 7.4
CHANGES IN VEGETATION COVER INFERRED FROM 1984 AND 1995 AERIAL PHOTOGRAPHS

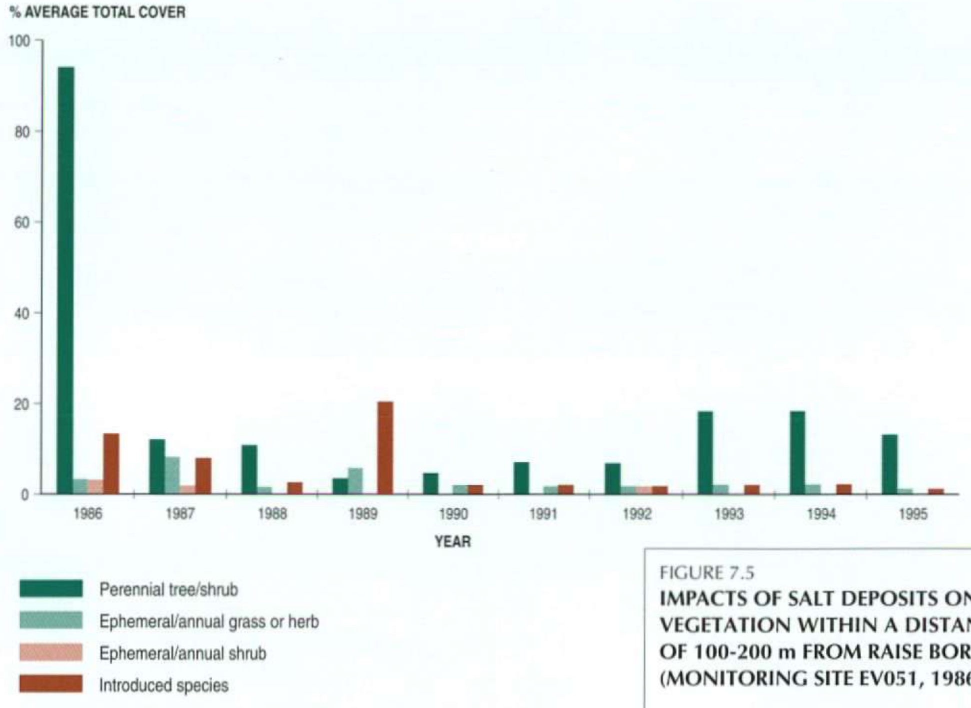


FIGURE 7.5
IMPACTS OF SALT DEPOSITS ON VEGETATION WITHIN A DISTANCE OF 100-200 m FROM RAISE BORES (MONITORING SITE EV051, 1986–95)

Impacts of salt deposition from raise bores

Salt emissions originate from the local aquifer and are brought to the surface entrained in the mine ventilation raise bore airstreams. These emissions have been shown in the past to impact adversely on the local vegetation if the emission volumes are significant (WMC—Olympic Dam Operations 1994, 1995). The impact of salt emissions from raise bores was not predicted in the 1983 EIS.

Vegetation response to the impact of salt deposition and subsequent recovery following mitigation is most clearly evident at monitoring site EV051. Salt deposition from one of two raise bores resulted in localised loss of the dominant perennial species (narrow-leaved hopbush) cover at this site prior to 1988. This reduction can be seen in Figure 7.5.

Approximately 90% of the original perennial cover had been lost within a distance of 100–200 m prior to mitigation measures being established in 1989. Localised vegetation loss in the vicinity of raise bores can be seen in Figure 7.6 (raise bore RB4).

Mitigation measures established to ameliorate impacts of salt deposition, combined with above-average rainfall in 1989 and 1992, have allowed a partial recovery of perennial species. Mitigation measures consisted of the installation of emission inverters at the vents of raise bores, as described in Read (1996). Salt effects now appear to be largely controlled or localised where control is not complete (Fatchen Environmental 1996).

To minimise the impact of salt emissions, all new raise bores would be fitted with salt interception devices as they become operational.

Gaseous emissions

Gaseous emissions from the metallurgical plant were recognised as having potentially adverse effects on vegetation in Kinhill – Stearns Roger (1982). During 1989, emissions (probably of sulphur dioxide) caused significant defoliation and other injury to tall shrub and tree species close to the metallurgical plant (Fatchen and Associates 1989).

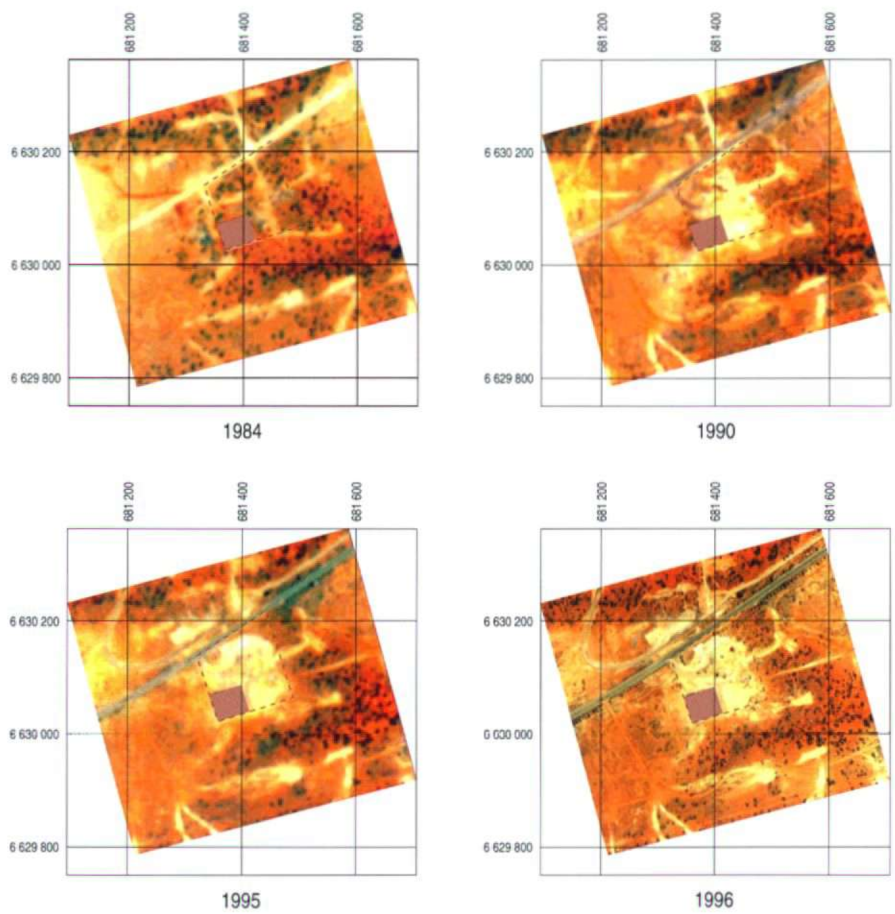


FIGURE 7.6
VEGETATION LOSS AT RAISE BORE 4 (RB4)—1984, 1990, 1995, 1996

N 0 200 m

Raise bore
Vegetation change area

Reductions in vegetation cover, and shrub deaths, remain at a higher level in developed portions of the Special Mining Lease (Area 2) than elsewhere (Figure 7.7), especially around the metallurgical plant and the tailings retention facility (Fatchen Environmental 1996).

To determine the extent of this impact area, a monitoring site with a suitable time series record of total perennial tall shrub cover located approximately midway between the metallurgical plant and the tailings retention system was examined. Figure 7.8 presents data from monitoring site EV061 prior to its closure as a result of construction works.

By 1990 gaseous emission impacts had reduced from the levels experienced in 1989, and further reductions were noted in 1991 following the installation of taller stacks for the anode furnaces (Fatchen Environmental 1996). Vegetation damage is currently limited to an area within 200–300 m of the metallurgical plant (Fatchen Environmental 1996). No effects have been observed beyond the boundary of the Special Mining Lease.

Off-road driving

Although WMC has banned vehicles from being driven off-road in the Project Area, this activity has still occurred along some abandoned vehicle tracks and infrastructure corridors

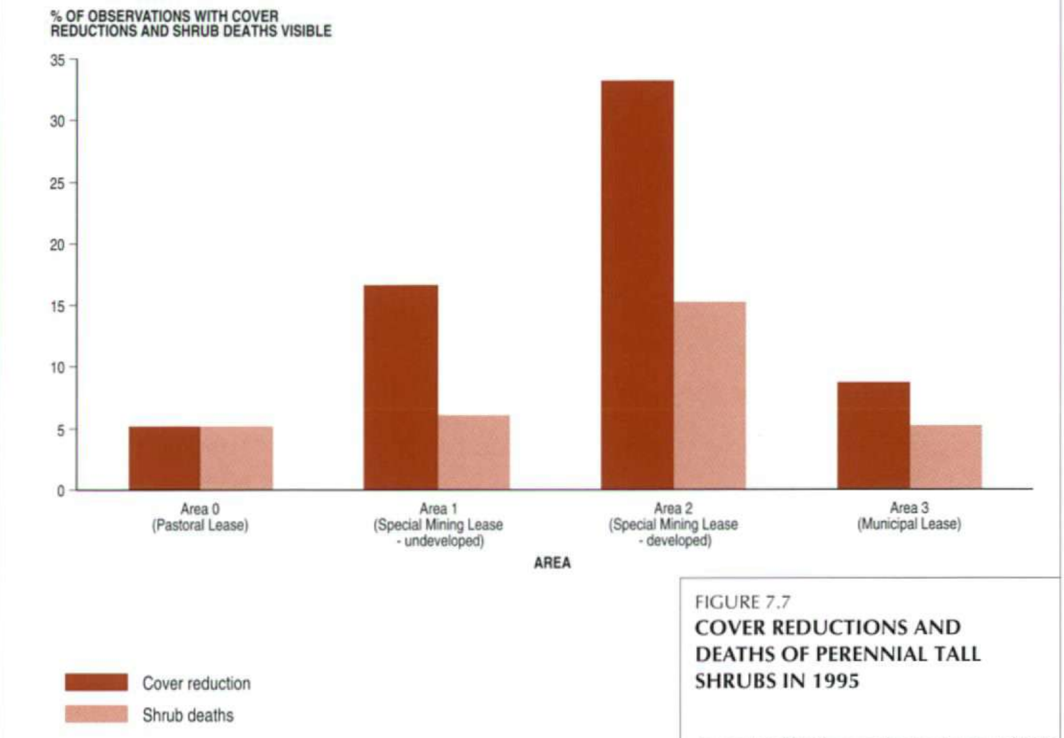


FIGURE 7.7

COVER REDUCTIONS AND DEATHS OF PERENNIAL TALL SHRUBS IN 1995

Source: Modified from Fatchen Environmental 1996

and through dunes, primarily within or near the municipal areas. Natural regeneration processes have been adversely affected by this disturbance and small areas of erosion and loss of sand dune vegetation have occurred. WMC is examining options to mitigate these impacts, including ongoing educational programmes for staff and townspeople and the dedication of specific areas for off-road vehicle use.

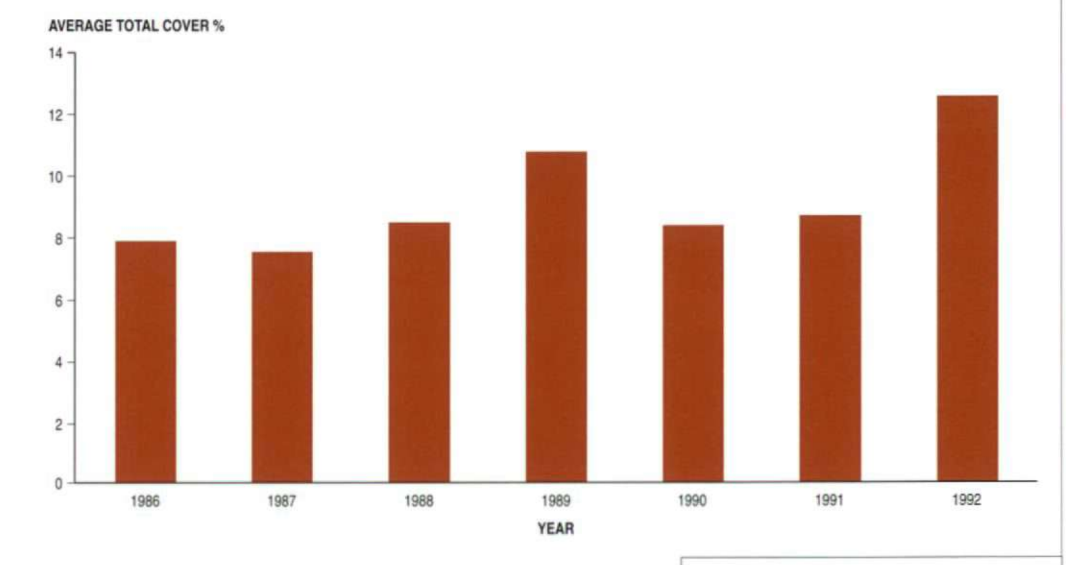


FIGURE 7.8

AVERAGE TOTAL COVER OF PERENNIAL TALL SHRUB SPECIES– MONITORING SITE EV061 1986–92

Dust deposition

Over the whole project life, there have been occasional instances when dust deposition has been sufficient to defoliate tall perennial shrubs. At one site, approximately 0.4 ha of tall perennial shrubs were partially defoliated by dust deposition in 1995 (Fatchen Environmental 1996). This event was unusual and has been attributed to abnormal levels of track usage during a particular construction project.

To mitigate this impact, unsealed roadways are watered more frequently to suppress dust when heavily used. This would continue to apply during the construction period of the Expansion Project.

Erosion impacts

Reductions in total vegetation cover invariably lead to wind erosion and sand movement on sandhills. Reductions in vegetation cover sufficient to increase sand movement have been recorded in areas close to the metallurgical plant and the tailings retention system; however, as major blowouts pre-date development, these areas may be historically less stable than other areas in the region.

Over-grazing in the region (e.g. by stock, rabbits and kangaroos) may accelerate erosion by destroying vegetation cover. Stock has been excluded from the Project Area since the commencement of mining and WMC monitors rabbit and kangaroo numbers.

It is possible that salt deposition and low concentration of gaseous emissions may be contributing to sand mobility observed in some areas of the Special Mining Lease (Fatchen Environmental 1996). WMC has implemented mitigation measures to minimise impacts of salt deposition and gaseous emissions as described above.

Drill pads

Drill pads are required to enable subsurface drilling and sampling of rock strata. They are generally located over the orebody and adjacent areas and have an average size of 50 m long by 20 m wide (1,000 m^2). When practicable, these pads are located on a naturally bare surface. However, most drill pads require some amount of clearance of vegetation and, in order to allow access, dunes and dune bases generally require a clay or, more commonly, limestone rubble layer to be deposited over the soil surface.

Badman (1992) provides a full description of the methods used for drill pad rehabilitation by WMC, and this type of rehabilitation has been undertaken annually and progressively on site since 1983. Rehabilitation comprises deep ripping by a bulldozer using 1 m tynes to break up compacted soil, followed by the spreading of seeds of indigenous species typical of the vegetation surrounding the drill pad.

In general, the rehabilitation programme has been extremely successful, although the speed of plant colonisation, growth and spread is totally dependent on rainfall. The fastest and most successful rehabilitation occurs on drill pads that receive average to above average rainfall within one year of ripping and seeding.

7.2.6 Terrestrial vegetation—predicted impacts of the Expansion Project and their mitigation

This section discusses the expected impacts of the Expansion Project on the vegetation in the Project Area. Table 7.4 provides a detailed description of the direct land disturbance impacts expected.

Table 7.4 Estimated area of land disturbance for the proposed expansion in the Project Area[1]

Description	Area (ha) (200,000 t/a copper production)	Area (ha) (350,000 t/a copper production)
SPECIAL MINING LEASE		
Backfill quarry	227	227
Mine water disposal ponds	60	60
Process water dams	16	16
Sewage treatment lagoons	1	1
Metallurgical plant and mine facilities	53	53
TRS including evaporation pond (paddock method option)	250	580
TRS including evaporation pond (CTD option)	700	1,200
Total area paddock method TRS	**607**	**937**
Total area CTD TRS	**1,057**	**1,557**
MUNICIPAL LEASE		
Residential development	25	71

1 *Project area = Special Mining Lease area (17,974 ha) plus Municipal Lease area (11,040 ha).*
Note: Figures rounded up to nearest hectare.
TRS = tailings retention system.
CTD = central thickened discharge.

Special Mining Lease

The type of tailings retention system to be constructed has a relatively large influence on the total area of impact. The conventional, or paddock, tailings retention system would require an area of 250 ha for expansion to 200,000 t/a copper production, and a further 330 ha for expansion to 350,000 t/a copper production. In comparison, a central thickened discharge tailings retention system would require 700 ha for expansion to 200,000 t/a copper production and a further 500 ha for expansion to 350,000 t/a copper production.

Of the total area of vegetation to be cleared, the major portion (greater than 95%) is associated with widely spaced dunes, with the remainder comprising vegetation associated with high-density dunes. The greatest impact is predicted to occur to communities of mulga woodland/sandhill wattle tall open shrubland that are present on the dunes, and saltbush/low bluebush low open shrubland in the interdune swales. Other communities that are predicted to be impacted include mulga woodlands and saltbush low open shrubland.

These vegetation communities are present throughout the large areas of dunefield in the region; hence, the small proportion of the total area that would need to be cleared for the proposed expansion is not significant. In addition, government approval for development of the Special Mining Lease area has been previously granted. However, land surface disturbance and vegetation clearance of any type would be kept to the minimum necessary for the expansion, and disturbed areas rehabilitated promptly.

A total of ten vegetation monitoring sites and two vegetation rehabilitation control sites would be displaced by the expansion in the Special Mining Lease area. These vegetation monitoring sites would be replaced with sites with similar landform and vegetation types to enable the continued monitoring of potential impacts on similar ecosystems. The vegetation rehabilitation control sites would also be replaced following procedures outlined in Chapter 15.

WMC—Olympic Dam Operations (1990, 1991) report that damage to areas of vegetation within a 3 km radius of the metallurgical plant occurred during 1989, the first year of full production. As noted in Section 7.2.5, with implementation of improvements in air emissions control from the metallurgical plant, vegetation damage is now confined to isolated instances of foliage damage within approximately 200–300 m of the metallurgical plant.

As described further in Section 9.2, ground-level concentrations of sulphur dioxide associated with expansion to copper production of 200,000 t/a and 350,000 t/a would, in normal operating conditions, be much less than those from the existing plant, and less than the relevant national or South Australian Environment Protection Authority air quality goals.

In addition, improved and additional control equipment would result in fewer instances of abnormal operating conditions, which produce higher levels of sulphur dioxide emissions than normal operating conditions. Abnormal operating conditions would be restricted to emergency venting of smelter off-gases (predicted in Section 3.5 to occur less than eight hours per year) and periods during the acid plant start-up. During these periods, emissions would be vented from stacks 90 m in height (30–50 m higher than the existing stacks), resulting in partial mitigation of high ground-level concentrations of sulphur dioxide.

However, if the abnormal conditions occur in combination with meteorological conditions that are not conducive to mixing and dispersion of the emissions, such as a low height temperature inversion and still air conditions, ground-level concentrations of sulphur dioxide sufficient to cause localised damage to vegetation in close proximity to the metallurgical plant could continue to occur but at a reduced frequency. It is expected that any such effects would occur only within the Special Mining Lease.

Municipal Lease

It is estimated that approximately 25 ha of the Municipal Lease would be disturbed by the proposed expansion to 200,000 t/a copper production, and a further 46 ha with expansion to 350,000 t/a copper production. However, planning for residential expansion includes the retention, where possible, of stands of white cypress pine, western myall and mulga. Hence, the actual clearance of vegetation is expected to be less than these estimates.

The vegetation that would be impacted in the Municipal Lease area is associated with both widely spaced and high-density dunes. The greatest impact is predicted to affect communities of mulga woodland/sandhill wattle tall open shrubland that are present on the dunes and saltbush/low bluebush low open shrubland in the interdune swales. Other communities expected to be impacted include mulga woodland and white cypress pine woodland. Each of these communities is present throughout the large areas of dunefield in the region; hence, the small area of clearance required for the residential development is not regarded as significant.

No vegetation monitoring or rehabilitation control sites in the Municipal Lease area would be directly impacted by the expansion.

7.2.7 Vegetation monitoring

A vegetation monitoring programme was established for the Project Area in 1981 to provide an understanding of:

- relative influences and effects of the development and other land uses (both to monitor impacts and as an input to site management);

- the relationship of vegetation to landscape processes and integrity;
- normal seasonal and long-term changes in vegetation.

Since 1981 all vegetation monitoring has been carried out by WMC staff or independent environmental consultants. Full details of the vegetation monitoring programme are provided in the EMMP (WMC—Olympic Dam Corporation 1996a), and a summary of the programme is provided in Chapter 15 of this EIS. This vegetation monitoring programme would be maintained during and following the proposed expansion.

Chapter 14 provides a description of the existing rehabilitation programme, which would continue at the site to mitigate the effects of unavoidable vegetation clearance associated with site activities.

7.3 FAUNA

This section discusses the species of mammals, birds, reptiles, amphibians and macroinvertebrates that have been recorded in the region and the Project Area, and that are monitored as indicators of the project's environmental impact in the region and Project Area. Data obtained from WMC's monitoring programmes allow for an assessment of past and current project impacts, and enable potential impacts of the project's expansion on fauna to be predicted.

The presence of pest animal species is discussed as a separate issue in Section 7.3.7.

Prior to Kinhill – Stearns Roger (1982), there was limited knowledge of the faunal composition or species diversity of the region and in the vicinity of the Project Area. Kinhill – Stearns Roger (1982) accurately predicted the presence, or likely presence, of 95% of all species of mammal, reptile, bird and amphibian species recorded in the Project Area (Read 1994).

Legislation and policy

The international obligations potentially applicable to WMC include:

- The Convention on the Conservation of Migratory Species of Wild Animals 1979 (Bonn Convention);
- The Convention on Wetlands of International Importance Especially as Waterfowl Habitat 1971 (Ramsar Convention);
- Japan–Australia Migratory Birds Agreement 1974 (JAMBA);
- China–Australia Migratory Birds Agreement 1986 (CAMBA).

While the Ramsar Convention focuses on the conservation of internationally important wetlands, the Bonn, JAMBA and CAMBA conventions consider the protection of species.

In addition, Australia ratified the International Convention on Biological Diversity in 1993, and a National Strategy for the Conservation of Australia's Biological Diversity has been prepared (Department of the Environment, Sport and Territories 1996a). This strategy has implications for all levels of government, the private sector and individuals, since its primary focus is the identification, conservation and management of Australia's indigenous biological diversity. WMC has voluntarily adopted the principles of the National Strategy.

WMC also has national obligations under the 1997 Wetlands Policy of the Commonwealth Government of Australia, and the *Endangered Species Protection Act 1992* (Cwlth), and State obligations under the *National Parks and Wildlife Act 1972* (SA). Schedules to both Acts list species of threatened conservation significance.

WMC's Environment Policy states that the company will observe all environmental laws and, consistent with the principles of ESD, will 'conserve important populations of flora and fauna that may be affected by our activities'. Application of the Olympic Dam Statement of Environmental Commitment and the EMMP further reinforces WMC's environmental protection and management of the Project Area. The protection of native and migratory fauna and their habitats is also managed through Commonwealth and State legislation and a number of international and bilateral agreements.

Categories of threat based on the definitions of the International Union for Conservation of Nature and Natural Resources (IUCN) have been assigned to terrestrial fauna and birds (International Union for Conservation of Nature and Natural Resources 1996). While the IUCN identifies species of international conservation significance, the *Endangered Species Protection Act 1992* (Cwlth) identifies species of national significance. Species of State significance are listed in Schedules of the South Australian *National Parks and Wildlife Act 1972*. Both national and State conservation agencies have adopted the IUCN definitions (albeit in slightly modified form) to assign conservation status to species and allow for consistent interpretation of terminology across the levels of conservation significance.

7.3.1 Mammals

Mammals in the vicinity of Olympic Dam have been comprehensively surveyed from the early 1980s to 1996, through all seasons and in diverse habitat and terrain types.

Table J.1 in Appendix J summarises regional and Project Area fauna species confirmed or predicted to occur in 1982, and those subsequently recorded in the region and the Project Area.

In addition to WMC survey data, which comprise the largest and most comprehensive long-term data set, information from fauna surveys of the region conducted by organisations such as the Department of Environment and Natural Resources (R. Brandle, Department of Environment and Natural Resources, pers. comm., December 1996) has been included in this section.

Mammals in the region and their conservation significance

Species of threatened conservation significance known or potentially present within the region include plains rat *(Pseudomys australis)* and yellow-bellied sheathtail-bat *(Saccolaimus flaviventris).*

The plains rat is of international and national significance and is assigned the status of threatened by the International Union for Conservation of Nature and Natural Resources (1996), and vulnerable under the *Endangered Species Protection Act 1992* (Cwlth). There has been a population decline in plains rat of 50–90% (Lee et al. 1995). This species either has been recorded in or is believed to range over areas of land used by WMC.

A National Action Plan has been prepared for the plains rat (Lee et al. 1995). This plan assesses the status of the species using objective criteria, reviews the reasons for its decline, and recommends actions that should arrest the species decline and secure its future.

The yellow-bellied sheathtail-bat has only been recorded fourteen times in South Australia, and is considered to be rare. This species is common in other Australian states, but is probably not resident in the region and is a seasonal, migratory species that passes through South Australia between March and June (T. Reardon, South Australian Museum, pers. comm., January 1997).

Some species that were predicted to exist in the vicinity of Borefield B are not listed in Appendix J as being present in the region and the Project Area. The predicted presence of these species was based on WMC and South Australian Museum records. However, the absence of recent recordings of these species indicates that the probability of their presence in the region and the Project Area is low or nil. These additional species include greater stick-nest rat *(Leporillus conditor),* spinifex hopping-mouse *(Notomys alexis),* black-footed rock-wallaby *(Petrogale lateralis),* sandy inland mouse *(Pseudomys hermannsburgensis),* dusky hopping-mouse *(Notomys fuscus),* long-haired rat *(Rattus villosissimus)* and Finlayson's cave bat *(Vespadelus finlaysoni)* (WMC—Olympic Dam Corporation 1995a). Although one spinifex hopping-mouse was found (killed by a cat) in the Roxby Downs township, this species has never been recorded in the Roxby Downs region, and almost certainly was introduced into the Project Area from elsewhere (WMC—Olympic Dam Operations 1990).

In addition, sub-fossil records from a long-established owl roost north of Lake Torrens, north-east of the Project Area, have identified bone fragments of many rare mammals, including bilby *(Macrotis lagotis)* and the extinct pig-footed bandicoot *(Chaeropus ecaudatus).* Faeces (scats) of common brushtail possum *(Trichosurus vulpecula)* and short-beaked echidna *(Tachyglossus aculeatus)* have also been identified (G. Medlin, South Australian Museum, pers. comm., December 1996). The probability of brushtail possum occurring in the Project Area is considered to be extremely low, with zero probability for bilby and pig-footed bandicoot. The short-beaked echidna was reported by WMC in the Project Area and in Andamooka for the first time in 1996.

Mammals in the Project Area

There are two mammal species of State conservation significance recorded within the Project Area, these being Forrest's mouse *(Leggadina forresti)* and desert mouse *(Pseudomys desertor).* Forrest's mouse has been recorded at three different sites in the Project Area. However, the area had been surveyed annually for seven years prior to the first recorded capture (WMC—Olympic Dam Operations 1994). Forrest's mouse is classified as rare in South Australia; however, its population is considered to be stable by Lee et al. (1995). The desert mouse has also been recorded in the Project Area (WMC—Olympic Dam Operations 1993) and is classified as insufficiently known in South Australia (Lee et al. 1995); however, this species is considered widespread and secure in the north-west of South Australia (Read et al. in prep.).

The native mammal species known to occur within the Project Area are:

- short-beaked echidna *(Tachyglossus aculeatus)*
- Giles' planigale *(Planigale gilesi)*
- fat-tailed dunnart *(Sminthopsis crassicaudata)*
- stripe-faced dunnart *(S. macroura)*
- western grey kangaroo *(Macropus fuliginosus)*
- euro *(M. robustus)*
- red kangaroo *(M. rufus)*
- lesser long-eared bat *(Nyctophilus geoffroyi)*
- inland broad-nosed bat *(Scotorepens balstoni)*
- inland forest bat *(Vespadelus baverstocki)*
- white-striped freetail-bat *(Nyctinomus australis)*
- Forrest's mouse *(Leggadina forresti)*
- Bolam's mouse *(Pseudomys bolami)*
- desert mouse *(P. desertor)*
- dingo (*Canis lupus dingo,* naturalised species).

Two additional mammal species have been recorded in similar habitats to those found in the Project Area—narrow-nosed planigale *(Planigale tenuirostris)* and kultarr *(Antechinomys laniger)*. The narrow-nosed planigale has been recorded just north of the Special Mining Lease area on two occasions (Read 1994), and may eventually be found inside the boundary of the ungrazed Project Area.

The kultarr inhabits stony or sandy areas where grasses and small bushes constitute the principal vegetation, and in Acacia shrubland (Strahan 1995). While Olympic Dam is on the south-eastern margin of the known distribution of this species, it is possible (although not probable) that this species may eventually populate the immediate region of the Project Area.

7.3.2 Expansion Project impacts and mitigation—mammals

Many native mammal species previously distributed in the region have been extinct for between fifty and 100 years. The species that remain are either adaptable opportunists able to survive in the altered environment, or those that have developed avoidance behaviour that protects them from predation.

Population densities of small mammals in arid environments are often low owing to relatively large home ranges and territories. It is possible that other threatened mammal species may eventually occur in the Project Area owing to extension of their range, control of introduced predator species or through the reintroduction of particular species.

WMC's small-mammal monitoring programme provides an indication of mammal populations. Owing to the low population density of native mammals and their relatively slow reproductive response to favourable environmental conditions, major variations in manual capture rates are primarily determined by variations in numbers of the introduced house mouse (WMC—Olympic Dam Corporation 1996b), which is the most abundant small mammal species in the Project Area, but only following favourable breeding conditions.

Overall, mine and processing plant operations do not appear to have had a significant impact on small mammal populations in the Project Area. Furthermore, continual improvements to emission levels from the smelter, metallurgical plant and raise bores have improved environmental conditions in the immediate vicinity of these operations.

Large mammals

The red kangaroo population has increased in numbers to artificially high levels following the provision of sources of fresh water and increased food resources following the removal of cattle from the Project Area. This type of habitat modification has been repeated throughout the pastoral areas of Australia following the provision of stockwater sources. Ecosystem modifications of this type are generally considered to be environmentally acceptable where they provide native wildlife with a reliable source of drinking water in an area of unreliable rainfall.

The Olympic Dam evaporation ponds are surrounded by a 2 m high mesh fence that excludes the majority of larger and medium-sized mammals, effectively minimising the effect of the ponds on these species. The lower 0.3 m of the fence is also covered with fine mesh to exclude smaller mammals and reptiles. The proposed extensions to the evaporation ponds would be similarly enclosed. The tailings retention system is raised in height and reinforced with rip-rap; hence the incidence of kangaroos and other mammals approaching this area is low. Prior to erection of fencing, there had been occasional incidents of kangaroos becoming bogged in the evaporation ponds (WMC—Olympic Dam Operations 1989). These animals were released where practicable.

Kangaroos in the Project Area occasionally sustain injuries or are killed owing to collisions with vehicles on the roads and with fences. Green roadside vegetation resulting from water run-off from the road, and rain-collecting depressions such as borrow pits adjacent to roads, encourage kangaroos and other large animals to roadsides to eat and drink, thereby increasing the chance of a collision with a vehicle. Most roads in the Project Area have been constructed using material from the northern or Axehead quarries and not from roadside borrow pits (WMC—Olympic Dam Operations 1995). New roads would, in general, also use material from these quarries, reducing further potential for roadside collisions.

Small mammals

The loss of small areas of mammal habitat within the Project Area would be unavoidable with the proposed expansion. About 32 ha of the 180 km^2 Special Mining Lease area have been affected by above-ground mine infrastructure development. When the Municipal Lease is included, the impacted area is expected to increase to a maximum of 1,789 ha with the proposed expansion to 200,000 t/a copper production, and to about 2,328 ha with expansion to 350,000 t/a copper production.

The habitats that would be impacted are part of the Moondiepitchnie environmental association within the region and the Project Area. None of these habitats is essential to the survival of any mammal species. The predicted potential impacts are the loss of individuals of regionally common species through direct construction impacts, and displacement of other individuals that may later succumb to predators, stress, or territorial conflicts during attempts to re-establish a home range.

Of the species recorded in the Project Area, only desert mouse was believed to be rare in South Australia. It has been recorded only twice in the Project Area and twice just outside the Project Area, and then only after several years of mine operations. However, recent trapping surveys have indicated that the species is secure and widespread throughout its range (Read et al. in prep.; C. Watts, South Australian Museum, pers. comm., November 1996).

Bats

Bats in the region need trees as roosts and as habitats for their insect prey. Although trees of any type are important, those with loose bark, hollow branches and trunks (e.g. western myalls) are preferred, and these are present in a zone across the northern and southern sectors of the Municipal Lease. Clearing of these trees for the initial development of Roxby Downs during the 1980s was minimised. Likewise the design of the proposed town expansion would ensure minimal impact on this tree belt, and every effort would be made to retain other species.

WMC's policy of maintaining existing vegetation, and its active rehabilitation programme, would ensure that neither large nor significant areas of bat habitat would be impacted by the project expansion. WMC does not currently undertake routine survey or assessment of bat populations in the Project Area, although a bat survey was undertaken as part of the Borefield B project (Kinhill Engineers 1995).

In general, bats benefit from human development in arid environments. Permanent open water sources such as dams, ponds and even small open tanks attract flying insects, thereby providing an artificially concentrated food source for bat species, while some buildings provide secure roosting areas (Reardon 1995). A proposed additional water treatment pond to treat the increased volume of sewage effluent, together with expanded process water ponds at Olympic Dam, would be likely to attract flying insects and provide an additional food source for bats. Lights from the mine area and township also attract flying insects, further increasing the benefit to bat species.

7.3.3 Birds

The Project Area and adjoining lands are contained in the Eyrean faunal subregion, which encompasses the Australian arid zone (i.e. 70% of the continent). Most of the bird species of this zone have very large geographical ranges, many almost spanning the continent, with relatively few species restricted to small areas.

Despite the aridity of the region, the South Australian section of the Lake Eyre Basin supports a diverse avifauna of 145 species of terrestrial birds and eighty species of water and shore birds after episodic rain has filled wetlands in the region (Badman 1991; Reid et al. 1990). An example of this abundance and diversity is Lake Eyre, a large ephemeral wetland north of Olympic Dam. In December 1991, after rain had inundated the area, thirty species of water birds and shore birds and more than 300,000 individuals were recorded in this area. These data were considered to underestimate true abundance by 50% (Kingsford and Porter 1993).

In addition, the Arcoona Lakes, situated between Woomera and Roxby Downs, provide a temporary habitat for large numbers of water birds. Following flooding rains in the region in 1989, up to 150,000 water birds of fifty-six species were recorded in these ten temporary lakes and associated swamps (Read and Ebdon in prep.). Of particular interest was the presence of large numbers of freckled duck *(Stictonetta naevosa)*, which is a rare species.

Prior to 1980 and the commencement of ornithological surveys for Kinhill – Stearns Roger (1982), the Olympic Dam region was one of the most poorly known avifaunal regions in South Australia (Reid 1982). Fatchen and Reid (1980) predicted 120 species with a moderate to high probability of occurring, and a further sixty-four species with a low probability of occurring in the region. Although 83% of the species predicted to be residents or frequent visitors to the region were recorded in Kinhill – Stearns Roger (1982), only 26% of the species predicted to be potential visitors to the region have subsequently been confirmed as present (Read 1994).

Bird habitat

Bird habitats in the region mostly comprise the vegetation types contained within dunefields, stony tablelands, and local drainage areas. Two important habitats that are widespread in the southern arid zone but generally lacking in the Olympic Dam region are eucalypt-lined watercourses and hills or ranges.

Based on data in Kinhill – Stearns Roger (1982), of the three principal vegetation types in the project area (dunefield, stony tableland, and local drainage), dunefields support the greatest structural diversity of habitats and communities and also the largest number of bird species and individual birds. Unpublished data from Olympic Dam biologists support this finding, and further indicate that bird species richness is greatest in shrubland/woodland associated with dunefields. In addition, the largest numbers of individual birds also tend to occur in the dunefields, particularly around waterbodies.

Regional bird species

A total of 175 bird species have been recorded in the region. Table J.2 in Appendix J provides a full listing of the species recorded since 1980. The WMC EMMP annual reports and Read (1994) provide more detailed data about initial and subsequent observations of each species in the region. A recent survey by Brandle (R. Brandle, Department of Environment and Natural Resources, pers. comm., December 1996), conducted approximately 50 km south-east of Olympic Dam, did not find any species additional to those listed in the WMC EMMP annual reports (e.g. WMC—Olympic Dam Corporation 1996b) or Read (1994).

Bird monitoring and observations in the region by WMC environmental staff between 1982 and 1996 have resulted in recordings of fifty-nine bird species additional to those recorded in Kinhill – Stearns Roger (1982). Many of these species were recorded subsequent to 1989, after heavy rains produced favourable conditions for many water birds (Read 1994).

Seasonal factors are also responsible for the presence or absence of a number of species at any given time, and arid zone birds exhibit varying degrees of migratory behaviour. Some species are vagrants and were not predicted to occur, and are outside their normal range when they do; for example, great crested grebe *(Podiceps cristatus)*, peregrine falcon *(Falco peregrinus)*, plains-wanderer *(Pedionomus torquatus)* and ruddy turnstone *(Arenaria interpres)*. Some species are frequent visitors, on either a seasonal (migratory) or irregular (nomadic) basis; for example, masked woodswallow *(Artamus personatus)*, white-winged triller *(Lalage sueurii)* and rainbow bee-eater *(Merops ornatus)*. Other species are permanently resident in the region; for example, white-winged fairy-wren *(Malurus leucopterus)*, variegated fairy-wren *(M. lamberti)*, black-faced woodswallow *(Artamus cinereus)* and zebra finch *(Taeniopygia guttata)*. Of the species recorded for the Olympic Dam region, the majority were either nomadic (47%) or resident (26%).

Appendix J provides a list of the bird species recorded for the Arcoona region lakes adjacent to the power transmission line. Additional information for the regions containing WMC infrastructure developments is provided in Kinhill Engineers (1995) and WMC—Olympic Dam Operations (1992). Bird species within these regions are not discussed further, as these developments have already been assessed for environmental impacts by the South Australian Government (Kinhill Engineers 1995; Kinhill – Stearns Roger 1982; WMC—Olympic Dam Operations 1992). Bird species in the vicinity of the transmission line corridor are discussed in Chapter 11.

Threatened species

Twenty-one vulnerable or rare species are listed under the *National Parks and Wildlife Act 1972* (SA) as occurring in the region (Table 7.5). Two species are considered to be vulnerable by Garnett (1992); namely, plains-wanderer and thick-billed grasswren *(Amytornis textilis modestus)*. One of these species, plains-wanderer, is of international and national significance, being listed by the International Union for Conservation of Nature and Natural Resources (1996) as threatened and in the *Endangered Species Protection Act 1992* (Cwlth) as a vulnerable species. There have been only two recorded sightings of plains-wanderer, one during 1990 and one in 1996, each of one bird only. Both observations were made within the Roxby Downs township.

The freckled duck, grey falcon *(Falco hypoleucos)* and thick-billed grasswren are the only other species recorded in the region that are listed by the International Union for Conservation of Nature and Natural Resources (1996) and Garnett (1992). The freckled duck was first recorded in the region in 1981, and a population of over 5,000 was recorded at Arcoona Lakes in 1992. The thick-billed grasswren was first recorded in 1993. The thick-billed grasswren and grey falcon are not residents of the Olympic Dam region; however, they have been recorded around Lake Eyre and in the borefields region.

Garnett (1992) provides action plans for each of the two vulnerable species (plains-wanderer and thick-billed grasswren), which include, in summary, the following:

- ***Plains-wanderer:*** The conservative population estimate of this species is 10,000 individuals in Australia in good years. It remains vulnerable to many land use practices (e.g. clearance of habitat for agriculture and overgrazing by stock and rabbits), which have caused its disappearance from coastal parts of its former range. There is no management action specific to the Project Area, as the species is a non-breeding vagrant in the region. Management actions would be developed by WMC if the species status changed within the Project Area.

- ***Thick-billed grasswren:*** Although this species is apparently common in parts of its remaining range, it has disappeared from large areas of its former range for reasons that are not clearly understood. There is no management action specific to the Project Area, as the species is resident outside the area. Management actions would be developed by WMC if the species status changed within the Project Area.

Table 7.5 Threatened bird species recorded or potentially occurring within the Olympic Dam region

Common name	Scientific name	Status				Species distribution status
		National Parks and Wildlife Act 1972 (SA)	*Endangered Species Protection Act 1992* (Cwlth)	IUCN	Garnett	
Musk duck	*Biziura lobata*	V	–	–	–	N
Freckled duck	*Stictonetta naevosa*	V	–	T	R	N
Australasian shoveler	*Anas rhynchotis*	R	–	–	–	N
Little egret	*Egretta garzetta*	V	–	–	–	N
Intermediate egret	*Ardea intermedia*	R	–	–	–	N
Black-breasted buzzard	*Hamirostra melanosternon*	V	–	–	–	N
Grey falcon	*Falco hypoleucos*	V	–	T	R	Va
Peregrine falcon	*F. peregrinus*	V	–	–	–	Va
Brolga	*Grus rubicunda*	V	–	–	–	Va
Baillon's crake	*Porzana pusilla*	R	–	–	–	N/Va
Australian bustard	*Ardeotis australis*	V	–	–	–	N
Plains-wanderer	*Pedionomus torquatus*	E	V	T	V	Va
Bush thick-knee	*Burhinus grallarius*	E	–	–	Sc	Va
Latham's snipe	*Gallinago hardwickii*	V	–	–	–	S/Va
Eastern curlew	*Numenius madagascariensis*	V	–	–	–	S/Va
Flock bronzewing	*Phaps histrionica*	V	–	–	–	N/Va
Major Mitchell	*Cacatua leadbeateri*	V	–	–	–	N
Blue-winged parrot	*Neophema chrysostoma*	V	–	–	–	N/S
Thick-billed grasswren	*Amytornis textilis modestus*	V	–	T	V	P
Painted firetail	*Emblema picta*	R	–	–	–	Va

E Endangered.
N Nomadic (long-distance movements).
P Presence has been recorded; however, resident outside of region.
R Rare.
S Seasonal visitor.
Sc Special concern.
V Vulnerable.
Va Vagrant (outside normal recognised range).
– Not relevant.

Note: *All status categories used are in accordance with the IUCN categories (International Union for Conservation of Nature and Natural Resources 1996).*

Sources: National Parks and Wildlife Act 1972 *(SA)*; Endangered Species Protection Act 1992 *(Cwlth); Department of Environment and Natural Resources 1993; International Union for Conservation of Nature and Natural Resources 1996; Garnett 1992.*

There is no habitat essential to wader birds in the Project Area or immediate region. There are also no recorded resident (breeding) bird species in the Project Area that are protected under the Bonn, JAMBA and CAMBA international agreements.

Regionally significant species include splendid fairy-wren *(Malurus splendens)*, hooded robin *(Melanodryas cucullata)* and spotless crake *(Porzana tabuensis)* (Kinhill – Stearns Roger 1982; D. Niejalke and J. Read, WMC, pers. comm., February 1997). The Olympic Dam region represents the limit of the range of these widespread species. Although the conservation status of these species is one of regional significance, the Olympic Dam region is relatively unimportant for the species, particularly for the spotless crake.

A banding and colour-banding study combined with detailed observations by WMC environmental staff indicates that splendid fairy-wrens are largely restricted to an area of high sand dunes with dense vegetation east of the Olympic Dam Village. Splendid fairy-wrens have remained in the area in a relatively stable population, with a bird banded in 1987 recaptured in 1995. While hooded robins are less sedentary, they are still recorded regularly on the Special Mining Lease, north-west of Whenan Shaft. Successful breeding of the species was recorded in 1994 and 1995. There is no evidence that development in the Project Area has had any adverse impact on either species.

7.3.4 Expansion Project impacts and mitigation—birds

A detailed retrospective review of the fauna component of Kinhill – Stearns Roger (1982) found that the latter document was both an accurate and a useful appraisal of the regional avifauna and project impacts (Read 1994). The following discussion includes the findings of this review.

Benefits

Twenty-four bird species were predicted to benefit from activities at Olympic Dam following vegetation clearance, increased water and food supply and increased nesting sites (Kinhill – Stearns Roger 1982). Preliminary analysis of quantitative data and observations by environmental staff indicate that all but six of these species (Table 7.6) now occur more frequently within the developed zone of the Project Area, where they make use of artificial nest sites and/or increased water or food supply. Although not predicted to do so in Kinhill – Stearns Roger (1982), other species to benefit have been white-breasted woodswallow *(Artamus leucorynchus)*, white-plumed honeyeater *(Lichenostomus penicillatus)* and striated pardalote *(Pardalotus striatus)*.

Table 7.6 Birds that have benefited from project development and likely beneficial factors

Bird species	Increased water/food supply	Increased nesting sites	Establishment of eucalypt trees	Presence of rubbish dumps
Emu	X	–	–	–
Black kite	X	–	–	X
Nankeen kestrel	X	X	–	–
Masked plover	X	–	–	–
Crested pigeon	X	–	–	–
Budgerigar	X	–	–	–
Red-backed kingfisher	–	X	–	–
Striated pardalote	X	X	X	–
White-plumed honeyeater	X	–	X	–
Magpie-lark	X	X	–	–
Willie wagtail	X	–	–	–
White-breasted woodswallow	X	X	X	–
Australian raven	X	X	–	X
Little crow	X	X	–	X
Zebra finch	X	X	–	–
White-backed swallow	–	X	–	–
Welcome swallow	–	X	–	–
Fairy martin	–	X	–	–

– *Not relevant.*

General impacts

The five species that do not appear to have benefited (brown falcon, little button-quail, Australian magpie, Richard's pipit and brown songlark) are those that were expected to have gained advantage from more open habitat (i.e. their preferred habitat) following vegetation clearance.

The principal aim of the latter programme is to monitor zebra finch populations adjacent to waterbodies. Zebra finches are very abundant in the Project Area, their presence and population size being determined by the presence of permanent waterbodies.

Details and data from the monitoring programmes are provided in each of the publicly available EMMP annual reports provided to the State Government.

7.3.5 Reptiles and amphibians

Reptiles are the most numerous and diverse terrestrial vertebrate group in arid Australian environments, including the Olympic Dam region. Table J.4 in Appendix J presents the cumulative total of species confirmed by WMC monitoring and fauna surveys since 1980. Chenopod shrublands are common in dune swales in the Project Area and the region, and this habitat supports a particularly diverse reptile community. (Read 1992, 1995; Read and Badman 1990). Only one species of amphibian has been found in the region and the Project Area.

Reptiles in the region

Forty-five species of reptiles have been found in the region of Olympic Dam. None of these species is listed as vulnerable, rare or endangered under Commonwealth or State legislation. An additional twenty-eight species of reptile have been recorded in similar habitats outside the study region identified for this assessment. Table J.5 in Appendix J presents these additional species. Of these species, ten are of conservation significance and have been recorded either in the borefields region or in association with, or in the general vicinity of, WMC infrastructure. The species include three dragon species, gibber dragon *(Ctenophorus gibba),* Lake Eyre dragon *(C. maculosus)* and red-barred dragon *(C. vadnappa);* Pernatty knob-tailed gecko *(Nephrurus deleani);* and populations of two skink species, *Lerista dorsalis* and *L. bougainvillii.*

All three dragon species are considered potentially vulnerable (Kennedy 1990) and specific safeguards to protect these species have been implemented in the past during infrastructure construction phases.

The Pernatty knob-tailed gecko is also considered a potentially vulnerable species and has a limited geographical range (Kennedy 1990). The *Lerista* populations are morphologically distinct from other populations in much of the region, and require further study to assess their biological and conservation significance (M. Hutchinson, South Australian Museum, pers. comm., December 1996). WMC has commissioned a study to assess the taxonomy of these skinks. Notwithstanding this commitment by WMC, it is unlikely that any of these species or populations would be present in the Project Area.

Reptiles in the Project Area

Forty-one reptile species have been recorded in the Project Area. Of the species present in the Project Area, four species are relatively uncommon *(Ctenotus leae, Lerista muelleri, Morethia boulengeri* and *Ramphotyphlops bituberculatus),* with less than ten specimens of each species recorded over twelve years of surveys (Read 1994). Although captured in low numbers, these species do not have an assigned conservation status under Commonwealth or State legislation.

One other species in the Project Area is represented by a single specimen, woma python *(Aspidites ramsayi),* and is of particular interest. The central Australian population of this species is not threatened (Cogger 1992). The Draft Threatened Species Strategy of South Australia (Department of Environment and Natural Resources 1993) records this species as rare and the International Union for Conservation of Nature and Natural Resources (1996) records it as endangered. Read (1994) suggests that this animal may have been transported to Roxby Downs; however, the recording may represent a considerable southerly extension of the species range. All other species are relatively abundant throughout wide distributions.

Amphibians

One amphibian species, trilling frog *(Neobatrachus centralis),* is recorded for the region and the Project Area. This burrowing species aestivates (becomes dormant) during drought conditions but is common on the ground surface following heavy rains. WMC's amphibian monitoring programme examines physical abnormalities in this species in relation to radionuclide levels (Section 7.3.9).

7.3.6 Expansion Project impacts and mitigation—reptiles and amphibians

Of the reptile species present in the Project Area, none is exclusive to the Olympic Dam region and most, if not all, have a wide distribution in central Australia and apparently stable population numbers. As the Project Area occupies less than 2% of the Moondiepitchnie environmental association in the region, with similar habitat types replicated throughout the association, it is unlikely that the proposed mine and township expansion would significantly impact regional reptile populations. Separate mitigation strategies have previously been proposed for WMC projects and activities that may have an effect outside the Project Area.

Vegetation clearance in the Project Area for the Expansion Project (Table 7.4) will cause an overall minor reduction in the habitat area available to reptile species. In addition, an unknown number of individuals would be expected to die or be displaced during construction.

The most significant regional and local threats to reptiles are major, widespread habitat modifications resulting from some aspects of pastoral activities, and the introduction and expansion of populations of pest predators such as cats and foxes.

Some large reptile species, such as Gould's goanna *(Varanus gouldii),* mulga snake *(Pseudechis australis)* and western brown snake *(Pseudonaja nuchalis),* have benefited in the past from house mouse population increases following favourable breeding conditions. Snakes that pose a threat to people are removed to other areas by site environmental staff.

An indirect, negative effect of further development and rabbit population increases in the recent past has been the increase in the feral cat population. Based on gut analyses of cats that have been killed, at least twenty-one species of reptile have been recorded as eaten by feral cats (WMC—Olympic Dam Corporation 1996b). The release of unwanted domestic cats into the wild by Roxby Downs residents is actively discouraged by WMC. WMC environmental personnel also conduct an active feral cat control programme of trapping and opportunistic shooting, and this programme will continue.

An examination of changes in reptile diversity, abundance and reproductive success has been undertaken by WMC to assess changes in reptile populations owing to existing operations. Figure 7.9 presents data on the reproductive success for females of several gecko species at five sections in the Project Area with different disturbance factors.

Following an initial decrease in breeding success, there has been a measurable increase in the breeding success of geckos and in capture rates of reptiles in close proximity to the metallurgical plant (WMC—Olympic Dam Operations 1995). Reproductive success rates were substantially lower in close proximity to the smelter and raise bores compared with control sites. However, success rates in these areas have improved following mitigation measures undertaken by WMC to decrease sulphur dioxide and salt emissions from these sources (WMC—Olympic Dam Corporation 1996b). Additional pollution control measures to be implemented as part of the Expansion Project at the smelter and at all new raise bores would further mitigate possible effects on reptiles.

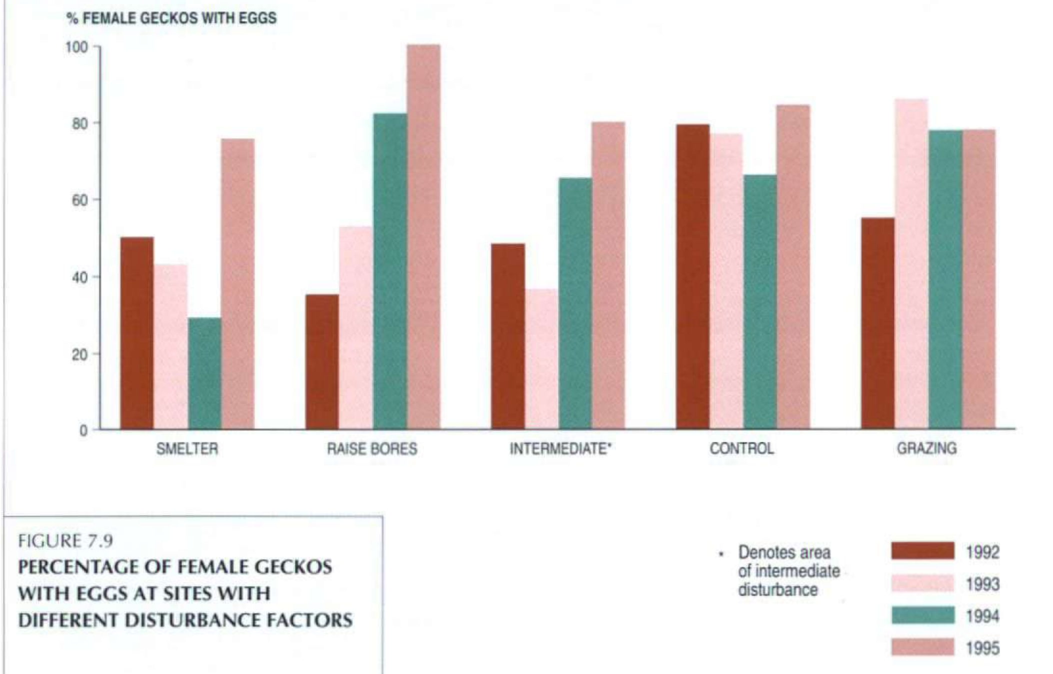


FIGURE 7.9
PERCENTAGE OF FEMALE GECKOS WITH EGGS AT SITES WITH DIFFERENT DISTURBANCE FACTORS

A very visible impact on the reptile fauna within the Project Area is the road kills of Gould's goannas and shingleback lizards over spring and summer (WMC—Olympic Dam Operations 1989). However, the recorded incidence of these road kills is low, at approximately one individual per week at certain times of the year, although many road kills may go unrecorded. Both these lizard species remain common in the Project Area and the region.

Many frog species can be sensitive to radiation, and the trilling frog commonly inhabits claypans, which are regions of natural heavy metal and radionuclide accumulation. Animals that inhabit contaminated claypans are likely to be exposed to contaminant levels that may induce deformity. Read and Tyler (1990) found that the incidence of abnormalities among frogs in the Project Area and the region was comparable to those recorded in other countries. Low levels of radionuclides are present in tadpoles of this species, but radionuclides do not appear to be accumulating or influencing abnormality levels (Read and Tyler 1994).

7.3.7 Introduced and proclaimed animal species

Settlement of remote areas in Australia since the mid-1800s provided an opportunity for some domestic and introduced animals to prosper as pest species owing to limited or no competition for resources such as food and shelter. Often associated with settled areas are domestic, feral and semi-feral animals that, owing to their high rates of fecundity, breed wild populations. The lack of competition for resources in the region of remote settled areas provides individual animals (which have often escaped confinement or been abandoned) and existing breeding populations with the opportunity to secure available niches. The animal species discussed in this section are considered in order of relative abundance and importance.

In regions throughout much of Australia, wild populations of a number of species, including European rabbit *(Oryctolagus cuniculus)*, cat *(Felis catus)*, fox *(Vulpes vulpes)*, dingo *(Canis lupus dingo*, naturalised species) and dog *(C. familiaris)*, have caused the decline of communities, habitats and native animal, and in some cases pest animal, populations. The impacts of these animals are listed in Appendix J. Further discussion on the inclusion of dingo in this group is also provided in Appendix J.

Schedule 3 of the Commonwealth *Endangered Species Protection Act 1992* considers the impacts of European rabbit, cat and fox to be major threatening processes for native flora and fauna. Control of proclaimed animals in South Australia is under the *Animal and Plant Control (Agricultural Protection and Other Purposes) Act 1986* and the *Dog Fence Act 1946*. The former Act provides guidelines for the possession, sale, release, control and destruction of proclaimed animal species, while the latter provides legislation for the control of dingoes and wild dogs.

National and State policies that include provision for introduced animal control programmes and strategies include the following:

- National Landcare Programme—Development of programmes to manage vertebrate pests through regional landcare groups, which develop pest animal control strategies that best suit their regional conditions.
- National Invasive Species Programme—A national strategy for invasive, introduced plant and animal species control.
- Australian and South Australian National Parks and Wildlife Service—An agency covering vertebrate pest control in National Parks.
- Save the Bush Programme—A programme that includes pest control for the conservation of vegetation communities and habitats.
- Endangered Species Programme—A programme for control of threatening processes.

As discussed in Section 7.1.3, WMC has a commitment to the environment through its corporate environmental policy. As part of this commitment on site, WMC has implemented a series of management and control programmes that include a proclaimed animal species control programme. This programme focuses on the control of rabbits, cats and foxes in the Special Mining Lease and Municipal Lease areas.

Regional introduced and proclaimed animals

Introduced animal species recorded in the region are listed in Table 7.7. Table 7.8 describes the impacts of the common introduced animals of the region on the native plants and animals.

Table 7.7 Introduced species recorded or observed in the region

Common name	Species name	Regional status
European rabbit	*Oryctolagus cuniculus*	Common
Cat	*Felis catus*	Common
House mouse	*Mus musculus*	Common
Fox	*Vulpes vulpes*	Common
Dingo	*Canis lupus dingo*	Rare
Wild dog	*C. familiaris*	Uncommon

Sources: Adapted from Baker 1992; Kemper 1990; Z. Bowen, WMC, pers. comm., November 1996; R. Downward, Animal and Plant Control Commission, pers. comm., December 1996.

The introduced and proclaimed animal species that occur in the region are also present throughout South Australia generally, and were present prior to development in the Project Area. The dominant introduced animals present in the region are mammal species, in particular rabbit, cat, house mouse and fox. Hoofed introduced mammals are also present; however, these tend to be confined to remote areas where ranges are large and competition for resources is low, such as the borefields region.

Table 7.8 Summary of impacts associated with major regional introduced animal species

Common name	Animals		Plants	
	Main species affected	Mode of impact	Main species affected	Mode of impact
European rabbit (herbivore)	Birds and mammals	Competition for food and shelter; changes to floristic composition of habitats; suppression of long-lived perennial plant regeneration; prey for native predators as well as foxes and cats	Many species of grasses, forbs, seedlings and young trees and the bark of older trees (e.g. *Acacia, Callitris)*	Direct grazing; indirect impacts include increased soil erosion and increased competition from subsequent colonisation by introduced plants
Cat (carnivore)	Birds, small mammals and rodents, reptiles, amphibians and invertebrates	Predation, competition and possibly transfer of disease	None	None
House mouse (omnivore, primarily granivore).	Unknown range of small omnivorous mammals and invertebrates	Competition for food and nesting burrows; prey for native predators, foxes and cats	Unknown range of grasses and other vegetation	Seed grazing of an unknown range of grass and tree species
Fox (omnivore)	Birds, small to medium-sized mammals, reptiles, amphibians and invertebrates	Predation and competition; introduction and spread of disease	Not known	Will eat fruit and some plants

A description of each of the pest species listed in Table 7.7 is provided in Appendix J. The nomenclature used throughout this section follows Strahan (1995).

Introduced and proclaimed animals in the Project Area

Roxby Downs township is enclosed by a 13 km rabbit-proof fence (J. Read, WMC, pers. comm., December 1996). Fencing in the Project Area was completed in 1986–87.

Kinhill – Stearns Roger (1982) reported four introduced mammal species in the Project Area—European rabbit, cat, house mouse and fox. These species are still present and population numbers vary with environmental conditions. Long-term fluctuations in population numbers are generally associated with drought and rainfall. Table 7.9 provides details of vertebrate and invertebrate species within the Project Area from 1982 to 1996.

A regular monitoring and eradication programme for introduced large mammals is conducted both inside and outside the Municipal Lease fence by WMC personnel to assess impacts on the local environment and control these species (Badman et al. 1996). The programme includes:

- spotlighting every two months along predetermined routes inside and outside the rabbit-proof fence and north of the Whenan Shaft;
- routine searches and fumigation of rabbit warrens with phostoxin gas, coupled with opportunistic shooting;
- opportunistic shooting or wire cage trapping of cats and foxes in the Project Area.

The rabbit control programme is generally only conducted inside the rabbit-proof fence; however, control methods are also used where rabbits threaten amenity plantings and vegetation rehabilitation areas (WMC—Olympic Dam Corporation 1996b). It is suspected that Rabbit Calicivirus Disease reached the Roxby Downs region in mid to late 1996, but this has yet to be confirmed by laboratory analysis (Z. Bowen, WMC, pers. comm., November 1996).

Active control of cats and foxes is undertaken opportunistically and when necessary. The population density of house mouse is not specifically monitored, except as part of other monitoring programmes, as this species is not considered a significant environmental threat in the Project Area.

The locations of monitoring points and routes for large introduced mammals are provided in Chapter 15.

Table 7.9 Past and present abundance of introduced vertebrate and invertebrate species in the Project Area

Common name	Species name	1982 status	Present status (1996)	General range	Formal control programme
European rabbit	*Oryctolagus cuniculus*	Very abundant	Common (11.5 animals/km^2)[1]	Mi/Mu	Yes
Cat	*Felis catus*	Abundant	Common (1.3 animals/km^2)[1]	Mi/Mu	Yes
House mouse	*Mus musculus*	Common	Common/seasonal	Mu	No
Fox	*Vulpes vulpes*	Common	Common (0.3 animals/km^2)[1]	Mi/Mu	Yes
Dingo/wild dog	*Canis lupus dingo/ C. familiaris*	Not recorded	Rare	Mi/Mu	No
Black rat	*Rattus rattus*	Not recorded	Two recorded in May 1993	Mu	No
Spotted turtle-dove	*Streptopelia chinensis*	Not recorded	Breeding pair first recorded July 1993; last recorded August 1994	Mu	No
Feral pigeon	*Columba livia*	Not recorded	Rare	Mu	No
House sparrow	*Passer domesticus*	Not recorded	Common	Mu	No
Common starling	*Sturnus vulgaris*	Not recorded	Low in numbers	Mu	No
Honey-bee	*Apis mellifera*	Not recorded	Introduced in 1990; removed in December 1995	–	No
Black Portuguese millipede	*Ommatoiulus moreletii*	Not recorded	Uncommon	Mu	No
White snail	*Helicella virgata*	Not recorded	Uncommon	Mu	No
Brown snail	*Helix aspersa*	Not recorded	Common	Mu	No
Conical snail	*Cochlicella ventrosa*	Not recorded	Uncommon	Mu	No
Slug	*Milax gagates*	Not recorded	Uncommon	Mu	No
Slug	*Agriolimax agrestis*	Not recorded	Uncommon	Mu	No

1 *Population abundance estimates based on WMC monitoring data recorded within the vermin-proof fence.*

Mi Denotes range is generally in the Special Mining Lease area.

Mu Denotes range is generally in the Municipal Lease area.

Sources: Kinhill – Stearns Roger 1982; WMC—Olympic Dam Corporation 1996b.

Figures 7.10, 7.11 and 7.12 show the abundance of rabbit, cat and fox populations within the rabbit-proof fence compared with areas outside the fenced area in the period 1989–96.

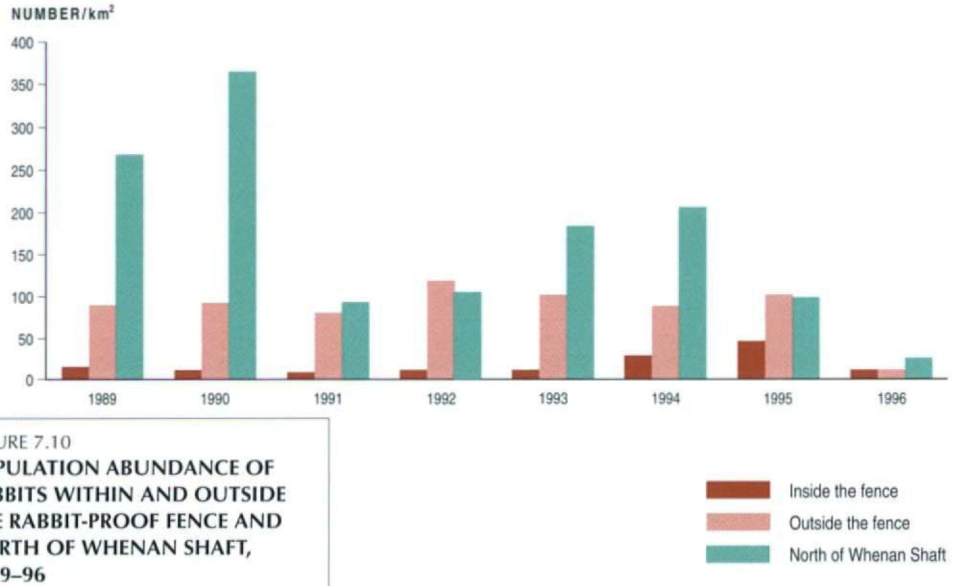


FIGURE 7.10
POPULATION ABUNDANCE OF RABBITS WITHIN AND OUTSIDE THE RABBIT-PROOF FENCE AND NORTH OF WHENAN SHAFT, 1989–96

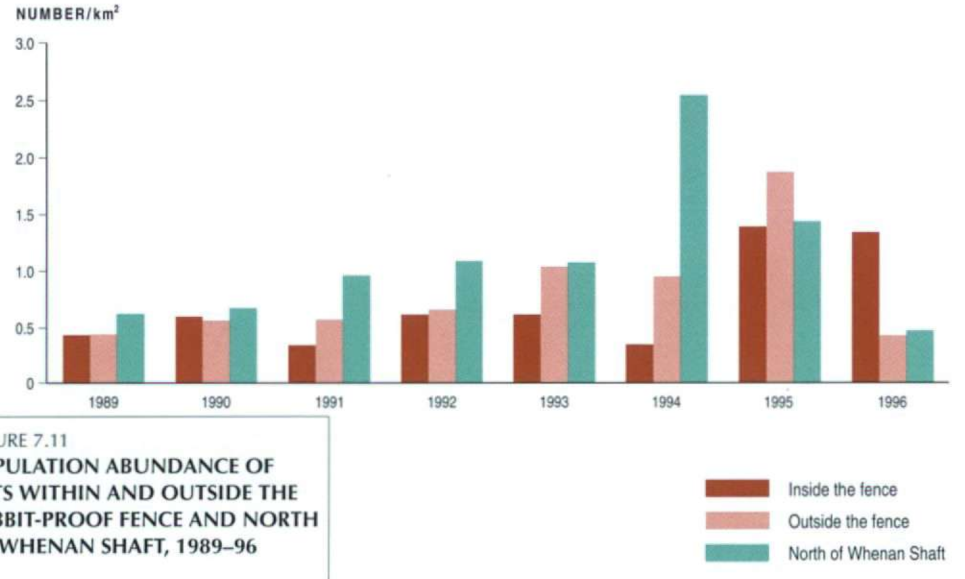


FIGURE 7.11
POPULATION ABUNDANCE OF CATS WITHIN AND OUTSIDE THE RABBIT-PROOF FENCE AND NORTH OF WHENAN SHAFT, 1989–96

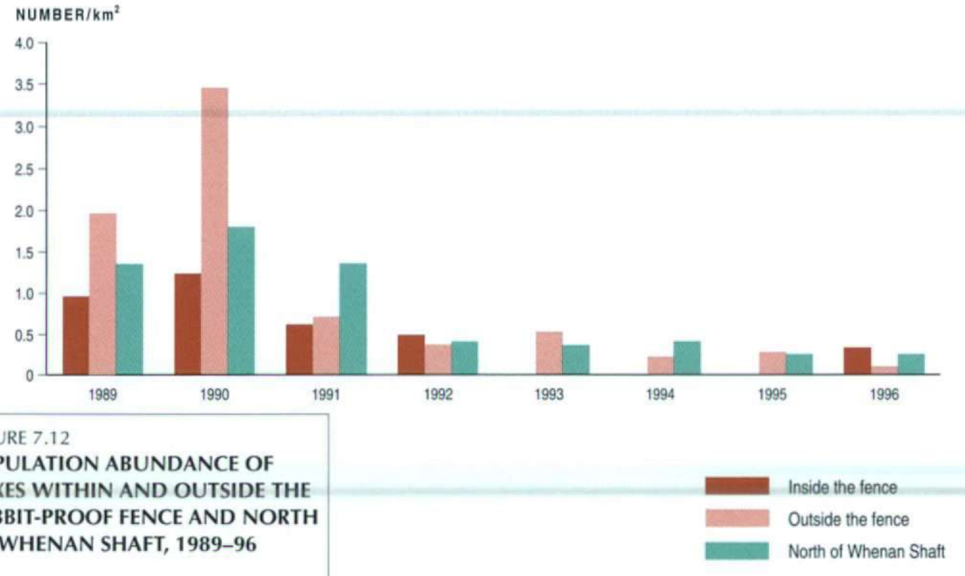


FIGURE 7.12
POPULATION ABUNDANCE OF FOXES WITHIN AND OUTSIDE THE RABBIT-PROOF FENCE AND NORTH OF WHENAN SHAFT, 1989–96

These data were recorded by WMC during the monitoring programme and show that:

- the overall population density of rabbits was erratic in the period 1989–93, with a massive decline since 1994;
- there has been an overall increase in the population density of cats in the period 1989–94, particularly north of Whenan Shaft. However, while high population numbers occurred inside the rabbit-proof fence during 1995 and 1996, there has been a decline in population numbers outside the fence, including north of Whenan Shaft, since 1994;
- there has been an overall population decline in foxes since 1989, although an increase in numbers was recorded inside the rabbit-proof fence in 1996.

Population abundance data based on the monitoring programme are provided in Table 7.9.

Expansion project impacts and mitigation

The introduced species present in the Project Area occur throughout the region and much of southern and central Australia. Potential impacts of the proposed Expansion Project are expected to be minimal and, if present, localised, and include an increase in the:

- abundance of existing unmanaged pest animal populations in and adjacent to landfills;
- number of larger solitary introduced animals (possibly dingoes and probably cats) that venture into settled areas to feed on smaller pest animal species (house mouse) owing to the increased abundance of these smaller animals;
- number of introduced bird species, including house sparrows, feral (and wayward racing) pigeons, and starlings, that have in the past benefited from development and settlement at Olympic Dam and Roxby Downs.

There are not expected to be any significant regional impacts from introduced and proclaimed animal species as a result of the expansion.

Monitoring of introduced and proclaimed animal species would continue and would be expanded to include assessment of all new disturbance areas. Reporting of the presence, abundance and control of these species, including invertebrates, would be included in the WMC EMMP annual reports.

The presence and efficacy of the Rabbit Calicivirus Disease would be investigated further and incorporated in the ongoing monitoring and management programme. Additional programmes to control rabbits immune to Rabbit Calicivirus Disease would be established.

7.3.8 Macroinvertebrates

It is estimated that there are in excess of 500 species of macroinvertebrates (hereafter referred to as invertebrates) in the region (WMC—Olympic Dam Operations 1991); however, the species diversity of invertebrates likely to be recorded at any one time is dependent on seasonal conditions. During a three-month survey by WMC over the summer of 1990–91, 113 insect species were recorded (WMC—Olympic Dam Operations 1991). While this diversity and these species are of scientific interest, they are of limited known value as possible indicators of environmental change. Among the more useful invertebrate indicators are ant species, some of which have long-lived and generally stable communities (Greenslade 1979).

As is the case for much of Australia, an assessment of microinvertebrate faunal composition and abundance in the region has not been undertaken. In addition, few investigations have been carried out into the aquatic macroinvertebrates and microinvertebrates of ephemeral waterbodies in the region.

Ants

Read (1996) reports that eighty ant species have been recorded in the Project Area. Of these, *Iridomyrmex* was the most abundant genus, represented by twenty-one species. Other genera represented include *Melophorus* (seventeen species), *Monomorium* (twelve species) and *Pheidole* (eight species).

There are at least four, recognisably distinct, functional groups of ants. These groups and their relevant features are presented in Table 7.10. Generalist, opportunist and other ant group species must adapt and conform to patterns established by dominant ants (Greenslade 1979).

Table 7.10 Functional groups and relevant features of common ant genera in the Project Area

Functional Group	Genera	Relevant features
Dominant ants	*Iridomyrmex*	Highly abundant, active and aggressive; able to monopolise resources
Generalist Myrmicines	*Monomorium* *Pheidole* *Crematogaster*	Unspecialised behaviour but successful competitors owing to rapid recruitment and effective defences
Opportunists	*Rhytidoponera*	Extremely unspecialised behaviour; poor competitors
Other species	*Melophorus* *Campanotus* *Tetramorium* *Myrmecia* *Tapinoma* *Meranoplus*	Variety of subordinate or highly specialised ants, usually with features that reduce interactions with other ants

Sources: Andersen 1990; WMC—Olympic Dam Operations 1991.

Opportunist ant species experience major fluctuations in population numbers in response to the availability of resources and to changes in the numbers of dominant ants or species.

Dominant and generalist ant species out-compete opportunists and others in undisturbed environments (Andersen 1990). As disturbance increases, other specialist and less-competitive ants increase in numbers. Therefore, a change in the ratio of dominant ant species to opportunist and specialised ant species is indicative of environmental disturbance.

There are considerable differences in the ratios of ants of the three major functional groups at the sites along a transect through and beyond the metallurgical plant. Colonising ants appear to be more abundant in close proximity to the metallurgical plant, and dominant ant species become increasingly abundant with distance from the plant.

Further discussion of the use of ants to indicate project impacts in the vicinity of the metallurgical plant is presented in Section 7.3.10.

Three genera of ants *(Iridomyrmex, Melophorus* and *Monomorium)* dominate the ant fauna at control sites and at sites remote from the metallurgical plant. Although the trends in the data are not entirely consistent, dominant ants appear to be most abundant in regions of either high or minimal disturbance. This does not fully accord with previously published information (e.g. Andersen 1990). The dominance of these ants in highly disturbed sites has been attributed to the high proportion of a local form of *Iridomyrmex, I. rufoniger,* and also to *I. virideaneus,* which both include large areas of bare ground as favoured habitats.

7.3.9 Summary of impacts of the expansion on terrestrial fauna

This section discusses the impacts of the expansion on the terrestrial fauna and habitats present in the Project Area.

Special Mining Lease

As discussed in Section 7.2.6, land disturbance of between 607 ha and 1,057 ha is expected to occur as a result of the expansion to 200,000 t/a copper production. The disturbance area increases to between 937 ha and 1,557 ha with expansion to 350,000 t/a copper production. The majority of the area that would be impacted consists of widely spaced dunes with some small areas of high-density dunes. The dominant vegetation communities in these dunefields are mulga woodland/sandhill wattle and hopbush tall open shrublands on the dunes and saltbush/low bluebush low open shrubland in the interdune swales.

The mulga woodland/sandhill wattle tall open shrubland vegetation community on the dunes provides a diversity of habitats for a range of mammal, bird and reptile species. In addition, the dunes provide habitat for many species of burrowing animal species, particularly reptiles and small mammals. Regionally, the dunefields and these vegetation communities are extensive; hence, the animals that inhabit these dunefield areas are not restricted to the areas that are expected to be impacted.

It is unlikely that the habitat and survival of any animal species would be threatened by the implementation of the proposed expansion. Owing to past construction of infrastructure and plant and ongoing road traffic and noise, major habitat areas occur some distance from the mine and plant areas. It is expected, however, that there would be short-term disruptions to animals that inhabit the impact areas while alternative habitats are sought. The mobility of most animal species would minimise the chance of injury or death in the impacted areas. Two permanent fauna monitoring sites in the Special Mining Lease area would be directly impacted by the Expansion Project. These sites would be replaced with sites selected from nearby, similar habitats.

Municipal Lease

As discussed in Section 7.2.6, additional land and vegetation disturbance of up to 25 ha of the total Municipal Lease area would be expected as a result of the expansion to 200,000 t/a copper production. The additional disturbance area increases up to 71 ha with expansion to 350,000 t/a copper production. The area of the Municipal Lease that would be impacted comprises widely spaced and high-density dunes and is dominated by several vegetation communities, such as mulga woodland, sandhill wattle tall open shrubland, native pine woodlands on the dunes, and western myall woodland and saltbush/low bluebush low open shrubland on the interdune swales.

The woodland and tall shrubland vegetation on the dunes provides a multi-strata and highly diverse habitat for a variety of animal species. This habitat is not unique in the region and is repeated consistently over a wide area; hence, it is not expected that any significant animal species or habitats would be threatened as a result of the expansion. In addition, major habitats are located some distance from existing town development and the associated and ongoing traffic and residential noise.

The retention and linking of some vegetation communities within the new residential development would provide inferior habitats within the residential area and, more importantly, corridors to pristine habitats external to the town. In the short term, however, it is expected that there would be disruptions to animals that inhabit the impacted areas, although the mobility of most animal species would minimise the chance of injury or death in these areas during this time. No permanent fauna monitoring sites would be directly impacted by the Expansion Project.

Noise impacts on fauna

In general, the acoustic environment associated with the expansion would be similar to, although slightly noisier than, the existing conditions in the Special Mining Lease and the Municipal Lease (Section 9.5).

All vertebrate species would continue to avoid the immediate region of the metallurgical plant, including the major point sources of noise detailed in Section 9.5 (e.g. shaft furnace, autogenous mill and anode furnace). The predicted average noise levels of 60–62 dBA (following expansion) in areas surrounding the metallurgical plant would be unlikely to result in a disturbance response by vertebrate species as many species show a high level of habituation to this constant noise at this level.

In general, noise levels in excess of 75 dBA are required before a response occurs in most vertebrates (Department of Defence 1995). Consequently there is not predicted to be any change in the distribution and abundance of vertebrate and invertebrate species owing to noise resulting from the expansion.

7.3.10 Fauna monitoring

Fauna monitoring in the Project Area is principally designed to determine the nature, extent and degree of any impacts, positive and negative, of the project on fauna. As outlined in Chapter 15, all major vertebrate groups are monitored, as well as some invertebrates (ants), as part of an annual ongoing programme.

Where practicable, terrestrial vertebrate monitoring studies are used to measure quantitatively the impacts of WMC's activities. Chenopod shrubland is the most important habitat for reptiles (Read 1992), and is therefore used for a range of detailed ecological monitoring studies. Monitoring data are used to compare species diversity, capture rates and breeding patterns both within and in the immediate vicinity of the Project Area. WMC's monitoring programme is comprehensive and, based on its review as part of this EIS and with a few modifications, would be suitable to monitor impacts associated with post-expansion activities.

Table 7.11 summarises the monitoring undertaken for the Olympic Dam region fauna monitoring programme.

Table 7.11 Olympic Dam fauna monitoring summary

Location	Monitoring	Frequency
Terrestrial vertebrate pitfall sites	Total vertebrate abundance, sex, length, weight, age and breeding condition	Annually
Olympic Dam region	Frog abnormalities	Opportunistically
Ant monitoring sites	Ant genera diversity and abundance	Annually
Bird monitoring sites	Bird species density	Annually
Olympic Dam region	Bird species inventory	Monthly
Large mammal transects	Large mammal densities	Every two months

Source: WMC—Olympic Dam Corporation 1996a.

Terrestrial vertebrates

The terrestrial vertebrates monitoring programme conducted by WMC includes large and small mammals, reptiles and amphibians. Records of all animals' (except large mammals) sex, length, weight, age and breeding condition are collected. Results of these studies are presented in the EMMP annual reports. A separate study to determine life spans is part of a research programme.

Large native and pest mammal species assessed include kangaroos, rabbits, cats and foxes. Kangaroo and rabbit numbers directly affect the condition of the vegetation within the Project Area and region, and also affect the success of rehabilitation measures and amenity plantings. Likewise, cat and fox numbers impact on native vertebrate populations. Therefore, large mammals have the potential for a major impact on the ecology of the region. Large mammal populations are monitored and, if necessary, rabbits, cats and foxes are controlled.

Kangaroos, rabbits, cats and foxes are counted every two months along three spotlight transects, each of approximately 20 km. Transects are located in the sand dunes inside the rabbit-proof fence, immediately outside the rabbit-proof fence, and in the more-open country north of Whenan Shaft. Densities of all four species are calculated and compared with previously collected data.

In the Project Area, kangaroo population densities are monitored by WMC. Since 1989, the first year of records, population levels have fluctuated from zero to the highest recording of twenty-two kangaroos per km^2 in mid-1993 (WMC—Olympic Dam Corporation 1996b). Kangaroo numbers are not regulated within the Project Area; however, the Kingoonya Soil Conservation District Plan (Kingoonya Soil Conservation Board 1996), which incorporates the Project Area, ensures that kangaroos are controlled if they reach levels sufficient to cause environmental damage, as defined by the South Australian *National Parks and Wildlife Act 1972* (WMC—Olympic Dam Corporation 1996a). Where major or significant damage to pastures or improvements is demonstrated, the Department of Environment and Natural Resources may issue licences to reduce kangaroo population numbers. WMC has not controlled kangaroo numbers in the Project Area since 1995.

Small terrestrial vertebrates are trapped using pitfall traps, which are placed permanently in selected locations and opened for each trapping period. Other areas or sites are assessed and monitored as required: for example, monitoring of construction programmes in the Project Area and the Borefield B project.

An additional study of trilling frogs is conducted opportunistically when weather conditions favour their emergence and/or breeding. Skeletal abnormality levels in frogs and radionuclide concentrations in tadpoles are investigated using amphibians captured close to the mine and metallurgical plant, and at control sites remote from Olympic Dam (WMC—Olympic Dam Corporation 1996a).

Invertebrate monitoring—ants

Monitoring of invertebrates is an important part of the fauna monitoring programme. Ants are believed to be sensitive indicators of environmental condition and disturbance and have therefore been chosen as the most practical and useful invertebrate group to monitor.

Metallurgical plant emissions are considered to be the only environmental pollutants with the potential to affect the undeveloped sections of the Project Area; therefore, these emissions have been a focus of the ant monitoring study. Ants are surveyed each year along a transect passing through the metallurgical plant, in the direction of the prevailing wind, and at control sites. The abundance of ants at each location is assessed by counting, and data from near the operation and control sites are compared in an attempt to identify impacts. Results to date have been inconclusive.

In order to improve the ant monitoring programme, increased assessment of sites would be necessary. This would provide additional information for assessment of spatial and temporal variations in ant distribution. A greater understanding of ant ecology and taxonomy would be necessary before ants could be used as unequivocal indicators of environmental condition in the Special Mining Lease area (Read 1996).

7.4 MOUND SPRINGS

Mound springs are naturally occurring outlets for water discharging under pressure from the Great Artesian Basin. They are located around the margin of the Great Artesian Basin in

Queensland, north-western New South Wales, and northern and north-eastern South Australia, with the majority occurring in South Australia (Ponder 1986). The absolute age of the mound springs is not known; however, the onset of spring activity is thought to be greater than 8,000 to 10,000 years ago (Boyd 1990; Habermehl 1982) and several extinct spring mounds (e.g. Hamilton Hill and Beresford Hill springs) are thought to have been active during the Pleistocene age.

Considerable information on mound springs has previously been presented in Kinhill – Stearns Roger (1982), Kinhill Stearns (1984) and Kinhill Engineers (1995). Locations of mound springs in the vicinity of Borefields A and B are shown in Figure 7.13.

Ponder (1986) and Thomson and Barnett (1985) indicate that springs in Australia and South Australia are generally associated with:

- geological faults through which water flows to the ground surface
- bedrock outcrops that interrupt groundwater flow from aquifers
- thin or no rock cover above an aquifer.

The outflow water of South Australian mound springs originates primarily from recharge areas associated with the Great Dividing Range in Queensland, and along the western margins in

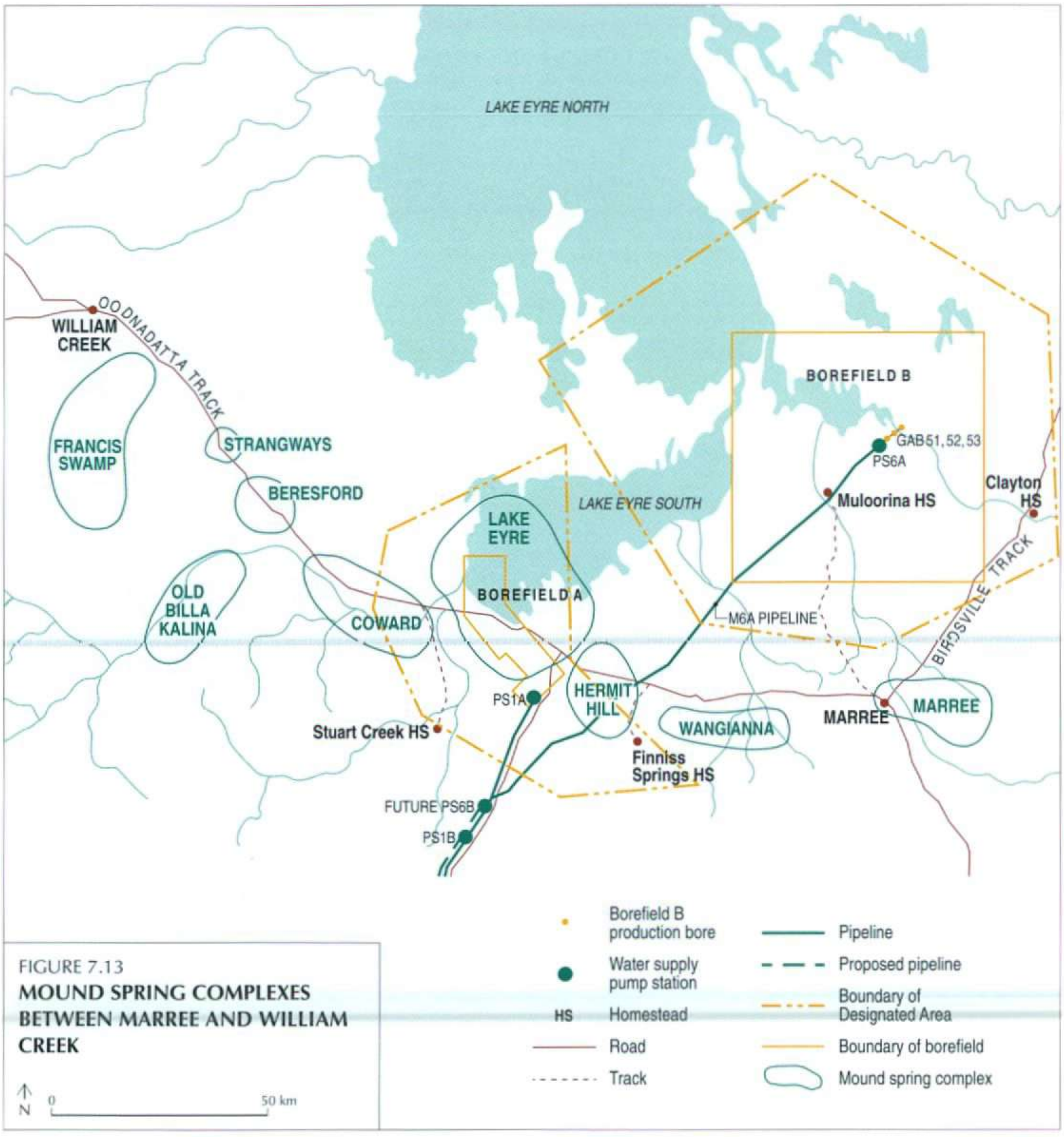


FIGURE 7.13
MOUND SPRING COMPLEXES BETWEEN MARREE AND WILLIAM CREEK

the uplands west of Lake Eyre and the Simpson Desert in South Australia. The water from these recharge areas slowly percolates through the basin at a rate of 1–5 m per year (Habermehl 1980). The water outflow from most mound springs is generally low, ranging from less than 0.1 L/s to 7.5 L/s (Habermehl 1982; WMC—Olympic Dam Corporation 1996b), although flow rates of 162 L/s are recorded at Dalhousie Springs.

Mound springs are estimated to discharge approximately 5% of the total water flowing from the Great Artesian Basin (Section 4.2.1). The outflow waters are warm, with average temperatures of 20–35°C, although extremes of 14°C and 46°C have been recorded (Boyd 1990). Most outflow waters are neutral to alkaline (pH 7–10) and high in soluble salts, including sodium, bicarbonate, carbonate and chloride (Kinhill Stearns 1984; WMC—Olympic Dam Corporation 1996b).

7.4.1 Mound springs conservation values

Many of the South Australian mound springs contain endemic and relict plant species (Fatchen and Fatchen 1993) and endemic invertebrate animal species that have undergone genetic differentiation and speciation as a result of the isolation of each group of springs by large tracts of arid land (Ponder 1986; Ponder et al. 1989).

Some mound springs provide valuable scientific information about changes in local plant communities and water flow characteristics over approximately 2,000 years through pollen and radiocarbon dating studies (Boyd 1994). Mound springs also provide the environment necessary for aquatic invertebrates with poor dispersal capabilities and total dependence on water throughout their life cycles, such as some molluscs and crustaceans, to occur in an otherwise arid region (Ponder 1994). In addition, they are a valuable water source for some larger native vertebrate animal species.

Mound springs have provided focal points as water sources for Aboriginal people, explorers and settlements, especially those settlements associated with the pastoral industry. Degradation of some of the springs has occurred owing to stock damage over the last 100 years (Ponder 1986). This degradation has adversely affected habitats, fauna and flora of some mound springs.

The proliferation of artesian bores in the early 1900s, and the subsequent uncontrolled flow of water, caused a considerable reduction in the potentiometric surface of the Great Artesian Basin, resulting in a reduction in mound spring flows (Section 4.2). The rehabilitation of more than 90% of artesian bores within the South Australian portion of the Great Artesian Basin since 1977 has reduced the uncontrolled water flow by approximately 115 ML/d (Sampson 1996).

The conservation of mound springs is therefore important from cultural, historical, biological and scientific perspectives. In particular, the mound springs provide an important research area for prehistoric, historic, evolutionary, ecological and biogeographical studies. Australian aquatic fauna conservation has primarily focused on vertebrates and, although some conservation measures have also incidentally aided the conservation of invertebrates, additional measures are required for some invertebrates.

In relation to mound springs, conservation measures required include the protection of the waterbodies and associated vegetation and the proper management and conservation of artesian water sources. Ponder (1994) reports that more than forty species of biologically unique aquatic invertebrates inhabit artesian springs in Australia, and that these rely on the continued presence of artesian water. The existence of these invertebrates has been threatened since extraction of artesian water commenced in the late 1800s and mound spring discharge rates declined.

Several mound springs and spring groups and their surrounds have been recognised as historically or culturally significant and have, as a consequence, been listed in the

Register of the National Estate (D. Heap, Australian Heritage Commission, pers. comm., November 1996). Details of all springs and spring groups listed by the Australian Heritage Commission (now the Australian and World Heritage Group of Environment Australia) are provided in Table 7.12. There are numerous other sites associated with mound springs that display evidence of past human occupation; however, these sites are not registered with the Australian Heritage Commission. Further discussion on the presence of Aboriginal people at mound springs can be found in Section 6.3.

The wetlands of the Lake Eyre mound springs are registered under the Directory of Important Wetlands in Australia as being of national importance (Australian Nature Conservation Agency 1996b).

Table 7.12 Sites associated with South Australian mound springs listed in the Register of the National Estate

Nearest town	Site class	Location	Area (ha)
Copley	Aboriginal	Twelve Springs Aboriginal sites	180
Coward Springs	Natural	Blanche Cup Springs area	700
	Aboriginal	Bidalina Aboriginal site	300
Marree	Natural	Lake Eyre and environs	2,100,000
William Creek	Historic	Strangways Springs site	n.a.
Oodnadatta	Natural	Dalhousie Springs	7,500
	Natural	Dalhousie Springs area	19,000
	Historic	The Peake Group	n.a.

n.a. Not available.
Source: Australian Heritage Commission (now the Australian and World Heritage Group of Environment Australia).

In addition, it is possible that the Australian mound springs, as unique ecological communities, could be nominated for listing under the Commonwealth *Endangered Species Protection Act 1992* (J. Pook, Biodiversity Group, Environment Australia, pers. comm., October 1996).

7.4.2 Classification of mound springs

A range of classifications has been used to describe mound springs. Springs are considered to be active when there is sufficient water flow to maintain an outflow channel; waning when the water flow rate has considerably reduced and the spring has become a damp seep; non-active when the water flow has ceased; and extinct if water has not discharged for a considerable time. Some non-active springs have been known to resume flowing following local changes in water pressure. Extinct springs are evidenced by the absence of mound spring wetland vegetation and/or pronounced weathering of the mound (Kinhill Stearns 1984).

Mound springs have a diversity of forms. Some display a mound of mud, sand or calcareous materials deposited from the outflow water; others have not formed a mound and have a strong surface flow and large wetland; and some are no more than a damp seep. Figure 7.14 shows a typical mound spring in cross-section.

Active mound springs usually comprise three main parts: the vent and associated vent pool, the outflow channel (or channels) from the vent, and the tail. However, not all springs have all three components. In the Lake Eyre supergroup, especially the Hermit Hill spring complex, the depth of water in the vent, which may be a small opening or a pool, generally does not exceed 2–3 cm, and is often only a few millimetres in the outflow channels and tails (Ponder et al. 1989).

Mound springs are classified into groups, complexes and supergroups. Mound spring groups are usually associated with a local geological fault or fracture. Spring complexes consist of

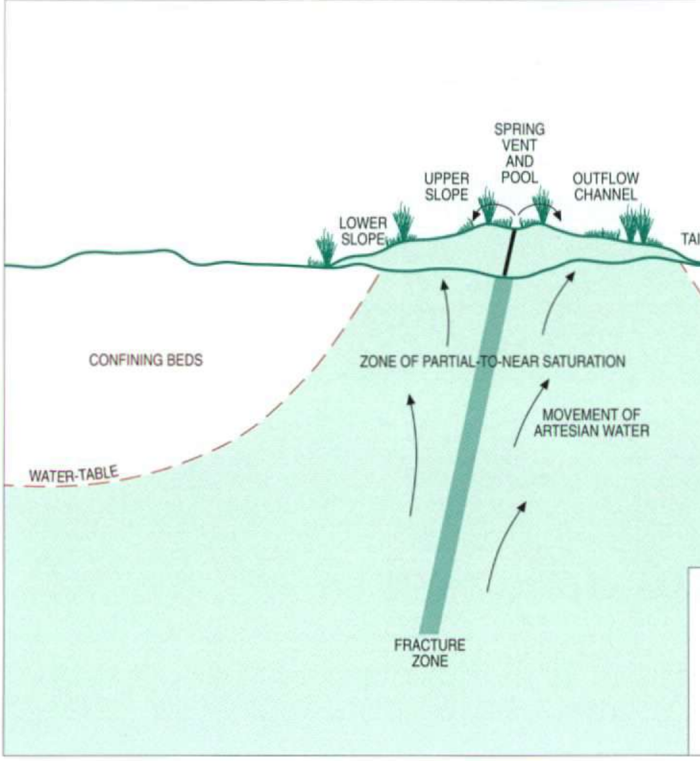


FIGURE 7.14
CROSS-SECTION OF A TYPICAL MOUND SPRING AND ITS MORPHOLOGY

Source: Williams and Holmes 1978

an assemblage of spring groups that are in close proximity, of a similar type (i.e. similar water chemistry), and generally within the same hydrological catchment (Kinhill Stearns 1984).

Spring complexes are grouped into supergroups based on location and spring morphology similarities (Ponder 1986). There are eleven spring supergroups associated with the Great Artesian Basin, three of which are located in South Australia—the Lake Frome, Lake Eyre and Dalhousie supergroups (Ponder 1986). Owing to the location of the WMC borefields and the potential for drawdown effects on some of the Lake Eyre supergroup springs, the springs within this supergroup have been the subject of continued assessment and monitoring by WMC. Figure 7.15 shows the WMC borefields and mound spring groups that are monitored by WMC.

To assist with research, assessment, monitoring and management, the mound springs within the region have each been allocated a unique alphanumeric code. This numbering system was devised by WMC to identify the spring complex, spring group and individual spring. In the WMC system, the first letter indicates the spring complex, the second and third letters indicate the spring group and the following three numbers indicate the individual spring within that spring group (Kinhill Stearns 1984). For example, the spring identifier HHS125 refers to spring 125 in the Hermit Springs spring group (HS) in the Hermit Hill spring complex (H). Other agencies, such as Mines and Energy South Australia and the Australian Museum, use their own spring identification system.

7.4.3 Review of past impact predictions

Table 7.13 outlines the previously predicted impacts of the WMC operations on the mound springs biological environment as described in Kinhill – Stearns Roger (1982), Kinhill Stearns (1984) and Kinhill Engineers (1995). The predicted impacts on mound spring water discharge have been presented in Section 4.5.

The changes to the biological environment of mound springs that have occurred since these impact predictions were made are discussed in detail in the mound springs flora and fauna sections (Sections 7.4.4 and 7.4.9).

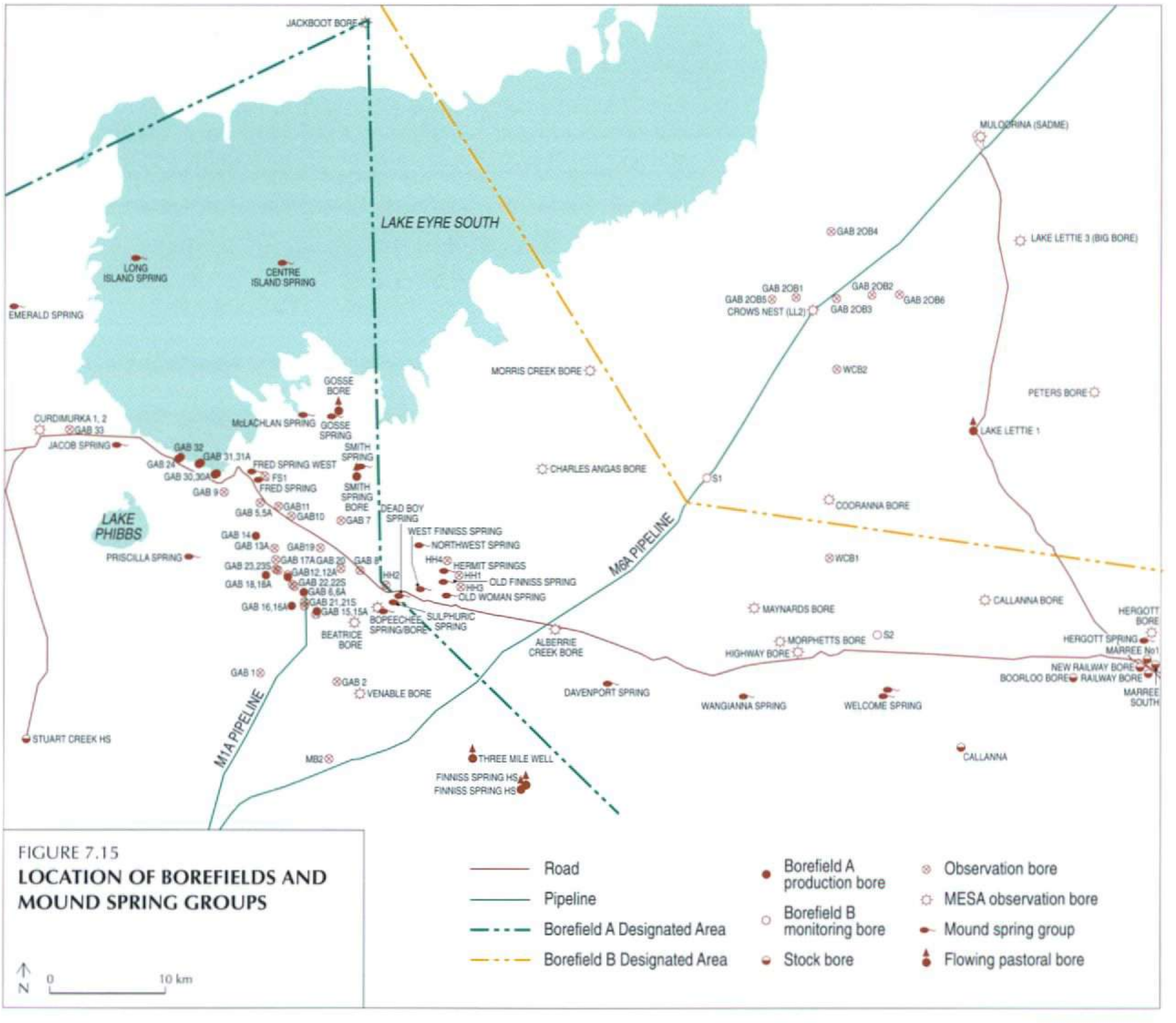


FIGURE 7.15
LOCATION OF BOREFIELDS AND MOUND SPRING GROUPS

Table 7.13 Summary of predicted impacts on mound springs biological environment

Source document	Impact
Kinhill – Stearns Roger, 1982	Introduction of stock—changes in the aquatic plant community resulting in masses of filamentous algae, due possibly to organic pollution, could be expected to cause oxygen depletion under certain conditions.
	Stock removal—fencing of springs to prevent stock access would decrease organic pollution and allow the re-establishment of a natural, balanced macrophyte community.
	Major flow reduction for some mound springs including Beatrice, Bopeechee and Priscilla.
	Bore-capping may increase flow rates, thereby providing the potential for recolonisation by fish and microcrustacea. Alternatively, a dramatic increase in flow rate might be detrimental, reducing the retention time of pools to a point where the turnover time of planktonic organisms might be insufficient to maintain the population.
Kinhill Stearns, 1984 (drawdown impacts)	Significant discharge reductions would be confined to degraded springs with little conservation significance (e.g. Beatrice, Venable, Priscilla).
	Moderate to minor flow reductions to springs with some conservation significance (e.g. West Finniss and Bopeechee) would only occur if there were a semi-permeable ridge between the north-eastern and south-western borefield groundwater sub-basins.
	Moderate to minor flow reductions to other springs in the north-eastern sub-basin with no particular conservation significance (e.g. Northwest, Fred, Dead Boy, Sulphuric) would depend on the existence of a semi-permeable ridge between the north-eastern and south-western groundwater sub-basins.

Table 7.13 Summary of predicted impacts on mound springs biological environment (continued)

Source document	Impact
Kinhill Stearns, 1984 (drawdown impacts) (continued)	Discharge reduction of approximately 10% is likely to: • dry out many of the damp (non-flowing) mounds and seepages that support vegetation and aquatic fauna so that available habitat is lost; • increase grazing (stock and feral animals) pressure on larger springs as smaller springs dry out. Discharge reduction of approximately 20–50% is predicted to have the following effects: • many small springs would cease to flow; • larger springs would be isolated owing to reduction in the number of smaller springs; • recolonisation capability would be reduced owing to isolation of larger springs and the reduced number of springs. Discharge reduction of greater than 60% and less than 100% is predicted to have the following effects (e.g. Beatrice, Venable, Priscilla): • only the very largest springs would contain aquatic fauna; • there would be significant loss of wetland flora, as the area of wetland flora that can be supported is directly related to spring flow. 100% discharge reduction is predicted to cause the total loss of aquatic fauna and wetland vegetation.
Kinhill Engineers, 1995	Additional flow (10%) loss for Bopeechee is predicted if Borefields A and B are used under some pumping scenarios. No additional impacts on mound spring flows. Reinjection—the Borefield A reinjection programme, which includes the partial restoration of water pressure to Bopeechee spring group, is expected to reverse the impacts of reduced discharge and impaired ecological conditions at this spring group.

7.4.4 Mound springs vegetation—vascular

This section describes and discusses the vascular flora associated with the mound springs in the region of the WMC borefields.

The mound springs vegetation contains biogeographically important relict species, as well as the endangered endemic species salt pipewort *(Eriocaulon carsonii),* and provides a range of essential habitats for some endemic invertebrate animal species, as described in Section 7.4.9 (Fatchen and Fatchen 1993; Symon 1985). The preservation of these floristically significant communities is of particular scientific and conservation importance.

Yearly monitoring of the mound springs flora has been undertaken since 1983. Individual springs (419 in 1995) in twenty-seven spring groups in the Lake Eyre supergroup are sampled (WMC—Olympic Dam Corporation 1996a). Table K.1 in Appendix K provides a list of the mound springs assessed during this monitoring programme. Important findings of the vegetation monitoring programme were previously reported in WMC EMMP annual reports and summarised in WMC—Olympic Dam Corporation (1996b), which is based on Fatchen and Fatchen (1993).

These findings include the following:

- Species richness and diversity are largely independent of the total area of the spring, and are directly related to the number of springs in a group.
- The springs are highly dynamic physical and biological systems.

In addition, the monitoring programme has provided a series of important observations that support the need for regular monitoring and have assisted in the understanding of the dynamic nature of mound springs.

The observations include the following:

- Significant changes in the springs' vegetation have resulted from the removal of domestic stock from Finniss Springs Station after 1984. This removal resulted in increases in the size of vegetated wetlands; changes in plant dominance; increased plant biomass, which in turn contributed to increased water use through transpiration, some capping of vents by plant growth, and a reduction in the amount of free water at the surface; and changes in species diversity. It also indirectly contributed to reductions in the populations of salt pipewort, it being out-competed by species previously held at low levels by grazing. No equivalent changes occurred at springs in which vegetation continued to be grazed by stock.

- Early drawdown effects were immediately obvious in the vegetation at Priscilla mound spring and Venable bore (both now extinct).

- Until 1993, no major changes to vegetation caused by drawdown were obvious in groups other than Priscilla mound spring and Venable bore; however, slight reductions in the area of living wetland vegetation at Bopeechee were noted in 1993. These reductions correlated with reduced bore and spring flows, and almost certainly pointed to drawdown effects from Borefield A.

- The 1995 monitoring data from Bopeechee, following adjustments for the water extraction regime, were equivocal; that is, some aspects monitored showed little change, while others suggested that probable drawdown effects were continuing. Spring flow data showed some recovery from the reduced flow rates measured in early 1994.

- The predicted decline of springs in the Beatrice group has taken longer than expected to affect the vegetation in a clearly discernible way. Mound springs in this group have displayed distinct signs of waning, although observed reductions in the area of vegetated wetland at Beatrice bore are not directly related to reduced spring or bore flows but to the redirection of water flow by vegetation.

- Mean species richness remained significantly higher than in the 1983 baseline in unstocked spring groups at Hermit Springs, Bopeechee, Beatrice, Dead Boy and Sulphuric, but not in Old Finniss, Old Woman or West Finniss. The increase at Beatrice is attributed to the invasion of dryland plant species on mounds. The species richness decline at West Finniss was caused by the domination of mound springs by common reed and bare twigrush following the cessation of grazing in 1984. There was no difference in mean species richness in the spring groups of the Lake Eyre supergroup still available to domestic grazing.

- The very large Hermit Springs and the smaller, but more compact, West Finniss spring groups continued to be significantly more floristically diverse than any of the other spring groups. The greatest species diversity was recorded at Hermit Springs and West Finniss spring groups during 1986–87, as a consequence of destocking Finniss Springs Station in 1984. Peak diversity was reached during the transition from bore-drain sedge dominance to common reed dominance. This was followed by a decline in diversity until 1992, as the abundance of bore-drain sedge reduced and common reed became dominant in most springs. The appearance of the flood-introduced, non-wetland, tall shrub species native myrtle *(Myoporum montanum)* and native willow *(Acacia salicina)* in 1992 again increased species diversity.

- The endangered salt pipewort present in Hermit Springs was disadvantaged by the removal of stock. In the 1983 baseline survey, this species was found as a co-dominant with bore-drain sedge in several springs, growing in the central vent out of reach of stock. Stock grazing was suppressing growth of the common reed; however, after removal of stock, common reed established on most vents. Salt pipewort populations decreased by at least 50% and numerous local extinctions were recorded. This decline now appears to have halted.

- Significant recolonisation of salt pipewort was recorded at Hermit Springs spring group (HHS172–173) following a fire in the summer of 1993–94. The first appearance of salt pipewort at Gosse spring group was recorded in 1995, with its dispersal to this spring group being attributed to water birds.
- Vegetated wetland areas in springs where grazing was discontinued peaked over the period 1987–90, depending on the group. In most cases there has been some decline since, but vegetated wetland areas generally remain larger than in 1983, despite the far greater water demand brought about by the major increase in plant biomass following the removal of domestic stock.
- Water flow rates at Bopeechee appear to have stabilised since 1995 through the Borefield A reinjection programme (Section 4.2), and the reduction in vegetated wetland area has halted although not reversed. The reversal process may take a number of years of reinjection and the enforced exclusion of large pest herbivores and stock.

A synthesis of all mound spring vegetation monitoring databases from June 1983 to June 1992 was undertaken by Fatchen and Fatchen (1993). A summary of the important features of this synthesis is as follows:

- Spring-specific flora is depauperate (eight to ten dominant wetland species) compared with surrounding vegetation communities.
- The most diverse flora is present in the largest spring groups within the Hermit Hill spring complex.
- Salt pipewort, an endangered species listed under the *Endangered Species Protection Act 1992* (Cwlth), is present within the Hermit Hill spring complex, as are species of biogeographic significance, namely cutting grass *(Gahnia trifida),* bare twigrush *(Baumea juncea),* and sea rush *(Juncus kraussii).*
- The Hermit Hill spring complex occurrence of salt pipewort represents the major portion of the total population of this species in South Australia and Australia.
- There is little similarity between the floristic composition of mound springs and bore drains; hence, to conserve mound springs vegetation it is necessary to conserve mound springs.

Prior to Fatchen and Fatchen (1993), Symon (1985) reported on many of these issues, including the number of plant species confined to the springs, the paucity of these species at bores, and the effects of land management on the mound springs vegetation.

The dominant species associated with mound springs are those aquatic species that have a frequency of occurrence above 10%, these being bare twigrush, bore-drain sedge *(Cyperus laevigatus),* salt pipewort, common fringe-rush *(Fimbristylis dichotoma),* cutting grass, sea rush, common reed *(Phragmites australis),* salt couch *(Sporobolus virginicus)* and cumbungi *(Typha domingensis)* (Fatchen and Fatchen 1993; D. Niejalke, WMC, pers. comm., November 1996). Several 'species pairs' have also been recorded under these species names. Species pairs are closely related species of the same genus that are so similar to each other that they cannot be consistently differentiated in the field. The dryland species *Myoporum montanum* and *Calocephalus* sp. aff. *platycephalus,* which are present on the edge of mound springs, have a frequency of occurrence of 4% or more. All other aquatic and semi-aquatic species occur only at very low frequencies; that is, less than 2%.

A list of all species recorded at the monitored springs is provided in Table K.2 in Appendix K.

The data in Table K.4 in Appendix K show that Hermit Hill spring complex, and Hermit and West Finniss spring groups in particular, has the most diverse flora (Fatchen and Fatchen 1993). Bore-drain sedge is the most frequently occurring species throughout the spring complexes and spring groups. The occurrence of this species is closely matched by common

New species—*Calocephalus* sp. aff. *platycephalus*

Calocephalus sp. aff. *platycephalus* is a small (8–50 cm tall) perennial herb and is probably a new, undescribed species of daisy, first thought to be a distinct species by WMC botanist, Frank Badman. Specimens of *Calocephalus* sp. aff. *platycephalus* have been collected immediately adjacent to South Australian mound springs in the Lake Eyre and Lake Frome supergroups only. This species is currently being described (P. Short, Northern Territory Herbarium, pers. comm., December 1996).

7.4.6 Mound springs vegetation—non-vascular

Data concerning non-vascular vegetation in mound springs was reported for Wangianna, Welcome, Hergott and Wirringina spring groups in Kinhill Engineers (1995). That assessment recorded thirty-five photosynthetic algae taxa and two non-photosynthetic protozoan taxa (Table K.3 in Appendix K).

A species of particular interest was a mat alga, *Compsopogon* (probably *C. coeruleus),* recorded in one spring in the Wangianna spring group (WWS002). This species had previously been recorded in collections from the south-east regions of Australia and eastern Queensland (Burns 1994). In addition, Skinner (1989) reported on the commonly occurring filamentous algae collected from Dalhousie, Blanche Cup and Welcome springs. The greatest diversity of algae was recorded at Dalhousie springs, with eleven species, while five species were recorded at Blanche Cup and one at Welcome. Blue-green algae are very abundant and conspicuous in mound springs water. Some mound springs host species that accumulate calcium carbonate and play an important role in mound formation.

7.4.7 Review of past impact predictions—vegetation

Predictions of the impact of the Olympic Dam Project on the vegetation of the mound springs were presented in Kinhill – Stearns Roger (1982), Kinhill Stearns (1984) and Kinhill Enginers (1995). The impacts presented in those documents were considered to be potential effects of the predicted reduction in mound spring water discharge.

It was predicted that the expected flow reductions in mound spring water discharge would result in a reduction of the vegetated wetland area that could be sustained around some mound springs (Kinhill – Stearns Roger 1982). In addition, extinction of a spring within a spring group following a decrease in water discharge would reduce the opportunities for rare species to colonise. As an example, salt pipewort would have reduced opportunities for further colonisation within the limited number of mound spring groups in which it was present (Kinhill Stearns 1984).

Kinhill Engineers (1995) predicted that development of Borefield B would reduce the need for water from Borefield A. This would reduce the effects of drawdown on mound springs. In addition, the Borefield A reinjection programme would reverse some of the drawdown effects on the mound springs in the Bopeechee spring group.

The following results and conclusions were reported in the 1995 spring vegetation monitoring programme (WMC—Olympic Dam Corporation 1996b):

- Two springs within Gosse spring group show increases in flow assumed to be related to the plugging of a nearby free-flowing bore.
- Changes in spring vegetation caused by reduced spring flows resulting from artesian water extraction are minor in comparison with those caused by other factors, especially damage by stock and pest animals.
- The impact of drawdown has been generally as predicted in 1982 and as further revised in 1984 and 1995.

- The establishment of Borefield B during 1996 is expected to at least halt the drawdown trends and probably to reverse them.
- Fire would appear to be a successful tool for managing plant species of special conservation significance. Fire tends to suppress the growth of common reed long enough for opportunistic species, such as bore-drain sedge, to increase in cover at the burnt mound spring and become temporarily dominant.
- Mound springs vegetation area and composition have limited use as indicators of drawdown influences over short time frames, and can provide potentially misleading information if used independently of other factors to detect aquifer drawdown impacts. Drawdown impacts are difficult to determine using vegetation areas owing to the time lag between reduced water flow rates and declines in vegetated area.

Fatchen and Fatchen (1993) report that while there is a relationship between spring flow and vegetated area, this factor alone is a poor indicator of drawdown influences. Other influences, including local or regional drought, increased evaporation or evapotranspiration rates, and stock damage can mask the long-term changes associated with drawdown and prevent the predictive use of the data. Records of spring extinctions in the past have shown that an extinction can occur without early warning; that is, without a significant reduction in the vegetated area or flow rate prior to extinction.

7.4.8 Vertebrate fauna

A range of vertebrate fauna species have been recorded in the vicinity of mound springs. No terrestrial species is dependent on the mound springs or considered to be threatened by extraction of water by WMC from the Great Artesian Basin; however, some fish species are dependent on water from mound springs. Consequently, information related to vertebrate fauna other than fish has been provided in Appendix K.

Fish

Nine fish species have been recorded in mound springs of South Australia (Table 7.15), the most common of these being desert goby *(Chlamydogobius eremius)* and Lake Eyre hardyhead *(Craterocephalus eyresii).* The International Union for Conservation of Nature and Natural Resources (1996) lists two of these species, Dalhousie goby *(Chlamydogobius gloveri)* and Dalhousie hardyhead *(Craterocephalus dalhousiensis)*, as threatened. The presence of fish species in mound springs (and other areas of permanent water) within this region is significant from a scientific and evolutionary perspective (Boyd 1990; Habermehl 1982; Larson 1995).

Table 7.15 Fish species associated with mound springs

Common name	Species name	Status
Dalhousie catfish	*Neosilurus* sp. nov. 1	Restricted to Dalhousie Springs; common and abundant
Mosquito fish[1]	*Gambusia holbrooki*	Abundant
Fly-specked hardyhead	*Craterocephalus gloveri*	Common at Dalhousie Springs
Lake Eyre hardyhead	*C. eyresii*	Common and abundant
Dalhousie hardyhead	*C. dalhousiensis*	Restricted to Dalhousie Springs; common and abundant
Spangled perch	*Leiopotherapon unicolor*	Extremely common, frequently abundant
Purple-spotted gudgeon	*Mogurnda* sp.	Restricted to Dalhousie Springs; common
Desert goby	*Chlamydogobius eremius*	Common and abundant
Dalhousie goby	*C. gloveri*	Restricted to Dalhousie Springs; common

1 *Introduced species.*

Source: Adapted from Glover 1990; Mitchell 1985.

Of the 634 mound springs of the Lake Eyre and Lake Frome supergroups surveyed by WMC in 1995 and 1996, twenty spring groups provided habitat for indigenous and locally endemic fish species (Table 7.16). Recent genetic and morphological analysis of populations of desert goby indicate that there are five species Australia-wide. Of these five species, two are present in isolated locations in central Queensland, and one in the Northern Territory, one is restricted to the mound springs of the Dalhousie supergroup, and another is restricted to the mound springs of the Lake Eyre supergroup (Larsen 1995; M. Adams, South Australian Museum, pers. comm., December 1996).

Table 7.16 Distribution of fish species in the Lake Eyre supergroup mound springs

Spring complex	Spring group	Desert goby	Lake Eyre hardyhead	Purple-spotted gudgeon	Mosquito fish[1]
Beresford Hill	Beresford Hill	X	–	–	–
Coward	Blanche Cup	X	–	–	–
	Jersey	X	–	–	–
	Little Bubbler	X	–	–	–
Francis Swamp	Francis Swamp	X	X	–	–
Hermit Hill	Dead Boy	X	X	–	–
Mount Denison	Unnamed group	X	–	–	X
Mount Dutton	Big Cadna-owie	X	–	–	–
	Ockenden Proper	X	–	–	–
Neales River	Hawker	X	X	–	–
	The Fountain	X	–	–	–
Neales River	Outside	X	–	–	X
Peake Creek	Birribiana	–	–	X	–
	Cootanoorinna	X	–	–	–
	Cardajalburrana	X	–	–	–
	Nilpinna	X	–	X	–
	Old Nilpinna	X	X	–	–
	Warrangarrana	X	–	v	–
	Weedina North	–	–	X	–
Wangianna	Welcome	X	–	–	–

1 *Introduced species.*
– *Not recorded.*
Source: D. Niejalke, WMC, pers. comm., November 1996.

The differences in the genetic composition of the desert goby populations identified by Adams (M. Adams, South Australian Museum, pers. comm., December 1996), although minor, indicate that either gene flow currently occurs sporadically or that, in evolutionary time, the populations have only recently become isolated. These isolated populations of desert goby are considered endangered due to increased pastoral activities and a reduction in the aquifer water table (Larson 1995).

The introduced mosquito fish *(Gambusia holbrooki)* has been recorded in two spring groups within the Lake Eyre supergroup, both of which also have indigenous and locally endemic fish species. Mosquito fish, a pest species in Australian freshwater systems, has caused adverse impacts on native freshwater fishes, frogs and possibly invertebrate species through competition for resources and ecological niches (McLennan 1996).

Additional data on the distribution of fish in the mound springs were sought from the South Australian Research and Development Institute during the preparation of this EIS, but were not available.

Analysis of the WMC mound spring data records indicates that the presence of fish at springs is dependent on the presence of flowing water and, in particular, springs with large areas of flowing water (pools) plus a tail and a visible or strong flow.

7.4.9 Invertebrate fauna

Mound springs in arid South Australia are an important habitat for aquatic and wetland invertebrates, particularly endemic species, with only creekbeds (with deep-rooted trees) supporting an overall richer species diversity in the arid zone (Greenslade 1985).

The mound springs provide a suitable, and in many cases essential, habitat for the larval stages of some insect species, including many species of flies (Davies 1988). Many insect species rely on the presence of water throughout their life span, living either on the surface of the water or within it. The mound springs provide a habitat that is distinct from that available at nearby bores, creek beds and the surrounding arid environment; that is, mound springs provide a permanent habitat unlike that provided by arid zone creeks and bores, and mound springs fauna is not representative of that which occurs elsewhere in arid Australia (Greenslade 1985).

Greenslade (1985) identified and recorded over ninety species of insects associated with South Australian mound springs and their surrounding dryland habitats.

The South Australian mound springs provide habitats for a range of invertebrates of biological and conservation significance, including endemic species and many species currently not known. Hence, further fauna surveys are essential to the understanding of the ecology of mound springs.

Spiders

In addition to fifteen species of spiders recorded by Greenslade (1985), WMC environmental staff have recorded thirty-eight species of spider associated with the wetlands of mound springs (Table K.9 in Appendix K). Many of these species are likely to be undescribed species, and some are considered to be of ecological significance (D. Hirst, South Australian Museum, pers. comm., November 1996), including:

- *Dolomedes facetus*—not previously recorded in South Australia, although common in Queensland and New South Wales;
- *Alistra* sp.—relatives normally found in high rainfall areas and may be a relict species;
- *Lycosa* spp. (three species) and *Trochosa* spp. (four species)—some species appear to be confined to the mound springs and may possibly be confined to particular spring complexes;
- *Dunedinia* sp. and *Laetesia* sp.—probably confined to the mound springs and may be relict species.

Not enough is known about the spiders recorded at mound springs to draw conclusions about species generally, and endemic species in particular. Hence, further research would be necessary to confirm the distribution of species.

The presence of wetland spiders and other invertebrate fauna specific to the mound springs is important in understanding the significance of habitats provided by mound springs in the arid zone of Australia. WMC environmental staff are continuing to survey the mound springs wetlands for spiders with the aim of adding to their existing reference collection and establishing a database of wetland species. The database will assist in the assessment of biological, conservation and management significance and the conservation of mound springs invertebrate fauna. Additional undescribed species are expected to be recorded as part of this continuing survey work.

Most hydrobiids, including most of the species found in the mound springs, are fully aquatic. However, *Fonscochlea zeidleri* is unusual for the family (even when all species are considered world-wide) in being amphibious. This species lives along the edge of the water on damp substrate, sometimes partially buried in damp soil. All other species need to be submerged to survive, even if only covered by a thin film of water. If stranded, these species quickly dehydrate and die (Ponder et al. 1989). Up to five species can be found in any one spring. However, in most of the small springs in the Hermit Hill complex, only *Trochidrobia punicea* and *Fonscochlea accepta* are found.

All the species found in the Lake Eyre supergroup are listed by the IUCN as threatened or near threatened (International Union for Conservation of Nature and Natural Resources 1996), and their conservation has been discussed by Ponder (1995).

The distribution of all species is provided in Table K.4 in Appendix K.

In the past, the identification and description of hydrobiid species was based on morphological differences. More recent studies by Ponder et al. (1995, 1996) have used electrophoretic data to assist with the identification and description of species.

As a result of these recent assessments, the genetic diversity of hydrobiids in different spring groups has been recognised as being generally associated with the distance and isolation of spring groups from each other. In their recent study of the Lake Eyre supergroup hydrobiids, Ponder et al. (1995) showed that there were several morphologically uniform populations that contained considerable genetic variation and divergence because of their poor dispersal capabilities (also Colgan and Ponder 1994; Ponder 1994). These findings compare favourably with previous evidence that hydrobiids speciate readily when confined to isolated populations (cited in Ponder et al. 1995).

Ponder et al. (1995) also recorded that hydrobiids in smaller mound springs in the same spring group have greater genetic differentiation than those in larger mound springs within the same spring group. They suggest that larger springs may have greater colonisation mechanisms than those in smaller springs, therefore providing a greater gene pool, and that smaller springs may be the senescent stage of once large springs that now, because of reduced size, have a much-reduced gene pool.

Although their study surveyed ninety-six populations in thirty-two springs representing eighteen spring groups, only six populations were examined from the Hermit Hill spring complex. However, these were sufficient to show that there is considerable genetic divergence between some of the populations within the complex.

The survival of non-marine molluscs is threatened in many parts of the world owing to their restricted habitat and the threat of disturbance and destruction to these habitats (Ponder 1994). Arid zone hydrobiids inhabit very discontinuous habitats and, owing to their limited dispersal abilities, can be restricted to only one spring or a few adjacent springs. Therefore, habitat destruction could lead to rapid extinction.

To summarise, the recent assessments and analysis conducted by Ponder et al. (1995; 1996) support the findings of previous reports (Ponder 1986; Ponder et al. 1989) by confirming that hydrobiids are an ecologically significant and diverse invertebrate group that are potentially under threat from some artesian water and pastoral management strategies.

Ostracods

Ostracods (Cyprididae) have been recorded in seventy-four spring groups within the Lake Eyre supergroup, and have also been recorded in one spring group within the Lake Frome supergroup. *N. dirga* is a small (1.5 mm long), green-grey bivalve crustacean that can occur in mound springs in very high numbers, and was first identified in springs and spring seeps in the Strangways–Curdimurka area, south-west of Lake Eyre (De Deckker 1979). Two other species of ostracods were identified in temporary pools and mound springs in the same area; however, *N. dirga* is the most commonly and widely distributed species (De Deckker 1979; Mitchell 1985).

Preliminary genetic analysis by M. Adams (South Australian Museum, pers. comm., December 1996) reports genetic differences between ostracod populations in some adjacent springs and that moderate to high levels of genetic diversity are present in populations. Additional work is required to determine the number of species.

Ostrocods are generally recorded in springs with a continuous flow of water that flows into a well-formed tail and a dense cover of vegetation. Ostracods are most commonly present in springs with little or no stock or pest animal damage; however, they are occasionally recorded in extensively damaged springs.

Amphipods

A species of amphipod that has not been formally described and is referred to as *Austrochiltonia* sp. (Hyalellidae) has been recorded in forty-one spring groups within the Lake Eyre supergroup and similar species are also known from the Dalhousie and Barcaldine (Edgbaston Springs in Queensland) supergroups.

An additional species *(Phreatochiltonia anophthalma)* has also been recorded at springs within the region of Dalhousie Springs in South Australia, and in interstitial waters in the Flinders Ranges (W. Williams, University of Adelaide, pers. comm., April 1997).

Amphipods are common throughout southern Australia, but are confined to mound springs in arid Australia, with their northern limit being in the region of Dalhousie Springs in South Australia (Zeidler 1989). Genetic analysis of several amphipod populations has identified at least three separate species of amphipod, although additional species are expected to be identified following further surveys and analysis (M. Adams, South Australian Museum, pers. comm., December 1996). Amphipods are generally found in springs with continuously flowing water and a well-formed tail. Unpublished data indicate that the presence of stock and pest animal damage does not generally limit their presence.

Isopods

The aquatic isopod *Phreatomerus latipes* (Amphisopidae) is a common invertebrate recorded at forty-six spring groups within the Lake Eyre supergroup. This species belongs to a very ancient group of crustaceans that have fossilised remains dating back 120 million years (Wells et al. 1984). The aquatic isopods of the Lake Eyre supergroup are scientifically significant owing to their isolation from southern Australian species.

This species is generally found in springs that have a continual flow of water into a well-formed tail and a dense cover of sedge vegetation. Adult isopods appear to prefer the shallow and slow flowing water towards the end and margins of the spring tail, whereas juveniles appear to prefer the faster flowing water nearer the spring vent (Kinhill Stearns 1984).

M. Adams (South Australian Museum, pers. comm., December 1996) indicates that electrophoretic analyses show that populations of this species are relatively homogeneous, but there are sufficient differences between some populations to warrant a more detailed genetic study.

Unpublished data indicate that stock and pest animal damage to springs appears to have an adverse affect on the presence of isopods, although they have been recorded in extensively damaged springs.

7.4.11 Review of past impact predictions—mound springs invertebrate fauna

The impact of project-related extraction of Great Artesian Basin water on the invertebrate fauna of the mound springs was predicted in Kinhill Stearns (1984) and updated in Kinhill Engineers (1995). The major potential impact identified in these references was the possible reduction in mound spring water discharge rates due to aquifer drawdown, leading to a reduction in the available habitat.

Monitoring of the mound springs fauna has been undertaken since 1986 and monitoring data have been reported annually in the WMC EMMP Annual Reports. Eighteen individual springs in ten spring groups in the Lake Eyre supergroup are currently monitored.

Several spring groups included in the mound spring invertebrate fauna monitoring programme (MSFMP) were predicted to experience impacts associated with increased drawdown and decreased discharge rates owing to operation of Borefield A (Kinhill Stearns 1984), whereas others were predicted to experience no impacts. Kinhill Engineers (1995) discusses the actual impacts of the project and provides further predictions in relation to the operation of Borefields A and B.

The MSFMP data reviewed and analysed by Walker (1996) identified an overall downward trend in the population abundance of all four endemic invertebrate fauna groups since the inception of the programme in 1986, including springs with little or no change in water flow. Quantification of this overall decline was not possible owing to the erratic nature of the data, and direct association between this decline and drawdown influences could not be identified. Potential causes could include variations in habitat and spring water flow owing to drought, floods, season, vegetation changes and damage by cattle or pest animals.

Table 7.18 provides a comparison of predicted and actual impacts on the spring groups in the MSFMP and incorporates results of the MSFMP population abundance data analysis.

After data review and analysis of MSFMP data during the preparation of Kinhill Engineers (1995) and this EIS (Walker 1996), the following observations were made:

- Results were erratic, particularly due to seasonal changes.
- Significant disturbances occurred in the population density of mound springs fauna during 1991–92 and 1994.
- Trends in mound springs fauna population abundance are generally downward and apparently independent of flow.

Downward trends in the population density of mound springs in the MSFMP were also identified in Kinhill Engineers (1994a), particularly in springs HBO004 (Bopeechee group), HHS029 and HHS125, formerly recorded as HHS130A (Hermit group), HOF004 and HOF033 (Old Finniss group), and HOW009 (Old Woman group).

Springs and the endemic mound springs fauna that inhabit them are thought to respond to a range of environmental stimuli and conditions, such as vent plugging by vegetation, seasonal change, drought, flood, stock and pest animal damage, and drawdown. Hence, the downward trends identified by Walker (1996) and Kinhill Engineers (1994a) cannot be attributed to one particular factor.

It is apparent, however, that flow reductions at spring groups predicted to have significant impacts (Venable and Priscilla), and also at Bopeechee spring group, have caused a reduction in the available preferred habitat for endemic fauna and subsequent declines in the population density of these fauna.

Table 7.18 Predicted and actual impacts on MSFMP spring groups (Lake Eyre supergroup) and observed impacts on endemic mound springs fauna

Spring complex	Spring group	Flow change		Observed change in endemic fauna
		Predicted[1]	Actual	
Hermit Hill	Venable (bore)	Total (100%) flow reduction.	Total (100%) flow reduction at HVS001 (extinct May 1990)[2].	Total loss of all endemic fauna by 1991.
Lake Eyre	Priscilla	Significant (60–75%) flow reduction.	Total (100%) flow reduction at LPS001 (extinct late 1990)[2].	Total loss of all endemic fauna by 1988.
Hermit Hill	Bopeechee	Moderate (20–30%) flow reduction.	Significant (43%) flow reduction at HBO004[2]; significant downward trend in flow at HBO011; significant (approximately 80%) flow reduction at nearby Bopeechee Bore[3].	Spring HBO004—decline in all endemic fauna.
	Dead Boy	Minor (10–17%) flow reduction.	No observable trend in flow at HDB005.	Spring HDB005—decline in all endemic fauna.
	Sulphuric	Minor (8–15%) flow reduction.	Insufficient data to recognise trends for HSS000; no observable trend in flow at HSS011; negligible downward trend in flow at HSS012.	Springs HSS000 and HSS012— decline in all endemic fauna.
	West Finniss	Minor (10–13%) flow reduction.	Data not available for springs HWF026 and HWF029; insufficient data to recognise trends for HWF003 and HWF048; moderate (approximately 20%) reduction in artesian pressure at nearby HH2 bore.	Spring HWF026—decline in all endemic fauna. Spring HWF029—decline in all endemic fauna.
Lake Eyre	Gosse	Very minor (<5%) flow reduction.	Data not available for spring LGS004; no observable trend in flow at LGS002; insufficient data to recognise trends for Gosse Bore[3].	Spring LGS004— only ostracods present, insufficient data to analyse trends.
Hermit Hill	Hermit Springs	Very minor (<5%) flow reduction.	Slight upward trend in flow at HHS028; insufficient data to recognise trends for HHS035, HHS101 and HHS125; slight downward trend in flow at HHS137; moderate (36%) flow reduction at HHS170[2]; negligible change in Great Artesian Basin water-level at nearby HH4 bore[3].	Spring HHS029—decline in all endemic fauna. Spring HHS035—increase in hydrobiids, no observable trends with other endemic fauna. Spring HHS101—total decline in all endemic fauna due to the cessation of water flow by 1995. Spring HHS125—decline in all endemic fauna. Spring HHS137—insufficient data to analyse.

Table 7.18 Predicted and actual impacts on MSFMP spring groups (Lake Eyre supergroup) and observed impacts on endemic mound springs fauna (continued)

Spring complex	Spring group	Flow change		Observed change in endemic fauna
		Predicted[1]	Actual	
	Old Woman	Very minor (<3%) flow reduction.	No observable trend in flows at HOW009 and HOW015; insufficient data to recognise trends for HOW025; negligible change in Great Artesian Basin water-level at nearby HH3 bore.	Spring HOW009—decline in all endemic fauna. Spring HOW015—decline in all endemic fauna.
	Old Finniss	Very minor (<2%) flow reduction.	Insufficient data to recognise trends for HOF004 and HOF033; moderate downward trend in flow at HOF081; marginal increase at HOF096[2]; negligible change in Great Artesian Basin water-level at nearby HH1 bore[3].	Spring HOF004—decline in all endemic fauna. Spring HOF092—decline in all endemic fauna.
Wangianna	Davenport	Very minor (<1%) flow reduction.	Virtually zero reduction at WDS001[2].	Spring WDS001—decline in all endemic fauna.

1 *Adapted from Kinhill Stearns 1984.*

2 *Denotes information obtained from Kinhill Engineers 1995.*

3 *Denotes information obtained from AGC Woodward – Clyde 1996.*

7.4.12 Mound springs monitoring

As the mound springs may be impacted by water extraction, the Indenture requires WMC to maintain a monitoring system approved by the State Government, and to provide results of the monitoring programme in the annual report of its EMMP. Comprehensive monitoring programmes to monitor and detect any project-induced changes in mound springs vegetation, aquatic fauna, flow rates and water chemistry have been developed and implemented by WMC and its consultants.

WMC's monitoring programme is detailed in the EMMP 1996 (WMC—Olympic Dam Corporation 1996a). The EMMP is reviewed every three years by WMC and the State Government, which recommends improvements where necessary.

7.4.13 Expansion Project impacts—predictions and mitigation

This section discusses the predicted impacts on mound springs vegetation and fauna as a result of the Expansion Project and the associated additional water abstraction from the Great Artesian Basin.

A summary of these impacts is provided in Table 7.19. In general, the predicted impacts are positive; that is, either little reduction, or enhanced flow.

Table 7.19 Predicted impact of Expansion Project on mound springs

Hydrological zone/spring group	Predicted % change in flow 1996–2016[1]	Predicted impacts to mound springs vegetation	Predicted impacts to mound springs fauna
BOREFIELD A ZONE			
Beatrice Jacob[2]	100% increase in flow expected.	Moderate increase in wetland area; possible colonisation of additional wetland species as available habitat increases and propagules are transported by fauna (particularly birds.	Predicted increase in flow rate and associated greater wetland area, therefore opportunities for invertebrates to increase in numbers or be reintroduced.
Fred Venable	Significant increase in subsurface water-level and pressure expected.	Potential increase in surface flow leading to potential increase in wetland area and possible colonisation of additional wetland species.	Potential opportunities for reintroduction of vertebrate and invertebrate fauna.
Priscilla[2]	n.d.	No change expected.	No change expected.
NORTH-EASTERN SUB-BASIN			
Bopeechee	Up to 17% increase in flow in 1997 and 1998 followed by gradual decline, resulting in overall small increase of 2%.	Minor increase in wetland area and potential increase in species diversity and richness as additional species re-establish as a result of increases in flow in 1997 and 1998. Wetland area and species diversity and richness may decline in the long term from a peak in 1997–98 owing to gradual decline in spring flow. Long-term impacts expected to be insignificant.	Predicted increase in flow rate and associated greater wetland area, therefore opportunities for invertebrates to increase in numbers or be reintroduced. Long-term impacts expected to be insignificant.
Sulphuric Dead Boy	Up to 13% increase in flow in 1997 and 1998 followed by gradual decline, resulting in overall decline of less than 1%.	Moderate increase in wetland area and potential increase in species diversity and richness as additional species re-establish resulting from increases in flow in 1997 and 1998. Wetland area and species diversity and richness may decline in the long term from a peak in 1997–98 owing to gradual decline in spring flow. Long-term impacts expected to be insignificant.	Potential opportunities for existing fauna population numbers to increase and for introduction of additional vertebrate and invertebrate fauna in the short term. Long-term impacts expected to be insignificant.
West Finniss	Up to 5% increase in flow in 1997 and 1998 followed by a gradual decline, resulting in an overall decline of 1%.	Potential minor increase in wetland area. Overall insignificant impacts to wetland area and species diversity and richness.	Minor increase in the opportunity for additional vertebrate and invertebrate fauna to establish. Long-term impacts expected to be insignificant.
WESTERN LAKE EYRE SOUTH GROUP[3]			
Centre Island Emerald Gosse	Up to 6% increase in flow in 1998 and 1999 followed by a gradual decline, but resulting in an overall small increase of up to 0.5%.	Potential minor increase in wetland area. Overall insignificant impacts to wetland area and species diversity and richness.	Minor increase in the opportunity for additional vertebrate and invertebrate fauna to establish. Long-term impacts expected to be insignificant.
Long Island	As above to 1999, thereafter overall decline of 1.5%.		
McLachlan	Large increase in flow in 1998 and 1999 (up to 18%) followed by gradual decline, but resulting in an overall increase of 12.5%.	Increase in wetland area and possible re-establishment of additional wetland species, therefore increasing species diversity and richness. Minor changes overall to wetland vegetation.	Predicted increase in flow rate and associated greater wetland area, therefore opportunities for invertebrates to increase in numbers or be reintroduced.

Table 7.19 Predicted impact of Expansion Project on mound springs (continued)

Hydrological zone/spring group	Predicted % change in flow 1996–2016[1]	Predicted impacts to mound springs vegetation	Predicted impacts to mound springs fauna
SOUTHERN MARGIN EASTERN ZONE			
Davenport Welcome	3–4.5% decline.	Overall insignificant impacts to wetland area and species diversity and richness.	Insignificant impacts to existing fauna population numbers and colonisation opportunities.
Wangianna	16.5% decline.	Moderate to minor decline in wetland area of larger spring; drying out and loss of some wetland vegetation at small vents.	Potential decline in existing fauna population numbers.
Hergott	6% decline.	Potential minor decrease in wetland area. Insignificant impacts. Colonisation opportunities for additional species, particularly rare and endangered species, may be limited.	Minor to insignificant impacts on population numbers of existing fauna and colonisation/re-establishment opportunities.
SOUTHERN MARGIN WESTERN ZONE			
Smith	Large increase in flow from 1997 to 1999 followed by overall decline of 1.75% in flow in 2016.	Some increase in wetland area and potential increase in species diversity and richness as additional species re-establish as a result of flow increases in 1997 and 1998. Wetland area and species diversity and richness may decline from a peak in 1997–98 in the long term owing to gradual decline in spring flow. Long-term impacts expected to be insignificant.	Potential opportunities for existing fauna population numbers to increase and introduction of vertebrate and invertebrate fauna in the short term. Long-terms impacts expected to be insignificant.
Hermit Hill	Up to 1% decline.	Insignificant impacts to wetland area, or species diversity or richness.	Insignificant impacts on existing fauna population numbers and colonisation opportunities.
Old Finniss Old Woman Northwest	1% decline 0.5% decline. n.d.		
Pigeon Hill	n.d.	Wetland vegetation associated with artesian springs not present at this spring group.	Insignificant impacts on existing non-endemic fauna population numbers and colonisation opportunities.
CURDIMURKA–STRANGWAYS ZONE		No impacts expected owing to distance of springs from borefields.	No impacts expected owing to distance of springs from borefields.
Horse[2]	n.d.		
Anna[2]	n.d.		
Blanche Cup[2]	n.d.		
Strangways[2]	n.d.		

1 *Values are approximate (WMC Resources 1997).*
2 *Spring groups outside the ODEX1 domain (WMC Resources 1997).*
3 *Hydrobiids, amphipods and isopods are naturally absent from all springs in the Western Lake Eyre South Group.*
n.d. No data available.

Mound springs vegetation

The overall adverse impacts of the Expansion Project (and additional water abstraction) on the mound springs vegetation are predicted to be nil or minimal, as predicted water abstraction has been kept to a minimum and it is planned that the greater proportion of water is to be drawn from Borefield B which is distant from the environmentally sensitive mound springs groups.

The greatest positive impacts are predicted to occur at those spring groups located in close proximity to Borefield A. Reduced abstraction of water from this borefield is expected to increase subsurface water pressure, thereby increasing the flow rate at those springs that have been, or may have been, impacted by abstraction. In addition, spring groups that have ceased flowing due to high levels of water abstraction from Borefield A may recommence flowing. These positive impacts are expected to increase the overall wetland area of some, and possibly all, springs and increase the opportunity for the colonisation or re-establishment of wetland vegetation species, including rare or significant species (such as bare twigrush and cutting grass) and the endangered salt pipewort.

Minor to moderate negative impacts are predicted for spring groups that are located in close proximity to Borefield B (southern margin eastern hydrological zone). The greatest impact is predicted to occur at Wangianna spring group. Wangianna spring group comprises two to three spring vents with very little wetland vegetation and several extinct mounds. The main spring, Wangianna Spring, has been highly modified and a well has been dug into the main spring vent. The wetland vegetation at this spring group lacks the endemic and relict plant species of special conservation significance that are present at spring groups such as Hermit Hill (Kinhill Engineers 1995). The wetland vegetation at the three other spring groups within this hydrological zone (Welcome, Davenport and Hergott) is also considered of low conservation value owing to low species diversity and the absence of species, or suites of species, of conservation significance.

These predicted impacts are expected to be assessed as part of the ongoing mound springs vegetation monitoring programme. Additional research on the ecology of salt pipewort, which is being undertaken by WMC environmental personnel, is expected to assist with understanding the reproductive and dispersal characteristics of this species. The scope for further research on mound springs vegetation is outlined in Section 15.1 and includes research on the potential use of remote sensing and GIS technology in assessing mound springs vegetated wetland areas and conditions, predictive modelling of drawdown impacts, and ongoing field monitoring.

Mound springs fauna

The overall impacts on mound springs fauna are also expected to be minimal. The predicted increase in flow rates and associated wetland area at spring groups in close proximity to Borefield A is expected to increase the availability of preferred fauna habitats. This increase in available habitat will provide the opportunity for existing fauna to increase in population numbers and for additional species to colonise. In addition, the opportunity for dispersal of vegetation and microfauna, particularly endemic invertebrates, within and between spring groups (and subsequent genetic mixing) may increase if the presence of 'carrier' species (e.g. birds) increases.

Table 7.20 provides details of the endemic invertebrate mound springs fauna recorded at spring groups within the southern margin eastern hydrological zone.

Table 7.20 Endemic invertebrate fauna recorded at spring groups within the southern margin eastern hydrological zone

Fauna group	Wangianna	Welcome	Hergott	Davenport
Hydrobiid				
Fonscochlea	Not present	Common	Not present	Common
Trochidrobia	Not present	Common	Not present	Common
Ostracod	Not common	Common	Not common	Common
Amphipod	Not present	Common	Not present	Common
Isopod	Not present	Common	Not present	Common

The negative impacts predicted at springs within this hydrological zone, particularly Wangianna and Hergott spring groups, are expected to have minimal impacts on endemic mound springs fauna. Both these spring groups have been highly modified and have a very low occurrence to absence of mound springs fauna, particularly endemic invertebrate fauna.

Davenport and Welcome spring groups, which are predicted to experience a reduced water flow of 3% and 4.5% respectively, provide habitat for birds, spiders and endemic invertebrate fauna; however, the small reduction in flow is expected to have minimal impact on these fauna groups.

Monitoring of mound springs fauna has been ongoing since 1986. The monitoring programme assesses the presence and abundance of endemic mound springs invertebrate fauna and the species diversity of wetland invertebrate fauna. A full description of the monitoring programme is provided in Kinhill Engineers (1994b and 1996). This monitoring will continue and, where possible, be expanded to incorporate research on species confined to the mound springs and the monitoring of additional species, including spiders. Further details on future monitoring and research are provided in Section 15.1.

CHAPTER 8

TAILINGS MANAGEMENT

CHAPTER 8 TAILINGS MANAGEMENT

This chapter considers the management of tailings for the proposed future operations at Olympic Dam. A brief description of the existing facilities is provided, including the chemical composition and observed physical properties and behaviour of the tailings. Also described are the two options of tailings management being considered—continuation of the existing paddock method or introduction of a new option, central thickened discharge. The discussion of environmental management focuses on hydrology, particularly the containment of tailings liquor. The chapter concludes with an overview of proposals for the eventual decommissioning and rehabilitation of the tailings management system, which are described in greater detail in Chapter 14.

8.1 OVERVIEW OF EXISTING FACILITIES

8.1.1 Description

The relationship of the principal components of the existing tailings management system at Olympic Dam is shown in Figure 8.1 and described below.

Tailings from the uranium extraction process are produced at the process plant as underflow from the countercurrent decantation (CCD) thickeners. Part of the thickener underflow can be directed to the tailings deslimes plant, where the sand (coarse) fraction is extracted by hydrocycloning for use in cemented aggregate fill (CAF) as underground mine fill.

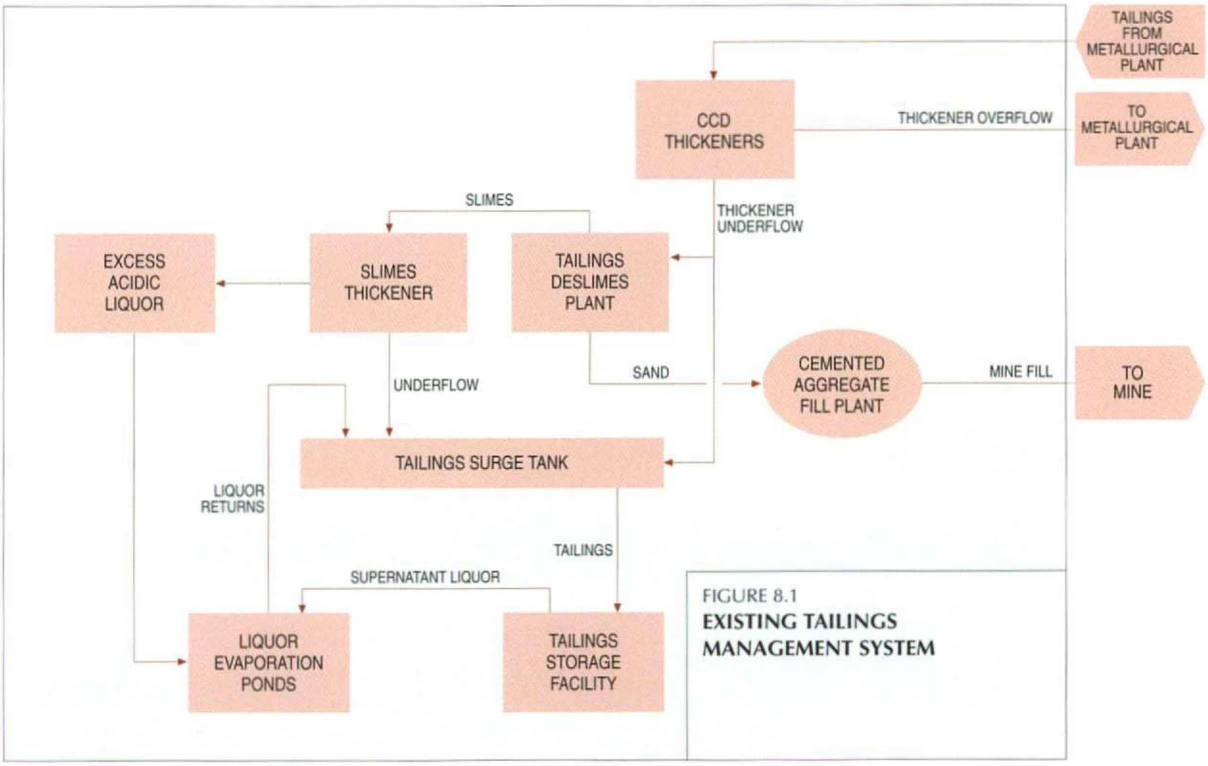


FIGURE 8.1
EXISTING TAILINGS MANAGEMENT SYSTEM

The cyclone overflow (slimes) is thickened in the slimes thickener, and the thickened underflow is combined with the remainder of the CCD underflow in the tailings surge tank. From there the tailings are pumped to the tailings storage cells via two tailings distribution pipelines, which are 300 mm diameter, high-density polyethylene (HDPE) lined steel pipelines, laid above-ground on concrete supports. The pipeline route is bunded for its entire length, with transverse bunds at regular intervals along the route to contain any spillage of tailings.

Excess acidic liquor from the slimes thickener passes to the liquor evaporation ponds together with other minor process waste streams. Supernatant liquor decanted from the tailings storage cells also passes to the evaporation ponds. A portion of the liquor is pumped from the evaporation ponds back to the tailings surge tank to reduce the build-up of salt in the ponds.

The present tailings production rate varies depending on whether or not the sand plant is in operation. The amount of tailings to be delivered to the tailings storage cells during 1996–97 is expected to be approximately 2.7 Mt.

The existing tailings retention system (TRS), shown in Figure 8.2 and described below, consists of the following:

- a paddock method tailings storage facility (TSF), which comprises three cells of approximately 190 ha total area, complete with tailings distribution pipelines and supernatant decant facilities;
- two liquor evaporation ponds, each divided into four cells with a combined evaporative area of 68 ha at a liquor depth of 1.5 m (50% of total depth) or 73 ha total area, which are used to dispose of supernatant tailings liquor and excess acidic process liquor by evaporation;
- an unlined mine water disposal pond, about 15 ha in area, used for disposal of excess groundwater pumped from the mine, partly by evaporation and partly by infiltration.

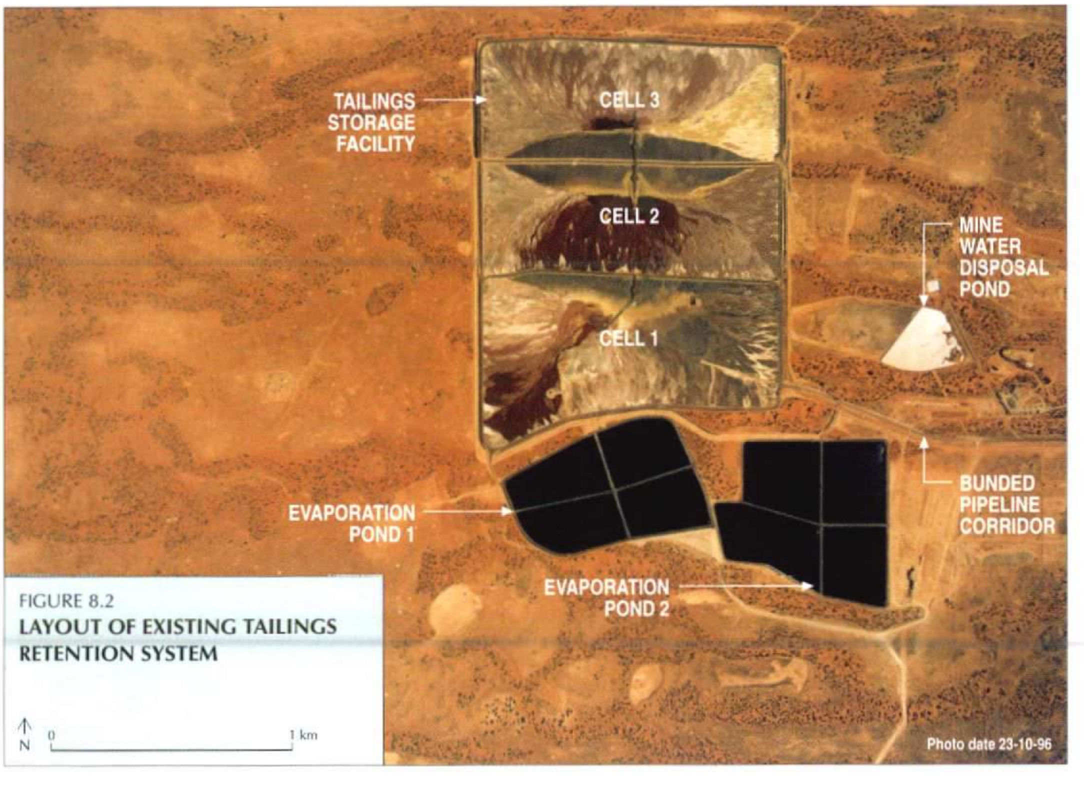


FIGURE 8.2
LAYOUT OF EXISTING TAILINGS RETENTION SYSTEM

The operation of the TRS was changed in 1994 and 1995 to its present arrangement. Previously the system comprised three tailings storage cells, a wash water evaporation pond and the mine water disposal pond. The system was modified in 1994 and 1995 to allow for:

- removal of tailings liquor from the top of the cells;
- evaporation of liquor and wash water in two separate, clay and HDPE-lined evaporation ponds. The wash water evaporation pond was decommissioned and the site remediated;
- increased groundwater monitoring using purpose-built monitoring bores.

These modifications were made to ensure minimum seepage from the tailings storage cells and the evaporation ponds. The modifications were completed in September 1995.

The remediation strategy did not provide for any change to the mine water disposal pond. It is considered that there are no environmental implications arising from seepage from the pond, as the mine water is the naturally occurring groundwater in the area. However, investigations into potential alternative sites have been undertaken, and construction of a new, larger mine water disposal pond at a new site is expected to be complete by the end of 1997.

The main components of the TRS are the TSF and the evaporation ponds. These are described below. Also discussed are the monitoring systems, observed effects and the Parliamentary inquiry conducted in 1995.

8.1.2 Tailings storage facility

The tailings are distributed and deposited in three tailings storage cells—cell 1, cell 2 and cell 3. Each cell is operated with its own decant arrangement. The perimeter walls of the cells were constructed using waste rock from the mine and locally quarried material. A 1 m thick clay inner facing minimises potential liquor migration through the walls. The outer face of the walls is protected from erosion by a 500 mm thick rock layer. The 8 m wide crest is presently at RL 110.5 m AHD which means that the height of the perimeter walls varies between approximately 6 m and 10 m above natural ground level. The perimeter wall is currently being raised by 3 m to increase the overall holding capacity of the TSF.

Tailings are deposited from outlets (spigots) spaced at 24 m intervals along a distribution pipe running along the perimeter walls. Generally, at any given time, the tailings are deposited from two sets of six spigots. A thin layer of tailings (approximately 100 mm thick) is deposited during each deposition cycle and allowed to dry for a period of about three to four weeks. The 100 mm thick layer reduces to about 60 mm during the drying process. The tailings are deposited in a slurry with a solids concentration of about 45–50% solids by weight. The tailings settle to form a beach, which has been observed to have an average slope of approximately 2% over the first 200 m and about 1% thereafter.

Field tests conducted on tailings deposited in cells 1, 2 and 3 indicate dry densities (weight of solids divided by volume of sample) of the order of 1.6–2.05 t/m^3, with an average of approximately 1.7–1.8 t/m^3. The moisture content of the tailings is approximately 20–25% by weight, which represents a pore saturation of 75–100%, with an average of about 90%.

8.1.3 Evaporation ponds

When the tailings beaches are fully established, supernatant liquor is collected in a central pond in each tailings cell and decanted via a decant tower to the liquor evaporation ponds. Until the tailings build up to a level that allows the liquor to flow into the decant tower, liquor is pumped to the ponds. All tailings supernatant liquor decanted from the cells, as well as excess acidic liquor from the process, are evaporated in the evaporation ponds EP1 (evaporative area at 50% pond depth of 31 ha) and EP2 (evaporative area at 50% pond depth of 37 ha).

A portion of the liquor from the evaporation ponds is returned to the tailings surge tank for combination with the tailings. This returned liquor then passes to the tailings storage cells, where some salts remain with the liquor within the pores of the tailings solids.

This process enables the concentration of dissolved salts in the evaporation ponds to be controlled, as excessively high levels would result in reduced evaporation rates and filling of the evaporation ponds with precipitates.

8.1.4 Management and monitoring systems

Management and monitoring systems for the existing TRS, described below, are well established and would be extended to cover the expanded facilities constructed as part of the Expansion Project.

Management of the TRS involves the collection of operational data, assessment of these data and planning for future development of the system. Management also involves operational staff checking the TRS several times a day, and making adjustments where necessary, including:

- checking the integrity of the piping
- checking the pump operation
- changing the location of operating (discharging) spigots
- checking the development of tailings beaches
- checking and adjusting the operation of the evaporation ponds.

The monitoring systems implemented as part of tailings management include measurement of:

- flow rates in the tailings delivery, supernatant liquor and acidic liquor pipelines to the evaporation ponds, and return liquor from the evaporation ponds to the tailings surge tank;
- liquid levels in the evaporation ponds;
- meteorological data, including evaporation and rainfall;
- groundwater quality and levels.

The flow rate, liquid level measurements and meteorological data are used in liquor balance calculations to monitor for any apparent loss of liquor. The current groundwater monitoring system at Olympic Dam is described in Section 4.6.

A liquor balance calculation is carried out and reported quarterly on each cell of each evaporation pond. The liquor balance includes:

- liquor inputs and outputs from flow measurements;
- estimates of evaporation, using measured meteorological data adjusted for the size of the pond and the salinity of the liquor;
- rainfall input from measured meteorological data;
- changes in volume stored by calculation from depth measurement.

The liquor balances for the evaporation ponds are based on data that can be accurately measured, and can be used to identify any loss of containment before the loss begins to have any environmental effects. In the event that loss of containment is detected by the liquor balance, the evaporation cell would be isolated, drained, cleared and inspected prior to any necessary repairs.

A liquor balance calculation is also undertaken for each cell of the TSF. However, these liquor balances require the estimation of a number of significant components and are therefore only used to provide an indication of any major discrepancies and long-term trends in the liquor balance. This liquor balance is reported every six months.

Senior officers of the South Australian Health Commission, the South Australian Department of Mines and Energy (MESA) and the Environment Protection Authority inspect the TRS every three months as part of the quarterly environmental radiation review. The reviews are accompanied by a report which outlines the operational and radiological issues associated with the system. An annual report is also issued to regulatory authorities, and outlines and summarises the results of the monitoring programme for the full year.

8.1.5 Observed effects on groundwater systems

As described in Section 4.6, the past operations at Olympic Dam have resulted in the formation of localised, elevated groundwater levels under the TRS. Such a localised elevation of groundwater is referred to as a groundwater mound. The formation of the groundwater mound has been attributed to seepage from the TRS. The elevated groundwater levels were subject to intensive investigation from 1993 to early 1994, and announced publicly in February 1994.

Investigations into the seepage, together with the greatly increased monitoring activities of WMC referred to above, indicated that there were at least three sources of the rise in groundwater levels—the tailings storage cells, the mine water disposal pond and the wash water evaporation pond. To date, it has not been possible to identify the relative contribution from these sources with any precision.

Recent groundwater monitoring results, described in Section 4.6, indicate that while groundwater levels beneath the tailings storage cells are currently decreasing, those under the mine water disposal pond are increasing. These results are consistent with the view that the pond has been a significant contributor to the seepage. Seepage from the mine water disposal pond is natural groundwater arising from drainage of the underground mine. This seepage essentially constitutes recirculation of this natural groundwater, with some concentration of the dissolved salts due to evaporation. Seepage from this pond therefore does not require control.

The groundwater monitoring results also indicate that the modifications made to the TSF have fulfilled the objective of ensuring minimum seepage from this facility. Relocation of the mine water disposal pond as part of the Expansion Project would remove the question of seepage from this facility affecting groundwater monitoring results for the TRS.

Ongoing groundwater sampling and analysis around the TSF area have confirmed that neutralisation of the acidic tailings liquor and attenuation of metals and radionuclides as predicted in the 1983 EIS do occur, and that the quality of seepage water after attenuation is similar to that of the naturally occurring groundwater of the area.

Geochemical studies (Environmental Geochemistry International 1995a, 1995b) show that the soils of the Olympic Dam area have considerable potential for acid neutralisation and attenuation of contaminants. This potential is indicated by the acid neutralising capacity (ANC) of the soils, which may be compared with the classification of low (less than 10 kg H_2SO_4/t), medium (10–50 kg H_2SO_4/t) or high (greater than 50 kg H_2SO_4/t). The ANC of the soil types under the TRS is indicated in Table 8.1 overleaf.

The results of laboratory geochemical tests (Environmental Geochemistry International 1995a) are also reproduced in Figure 8.3 (overleaf) as a plot of pH of leach liquor against the volume of tailings liquor (measured as pore volumes) used in the leach test.

Table 8.1 Acid neutralising capacity (ANC) of Olympic Dam soils

Soil type	ANC range (kg H_2SO_4/t)	ANC classification
Dune sand	2–4	low
Swale material	15–17	medium
Claypan material	9	low
Calcareous clay	139	high
Dolomite	975–1,041	high

Source: Environmental Geochemistry International 1995a.

Studies conducted on site confirm the results of the laboratory investigations. Although it is not possible to quantify the amount of acid liquor that may have passed through soils at any particular location, drill holes at the existing tailings storage cells showed that, within 1.5 m of the base of the tailings, the pH of the soils increased to 7. A pH of 7 is neutral, being neither acidic (pH below 7) nor alkaline (pH above 7).

Therefore, the test results indicate that the acidic tailings liquor was neutralised within 1.5 m of the base of the tailings. The test results also showed that radionuclides and metals were reduced to background levels within 1–2 m of the base of the tailings.

The conclusion from the results of all the investigations is that the TRS seepage has had no adverse impact on the environment or the health of employees or members of the public.

The reasons for this are:

- The seepage lies within the influence of the mine cone of depression, and therefore flows towards the mine. The Expansion Project would result in an increase in underground mining activities and a further increase in the area of the mine cone of depression.
- The naturally occurring groundwater is some 50 m below the surface.

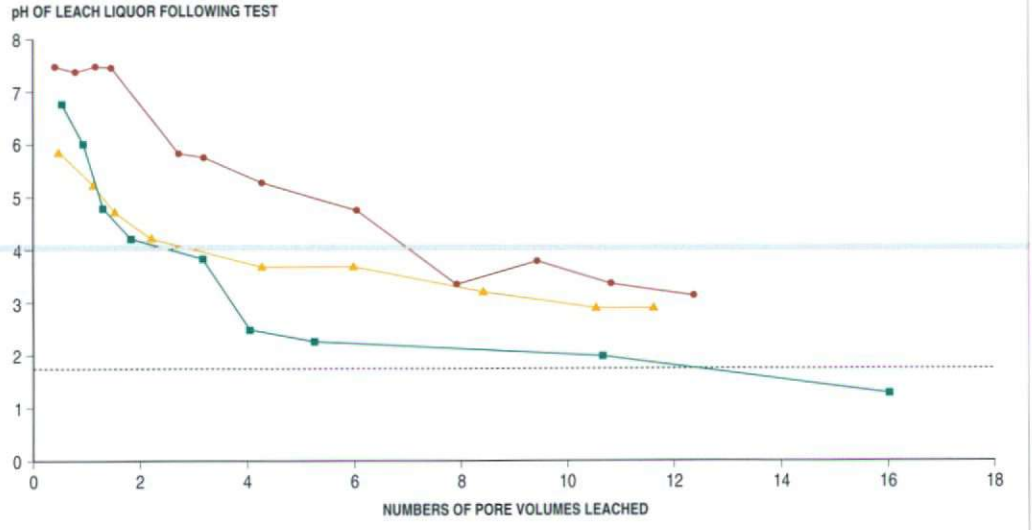


FIGURE 8.3
GEOCHEMICAL TEST RESULTS FOR NEUTRALISATION OF ACIDIC SEEPAGE

Source: Environmental Geochemistry International 1995a

- The naturally occurring groundwater is of extremely poor quality, being more salty than sea water, and cannot be consumed by humans or animals or used for irrigation. Shallow and deep groundwater in the area also contains detectable background levels of metals, including uranium and radium (Kinhill – Stearns Roger 1982).
- Metals and radionuclides in the seepage water are attenuated or filtered out at the base of the TRS.
- Any seepage from the mine water disposal pond is considered to have a very low potential for environmental impact, as any seepage would recycle natural groundwater in the area.

It is also evident that the remedial measures undertaken in 1994 and 1995 are becoming effective. This aspect is discussed further in Section 4.6.

8.1.6 Environment, Resources and Development Committee inquiry (Parliament of South Australia)

The seepage of water from the TRS was also the subject of an inquiry by the Environment, Resources and Development Committee of the Parliament of South Australia. The inquiry was conducted in 1995 and the findings and recommendations were contained in a report dated April 1996 (South Australia, Parliament 1996).

The committee's findings with regard to the probable cause of the seepages are contained in the following extract from its report:

> The Committee finds that the leakage at Roxby Downs has probably resulted from:
>
> - long-term leakage from the unlined mine water evaporation pond;
> - long-term leakage from the unlined washwater evaporation pond, exacerbated by the presence of dolines in the pond;
> - sustained ponding of supernatant liquor over sections of the tailings storage cells;
> - direct contact between the tailings liquor and the floor of the tailings storage cells, particularly in the period immediately after the breaching of a temporary bund in Cells 2 and 3 when liquor flowed onto the bare surface of the cells.

The committee's findings with regard to the possible effects of the seepages included the following:

> The Committee finds that, on the basis of current evidence, there have been no harmful effects to employees, the local community or the environment arising out of the leakage from the tailings retention system at Olympic Dam and that it is highly unlikely that any such harmful effects will emerge in the future.

In addition to the above findings, the committee made a number of other findings relating to the design, operation and monitoring of the original TRS. These are not discussed further here because they have been addressed by the changes that were made to the operation of the original TRS (Section 8.1.1).

The committee made seventeen recommendations regarding ongoing and future operations at Olympic Dam. These recommendations are listed in Table 8.2 with a summary of the implications for the Expansion Project. Some of the recommendations, relating to the actions of Ministers and government authorities, are referred to in the table as matters for government.

Table 8.2 Implications of recommendations made by the Environment, Resources and Development Committee (Parliament of South Australia)

Recommendation	Implications for the Expansion Project
RECOMMENDATION 1 The Committee recommends that, in granting future approvals, the Minister for Mines and Energy should ensure that future tailings storage cells and evaporation ponds at Olympic Dam are located where soil cover is greater than in the existing tailings retention system.	The land available for the TRS expansion is constrained by the following factors: • areas of Aboriginal significance to the south and east of the existing TRS; • the location of the Special Mining Lease boundary to the west; • improved management resulting from containing TRS activities in one area. Because of these constraints it is not always possible to locate future facilities in areas of greater soil cover, hence engineering solutions involving good base preparation for tailings storage cells and composite lining systems for evaporation ponds have been developed for use in future.
RECOMMENDATION 2 The Committee recommends that the Olympic Dam operators continue their search for an effective method of locating small solution cavities and sub-surface weaknesses at Olympic Dam.	Research into this area has been intensive and is continuing. Current practices are considered to be the best available and involve: • examination of aerial photography • test pits and boreholes • electromagnetic surveys • proof rolling of the floor area. Proof rolling involves a number of passes with a heavy roller and subsequent inspection for any weaknesses in the foundations.
RECOMMENDATION 3 The Committee recommends that the Olympic Dam operators continue to record and research the behaviour of supernatant ponds in the existing storages in order to improve understanding of their impact on the environment.	Included as part of the existing monitoring programmes.
RECOMMENDATION 4 The Committee recommends that requests for approval for future developments at Olympic Dam beyond those considered in the course of the recent public Environmental Review should be made in a similarly public manner.	Public review is provided by this EIS.
RECOMMENDATION 5 The Committee recommends that, as with the recent Olympic Dam Environmental Review, future reviews should be carried out in accordance with guidelines issued by the Minister for Mines and Energy, which should be developed by the Minister following consultation with relevant agencies.	This EIS is prepared in accordance with guidelines (Appendix B) jointly issued by the South Australian Department of Housing and Urban Development and the Commonwealth's Environment Protection Group.
RECOMMENDATION 6 The Committee recommends that all aspects of the Olympic Dam tailings retention system should be separately managed and supervised by staff fully acquainted with the principles and details of the system's design and in consultation with those responsible for that design.	This recommendation has been fulfilled by WMC. The TRS is managed by competent staff, who are trained in the correct operation of the TRS and have access to expertise in tailings management and groundwater monitoring and modelling.

Table 8.2 Implications of recommendations made by the Environment, Resources and Development Committee (Parliament of South Australia) (continued)

Recommendation	Implications for the Expansion Project
RECOMMENDATION 7	
The Committee recommends that the Olympic Dam operators install sufficient, appropriately designed groundwater monitoring bores in and around the area of any proposed expansion of the tailings retention system to provide a proper range of background data about the impact of the proposed expansion.	Has been implemented for existing facilities. Would be implemented for the proposed expansion, including the monitoring of background data prior to construction.
RECOMMENDATION 8	
The Committee recommends that the Olympic Dam operators consider the installation of leakage detection equipment beneath the system's evaporation ponds as envisaged in its original design.	A range of leakage detection systems were evaluated, including that recommended by the Committee. The system adopted provides leakage detection by a combination of: • groundwater monitoring • water balance calculations. The leakage detection system using water balance calculations received a commendation in 1996 in the Engineering Excellence Awards of the Institution of Engineers, Australia. The same system would continue to be used in the expansion of the evaporation ponds.
RECOMMENDATION 9	
The Committee recommends that the Olympic Dam operators continue their search for a complete scientific understanding of the source of the leakage and of the hydrogeological flow patterns beneath the tailings retention system and, in particular that they consider the necessity for additional chemical analyses of water samples taken from beneath the system to enable the source and flow pattern of any leaked water to be better understood.	The monitoring programme is ongoing, and is under continual review. The programme provides adequate relevant information necessary for understanding the hydrogeology of the TRS and behaviour of the groundwater mound. Relocation of the mine water disposal pond will simplify the interpretation of monitoring results from the TRS area.
RECOMMENDATION 10	
The Committee recommends that the Minister for Health continues to ensure that national and state statutory radiation protection standards are consistent with the latest international standards and that they are rigorously enforced at Olympic Dam and elsewhere in the state to protect workers and the community.	Matter for government. However, the Indenture requires application of current national standards. The Committee's recommendation is also consistent with stated WMC policies (Chapter 1).
RECOMMENDATION 11	
The Committee recommends that the operators be encouraged to continue their commitment to improving their environmental management of Olympic Dam operations and that government agencies commit themselves to establishing environmental goals and overseeing their attainment while leaving the prime responsibility for day to day environmental management to the operators.	The first part of the recommendation is consistent with stated WMC policies (Chapter 1). The second part is a matter for government.
RECOMMENDATION 12	
The Committee recommends that the state government continues to support acceptable environmental outcomes at Olympic Dam by providing expert technical advice and assistance to the operators and that the expertise and experience of relevant Commonwealth agencies be called upon whenever necessary.	Matter for government.

Table 8.2 Implications of recommendations made by the Environment, Resources and Development Committee (Parliament of South Australia) (continued)

Recommendation	Implications for the Expansion Project
RECOMMENDATION 13	
The Committee recommends that the Minister for Mines and Energy reviews any statutory and practical impediments to the free flow of information about the environmental impact of Olympic Dam operations with a view to ensuring that all relevant information is freely available to interested members of the public.	Matter for government. However, it should be noted that the triennial Environmental Management and Monitoring Plan (EMMP), the Annual Environmental Management Report and the Annual Environmental Radiation Report have been made publicly available since 1991. Other information is made available in published brochures, and in WMC's annual Environment Progress Report.
RECOMMENDATION 14	
The Committee recommends that the Minister for Mines and Energy consult with the Olympic Dam operators, other relevant state and Commonwealth agencies and other interested bodies with a view to providing a forum for information exchange and policy consultation among interest groups on the effect of operations at Olympic Dam on the environment.	Matter for government. WMC is willing to consult with the Minister. It should be noted that WMC currently submits annual reports on the EMMP to the Minister, which MESA makes available to the public for the cost of reproduction. WMC also publishes an annual Environment Progress Report, and other brochures, which are freely available. Olympic Dam periodically holds open days for the public to visit the site.
RECOMMENDATION 15	
The Committee recommends that the Minister for Mines and Energy and the Minister of Environment and Natural Resources consult with the Olympic Dam operators and relevant government agencies with a view to establishing a system of periodic, independent, external, environmental audit arrangements in relation to Olympic Dam operations	WMC has implemented an external annual audit of the EMMP environmental monitoring process. This is in addition to periodic audits conducted by WMC's Corporate Environmental Group.
RECOMMENDATION 16	
The Committee recommends that the Minister of Mines and Energy encourages the Olympic Dam operators and agencies involved in monitoring activities at Olympic Dam to continue to publish the results of their monitoring and longer term research and to continue to contribute to the growing pool of knowledge about the environmental impacts of mining and, in particular, uranium mining.	WMC is a major contributor to the growth in knowledge of the Olympic Dam region. This information is documented extensively in public reports and information brochures. Refer also to Chapter 7, and to Chapter 15 for an overview of environmental monitoring and research by WMC staff in the Olympic Dam region. WMC staff regularly publish papers in professional journals.
RECOMMENDATION 17	
The Committee recommends that the state government continues to work with other governments, specialist research institutions and the mining industry to promote strategic research into environmental management and, in particular, research into the design, operation and rehabilitation of tailings retention systems.	Matter for government. However, it should be noted that there is considerable research into the design, operation and rehabilitation of tailings systems by the mining industry. In particular, the Australian Centre for Geomechanics, based in Perth, is a centre of excellence in this field, and regularly holds conferences and workshops.

8.2 CHARACTERISTICS OF TAILINGS

8.2.1 Rate of production

The rate at which tailings require disposal in the TRS is a function of the quantity of ore milled and the proportion of the sand fraction that is used as mine backfill. Table 8.3 provides a summary of the tailings quantities that would report to the TRS following the Expansion Project. Currently, about 4% of the tailings produced is used in mine backfilling. The objective for the Expansion Project is to increase this proportion to approximately 20%, and this figure has been used in the table.

Table 8.3 Approximate rates of tailings production

Copper production (t/a)	Mining rate (Mt/a)	Sand backfill (Mt/a)	Tailings reporting to TRS (Mt/a)
85,000 (existing)	3.0	0.1	2.7
200,000	9.0[1]	1.7	6.6[2]
350,000	17.0	3.1	12.5

1 *Can vary up to 9.25 Mt/a.*
2 *Can increase to 6.8 Mt/a.*

8.2.2 Physical characteristics

The metallurgical treatment process would essentially remain unchanged following the expansion, and hence the physical and chemical characteristics of the tailings following expansion can be determined reliably by testing the existing tailings. Laboratory measurements of the physical characteristics of the tailings, together with field experience to date, have been used to predict the performance of the TRS.

The following physical characteristics have been determined under laboratory conditions for the tailings:

- classification (particle size and density)
- sedimentation (drained and undrained)
- air-dried density
- consolidation and permeability.

A brief description of each characteristic is given below.

Classification

Classification tests have indicated that the tailings particles have a density of 3.2–3.6 t/m^3.

The particle size distribution indicates that, prior to sand removal, the tailings comprise 19% sand-sized, 76% silt-sized and 5% clay-sized material. The tailings also comprise approximately 50% medium-sized silt, with a minor tendency for the silt and clay particles to aggregate. Aggregation of particles results in the tailings settling slightly more rapidly than would be expected from the particle sizes.

Sedimentation

Drained and undrained sedimentation tests were carried out to determine the settling rate, volume of water release on deposition, and settled dry density of the tailings following deposition. The undrained tests showed a water release of 46% of the initial water volume, and the drained tests showed a water release of 62%.

The tests showed that drainage increases the average settled dry density of the tailings by approximately 25–30%.

Air-dried density

Air-drying tests were carried out on tailings samples to determine the effect of air drying after initial settling and removal of supernatant liquor, thereby simulating conditions expected following subaerial deposition. The air-drying tests showed that an absolute relationship between dry density and moisture content exists at moisture contents above 100% saturation. Below saturation, negative pressures develop in the liquid and these further consolidate the tailings. Drying below a limiting moisture content produces no further consolidation, and the density at this point represents the maximum that can be achieved by air drying of the tailings.

The average final dry density for the tailings in the air-drying test was 1.90 t/m^3. The time taken to achieve the final densities for the tailings samples was about eleven days at a daily evaporation rate of 4.7 mm/day. The final dry densities achieved following air drying represent an increase of about 23% over the densities achieved in the drained sedimentation test for the tailings.

Consolidation and permeability

Consolidation and permeability values were derived from the results of consolidation tests and permeability tests performed on saturated tailings samples.

The permeability tests showed permeabilities of 1.1×10^{-7} to 4×10^{-8} m/s for tailings dry densities in the range 1.31 to 1.56 t/m^3. The consolidation tests indicated that the tailings are moderately compressible and consolidate slowly.

8.2.3 Predicted tailings behaviour

The following summarises the predicted tailings behaviour under field conditions based on the characteristics determined by laboratory testing presented in Section 8.2.2.

Liquor release

The release of liquor following the deposition of tailings can be estimated from the drained and undrained sedimentation characteristics. The rate of release determines the amount of supernatant liquor reaching the supernatant pond that requires disposal in the evaporation ponds.

The tailings released 34% of the initial volume of liquor as supernatant in the undrained sedimentation tests, and 51% in the drained sedimentation test. The rate of supernatant release from the tailings was moderately slow, with 85–100% of the supernatant released after two days. This rate of supernatant release indicates that moderate evaporation would occur on the tailings beaches.

Tailings density

The laboratory results show that the final dry density for the tailings was about 1.90 t/m^3. Experience with other systems has shown that densities in the field are generally lower than those that can be obtained in the laboratory. It is therefore estimated that the field density for the tailings would be in the range 1.75 to 1.85 t/m^3.

This range is comparable to the results obtained from field tests conducted on the existing TSF (Section 8.1) which yielded densities of 1.7 to 1.8 t/m^3.

8.2.4 Chemical characteristics

The chemical characteristics of the tailings following the Expansion Project can be determined by analysis of tailings produced by the existing plant.

Typical weights for the chemical composition of the tailings solids are given in Table 8.4.

Table 8.4 Typical chemical constituents—tailings solids

Constituent	Weight (%)
Aluminium	4.36
Arsenic	0.0142
Barium	0.98
Calcium	0.70
Copper	0.137
Fluorine	1.29
Iron	27.2
Lead	0.0065
Magnesium	0.18
Manganese	0.0129
Potassium	1.94
Sodium	0.19
Uranium	0.0274
Zinc	0.0073

Typical values for the chemical composition of the tailings supernatant, as measured in EP1, are given in Table 8.5.

Table 8.5 Typical chemical constituents—tailings supernatant[1]

Constituent	Typical value
Calcium	990 mg/L
Chloride	5,800 mg/L
Copper	2,110 mg/L
Cyanide	Not detectable
Iron	21,400 mg/L
Lead-210	340 Bq/L
Polonium-210	520 Bq/L
Potassium	1,250 mg/L
Radium-226	5.2 Bq/L
Silica	1,700 mg/L
Sulphate	94,300 mg/L
Sulphuric acid	13,800 mg/L
Thorium-230	4,700 Bq/L
Uranium-238	3,300 Bq/L

1 *As measured in EP1.*

8.3 TAILINGS MANAGEMENT STRATEGIES

8.3.1 Alternative tailings storage systems

Two tailings storage systems are being considered for the expansion of the TRS:

- continuation of the existing paddock tailings storage method, with the construction of additional cells similar to the existing cells (described in Section 8.5);
- adoption of a new tailings storage method for the site, involving further thickening of the tailings slurry and discharge through central risers to form a final tailings profile resembling a series of intersecting flat cones (described further in Section 8.6).

The option of using the central thickened discharge (CTD) method is new to the site but not new to Australia. Existing mining operations using this method are located at Mount Keith (WA), Gove (NT), Elura (NSW) and Peak, near Cobar (NSW). Subject to the results of pilot trials and feasibility studies, this method is considered to offer economic and operational advantages at Olympic Dam over the conventional paddock type tailings storage. For example, the rate of tailings production at Olympic Dam would vary in future due to variations in ore grade and future expansions. The CTD method has been found elsewhere to provide greater operational flexibility in terms of the rate of production and deposition of the tailings.

The main disadvantage at Olympic Dam of the CTD option when compared with the conventional paddock type is that a greater land area would be required to store any given volume of tailings. In addition, drains and other structures would be required over the whole floor area not covered by tailings to control and collect supernatant tailings liquor. This is a consequence of the tailings beach advancing (developing) over the floor of the storage area for most of the operational life of the storage. In order to minimise seepage at Olympic Dam, the drains would need to be lined with clay or tailings. The feasibility of using the CTD method on the Olympic Dam tailings is subject to pilot trials currently conducted at Olympic Dam. For this reason, both tailings storage methods are presented in the following sections.

8.3.2 Location

Additional tailings storage that would be required following the proposed expansion would be located immediately to the west of the existing TSF (Figure 8.2). In the future, additional tailings storage would be developed to the north, as and when required.

8.4 PHYSICAL ENVIRONMENT OF THE TAILINGS STORAGE AREA

The proposed TRS expansion area is immediately west of the existing system. With the exception of numerous approximately east–west oriented longitudinal sand dunes, the site is generally level. The dunes reach a maximum height of about 8 m above the plain, and are composed of orange-brown sands characteristic of the northern deserts of South Australia. Interdune areas are often stony, and are generally poorly vegetated relative to the dunes. Several drainage depressions are present at topographic lows in the interdune areas. These depressions are often thickly populated by cane-grass and samphire.

General geological information on the region has been published by MESA in the form of 1:250,000 geological maps and associated notes. This information indicates that the proposed TRS expansion area is underlain by a thin cover of Quaternary to Tertiary sediments over Cambrian Andamooka Limestone, which is known to be karstic in places, with features such as dolines observed at the surface. Information on the geology and hydrogeology of the area in the 1983 EIS suggests that some Cretaceous sediments may be present over parts of the Andamooka Limestone.

Boreholes have been drilled and test pits excavated over the area that would be used for the expanded TSF. The most recent of these investigations, conducted by Golder Associates in 1995, involved the review of previous site exploration programmes and the excavation of a further 233 test pits over the area.

Soils and rock observed in the test pits excavated by Golder Associates in 1995 were similar to those logged in previous investigations. These materials have been divided into units on the basis of their likely geological age and origin, as shown in Table 8.6. In summary, the apparent geological history relating to the surficial deposits is one of variable weathering and erosion of the Andamooka Limestone (Unit F) followed by deposition of alluvial (Units E–B) and aeolian (Unit A) soils over some of the eroded surface.

Table 8.6 Summary of site materials in the tailings retention system expansion area

Unit	Description/observations	Geological age/origins and distribution	Usefulness as construction material/ease of excavation[1]
A	SAND Fine to medium-grained sand with about 5–25% fines. Orange to red-brown.	Probably aeolian. Present over most areas investigated.	Suitable for use as general fill. Low resistance to excavation.
B	ORANGE-BROWN SANDY CLAY/CLAYEY SAND Grades from fine to medium-grained clayey sand to sandy clay of medium plasticity Orange-brown to red-brown. Mostly dry near top, changing to moist with depth. Generally very stiff/dense. Calcareous.	Most likely formed by a combination of alluvial and aeolian deposition. Found throughout investigated areas at 0.2–1.2 m thickness.	Suitable for use as general fill. Low resistance to excavation.
C	BROWN CLAYEY SAND Fine to medium-grained orange-brown and brown clayey sand with about 25–50% low to medium plasticity fines. Generally moist and in a very dense state. May contain some white silty pockets, possibly consisting of sulphate. Observed to contain contain pockets of gypsum crystals up to 50 mm in size. May be calcareous near the top of the deposit.	Probably alluvial with minor aeolian input. Upper calcareous material may be due to leaching of calcium carbonate from overlying layers.	Useful as general fill. May be used as clay liner where calcium carbonate content and permeability permit. Low resistance to excavation.
D1	CLAYEY SAND/SANDY CLAY/ SANDSTONE Grades from fine to medium sand with few fines to sandy clay of medium plasticity, generally pale grey, pale brown and white. May include brown soil from overlying horizon. May contain gypsum, mainly as pockets of crystals less than 50 mm in size but occasionally as larger crystal occurrences cemented to low-strength boulders or a continuous rock mass. May be calcareous near the top of the deposit and contain pockets of green, grey or purple clay near the base of the deposit. Observed as calcareous silt in several test pits.	Probably alluvial with minor aeolian input. Calcareous material (sandstone) near upper extents may be due to leaching of calcium carbonate from overlying layers. Possibly of similar age to Unit C.	All materials except sandstone may be useful as general fill. Sandy clay and some clayey sand may be used as clay liner where calcium carbonate content and permeability permit. Soil materials offer low to medium resistance to excavation. Sandstone may require ripping or blasting.
D2	MIXTURE OF CLAY AND GYPSUM Variable 10–90% gypsum, but generally less than 40%. Clay is mostly of high plasticity, grey or green with yellow and red staining. Consistency is hard, with strength near that of very low-strength rock in some places. Gypsum is present in pockets and lenses of intergrown translucent crystals 5–400 mm in size. Rounded cobbles and boulders to 400 mm in size composed generally of chert, but in some cases of sandstone, have been observed in some test pits, particularly towards the base of the deposit. The clay is fissured, breaking into aggregations 3–50 mm in size.	Possibly Pleistocene. Possibly of alluvial/lacustrine origin. Found in all areas investigated, though not in every test pit. Thickness 1–8 m where observed.	Suitable for use as clay liner where gypsum content is below 50%. May be difficult to excavate when clay is very hard or gypsum content is high.
E	SILTSTONE/SANDSTONE Grades from siltstone to medium-grained sandstone; pale grey, but generally stained yellow, dark red brown or purple. Generally of very low to low strength, but observed as very dense sand or hard silt in some test pits. Appears to be near horizontally well bedded to laminated. Some subvertical veins of gypsum.	Possibly Early to Middle Tertiary. Probably of alluvial origin, found at the base of Unit D2 in thin bands.	Observed in small quantities only. Not suitable as liner material. General fill only. Generally very high resistance to excavation. Excavation not possible below about 0.4 m.

Table 8.6 Summary of site materials in the tailings retention system expansion area (continued)

Unit	Description/observations	Geological age/origins and distribution	Usefulness as construction material/ease of excavation[1]
F	CALCRETE/LIMESTONE BOULDERS/ LIMESTONE Consists of rounded calcrete gravel near the surface, often with limestone cores, grading to subangular boulders up to 1.5 m in size with depth. Most granular material occurs in a pale orange-brown, calcareous, clayey sand matrix. Boulders and the parent rock encountered at depth are mostly of low strength. Soils are generally friable Some limestone has been silicified; however, soils associated with this unit are all calcareous. The area is known to include karstic features, including dolines.	Cambrian. Weathered Andamooka Limestone. Covers much of the area to the north and west of the existing tailings retention system.	Permeability of much of the soil component is likely to be high in natural moisture/density state. May be useful as general fill. Medium to high resistance in boulders. Excavation not possible on boulders or continuous limestone at about 1.5 m depth.

1 *Relative to excavation with an approximately 30 t excavator equipped with a 1.4 m wide bucket and teeth suited for digging clay.*
Source: Golder Associates 1995.

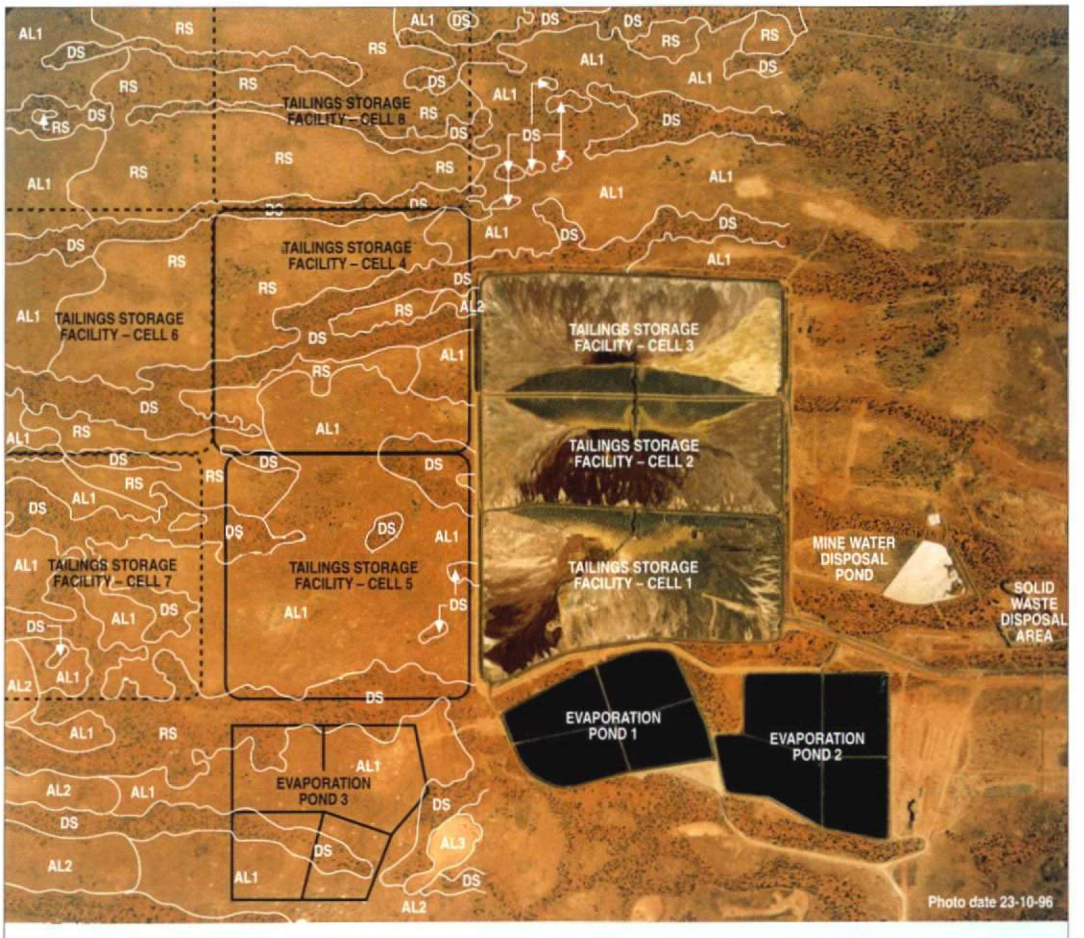
All of the identified units were observed beneath the proposed TRS expansion area. Intermediate units are missing in some zones, presumably as a consequence of variations in the level of the weathered limestone surface at the time of later alluvial and aeolian deposition and the differential weathering of these later deposits.

On the basis of the soil units encountered in the test pits and interpretation of aerial photographs, the TRS expansion area has been divided into five material cover types. Figure 8.4 shows the inferred boundaries of these cover types. Table 8.7 provides a description of the cover types and an assessment of their geotechnical properties based on site observations and the results of laboratory testing.

Table 8.7 Soil cover types in the tailings retention system expansion area

Type	Description	Geotechnical properties
DS	Composed mainly of dune sands (Unit A) forming approximately east–west oriented ridges across the area. Likely to be superimposed over other cover types.	Typically loose vegetation-stabilised sands of relatively high permeability. Dune cores may be calcareous[1].
AL1	Mainly alluvial soils in dune swales. Composed of a sequence of Unit B over Unit D1 and/or Unit D2. Thickness ranges over 2–20 m. May include some Unit A cover at the surface. May overlie Unit E in some locations.	Generally low-permeability, fine-grained soils varying from low to high plasticity and very stiff to hard consistency. Calcium carbonate[1] content is variable. *In situ* permeability is likely to be relatively low. Most likely source of non-calcareous clay liner[2].
AL2	Mainly alluvial soils in drainage depressions. Composed of a sequence of Unit B over Unit C, which overlies Units D and E in some locations. Soil thickness is mostly in excess of 3 m.	Generally low-permeability, fine-grained soils varying from medium to high plasticity and very stiff to hard consistency. Calcium carbonate[1] content is generally low and appears to decrease with depth. *In situ* permeability is likely to be relatively low. Possible source of non-calcareous clay liner[2].
AL3	Mainly alluvial soils in clay pans and therefore present in only small isolated areas. Similar to AL2 but with overlying brown clay of medium plasticity.	See remarks on AL2.
RS	Residual soils developed on limestone (Unit F) often with a thin alluvial soil cover (Unit B). Thickness of soil is less than 2 m in most locations.	Highly calcareous[1] soils and soil/rock mixtures. Observed to exhibit a porous, friable structure in many locations. Likely to possess a high *in situ* permeability relative to other cover types.

1 *ANC (Section 8.1) of soils mostly determined by calcium carbonate content, with high calcium content (calcareous) soils resulting in high ANC.*
2 *Non-calcareous clay used in the composite lining of evaporation ponds to ensure long-term integrity against seepage of acidic tailings liquors.*
Source: Golder Associates 1995.



———	Facilities for expansion to 200,000 t/a copper production (paddock method)
- - - - - -	Facilities for expansion to 350,000 t/a copper production (paddock method)
DS	Composed mainly of dune sands (Unit A) forming approximately east–west oriented ridges across the area. Likely to be superimposed over other cover types.
AL1	Mainly alluvial soils in dune swales. Composed of a sequence of Unit B over Unit D1 and/or Unit D2. Thickness ranges over 2–20 m. May include some Unit A cover at the surface. May overlie Unit E in some locations.
AL2	Mainly alluvial soils in drainage depressions. Composed of a sequence of Unit B over Unit C, which overlies Units D and E in some locations. Soil thickness is mostly in excess of 3 m.
AL3	Mainly alluvial soils in clay pans and therefore present in only small isolated areas. Similar to AL2 but with overlying brown clay of medium plasticity.
RS	Residual soils developed on limestone (Unit F) often with a thin alluvial soil cover (Unit B). Thickness of soil is less than 2 m in most locations.

FIGURE 8.4
INFERRED BOUNDARIES OF SOIL COVER TYPES

N 0 1 km

8.5 EXPANSION USING THE PADDOCK TAILINGS STORAGE SYSTEM

Expansion of the TSF would be necessary to accommodate increased tailings production resulting from the proposed expansion. Important aspects of the paddock system option are described below.

8.5.1 Storage area requirements

Among other important design criteria, the design of the expanded tailings facilities would be largely driven by seepage minimisation considerations, including minimising the amount of supernatant liquor and maximising evaporation from the tailings surface.

Operational experience with tailings drying behaviour combined with detailed water balance modelling indicates that all free liquor would be removed from the tailings surface if the rate of rise were restricted to approximately 1 m per year. This is equivalent to an area ratio (area of tailings storage per million tonnes of tailings deposited in one year) of 57 ha/Mt.a, assuming a dry density of tailings of 1.75 t/m^3.

For a tailings deposition rate of 6.6 Mt/a, corresponding to processing 9.0 Mt/a of ore, the total storage area required for a similar area ratio is about 376 ha. For deposition at a rate of 6.8 Mt/a, corresponding to processing 9.2 Mt/a of ore (Table 8.3), the total storage area required is 388 ha. These deposition rates can be accommodated using the existing cells (190 ha) and two additional cells of 100 ha each (total area 390 ha).

For expansion to 350,000 t/a copper production, corresponding to a mining rate of 17.0 Mt/a and a tailings deposition rate of 12.5 Mt/a, three further cells of 110 ha each would be required. This would provide a total storage area of 720 ha and a tailings storage capacity of 330 Mt.

8.5.2 Embankment construction

The perimeter embankment for the new cells would be constructed using either local swale and sand dune materials, or tailings material borrowed from within the storage, and would be shaped and zoned using sand, general fill and clay in such a manner as to:

- ensure stability under static and earthquake loading;
- minimise seepage of acidic tailings liquor through the embankment, thereby preserving embankment stability and avoiding future rehabilitation problems;
- minimise erosion on the outer face.

Figure 8.5 shows a typical cross-section of a starter embankment and subsequent lifts using the upstream construction method. This method involves subsequent construction of embankment lifts partially over consolidated tailings. Where tailings are used for the lift, a layer of clay would separate the tailings from the downstream erosion protection layer. The clay would provide a barrier to seepage and reduce radon migration.

A 4–5 m starter embankment would provide the storage volume required to facilitate the first embankment lift. Later lifts, up to a maximum height of 30 m, are possible only if the tailings on which the lift is to be founded have gained sufficient strength from consolidation and drying. The downstream faces of the embankments would be sloped at a maximum of 1 in 2.75 and would be sheeted with 500 mm of rock armouring to provide erosion protection.

8.5.3 Delivery and deposition of tailings

Delivery and deposition of tailings would be similar to the existing system. It would be necessary to install an additional tailings line, which would be contained within the existing pipe corridor over much of its route, and thereafter within a new bunded pipe corridor.

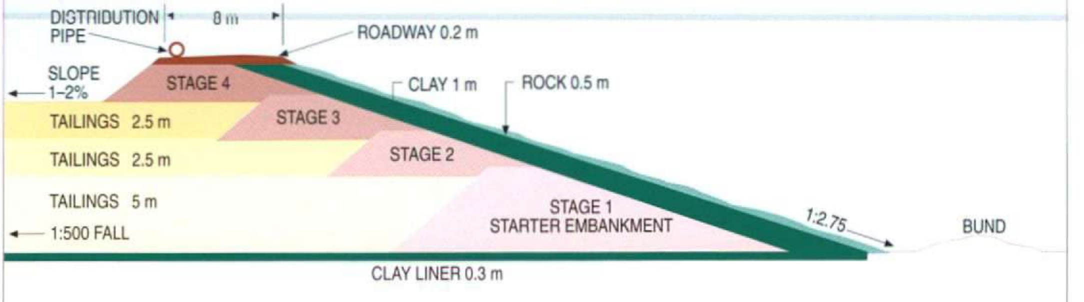


FIGURE 8.5
CROSS-SECTION OF TYPICAL EXTERNAL EMBANKMENT CONSTRUCTION

Deposition would also continue from spigots at about 24 m intervals along a distribution line located on the perimeter walls.

8.5.4 Floor preparation

To maximise supernatant water collection, the floor of the storages would be shaped by removing dunes and ridges where required, and by contouring (cut and fill) where necessary to provide a fall of about 1 in 500 towards the central decant. Temporary pumped decant facilities would be provided at any areas on the floor that were not free-draining towards the central decant facility.

The floor of the tailings storage would be prepared by providing a low permeability floor lining. Generally, it is intended that the floor preparation would be as follows:

- The soil/limestone interface would be located by means of electromagnetic survey and shallow bores and test pits.
- A low permeability clay liner would be placed over areas where the floor level would be in, or close to, sand or limestone, and would have a minimum thickness of 0.3 m.
- Where the floor is on clay, the near-surface clay would be prepared, if necessary, by ripping, conditioning and compacting to a suitable depth. The preparation would remove any cracks and potential flow paths in the near-surface layer.
- The floor would be proof rolled to identify any near surface dolines. Any dolines identified would be excavated and backfilled and capped with a clay seal.

In the event of the appearance of a doline (a fissure or solution cavity that may occur in limestone) during tailings deposition, the following approach would be adopted:

- A temporary earthen embankment would be placed on the tailings surface preventing further deposition of tailings into the doline, but enabling the remainder of the tailings area to be used for deposition.
- The hole or cavern would be backfilled and an impervious seal placed over the area.
- The temporary earthen embankments would be removed, and tailings deposition over the entire retention area recommenced.

8.5.5 Decanting of tailings liquor

Supernatant liquor would continue to be removed from the cells using central decants. The liquor would first flow to the decant return liquor ponds, from where it would be pumped to the evaporation pond system. The size of the supernatant pond would be kept to the practical minimum sufficient to ensure settling of solids from the supernatant tailings liquor.

Seepage from the central supernatant pond would be minimised by keeping the pond as small as practicable and providing an underdrainage system below the planned maximum extent of the supernatant pond. This underdrainage and decant system is shown in Figure 8.6.

As shown in Figure 8.6, the basin floor in the vicinity of the decant structures would also be provided with a low permeability clay layer or membrane to act as a barrier to seepage from the supernatant pond that would form adjacent to these structures.

8.5.6 Evaporation ponds

A total evaporation area of about 230 ha would be required for expansion of production to 200,000 t/a copper to allow disposal of decanted supernatant tailings liquor and excess acidic process liquor.

An additional four-cell evaporation pond of about 50 ha would be added to the existing 68 ha, bringing the total evaporative area to 118 ha. The evaporation pond area provided,

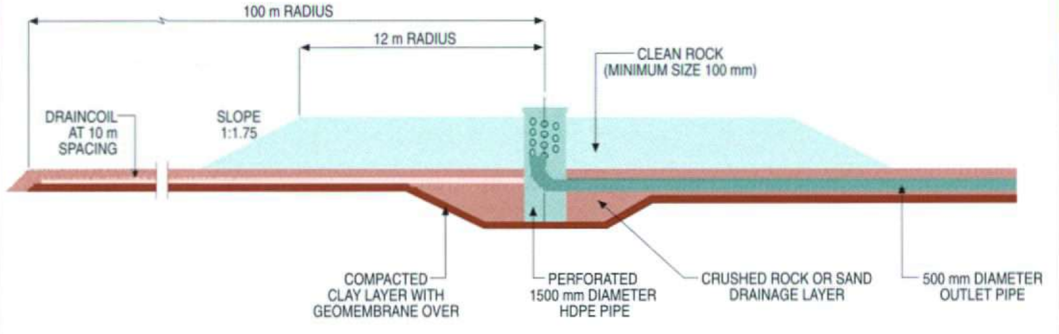


FIGURE 8.6
SECTION THROUGH TYPICAL DECANT STRUCTURE

Note: Not to scale

together with evaporation of liquor from the tailings surface, would be sufficient to enable all tailings liquor reporting to the central decant to be removed from the storage. Section 8.7 discusses the hydrology of the TRS should approval of the Expansion Project be granted.

For the second phase of expansion, to possible future production of 350,000 t/a copper, no further evaporation ponds are thought to be required, due to the additional water recycling to be carried out on site, and the additional evaporation area provided by the new cells. However, this would be evaluated during the detail design of the second expansion phase.

8.5.7 Stability considerations and final storage height

The overall height of the facility is not expected to be more than 30 m above the general level of the surrounding land. The tailings storage facility described in the 1983 EIS had a similar maximum height.

With the slow rate of rise used to maximise evaporation, the tailings are expected to be partially saturated and to have an adequate shear strength. Stable embankment slopes for higher storage heights would be determined using results from *in situ* field tests conducted prior to each raise. Preliminary stability analyses have indicated satisfactory minimum factors of safety for the proposed system—1.86 under static conditions and 1.44 under seismic conditions. A factor of safety greater than 1.00 indicates that the structures are stable.

8.6 ALTERNATIVE TAILINGS STORAGE SYSTEM—CENTRAL THICKENED DISCHARGE

The assessment of the CTD tailings method in this EIS is based on a preliminary conceptual design using tailings properties established from:

- laboratory scale test work on Olympic Dam tailings
- monitoring results from the existing conventional TSF
- experience gained from previous CTD field trials at other mine operations.

8.6.1 Field trials

Larger scale field trials have commenced at Olympic Dam to confirm and refine the tailings properties established previously. Using information from the field trials of a CTD system would ensure optimal design.

The current field trials have been designed to provide information on the following:

- the maximum tailings density that can be consistently achieved in the thickener. This is currently expected to be approximately 60% solids based on the results of small-scale testing. The tailings density is a significant factor in estimating the beach angle. The flow rate from individual outlets is another significant factor. If a low tailings density is used to estimate the likely beach angle, the conceptual design may include a larger number of central risers or a larger tailings storage area than necessary;
- the expected beach angles, determined with a greater confidence level and higher accuracy, over a range of tailings densities and tailings deposition rates;
- design parameters of the thickener, tailings disposal pump station and pipelines;
- the quantity of supernatant release correlated to a range of tailings densities;
- tailings drying performance.

The field trials involve the following activities:

- A pilot thickener has been installed to allow tailings to be thickened to various densities for deposition to trial cells.
- A series of four trial cells have been constructed to allow deposition of tailings at various densities. Deposition will be cycled from one trial cell to another allowing a period of deposition and a period of drying for each cell.
- A medium-scale trial has been established with a single riser on the surface of the existing TSF to assist with scaling up from the trial cells to the full scale.
- Monitoring of the trials will be carried out to determine beach angle, settled density, tailings drying, supernatant liquor recovery, thickener performance, and tailings rheology in each trial cell and for the medium-scale trial.

The equipment being used for the field trials was used for a similar purpose at the Mt Keith nickel mine in Western Australia. The trials are expected to be complete by May 1997, following two months of test work.

8.6.2 Storage area and height requirements

Initial calculations indicate that, at a solids content of 60%, an average beach slope of 2.5% may be expected for a CTD system using Olympic Dam tailings. This slope would provide a safe and economic solution to tailings storage.

Figure 8.7 provides an example of the size and possible position of a CTD storage. A circular storage would need to be approximately 700 ha (3 km in diameter) to store the tailings output of 132–136 Mt, the total amount of tailings produced at a rate of 6.6–6.8 Mt/a over about twenty years, for a nominal copper production rate of 200,000 t/a.

It is envisaged that the design height of the CTD outlets for a capacity of 132–136 Mt would be about 30–35 m above natural ground, that is, at about RL 130.0–135.0 m AHD. The CTD outlet towers would have a number of discharge points at different heights. As the level of tailings rose, the lower outlets would cease to flow, and flow would then commence at the next highest outlet. For expansion to 350,000 t/a copper production, a total area of

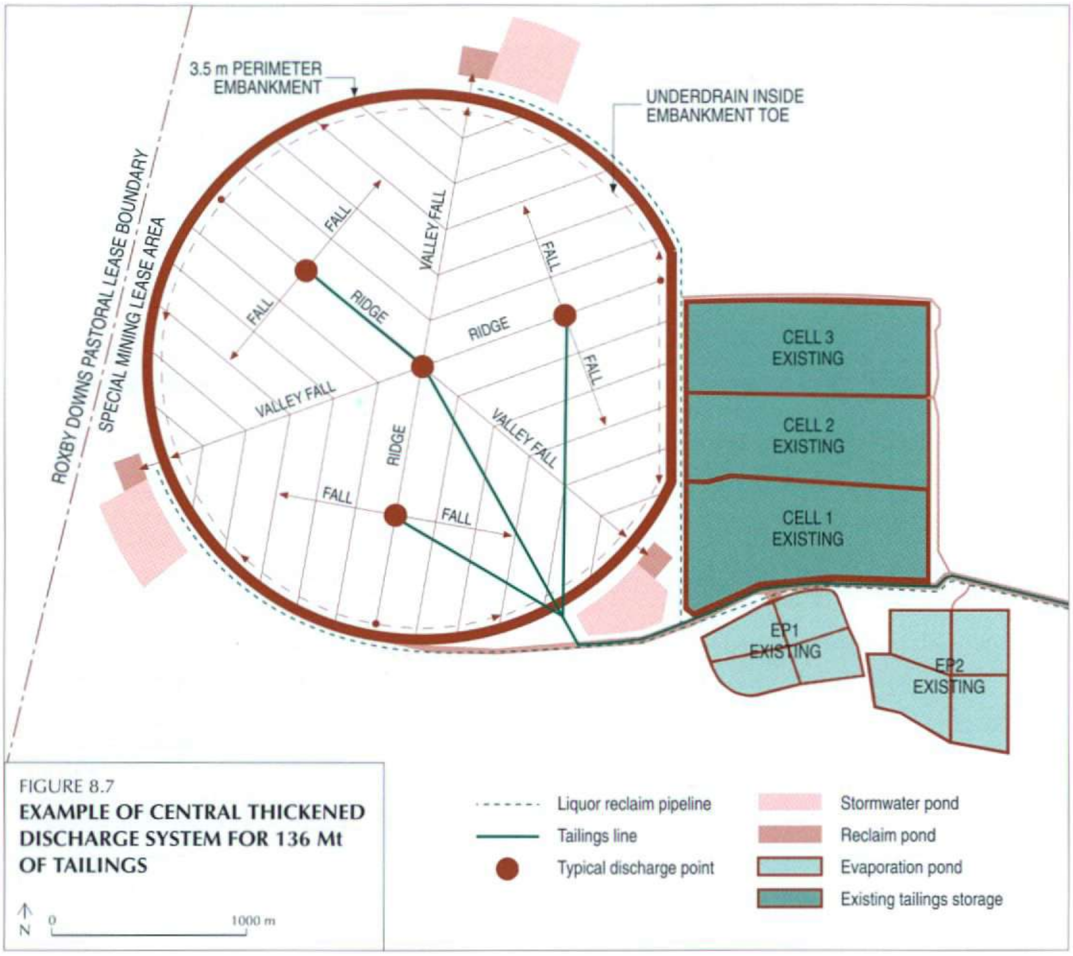


FIGURE 8.7
EXAMPLE OF CENTRAL THICKENED DISCHARGE SYSTEM FOR 136 Mt OF TAILINGS

approximately 1,200 ha would be provided for a CTD system to store 330 Mt of tailings solids. An example of a CTD of this size is provided in Figure 8.8.

8.6.3 Starter embankment construction

The perimeter embankment of the CTD cell would be approximately 2–4 m high and constructed from materials removed from within the storage area. It would be zoned in a similar fashion to the starter embankment in the paddock system. This would minimise seepage through the embankment, and prevent erosion of the outer face of the embankment.

8.6.4 Deposition of tailings

In the CTD system, the tailings would be deposited through raised outlets, one situated centrally within the storage and others spaced evenly from the centre. The deposited tailings would form beaches from the deposition points towards the perimeter walls, forming mound-like profiles.

The raised outlets would be self-supporting steel structures, treated in order to minimise corrosion from the acidic tailings liquor. Spigots would be provided for the full height of the outlets, arranged to be self-sealing as the height of the mounds grew. Tailings delivery to the base of the outlets would be in HDPE-lined steel piping, buried in the floor of the CTD area.

Special attention would be given to the stability of the tailings 'mounds', particularly in the early stages of development of the storage, when the mounds grow rapidly. It would be necessary to use several discharge points and interchange among these points to allow the

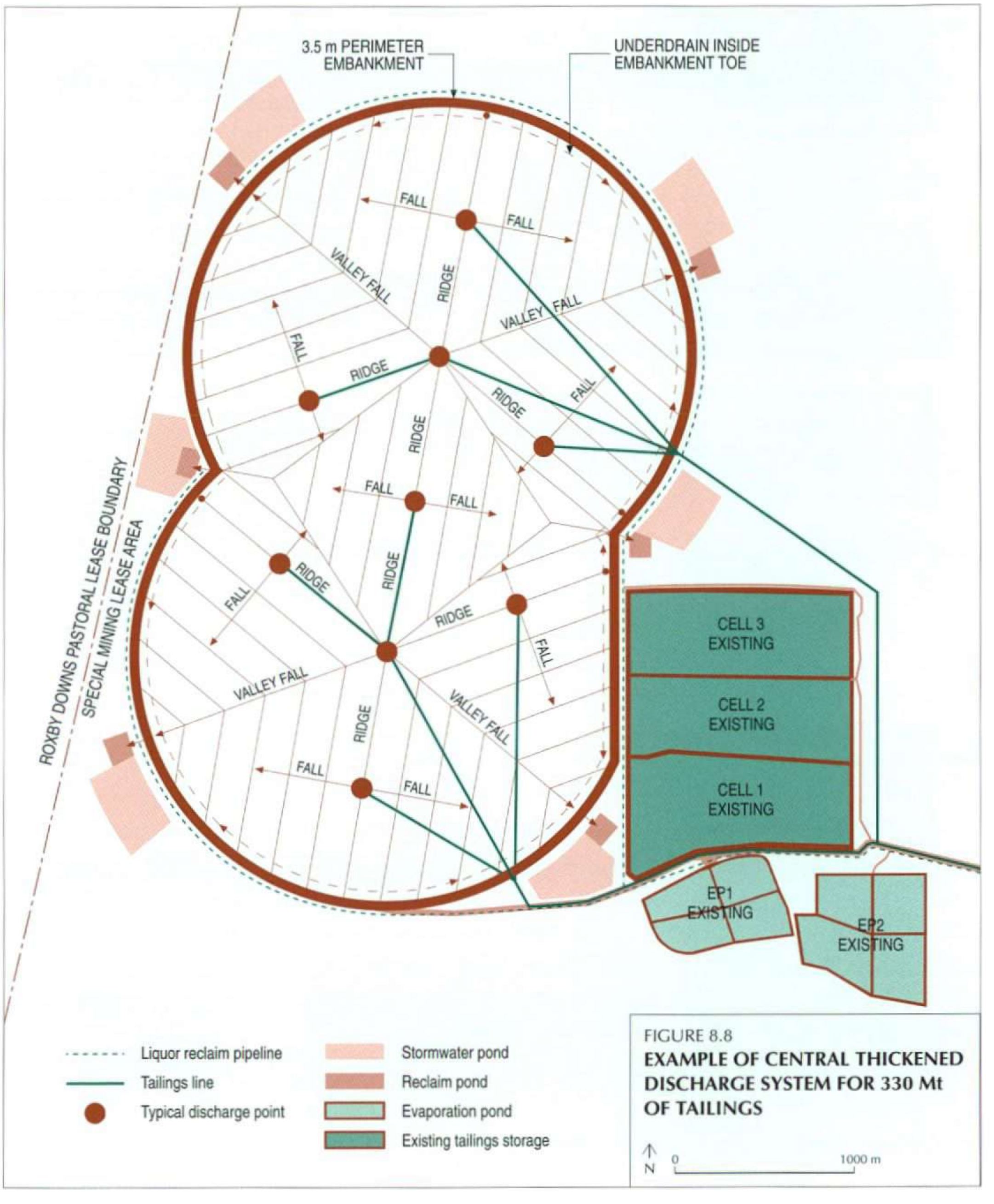


FIGURE 8.8
EXAMPLE OF CENTRAL THICKENED DISCHARGE SYSTEM FOR 330 Mt OF TAILINGS

tailings to dry in a manner that ensured the mound remained stable and the drainage pattern was properly maintained.

The field trials will provide the information needed to determine the number of discharges required. Figure 8.7 shows a general arrangement with four discharge points.

8.6.5 Collection and decanting of tailings liquor and rainfall run-off

As the CTD mounds grow, it would be necessary to construct and maintain a system of lined open drains to collect any supernatant liquor that might flow off the toe of the mound.

Tailings supernatant liquor and stormwater from normal rainfall events would be collected in lined reclaim ponds (Figure 8.7). Run-off from rainfall events of significant magnitude would overflow from the reclaim ponds into the adjacent stormwater ponds. The concentration of contaminants in such stormwater would be low owing to dilution of any contaminants in the tailings liquor by the stormwater. The stormwater would be recycled for reuse in the process or evaporated, depending on its quality.

8.6.6 Floor preparation

The base of the tailings storage area, including any identified dolines, would be prepared in a similar fashion to that described in Section 8.5. Any sand dunes would be removed and the sand stockpiled for future use.

The floor preparation would not be as extensive as for paddock-type storages, because:

- a large proportion of the liquor would be removed prior to deposition of the tailings;
- a larger area would be available for drying the tailings;
- drains lined with clay or tailings and other control structures would be provided to intercept and collect supernatant liquor;
- the decant liquor ponds would be lined with clay.

The results of further field trials and groundwater modelling would provide the data required to optimise floor preparation.

8.6.7 Evaporation ponds

A liquor balance would be carried out to size the evaporation area requirements once the optimum tailings solids content and the supernatant liquor release and drainage collection are estimated using the results of the field trials previously described. Consideration is being given to the development of a liquor distribution system to the surfaces of the existing tailings storages to minimise the area of new evaporation ponds and to reduce radon emanation from these surfaces. From the preliminary data available, it would appear that no additional evaporation ponds would be required for the expansion of production to 200,000 t/a copper. The hydrology of the TRS is discussed further in Section 8.7.

For expansion of production to 350,000 t/a copper, no further evaporation ponds are thought to be necessary, due to additional water recycling on site and the additional evaporation area provided by the CTD storage area. However, this would be addressed in detail should such an expansion be necessary.

8.6.8 Stability and final form considerations

As discussed earlier, the stability of the mound is more critical in the early stages of development when it increases more rapidly in size and height. For this reason, multiple discharges may be used to divide the flow to a number of mounds, which would grow more slowly. These mounds would eventually combine to form a single mound with a number of high points corresponding to the discharge points.

In later years, the rate of rise of the tailings mound would be reduced to very low values. The tailings material would dry sufficiently to ensure that the mound was stable under all conditions. It is also expected that dust generation from the surface would be low, as for the existing paddock system, owing to the formation of a stable crust on the surface of the tailings.

The field trials would provide the data needed to design a CTD system and filling strategy that ensured the mound would be stable under all operating conditions, including extreme meteorological (rainfall and wind) and seismic conditions, and to assess the potential for dust generation from the surface.

8.7 HYDROLOGY

8.7.1 Rainfall and evaporation

The average annual rainfall at Olympic Dam recorded over the period 1980–95 was approximately 200 mm. However, this period includes two years of high rainfall events. The long-term average annual rainfall is estimated to be 160 mm (Bureau of Meteorology 1988). The mean evaporation rate over the period 1980–95, measured in a Class A pan, is 2,788 mm/a.

Evaporation from open waterbodies, such as the evaporation ponds, is usually estimated by applying a 'pan factor' to the evaporation measured in a Class A pan and a reduction factor to take into account the concentration of salts in the liquor. A combined pan and salt reduction factor of 0.65 would be typical for the evaporation ponds at Olympic Dam. When rainfall is taken into account, the evaporation ponds are able to dispose of about 1.56 m^3/m^2.a of water.

Rainfall patterns for the region have been analysed by the Bureau of Meteorology to provide intensity–frequency–duration data for use at Olympic Dam in the design of stormwater management systems. The current data for the highest intensity (five minutes' duration) and highest total rainfall (seventy-two hours' duration) are summarised in Table 8.8, together with data for a twelve-hour duration storm.

Table 8.8 Design rainfall intensities at Olympic Dam

Average return interval (years)	5-minute duration storm (mm/h)	12-hour duration storm (mm/h)	72-hour duration storm (mm/h)
1	42.2	1.80	0.42
50	172.0	8.34	1.80
100	204.0	10.10	2.16
500	395.0	22.70	3.34

For a 1-in-500-year average return interval the highest total rainfall would be from a twelve-hour storm with an intensity of 22.7 mm/h over this duration.

8.7.2 Stormwater management

Stormwater management systems would be provided for in the expanded tailings management system. The stormwater management facilities would be designed to provide sufficient intensity and volume capacity for the design rainfall events. The average return interval selected for the design of each element would be determined by assessment of the hazards and consequences associated with failure of that element.

The stormwater management systems for the two alternative tailings management systems are described below.

Paddock tailings storage system

The stormwater storage capacity of the TSF would be sufficient to accommodate low probability rainfall events, for containment of any run-off that had been contaminated through contact with tailings or mixing with tailings liquor. It is considered that initial containment of run-off would not be a problem, beyond providing freeboard equivalent to the depth of the rainfall, as the facilities would not include external catchment areas.

Containment of the 1-in-500-year average return interval twelve-hour rainfall event would require a freeboard estimated at 235 mm in the evaporation ponds. A freeboard of 1 m would store the extreme 1-in-500-year event as well as make allowance for wave action.

The basins of the tailings storage cells would be shaped to have a nominal slope of 1 in 500 (0.2%) from embankment to the central decant. During initial filling of the cells, an extreme 1-in-500-year rainfall event would result in a stormwater pond covering approximately 90% of the surface of the cell. A 1-in-100-year rainfall event would result in coverage of approximately 65% of the cell area. After the beaches were fully developed, an extreme 1-in-500-year rainfall event would result in a stormwater pond covering approximately 30%

of the surface of each cell. A 1-in-100-year rainfall event would result in coverage of approximately 25% of the cell area.

Central thickened discharge system

Unlike the paddock tailings storage system, the CTD system would not be able to provide interim storages of stormwater on the tailings. Instead, an independent storage system, comprising a series of stormwater ponds and the perimeter embankment of the CTD (Figure 8.7), would store the collected stormwater for disposal by return to the process or by evaporation.

The stormwater ponds at a copper production rate of 200,000 t/a would have an operational storage volume of approximately 950 ML, equivalent to the run-off from a 1-in-100-year average return interval, seventy-two hour storm from the CTD area. For 350,000 t/a copper production the stormwater storage volume would be approximately 1,630 ML. Spillways would discharge to the surrounding drainage system any run-off from a 1-in-500-year rainfall event that could not be stored by the stormwater ponds. For such rare occurrences, the run-off would be significantly diluted by rainwater by a factor of about 50. Any contaminants would then be further diluted by regional run-off from the extreme event.

8.7.3 Evaporation pond requirements

For a production rate of 200,000 t/a copper, it is considered that no additional evaporation ponds would be required for the CTD option (Section 8.6). For the paddock option an additional evaporation pond (EP3) would be constructed. It would have a total evaporative area of about 50 ha, and would be divided into four cells of approximately equal area. This would provide the additional pond area required for operation under average rainfall conditions for the paddock tailings storage system.

EP3's construction would be similar to that of the two existing evaporation ponds, including a composite lining system—a lower liner of compacted clay overlain by a synthetic liner. A bleed stream to the tailings surge tank would control the concentration of salts that would otherwise reduce evaporation rates and precipitate salts into the evaporation ponds.

As noted in Sections 8.5 and 8.6, it is considered that further expansion of the TRS for a possible future production rate of 350,000 t/a copper would not require the construction of additional evaporation ponds for either the paddock or CTD option.

8.7.4 Seepage

The rate of rise of tailings of 1 m/a for the paddock tailings storage system would achieve a situation of minimal seepage once the tailings beaches were fully developed. Seepage refers to the saturation of soil that may occur underneath the deposited tailings. In the CTD system the tailings would be partially dewatered prior to discharge and the rate of rise would be less than 1 m/a after the initial mounds were developed; hence the rate of seepage from the tailings beaches would also be minimal.

The design for the tailings storage facilities and evaporation ponds has been based on the requirement to ensure minimal practical seepage from the TRS. Features of the alternative paddock and CTD designs for achieving this include:

- containment of acidic plant and tailings liquor in synthetically lined ponds;
- provision of sufficient tailings storage area to ensure effective drying of tailings between deposition cycles;
- construction of a low permeability liner and drained area around the decant structure of each tailings storage cell (paddock design);

- shaping of the floor of each tailings storage cell to minimise ponding of supernatant tailings liquor during initial filling (paddock design);
- provision of a low permeability clay liner over the floor of each tailings storage cell to minimise infiltration of supernatant tailings liquor and rainfall run-off (paddock design);
- additional dewatering prior to discharge (CTD design);
- the use of sloped floors and lined trenches to direct water into decant areas (CTD design).

As discussed above, the focus of the design and future operation of the expanded TRS would be to achieve minimal practical seepage. Despite this, it is relevant to assess the likely impacts of any seepage. In this regard, monitoring results and other test work conducted on the existing facilities, as described in Section 8.1, provide a sound basis for making predictions.

The Andamooka Limestone which underlies the entire site, including the TRS, has been shown by experience to offer both advantages and disadvantages as a foundation to TRS facilities. The obvious disadvantage is the limestone's inherent permeability, requiring the proposed floor preparation and lining systems to minimise seepage.

An advantage of the Andamooka Limestone is its ability to neutralise acidic liquors and to remove metals (including radionuclides) from solution. This ability is available as a natural safeguard to minimise pollution.

Monitoring of groundwater underneath the existing TRS, which contains seepage from the previous operation of these facilities, has shown that it is of similar quality to naturally occurring groundwater in the region. The groundwater underneath the TRS has a measured salinity of about 25,000 mg/L and contains minor concentrations of copper, iron, manganese, nickel and uranium. With the exception of manganese, all dissolved metals are within a factor of 25 of the drinking water guidelines of the Agriculture and Resource Management Council of Australia and New Zealand (National Health and Medical Research Council and the Agriculture and Resource Management Council of Australia and New Zealand 1996). These guidelines also specify a maximum salinity of 1,000 mg/L, requiring a 25-fold reduction in groundwater salinity to achieve the guideline level. Regional groundwater also exhibits naturally elevated levels of manganese and, owing to its salinity of 20,000–40,000 mg/L, is not suitable for potable use or stock watering.

Another safeguard for the control of groundwater pollution is the presence of the cone of groundwater depression associated with the underground mining operation. As described in Section 4.6, this cone of groundwater depression currently dominates the local groundwater regime, resulting in groundwater flow from all directions towards the mine. This effect would continue to develop as the mine expands and is expected to persist for a long time, perhaps for centuries, after the cessation of mining.

Due to the attenuation of contaminants provided by the soils at Olympic Dam, radionuclide concentrations under the existing TRS are comparable to and generally less than those levels in regional groundwater. Therefore drainage of this groundwater to the mine would not increase radiation doses to mine workers, with monitoring showing existing doses well within acceptable guidelines. The issue of radiation exposure of mine workers is discussed in Chapter 10.

8.8 CONTROL OF FAUNA

The tailings liquor would continue to be saline and acidic (about pH 1.5), and to contain a range of dissolved heavy metals. Experience with the existing tailings storage cells has indicated a low rate of visits to these facilities by native fauna. This may be due to the lack of food at this facility, the need for fauna to climb the perimeter embankment, and the exposed nature of the tailings beaches. The rate of fauna visitation is expected to remain low with the expanded facilities.

Specific fauna control strategies are currently used at the evaporation ponds and these would be extended to include the expanded facilities. The control strategies include:

- fencing the evaporation ponds to prevent access by fauna. The mesh type fencing is 2 m high to exclude larger animals with additional fine mesh to about 0.3 m height to exclude small animals;
- using propane guns to deter visitation by birds;
- using another bird deterrent at night, developed on site, that takes advantage of birds' observed avoidance of intermittent rotating lights beamed across water surfaces. This has been successful because it discourages the landing of waterfowl at night.

8.9 RADON RELEASE FROM TAILINGS

As a consequence of the extraction of uranium, the tailings at Olympic Dam contain approximately 80% of the radioactivity associated with the original ore. The half-lives of some radionuclides contained in the tailings are such that the low level of radiological risk from the tailings management facilities must be considered in the long term. For example, the half-life of thorium-230 (^{230}Th) is 80,000 years (Figure 2.17). It is the identification of this risk and its mitigation that is the subject of the optimisation referred to in the ALARA (as low as reasonably achievable) principle.

Options for tailings disposal at Olympic Dam are:

- containing the tailings in engineered structures with covering layers to prevent erosion and dusting, and to limit the release of radon;
- returning the tailings to worked-out areas of the mine.

Some of the sand-sized fraction of the tailings is used at Olympic Dam as underground fill (Section 3.3), but for practical reasons the bulk of the tailings must be deposited into the tailings storage cells.

Release of radon from tailings to the atmosphere is the product of two mechanisms:

- liberation of the atom of radon gas by alpha recoil from the grain in which its parent radionuclide (radium) resides;
- transport of the radon gas through porous media to the open air.

The fraction of radon that is ejected from the mineral grain by alpha recoil is termed the emanation coefficient, and the transport is characterised by the diffusion coefficient. If the pore space is filled with water, the atom of radon is likely to stop before it embeds itself in an adjacent grain, but the diffusion coefficient in water is very much lower than it is in air, and it is probable that the radon atom will not reach the surface to be released to the atmosphere.

It is when a coating of moisture surrounds the grain, reducing the momentum of the ejected radon atom so that it comes to rest in an air space, that the probability is greatest of the atom diffusing to the surface and being released to the atmosphere. The rate of radon release from tailings surfaces per unit area is controlled by a number of factors, including:

- grade of tailings (usually expressed in terms of quantity of radium per gram of tailings)
- bulk density of tailings

- porosity of tailings
- depth of the tailings layer
- diffusion coefficient (related to moisture content and tortuosity factor).

The radium grade of the tailings varies from place to place and from time to time and depends on the grade of the ore processed. The average radium grade in Olympic Dam tailings is 6.98 Bq/g and the standard deviation is 1.65 Bq/g.

Radon release rates have been measured at Olympic Dam and cores of the tailings immediately underlying the radon sampling points have been taken and analysed for moisture content.

The average radon surface release rate measured is 1.27 $Bq/m^2.s$ and the standard deviation is 1.57 $Bq/m^2.s$. The geometric mean surface release rate is 0.65 $Bq/ m^2.s$. The wide spread of results is almost certainly due in part to the measurement method. The 'charcoal can' method (which has been used to date) is known to provide results which are difficult to reproduce both in time and in space. Two cans placed in very close proximity will often give widely different results. Recently an investigation into the reliability of the charcoal can method has resulted in a recommendation that future measurements be made using the accumulator drum method.

Radon atoms released from grains that lie below 2–3 m do not reach the surface, because they decay to solid radionuclides and are then not free to diffuse to the surface. Thus it is the moisture content of the surface 2 m which influences the surface release rate.

As the surface moisture content can be assumed to be similar for the paddock and the CTD systems, it follows that the radon flux would be a simple function of the surface area of the two systems. The total surface area using the CTD method would always be greater than the paddock method by a factor of about 1.7–1.8. Consequently the radon release rate would be greater by a similar factor.

8.10 IMPLICATIONS OF RADIATION CONTROL FOR REHABILITATION

The degree of stabilisation and rehabilitation of the TSF is dictated by the need to ensure that radiation doses to people are as low as reasonably achievable and less than levels considered acceptable.

The Olympic Dam region is arid and sparsely populated (with the obvious exception of Roxby Downs, which was built to service the project). The nearest centre of population is Andamooka, some 30 km east of the TSF. This town owes its continuing existence to opal mining and more recently to tourism. Pastoralism is the only other major land use in the region (Chapter 5), although the nearest homestead is some 24 km from the site. It is unlikely that the region would become more densely populated in the foreseeable future and it is probable that pastoralism would remain the major land use.

The choice of design criteria for the TSF is made somewhat arbitrary by the need to postulate future land use which may or may not occur. In countries where tailings are stockpiled in close proximity to towns, numerical criteria have been placed in regulations, but these criteria are formulated in terms of the emission of radon and not exposure of people. Thus, for example, in the United States the Nuclear Regulatory Commission has recommended a maximum flux from rehabilitated tailings of 0.074 $Bq/m^2.s$, while the Atomic Energy Control Board of Canada has recommended a limit of 0.074–0.370 $Bq/m^2.s$, the precise figure depending on the outcome of discussions with other regulatory agencies and the industry.

The natural flux of radon from Australian soils has been studied by Schery (1989) with the finding that the continental average is in the region of 0.022 $Bq/m^2.s$, with the maximum being 0.118 $Bq/m^2.s$. The error associated with the techniques used by Schery was estimated to be ±20%. Thus if the US and Canadian recommendations were adopted, the radon flux following rehabilitation of the TSF would be compatible with the natural levels in Australia.

Radiological criteria for the rehabilitation of the tailings disposal systems are predicated on several factors, including the need to:

- limit radon flux while the disposal systems are being used (to limit the dose to employees and members of the public living in the vicinity);
- limit the lift-off of dust from the tailings surface during the operation of the TSF;
- ensure the rehabilitated structures remain intact under climatic and seismological influences in the very long term;
- limit the quantity of radon released from the surface of the rehabilitated structures in the very long term;
- limit the contamination of underlying aquifers in the very long term;
- ensure that accidental intrusion into the tailings repository is avoided in the very long term.

These criteria are discussed overleaf.

Release of radon during operations

Measurements of radon and radon decay products in air near the TSF during operations have shown that natural ventilation is sufficient to disperse and dilute radon and radon decay products to very low levels within quite short distances. Figure 8.9 shows the reduction in the average radon decay product concentration with distance from the TSF.

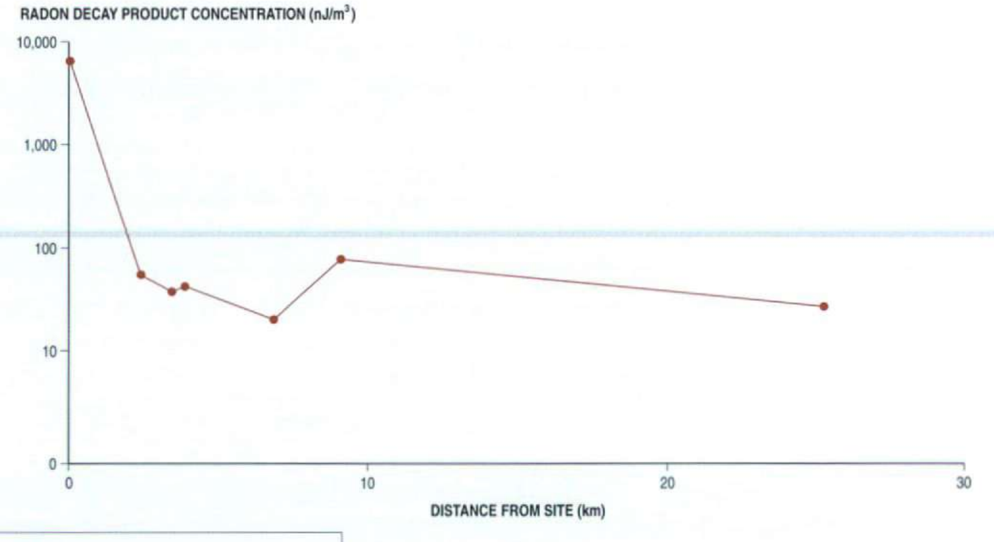


FIGURE 8.9
REDUCTION IN RADON DECAY PRODUCT CONCENTRATION WITH DISTANCE FROM THE SITE

The figure shows that by 3 km from the TSF the concentration falls by a factor of 500. It should also be noted that the TSF is not the only source of radon decay products influencing the measured concentrations shown. Contributions to the measured values are also made by natural radon decay products in the air, and by the mine vents, the stockpiles and the processing plant.

Active control of radon and radon decay products emanation is not proposed for the TSF during operations because of the natural capacity of the atmosphere to disperse and dilute it.

Dust lift-off

Dust monitoring around the perimeter of the TSF has shown that this facility is not a major emission source. This is because the smooth, flat, even grain size and moist surface of the tailings limit the processes that could lead to lift-off, such as saltation and creep. The tailings also form a crust upon drying. Potential for dusting is increased during mechanical working of the tailings, particularly when tailings are used in construction of the successive lifts of the walls, but water sprays are effective in limiting the release of dust.

Structural integrity of the rehabilitated tailings storage facility

Codes of practice on the containment of tailings in Australia and in the United States and Canada now call for a design life of 200 years and a structural life of 1,000 years. Experience in the construction of civil works to meet such criteria is available and would be applied in the design of the final form of the TSF.

Factors taken into consideration would include:

- control of erosion by control of drainage patterns and provision of rock armour to external surfaces of the TSF;
- selection of slopes for the perimeter embankments combined with the shear strength of consolidated tailings, so that the embankments are stable under seismic conditions.

Limiting radon release from the rehabilitated tailings storage facility

Strong et al. (1981) provide equations describing the transport of radon through tailings and covering layers. The choice of an acceptable radon flux rate is influenced by the potential exposure of people in the vicinity of the rehabilitated TSF. However, it is likely that the Olympic Dam area would remain sparsely populated, particularly following closure of Olympic Dam.

To achieve a reduction in radon release by a factor of 3–4 (that is, the higher range of the Canadian recommendations in recognition of the sparse population of the area), the information presented by Strong and her colleagues indicates a required cover depth of 1–2 m for dry cover, and 0.3–0.4 m for moist cover. Current planning for the rehabilitation of the TSF has been based upon the provision of 1 m of cover over the tailings surface, overlain by rock armour, which would have the effect of minimising both erosion and evaporation of moisture from the radon barrier layer.

Limiting contamination of the underlying aquifers

The control of seepage from the TSF following rehabilitation would be achieved by a contouring of the final surface and collection of rainfall run-off in areas where the collected water can be evaporated. In addition, establishment of native vegetation over the rehabilitated surface would control erosion and promote evapotranspiration of rainfall.

The process of geochemical amelioration of any seepage, described in Section 8.7, would continue following rehabilitation of the TSF. Water in the local aquifer is unfit for human, stock or crop use because of its radioactivity, its salinity, and its natural content of heavy metals, fluorides and sulphates. The long-term presence of the TSF would therefore not restrict any potential beneficial uses of the local groundwater.

Accidental intrusion into the rehabilitated tailings storage facility

It is possible that at some time in the future minerals contained in the tailings will become economically attractive and the tailings may be reworked. Deliberate reworking of the tailings implies that the necessary permits and safety principles will be in place. Accidental intrusion into the TSF in the future is not a credible event, particularly as the existence of Olympic Dam would be known well. However, as a further safeguard, WMC would erect permanent markers on the rehabilitated TSF and refer its location to the relevant authorities for inclusion on maps of the region.

CHAPTER 9

AIR QUALITY AND NOISE

CHAPTER 9

AIR QUALITY AND NOISE

This chapter summarises the effects on air quality and noise levels that would be caused by the Expansion Project. Existing meteorological data are used in combination with estimated emission rates to model the effects of gaseous emissions. These levels are compared with the limits set in the national air quality guidelines. Control requirements for dust and process emissions as applied to the Expansion Project are also discussed.

In the final section of the chapter, environmental noise levels that would be produced by the expanded plant are modelled and compared with existing noise levels and regulatory limits.

9.1 METEOROLOGY

Meteorology, which includes the wind regime and thermal structure of the local atmosphere, is the major factor influencing the transport and dispersion of airborne emissions. This section presents a meteorological summary for Olympic Dam. The measurements relevant to emission transport and dispersion are then presented to provide a basis for evaluation of atmospheric concentrations of emissions for the Expansion Project.

9.1.1 Climate and winds

For several years, weather information for Olympic Dam has been recorded at three automated weather stations (located at Roxby Downs, Olympic Dam Village and at a point known as Sandhill Station near the mine entry portal) and one manual weather station (located at the main gate of the plant and referred to as Main Gate Station).

Under the environmental management and monitoring plan (EMMP) adopted in 1996, weather information is recorded primarily at a new, automatic weather station (AWS) located in a swale approximately 500 m south-east of the metallurgical plant, with backup provided by the Main Gate Station (Figure 9.1).

The new weather station logs data automatically every thirty minutes. Wind speed, wind direction and standard deviation of wind direction data are collected at heights of 3 m and 10 m above ground level. Solar radiation and temperature data are collected at a height of 2 m above ground level. Barometric pressure and relative humidity data are collected at a height of 1.5 m above ground level. Rainfall data are collected at ground level.

Data from the Main Gate Station are manually recorded every three hours. Parameters recorded include temperature, rainfall, wind speed, wind direction, barometric pressure and relative humidity. The Main Gate Station is the primary site for recording evaporation. A summary of meteorological data for the period 1981–95 is presented in Table 9.1.

The climate at Olympic Dam is warm to hot in summer and mild to cool in winter. Generally, rainfall is intermittent and low. Heavy rainfall events can occur in any month. Significant rainfall events are usually associated with large-scale rain-producing systems, which typically involve an inflow of moist tropical air aloft accompanied by a closed cyclonic circulation, or trough, in the upper atmosphere. This can occur during surface anticyclones, but is usually associated with a surface low pressure system (Jensen and Wilson 1980).

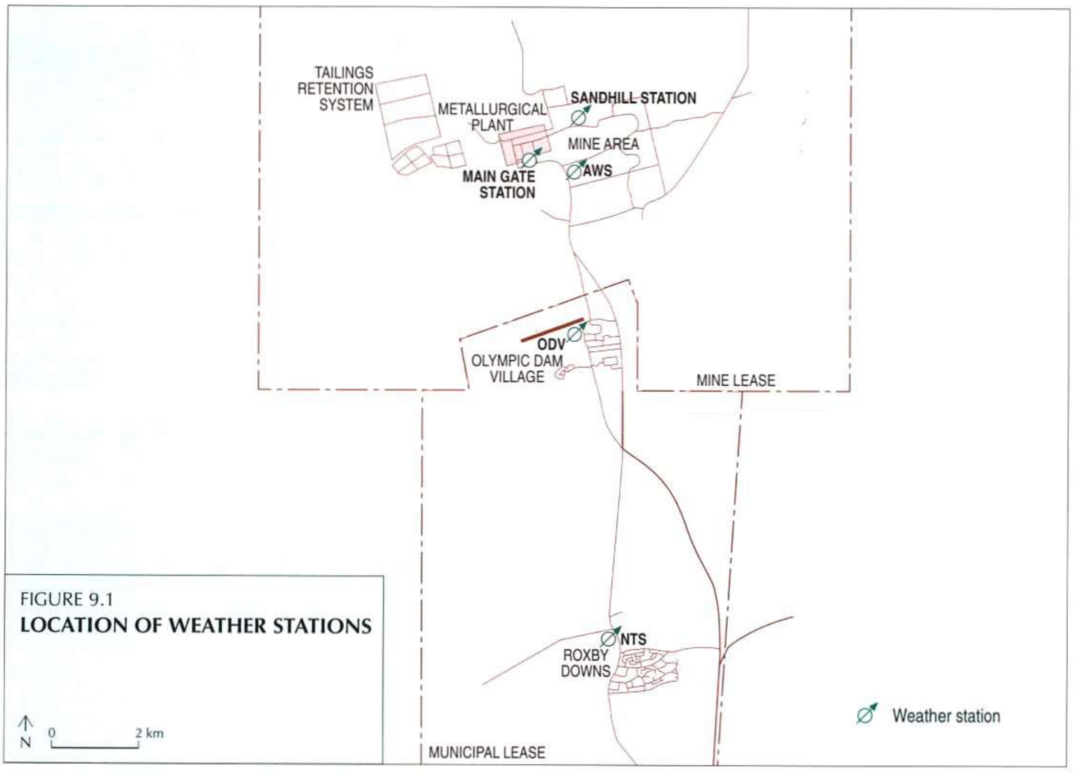


FIGURE 9.1
LOCATION OF WEATHER STATIONS

Average barometric pressures do not vary greatly throughout the year, but there is a general trend of higher pressures during winter (Table 9.1).

The most frequent wind directions on an annual basis are south to south-south-east (SSE) (Figure 9.2). These two sectors account for approximately 32% of all winds.

Table 9.1 Summary of atmospheric measurements, Olympic Dam 1980–95[1]

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
Temperature (°C)													
mean maximum	36.1	35.9	32.6	27.2	22.3	18.3	18.1	20.1	24.3	28.3	31.7	34.2	27.4
mean minimum	19.8	19.9	17.6	12.5	9.1	5.2	4.3	8.6	8.6	12.7	15.7	18.6	12.5
Average humidity (%)	34.8	34.8	36.5	45.0	61.0	68.4	61.5	53.2	46.3	38.5	34.7	37.9	46.1
Mean wind speed at 10 m (m/s)	4.0	3.9	3.6	3.2	2.9	2.8	3.0	3.5	3.9	4.2	4.2	4.2	3.6
Average barometric pressure (hPa)	1001.7	1001.8	1006.5	1010.3	1011.8	1012.9	1011.3	1011.0	1008.6	1005.6	1003.7	1001.4	1007.2
Average solar radiation (W/m^2)	294.6	265.4	225.5	176.4	121.8	101.4	114.6	146.9	195.2	243.4	278.5	277.0	203.4
													Total
Rainfall (mm)	13.5	20.7	32.9	5.4	20.4	15.7	10.4	12.9	9.9	17.0	11.6	29.3	**199.7**[2]
Evaporation (mm)	396.8	328.1	298.1	186.7	113.5	84.5	88.5	121.5	186.8	274.0	331.7	377.3	**2787.5**

1 *Temperature, rainfall and evaporation data recorded at the Main Gate Station. All other data except wind speed recorded at Sandhill. Wind speed recorded at Roxby Downs.*

2 *Rainfall includes data from two very wet years. The long-term annual average for the area is approximately 160 mm (Bureau of Meteorology 1988).*

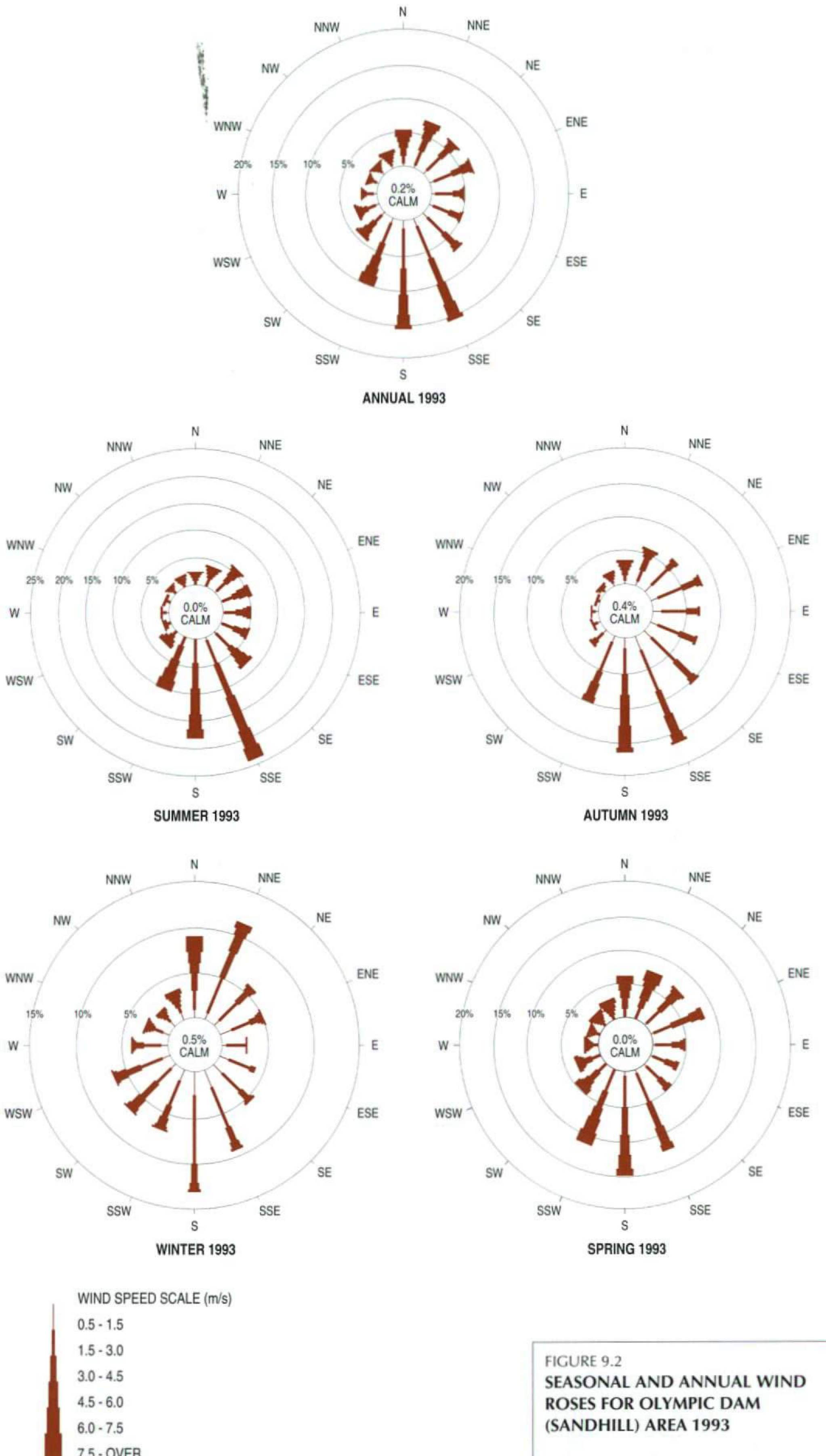


FIGURE 9.2

SEASONAL AND ANNUAL WIND ROSES FOR OLYMPIC DAM (SANDHILL) AREA 1993

In summer, the most common wind direction is SSE. The pattern is essentially similar in autumn, with a tendency to more southerly winds. During winter, winds are common both from the south and the north. Southerly winds account for approximately 13% of winds whereas those from the north and north-north-east account for 8% and 12%, respectively. During spring, the southerlies are again the most common winds, but there is a significant frequency of winds from the northerly directions. These wind patterns are reflected in the modelling of ground-level concentrations of gaseous emissions (Section 9.3). Maximum concentrations tend to occur in areas to the north and west of the plant site.

9.1.2 Meteorology of emission transport and dispersion

The vertical temperature profile (variation in air temperature with height above ground), wind speed, wind direction and atmospheric stability are key factors in the dispersion and transport of emissions.

Atmospheric stability influences horizontal and vertical mixing of air, which in turn affects the rate of dispersion of airborne pollutants. Stability conditions are classified by means of the various Pasquill atmospheric classes ranging from Pasquill A, the most unstable condition, through Pasquill D, a neutral condition, to Pasquill F, the most stable condition. The three most common methods of estimating stability classes are derived from:

- correlation of wind speed and insolation
- sigma theta—the value of the standard deviation of the wind direction
- the vertical temperature gradient.

Sigma theta data from the Sandhill Station have been used to determine stability classes for the purposes of dispersion modelling.

Table 9.2 presents a summary of Pasquill stability class occurrence data for 1993. Stability classes D and E dominate, occurring at a frequency of almost 70% of the total time. Neutral and stable conditions are more prominent overall than unstable conditions, and conditions tend to be more stable during the cooler months.

Table 9.2 Frequency of occurrence of Pasquill stability classes for 1993

Stability	Stability description	Standard deviation of wind direction (degrees)[1]	Occurrence (%)
A	Very unstable	25	10.5
B	Moderately unstable	20	4.7
C	Slightly unstable	15	8.4
D	Neutral	10	45.8
E	Slightly stable	5	23.7
F	Moderately stable	2.5	6.7

1 *Measured at a height of 10 m.*

Inversion layers and mixing heights

During stable conditions vertical stratification of the atmosphere occurs, accompanied by reduced atmospheric mixing. Temperature inversions are probable when these stable conditions occur. Nocturnal inversions at lower levels (100–400 m) predominate at Olympic Dam, and are usually associated with clear night-time skies and light winds.

Gaseous emissions tend to concentrate below the inversion layer under these conditions. As the sun rises, ground heating from solar radiation produces vertical convective currents and unstable conditions near ground level. This 'mixed layer' grows in height as the ground continues to heat up.

When the top of this layer (the mixing height) reaches the atmospheric layer where the emissions are concentrated, the entrained pollutants may be rapidly mixed to ground level. Ground-level concentrations of emissions typically reach their highest values under these conditions, i.e. under inversion break-up.

The mixing height is determined by mechanical turbulence and convection. Mechanical turbulence is generated by wind blowing over rough ground, and is dependent on wind speed and ground surface features such as the height and shape of buildings or vegetation.

For air quality modelling purposes, mixing heights were determined using a measure of surface roughness and temperature data (Appendix L).

9.1.3 Computer modelling

Computer modelling of emissions has been carried out using the Industrial Source Complex Model (ISC3-ST). The ISC3-ST model is described in Appendix L. Predicted 10-minute and 1-hour maximum concentrations and 1-year average concentrations at ground level have been determined for sulphur dioxide, oxides of nitrogen, carbon monoxide, hydrogen fluoride and particulates. These are considered to be the more significant components of the stack emissions in terms of their potential environmental impacts.

9.2 GASEOUS EMISSIONS

This section describes the sources and impacts of non-radioactive gaseous emissions from plant operations. Radioactive gaseous emissions are discussed in Section 8.9 and Chapter 10.

The emissions are evaluated against two general types of regulatory standards:

- those that control the amount, concentrations or conditions of emission release
- those that apply to ambient ground-level concentrations of pollutants in the air.

A description of the process and gas cleaning equipment that would be used for the Expansion Project is provided in Chapter 3.

The most significant sources of non-radionuclide air pollutants are the copper smelter furnaces and the acid plant.

The principal improvement in sulphur dioxide emission control for the new smelters will be the ducting of sulphur dioxide rich off-gases from the anode furnaces to the new acid plants. This will significantly reduce the short-term elevated sulphur dioxide emissions that occur from the operation of the existing anode furnaces during the oxidation phase.

9.2.1 Sulphur dioxide

Sulphur dioxide (SO_2) would be released from the copper smelter, the acid plant, and fuel burning equipment—the yellowcake calciner and the auxiliary boilers. Each of these sources is discussed below.

Copper smelter

The majority of off-gases from the new smelter would be processed through the associated acid plant where SO_2 conversion to sulphuric acid (H_2SO_4) takes place. Each new smelter (the flash smelter for the 200,000 t/a copper production expansion, and the matte smelter for possible further expansion to 350,000 t/a copper production) would be equipped with a 90 m high stack, and share a supporting structure with an associated acid plant stack of similar height.

The smelter stacks would be used principally to discharge cleaned furnace off-gases during certain stages of operation of the flash, anode and electric furnaces (as described in Section 3.5). The total short-term maximum SO_2 emissions from these sources are estimated to be 51.2 g/s at 200,000 t/a copper production and 91.0 g/s at 350,000 t/a copper production.

For the purposes of modelling the ground-level concentrations of SO_2, the maximum emission rates have been used for calculating both the short-term (10-minute and 1-hour) ground-level maximum concentrations and the annual ground-level concentrations. Thus the annual averages will be over-estimates.

During shut-down of the acid plant or electrostatic precipitator, flash smelter gases would be directed to a gas treatment system, and the flash furnace burner would be shut down, resulting in diminishing SO_2 emissions to about 1% volume after one hour (Section 3.5). Emissions of SO_2 for these periods are estimated at 5.0 g/s at 200,000 t/a copper production (maximum 9.0 g/s at 350,000 t/a).

During these operating conditions, ground-level concentrations would thus be lower than for normal operating conditions.

The smelter stacks would also be used to discharge ventilation gases from the smelter building, as collection of these gases would be necessary to ensure that the work environment within the smelter buildings met appropriate occupational health and safety standards. These gases would not contain sufficient concentrations of SO_2 to allow treatment within the acid plant and, after passing through a dust collection system, the SO_2 would be emitted via the smelter stacks at a rate of approximately 0.8 g/s at a copper production rate of 200,000 t/a, and 1.1 g/s at a copper production rate of 350,000 t/a.

The total short-term maximum SO_2 emissions from the flash smelter are thus 52.0 g/s at 200,000 t/a copper production, and from the flash and matte smelters the short-term maximum SO_2 emissions are 92.1 g/s at 350,000 t/a copper production.

Acid plant

Sulphuric acid for use in the metallurgical treatment plant would be produced from conversion of off-gases from the copper smelter and from the burning of elemental sulphur. Recovery of SO_2 would be maximised in the acid plant in order to minimise SO_2 emissions and to minimise the use of imported elemental sulphur.

Emissions of SO_2 from the existing acid plant in 1995–96 were measured at 4.2 g/s at a concentration of 1,500 mg/m^3. As described in Section 3.5, a new acid plant would be constructed for the expansion to 200,000 t/a copper production. Gas leaving this new acid plant would be discharged to the atmosphere via a 90 m high stack and contain no more than 2 kg of SO_2 per tonne of H_2SO_4 production, in accordance with the national emission guidelines. Emissions of SO_2 from the new acid plant stack have been estimated to be 12.7 g/s.

Further expansion to 350,000 t/a copper production would involve the construction of another acid plant, which would have a similar stack and similar emission characteristics. The total SO_2 emission rate from both acid plants at a copper production rate of 350,000 t/a is estimated at 22.2 g/s.

Fuel burning equipment

Sulphur contained in fuel used on site would be released as SO_2 on combustion. Boiler requirements for steam production would be largely satisfied by the use of waste heat from the smelter and acid plants. A supplementary fuel source is LPG, which contains negligible amounts of sulphur, and is used in the anode furnaces.

Minor amounts of sulphur would be contained in the diesel fuel used for yellowcake calcining. The ammonium diuranate feed to the calciner would contain minor amounts of sulphate, which might also dissociate and release SO_2. The yellowcake calciner gases would be cleaned by a scrubber prior to being emitted to atmosphere.

After scrubbing, the SO_2 emission rate from calcining would be approximately 0.022 g/s at 200,000 t/a copper production (0.038 g/s at 350,000 t/a). These emissions are insignificant compared with the smelter emissions.

9.2.2 Sulphur trioxide and sulphuric acid

Emissions of sulphur trioxide (SO_3) and H_2SO_4 (produced when SO_3 reacts with moisture) would occur from the acid plants. These plants would be designed to achieve stack SO_3 emissions of not greater than 75 mg/Nm^3 (dry) of SO_3 and H_2SO_4, expressed as SO_3.

9.2.3 Oxides of nitrogen

Oxides of nitrogen are produced in fuel burning equipment from the high temperature reaction of atmospheric nitrogen and oxygen in the combustion zone, and from the partial oxidation of nitrogenous compounds contained in the fuel. Emissions of oxides of nitrogen would be predominantly nitric oxide (NO), but also contain a minor proportion of nitrogen dioxide (NO_2). Most NO is converted to NO_2 within a few hours of release.

Anode furnace burners, fuelled by LPG, operate at 50% enriched air and would be the main source of nitrogen oxides. Emissions from the smelter are expected to be approximately 0.7 g/s at 200,000 t/a copper production and 1.2 g/s at 350,000 t/a copper production. The operating conditions of the diesel fuelled calciners are such that emissions of nitrogen oxides are expected to be negligible.

Small quantities of nitrogen oxides are emitted in the gold and silver refinery (Section 2.2 and Section 3.5). These gases are ducted to a caustic soda scrubber to minimise emissions. The nitrogen oxide emissions from this source are minor and are not considered further in the dispersion modelling.

9.2.4 Hydrogen fluoride

The only source of gaseous fluorides would be in the smelter off-gases. These would result from some of the fluorides originally contained in the ore reacting to form hydrogen fluoride (HF) during smelting of the copper. Hydrogen fluoride is not emitted from the hydrometallurgical plant as it remains in solution as a chemical complex.

Off-gases from the smelter would be passed through a gas cleaning train to remove the fluorides which would otherwise contaminate the vanadium pentoxide catalysts used in acid production. However, as a worst case assumption, if all fluoride entering the acid plant passes through the gas cleaning train, emissions of hydrogen fluoride would be of the order of 0.3 g/s at 200,000 t/a copper production (0.5 g/s at 350,000 t/a production).

9.2.5 Carbon monoxide

Carbon monoxide (CO) is released as a product of incomplete combustion of fuel. Minor amounts are expected to be released from the flash and electric furnaces, with total stack emissions estimated to be approximately 2.3 g/s at 200,000 t/a copper production (4.0 g/s at 350,000 t/a production).

9.2.6 Carbon dioxide

Carbon dioxide (CO_2) is produced by the burning of fuel and would arise from a number of sources, including power generation, petrol and diesel powered vehicles, standby electricity generators, and burning of LPG and coke in the smelter.

The current CO_2 production rate associated with Olympic Dam, including power generation, is approximately 398,023 t/a (as shown in Table 3.6). Following the expansion, emission rates are expected to increase to approximately 975,280 t/a at 200,000 t/a copper production, and 1,494,584 t/a at 350,000 t/a production.

9.2.7 Particulates

The smelters are the major source of particulates within the gaseous process emissions. Total particulate emissions from the smelters are estimated to be 1.9 g/s at 200,000 t/a copper production, and 3.3 g/s at 350,000 t/a production.

The chemical constituency of process off-gas particulates is described in Section 3.5. Copper, iron, sulphur and silica are the dominant components. Minor constituents include zinc, lead, bismuth, arsenic, alumina and lime. The particle size of virtually all emissions can be expected to be less than 10 µm (i.e. in the PM_{10} fraction). Thus the emission rates of total particulates are nominally equivalent to the PM_{10} fraction.

9.2.8 Process emissions summary

The levels of predicted emissions for the existing 85,000 t/a copper production and for 200,000 t/a and 350,000 t/a copper production are summarised in Tables 9.3, 9.4 and 9.5.

Table 9.3 Process emissions to atmosphere (85,000 t/a copper production)

Stack emission source	Emission (g/s, 1-hour basis)				
	Sulphur dioxide	Oxides of nitrogen	Hydrogen fluoride	Carbon monoxide	Particulates
Existing anode furnace No. 1 (oxidising)	300.4	0.155	–	0.5	0.4
Existing anode furnace No. 2	1.5	0.155	–	0.5	0.4
Existing acid plant	5.7	–	0.13	–	–
TOTAL	**307.6**	**0.31**	**0.13**	**1.0**	**0.8**

Table 9.4 Process emissions to atmosphere (200,000 t/a copper production)

Stack emission source	Emission (g/s, 1-hour basis)				
	Sulphur dioxide	Oxides of nitrogen	Hydrogen fluoride	Carbon monoxide	Particulates
New flash, electric and anode furnaces, and ventilation gases	52.0	0.73	–	2.3	1.9
Acid plant No. 2	12.7	–	0.30	–	–
TOTAL	**64.7**	**0.73**	**0.30**	**2.3**	**1.9**

Table 9.5 Process emissions to atmosphere (350,000 t/a copper production)

Stack emission source	Emission (g/s, 1-hour basis)				
	Sulphur dioxide	Oxides of nitrogen	Hydrogen fluoride	Carbon monoxide	Particulates
Flash, electric and anode furnaces, and ventilation gases	52.0	0.73	–	2.3	1.9
Acid plant No. 2	12.7	–	0.30	–	–
Matte smelter and ventilation gases	39.0	0.42	–	1.7	1.4
Acid plant No. 3	9.5	–	0.23	–	–
TOTAL	**113.2**	**1.15**	**0.53**	**4.0**	**3.3**

9.2.9 Comparison of emission concentrations with standards

The emission concentrations in the gas streams of plant stacks are required to meet the standards of the Air Quality Policy established under the South Australian *Environment Protection Act 1993.*

The national guidelines for control of emission of air pollutants from new stationary sources would also be met (Australian Environment Council and National Health and Medical Research Council 1986).

The existing anode furnace and acid plant stack gases are monitored bi-annually for acid gases, with samples being collected and analysed for sulphur-based acid gases (SO_2, SO_3 and acid mist). Acid gas emission tests are also conducted on the existing electric furnace off-gases. The results from this monitoring show variable levels of acid gases, the levels depending on the sulphur content in slag and the stage of the process.

The SO_2 concentration in the acid plant stack is monitored continuously, and the data are used by acid plant operators to monitor operating performance of the plant in order to minimise SO_2 emissions. The South Australian Environment Protection Authority (SA EPA) has granted WMC an exemption from meeting the limit for five hours following start-up to allow the plant to reach normal operating conditions.

Table 9.6 presents a comparison of the limits set by the SA EPA Air Quality Policy and the emission limits adopted for the design of the Expansion Project. It should be noted that limits for some parameters are determined by the need to achieve compliance for another air contaminant that will be in the same gas stream.

The design emission limits have generally been chosen to provide a margin to the SA EPA limit or the national guidelines. In some instances design limits have been chosen in anticipation of possible future new limits or guidelines. In all cases the design emission limit is within the applicable SA EPA limit and the national guideline.

Table 9.7 presents the current ambient air quality criteria adopted by the SA EPA, possible future criteria and the design criteria adopted for the Expansion Project. These ambient criteria apply to ground-level concentrations in the receiving environment.

The Expansion Project air quality design criteria apply individually to each design stage, and are less than the SA EPA criteria, in order to provide allowance for possible future plant expansion. Overall levels are required to meet the SA EPA criteria. The criteria also reflect possible future guidelines.

Table 9.6 Relevant SA EPA emission limits and national guidelines (mg/Nm^3, dry)

Pollutant	SA EPA limit	National guidelines	Project design limit	Notes
Antimony	10	–	5	
Arsenic	10	–	5	
Cadmium	3	3	2	
Lead	10	–	5	
Mercury	3	3	2	
Vanadium	–	–	2[1]	
Selenium	–	–	2[1]	
Tellurium	–	–	2[1]	
Cobalt	–	–	2[1]	
Manganese	–	–	2[1]	
Nickel	–	20	2	National standard may be reduced in future.
Total metals	10[2]	10[3]	7.5[4]	
Particulates	250	250	100	General processes (referenced to 12% CO_2 for boilers and incinerators).
Particulates	100	100	75	Heating or processing ores and metals.
Sulphur dioxide	–	–	1,200[5]	Other than acid plants.
Acid gases (H_2SO_4 plants)	3,000	–	2,500	As SO_3 equivalent (total of H_2SO_4, SO_3, SO_2).
SO_2 (H_2SO_4 plants)	–	2.0	2.0	Units are kg/t of 100% acid.
SO_2 (H_2SO_4 plants)	–	–	99.8%	Acid plants—conversion efficiency.
SO_3/H_2SO_4	100	–	75	As SO_3 equivalent.
SO_3/H_2SO_4 (H_2SO_4 plants)	–	0.075	0.075	Units are kg/t of 100% acid.
Oxides of nitrogen	350	350	300	Gaseous fuels >150,000 MJ/h heat input—limit referenced to 7% O_2.
	500	500	450	Liquid and solid fuels >150,000 MJ/h heat input—limit referenced to 7% O_2.
	–	–	400[6]	Non-combustion and non-acid plant sources.
Hydrogen sulphide	5	5	3	
Fluorine and compounds	50	50	20[7]	As HF equivalent.
Chlorine and compounds	200	200	150	As Cl_2 equivalent.
Carbon monoxide	1,000	1,000	750	

1 *Could be included in future metals standards.*
2 *Total of antimony, arsenic, cadmium, lead and mercury and their respective compounds.*
3 *Total of antimony, arsenic, cadmium, lead, mercury and vanadium and their respective compounds.*
4 *Total of antimony, arsenic, cadmium, lead, mercury, vanadium, selenium, tellurium, cobalt, manganese, nickel and their respective compounds.*
5 *Future possible limit is 1,400 mg/m^3.*
6 *Future possible limit is 500 mg/m^3.*
7 *Future possible limit is 20 mg/m^3.*

Table 9.7 Ambient air quality criteria ($\mu g/m^3$)

Pollutant	SA EPA criteria	Possible future criteria	Expansion Project design criteria[1]	Sources and notes
Nitrogen dioxide:				NHMRC
1-hour	320		210	1 exceedance/month
Carbon monoxide:				NHMRC
1-hour	40,000		23,000	
8-hour	10,000		6,000	1 exceedance/year
Total suspended particulates:				USEPA[2]
Annual	75[3]		50	
24-hour	260		175	
PM_{10} particulates:				
Annual		50	33	USEPA (under review)
24-hour		150	100	1 exceedance/year
$PM_{2.5}$ particulates:				USEPA review proposals
Annual		30	20	15–30 (mean)
24-hour		85	55	25–85
Lead:				NHMRC
3-month average	1.5	1.0	0.65	
Sulphur dioxide[4]:				NHMRC
Annual	60		40	Annual level in conjunction with particulate annual goal of 90 $\mu g/m^3$
1-hour	570[5]		350	
10-minute	700[5]		460	
Fluoride (as hydrogen fluoride):				ANZECC
12-hour		3.7	2.7	
1-day		2.9	1.9	
7-day		1.7	1.1	
30-day		0.84	0.55	
90-day		0.5	0.33	

1 Applies individually to each project expansion stage. Overall levels must meet SA EPA requirements.
2 Replaced by PM_{10} standards in the USA.
3 Geometric mean. NHMRC goal is 90 $\mu g/m^3$, annual mean.
4 SO_2 is at STP, others at 20°C.
5 Recently lowered from 700 $\mu g/m^3$ (1-hour) and 1,400 $\mu g/m^3$ (10-minute).
Notes: NHMRC = National Health and Medical Research Council
USEPA = United States Environment Protection Agency
ANZECC = Australian and New Zealand Environment and Conservation Council.

9.3 PREDICTION OF GROUND-LEVEL CONCENTRATIONS

Predictions for ground-level concentrations of SO_2, nitrogen oxides, carbon monoxide, particulates and hydrogen fluoride were derived by numerical modelling.

Modelling results are given for four cases:

- Case 1 represents the existing 85,000 t/a copper production plant.
- Case 2 represents the initial expansion to 200,000 t/a copper.
- Case 3 represents a 285,000 t/a copper production facility comprising the existing 85,000 t/a plant, with modifications made to ensure ground-level concentrations comply with ambient criteria, plus the proposed 200,000 t/a plant.
- Case 4 represents the possible future 350,000 t/a copper production facility, with the existing plant decommissioned.

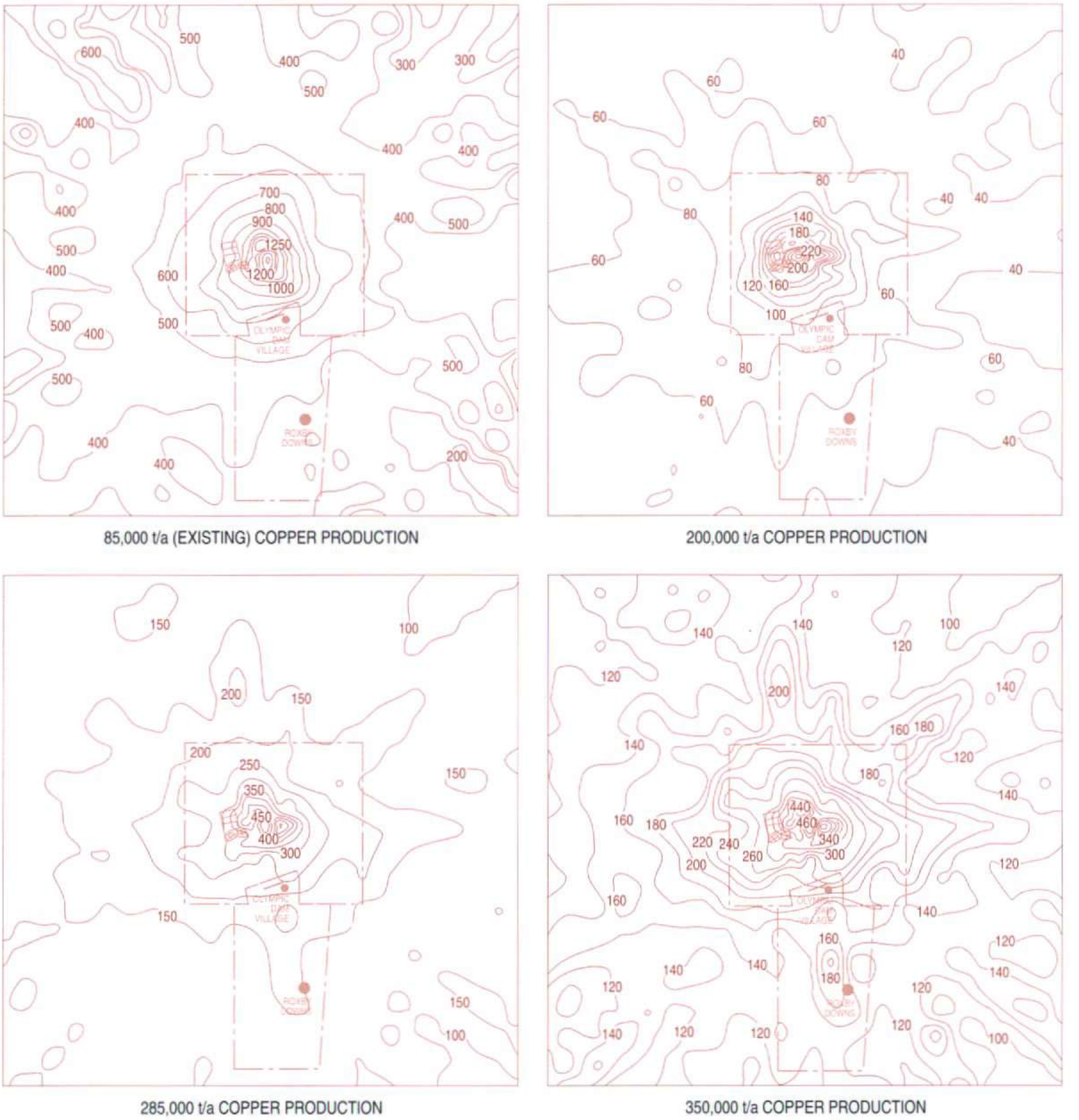


FIGURE 9.3
PREDICTED MAXIMUM 10 MINUTE SULPHUR DIOXIDE CONCENTRATIONS FOR VARIOUS RATES OF COPPER PRODUCTION

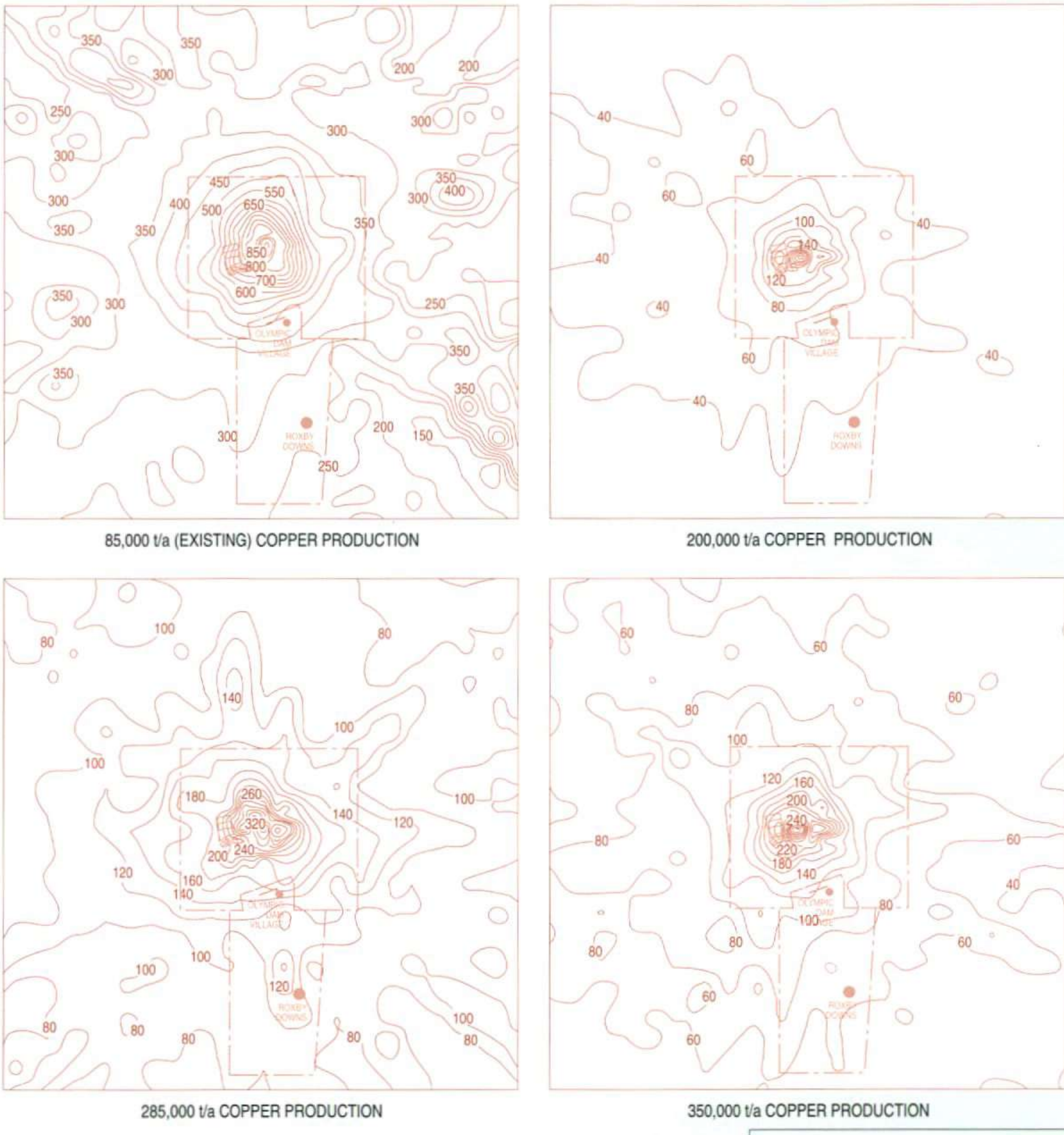
N 0 10 km

Note: All contours in ug/m^3
Refer to Table 9.8 for maximum values near plant

9.3.1 Sulphur dioxide

The predicted ground-level concentrations of SO_2 are presented in Figures 9.3 to 9.5. The contours do not represent a particular 10-minute or 1-hour period in the year, but are a composite showing the maximum values for the averaging period regardless of when it occurred. It should be noted that the contour intervals near the plant are too close to give a readable figure. Hence the three highest predicted values for the year are shown in Table 9.8.

Emissions of SO_2 from the existing 85,000 t/a plant (Case 1) result in significantly higher short-term ground-level concentrations compared with the new plant configurations (Cases 2 and 4). It can be seen that under routine operating conditions the model predicts that, for the existing plant, some exceedances of the 10-minute and 1-hour goals are likely



Note: All contours in ug/m^3
Refer to Table 9.8 for maximum values near plant

FIGURE 9.4
PREDICTED MAXIMUM 1HOUR SULPHUR DIOXIDE CONCENTRATIONS FOR VARIOUS RATES OF COPPER PRODUCTION

N 0 10 km

within the Special Mining Lease. However, exceedance of the 10-minute goal for the existing plant is predicted to occur only once per year at Olympic Dam Village. All other goals for SO_2 are predicted to be met for routine operating conditions.

Two matters should be noted with respect to the existing plant. The first is that the air quality goals have been made significantly more stringent since the plant was commissioned, and secondly the number of exceedances of the short-term goals will depend on the conjunction of unfavourable dispersion conditions with the operation of the anode furnaces in the early phases of oxidation when emissions of SO_2 are at their highest.

The general design philosophy for the expanded plant is to set stack heights and emission levels so that exceedances are not predicted even under the most unfavourable dispersion conditions

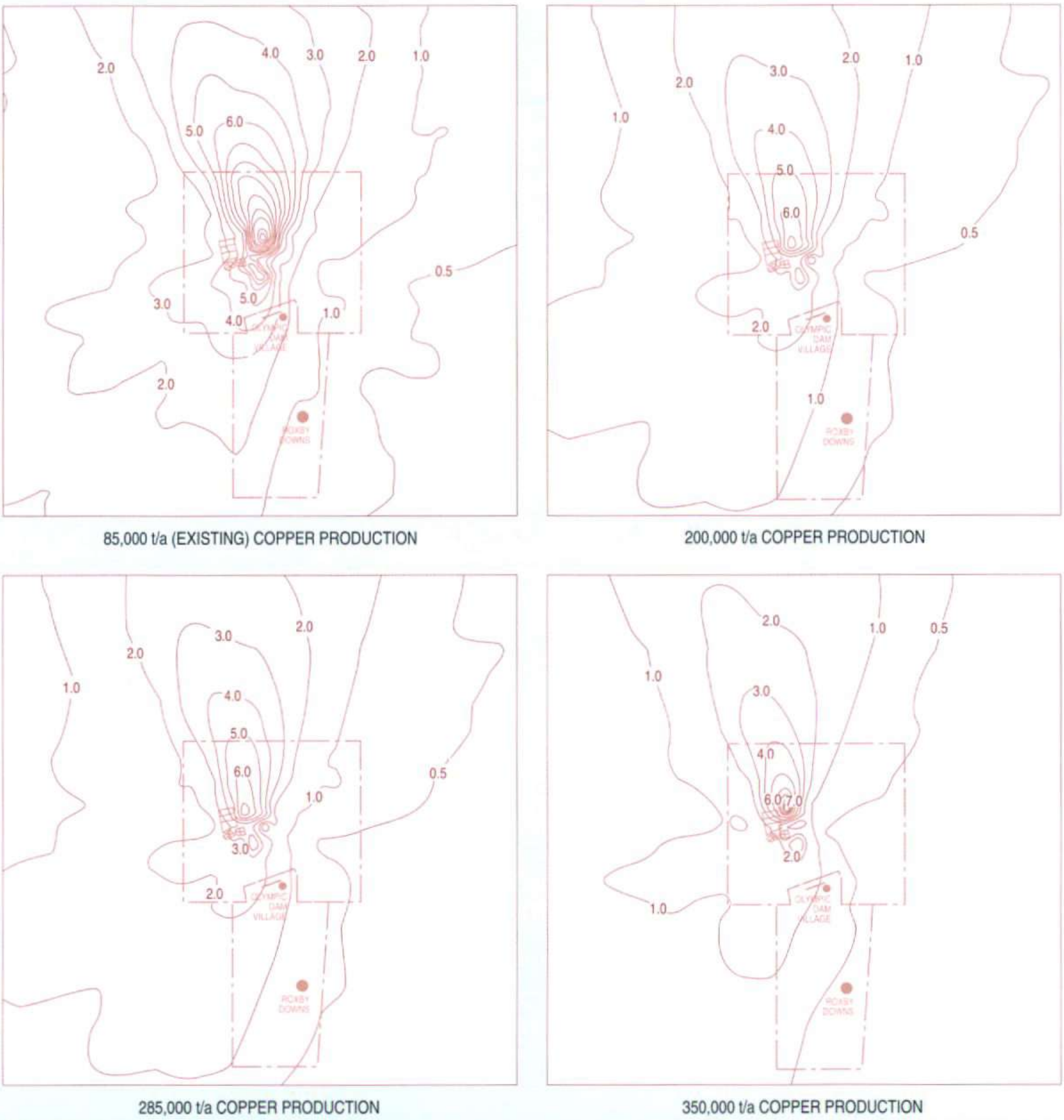


FIGURE 9.5
PREDICTED MAXIMUM ANNUAL AVERAGE SULPHUR DIOXIDE CONCENTRATIONS FOR VARIOUS RATES OF COPPER PRODUCTION

N 0 10 km

Note: All contours in ug/m^3
Refer to Table 9.8 for maximum values near plant

expected in the course of a year. This necessitates the redesign of the existing plant so that if it is used as part of the Case 3 development (285,000 t/a) the air quality goals will be met within the Special Mining Lease as well as outside it.

The envisaged treatment to do this involves scrubbing the anode furnace gases to remove 85% of the sulphur dioxide (the maximum readily achievable level) and increasing the stack height of the anode furnaces to 80 m and of the acid plant to 70 m.

The scrubbing process reduces the temperature of the emission, resulting in a decrease in the buoyancy and the plume rise of the emission. Increased stack heights are needed to overcome this effect. These upgrades, or programmes producing equivalent results, would be implemented if the Case 3 development proceeds.

Both 10-minute and 1-hour ground-level SO_2 concentrations are predicted to be significantly lower for the 200,000 t/a and 350,000 t/a plant configurations. The predicted worst case maxima are below both the current standards and the possible future air quality criteria (Table 9.7).

For all development cases, average annual SO_2 concentrations are well within the air quality standards.

Table 9.8 Highest predicted values for sulphur dioxide concentrations (μg/m³)

Sulphur dioxide concentration	Case 1 existing 85,000 t/a	Case 2 200,000 t/a	Case 3 285,000 t/a	Case 4 350,000 t/a	SA EPA air quality goal[1]
10-MINUTE					
Highest	2,026.5	311.8	693.4	527.2	700
Second highest	1,579.7	303.2	672.1	439.6	
Third highest	1,561.3	298.2	659.5	434.2	
1-HOUR					
Highest	1,417.1	218.1	484.9	368.7	570
Second highest	1,104.7	212.0	470.0	307.4	
Third highest	1,091.8	208.5	461.2	303.6	
ANNUAL					
Highest	17.6	7.0	9.8	11.8	60
Second highest	17.5	6.2	8.8	11.2	
Third highest	17.1	6.2	8.7	11.1	

1 *Sulphur dioxide goals were recently revised from 1,400 μg/m³ (10-minute) and 700 μg/m³ (1-hour).*

During acid plant start-up, the concentration of SO_2 in the tail gas of the new acid plants would average no more than 2,000 p.p.m. (5.71 g/Nm³) in the first two hours, falling to less than 1,000 p.p.m. (2.86 g/Nm³) in the next two hours and achieving design performance after four hours. An exemption under the SA EPA Act licence would be sought for these operating conditions, which would occur only a few times per year. A similar exemption applies to the existing acid plant in the current SA EPA licence.

9.3.2 Oxides of nitrogen

The two highest predicted values of oxides of nitrogen (NO_x) for the year, for each case, are shown in Table 9.9.

Table 9.9 Predicted highest and second highest oxides of nitrogen concentrations for different development cases (μg/m³)

Concentration of nitrogen oxides	Case 1 existing 85,000 t/a	Case 2 200,000 t/a	Case 3 285,000 t/a	Case 4 350,000 t/a	SA EPA air quality goal
1-HOUR					
Highest	49.7	4.5	49.7	6.1	320
Second highest	19.0	4.1	19.0	4.7	

For all development cases, the predicted highest ground-level concentrations of NO_x are well within the applicable air quality standards (Table 9.7). As with SO_2, the ground-level concentrations of NO_x are predicted to be significantly lower for Cases 2 and 4.

9.3.3 Hydrogen fluoride

The two highest predicted values of HF for the year are shown in Table 9.10. For all development cases, the predicted highest ground-level concentrations of HF are within the relevant (ANZECC) air quality guidelines (Table 9.7). Again, ground-level concentrations are predicted to be significantly lower for Cases 2 and 4.

Table 9.10 Predicted highest and second highest hydrogen fluoride concentrations for different development cases (μg/m³)

Hydrogen fluoride concentration	Case 1 existing 85,000 t/a	Case 2 200,000 t/a	Case 3 285,000 t/a	Case 4 350,000 t/a	ANZECC air quality goal[1]
12-HOUR					
Highest	2.32	0.63	2.43	0.93	3.7
Second highest	1.67	0.51	1.67	0.82	
24-HOUR					
Highest	1.45	0.48	1.45	0.66	2.9
Second highest	0.99	0.42	0.99	0.62	
7-DAY					
Highest	0.99	0.33	0.99	0.45	1.7
Second highest	0.67	0.29	0.67	0.42	
30-DAY					
Highest	0.12	0.15	0.16	0.25	0.84
Second highest	0.08	0.11	0.12	0.21	
90-DAY					
Highest	0.10	0.12	0.13	0.20	0.5
Second highest	0.06	0.09	0.10	0.17	
ANNUAL					
Highest	0.05	0.07	0.08	0.13	–
Second highest	0.04	0.06	0.08	0.12	

Note: 7-day and 90-day averages estimated from 24-hour and 30-day averages, respectively, using the 0.2 power law.

9.3.4 Carbon monoxide

The two highest predicted values of carbon monoxide for the year are shown in Table 9.11. For all development cases, the predicted highest ground-level concentrations of carbon monoxide are well within the applicable air quality standards (Table 9.7). Again, ground-level concentrations are predicted to be significantly lower for Cases 2 and 4.

Table 9.11 Predicted highest and second highest carbon monoxide concentrations for different development cases (μg/m³)

Carbon monoxide concentration	Case 1 existing 85,000 t/a	Case 2 200,000 t/a	Case 3 285,000 t/a	Case 4 350,000 t/a	SA EPA air quality goal
15-MINUTE					
Highest	262.5	19.7	262.5	26.9	–
Second highest	100.3	17.7	100.3	20.8	
1-HOUR					
Highest	198.9	14.9	198.9	20.4	40,000
Second highest	76.0	13.4	76.0	15.8	
8-HOUR					
Highest	25.5	6.5	25.7	8.7	10,000
Second highest	16.7	4.7	16.7	7.1	

9.3.5 Particulates

As indicated in Section 9.2.7, particulates have been modelled under the assumption that all particulates are within the PM_{10} size fraction. The two highest predicted values for PM_{10} from stack emission sources are shown in Table 9.12.

There are no specific air quality standards for PM_{10} set by the SA EPA. The USEPA standards of 150 µg/m³ for 24 hours and 50 µg/m³ annually are used as an indicator of possible future criteria (Table 9.7). For all development cases, the predicted highest ground-level concentrations of PM_{10} are well within the USEPA air quality standards.

Table 9.12 Predicted highest and second highest particulate concentrations for different development cases (due to stack emissions) (µg/m³)

PM_{10} concentration	Case 1 existing 85,000 t/a	Case 2 200,000 t/a	Case 3 285,000 t/a	Case 4 350,000 t/a	USEPA standard
1-HOUR					
Highest	7.5	6.9	11.3	11.7	–
Second highest	7.0	5.8	8.9	8.8	
24-HOUR					
Highest	2.4	1.4	2.4	1.9	150
Second highest	2.0	1.3	2.0	1.7	
ANNUAL					
Highest	0.23	0.16	0.25	0.28	50
Second highest	0.23	0.15	0.25	0.28	

9.4 OTHER EMISSIONS AND CONTROL REQUIREMENTS

In addition to gaseous emissions to the atmosphere, there are other emission control requirements relating to occupational exposure. These principally refer to occupational exposure to dusts and gases; to fugitive dust from plant operations, quarrying and traffic movements; and to emissions of process chemicals.

9.4.1 Occupational health standards

This section discusses the standards for occupational exposure to gases and dusts applicable to the Expansion Project, the sources of fugitive dust, and the types of process chemicals used and their control requirements.

Protective measures to provide for employee safety and control of spillages would be built into new plant elements as they were for the existing plant. The aim would be to eliminate or reduce to a minimum the need for employees to wear special protective clothing or respiratory protection. This aim accords with the preferred hierarchy of controls, recommended by the National Occupational Health and Safety Commission (WorkSafe Australia).

The principal regulations in relation to contaminants in the working environment come under the *South Australian Mines and Works Inspection Act 1920* and the *Occupational Health, Safety and Welfare Act 1986* and Regulations 1995. The latter Act refers to relevant standards and WorkSafe documents as part of the Regulations, including the following documents issued by the National Occupational Health and Safety Commission:

- Control of Workplace Hazardous Substances, 1994
- Exposure Standards for Atmospheric Contaminants in the Occupational Environment, 1995
- Guidance Note for Storage of Chemicals, 1990.

The commission's air quality guideline values are expressed in three ways:

- a time-weighted average (TWA) for an 8-hour working day

- a short-term exposure limit (STEL) for 15-minute exposure
- a peak exposure limit.

The relevant exposure standards applicable to the project are summarised in Table 9.13.

Table 9.13 Occupational exposure standards

Contaminant	*Mines and Works Inspection Act*	*Occupational Health, Safety and Welfare Act*	
		TWA	STEL
Carbon dioxide	5,000 p.p.m.	5,000 p.p.m.	30,000 p.p.m.
Carbon monoxide	50 p.p.m.	25 p.p.m.	–
Nitric oxides	5 p.p.m.	3 p.p.m. (NO_2)	5 p.p.m. (NO_2)
Hydrogen sulphide	5 p.p.m.	10 p.p.m.	15 p.p.m.
Respirable silica[1]	300 particles/m^3	2 mg/m^3	–
Coal (respirable dust)	–	3 mg/m^3	–
Oxygen	>20%	–	–
Sulphur dioxide	–	5.2 mg/m^3	13 mg/m^3
Sulphuric acid	–	1 mg/m^3	3 mg/m^3

1 *Currently under review by the Exposure Standards Expert Working Group.*

The definition of respirable dust is complex and depends on the density of the material and the shape of the particle. The respirable fraction is that fraction that is defined by a sampling efficiency curve, which depends on the settling velocity of the particle (AS 2985 – 1985).

9.4.2 Fugitive dust

Process materials

Relatively small amounts of dust result from raw materials that are handled and stored in bulk form. These materials include the following:

- sulphur, which would be burned as a make-up source of SO_2 in the acid plant
- sand sourced from local dunes, which is used as flux in the copper smelter
- coke used to augment fuel in the copper smelter.

Stockpile sizes

Stockpiles would be made sufficiently large to ensure a continuous supply to the plant. Sulphur must be transported by sea, which generally entails infrequent supply of bulk quantities. Therefore, provision has been made in the current plant for sulphur stockpiles with a capacity of up to 40,000 t each (approximately four months' supply) to allow storage of bulk deliveries and to provide against uncertainties in supply. Additional storage capacity of equivalent size would be provided for the expansions to 200,000 t/a and 350,000 t/a copper production. As sand is obtained locally and coke is sourced from Australian suppliers, a minimum amount of these materials would be maintained in stockpiles.

Handling facilities

In general, the greatest potential for dust emissions arises during the unloading and transfer of material, particularly while dumping or at conveyor drops on to stockpiles. The equipment and techniques already in use on the site have maintained fugitive dust concentrations at acceptable levels, and these measures would continue to be employed for the Expansion Project.

Dust emissions at stockpile discharge conveyors would be controlled using methods such as luffing conveyors or telescoping discharge chutes, and conveyors and transfer points would be enclosed or covered as necessary.

Sulphur and coke would continue to be transported to the site by truck, unloaded and conveyed to separate stockpiles. The stockpiles would be situated on concrete pads with concrete bunds around the perimeter. Front end loaders would reclaim these materials from within the concrete bund for transport to bins within the acid plant (sulphur) and smelter (coke).

Sulphur is transported as slated sulphur, which consists of pieces about 60 mm thick and of varying lengths and widths. As the pieces rub against each other during handling, some fine material will result. Minor amounts of these particles would be emitted during reclaim, while small quantities would be blown from the stockpile. The visual evidence from the existing stockpile indicates that dispersion of sulphur from the stockpile is relatively localised.

Sand sourced from local dunes would be kept in an unbunded open storage pad, with front end loaders reclaiming the sand for transport to bins adjacent to the copper smelter. During handling of sand, the same methods as those used for controlling dust from the other materials would be employed. In addition, sand from the local dunes is fine to medium grained, and has a low potential for generating dust.

Quarry

Dust would continue to be generated from the backfill quarry operations during drilling, blasting, loading and hauling, crushing and screening. However, these are normal quarrying activities that have not presented any serious dust generation problems to date.

Crushing and screening normally account for the largest portion of dust generated from quarries. Equipment for dust control, suppression or collection is used for conveyors and transfer points, crushers and screens. Water is used in drilling to limit fugitive dust emissions, while blasting methods are used that minimise the generation of excessive dust. Overall, generation of dust during quarry operations is, and would continue to be, controlled to maintain employee exposures to levels below those recommended by the National Occupational Health and Safety Commission.

Roads

Heavily trafficked roads throughout the site are sealed, thus eliminating these surfaces as a source of dust. These roads include:

- public roads between the town, village, plant, mine and airfield
- internal roads within the plant, store and workshop area
- roads in the mine area.

The lightly trafficked roads are surfaced but unsealed, and minor amounts of dust arise. These roads are used intermittently and are watered with mine water as necessary to control dust. This practice would continue following the proposed expansion.

9.4.3 Dust monitoring

Environmental dust monitoring has been carried out at Olympic Dam since 1988. There exists a good record of total particulate concentrations and dust deposition rates at sampling stations around the Olympic Dam site, including residential areas (Appendix L).

There are eight sites where high-volume dust sampling has been carried out. The most complete set of data from the high-volume sampling exists for the year March 1993 to February 1994. The highest dust levels, recorded as total suspended particulates (TSP), were recorded at the Sandhill site, where monthly average values reached a maximum of 66 $\mu g/m^3$. The average of all high-volume sampling results was 32 $\mu g/m^3$. Annual TSP dust levels are thus well below the SA EPA criterion of 75 $\mu g/m^3$ and the national guideline of 90 $\mu g/m^3$.

9.5 NOISE

9.5.1 Assessment methodology

An assessment was undertaken to identify potential noise impacts from the proposed expansion on residents of the Roxby Downs township and at Olympic Dam Village, using existing plant operations as a baseline. In addition, the predictions in the 1983 EIS (Vipac 1982) were reviewed and compared with existing operations to determine the validity of model predictions.

The predicted noise levels throughout the plant and beyond the site boundary were assessed by numerical modelling using an environmental noise model, and compared with the environmental requirements (SA EPA Regulations, 1994 Industrial Noise Policy, and the Australian Standard AS 1055–1989). The basic methodology used in the environmental noise model formulation involved several steps, as outlined below.

An audit of the primary equipment with significant noise generation characteristics was carried out for the three scenarios: existing (85,000 t/a copper production), first phase expansion (200,000 t/a), and possible future expansion (350,000 t/a). Estimates or measurements of equipment sound power levels were based on on-site measured data, the 1983 EIS data, manufacturers' data or library references for actual plant installed, and newly acquired data on additional or proposed plant machinery and noise sources.

Short-duration sound power was measured on site using sound intensity and engineering sound power measurement. The principal noise sources on site were identified as those sources with sound powers greater than 90 dBA and located primarily outside buildings.

The environmental noise model was developed within the SoundPlan software environment (Version 4.0) and included the effects of topography, propagation, shielding, reflections and the plant physical and acoustic details with modelling algorithms. The noise algorithms used in the modelling were the International Standard ISO 9613 (equivalent to Standard VDI 2714) and the CONCAWE method for meteorological effects.

Sound power data for the principal noise sources were combined with coordinate geometry data obtained from plant layout drawings. Approximately sixty plant buildings and structures were included in the models as barriers, reflecting walls, or both.

Predicted environmental noise levels were calculated for each phase of development and covered critical areas within the processing plant, along the plant fence line, at the Roxby Downs township and at Olympic Dam Village. Both point sound levels and noise contour plots, showing the spatial noise distribution, were produced (Appendix M).

9.5.2 Noise modelling results

Existing operations (85,000 t/a)

The total (summed) A-weighted sound power level (dBA) of the combined principal sources of noise for the existing plant was calculated from the above measurements to be approximately 140 dBA.

The major sources of acoustic power within the existing plant are:

- shaft furnace (138 dBA)
- autogenous mill and associated vibrating screen (134 dBA)
- anode furnaces (128 dBA)
- calciner scrubber fan (126 dBA)
- smelter flash furnace (125 dBA)
- electric furnace (124 dBA)
- mullock stockpile crusher (123 dBA)
- anode casting wheel (122 dBA)
- refinery cathode stripping machine (121 dBA).

There are also many other lesser noise sources within the plant including compressors, cooling towers and cooling tower fans.

The maximum operating sound power of each major noise source was calculated from several noise level measurements over the total emitting surface area. The actual sound pressure level at a point near (within a few metres from) a source is 20–30 dBA lower than the sound power level.

Predictions were carried out for the existing plant for a worst case operational scenario with all noise sources operating. Calm meteorological conditions were assumed (no wind and average temperature and humidity); such conditions are typical and are favourable for the propagation of noise. However, the worst case weather conditions would comprise a north wind, high humidity, cloud cover and temperature inversion, which is a rare occurrence.

Predicted sound levels within the plant, along the southern plant fence line, at Olympic Dam Village and at Roxby Downs township are shown in Table 9.14, together with measured sound levels. The nearest boundary of the Special Mining Lease where there is any development is adjacent to Olympic Dam Village, 5 km south of the project operations. The location of control points used in the modelling is shown in Figure 9.6.

FIGURE 9.6
NOISE MONITORING/CONTROL POINTS

There is generally close agreement between measured and modelled noise levels (approximately ±2 dBA), thereby providing confidence in the ability of the model to predict noise levels for expanded operations. The plant was not fully operating for measurements at control points 5 and 6. The meteorological conditions at the time of the measurements were still, clear and hot (35°C) with low humidity.

Table 9.14 Comparison of measured and modelled noise levels at control points

Control point	Maximum sound pressure level (dBA)	
	Measured noise	Model results
1 40 m from smelter building	76	78
2 Corner First Avenue and Second Street	63	64
3 Corner First Avenue and Ninth Street	64	67
4 Corner Fifth Avenue and Ninth Street	64	66
5 Southern plant fence line	60	65
6 South-eastern plant fence line	60	62
Olympic Dam Village	–	32
Roxby Downs township	approx. 30[1]	max. 20

1 *Background level (L_{95} dBA).*

The prominent noise sources at control point 1 are the various furnaces of the smelter, the most dominant source being the shaft furnace (contributing 75 dBA). The smelter building does not provide much acoustic shielding owing to the openings in the eastern, western and southern walls.

The dominant noise sources at control point 2 are the cooling tower and cooling tower fans. The cooling tower pumps are situated at ground level and are partially shielded by the cooling tower structure relative to the control point location.

Noise at control point 3 (across the road from the ammonia tanks) is dominated by the autogenous mill and the associated vibrating screen. The mullock crushers and the calcination scrubber fan also feature as significant sources at this control point.

The main sources of noise at control point 4 are the shaft furnace and the compressor station (exhaust fans on the western side). As a result of the shaft furnace having greater sound power than the other furnaces, and since it is located outside the eastern wall of the smelter building, the noise it generates propagates well to the east and south of the smelter area.

Noise levels along the Olympic Dam site fence line are generally less than 60 dBA and up to a maximum of 65 dBA from the model results with full plant operation (along part of the southern boundary). Modelled noise levels at Olympic Dam Village, adjacent to the southern boundary of the Special Mining Lease, are comparable with background noise levels.

The predicted noise levels at the Roxby Downs township are of the same order as those estimated in the 1983 EIS. Noise levels at Roxby Downs township owing to existing plant operations are calculated to be less than 20 dBA, which is in accordance with observations. In effect, the noise from the mine site and processing operations is not detectable within the township because background noise levels (L_{95} dBA) are of the order of 30 dBA.

The worst case weather conditions (see above) could cause an increase of 3–4 dBA in noise levels at the control points and 4–5 dBA increase at the village and township. Such differences are not considered significant and would occur only on rare occasions.

Expanded operations

The first phase expansion to 200,000 t/a copper production would involve the addition of a range of new plant structures, operating machinery and noise sources. The major new sources of noise are the addition of a larger autogenous mill and a new smelter, acid plant, oxygen plant and cooling towers, and extensions to the refinery complex and compressor station.

Other additional minor sources would be associated with the new copper and uranium solvent extraction area, feed preparation and flotation areas, countercurrent decantation and clarification area and tailings areas. For the purpose of noise assessment, the existing smelter, acid plant and oxygen plant are assumed to stop operating once the new plants come on-line.

The possible future expansion to 350,000 t/a copper production would include new noise sources associated with an additional smelter, acid plant, refinery complex, electrowinning complex and an additional autogenous mill, and lower level sources in new facilities for copper and uranium solvent extraction, feed preparation, flotation, countercurrent decantation and tailings. The noise assessment assumed new smelter buildings to be more enclosed than the existing smelter plant, and also assumed that they would have slightly quieter furnaces.

As in the existing operations, the environmental noise model was run for the two expansion scenarios to generate noise contour plots and single point noise levels (Appendix M). A comparison of predicted noise levels at the control points, Olympic Dam Village and Roxby Downs township is provided in Table 9.15.

Table 9.15 Comparison of predicted noise levels at site control points

Control point	Maximum sound pressure level (dBA)		
	Existing	200,000 t/a	350,000 t/a
1 40 m from smelter building	78	71	71
2 Corner First Avenue and Second Street	64	69	71
3 Corner First Avenue and Ninth Street	67	76	77
4 Corner Fifth Avenue and Ninth Street	66	72	71
5 Southern plant fence line	65	63	63
6 South-eastern plant fence line	62	65	67
Olympic Dam Village	32	34	34
Roxby Downs township	19	20	20

Noise levels along the Olympic Dam plant fence line would remain generally less than 60–62 dBA, with a maximum of 67 dBA (at control point 6) following the 350,000 t/a expansion. The predicted noise levels at Roxby Downs would continue to be approximately 20 dBA, and approximately 34 dBA at Olympic Dam Village, which is adjacent to the southern boundary of the Special Mining Lease.

The worst case weather conditions (see above) could cause an increase of 3–4 dBA in noise levels at the control points and a 4–5 dBA increase at the village and township. Such differences are not considered significant and would occur only on rare occasions.

9.5.3 Noise assessment

Environmental noise

The sound levels at the plant fence line would reach a maximum of 67 dBA (with full plant operations following the possible future 350,000 t/a expansion) along part of the southern fence line, and would be generally lower than 60 dBA elsewhere along the fence line. At Olympic Dam Village, adjacent to the southern boundary of the Special Mining Lease, the predicted noise level is 34 dBA. As these levels are below the criterion limit of 70 dBA for an industrial zone, noise levels from the plant expansion would therefore comply with the regulations of the South Australian *Environment Protection Act 1993*.

Sound levels in the township would increase marginally (1 dBA) owing to the Expansion Project. However, the noise levels from the plant would be some 5–10 dBA below the existing minimum background levels, and would therefore not be audible at most times. The predicted sound level of about 20 dBA is well below the criterion limit of 45 dBA at night for residential areas, and even less than the 40 dBA limit for rural areas; hence, the plant expansion would comply with regulatory limits.

Although noise levels at Olympic Dam Village would increase marginally (approximately 2 dBA) following the expansion, the noise levels would remain well below the 45 dBA limit for residential areas, even during worst case weather conditions.

Relative to the AS 1055 standard, the noise level exceeded for 10% of the time (L_{10}) at the plant boundary and in the village and township due to expanded plant operations is not expected to exceed the existing background level by more than 5 dBA.

Local traffic levels are likely to increase gradually over the expansion period. However, noise levels associated with this increased traffic (up to a maximum of 3 dBA increase in L_{10} (18-hour) level) are not expected to be significant or annoying.

Given that there would be no significant environmental noise impact caused by the Expansion Project, mitigation measures are not required.

Occupational noise

The Occupational Health, Safety and Welfare (OHSW) Regulations (1995) provide standards in the form of noise exposure limits for employees within workplaces. Compliance is stated as the required duty of employers in addition to the responsibility of employees.

The current site operates on a twelve-hour shift, which imposes a noise exposure limit of 83.2 dBA (Appendix M). The design philosophy for new plant and equipment associated with the expansion is based on reducing noise as much as possible. The design goal for noise exposure of process plant operators is 80 dBA or less, taking into account all potential noise sources and allowing for machinery deterioration.

The equipment contracts for the Expansion Project would include noise specifications as appropriate. Where practicable, engineering noise control would be used for reducing noise levels in key areas of the plant. A detailed assessment of occupational noise is provided in Appendix M.

Prolonged exposure to noise at 80 dBA is not considered to result in any discernible increase in the risk of noise-induced hearing loss. However, occupational noise levels would continue to be at sufficient levels in some areas to require control measures. The current control measures, which include the provision of hearing protection equipment, noise monitoring, signage and employee training, would continue.

CHAPTER 10

RADIATION

CHAPTER 10

RADIATION

The radiation associated with the mining and processing of uranium at Olympic Dam is considered in this chapter. Although the concentration of uranium in the ore at Olympic Dam is low (at approximately 0.06% uranium oxide) and therefore the magnitude of the radiation hazard is also likely to be low, the levels of radiation exposure of employees and members of the public need to be assessed, controlled and managed so that no unnecessary exposures take place.

WMC is obliged under the terms and conditions of the Indenture and the *Radiation Protection and Control Act 1982* (SA) to undertake and report assessments of radiation exposure of employees and members of the public arising from its operations. In addition, WMC is obliged to undertake measurements of environmental radiation to determine the magnitude and extent of any radiation arising from its operations.

This chapter is divided into four parts. The first part is a description of the framework for the regulation of radiation within which the Olympic Dam mine and processing plant operate. An overview of the most recent international recommendations relating to radiation protection is also given.

The second part of the chapter is an analysis of the radiation data that WMC has collected in order to assess radiation exposure of its employees. This analysis is then used to predict the likely effects of the Expansion Project on the magnitude of radiation exposure. It also discusses the numerical expression of risk associated with this level of radiation exposure.

The third part of the chapter is an analysis of changes in environmental radiation that can be attributed to the operations. This analysis is then used to predict the likely effects of the expanded operation on those levels.

The fourth and final part of the chapter is an outline of the Radiation Management Plan proposed for the expanded operation.

Appendix N contains a brief introduction to ionising radiation. Terms used in this chapter are explained in Appendix C and abbreviations in Appendix D.

10.1 RADIATION REGULATION AND HEALTH PHYSICS

10.1.1 Radiation regulation

The framework for the regulation of radiation in South Australia has not changed significantly since the 1983 EIS. Statutory responsibility for administration of the Acts and Regulations concerning radiation and radiation safety lies with South Australian Government agencies and is invoked in the Indenture (Clauses 10 and 11).

Clause 10 (1) states that the proponent shall comply with:

- the Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores 1987 (Australian Government Publishing Service 1987);
- the Code of Practice for the Safe Transport of Radioactive Substances 1990 (Australian Government Publishing Service 1990);

- the Code of Practice on the Management of Radioactive Wastes from the Mining and Milling of Radioactive Ores 1982 (Australian Government Publishing Service 1982);
- codes based on scientific studies and scientific assessment presently issued or to be issued from time to time by the National Health and Medical Research Council of Australia (NHMRC);
- codes or recommendations presently issued or to be issued from time to time by the International Commission on Radiological Protection (ICRP) or the International Atomic Energy Agency (IAEA).

Notwithstanding the foregoing, Clause 10 also requires the proponents to '. . . use their best endeavours to ensure that the radiation exposure of employees and the public shall be kept to levels that are in accordance with the principles of the system of dose limitation as recommended by the International Commission on Radiological Protection . . . as varied or substituted [sic] from time to time'.

Clause 11 has ramifications for the protection of the environment inasmuch as it requires the proponent to formulate and submit for approval a programme for the protection, management and rehabilitation (if appropriate) of the environment of the original Olympic Dam Project including arrangements for monitoring and studying sample areas to ascertain the effectiveness of such a programme. The clause also requires the proponent to provide all relevant raw data and to submit an annual interim report to the Minister. At three-yearly intervals, the proponent is required to submit a detailed report on the results of the programme during the previous three years.

In addition to the Indenture, the South Australian *Radiation Protection and Control Act 1982* has general provisions for control of radiation and includes a requirement that all operators wishing to mine and process radioactive ores must hold a licence to do so. The Olympic Dam licence is number LM1. Regulations under the Act include limits on radiation exposure.

In compliance with the provisions of the *Radiation Protection and Control Act* and Regulations, Clauses 10 and 11 of the Indenture, the codes and recommendations, WMC has measured and reported upon both occupational exposure to radiation and on radioactivity in the environment surrounding Olympic Dam. As new recommendations and scientific advice have been promulgated by national and international bodies, WMC has applied for approval to change various measurement protocols and dose assessment methods. All changes in methodology have been approved by the relevant authorities in advance of their formal adoption.

In respect of the environmental programme, WMC has embarked upon a course that is intended to ensure that its environmental management system reaches accord with the International Standard series ISO 14001.

10.1.2 Changes in radiation biology

In the years since the 1983 EIS, the ICRP has issued a new set of radiation protection recommendations in ICRP Publication 60 (International Commission on Radiological Protection 1991) and also in subsequent publications which give guidance on the application of the recommendations. These recommendations have been formally adopted in Australia as the *National standard for limiting occupational exposure to ionizing radiation* (National Health and Medical Research Council and National Occupational Health and Safety Commission 1995). The Standard is accompanied by recommendations.

The most significant change to the ICRP recommendations arises from a reinterpretation and extension of epidemiological data collected from studies on the survivors of the atomic bombing of Hiroshima and Nagasaki in World War II. When combined with a re-examination of the radiation fields produced by the two bombs, the epidemiological data showed a higher detriment per unit dose than was derived from earlier data. (Detriment is defined as the mathematical expectation of the amount of harm in the exposed group of people, taking into account both the probability and the severity of the different possible harmful effects.) These findings have been modified by the application of factors that account for differences in biological reactions to acute, as opposed to chronic, exposure, and they have been issued as new advice on recommended radiation dose limits. Dose limits are equivalent to detriment limits.

Radiation dose limits are set at a point where the combination of consequences (of exposure to radiation for protracted periods of many decades) is just short of 'unacceptable', and therefore 'just tolerable'. While this approach may seem partly subjective, it does allow consideration of a greater range of interrelated factors, called 'attributes'. The attributes associated with mortality include considerations of the age of the person at death and the number of years of life 'lost' if death occurs. The main health effects considered are cancer and hereditary effects.

The ICRP has also examined non-fatal conditions (morbidity) including certain cancers and hereditary disorders. Morbidity is taken into account in the setting of dose limits by summing the contributions for mortality and weighted morbidity to give an expression of aggregated detriment.

Other conditions, such as lethal effects on the embryo, malformations, mental retardation and induction of leukaemia, have all been considered by the ICRP in reaching its conclusions.

Prior to the publishing of ICRP Publication 60, the annual dose limit for people employed in occupations involving exposure to radiation was 50 millisieverts (mSv). The annual dose limit for members of the public was 1 mSv. In accordance with the new recommendations, the dose limit for such employees is now 100 mSv in any five-year period (with a subsidiary limit of 50 mSv in any one year), while the annual limit for members of the public remains at 1 mSv (with the qualifying statement that, in special circumstances, a higher value of effective dose could be allowed in a single year provided that the average over five years remains 1 mSv per year).

The framework and, in particular, the three principles of radiation protection have remained unchanged (International Commission on Radiological Protection 1991). These three basic principles are:

- No practice involving exposures to radiation should be adopted unless it produces sufficient benefit to the exposed individuals or to society to offset the radiation detriment it causes. (This is called the justification of a practice.)
- In relation to any particular source within a practice, the magnitude of individual doses, the number of people exposed, and the likelihood of incurring exposures where these are not certain to be received, should all be kept as low as is reasonably achievable, with economic and social factors being taken into account. This procedure should be constrained by restrictions on the doses to individuals (dose constraints), or the risks to individuals in the case of potential exposures (risk constraints), so as to limit the inequity likely to result from the inherent economic and social judgments. (This is called the optimisation of protection.)
- The exposure of individuals resulting from the combination of all the relevant practices should be subject to dose limits, or to some control of risk in the case of potential exposures. These are aimed at ensuring that no individual is exposed to radiation risks that are judged to be unacceptable from these practices in any normal circumstances. Not all sources are susceptible of control by action at the source and it is necessary to specify the sources to be included as relevant before selecting a dose limit. (This is called individual dose and risk limitation.)

In addition to the new dose limits and the renewed emphasis on protection principles, there has been a revision of the mathematical models that simulate the passage of radioactive material in the human body after intake. The so-called 'lung model' and the 'biokinetic' models have been revised as a result of a review of the research into the behaviour of particulate material entering the respiratory tract. The size of the particles, their solubility in body fluids and their chemistry have been studied and coded so that the translocation of matter from one body compartment to another can be simulated in the models.

The radiation dose that results from the passage of material through an organ is integrated (the period of integration being fifty years) and the dose is weighted by the radiosensitivity of individual organs and tissues. The equivalent 'whole body' dose, derived from the sum of the weighted doses, is an expression of the detriment arising from exposure to radiation.

10.1.3 Numerical expression of risk

The end result of the deliberations of the ICRP, in its study of epidemiological evidence and radiation biology, is a set of numerical probabilities of adverse outcomes as a result of exposure to radiation. These are summarised in Table 10.1.

Table 10.1 Probability coefficients for detriment from low doses of radiation

Exposed population	Occurrences per sievert[1]			Total
	Fatal cancer	Non-fatal cancer	Severe hereditary effects	
Exposed adult workers	0.04	0.008	0.008	**0.056**
Whole exposed population	0.05	0.01	0.013	**0.073**

1 *Rounded values.*

Source: International Commission on Radiological Protection 1991.

The difference between the probability coefficients for adult workers and for the whole population is explained by the difference in the age distribution of the two groups. The table shows the total lifetime probabilities and is a simplification of the actual outcomes, since our lifetime death probability is 100% and cannot be increased. The effect of radiation is to change the total probability at any given age. In Section 10.2.4 of this chapter, the probabilities shown in Table 10.1 are used to calculate expressions of risk for the Olympic Dam operations.

10.2 OCCUPATIONAL RADIATION

Uranium is a naturally occurring radioactive mineral. The uranium series is a decay chain comprising fourteen radionuclides (as shown in Figure 2.17). In its undisturbed state, the series is in secular equilibrium, that is, the activity of each member of the series is the same as that of the parent, uranium. One of the members of the decay series is the radioactive gas radon. Being a chemically inert gas, radon has the potential to escape from its site of production (it is the decay product of radium) and migrate to open air, where it decays to solid radionuclides of lead, polonium and bismuth.

The principal pathways of exposure by which employees at Olympic Dam may receive a radiation dose are:

- direct, external irradiation by gamma rays
- internal exposure from inhaled dust
- internal exposure from inhaled radon decay products.

Minor pathways are contamination of the skin and the ingestion of radioactivity.

The biological effect arising from internal radiation exposure in uranium mining is dominated by alpha irradiation. It is therefore necessary to analyse the radionuclides contained in air to determine the relative proportions of alpha-emitting radionuclides. It is also necessary to determine the size of the particles in which the radionuclides occur, since the size determines the depth to which an inhaled particle will penetrate in the respiratory tract. In radiation protection, size is expressed as the activity median aerodynamic diameter (AMAD) of the airborne particle cloud.

The AMAD describes the particle size where one-half of the radioactivity is associated with particles smaller than the AMAD and the other half of the radioactivity is associated with particles larger than the AMAD. Dust with an AMAD greater than 10 micrometres (μm) lodges predominantly in the upper airways (nose and throat) while dust with an AMAD below 1 μm lodges predominantly in the lower airways and the gas exchange regions (bronchioles and alveolar region).

Radiation exposures are assessed by measuring the exposure rate (or the concentration of alpha-emitting radionuclides associated with airborne dust and radon decay products) and combining these measurements with the exposure time and modifying factors such as the AMAD. The assessed exposures are then converted into an expression of radiation dose by multiplying the exposure by appropriate conversion factors derived from epidemiological studies in the case of radon exposure, or from mathematical modelling in the case of dusts. Modelling is used in the latter case because there is no direct human evidence of cancer as a result of inhalation of radioactive dusts (International Commission on Radiological Protection 1994).

10.2.1 Underground mine

Mining method

Underground mining at Olympic Dam is carried out mainly by the limited entry, sublevel, open stoping method, although there has been a small 'room and pillar' operation in the past. Stoping requires little direct exposure of the miners to the orebody itself, since drill levels and development headings are largely constructed in waste or mullock rock. It is intended that the current mining method will be employed in the expansion developments underground (Section 3.3.6).

Some changes to the materials handling systems are proposed. An electric train system would be used to haul ore to a new (third) crushing station and shaft. The trains would be driverless and controlled from a central control room. Crushing and loading would similarly be fully automatic and controlled from a remote location (Section 3.3.7).

Ventilation

The ventilation system (described in detail in Section 3.3.8) would be operated in a similar manner to that presently used. Secondary ventilation is required for dead ends and other areas not serviced by the primary ventilation system. Secondary ventilation and some local cooling systems would be used.

The current ventilation design criteria would continue to be used for the Expansion Project, and atmospheric conditions in the expanded underground operations would be similar to the present conditions.

Gamma radiation

Gamma radiation exposure rates have been measured in many areas of the mine. These rates are a function of the ore grade and the geometry of the area in which the measurement is taken. Since the mining method would not change, the following gamma dose rates are likely to be similar to those encountered in the expanded underground workings.

The actual gamma dose received by a person is also a function of the time that person spends at a particular location. Underground miners at Olympic Dam are provided with

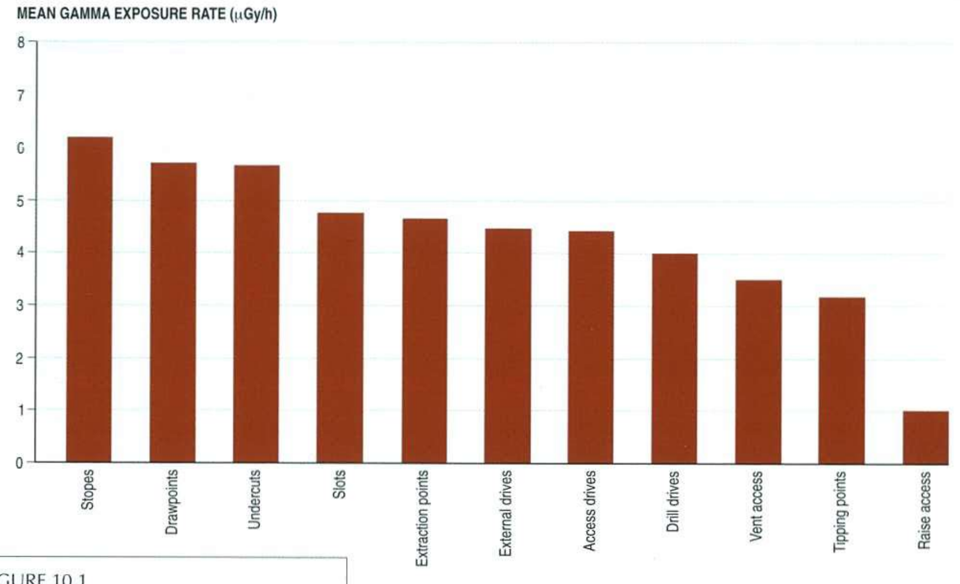


FIGURE 10.1
SUMMARY OF GAMMA EXPOSURE RATES IN THE MINE PURPLE STOPE AREA

thermo-luminescent dosimeter (TLD) badges, obviating the need to know the areas an individual visits in the course of his or her work, and the time spent at these areas.

Figure 10.1 shows a summary of the gamma exposure data from one stope complex (the Purple Stope area), while Figure 10.2 shows a summary of gamma exposure data from areas of the mine that are more frequently occupied. These demonstrate the difference in exposure rates between areas that are normally occupied and those where occupation is limited. Stopes are seldom entered by miners, whereas access drives and drill drives are visited more frequently.

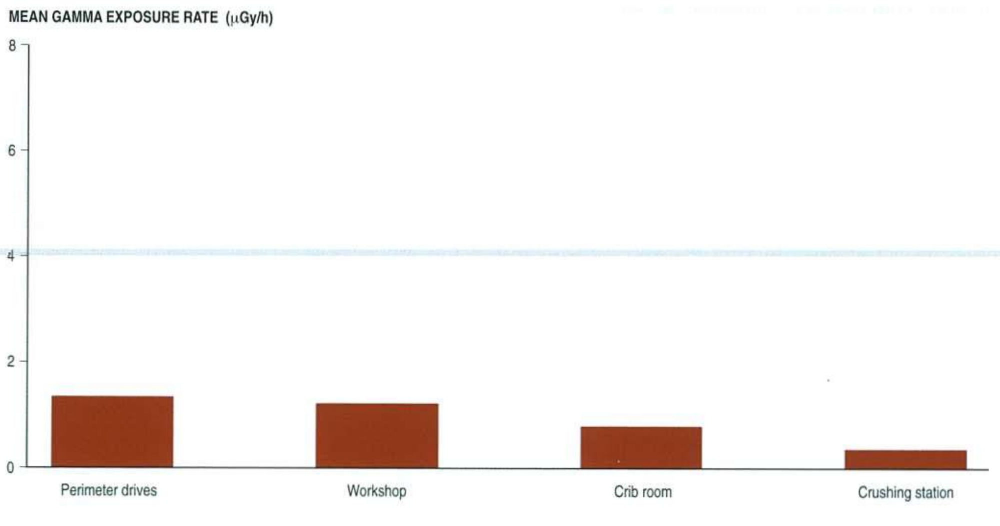


FIGURE 10.2
SUMMARY OF GAMMA EXPOSURE RATES IN FREQUENTLY OCCUPIED AREAS OF THE MINE

Concentration of alpha activity in air

The concentration of alpha-emitting radionuclides in dust and the concentration of radon decay products in air are largely functions of the ventilation system, although the grade of the ore influences the absolute concentration.

Radon decay products

The ventilation system has been designed to deliver air that is relatively free of radon decay products to work places. Even though the design is optimised, the actual concentrations of decay products are more a function of the daily control of local ventilation than of the design.

Measurements of radon decay products are made frequently in all areas of the underground workings. Many of these measurements are undertaken to test the ventilation system and are not necessarily used for the calculation of personal doses, since there may not be any people working in the areas sampled. Where measurements indicate action is warranted, people are prevented from entering the area until the ventilation system has been adjusted to reduce the concentration.

The measurements of radon decay products are not characteristic of the mining method or the overall ventilation design. Rather, they are a function of the local conditions that prevail at the time of the measurement. Gross ventilation design sets the envelope, but local control determines concentrations.

Figure 10.3 is a summary of measurements of mean concentrations of radon decay products undertaken in the Purple Stope area over some time. Areas that are more frequently occupied or visited are shown in Figure 10.4.

Alpha-emitting radionuclides in dust

Work practices are designed to minimise dust, and therefore to minimise the concentrations of alpha-emitters in the air. Dust-borne alpha-emitting radionuclides are measured by personal air samplers located close to individuals in various work categories. Figure 10.5 lists the eleven highest mean concentrations of alpha activity by occupational group.

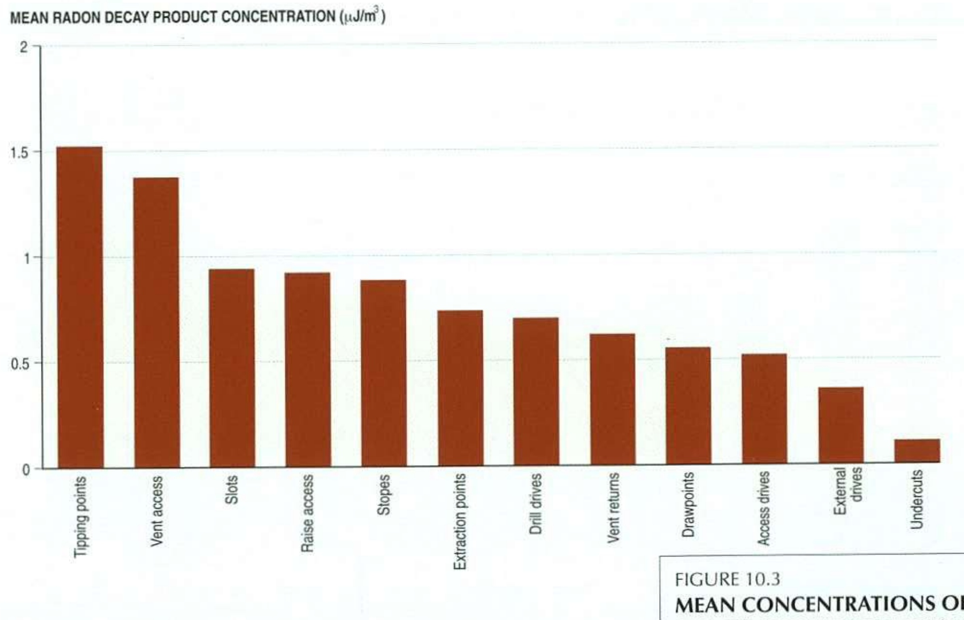


FIGURE 10.3
MEAN CONCENTRATIONS OF RADON DECAY PRODUCTS IN THE MINE PURPLE STOPE AREA

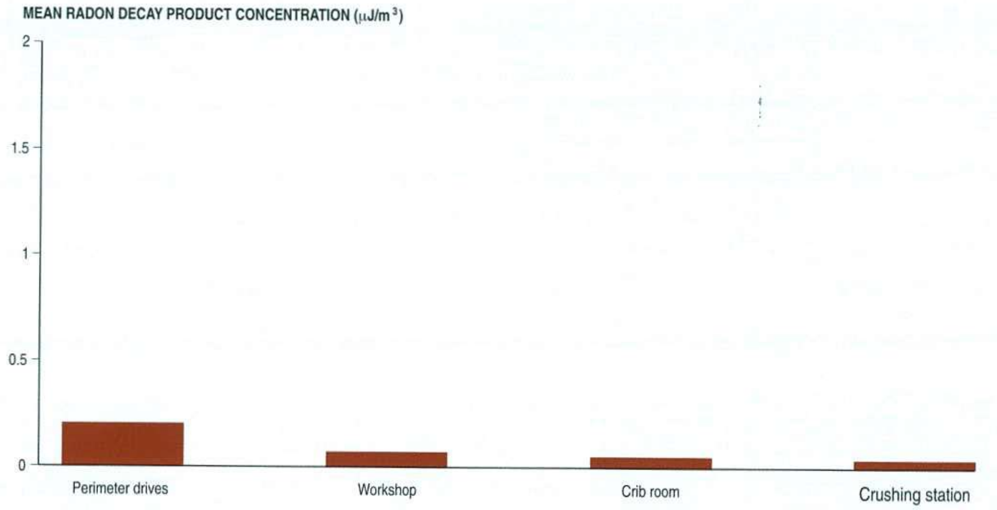


FIGURE 10.4
MEAN CONCENTRATIONS OF RADON DECAY PRODUCTS IN FREQUENTLY OCCUPIED AREAS OF THE MINE

Underground radiation doses

In order to calculate radiation doses to underground personnel, records are kept of the time each person spends in each location during his or her working day. These 'PLOD' times (*P*erson, *L*ocation, *O*ccupation, *D*escription) and locations are combined with the measurement data, and doses assigned accordingly. The dose conversion factor for the mine is based on the assumption of secular equilibrium of the uranium decay series and an AMAD of 5 μm (Hondros 1987).

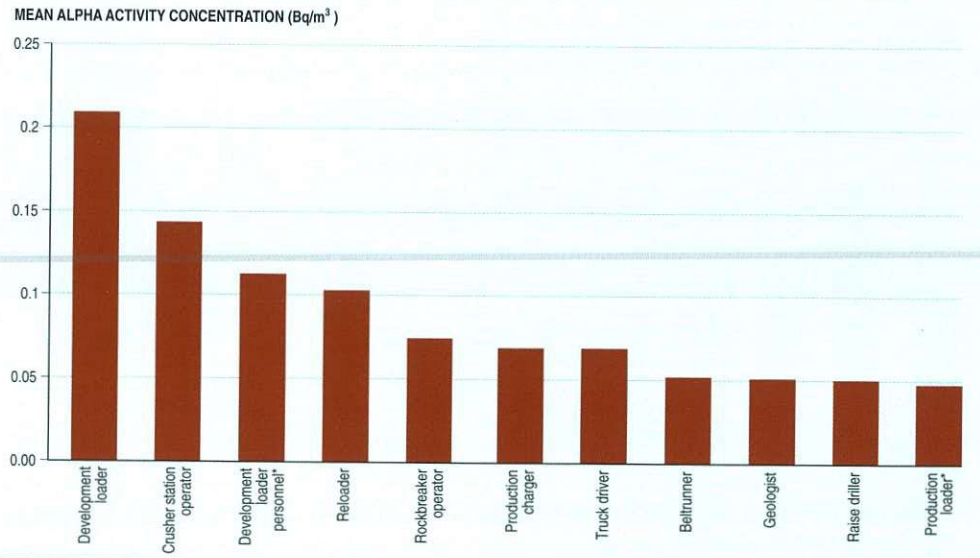


FIGURE 10.5
MEAN ALPHA ACTIVITY CONCENTRATION IN AIR BY WORK CATEGORY

* With respiratory protection

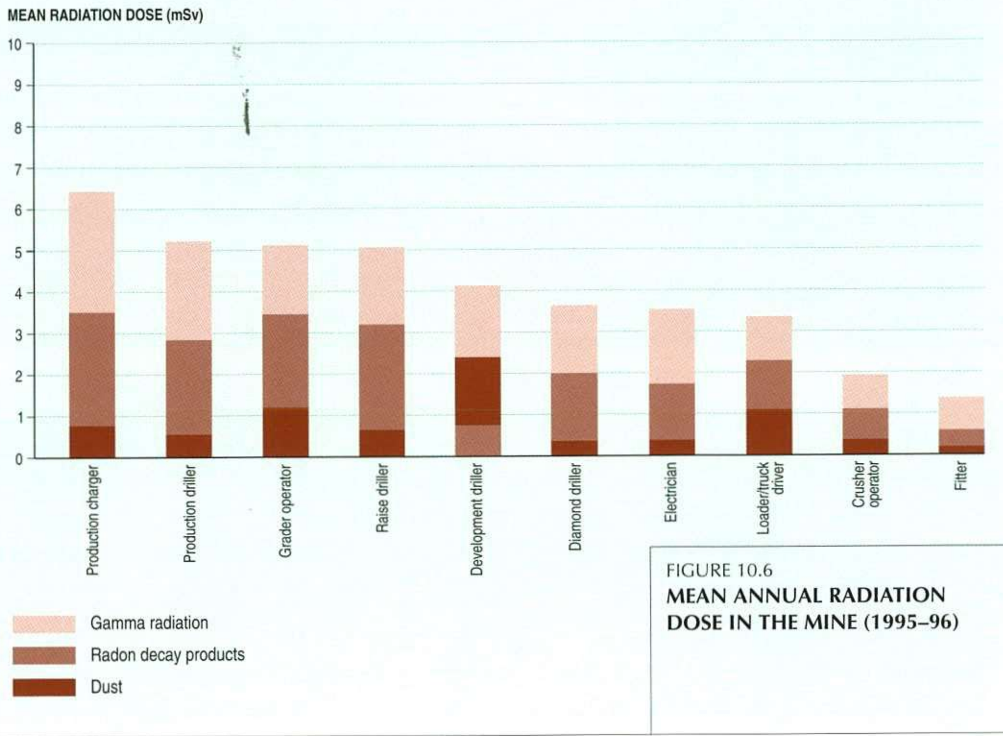


FIGURE 10.6
MEAN ANNUAL RADIATION DOSE IN THE MINE (1995–96)

Figure 10.6 shows a summary of the data from the monitoring year 1995–96.

The mean dose for each work category is well below the single year limit of 50 mSv, and also below the limit of 20 mSv per year, averaged over a period of five consecutive years.

It is not expected that the implementation of the Expansion Project would increase the radiation doses, although their distribution may change owing to the change in ore handling brought about through the use of driverless trains and remotely controlled crushing and loading stations.

10.2.2 Metallurgical plant

Process description and radionuclide balance

The metallurgical plant is designed to extract economic minerals from the complex ore of the Olympic Dam deposit. (A detailed discussion of ore processing is presented in Section 3.5. The following description refers particularly to the radionuclide balance.)

Ore enters the processing plant via a grinding circuit which produces a slurry of finely ground ore. The slurry passes to a flotation circuit, where copper sulphide particles (including gold and silver) become attached to bubbles and are floated to the surface. Non-sulphide minerals, including uranium, do not float and are extracted from the base of the flotation tanks as 'flotation tailings'.

The copper concentrate contains the bulk of the gold and silver together with a small amount of uranium. Once the minerals pass into the liquid phase, it can no longer be assumed that members of the uranium decay series are in secular equilibrium (Appendix N).

The copper concentrate is leached in sulphuric acid to dissolve as much as possible of the contained uranium, and the leach liquor then reports to the solvent extraction circuit. The flotation tailings are leached separately to dissolve as much as possible of the uranium and any remaining copper, and then washed in countercurrent decantation tanks. The sand fraction of the flotation tailings is used for mine backfill, and the slime fraction is sent to the tailings retention system. The overall efficiency of the uranium recovery is approximately 70%.

The leach liquor containing the uranium and copper is clarified prior to being sent to a solvent extraction plant. There, copper sulphate solution is extracted from the liquor and sent to the copper refinery for recovery of copper by electrowinning. The liquor continues to another solvent extraction circuit where uranium is extracted and purified into a solution of ammonium sulphate. Ammonia gas is used to precipitate ammonium diuranate (ADU), commonly called 'yellowcake' because of its bright yellow colour.

The ADU is thickened and then roasted in a calciner to drive off ammonia and water and to produce a concentrate comprising a mixture of uranium oxides, principally U_3O_8. The now dark-green product is packed into 205 L drums for export.

Copper concentrate from the flotation cells is dried and mixed with a silica flux and recycled dust from the smelter; it is then fed, along with oxygen, into a flash furnace which produces slag and blister copper. The slag is passed to an electric furnace, where the oxidised copper is reduced with coke and recovered as blister. The blister copper from the flash and electric furnaces passes to an anode furnace for further refining. The process has two stages—an oxidation stage to remove sulphur, and a reduction stage to remove oxygen. Once purified, the copper is cast into anodes; these are then sent to the refinery where copper is recovered by electrorefining as high purity cathode. The gold and silver, which are released from the anodes during electrorefining, are recovered by further refining processes.

In the flash smelting reaction, the sulphur fraction of the copper sulphide is oxidised to produce sulphur dioxide which is converted in the acid plant to sulphuric acid for use in the leach circuits.

Radionuclides contained in the ore will report to different process streams depending on their chemistry. Since it is the concentration of individual radionuclides in each process stream that governs the magnitude of the radiation exposure at each physical location in the processing plant, it is necessary to trace the paths of the radionuclides and then to apply the appropriate factors for each area that convert exposures to doses. Figure 10.7 shows a simplified radionuclide balance for the treatment plant.

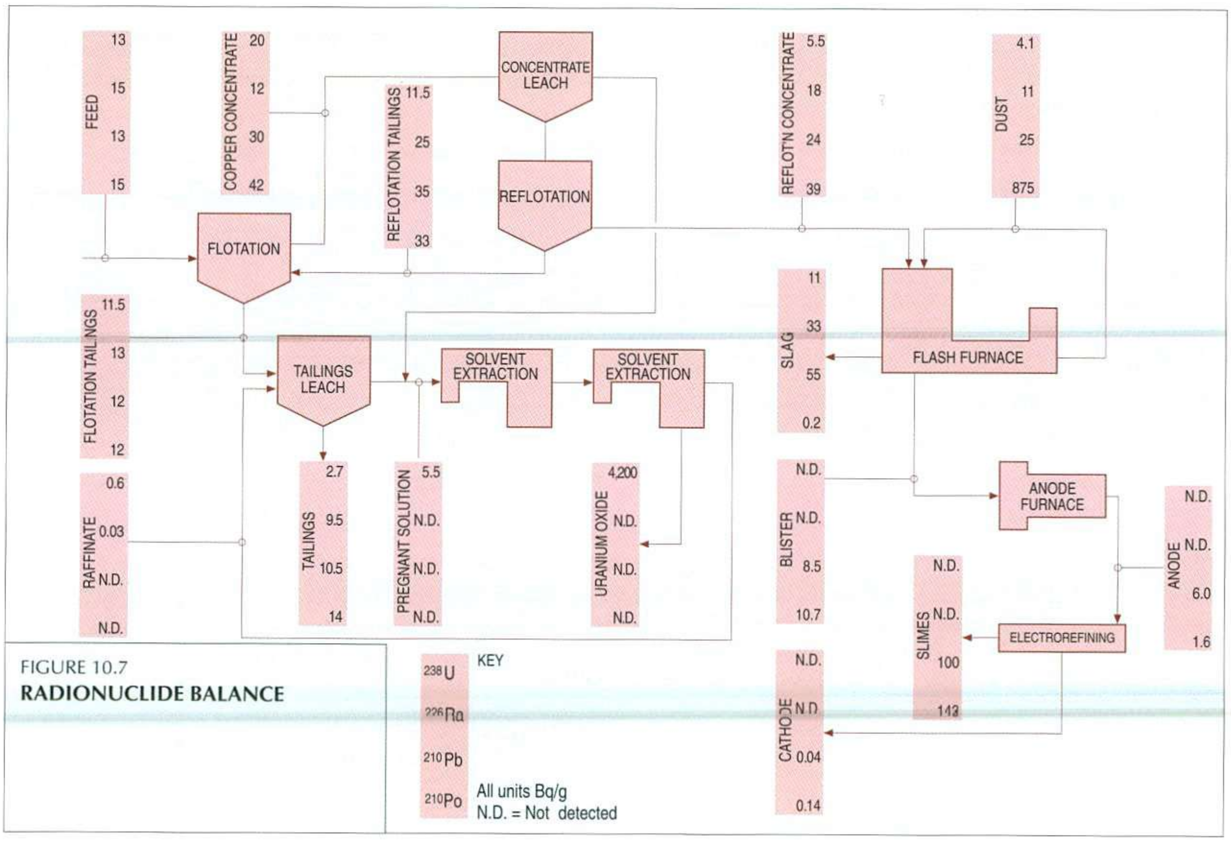


FIGURE 10.7
RADIONUCLIDE BALANCE

Although the figure shows the concentration of radionuclides in process streams, a knowledge of these cannot be converted into an expression of internal radiation exposure because it is the concentration of radionuclides in the inhaled air that is significant. It is only during maintenance or accidental spillage that employees may come into contact with the radionuclides in the process streams.

In each of the main process areas, high-volume air samplers have been deployed to measure airborne radionuclides. These measurements have been normalised (by expressing the components as a percentage of the total activity) and plotted in Figure 10.8 to show the relative concentrations of five airborne radionuclides in various areas of the processing plant.

Particle size analyses and intake-to-dose conversion factors

Particle size analyses have been carried out using inertial separation devices of the cascade impactor type. The results, expressed as the AMAD, vary from 0.2 µm in the smelter to more than 20 µm in some areas of the processing plant.

Although smaller quantities of other radionuclides are present, Figure 10.8 provides an indication of the atmospheric composition of the significant radionuclides in each area of the plant. This radionuclide characterisation forms the first part of the derivation of the dose conversion factors (DCFs) that WMC has used in its assessment of radiation doses; the AMADs provide the second part. When measurements of AMAD indicate particle sizes greater than 20 µm a default value of 20 µm is used since the ICRP lung model does not accommodate AMADs greater than this value.

Potential exposure

In this analysis the term 'potential exposure' is used to describe the radiation exposures that could be received in particular locations within the mining and processing facilities, if a person were to be physically at that location for an entire working year. The term is not used in the same sense as the concept of 'potential exposure' found in the most recent recommendations of the ICRP.

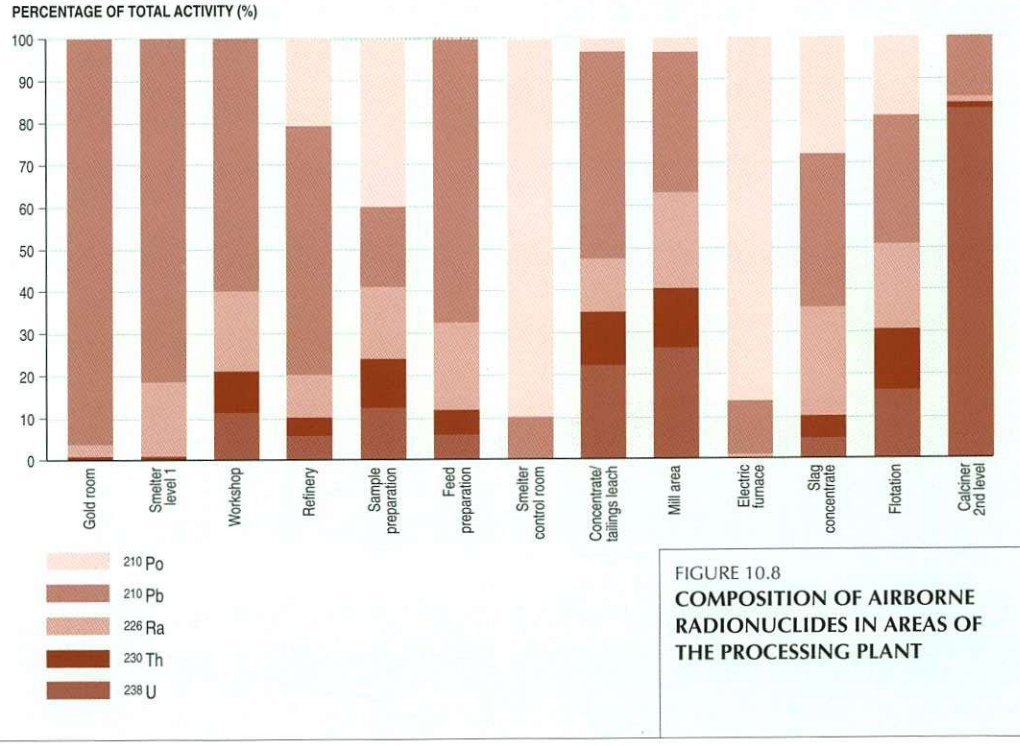


FIGURE 10.8
COMPOSITION OF AIRBORNE RADIONUCLIDES IN AREAS OF THE PROCESSING PLANT

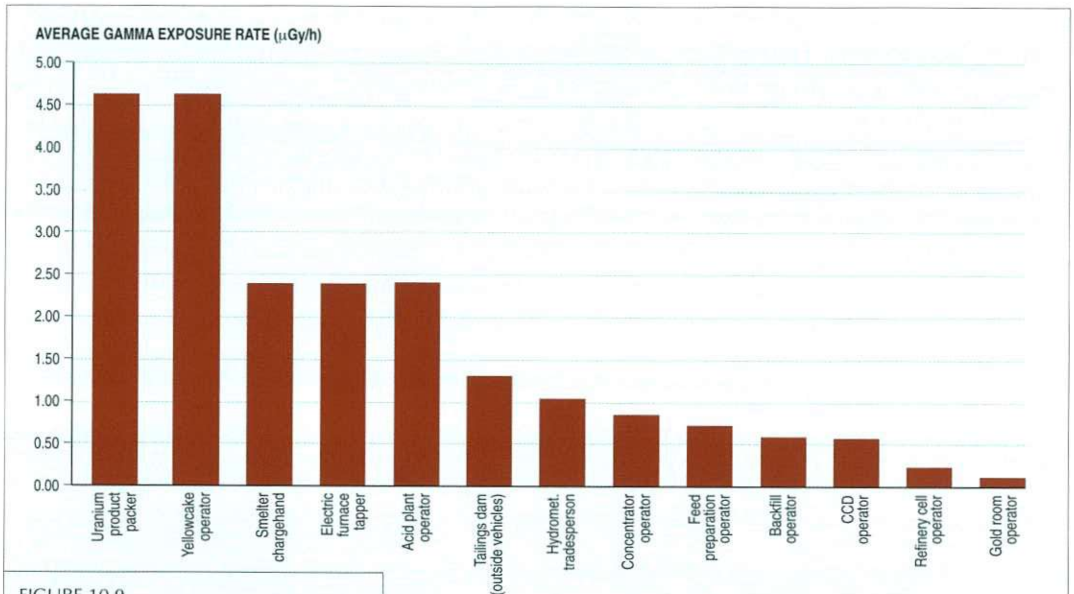


FIGURE 10.9

FIVE-YEAR SUMMARY OF GAMMA RADIATION MEASUREMENTS IN THE PROCESSING PLANT (1991–95)

This analysis of potential dose was carried out to identify areas of the operation and categories of work that could lead to employees accumulating radiation doses greater than 5 mSv per year. These areas and categories of work were then subjected to optimisation to explore methods and designs that could reduce the potential exposures.

Measurements of gamma radiation and the concentrations of alpha-emitting radionuclides in air in the various sections of the processing plant, taken during 1991–95, have been analysed and are summarised in Figures 10.9 and 10.10, respectively.

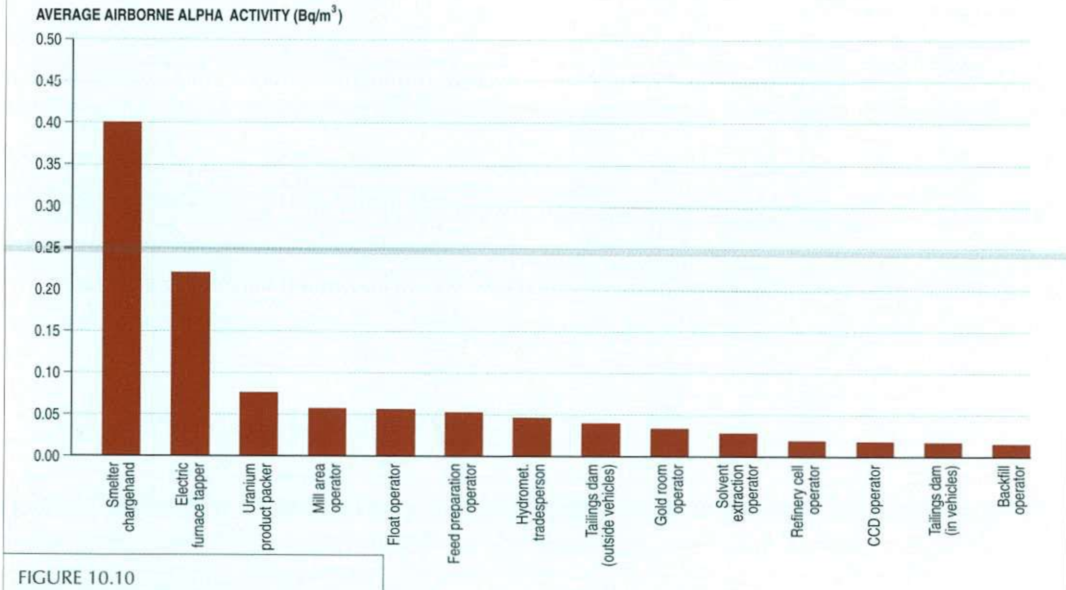


FIGURE 10.10

FIVE-YEAR SUMMARY OF AIRBORNE ALPHA ACTIVITY MEASUREMENTS IN THE PROCESSING PLANT (1991–95)

Several methods of measurement are used. 'Personal' measurements are made of exposure to alpha-emitting nuclides in air by issuing personal air samplers to individuals in the work categories shown in the figures; 'area' samples are taken by unattended air samplers positioned in various areas of the processing plant. For gamma radiation, 'personal' exposure is measured by TLDs and also by a hand-held gamma meter taking 'spot' measurements at various locations.

In the following analysis it should be noted that the graphs show the radiation doses that would be acquired if a person spent his or her entire working year performing the specified task, or standing at the specified location within the plant. This, of course, is not what happens, but the purpose of the analysis is to identify work categories and geographic locations within the plant that have the greatest potential radiation exposure. Section 10.2.4 examines the actual exposure of employees.

Combining the exposure to gamma radiation and to alpha radiation in air provides a picture of the potential exposure for each of the work categories shown in Figures 10.9 and 10.10.

The combined exposures, modified by the DCFs for each area, are shown in Figure 10.11.

The graph shows the potential dose for full-time occupancy (which is taken to be 2,000 hours per year). It can be seen from Figure 10.11 that work categories associated with the smelter and the uranium product packing have the highest potential doses. The data used for this assessment are taken from the records of measurements made on individuals wearing 'personal' air sampling pumps, combined with 'area' measurements of gamma exposure rates. When the data for area measurements are assessed, as is shown in Figure 10.12, it is possible to identify some additional areas of the plant for consideration with a view to reducing the potential exposure rates and, therefore, the potential doses.

Doses have been calculated assuming full-time occupancy and no use of protective devices such as respiratory protection masks. It can be seen in Figure 10.12 that it is the smelter area and the calciner areas that require particular attention in the design phase in order to reduce the potential doses.

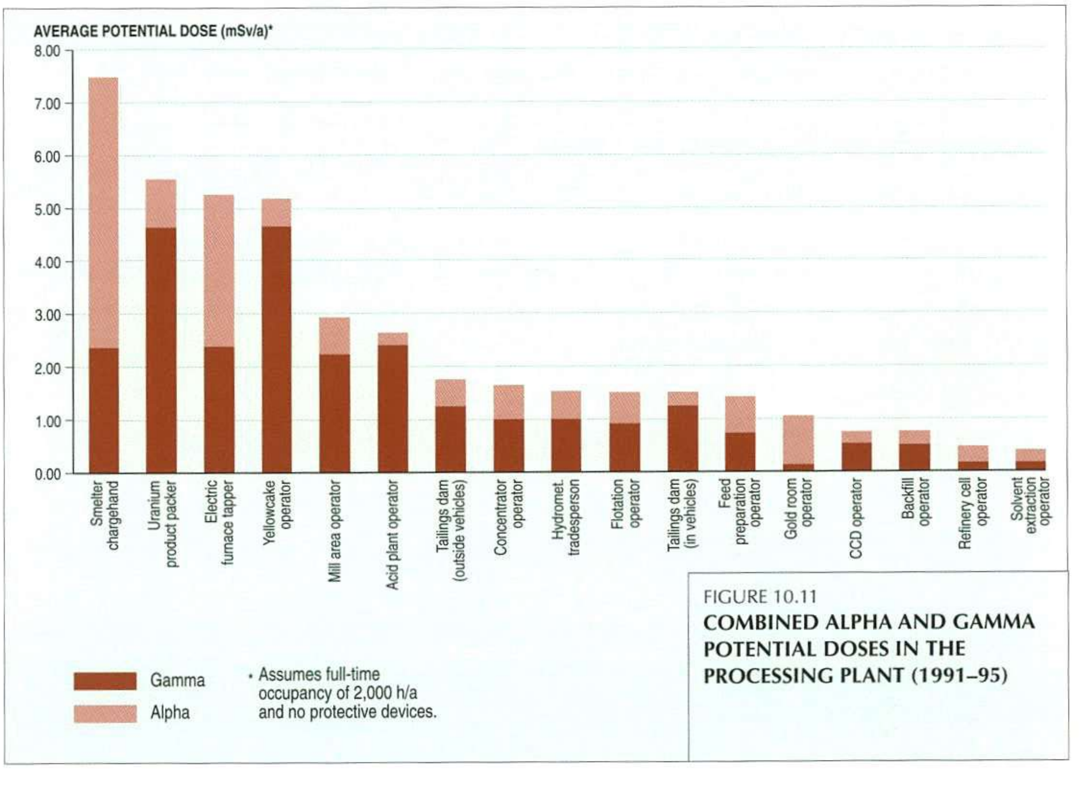


FIGURE 10.11

COMBINED ALPHA AND GAMMA POTENTIAL DOSES IN THE PROCESSING PLANT (1991–95)

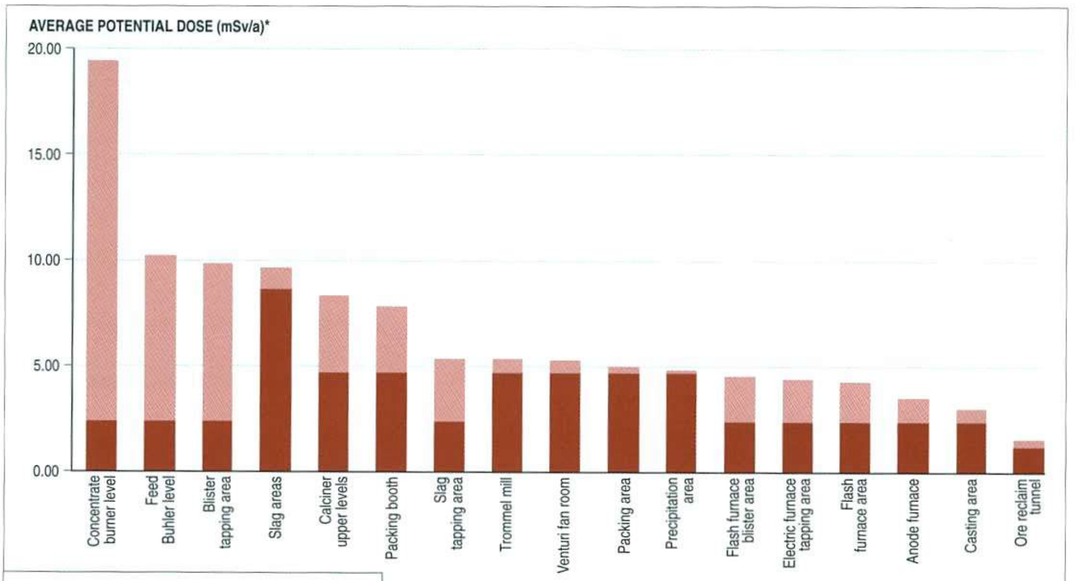


FIGURE 10.12
COMBINED ALPHA AND GAMMA POTENTIAL DOSES BY AREA IN THE PROCESSING PLANT (1991–95)

Changes in exposure rates over time

The previous sections have shown the potential exposure rates in terms of both the work categories and the geographical areas of the processing plant. The figures were constructed from data gathered over the period 1991–95. In this period, and in the following year (1996), the exposure rates have varied because of changes in processes and management practices. However, the overall radiation exposures have remained largely the same in all areas of the processing plant. At the same time the amount of ore mined at Olympic Dam has increased steadily.

The annual mean radiation doses in the mine and the processing plant, and the increase in the amount of ore mined between 1990 and 1996, are shown in Figure 10.13.

Predicted exposures for the processing plant

It can be seen that the exposure rates are not directly related to production rates, and thus an increase in exposure rates cannot be predicted for the Expansion Project from production figures alone. This is, in part, because past increases in production rates have been accompanied by the progressive implementation of management practices and engineering controls to restrict radiation exposures.

In addition, the opportunity presents itself for examining the design of new and expanded facilities in the light of operating experience so that specific areas and work functions can be targeted for redesign and optimisation of radiation protection. For instance, a new smelter is proposed and a new calciner will be built, so the potential exposures for these areas may be reduced further by careful planning and design.

The increase in throughput of the plant would not increase the number of hours of work for any individual, and the exposure times would therefore remain the same. Nor would the uranium grade (and thus the radiation potential) of the ore increase as a result of the Expansion Project.

Apart from the new smelter and calciner, most areas of the processing plant would continue to exhibit similar alpha and gamma exposure rates. Figure 10.14 shows the mean annual

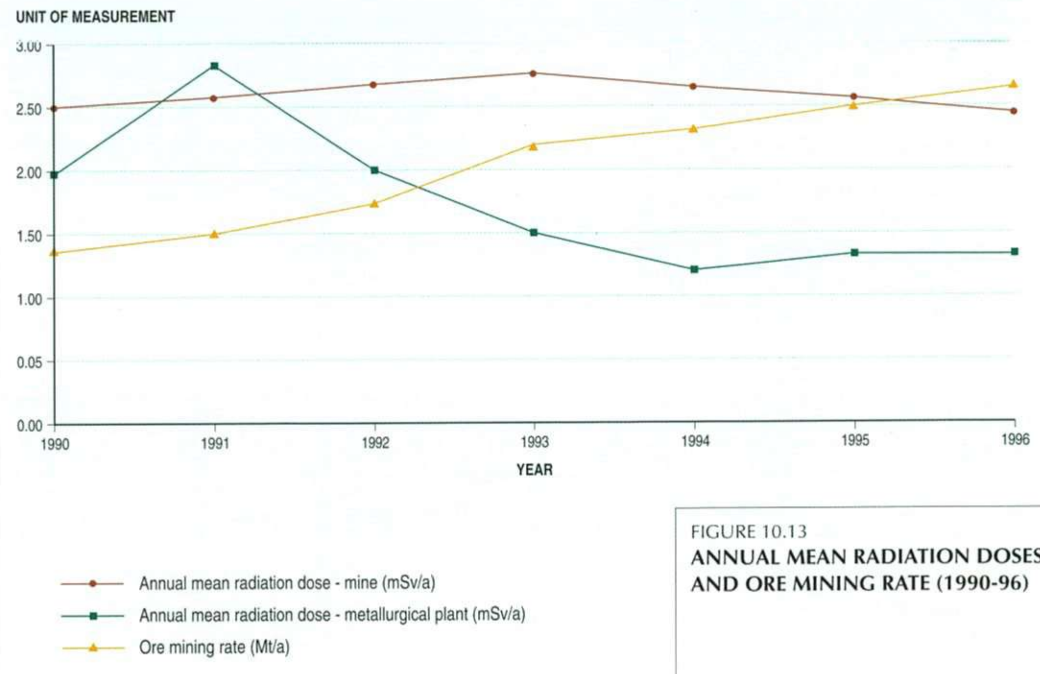


FIGURE 10.13
ANNUAL MEAN RADIATION DOSES AND ORE MINING RATE (1990-96)

radiation dose for 1995–96 by plant area; Figure 10.15 shows the distribution of individual doses for the same year.

The data in Figure 10.15 are for 452 employees. The maximum radiation dose was 8.4 mSv to an employee in the smelter; employees from the smelter returned the top forty-two radiation doses. The chart shows that all doses are well below the single-year limit of 50 mSv and the average annual limit of 20 mSv.

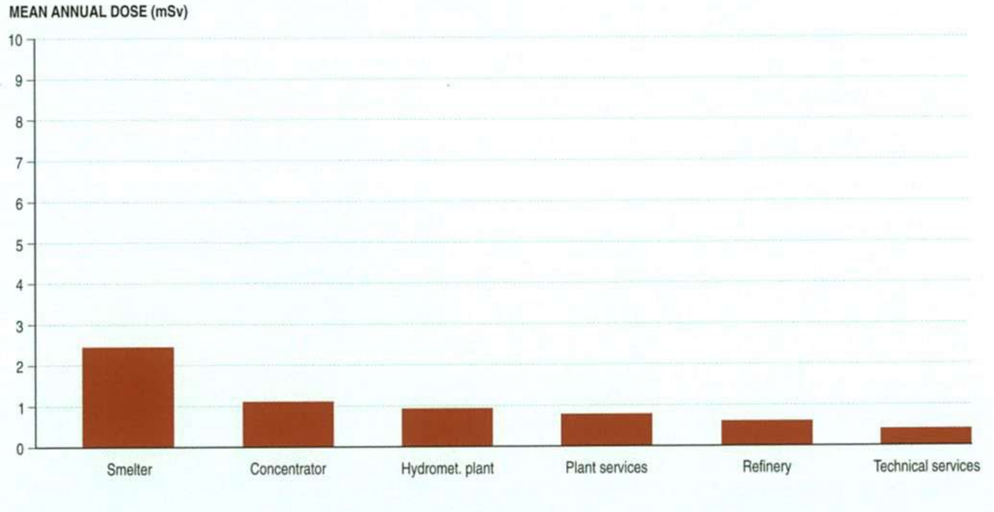


FIGURE 10.14
MEAN ANNUAL RADIATION DOSES BY PLANT AREA (1995–96)

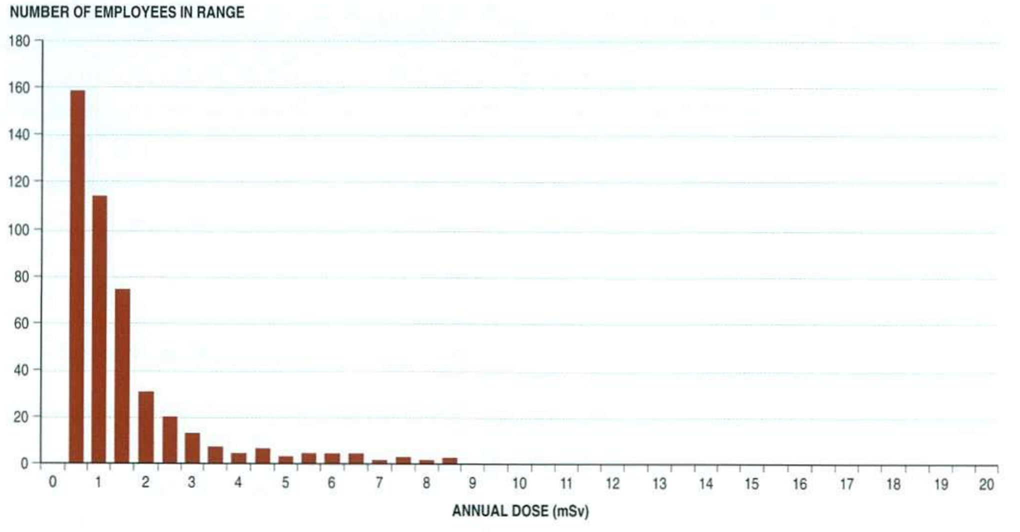


FIGURE 10.15
DISTRIBUTION OF INDIVIDUAL RADIATION DOSES FOR 452 PROCESSING PLANT EMPLOYEES (1995–96)

Features of the first phase of the Expansion Project (to take production to 200,000 t/a of copper as described in Section 3.4.1) are:

- a new stockpile;
- a new autogenous mill and additional cells in the copper concentrator area;
- expansion of the tailings leach area, with the provision of additional countercurrent decantation tanks, a clarifier and two high-compression tailings thickeners;
- a new calciner;
- expansion and modification of the solvent extraction circuit;
- construction of a new smelter complex and associated acid plant (the existing smelter and acid plant may be used for the processing of other South Australian ores or imported copper concentrates);
- expansion of the copper refinery;
- the addition of two new tailings cells of 100 ha each (an alternative design is discussed further in Chapter 8), increasing the total storage area to 390 ha;
- a new lined evaporation pond.

Relevant features of the second phase of the Expansion Project (to take production to 350,000 t/a of copper as described in Section 3.4.2) are:

- additional grinding facilities
- additional flotation cells
- additional clarifiers and tailings thickeners
- expansion of the copper and uranium solvent extraction area
- duplication of the electrowinning and electrorefining complex

- duplication of the feed preparation area for the copper smelter
- construction of a third smelter and acid plant.

A production rate of 350,000 t/a of copper would necessitate the construction of a further three tailings cells of approximately 110 ha each, to give a total storage area of 720 ha.

The following sections of this chapter consider the possible effects on radiation exposure of the additional features. It should be noted that not all of the additional features would affect radiation exposure and only the new smelter complex is described in detail.

10.2.3 Potential dose reductions in the new smelter complex

The design of a new smelter to accommodate increased production of copper in the Expansion Project offers the opportunity to effect reductions in radiation doses to employees in this area. Analyses have shown (Section 10.2.2) that the existing smelter is the source of the highest radiation doses to workers in the metallurgical plant. The design team working on the new smelter has used the knowledge gained from operating the existing smelter to optimise the radiation protection features of the new smelter complex. The features of the new smelter that will lead to reductions in exposure are described here, together with an estimate of the dose reductions achievable during operation of the new smelter.

Reduction of polonium and lead isotopes in fumes by process design

Polonium and radioactive lead isotopes are found in fumes in the air of the smelter building and contribute the greatest proportion of the inhalation dose to operators in the current smelter. In the design of the existing smelter, dust collected in the waste heat boiler and electrostatic precipitator is recirculated to the flash furnace, except for a bleed stream which is directed to the hydrometallurgical circuit. Polonium-210 (^{210}Po) volatilises in the furnace reaction shaft and condenses on the surfaces of the finest dust particles as the gas stream is cooled through the waste heat boiler and electrostatic precipitator. The levels of ^{210}Po are highest in the electrostatic precipitator dust, and this material is the main source of the bleed. Most of the dust collected from the waste heat boiler is returned to the flash furnace.

The bleed effectively controls the level of ^{210}Po in the smelter blister and slag products and hence the level of any fumes emitted from tapping points. The new smelter will be equipped to bleed a greater proportion of the circulating dust to the leach circuit thereby providing an increased capability to lower the ^{210}Po in the smelter environment.

The dust bleed mechanism is a screw feed that reduces potential release of dust to the atmosphere. Not all of the dust can be bled from the circuit because a certain proportion of it is required for temperature control in the furnace. It is intended that approximately 60% of the electrostatic precipitator dust and 40% of the waste heat boiler dust will be bled.

Lead-210 (^{210}Po) reports largely to the flash furnace slag and remains with the electric furnace slag provided the reducing conditions in the electric furnace are not extreme. The electric furnace is operated to give a predetermined level of copper remaining in the slag, so minimising the amount of ^{210}Pb passing into the blister copper and hence the level of any fume emitted from tapping points.

An improved design for the collection of fugitive emissions around tapping points will be incorporated in the design of the new smelter.

Reduction of polonium and lead isotopes in building air

Several trials have been undertaken in the existing smelter building to effect a reduction in the concentration of radionuclides in building air. The ventilation of the building has been improved and air-control curtains have been provided around tapping holes. These trials have proved partially successful, but it is generally the case that retrofitted controls are less successful than controls incorporated at the design stage.

In the new smelter, the launders will be short, without elbow bends, and covered by hoods. These will be ducted to the single air extraction system which will collect fumes from several process areas. Tapping points will also be provided with hoods connected to the air extraction system, diverting fume from the building into the collection system. Slag tapping will be automatic and the operator will be physically remote from the tapping points. An automatic mud gun will be used to plug the tapping holes.

The electric furnace will discharge into a launder run to the two anode furnaces, eliminating the need for hot-metal transfer by ladle. The launders will be covered and connected to the air collection system. The anode furnaces will discharge via covered launders to two casting wheels, which will also be equipped with hoods connected to the air collection system.

As far as possible, control rooms and control points will be enclosed in air-conditioned cabins remote from the smelter floor. Cameras will provide the necessary vision to operators. Where it is not possible to place the operator in a cabin, sealed respite cabins will be placed at strategic locations so that operators can retreat to an air-conditioned environment when they are not required on the floor.

A further reduction in the release of dust and fume to the building air will be achieved by improving the clean-up and maintenance services. Through-ways large enough to accommodate small front end loaders will be provided so that any spillage can be quickly and efficiently removed.

An automatic sampler will be tested on the existing feed Buhler to reduce the amount of spillage experienced with the current manual sampling method. If the trial proves successful, the new smelter will incorporate an automatic sampler in its design.

Other process improvements

Other improvements to systems and designs have less direct impact on radiation exposure reduction but are nevertheless important elements in occupational hygiene practice.

Dust collection and air handling systems

All dust collection and air handling systems will be located in one area of the new smelter complex. Each element of the dust collection system will have spare capacity to enable one or more elements to be taken off-line for maintenance without disrupting production. This will make it possible to plan maintenance for times that are not dictated by production schedules.

Off-gas from the electric furnace will be cooled and passed to a wet scrubber and electrostatic precipitator, then to the stack. The off-gas hoods and ducts for the anode furnace are designed for a gas residence time of 2 s (to allow carbon monoxide, or CO, to burn off) before the gas is cooled, scrubbed in a venturi scrubber, passed through a packed bed (to remove sulphur dioxide, SO_2) then through the electrostatic precipitator to the stack. Gas from the flash furnace is cooled to approximately 350°C before it passes to the electrostatic precipitator and thence to the stack.

In the event that the electrostatic precipitator has to be taken completely off-line, the off-gases will be diverted to a hydrosonic scrubber and will not be vented directly to the atmosphere as is the current practice. Caustic soda will also be added to improve the efficiency of SO_2 removal.

Feed preparation area

The filter presses in the feed preparation area will be enclosed and the building will feature easily cleaned floors and interior surfaces. The feed preparation building is a self-contained and separate building.

Feed will pass on closed conveyors to two steam coil dryers and thence through a pneumatic system to two 1,000 t storage tanks. Nitrogen will be used to transport the feed to eliminate the potential for fire. Ventilation air will be ducted to a fabric filter for removal of dust prior to being released to the atmosphere.

Stack

The main smelter stack will be a double flue arrangement 90 m high, supported by an external steel frame. One flue will be constructed of fibre-reinforced plastic and will be used for the scrubbed smelter and ventilation gases. The second flue will be constructed of steel and will serve the acid plant.

Potential dose reductions

There are two ways of expressing the results of optimisation leading to dose reduction. The first is an expression of the effects of optimisation on the collective dose, that is the total dose to all exposed individuals delivered by the practice or operation. The second is an expression of the change in the distribution of the individual doses to the exposed people.

Collective dose

The collective dose is the sum of each individual dose and is obviously largely dependent on the number of individuals in the exposed group. The new smelter has been designed to be operated by fewer staff than the existing smelter, and the features leading to ease of maintenance and clean-up will also lead to a reduction in the total number of people. These features combine to produce a potential collective dose that is more than a factor of 2 lower than the current collective dose.

Individual dose distribution

The effect of the optimisation of the new smelter will be to lower the average dose to the operators. What is more significant is that it will reduce the magnitude of the higher doses and the number of people in the higher dose range because attention has been paid to the points in the smelter where the higher doses are being experienced.

Design criteria have been set for the dust and fume concentrations in air which, together with the reduction in polonium and lead recycling, will reduce the dose from the inhalation pathway. Changes in the handling of the slag will reduce the gamma exposure rates from this source.

The design dust concentration criterion is a factor of four below the current dust concentrations. Taking a conservative reduction factor of three and applying it across the full range of individual doses, the average dose would become 0.79 mSv should this be achieved, instead of the present 2.38 mSv. Figure 10.16 shows the potential shift in individual dose distribution.

Whereas the highest annual dose to smelter workers is currently about 8.4 mSv, the objective of the optimisation measures outlined above is to restrict the annual dose from the new smelter to below 4 mSv.

10.2.4 Numerical risk assessment

Epidemiological studies

That it is possible for radiation to cause biological effects is known from various epidemiological studies conducted into the health of people who have been exposed to relatively large doses of radiation. These studies rely for their findings on being able to distinguish excess numbers of adverse health effects against a background of similar effects which occur in all populations.

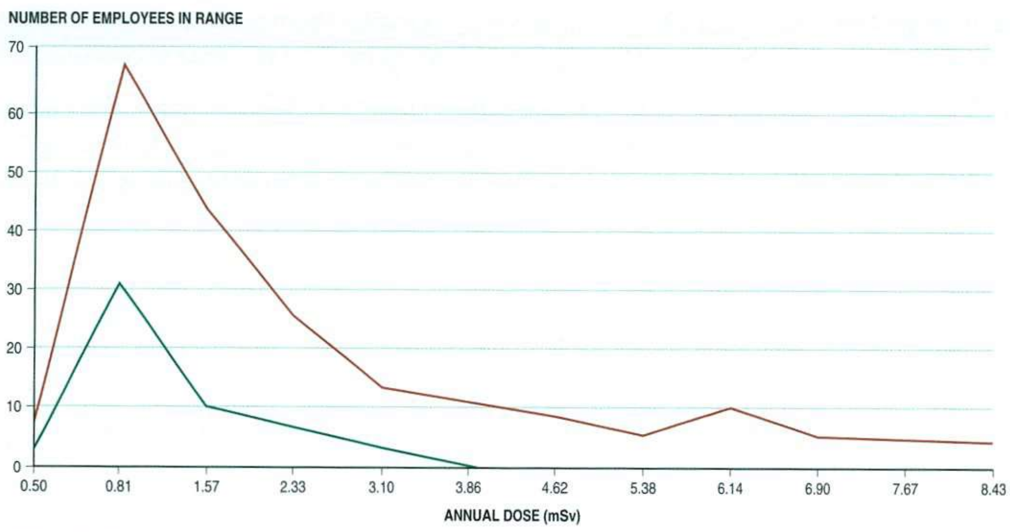


FIGURE 10.16
POTENTIAL DISTRIBUTION OF INDIVIDUAL DOSES IN THE NEW SMELTER

For example, studies continue into the health of people who were either irradiated by the nuclear bombing of Hiroshima and Nagasaki in Japan during World War II or whose parents were irradiated by the bombing. The study population is divided into cohorts (or subgroups) of people irradiated to different degrees by virtue of their distance from the epicentres of the bombs or the degree of shielding afforded by the buildings in which they found themselves when the bombs detonated. A control population is also studied, which is a population that was not irradiated by the bombing, but is similar in all other respects (age, demography and lifestyle) to the exposed cohorts.

The number of health effects in each cohort and the control group is determined by medical checks at regular intervals. Deaths are recorded together with details of the cause of death. In this way the health effects at the various radiation doses experienced by each cohort can be compared with the underlying or background health effects experienced by the control group. The 'excess' effects in each cohort, that is, the difference between the background number and the observed number, can be recorded.

The survivors of the atomic bombings are not the only group that has been studied in this fashion. Comprehensive summaries of other studies can be found in, for example, the reports published by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), the National Research Council's fifth Committee on the Biological Effects of Ionising Radiation (BEIR V), and the ICRP.

Studies on human populations are complicated by numerous factors including the fact that the underlying health of different populations varies according to lifestyle, public health and geographic factors, as well as the level of available medical services. Findings in one population may not be easily transferred to another population.

Epidemiological studies of human populations are supplemented by radiobiological studies into the effects of radiation in non-human populations. Whereas the studies on humans are aimed at shedding light on the dose–effect relationship, the studies on non-human populations are largely aimed at elucidating the biological mechanisms of carcinogenesis. These studies cannot be used to infer effects in humans directly because of the problems associated with transferring findings from one species to another.

The aim of both the epidemiological studies and the radiobiological studies is to construct a graph from which the health effects at any level of irradiation can be predicted. This is illustrated by the example portrayed in Figure 10.17, which shows several features.

The dots represent the mean number of excess health effects (scaled on the vertical axis) at each radiation dose (scaled on the horizontal axis). The lines through each dot represent the degree of uncertainty associated with each mean; thus there is uncertainty associated with both the radiation dose to which each population was exposed, and with the number of health effects that can be unequivocally ascribed to radiation as opposed to any one of many other influences on health.

The figure also shows that in the lower dose range the uncertainties are larger than in the higher dose ranges. At even lower doses, there are no data points, the reason being that no studies have the statistical power to define the relationship in this region.

The pragmatic (and the regulatory) response to the gap in the data has been to draw a straight line through the data points at relatively high radiation doses, and to extend this line to the zero point on both axes. The result is the 'linear no-threshold hypothesis', which is shown in Figure 10.18.

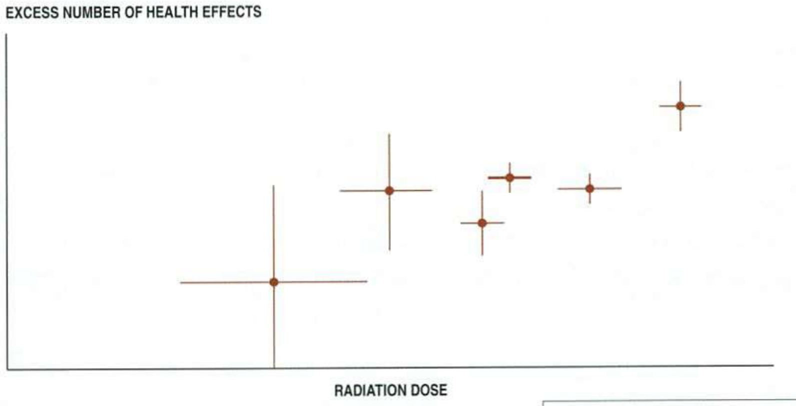


FIGURE 10.17
EXAMPLE OF RESULTS FROM EPIDEMIOLOGICAL STUDIES

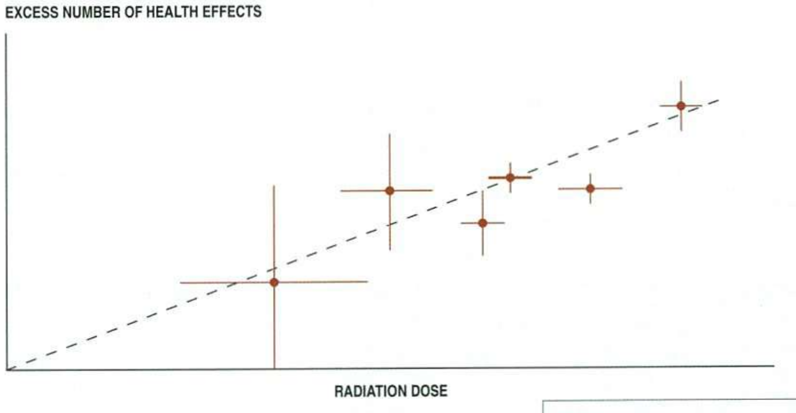


FIGURE 10.18
EXAMPLE OF THE LINEAR NO-THRESHOLD HYPOTHESIS

The inference that can be drawn from this extrapolation is that even minute radiation doses have the potential to cause a health effect.

If a linear no-threshold hypothesis is postulated, it follows that numerical expressions of risk can be made at any level of dose, down to zero. It is a relatively simple matter to interpolate from the graph a risk associated with a measured or calculated dose. The radiation doses calculated for employees and members of the public arising from operations at Olympic Dam can be treated in this way. However, the radiation doses received by employees at Olympic Dam fall into the region of the dose–effect graph (Figure 10.17) in which the real risk of an effect cannot be determined accurately although the linear hypothesis is assumed to hold true for doses ranging over many orders of magnitude. The inference remains that risk coefficients are directly proportional to dose, even at natural background levels of exposure, in spite of statistically powerful evidence to the contrary (Patterson 1997).

The main scientific use of the estimation of risk from the hypothesis is the practice of radiation protection. This practice is the application of principles of radiation protection (see Section 10.1.2) which are designed to limit risk, whatever the absolute magnitude of the risk happens to be. The conversion of radiation exposures to dose requires the application of several conversion factors and models. It must be remembered that the models provide average values for large populations (often without regard to differences in age, sex, physiology or lifestyle) and will not provide an accurate measure of risk to an individual.

The step from dose to risk has several more averaging and modelling stages. If the object of converting small radiation doses into expressions of risk is to predict future outcomes for either individuals or small populations of exposed individuals, the exercise is likely to mislead. Risk at low doses should not be based on the linear no-threshold hypothesis. The linear no-threshold hypothesis falls short of the definition of science as expounded by Ziman (1968) and Hartley (1995). Quantification of risk should be based on scientific evidence.

Data from many studies at low doses and studies on small exposed populations are viewed by one group of people as being consistent with the linear no-threshold hypothesis, by a second group as being inconsistent with the hypothesis, and by a third group as being consistent with both positions. Even at relatively high doses there is compelling evidence that risk coefficients are not directly proportional to dose (Yonehara et al. 1995). The power of some studies is insufficient to prove or disprove the hypothesis. These studies, as a class, prove very little, if anything, but they may persuade people that because there is no positive proof, the risk is acceptably small. They also fuel a controversial debate that would not exist if the risk assessments were based on a testable hypothesis (Gough 1996). The power of other studies to demonstrate that the linear no-threshold hypothesis is an unreliable tool over its lower and middle ranges is not taken into account in the practice of radiation protection.

Radiation risk at uranium mines

Given these qualifications, it is necessary to treat with caution the conversion of calculated radiation doses into numerical expressions of risk. It would, for example, be an inappropriate use of the linear no-threshold hypothesis to apply a risk prediction to an individual and to leave that individual with the impression that the prediction accords with a 'real' risk. It would be less misleading to derive a risk prediction for the entire population of uranium miners, but it would need to be recognised that the risk could also be zero (Health Physics Society 1996).

Any such population risk assessment should provide a range of risk values from zero to a theoretical maximum risk. The EIS process is an attempt to provide the best scientific information that can be derived. Once in operation, the facilities become subject to the regulatory process where the scientific arguments concerning the linear hypothesis become redundant and the practice of radiation protection becomes paramount.

The annual collective dose for employees at Olympic Dam reported for 1996 is given in Table 10.2.

Table 10.2 Annual collective dose for employees at Olympic Dam, 1996

Employment area	Number of people	Collective dose (Sv)	Average individual dose (mSv)
Surface facilities	706	0.65	0.92
Underground mine	480	1.05	2.19
Combined workforce	**1,186**	**1.70**	**1.43**

Assuming that the average annual dose remains substantially the same, a table of relative risks at various ages can be constructed using the ICRP risk coefficient (Table 10.3). The numbers have been extrapolated from the tables of conditional death probability rates of the ICRP (1991), using the multiplicative risk model.

The table can best be understood if one imagines two groups of people, all aged 18, who take up employment at Olympic Dam, and who all work at Olympic Dam until they retire at age 65. As the groups reach the ages shown in the first column, each group's probability of death from exposure to radiation is shown in the second and third columns. For example, when the group shown in the second column reaches the age of 65, the probability is that 0.06 people will die from exposure to radiation.

Table 10.3 Risk at various ages for two populations of Olympic Dam employees

	Occurrence of death in the defined population	
Age	1,186 employees, annual average dose 1.43 mSv per person	141 employees, annual average dose 5 mSv per person
20	0.00	0.00
25	0.00	0.00
30	0.00	0.00
35	0.00	0.00
40	0.01	0.00
45	0.01	0.00
50	0.02	0.01
55	0.03	0.01
60	0.05	0.02
65	0.06	0.03
70	0.08	0.03
75	0.09	0.04
80	0.09	0.04
85	0.06	0.03
90	0.03	0.01
95	0.01	0.00
100	0.00	0.00

One criticism of this approach to risk estimation is that some individuals may be exposed to annual doses that exceed the collective average by significant amounts. An analysis of the individual doses at Olympic Dam has shown that the distribution of individual doses is highly skewed, that is, the majority of employees receive small annual doses and a few receive higher annual doses. If one were to take only the small group of employees (141 out of a total of 1,186) who receive annual average doses of 5 mSv, the number of deaths in this group is shown in the third column of the table. Again, it must be understood that the assumption has to be made that these 141 employees start work at age 18 and continue to receive 5 mSv per year, every year, until they retire at age 65.

Comparison of risks

There is no simple answer to the question of how these calculated, theoretical risks compare with more familiar risks, such as industrial or vehicle accidents. If the risk at 20 mSv per year is said by the ICRP to be 'just tolerable', then it should be clear that the risk at Olympic Dam is between this boundary and zero. Since the ICRP derived its recommended annual dose limit (in part) from comparisons between radiation effects and the risks associated with 'safe' industries, it follows that the risk from radiation at Olympic Dam places the operation well within the original ICRP definition of a safe industry. The ICRP now recommends that limits on radiation exposure should be set at levels on the border between 'tolerable' and 'unacceptable'. This is a somewhat different approach from that formerly adopted.

Figure 10.19 shows the theoretical risk of death due to cancer at various ages and annual radiation doses.

It is noted that the current annual average dose at Olympic Dam of 1.43 mSv.

There are other risks associated with underground mining and metallurgical processing, and the real or theoretical risk associated with radiation is additional to these risks. All risks should be managed on the basis of their relative magnitude; Section 10.4 considers the management of radiation risks.

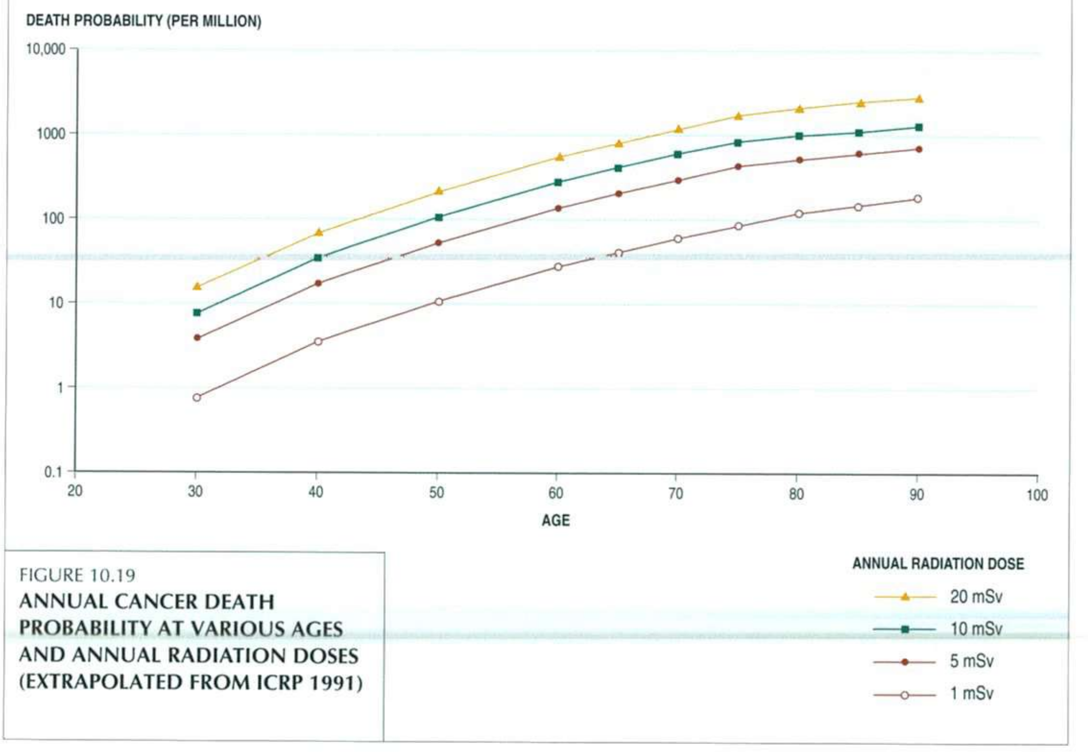


FIGURE 10.19
ANNUAL CANCER DEATH PROBABILITY AT VARIOUS AGES AND ANNUAL RADIATION DOSES (EXTRAPOLATED FROM ICRP 1991)

10.2.5 Radiation dose to transport workers

Uranium oxide product would continue to be packed into 205 L steel drums and loaded into standard shipping containers for transport to Port Adelaide. Two types of truck are used, 'B-doubles' and singles. Measurements have been made of the gamma radiation dose rate at the driving position in the trucks used, at the surface of the shipping containers, at 1m from the containers, and at 2 m from the containers. A summary of these measurements is given in Table 10.4.

Table 10.4 Gamma dose rates from shipping containers

Position	Gamma dose rate ($\mu Gy.h^{-1}$)
Driver's seat	1.0
Surface of container	23.0
1 m from container	12.0
2 m from container	5.3

Currently, Olympic Dam produces 1,500 t/a of uranium oxide, which is equivalent to approximately 75 shipping containers per year, requiring approximately three to four convoys to transport the uranium oxide to Port Adelaide.

Uranium oxide production would increase to 4,630 t/a at a copper production rate of 200,000 t/a and reach 7,730 t/a at a copper production rate of 350,000 t/a. The radiation dose to drivers from each of these production rates, given in Table 10.5, would for all cases be much less than 1 mSv/a which is the annual limit for members of the public.

Table 10.5 Predicted radiation doses to truck drivers

Uranium oxide production rate (t/a)	Number of convoys	Annual radiation dose[1] (mSv)
1,500	3–4	0.03
4,600	6–8	0.08
7,900	10–14	0.11

1 *Based on the number of convoys and the turn-around time, using the same drivers for each convoy. These are total doses, without background subtraction.*

10.3 ENVIRONMENTAL RADIATION

Radionuclides that leave the site of operations are transported into the environment by one or more pathways, as follows:

- atmospheric
- direct gamma
- surface water
- groundwater.

The atmospheric pathway is the route by which radon gas, radon decay products and radionuclides in dust are transported from their sites of release.

The direct gamma radiation pathway can be discounted in the case of Olympic Dam, both because the gamma rays are attenuated in air and because the dose rate is almost inversely proportional to the square of the distance from the site of the emission. At the distances from the mine where people live, gamma rays arising from the operation cannot be detected, and the dose from direct gamma radiation arising from the operation is zero.

The surface water pathway between the site of operations and people living in the area is cut off by bunding and collection ponds, which prevent the surface transport of water beyond the boundaries of the site of the emission. There is also no natural drainage leading from the site to inhabited areas, since the topography is dominated by sand dunes and swales which drain to small local clay pans.

The groundwater pathway is interrupted by chemical and physical effects. The chemical effect is the filtering of contaminants from the water front by processes that include ion exchange whereby chemical and radionuclide pollutants are trapped by clays and soils in their path. The physical limitation on the passage of radionuclides from groundwater to people is the fact that, at Olympic Dam, the aquifers into which pollutants could flow are of such high salinity that their direct use for either human or stock consumption is not possible. The vertical distance to the first aquifer is at least 50 m and the distance to the second is at least 140 m. There is no surface expression of these aquifers.

Pathway analysis, such as that outlined by the International Commission on Radiological Protection (1978), is further simplified at Olympic Dam, since many of the potential concentration and dilution stages in theoretical pathways do not reach people. Figure 10.20, for example, shows pathways through deposition of radionuclides on soil, to ingestion by animals, and ingestion of animals by people. However, people living in the vicinity of Olympic Dam do not eat the indigenous animals and the lease areas have been destocked; crops are not grown in the area, nor do people eat the indigenous plants. These pathways are therefore truncated and do not contribute to the radiation dose of people.

Nevertheless, the Radiation, Environment, Safety and Quality Department at Olympic Dam has investigated all the pathways shown on the diagram (with the exception of crops, since there are none) and the results of the investigations are discussed in this section. Figure 10.21 shows the locations of the monitoring sites from which the data in the following sections are derived.

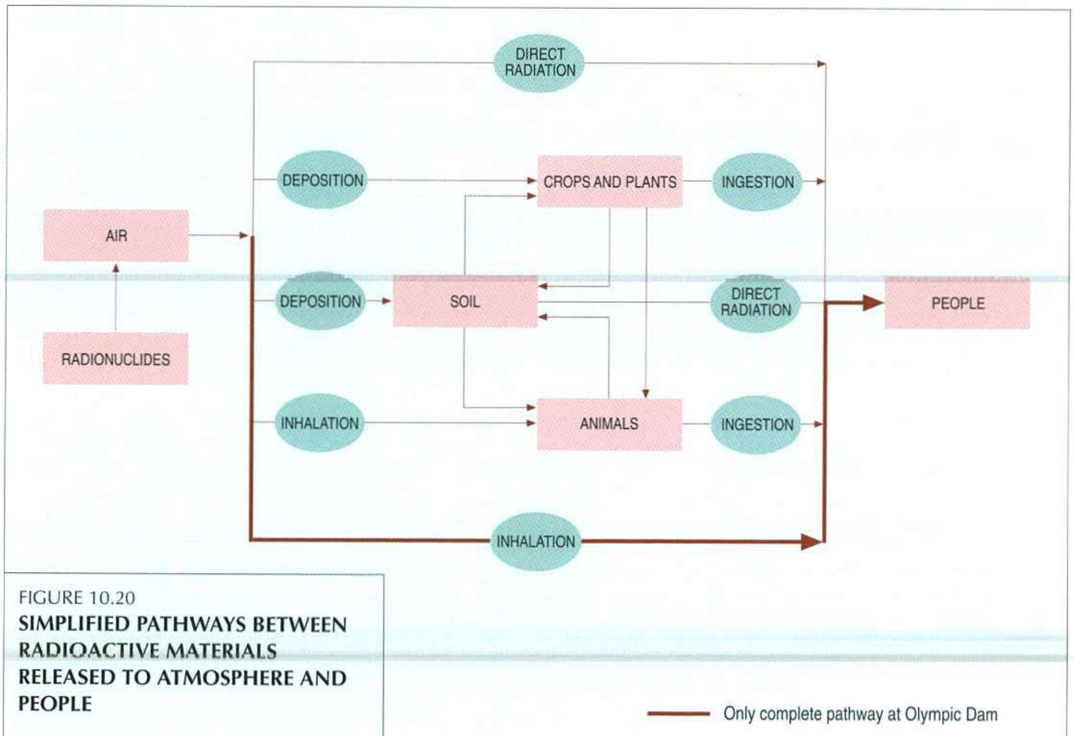


FIGURE 10.20
SIMPLIFIED PATHWAYS BETWEEN RADIOACTIVE MATERIALS RELEASED TO ATMOSPHERE AND PEOPLE

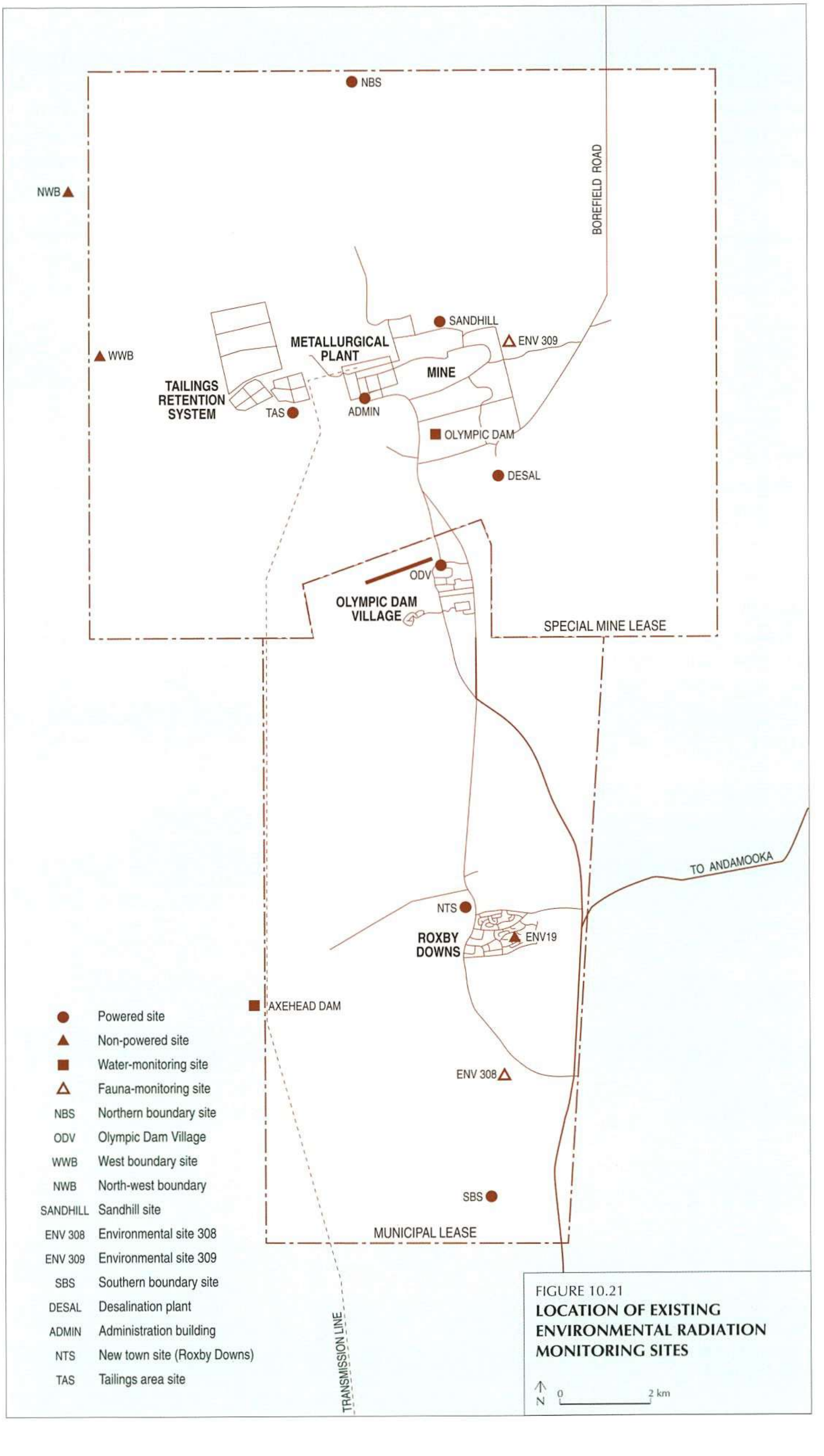


FIGURE 10.21
LOCATION OF EXISTING ENVIRONMENTAL RADIATION MONITORING SITES

10.3.1 Atmospheric pathway

The atmospheric pathway is the only pathway that is complete—radionuclides released from the operations area are transported to where people live. Atmospheric processes disperse the radionuclides and dilute the concentrations. Measurements are made at several distances from the operations area and at locations where people live. It is these measurements that are used to calculate radiation doses to members of the public living in the two communities nearest Olympic Dam, namely Olympic Dam Village and Roxby Downs.

Radionuclides in dust

Two programmes have been conducted to measure the concentration of radionuclides in dust samples taken at various sites surrounding the operations area. One programme consists of 'passive' dust collectors into which dust (and rainwater) falls. The programme is designed to detect the distribution of dust arising from the operations. The second programme consists of several sites at which samples of air and dust are collected by high-volume air samplers and filters.

Passive dust sampling programme

The passive dust sampling programme provides qualitative information about the relative magnitude of dust fallout at each collection point, whereas the air samplers provide quantitative information on the concentration of dust and radionuclides in the air.

Although the passive collection programme has recently been changed in the light of an analysis of the data for the years 1988–96, the programme as it stood until 1996 is described here.

Each six months, dust was collected from forty-nine passive dust samplers. The samplers consisted of a funnel located over a sample bottle. The forty-nine individual samples were composited into fifteen samples, each representing a geographic area. The dust was weighed and analysed for five radionuclides (^{238}U, ^{230}Th, ^{226}Ra, ^{210}Po and ^{210}Pb). Using the collection area of the funnels, it is possible to make an estimate of the dust deposition rate (expressed as mg/m^2.d) and of the radionuclide concentration in the dust (expressed as mBq/m^2.d). Figure 10.22 shows the concentration of uranium in the dust in relation to distance from the mine and processing plant.

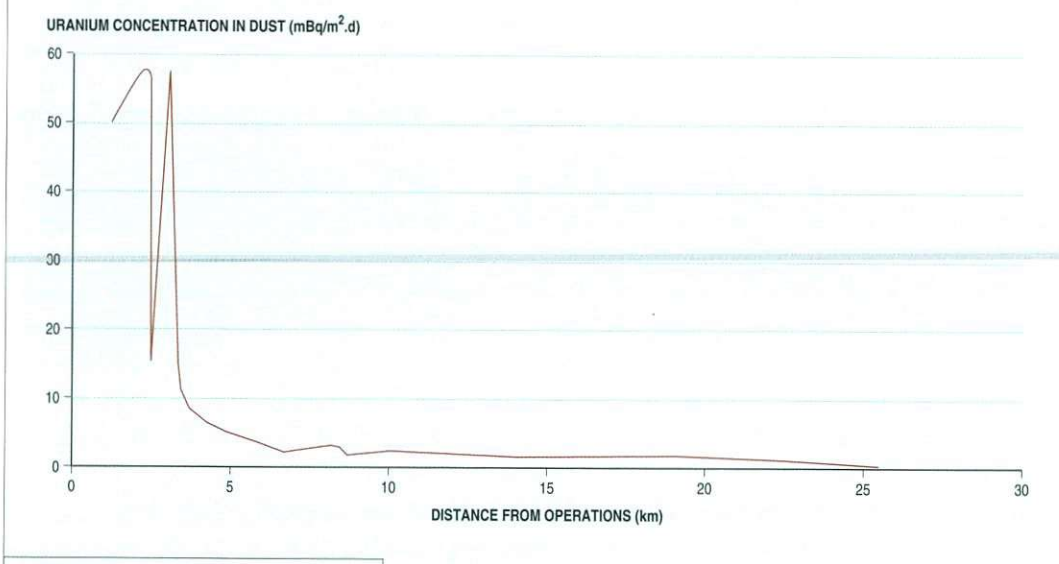


FIGURE 10.22
URANIUM CONCENTRATION IN DUST WITH DISTANCE FROM MINE AND PROCESSING PLANT OPERATIONS

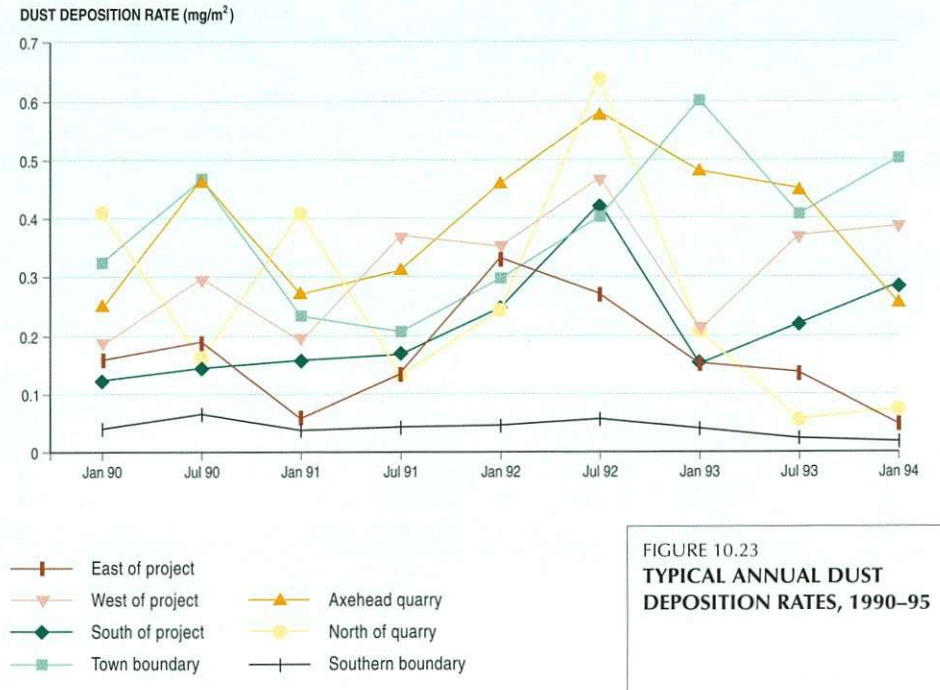


FIGURE 10.23
TYPICAL ANNUAL DUST DEPOSITION RATES, 1990–95

It can be seen from the graph that within approximately 5 km of the site the uranium concentration has fallen sharply to values that are less than one-fiftieth of the maximum value close to the site. The large differences between the uranium concentrations in dust close to the site are due to the close proximity of the collection sites to individual radioactive dust sources.

The data have also been analysed to determine temporal changes in deposition rates that may be related to operations at the site. Figure 10.23 shows the annual changes in dust deposition rates for seven of the passive collection areas.

No trend that could be attributed to operations at the mine and treatment plant was observed. Annual changes are evident, but these are more likely to be due to differences in annual meteorological conditions.

In summary, the passive dust measurement programme appears to show that close to the site it is possible to detect fallout of dust that is likely to be related to operations. However, annual changes in dust deposition rates do not appear to be a result of operational factors.

High-volume air sampling programme

High-volume air samplers are located at eight sites that are provided with 240 V power. The locations of these sites are shown in Figure 10.21. Weighed filters are inserted into the samplers each week. At the end of each week, the filters are collected and weighed again. Each month, the four filters from each sampler are digested in hydrofluoric acid and the residue is used for determining concentrations of radionuclides and some heavy metals, notably copper. Figure 10.24 shows how the concentration of dust in air and the concentration of uranium in that dust vary with distance from the centre of the operational area.

The changes in concentration of dust at various sites were examined to see if the measured concentrations could be related to activities in the operational areas. Figure 10.25 shows the concentrations of dust (in units of $\mu g/m^3$) and uranium (in units of $\mu Bq/m^3$) measured at the Sandhill site, which is very close to the ventilation shafts which service the underground mine; it is also close to the area where ore is currently stockpiled and where mullock was stockpiled until recently. The changes in concentration are probably due to both activities

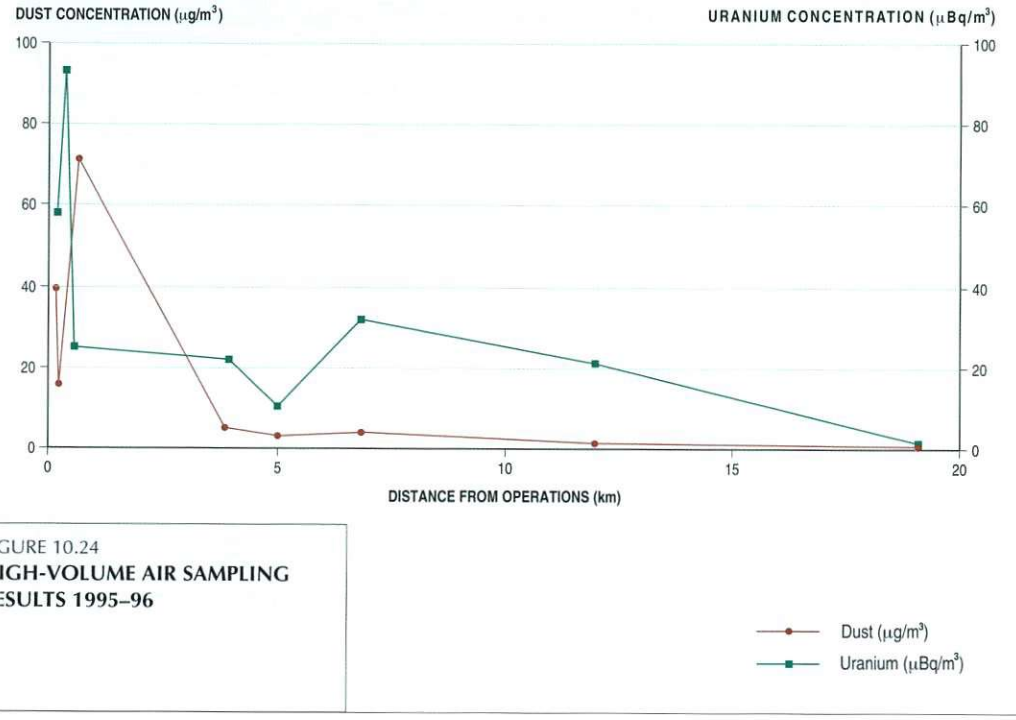


FIGURE 10.24
HIGH-VOLUME AIR SAMPLING RESULTS 1995–96

taking place close to the air sampler (movement of vehicles and ventilation shafts) and the effects of rainfall and wind speed.

Figure 10.26 shows the measurement results for the Southern Boundary site, which is some 19 km south of the operations area and is therefore unlikely to be greatly influenced by the factors that affect the concentration of dust at the Sandhill site.

The dust concentration at the Southern Boundary site is significantly lower than at the Sandhill site, which reflects the relative lack of vehicle movement in the area. The concentration of

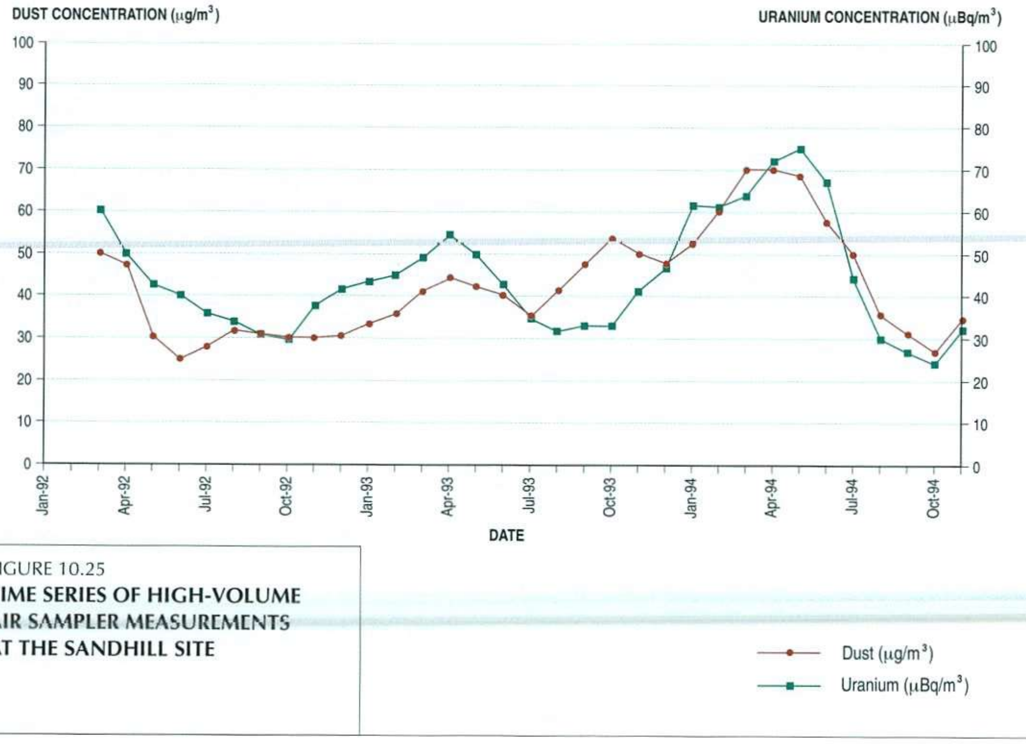


FIGURE 10.25
TIME SERIES OF HIGH-VOLUME AIR SAMPLER MEASUREMENTS AT THE SANDHILL SITE

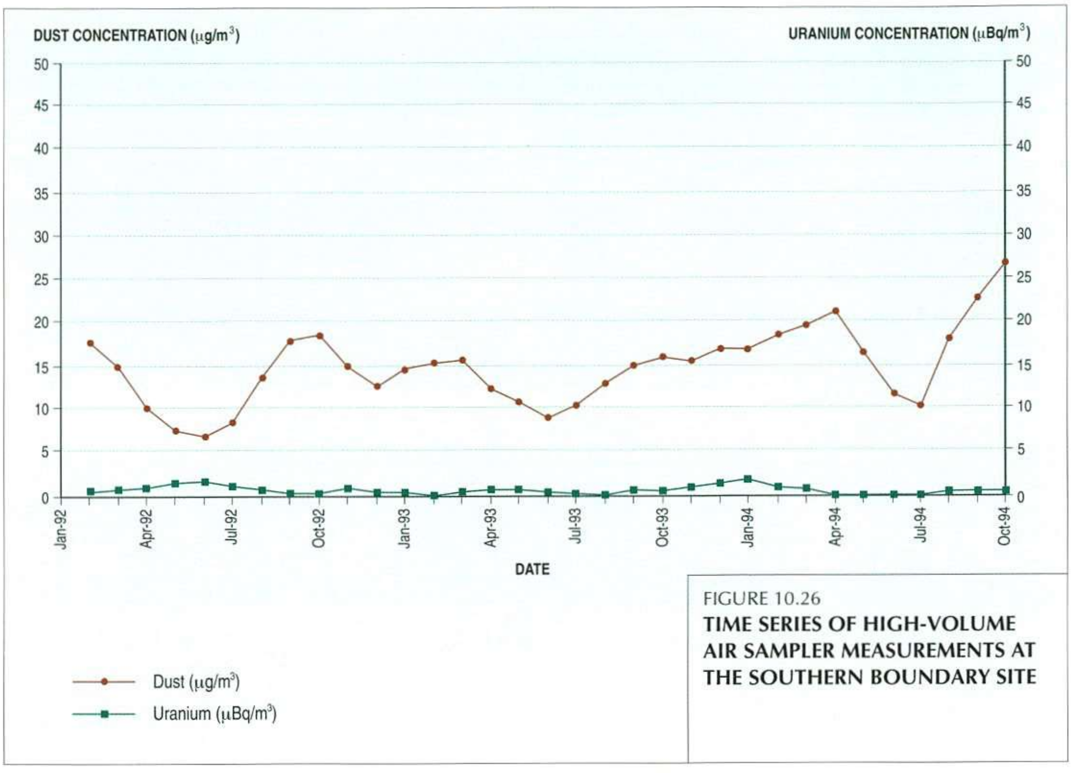


FIGURE 10.26
TIME SERIES OF HIGH-VOLUME AIR SAMPLER MEASUREMENTS AT THE SOUTHERN BOUNDARY SITE

uranium in the dust is also very much lower, which reflects the distance of the Southern Boundary site from the sources of the uranium, namely the movement of ore and the air vented from the underground mine.

In summary, the data from the high-volume air sampling show that activities centred on the metallurgical plant and the mine influence the concentration of dust in the immediate vicinity of these sites; this influence becomes undetectable beyond a distance of approximately 5 km. The magnitude of the concentrations measured is influenced by factors that include activities in the immediate vicinity of the samplers, but it is also influenced by meteorology, principally rainfall and wind speed and direction.

Radon decay product concentrations in air

Radon decay product concentrations are measured continuously at eight monitoring sites shown in Figure 10.21. Figure 10.27 shows the diurnal variation in radon decay product concentrations at seven of the sites. The Northern Boundary site is not shown because the concentrations measured there have been shown to be influenced by a local anomaly to the north of the Olympic Dam site, thus masking any influence the emission of radon from the mine, process plant and waste management system may have on the measured concentrations at the Northern Boundary site. The location of this site has subsequently been changed to overcome the influence of the local anomaly.

The figure shows a typical diurnal pattern, in which the concentration rises in the pre-dawn hours under the influence of low lateral wind speeds and reduced vertical mixing, due to inversions in the adiabatic lapse rate. As the sun rises and warms the ground, the inversion breaks down and the normal lapse rate is re-established. This leads to greater mixing and, together with surface winds, dilutes the radon decay concentrations.

The Sandhill site is close to and surrounded by ventilation outlets from the underground mine and the concentrations measured here are thus subject not only to meteorological conditions, but also localised sources of high concentrations.

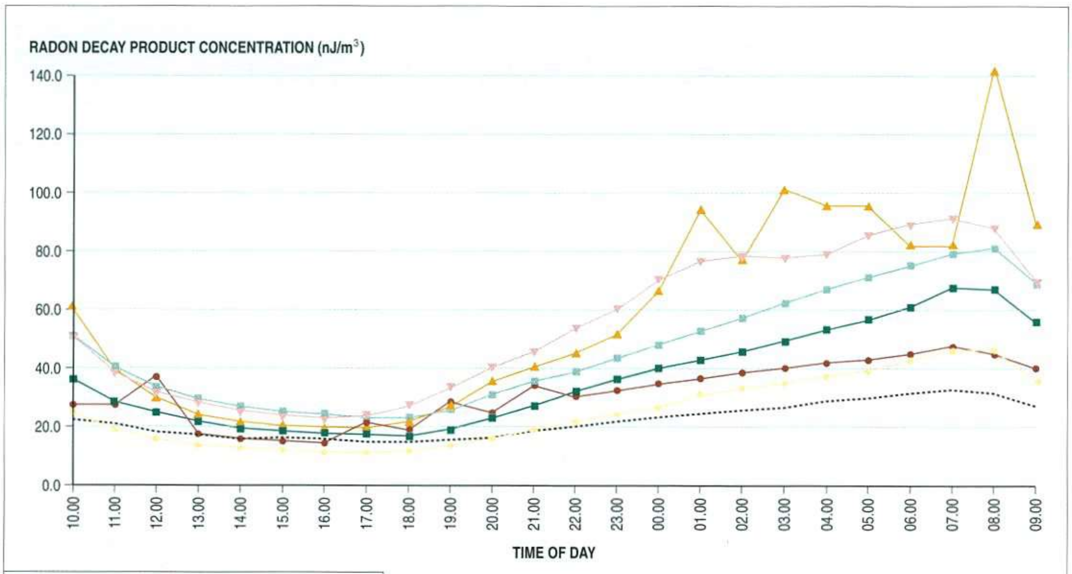


FIGURE 10.27
DIURNAL VARIATION IN RADON DECAY PRODUCT CONCENTRATIONS

Note: Refer to Figure 10.21 for location of monitoring sites

Figure 10.28 shows how the concentration of radon decay products varies over an eighty-five day period. The influences of both the diurnal variations shown in Figure 10.27 and the day-by-day variations shown in Figure 10.28 make it problematic to reduce the measured concentrations at a particular site to simple expressions that can be used to demonstrate the influence of the mine, processing plant and waste management facilities on the natural background levels of radon decay products. Figure 10.29 is constructed from the average radon decay product concentration over a five-year period and shows the decrease in

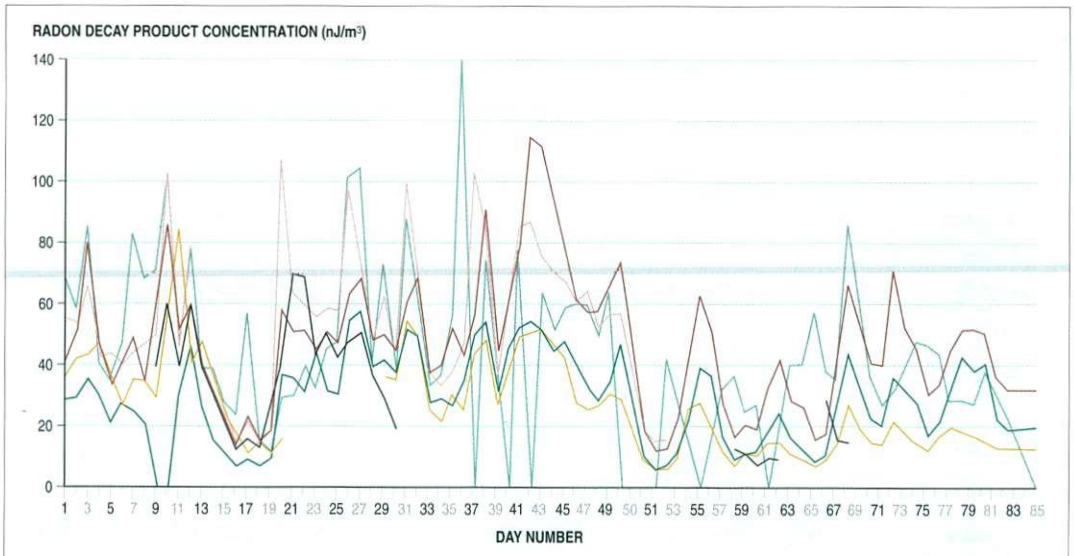


FIGURE 10.28
RADON DECAY PRODUCT CONCENTRATIONS OVER AN 85-DAY PERIOD

Note: Refer to Figure 10.21 for location of monitoring sites

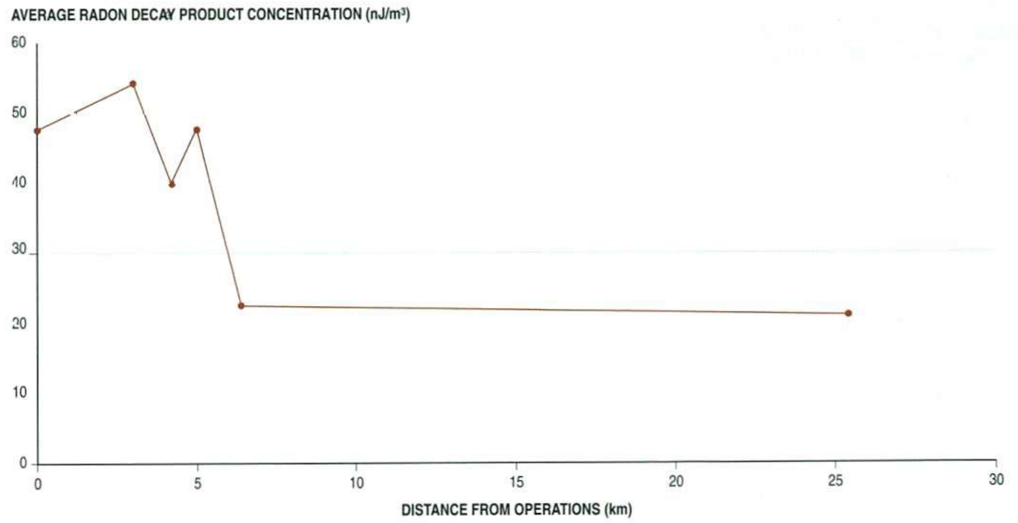


FIGURE 10.29
AVERAGE RADON DECAY PRODUCT CONCENTRATION WITH DISTANCE

concentration with increasing distance from the mine, processing plant and waste management facilities.

Beyond a distance of approximately 5 km the concentration falls to background levels, implying that the influence of the operation is geographically confined within a relatively short distance of the site.

10.3.2 Member of the public dose assessment

Sections 10.3.1 and 10.3.4 discuss the measurements made of radiation in the environment at points along the atmospheric and water pathways. The only pathway that connects the operations at Olympic Dam to people is the atmospheric pathway (Figure 10.20). It is along this pathway that radon decay products and dust are transported. The concentrations of radon decay products and dust in the atmospheric pathway have been described in Section 10.3.1.

It is a requirement of the Code of Practice on Radiation Safety in the Mining and Milling of Radioactive Ores that an assessment should be made of the radiation dose to members of the public living in the vicinity of uranium operations. Further, it is a requirement that the dose to the most exposed group of members of the public arising as a result of the operation should be restricted to less than 1 mSv on average, per year, over and above background.

In order to meet the requirements of the code, it is necessary to determine the background levels of dust and radon decay products and subtract these from the total concentrations, the residual then being attributable to the operations. The residual is turned into an expression of radiation dose by converting the exposures into equivalent doses through the use of appropriate conversion factors.

Prior to operations commencing at Olympic Dam, measurements were made of radon decay product concentration and of dust; however, it has subsequently been shown that the natural levels of these parameters vary on time scales which are greater than the time period for which data were gathered prior to operations. In other words, background levels of radiation in the environment vary from year to year, with no one year being necessarily 'typical' of the levels over periods of tens of years. Similar findings have been deduced from data at the Ranger uranium mine in the Northern Territory. It is thus not appropriate to use the pre-operational data at Olympic Dam and simply subtract this from the subsequent years of operation. In some years this would lead to there being negative concentrations of radon decay products and dust, clearly an absurdity.

A method of data analysis termed the 'sector-subtraction' method has been employed in this EIS. Data files containing hourly radon decay product concentrations at each of eight monitoring sites are combined with meteorological data files. The database is filtered to provide two sets of data for each location. The first set consists of hourly radon decay product concentrations for those hours when the wind is blowing from the mine, processing plant and waste storage facility (the operation) towards the monitoring site. This set contains concentrations that will have a component attributable to the operations. The second set consists of radon decay product concentrations for those hours when the wind is blowing from any other direction. This second set contains concentrations due entirely to background, or non-operation-related levels.

Subtracting the second set of data from the first provides a residual concentration that can be attributed to the operations. It is the residual concentration that is subsequently used in determining the member of the public dose.

High-volume dust sampling at Olympic Dam Village (ODV) and at Roxby Downs township (NTS) provides data on the annual average concentration of radionuclides in dust. The data are not processed using a sector-subtraction method. Dust concentrations are used directly in calculating the radiation dose to members of the public living in the two locations.

Table 10.6 contains the results of radiation dose assessments at the ODV and NTS sites for the past five years. The relevant factors for the assessments are as follows:

- AMAD (dust), 1 μm;
- exposure duration, 8,760 h/a;
- breathing rate (assuming a mixture of 'light activity', non-occupational activity, and resting), 0.958 m^3/h.

The dose conversion factors (inhalation) for the assessments are as follows:

- for radon decay products, 1.1 mSv/(mJ.h/m^3);
- for radionuclides in dust, 6.2×10^{-3} mSv/αdps (where αdps = alpha disintegrations per second).

Table 10.6 Radiation doses to members of the public at ODV and NTS, mSv

Year	ODV		NTS		Effective dose due to operations	
	Radon decay products	Radio-nuclides in dust	Radon decay products	Radio-nuclides in dust	ODV	NTS
1991–92	0.027	0.00020	0.015	0.00006	0.027	0.015
1992–93	0.021	0.00016	0.013	0.00004	0.021	0.013
1993–94	0.019	0.00014	0.012	0.00004	0.019	0.012
1994–95	0.027	0.00014	0.015	0.00008	0.027	0.015
1995–96	0.016	0.00026	0.031	0.00013	0.016	0.031

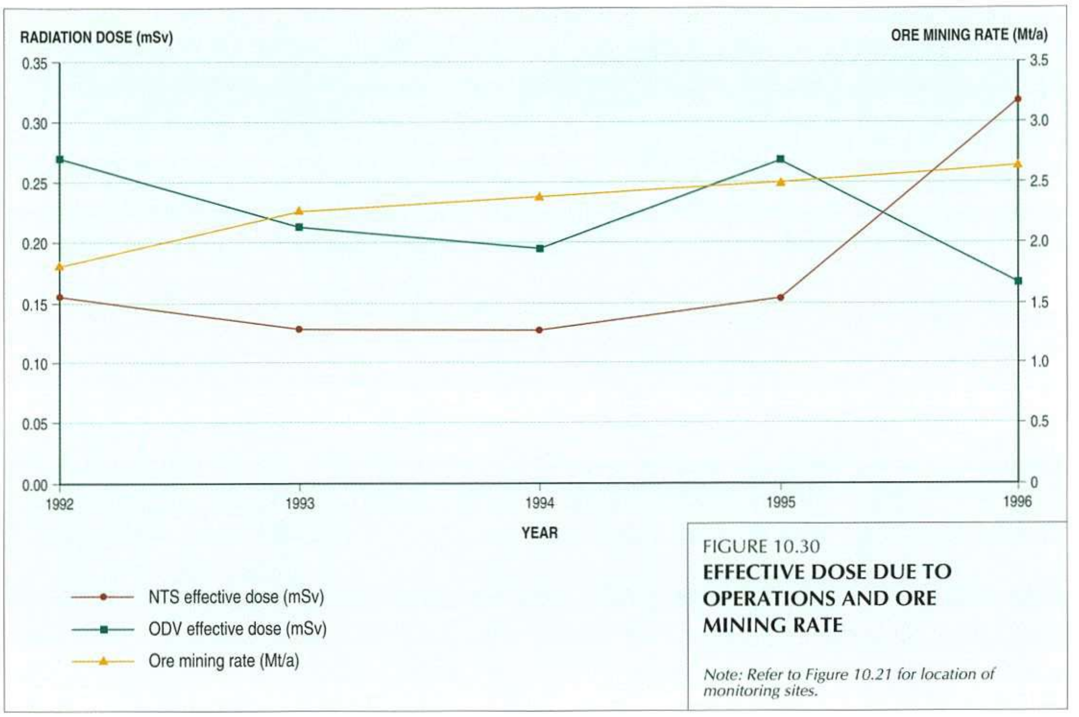


FIGURE 10.30
EFFECTIVE DOSE DUE TO OPERATIONS AND ORE MINING RATE

Note: Refer to Figure 10.21 for location of monitoring sites.

Figure 10.30 shows the effective dose due to operations and the annual production rate of the Olympic Dam mine.

ODV is closer to the site of operations than NTS and yet the data show that while the absolute magnitude of the radiation dose due to operations at ODV is greater than that at NTS (except in 1995–96), the radiation dose is not correlated with the mine production rate, suggesting that any influence the operations have on the radiation dose at ODV is small.

No explanation for the increase in radiation dose at NTS in 1996 presents itself, and the fact that the radiation dose is greater at NTS than it is at ODV (which is much closer to the operations) cannot be easily explained. Nevertheless, the radiation doses at the two sites do not seem to be influenced by the magnitude of the operation as measured by the production rate.

The radiation doses at ODV and NTS are between 1% and 3% of the annual average dose limit for members of the public of 1 mSv (over and above background).

10.3.3 Prediction of radiation dose to members of the public due to the proposed expansion

Had the radiation doses at ODV and NTS (presented in Section 10.3.2) been strongly correlated with mine production rate, predicting the magnitude of the doses arising from the expansion would simply be a matter of multiplying the doses by a factor representing the increase in production. It can be seen, however, that the doses are not correlated with production rate and that factors such as annual meteorological conditions influence the magnitude of the doses.

The first stage of the Expansion Project would see the production increase from its current level by a factor of approximately 2.4, from 85,000 to 200,000 t/a of copper. Subsequent expansion to 350,000 t/a copper, from in-mine production, would increase the current level of production by a factor of 4.2. By using these factors, and assuming that the radiation doses at ODV and NTS are correlated with production rates, the predicted doses could be calculated to provide an upper bound estimate of the likely radiation doses. Table 10.7 shows the results of these assumptions and calculations.

Table 10.7 Upper bound estimates of radiation doses due to the proposed expansion

Production rate (copper t/a)	Olympic Dam Village (mSv)	Roxby Downs (mSv)
85,000[1]	0.022[2]	0.017[2]
200,000	0.053	0.042
350,000	0.092	0.073

1 *Current production rate.*

2 *Average of 1991–96 data.*

Note: Assumes radiation doses are correlated to production rate.

10.3.4 Water pathways

Figure 10.31 shows the groundwater and surface water pathways postulated by the ICRP. Although neither pathway reaches people living in the vicinity of Olympic Dam, measurements have been made of the concentration of radionuclides in the surface water and groundwater. The measurements are not made in order to calculate a radiation dose to people, but to investigate the integrity of the containment systems; the concentrations cannot be directly compared with intake limits for members of the public.

Surface waters

The surface water collectors and ponds, which are used for containment of process liquors or site run-off, are all within the project area and do not discharge water into the

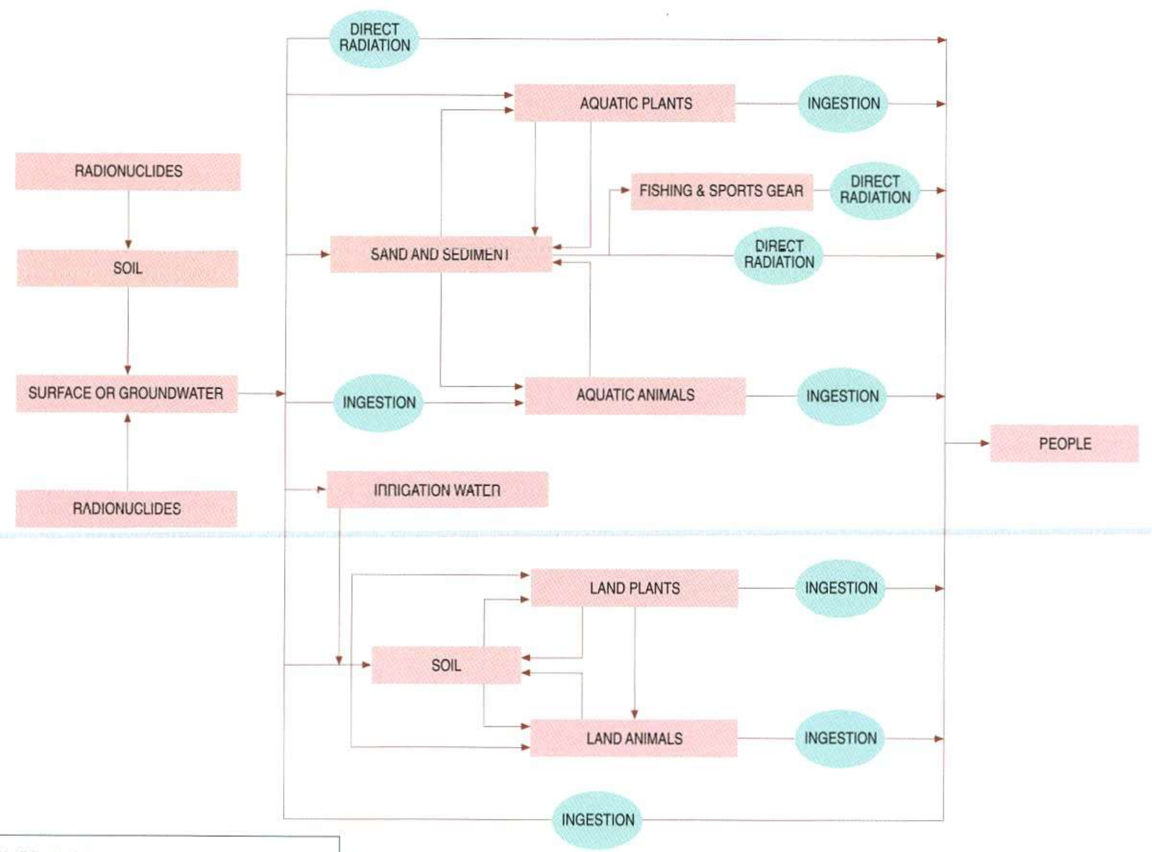


FIGURE 10.31
SIMPLIFIED PATHWAYS BETWEEN RADIONUCLIDES RELEASED TO GROUND OR SURFACE WATERS AND PEOPLE

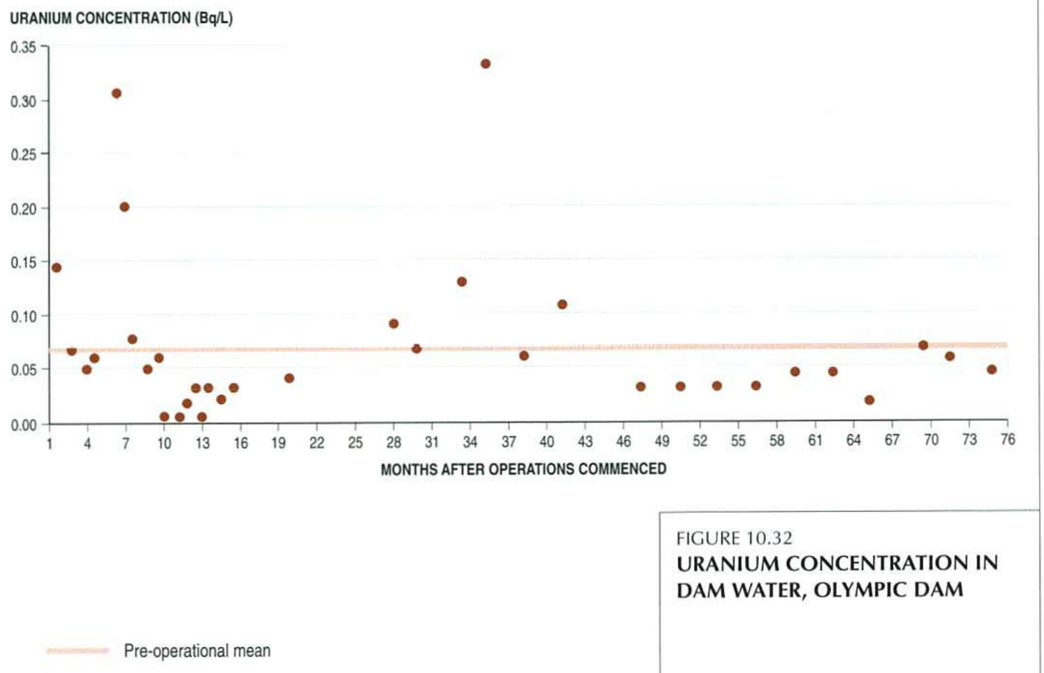


FIGURE 10.32
URANIUM CONCENTRATION IN DAM WATER, OLYMPIC DAM

surrounding area. Potentially contaminated surface waters therefore have no expression outside the operations area and contribute no radionuclides to the external environment.

Measurements have been made of the radionuclide concentrations in waters of several dams located at radial distances up to 16 km from the mine and processing site. Figure 10.32 and Figure 10.33 show the concentration of uranium in two of the dams, Olympic Dam (1.9 km from the centre of operations) and Axehead Dam (16 km from the site). Figure 10.32 shows the mean of the uranium concentrations that were measured before operations commenced,

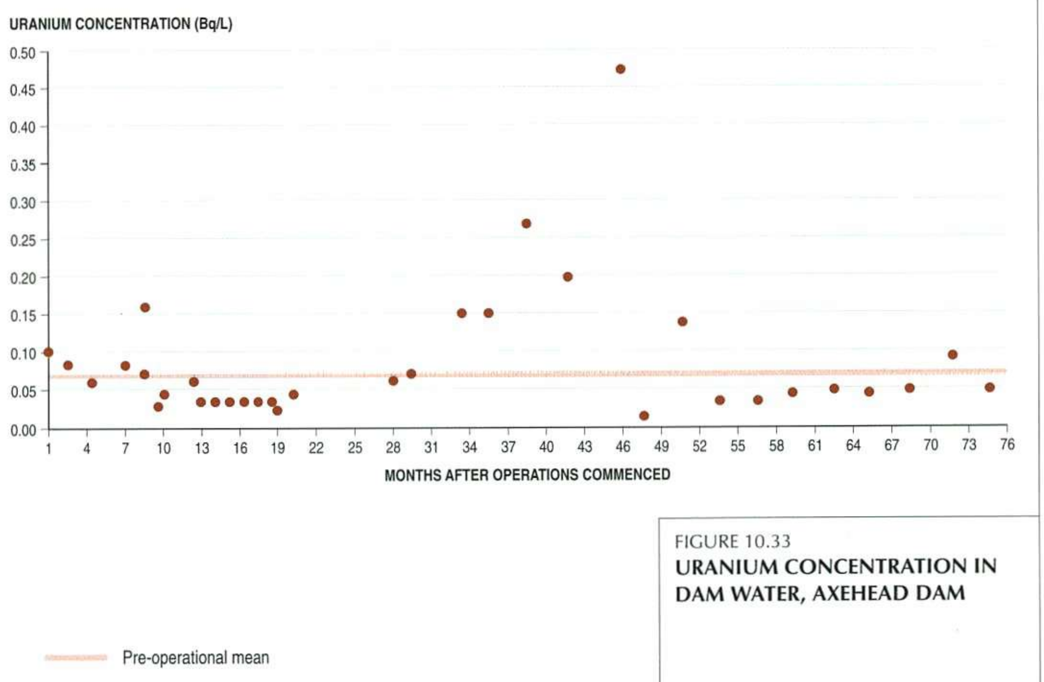


FIGURE 10.33
URANIUM CONCENTRATION IN DAM WATER, AXEHEAD DAM

and the data points measured since the operation started. The great variability in the measured concentration is almost certainly due to the great variability in rainfall. As the water in the dam evaporates, the concentration of uranium rises. Rainfall in the area is unpredictable, with long dry periods and short high-intensity storms. Some of the variability may be only apparent because of the difficulties associated with the radiochemical techniques necessary for measuring such low concentrations, repeatably, and over long time periods.

Axehead Dam is some 16 km from the site, but the concentrations shown in Figure 10.33 are of the same order of magnitude as those measured at Olympic Dam, confirming the opinion that the concentrations are not a consequence of dust fallout, but of natural climatic variations.

In conclusion, the results of the surface water monitoring programme do not demonstrate an environmental impact from the operations. The surface waters are not part of the pathway leading to the consumption of water by humans, and are therefore not used in an estimate of dose for members of the public.

Groundwater

Chapter 4 describes the impact of current operations on groundwater under the Olympic Dam site, and the future operations which would follow the implementation of the Expansion Project (Section 4.6). Of particular importance are issues associated with the operation of the tailings retention system which is described in greater detail in Chapter 8. The previous operations at Olympic Dam have resulted in the formation of a localised, elevated groundwater mound. The formation of the groundwater mound has been attributed to seepage from the tailings system.

The conclusion from the results of all the investigations into this seepage event, as described in Section 8.1, is that the tailings retention system seepage has had no adverse impact on the environment or the health of employees or members of the public.

The reasons for this are:

- The seepage lies within the influence of the mine cone of depression, and the system is thus self-impounding. The Expansion Project would result in an increase in underground mining activities and a further increase in the mine cone of depression.
- The naturally occurring groundwater is some 50 m below the surface.
- The naturally occurring groundwater is of extremely poor quality, and cannot be consumed by humans or animals or used for irrigation. Shallow and deep groundwater in the area also contains levels of metals, including lead, manganese, iron and radium above human drinking water standards (1983 EIS).
- Metals and radionuclides in the seepage water are attenuated or filtered out at the base of the tailings retention system.

For the Expansion Project, the design for the tailings storage facilities and evaporation ponds has been based on the requirement to ensure minimum practical seepage from the tailings retention system.

Any seepage that reaches the groundwater (at 50 m depth) would undergo geochemical amelioration (Section 8.1.5) as the infiltrated liquor passed through the underlying soils and dolomite before mixing with water already high in salts, and containing detectable levels of radium and heavy metals. Background salinities of groundwater exceed 20,000 mg/L, making it unsuitable for either stock or human consumption. Background radium-226 levels up to 2.6 Bq/L (i.e. more than six times the desirable level for stock and human consumption) have been measured. Background iron, manganese, lead, fluoride and sulphate levels in the groundwater also exceed human consumption standards.

Furthermore, the cone of depression associated with dewatering for mine operations would encompass this groundwater during the lifetime of the Expansion Project and for a considerable period of time afterwards (Section 4.6.5). Thus any seepage would flow towards the mine in the short term and gradually migrate and disperse in the long term.

Radionuclides in fauna

The concentrations of several radionuclides have been measured in fauna of the area, both before and after operations commenced. Samples of rabbits, steers and sheep have been analysed, and subsamples of flesh, bone and liver have also been analysed. The average concentrations are listed in Table 10.8.

The results are difficult to evaluate since most of the samples displayed concentrations that were less than the detection limit of the analytical techniques. For example, of the 120 uranium analyses conducted on samples taken from rabbits, only 4 showed uranium concentrations above the detection limit; for sheep, there were 52 samples analysed, with only 14 above the uranium detection limit; and for steers, of 42 samples analysed, only 8 were above the detection limit. A greater proportion of analyses for ^{230}Th, ^{210}Pb and ^{210}Po were above the detection limits, albeit not for all types of sample or subsample.

Within the limitations of the data it would appear that the radionuclide concentrations in fauna samples do not show significant differences between pre-operational and operational levels.

Comparisons were also made between animals in close proximity to the operations area and animals remote from the site. Environmental monitoring site 309 is approximately 1 km from the eastern edge of the operations area, site 308 is 18 km south of the operations area and the West Boundary site is approximately 5 km west-south-west of the western edge of the operations area.

Table 10.8 Average concentration of radionuclides in fauna samples (pre-operational concentrations are shown in brackets)

Sample	^{226}Ra (mBq/g)		^{210}Pb (mBq/g)		^{210}Po (mBq/g)
RABBIT					
All samples	1.8		1.8		5.4
Bone	4.4		5.6		13.0
Liver	1.3		<MDL[1]		4.1
Flesh	0.11	(0.37)	0.26	(0.44)	0.79
SHEEP					
All samples	1.6	(1.75)	23.0	(30.0)	17
Bone	4.3	(4.9)	51.0	(75.0)	57
Liver	0.02	(0.054)	9.0	(14.0)	6.3
Flesh	0.11	(0.310)	0.68	(1.3)	0.60
STEER					
All samples	1.6	(1.48)	6.7	(9.0)	6.4
Bone	4.6	(4.1)	15.0	(23.0)	16.0
Liver	0.08	(0.17)	4.1	(3.8)	9.6
Flesh	0.08	(0.17)	0.05	(0.14)	<MDL[1]

1 *Less than the minimum detection limit.*

In summary, the data are unable to demonstrate any impacts arising from the operations because there is no correlation between animal capture distance and radionuclide concentration.

Radionuclides in vegetation

The measurement of radionuclide concentrations in samples of plants collected at several locations was undertaken prior to operations commencing and at regular intervals thereafter.

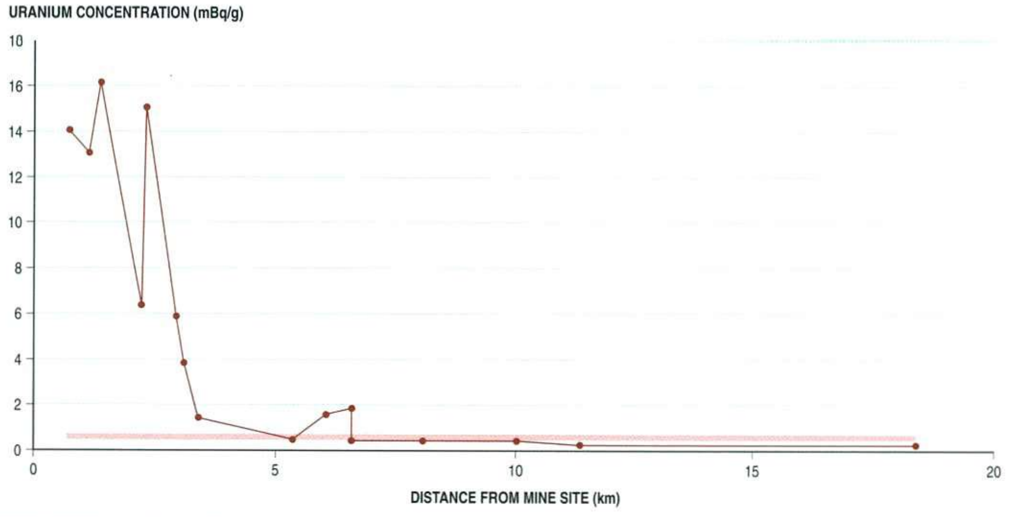


FIGURE 10.34
URANIUM CONCENTRATION IN VEGETATION SAMPLES WITH DISTANCE FROM MINE SITE

Samples of cane-grass, hopbush, saltbush, mulga, umbrella bush and bluebush were analysed for ^{238}U, ^{226}Ra, ^{230}Th, ^{210}Pb and ^{210}Po. Figure 10.34 shows the variation of average ^{238}U concentration in all vegetation samples with distance from the mine site as an example of the rapid decrease in concentration. Beyond approximately 5 km the concentration has fallen to background levels, which were measured prior to operations commencing.

A time series analysis of the concentration in ^{238}U is shown in Figure 10.35 for a monitoring site 1 km from the site. The changes in concentration cannot be attributed to operations at

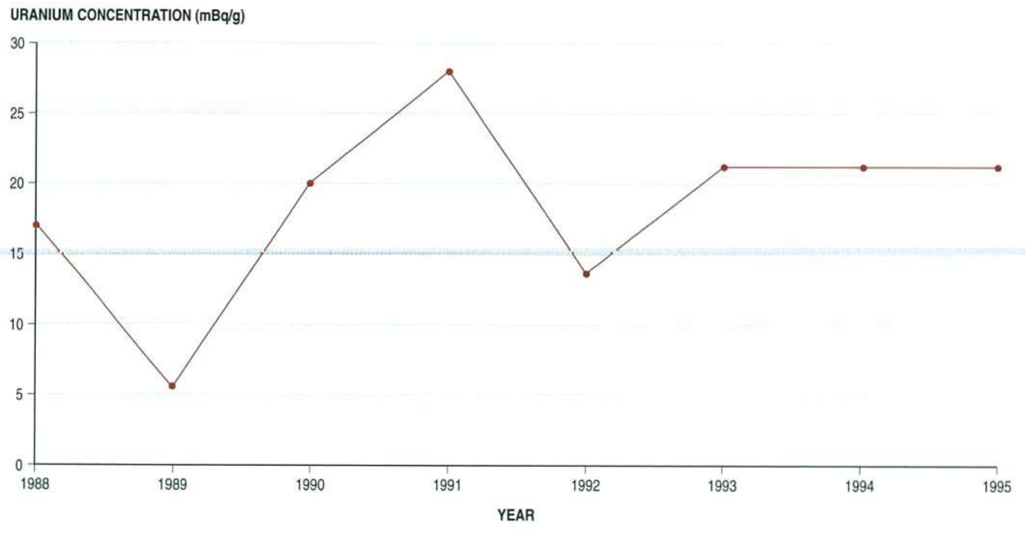


FIGURE 10.35
VARIATION OF AVERAGE URANIUM CONCENTRATION IN VEGETATION SAMPLES WITH TIME - 1km FROM MINE SITE

the site, but reflect annual meteorological conditions, particularly rainfall, since rain washes radionuclides from the leaves of plants.

In summary, the programme to measure radionuclide concentrations in vegetation samples shows results similar to those of the dust monitoring programmes. Impact from the operations cannot be detected beyond approximately 5 km from the site.

10.4 RADIATION MANAGEMENT PLAN

The Olympic Dam operation has been subject to external scrutiny since it began in 1983.

After the publication of the original EIS, approval was sought and obtained to implement an environmental monitoring programme and a radioactive waste management plan. These two documents were prepared in accordance with requirements of the Indenture.

In 1996, the environmental monitoring programme and waste management plan were amalgamated into the environmental management and monitoring plan (EMMP) described in Chapter 15.

The results of all environmental monitoring programmes, including environmental radiation data, are made available to the regulatory agencies on a quarterly and annual basis. The reports describe the measurements made and present analyses of any changes that have occurred in the reporting period. The annual reports are public documents.

An annual report is also prepared and submitted to the State Government in accordance with the Radiation Licence LM1. This report contains the radiation dose assessments made for all employees and for groups of members of the public. It contains confidential personal data and is not released to the public. However, a summary of these data is prepared and made available to the public annually in the form of a short pamphlet.

The radiation safety and environmental staff at Olympic Dam have also initiated research into several aspects of radiation measurement and safety, and have published papers in professional journals.

In addition to the monitoring and reporting programmes, there is an approval process through which WMC seeks formal approval to undertake any activity or change any process that has the potential to change the radiation exposure of either employees or members of the public.

WMC is currently developing an environmental management system (EMS) which is consistent with the ISO series 14001. In time this system will be extended to incorporate occupational health and safety issues. The ISO standards form the basis of a third-party accredited system.

In principle, the expansion of the facilities will not change the present approach to radiation safety and the operation will remain under scrutiny by regulatory agencies and by the scientific and general communities.

This chapter has identified and evaluated a number of potential exposure pathways to both employees and members of the public arising from the Expansion Project. The aim of this section is to describe the methods of verifying predicted radiation exposures and of managing the exposure situations so that employees and members of the public receive the minimum radiation doses practically achievable.

The principles of radiation protection have been encapsulated in a table by Strom (1996). Table 10.9 is a modified version of the Strom table and shows those principles that apply to the Olympic Dam operation.

Table 10.9 Principles and commandments of radiation protection

Principle	Commandment (familiar)	Commandment (technical)
Time	Hurry (but do not rush)	Minimise exposure and intake time
Education	Understand safety policy	Maximise knowledge through training
Distance	Stay away from it	Maximise distance
Dispersal	Disperse and dilute it	Minimise concentration, maximise dilution
Source barrier	Keep it in	Maximise containment, minimise release
Personal barrier	Keep it out	Minimise entry into the body of radioactive materials
Housekeeping	Keep areas clean	Minimise surface contamination
Personal hygiene	Keep it off you	Wear appropriate clothing, wash thoroughly
Optimal technology	Choose best technology	Optimise risk–benefit–cost figure
Limit other exposures	Don't compound risks	Minimise exposure to other agents

In practical terms the principles in Table 10.9 can be translated into actions at Olympic Dam that will achieve the main aim, that of dose minimisation. Table 10.10 is a summary of practical measures that apply at Olympic Dam.

Table 10.10 Practical radiation safety at Olympic Dam

Practice	Action
Equipment design	Include radiation protection staff in design processes
Equipment choice	Optimise protection–cost balance
Ventilation design	Plan and control ventilation to minimise exposure
Train employees	Conduct induction and training programmes
Emission control	Limit emission at source
Radiation monitoring	Provide data for decision-making
Housekeeping	Bund all spillage areas, conduct regular clean-ups
Dose assessment	Concentrate efforts at higher doses

10.4.1 Radiation monitoring programmes

There are two distinct purposes in radiation monitoring programmes:

- to provide data for dose assessment
- to provide information that enables radiation exposures to be controlled.

The dose assessment monitoring is further divided into three parts:

- assessment of doses to members of the public
- assessment of doses to non-designated employees
- assessment of doses to designated employees.

Dose assessment for members of the public

Table 10.11 shows the elements that make up the monitoring programme for assessing doses to members of the public.

Table 10.11 Monitoring elements of dose assessment for members of the public

Pathway	Element	Method
Atmospheric	Radon decay products	Sector-subtracted continuous measurement
Atmospheric	Long-lived alpha-emitting radionuclides in air	High-volume air sampler
Atmospheric	Meteorology	Characteristics of wind speed, direction and atmospheric stability

The annual dose to members of the public is calculated from the results of the monitoring programmes and expressed as the dose, over and above background dose, that can be attributed to the operations.

Dose assessment for non-designated employees

In the Commonwealth Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores (1987), non-designated employees are those whose annual radiation dose is unlikely to exceed 5 mSv/a. The large majority of employees who work in the metallurgical plant fall within this definition. The method of dose assessment for non-designated employees and for mine employees working on the surface is that of work-group measurement combined with exposure time.

In the work-group method, measurements made randomly in time and geographic area are used to compile a database of exposure conditions which is then combined with a database of each individual's work category to produce an estimate of the dose to each individual, even though that individual might not have been subject to personal monitoring. Table 10.12 shows the elements of the monitoring programme for non-designated employees.

Table 10.12 Monitoring elements of dose assessment for non-designated employees

Pathway	Element	Method
Inhalation	Long-lived alpha-emitting radionuclides in dust	Area sampling using low-flow-rate air samplers
Inhalation	Radon decay products	Random sampling using single gross alpha measurements
Direct gamma		Audit measurements using TLD monitors

Dose assessment for designated employees

Designated employees are those whose annual radiation dose may exceed 5 mSv/a. For this group of employees it is important to undertake measurements that rely on personal measurements. Personal samplers for exposure both to dust and to direct gamma radiation are used, and trials have been undertaken to determine the best equipment for sampling individuals' exposure to radon decay products in the underground mine. Until such devices have been tested and proved, the programme of area measurements will continue. Table 10.13 shows the elements of the dose assessment programme for designated employees.

Table 10.13 Monitoring elements of dose assessment for designated employees

Pathway	Element	Method
Inhalation	Radon decay products	Area sampling supplemented by personal measurements
Inhalation	Long-lived alpha-emitting radionuclides in dust	Personal air samplers
Direct gamma		Personal TLD monitors

Radiation safety during construction and commissioning

The Olympic Dam Expansion Project will take place in close proximity to existing production facilities which will continue in operation throughout the construction and commissioning phases of the new developments. During these phases, a programme of monitoring and assessment will be carried out separately from the routine monitoring.

This programme will have two purposes. The first will be to ensure that radiation safety measures are adhered to by the contract workforce and that assessments can be made of the radiation exposure of construction and commissioning staff. The second purpose will be to verify that the new processes and equipment are operating within the design criteria established for radiation safety purposes.

The frequency and types of measurements taken during construction and commissioning are usually different from those taken during routine operations. The separate monitoring and assessment programme for the construction and commissioning will be submitted for approval to the South Australian Health Commission.

10.4.2 Radiation control measurements

In addition to assessing radiation doses, the current programme of actively controlling radiation exposures and limiting the resulting doses and releases of radiation to the environment will be extended to accommodate the proposed expansion at Olympic Dam.

Radiation control can be achieved in several ways:

- The design of new equipment or new techniques can be examined to ensure that any resulting radiation exposure is reduced to the minimum that is practically achievable.
- Sources of radiation can be monitored to ensure that engineering controls designed to limit emissions are operating effectively.
- Receptor sites in the vicinity of the operations can be monitored to observe the changes in radiation parameters that can be attributed to the operation.
- Processes that lead to radiation exposure can be examined to identify opportunities for further reductions in exposure.
- Personnel can be trained to consider radiation safety to be an integral part of their job specification.
- Management systems can be established to ensure that safety systems are effective and can react to new information or circumstances.

A programme to implement the ALARA principle—'as low as reasonably achievable, social and economic factors being taken into account'—will form an integral part of the management of radiation safety. Annual audits will be conducted to identify issues with the potential to affect radiation exposures. The ALARA programme will incorporate the control measures outlined above.

10.4.3 Research programme

In addition to its obligations under the codes, the Indenture and the *Radiation Protection and Control Act 1982*, WMC has undertaken research into various aspects of radiation exposure and control. Recent projects include:

- comparative studies of the use of personal monitoring in the underground mine, especially the measurement of exposure to radon decay products;
- characterisation of the AMAD (activity median aerodynamic diameter) of dust clouds to enable more accurate dose assessment;

- radionuclide determinations in process streams to increase understanding of the radiochemistry of the process and to enable mitigation of exposures at various points in the process.

In the first year of operating the new equipment associated with the Expansion Project, the number and type of research projects will increase in order to characterise the effects of the new facilities and to provide data on parameters used in dose assessments.

10.4.4 Radiation safety: Management structure

The current structure of the WMC Radiation, Environment, Safety and Quality Department is shown in Figure 2.19.

The full complement of the group is currently forty-six people. The Expansion Project will not increase the number of people required to conduct the routine environmental and safety programmes, but additional staff will be contracted as required to assist with the management of environmental and safety issues during construction and commissioning.

CHAPTER 11

PROJECT INFRASTRUCTURE AND TOWNSHIP DEVELOPMENT

CHAPTER 11

PROJECT INFRASTRUCTURE AND TOWNSHIP DEVELOPMENT

This chapter considers the additional infrastructure requirements for Olympic Dam operations associated with the Expansion Project, including water and electricity supply, transportation, telecommunications and solid waste disposal. Also described are the infrastructure needs of the Roxby Downs township, including water supply, sewage disposal and township development.

Infrastructure requirements arising from the proposed expansion of Olympic Dam would typically be incremental extensions of existing regional infrastructure services, shown in Figure 11.1. Although the water and electricity supply requirements are described, these items of infrastructure have already received all the necessary approvals to allow their construction.

11.1 WATER SUPPLY

This section describes the approved water supply system, and summarises the environmental assessment and consultation undertaken for the recently commissioned first stage of the Borefield B development. Water management issues, including the hydrogeological effects of water extraction from the borefields, are considered separately in Chapter 4, and the biological impacts on mound springs ecology are described in Chapter 7.

Water for Olympic Dam and the township of Roxby Downs is drawn under special water licences from Borefields A and B in the south-west of the Great Artesian Basin, and pumped via buried pipelines to Olympic Dam. The arrangement of the water supply system is shown in Figure 11.2.

The levels of total dissolved solids in the untreated Great Artesian Basin water are too high for potable use, and therefore potable water is provided at the plant and Roxby Downs using a reverse osmosis desalination plant.

Both potable and raw water are stored at Olympic Dam to compensate for interruptions to the supply, provide for seasonal fluctuations in demand, and meet emergency requirements. The reject brine from the reverse osmosis desalination plant is mixed into the plant process water supply.

11.1.1 Borefield A

Abstraction from Borefield A, approximately 100 km north-east of Olympic Dam, commenced in 1983 from a single production bore. Five additional bores came into production during 1988, and a further three in 1992. Water is piped to the desalination plant at Olympic Dam via the M1 pipeline, adjacent to the Borefield Road. The average rate of abstraction from the borefield in 1995–96 was 15.0 ML/d.

The commissioning of Borefield B will permit reduction of abstraction at Borefield A. Commissioning of Borefield B commenced in November 1996. At that time the abstraction rate from Borefield A was reduced to the present rate of approximately 5–6 ML/d, with the balance of demand being supplied from Borefield B.

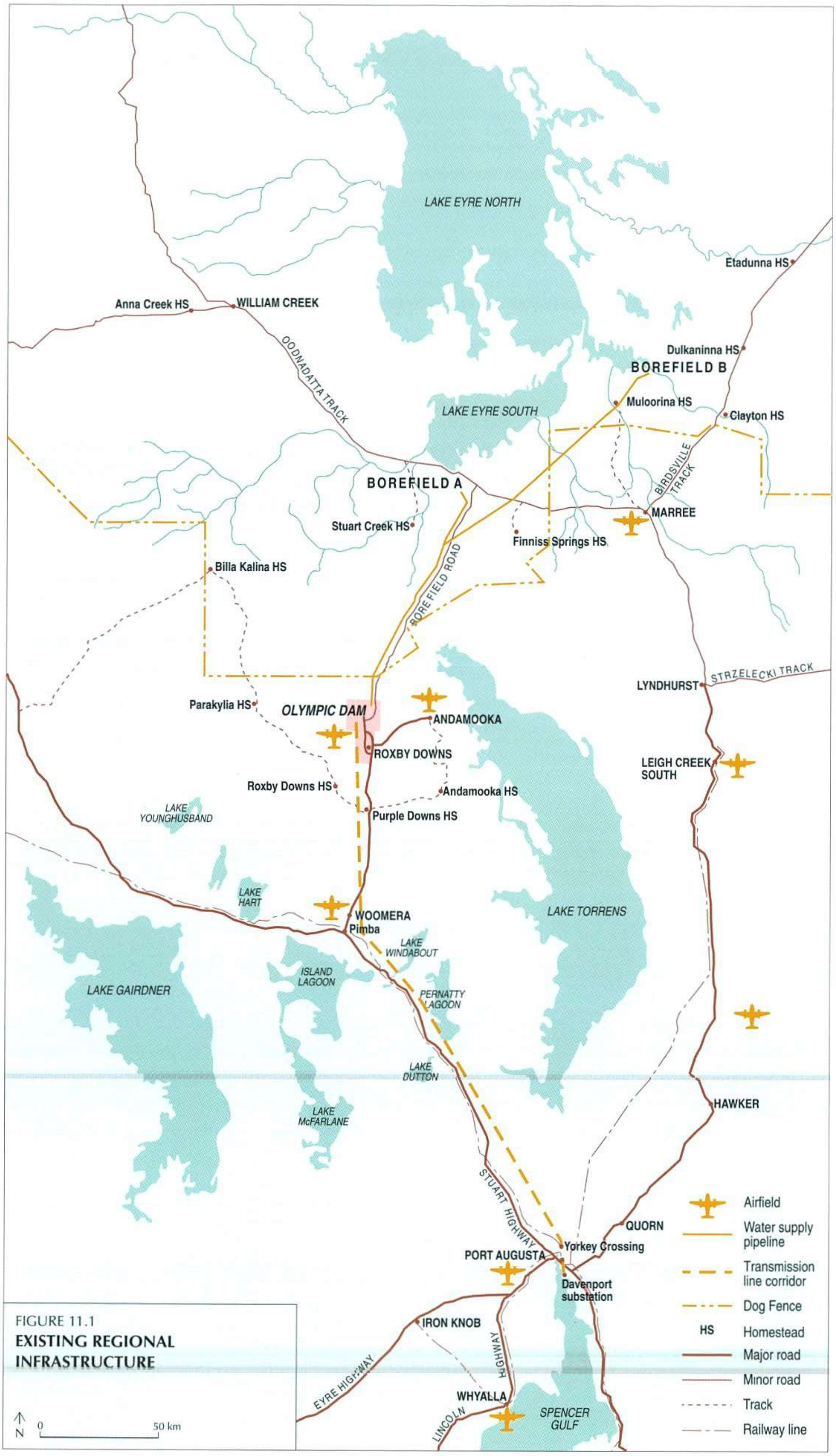


FIGURE 11.1
EXISTING REGIONAL INFRASTRUCTURE

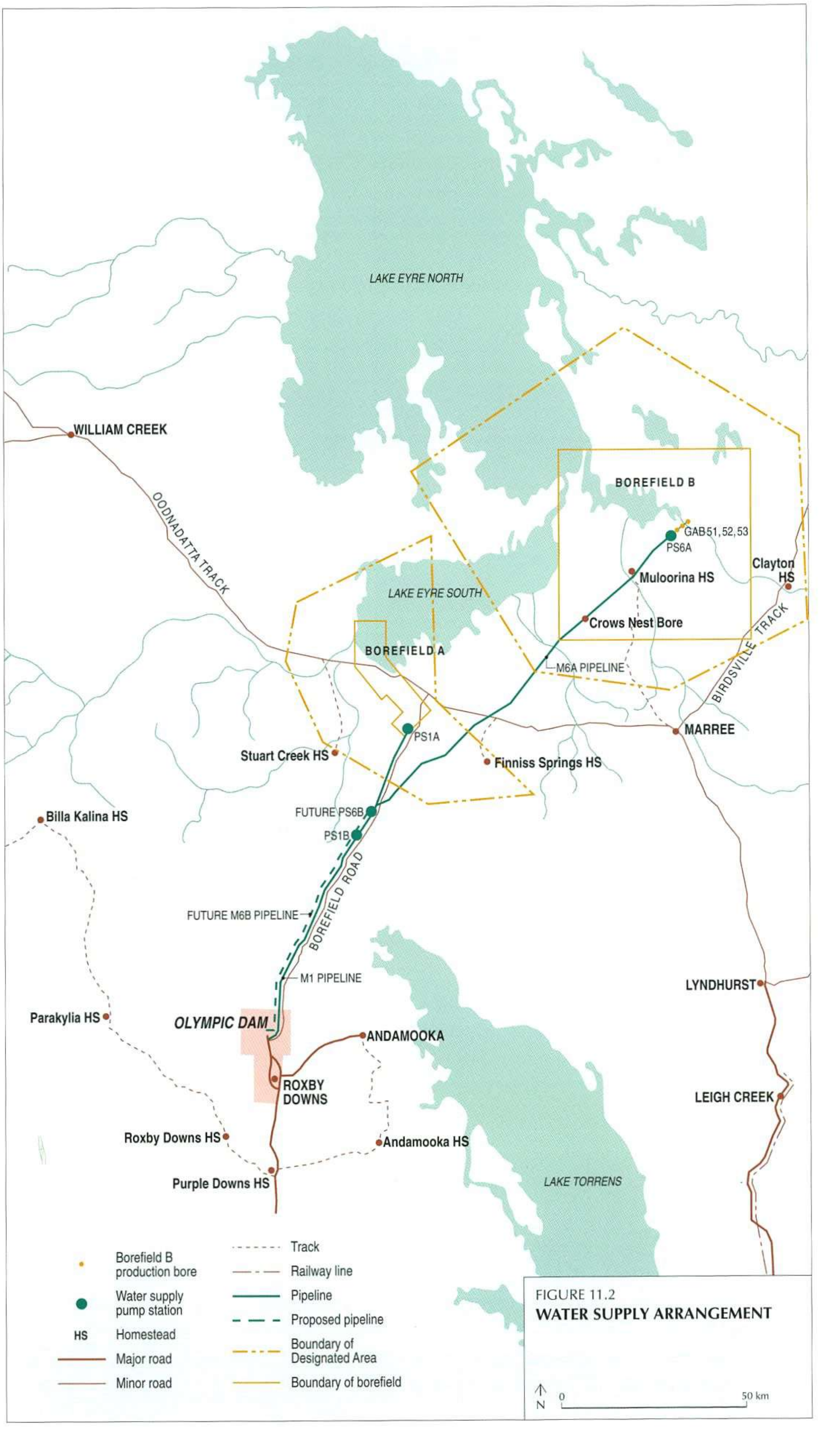


FIGURE 11.2
WATER SUPPLY ARRANGEMENT

11.1.2 Borefield B

Approval process

The requirement for Borefield B was identified in the 1983 EIS, which envisaged a location approximately 55 km north-east of Borefield A in the general area of Crows Nest Bore (Figure 11.2). It was predicted that the borefield would have an abstraction rate of 27 ML/d via seven to ten production bores. The initial approval for the borefield was conditional on confirmation of its location, and the undertaking of further detailed hydrogeological and environmental surveys and assessments.

More rigorous hydrogeological assessment and modelling of drawdown effects in the region for a revised abstraction rate of 33 ML/d at this location indicated that it was desirable to locate the borefield 55 km further to the north-east, a total distance of 110 km from Borefield A.

The modelling and hydrogeological assessment for the revised location, and the predicted construction and operational impacts of the development, were described in the Borefield B Supplementary Environmental Studies (SES) report (Kinhill Engineers 1995a).

The Borefield B development was formally approved by the issue of a Special Water Licence in November 1995. The SES report described the development of Borefield B in two stages, and the project was approved on this basis.

Staged construction

Stage 1, completed in October 1996, involved the installation of three production bores and seven observation bores, and the construction of a buried pipeline (M6A) between bore GAB51 and the M1 pipeline (as shown in Figure 11.2). Stage 1 also included associated access roads and a forward pump station (PS6A) at Bore GAB51 within a 100 m wide easement. Only bore GAB51 is currently in operation, although bores GAB52 and GAB53 have been commissioned to meet the predicted water requirement.

A specific Environmental Code of Practice (ECP) was prepared for the construction of Stage 1 (Kinhill Engineers 1995b). The ECP was incorporated into the construction contract, and diligently followed. A monitoring and audit programme provided for compliance with the ECP during construction. The Stage 1 Borefield B project won an Environmental Excellence Award for Corporate Commitment at the Resources 96 conference in Adelaide, December 1996.

Stage 2 of the Borefield B development will include the installation of an additional pipeline (M6B) beside the M1 pipeline to Olympic Dam, the extension of the M6A pipeline to bores GAB52 and GAB53, the construction of a new pump station (PS6B) at the junction of the M1 and M6A pipelines, and the decommissioning of pump station PS1B. The M6B pipeline will be located on the western side of the M1 pipeline.

The following summary of the environment of Borefield B and the pipeline corridor is taken from the SES report (Kinhill Engineers 1995a).

Pipeline corridor selection

It was originally considered that the Borefield B pipeline would connect with the M1 pipeline at Borefield A. Subsequent engineering, cost optimisation and environmental and heritage assessments revised this concept, providing a relatively straight corridor alignment that connected with the M1 pipeline approximately 30 km south of Borefield A. A strategy of avoiding environmental and Aboriginal heritage sites was adopted in determining the final alignment of the pipeline.

Environmental description

Borefield B and approximately 50 km of the northern section of the pipeline corridor are located in the Muloorina environmental association (Laut et al. 1977), which consists of a gently undulating plain of alluvium and aeolian sand with occasional north–south trending dunes. Extensive surface gibber deposits derived from a wide variety of parent rocks are a feature of the landscape. Claypans and drainage line floodplains are minor occurrences, with the Frome and Clayton rivers being significant features in this association. Vegetation is primarily sparse saltbush and bluebush low shrubland, and grassland. Acacia shrubland over sandhill cane-grass *(Zygochloa paradoxa)* dominates on the dunes, and riparian coolibah *(Eucalyptus coolabah)* woodland over *Acacia* spp. dominates in the river courses.

The remainder of the pipeline corridor is located within the Marree environmental association, which largely comprises gently undulating gypcrete/siltstone tablelands and porcellanite plains, with numerous sand dunes and a few gypcrete escarpments. Entrenched, intermittent creeks are frequent, varying in width between 5 m and 500 m. Vegetation is typically a mixed cover of saltbush and bluebush with an understorey of grasses and forbs, and fringing woodlands on creek margins and floodplains.

Extensive surface gibber deposits are a feature of the landscape, forming a protective seal to the underlying dispersive desert soils. Undisturbed, the surface is generally stable, with a low susceptibility to accelerated wind and/or water erosion. Exceptions to this are the generally unvegetated low escarpments and dissection slopes, which frequently consist of shallow clay overlying highly weathered siltstone and for which specific mitigation measures were implemented through the ECP.

Flora

Field surveys recorded no plant species listed in Schedule 7 (Endangered Species), Schedule 8 (Vulnerable Species) or Schedule 9 (Rare Species) of the *National Parks and Wildlife Act 1972* (SA), the *Endangered Species Protection Act 1992* (Cwlth), or the 1993 Draft Threatened Species Strategy for South Australia (Department of Environment and Natural Resources 1993). Although introduced plant species occur within the region, they do not cause significant environmental management problems.

Any sites of flora or habitat significance identified along the pipeline route were protected by temporary fencing and signage during construction. Further information on the mitigation measures is available in the ECP (Kinhill Engineers 1995b).

Fauna

The majority of vertebrate species recorded during fauna field surveys and pipeline trench clearing, or identified from the records, are widely represented throughout the arid areas of central Australia, and are generally common within the region.

The exceptions are the potentially vulnerable Australian bustard *(Ardeotis australis)* and gibber dragon *(Ctenophorus gibba)*, both listed in Kennedy (1990), and plains rat *(Pseudomys australis)* and dusky hopping-mouse *(Notomys fuscus)*, both listed in International Union for Conservation of Nature and Natural Resources (1996).

Prior to construction, the plains rat was last recorded in the borefield area near Crows Nest Bore over thirty years ago. Fifteen animals were captured during construction of the pipeline in cracking clay habitat, approximately 10 km north-east of the pipeline junction. The study work associated with the pipeline construction confirmed an extension of the known habitat area of the plains rat. This population is currently being monitored by the South Australian Department of the Environment and Natural Resources (DENR).

A solitary gibber dragon was captured in rocky habitat on a breakaway gibber plain near Alberrie Creek before construction, and an unconfirmed sighting was made in similar habitat during monitoring of the pipeline trench reinstatement. Bustards were observed on the gibber plains north-east of Muloorina Station before and after construction.

Preferred habitats for the dusky hopping-mouse are desert sand dunes typical of the land systems to the north. These are not represented in either the pipeline corridor or the borefield, and no observations of this animal were recorded.

Careful route selection avoided most areas of habitat significance. Vegetation clearance within riparian woodland communities, particularly coolibah trees, was minimised to conserve their important habitat values. The pipeline route was subject to final careful alignment on site to avoid loss of any mature coolibah trees and most mature acacia trees.

Pipeline construction is considered to have had only a temporary, minor impact on native fauna, and there is no evidence that the habitat and survival of any endangered species have been threatened by the pipeline and borefield development. Further assessment of fauna along the route will be carried out as part of the post-rehabilitation process.

Cultural and heritage issues

As noted in Section 6.3, Aboriginal heritage surveys were undertaken in the late 1980s and early 1990s as part of the environmental studies for the extension of Borefield A, and for the Borefield B corridor. At that time it was proposed to site Borefield B near Crows Nest Bore.

All sites of ethnographic significance were avoided in the selection of the pipeline corridor to Crows Nest Bore. Eighteen archaeological sites were identified in the pipeline corridor, and the pipeline was realigned to avoid these sites.

In the later work on the pipeline corridor north of Crows Nest Bore (Kinhill Engineers 1995a), no ethnographic sites of significance were identified. The corridor had already been moved to avoid the principal ethnographic site in the area. Four archaeological sites (as distinct from isolated artefacts or background scatter) were located during field surveys. The pipeline was realigned to avoid these archaeological sites.

During construction, each archaeological site was protected by temporary fencing and signage. The signage did not differentiate between environmentally sensitive sites and sites of Aboriginal heritage significance.

The following Aboriginal groups with an interest in the Borefield B area were consulted:

- Dieri Mitha Council Inc.
- Arabunna People's Committee
- North-east Land Council
- Kuyani Association Inc.

A breach in the trackbed of the abandoned Alice Springs – Port Augusta railway at Alberrie Creek was the only item of European heritage affected by the pipeline construction.

Land use

The pipeline traverses pastoral land for its entire length within a 100 m wide easement negotiated with landholders in accordance with Clauses 13(17) and 31 of the Indenture. Being buried, the pipeline neither restricts stock movements nor alienates grazing land. As required by Clauses 13(13) (a) and (b) of the Indenture, as amended, third-party use of the water supply is provided along the pipeline through takeoffs for stockwater or other purposes.

Drawdown effects on pastoral water supplies from the development of Borefield B are considered in Chapter 4.

Stage 2 construction impacts

The principal impacts from construction of Stage 1 of the Borefield B development were those associated with:

- vegetation clearance
- soil disturbance
- temporary disruption to pastoral operations and stock management.

These impacts would also be expected for the Stage 2 development, but to a lesser extent because the M6B pipeline would parallel the M1 pipeline and the Borefield Road. In addition, there are no major creek crossings or sensitive escarpments along the route.

The expected construction impacts and mitigation measures for Stage 2 are described in detail in the approved SES report (Kinhill Engineers 1995a). The ECP for Stage 1 (Kinhill Engineers 1995b) will be adapted for Stage 2. The ECP will be included in the construction contract, and will require the contractor to submit a work method statement to WMC describing proposed specific mitigation measures.

The construction work will be subject to the issue of an environmental clearance form from WMC's Expansion Project Environmental Adviser before construction starts. The ECP will also be distributed to all construction personnel as part of an induction training programme for the project, and be signed off by each recipient.

11.1.3 Monitoring and auditing

Environmental reporting obligations for the Olympic Dam Project are set out in Clause 11 of the Indenture, as amended. WMC is required to provide triennial environmental management programmes for Ministerial approval, to implement such programmes once approved, and to report quarterly and annually to the Minister for Mines and Energy on such implementation. There is also provision for a response mechanism for sudden events causing potentially significant environmental concerns.

Monitoring and auditing during construction of the pipeline assessed environmentally sensitive areas in particular, and the work in general, for:

- compliance with the ECP
- evidence of degradation or regeneration
- the nature, extent and cause of additional impacts
- soil surface condition, particularly signs of accelerated erosion
- waste disposal and pollution
- site restoration.

The effectiveness of rehabilitation is included in ongoing regional flora and fauna monitoring programmes undertaken by WMC. Information on these programmes is provided publicly in the triennial Environmental Management and Monitoring Plan, and in the annual Environmental Monitoring Reports.

11.2 ELECTRICITY SUPPLY

The expansion of Olympic Dam to the approved production rate of 150,000 t/a copper will require additional transmission line capacity from Port Augusta. This will be provided via a new 275 kV transmission line, currently under construction, parallel to the existing 132 kV transmission line from Port Augusta to Woomera and Olympic Dam for most of its length.

The existing 132 kV transmission line and the 275 kV line currently under construction will be adequate for production of 200,000 t/a copper, and for 285,000 t/a copper using imported concentrates. Additional transmission capacity is proposed for the possible future expansion to 350,000 t/a copper production, to ensure security of the power supply.

This would involve the provision of a second 275 kV line by decommissioning the existing 132 kV transmission line and replacing it with a new 275 kV transmission line paralleling the 275 kV line presently under construction. This second 275 kV line would extend along the same alignment as the existing 132 kV line for its route, apart from two minor route deviations described below.

This section provides a summary description of the physical, biological and Aboriginal heritage environments of the transmission line corridor already approved by the State Government; identifies the impacts expected during the current construction period; and presents the mitigation measures for the amelioration of those impacts.

11.2.1 Project electricity supply

Electricity is currently supplied to Olympic Dam via a 132 kV transmission line from Pimba, near Woomera, tying into the ETSA Corporation (ETSA) 132 kV supply to Woomera from Port Augusta (as shown in Figure 11.1). The Indenture foreshadowed the construction of a parallel 275 kV supply between Davenport and Olympic Dam, which was approved in principle in the 1983 EIS process subject to heritage studies and further assessment of alternative corridor alignments. These studies were completed prior to final approvals being granted by the State Government.

The present supply has a maximum capacity of nearly 50 MW, which is at capacity for existing production levels. However, it is insufficient for the planned production increase to the approved production rate of 150,000 t/a.

With the exception of the initial section at Port Augusta, and for approximately 11 km south-east of Woomera, the new line will parallel the existing 132 kV line. At Port Augusta, the first 10 km section will follow the existing transmission line to Leigh Creek, before deviating to the west to join the existing Woomera line near Yorkey Crossing. At a point approximately 12 km south-east of Woomera, the new transmission line will again separate from the existing line for a distance of 11 km, bypassing the Pimba substation and avoiding a number of sites of Aboriginal heritage significance in the area.

With the accelerated Expansion Project construction schedule, the new 275 kV line is expected to be complete in January 1998.

From Davenport to Yorkey Crossing, the conductors will be supported on 45 m lattice towers at spacings of 350–450 m. From Yorkey Crossing to Olympic Dam, guyed towers 50–55 m high at spacings of 500–550 m will be used. A minor deviation from the 1983 EIS 275 kV transmission line route will occur near Port Augusta, to comply with the revised Port Augusta Development Plan of 1985. There will be another minor deviation east of Woomera, to avoid areas of Aboriginal heritage significance.

The corridor for the dual lines will be approximately 130 m wide (an increase of 30 m over that originally predicted in the 1983 EIS), providing a separation of 80–90 m between the two lines. Figure 11.3 shows the typical arrangement of the transmission line corridor north of Yorkey Crossing.

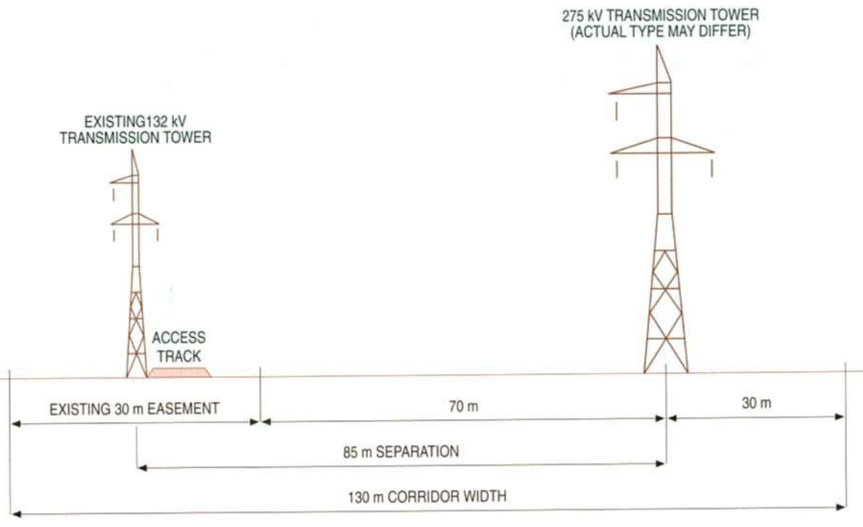


FIGURE 11.3
TRANSMISSION LINE CORRIDOR, TYPICAL ARRANGEMENT

The new configuration was necessary to comply with provisions of the *Electricity Corporations Act 1994* (SA), and ETSA standards. The following minimum line clearance standards have been adopted:

- 8 m vertical ground clearance
- 12.5 m vertical clearance over railways
- 12.5 m and 10 m vertical clearance over major and minor roads respectively
- 7 m clearance over vegetation.

Tower locations and the alignment have been determined by cost optimisation, engineering, environmental and Aboriginal heritage considerations. Corridor access will be along the existing service track except where necessary for the two deviations, for which new access tracks will be constructed. Some refurbishment of the existing track will be undertaken to repair any pre-existing damage and provide improved access for the delivery of materials and equipment. Vegetation clearance or disturbance will be restricted to the essential minimum for both construction requirements and the statutory clearance for the conductors.

A specific ECP has been prepared for construction of the transmission line (Kinhill Engineers 1997a). The ECP provides guidelines directed at minimising and avoiding, where possible, environmental impacts associated with construction, and identifies the monitoring and inspection requirements of the project. The requirements of the ECP have been incorporated into construction contracts, and will continue to be monitored for implementation and effectiveness, and independently audited for compliance.

In accordance with the ECP procedures, the contractor is required to prepare work method statements detailing the extent of environmental disturbance and proposed remediation. The work is subject to the issue of an environmental clearance form from WMC's Expansion Project Environmental Adviser before construction starts. The ECP is also distributed to all construction personnel as part of an induction training programme for the project, and is signed off by each recipient.

The ECP will be updated and used in a similar manner for the second 275 kV transmission line, which will replace the existing 132 kV line in the possible future expansion to 350,000 t/a copper production.

11.2.2 Environmental impacts on the transmission line corridor

Environmental impacts and mitigation measures for the transmission line corridor were considered in the 1983 EIS. Since then, and in fulfilment of commitments in the EIS, further detailed flora and fauna assessments (WMC—Olympic Dam Operations 1992) and surveys of Aboriginal archaeology and ethnography were undertaken as part of a site avoidance strategy adopted by WMC for the engineering design of the transmission line.

Aboriginal cultural heritage assessments involved consultation with those Aboriginal groups identified by the Department of State Aboriginal Affairs (DoSAA) as having an interest in the land traversed by the corridor, as well as other groups identified by WMC as possibly having an interest. The corridor and critical design issues have also been assessed by ETSA (ETSA Corporation 1996).

In identifying the potential impacts on the transmission line corridor, the text below summarises the general environmental characteristics of the corridor, referenced to the environmental associations of Laut et al. (1977). Discussion of specific impacts and mitigation measures then follows for the broad categories of:

- terrain
- vegetation
- fauna
- Aboriginal heritage
- land use
- induced electrical fields.

Description of the transmission line corridor

The transmission line corridor crosses seven environmental associations between Davenport and Olympic Dam. These indicate a generally alternating landform pattern of dunefields and tablelands. Locations of the main environmental features of the transmission line corridor are shown in Figure 11.4.

- ***Arden environmental association (7.2.1):*** From Davenport substation to Yorkey Crossing (17 km), the corridor traverses a mix of drainage channels and salt lagoons, yellow and red dunefields and salt marshes on the eastern side of Spencer Gulf. Drainage is into either Spencer Gulf or land-locked saltpans.

  Vegetation of the low-lying saline areas is dominated by *Halosarcia* spp., with bladder saltbush *(Atriplex vesicaria)* and black bluebush *(Maireana pyramidata)* on higher ground and in swales which also contain small areas of western myall *(Acacia papyrocarpa)* sparse low woodland. Dunefield vegetation consists of tall shrubland, low shrubland and hummock grassland. Tall shrublands are dominated by sandhill wattle *(Acacia ligulata)*, Burkitt's wattle (*A. burkittii)*, narrow-leaved hopbush *(Dodonaea viscosa* subsp. *angustissima)* and bullock bush *(Alectryon oleifolius* subsp. *canescens)*. Low shrubland species include bladder saltbush and nitrebush *(Nitraria billardierei)* with hummock grasslands of sandhill cane-grass.

- ***Simmens environmental association (7.1.1):*** The corridor traverses this association for 14 km to the north-west of Spencer Gulf. Where crossed, the association consists of a plateau with steep escarpments and long footslopes leading down to Spencer Gulf. Drainage is by short, steep gullies onto the floodplain of the gulf.

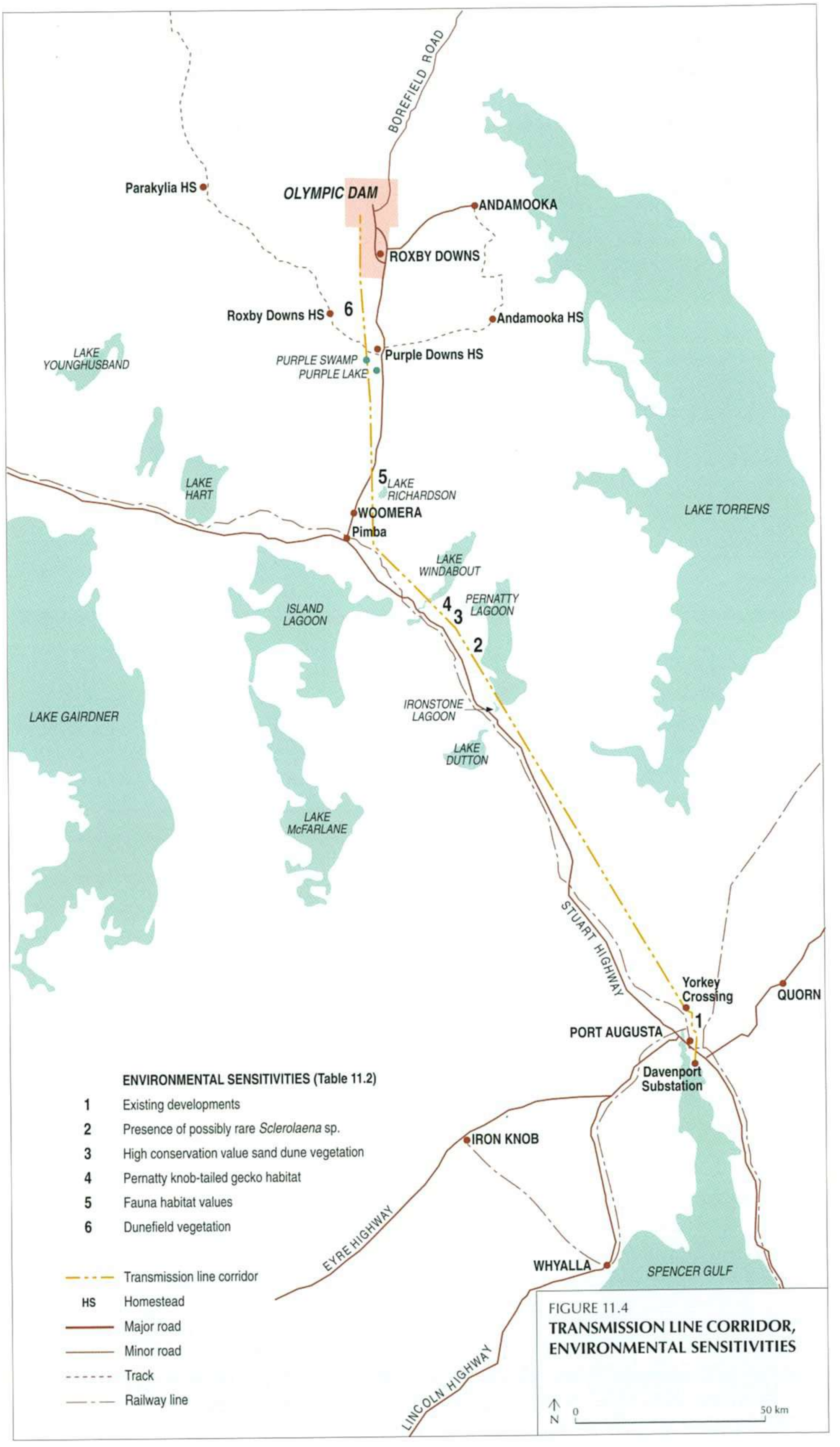


FIGURE 11.4
TRANSMISSION LINE CORRIDOR, ENVIRONMENTAL SENSITIVITIES

Vegetation of both the plateau and slopes is dominated by low chenopod shrubland and occasional low sparse woodland with a chenopod shrub understorey. Bluebush *(Maireana sedifolia)* is the dominant species on the higher rises, with black bluebush, slender glasswort *(Sclerostegia tenuis)* and bladder saltbush in the lower areas. The understorey comprises ephemeral grasses and herbs including introduced species such as burr-medic *(Medicago polymorpha)*, Wards weed *(Carrichtera annua)*, *Hypochoeris* spp., red brome *(Bromus rubens)* and *Stipa* spp. Drainage gullies are generally devoid of any trees, with only a few tall shrubs such as mallee riceflower *(Pimelea microcephala)* and bullock bush, the main vegetation being *Maireana* spp. and bladder saltbush with rock sida (*Sida petrophila)* and Australian boxthorn *(Lycium australe)*.

- ***Hesso environmental association (7.3.11):*** This association is traversed for 76.5 km south of Ironstone Lagoon, representing the greatest distance of any of the environmental associations. A large sandplain is the major feature of the northern section of this association, with calcareous rises towards the centre portion and low sand ridges to about 6 m in height to the south. Drainage is mainly internal, with only a few distinct watercourses in the southern section.

  The northern sandplain is dominated by western myall open woodland, with large areas of mulga *(Acacia aneura)* and lesser occurrences of Burkitt's wattle, false sandalwood *(Myoporum platycarpum)*, *Senna* spp., *Eremophila* spp. and *Santalum* spp. The understorey is typically low chenopod shrubland of black bluebush, *Maireana campanulata*, bluebush and bladder saltbush, and ephemeral herbs and grasses. The southern dune system comprises low woodlands of white cypress pine *(Callitris glaucophylla)*, mulga, false sandalwood and black oak *(Casuarina pauper)*, with western myall in the swales, and tall shrublands dominated by horse mulga *(Acacia ramulosa)*, Burkitt's wattle, sandhill wattle, narrow-leaved hopbush, *Santalum* spp., pituri *(Duboisia hopwoodii)*, *Senna* spp., *Eremophila* spp. and bullock bush. Understoreys are typically chenopod low shrubland. Calcareous rises have low shrublands of bluebush, bordered on the lower slopes by western myall and mulga low woodlands.

- ***Mount Gunson environmental association (7.3.15):*** The corridor passes through this association for 20.5 km to the north of Ironstone Lagoon. The association comprises low hills, small areas of undulating plateau and deep rocky drainage lines. The whole is overlain with a gibber or rock surface. Drainage is into cracking clay (gilgai) depressions and into Pernatty Lagoon to the east.

  Plateau surfaces and footslopes have low chenopod shrublands of bladder saltbush, low bluebush *(Maireana astrotricha)* and slender glasswort as the dominant species, with woolly bluebush *(Maireana eriantha)* on many of the steeper slopes. Understoreys are mainly ephemeral herbs. Fringing vegetation of the deep drainage channels includes black oak and mulga, with tall shrubs including dead finish *(Acacia tetragonophylla)*, *Senna* spp., *Eremophila* spp. and bullock bush. Understoreys are typically *Maireana* spp. and bladder saltbush low shrubland, with an ephemeral herb ground stratum.

- ***Oakden environmental association (7.3.13):*** This association is traversed by the corridor for 17 km to Lake Windabout, and comprises a low dunefield with a few outcropping low hills. Dunes average about 6 m in height and are well vegetated and relatively stable, except for the whitish sand dunes bordering the east side of Lake Windabout. Drainage is mainly internal except in close proximity to the lake.

  The white sand dunes support a tall open shrubland of mainly sandhill wattle, with a generally sparse ephemeral herb and occasional grass understorey. The remaining red sand dunes support a more diverse flora of mulga, horse mulga, sandhill wattle, Burkitt's wattle, narrow-leaved hopbush, pituri, bullock bush and false sandalwood. Understoreys are typically grasses and ephemeral herbs. Swale areas support western myall and mulga with a chenopod or grass understorey.

- ***Woomera environmental association (7.3.20):*** The corridor traverses this association for 63 km north from Lake Windabout, then passes through the Moondiepitchnie association for 8.5 km, before re-entering the Woomera association for a further 2.5 km. The association comprises a broad, undulating gibber plateau, becoming less undulating in the north. Undisturbed, the gibber surface is generally stable, with a low susceptibility to accelerated water erosion. Steep slopes border the drainage channels, which terminate in gilgais, swamps and small lakes that do not flow on to larger drainage systems.

  Vegetation is chenopod shrubland dominated by bladder saltbush, with a grass and herb understorey. *Maireana* spp. are also common, particularly bluebush, low bluebush and black bluebush. Dunefields bordering some of the lakes and watercourses, and at The Pines ruins east of Woomera, support a depauperate acacia shrubland with scattered white cypress pine and bullock bush, and a sparse, ephemeral herb understorey.

- ***Moondiepitchnie environmental association (7.4.6):*** The final section of the corridor north to Olympic Dam traverses this association for a total distance of 48.5 km. The association consists of parallel east–west oriented, mostly stable, red dunes having an average height of about 6 m and overlying an undulating plateau. Andamooka Limestone underlies the whole area, with silcrete-capped rises evident in places between the dunes. Drainage is typically into terminal claypans, with some into Purple Swamp and Purple Lake in the southern extension crossed by the corridor.

  Dune vegetation is low woodland/tall shrubland dominated by white cypress pine, narrow-leaved hopbush, horse mulga, sandhill wattle and bullock bush, with a tussock grass and ephemeral herb understorey. Swales are frequently dominated by western myall and mulga, with lesser occurrences of dead finish, elegant or prickly wattle *(Acacia victoriae)* and *Santalum* spp. Understoreys in the swales are either tussock grasses or chenopod shrubs. Ray grass *(Sporobolus actinocladus)* is common on gibber-covered swales, particularly in the northernmost section of the corridor.

Terrain impacts and mitigation

The impacts of the existing access track and 132 kV transmission line tower footings have been minor (ETSA Corporation 1996). Any additional terrain impacts will be incremental to those of the existing 132 kV transmission line, or of other developments and activities in the Port Augusta area within, or adjacent to, the corridor. Given the existing conditions, the additional transmission line could not be considered to have as great an effect as that of a new development on an otherwise development-free area.

Use of the same access track for construction and maintenance of both the 275 kV transmission line under construction and the future new 275 kV line will limit any further impact. The only additional access tracks required are those for the two minor route deviations and those to each transmission tower site. These latter tracks will also be used as fabrication areas, to minimise the extent of disturbance required.

At each transmission tower site an area will need to be cleared for assembly and erection of the towers. Wherever possible this activity will take place on the final section of the access track to minimise disturbance. Overall, the clearance of individual transmission tower sites is not expected to exceed an area of approximately 0.15 ha.

Undisturbed surfaces are generally stable, with a low susceptibility to accelerated wind and/or water erosion, although all disturbed surfaces can be subject to erosion unless properly reinstated. The potential construction impacts on the various landform types are shown in Table 11.1.

Mitigation measures for each of the above landform types are directed particularly at the control of erosion, and are considered in the following paragraphs.

Table 11.1 Potential construction impacts on landform types

Landform description	Potential construction impacts
TABLELANDS AND PLAINS Almost flat tableland surface with no dune ridges present	• Interception and concentration of surface flows • Erosion of dispersive soils • Rutting of surface by construction traffic in wet weather
ESCARPMENT SLOPES Dissected slopes of the tableland	• Interception of surface flows • Channelling of flows alongside embankments • Scarring and erosion of surfaces caused by difficult working conditions • Alteration to sediment movement pattern
DRAINAGE DEPRESSIONS Broad concave depressional drainage areas that can contain sand ridges	• Alteration to areas of swamplands and claypans • Accelerated erosion from erection of structures in drainage channels
SAND DUNES AND SHEET SANDS Almost flat tableland surface with sand ridges and sheet sands	• Loss of vegetation, leading to increased sand movement • Localised sand movements caused by corridor construction through dune ridges • Alteration to drainage patterns and sediment transport within swales • Creation of hardpan surfaces • Loss of sand from the windward side of structures

Source: Adapted from Kinhill – Stearns Roger 1982.

- ***Tablelands and plains:*** Tableland surfaces generally are not susceptible to wind erosion, but can be susceptible to water erosion if the gibber surface mantle is disturbed, exposing the underlying dispersive desert soils. Leaving the gibber surface undisturbed is therefore the optimum method for the prevention of erosion. This will not be possible on areas of existing disturbance; however, minimising the removal of the protective gibber mantle will assist erosion control.

  This will be achieved by:

  - rolling instead of grading
  - limiting the extent of additional grading
  - ensuring that all windrows are removed from tracks and watercourse crossings
  - ceasing construction traffic movements after significant rain
  - confining all vehicles to the access or other designated tracks
  - limiting off-road vehicle movements during line stringing.

  Tower pads will not usually be graded. Where grading is unavoidable, gibbers will be stockpiled for later respreading during site rehabilitation. Towers will not be constructed in watercourses.

  All watercourses in the tableland associations have sufficient gradients and flow rates to ensure that any minor windrows left across channels will be washed away following the first significant rainfall event.

  Rehabilitation work undertaken at Olympic Dam has shown that revegetation of disturbed gibber tableland surfaces is rapid with average and above average rainfall, and can be improved by the ripping of compacted areas to trap wind-blown seed and improve water penetration. Ripping is undertaken along the natural contour to minimise erosion.

- ***Escarpment slopes:*** Water erosion is an existing problem on some of the steeper escarpment slopes in the Mount Gunson and Simmens environmental association sections of the 132 kV transmission line between Port Augusta and Woomera. As such, any further erosion would be a continuation of the existing conditions rather than a new impact. In addition to the previous mitigation measures, any necessary repairs to the existing track and the formation of tower pads in these areas will involve incorporating appropriate cross-drains and catch banks to inhibit and reduce the velocity of downslope surface flow. Sediment movement and accretion will be allowed for in the design of any drainage structures.

- ***Drainage depressions:*** Construction will be avoided to the maximum extent possible in drainage depressions and stream channels. The few low areas are generally narrow enough to be traversed by a single span. Exceptions to this occur at Lake Windabout, where the transmission line towers will be placed adjacent to the existing towers to avoid having to construct additional causeway access to them, and at Purple Swamp, where one or more towers will need to be constructed on its bed. For the latter, the engineering problems are well known and will be dealt with by accepted engineering measures.

- ***Sand dunes and sheet sands:*** The dune systems traversed by the corridor are generally stable and well vegetated, despite intensive grazing by livestock and/or rabbits. Disturbance of the dunes in the Arden environmental association is particularly severe under the combined impacts of grazing by domestic and feral animals, off-road driving and other activities associated with proximity to Port Augusta.

  Dunes along the corridor will be crossed at, or close to, right angles to their east–west orientation wherever practicable, avoiding as far as possible the crests or flanks. Track and power line construction will be over, rather than through, the dunes. Some dune crossings will be sheeted with clay to enable trucks to cross during construction and to minimise the potential for sand dune blowouts along the corridor. Where the construction of transmission towers on dune ridges cannot be avoided, the sites will be similarly stabilised. Suitable material will be taken from borrow pits established in the dune swales, with all borrow pits being progressively rehabilitated after use.

  Vegetation clearance will be minimal and strictly controlled. Species such as sandhill wattle, Burkitt's wattle and narrow-leaved hopbush rapidly recolonise disturbed areas following good rainfall. Where removal of vegetation is unavoidable, these species will be removed in preference to those that grow more slowly or regenerate less successfully. Because tower sites and the access tracks will remain largely unsurfaced, water run-off is not seen as a major problem in dunefield areas.

Vegetation impacts and mitigation

Vegetation is typically low saltbush and bluebush shrubland on the gibber plains and low hills, with low open woodland and tall shrubland on the sheet sands and dunefields. The transmission line corridor supports a large introduced plant population in its southern parts, and has been subjected to disturbance and modification of native vegetation by grazing and other land uses.

No plant species that have been recorded along the transmission line corridor are listed as endangered or vulnerable under the schedules of the *National Parks and Wildlife Act* and amendments. Two species—*Anacampseros australiana* and sandalwood *(Santalum spicatum)*—are listed as rare under Schedule 9 of this Act.

Anacampseros australiana was recorded at two locations in the Mount Gunson environmental association and at one location in the Woomera environmental association. Only one to a few plants were recorded in each instance. Both sites in the Mount Gunson environmental association were in or at the head of deep rocky gullies and will not be disturbed during construction. Once the locations of tower sites in the Woomera environmental association have been precisely determined, they will be examined for the presence of this species, and the sites adjusted accordingly. Plant locations will also be clearly marked to avoid accidental damage.

The sandalwood species was recorded at fourteen sites along the corridor. Occurrence was restricted to single plants, usually small and old specimens. No regeneration was recorded, possibly due to grazing pressures. Individual tower sites will be adjusted as necessary to avoid this species, which will also be clearly marked to avoid accidental damage.

A species of *Sclerolaena* (bindyi), recorded by WMC 18 km south-south-east of Lake Windabout, could not be identified by the South Australian State Herbarium. Occurring over an area of at least 1 km in length by several hundred metres in width on undulating gibber plains, the plant is most likely to be an undescribed species. The corridor avoids most of the plant's recorded location, and individual towers will be positioned as necessary to avoid disturbance of this species.

Other species occurring along the corridor, and recorded as rare in the 1983 EIS, have since been removed from the schedules of the *National Parks and Wildlife Act.* Although these species are no longer listed and occur regularly within the corridor, care will be taken to minimise disturbance to them during construction.

It is expected that overall construction of the new transmission line will not have as great an environmental impact as most other land uses in the area. Impacts of the existing line have been minimal, and those from construction of the new transmission line are expected to be less. Although some lopping of tree branches may be necessary for conductor clearance and line stringing, use of the existing access track in most parts of the corridor will limit the extent of additional vegetation removal.

Thus vegetation clearance will be the minimum consistent with safe construction and statutory requirements, and will be controlled through implementation of the construction ECP. Limits of clearance will be clearly defined before construction begins, and ecologically significant vegetation identified by signage and protected by temporary fencing. Alignments of new access tracks will be adjusted as necessary to avoid damage to mature trees and to minimise damage to other vegetation. Vehicular access will be strictly controlled during the construction period.

Fauna

The transmission line traverses a range of arid and semi-arid habitats that are rich in reptiles and also support a diversity of bird and native mammal species. Most of the species are widespread and abundant. Rabbits are, at times, particularly prevalent, although numbers have reduced significantly following release of the Rabbit Calicivirus Disease. Feral cats and goats are also present.

There is a large diversity of birds in the region, particularly in the well vegetated sand dunes, which provide habitats more favourable than surrounding areas. When they contain water, the several lakes adjacent to the construction corridor also become important habitats for waterbirds.

The dunes on the south-east shore of Lake Windabout are the principal habitat of the Pernatty knob-tailed gecko *(Nephrurus deleani).* This gecko has a very restricted range, and hence is considered to be endangered (International Union for Conservation of Nature and Natural Resources 1996). It principally inhabits dune crests vegetated with sandhill wattle and narrow-leaved hopbush, occupying burrows that could be destroyed by compaction from vehicles or construction plant.

The corridor passes in close proximity to several salt lakes on the Arcoona tableland between Woomera and Olympic Dam. The slate rock areas associated with tea-tree *(Melaleuca* *pauperiflora)* near the shoreline of Lake Richardson are an important regional habitat of the lizard *Lerista bougainvillii*. The corridor traverses this habitat where it crosses Wirrawirralu Creek near the lake.

Localised areas of cane-grass swamps and gilgais in gibber country are frequently characterised by relatively fertile cracking soils supporting a high diversity of animal life. Several species of dunnart and planigale are found predominantly in this habitat, and the lizard *Lerista dorsalis* appears to preferentially occur in these run-on drainage areas within the Arcoona tableland. Both *L. dorsalis* and *L. bougainvillii* in this region show marked differences from other populations of the same species, and should be regarded as significant. WMC has commissioned a taxonomic study of these species.

Additional fauna surveys are proposed to be undertaken before, during and after construction of the transmission line, in particular to investigate further the habitat and abundance of *N. deleani, L. dorsalis* and *L. bougainvillii* in the transmission line corridor.

Environmental sensitivities

Table 11.2 summarises those particular sites where environmental sensitivities are likely to be significant. These sites are also shown in Figure 11.4.

Table 11.2 Specific environmental sensitivities of selected sites

Location and general description of site	Environmental sensitivity
1 Port Augusta	Infrastructure development.
2 Pernatty Lagoon	Potential occurrence of new, possibly rare species of *Sclerolaena* (bindyi).
3 Dunefields and sandplains south of Lake Windabout	High conservation value, good condition low woodland and tall shrubland vegetation communities. Potential wind erosion and dune blowout on cleared surfaces unless stabilised.
4 Lake Windabout	Unstable white sand dunes on south-east bank with generally sparse herb and grass understorey. Potential for wind erosion and dune blowout. Principal habitat of vulnerable Pernatty knob-tailed gecko.
5 Arcoona tableland north of Woomera	Cane-grass swamps and gilgais. Fauna habitat values in slaty rock regions associated with tea-tree.
6 Dunefields south of Olympic Dam	High conservation value low woodland vegetation communities (western myall).

Mitigation measures for the conservation of fauna habitats will generally accord with those for vegetation clearance and soil disturbance discussed previously.

All native fauna are protected by legislation. This is endorsed by WMC in its Environmental Policy and in the ECP. Construction personnel will not be permitted to bring firearms, traps, pets or exotic animal species of any description into the area.

Aboriginal heritage sites

Aboriginal heritage surveys of the transmission line corridor adopted a site avoidance strategy for determining the final alignment of the corridor and the location of towers. Field surveys and assessment were undertaken in consultation with the following Aboriginal groups having an acknowledged traditional association with the land:

- Andamooka Land Council
- Kokotha People's Committee
- Nukunu Heritage Committee

- Kuyani Association
- Barngala Consultative Committee.

Kinhill Engineers (1997b) recorded forty-five archaeological sites along or close to the corridor between Port Augusta and Olympic Dam. Of these, nineteen were previously recorded by Gara (1986) north of Woomera. All but one of these forty-five sites are surface artefact scatters located exclusively within sand dunes and sheet sands, confirming the prediction of the 1983 EIS. The remaining site is a silcrete quarry.

All archaeological sites in close proximity to construction sites, or assessed as being at possible risk of inadvertent disturbance during construction, are being protected by temporary fencing and/or signage. Signage does not differentiate between archaeological and other environmentally sensitive sites. Where archaeological materials occur between tower sites, particular care is being taken to minimise site disturbance during cable stringing.

Ethnographic sites of significance to Aboriginal people applicable to the selection of the route of the transmission line corridor were considered in detail. A number of alternative corridor alignments were investigated, and the finalised routing of the transmission line ensures that no ethnographic sites are affected by construction. Out of respect for the wishes of Aboriginal people, to help with preservation of the sites, and in keeping with legislative requirements, the whereabouts of both the ethnographic and archaeological sites are not made known to the general public, and are thus not identified in this document.

Land use

In all, some twenty-six separately titled land holdings will be traversed by the transmission line corridor. With the exception of its initial section, which skirts the outer development area of the City of Port Augusta, the corridor is located almost entirely on pastoral land used primarily for sheep grazing. The transmission line will not restrict livestock movement or alienate land from existing land uses.

The following pastoral properties will be traversed:

- Corraberra
- Mount Arden
- Kootaberra
- Oakden Hills
- Pernatty
- Arcoona
- Purple Downs
- Roxby Downs.

In accordance with Clauses 18(11) and 31 of the Indenture, corridor easements are being negotiated with affected landholders. Consultation with landholders and Aboriginal groups will continue during the construction period.

The flight path for aircraft approaching the Kootaberra Station airstrip from the west will be over the transmission line corridor. WMC has paid compensation to the lessee for the extension of the airstrip.

Orange marker spheres will be attached to the power line to indicate its presence to approaching aircraft, and the design will comply with the recommendations of the Federal Civil Aviation Safety Authority as they apply to structures within the approach funnel. A further option is to extend the runway away from the transmission line.

Access to and within the corridor during construction will be via the service track or station roads and tracks. Unauthorised public access for such activities as recreational off-road driving, particularly close to Port Augusta, is currently actively discouraged by most landholders, sometimes by the use of locked gates. This is not expected to change following completion of construction.

Induced electrical fields

Induced electrical fields exist near all high voltage transmission lines. The National Health and Medical Research Council's guidelines for human exposure to these electrical fields have been applied during design of the transmission line. Exposures are well below the guideline values.

11.3 TRANSPORTATION

Existing transportation infrastructure would continue to be used during construction and following the expansion of operations at Olympic Dam. These are shown in Figure 11.1 and described in the following sections, together with the predicted use of each network and any upgrading that may be required.

11.3.1 Roads

For the purpose of this assessment, the regional roads shown in Figure 11.1 have been categorised as follows:

- Major roads: These roads are primary routes carrying relatively heavy traffic volumes. The principal major roads are sealed. Major roads usually receive the highest maintenance.
- Minor roads: These roads are generally unsealed and provide the main connection to and between major roads. They carry comparatively less traffic and receive less maintenance than major roads.
- Tracks: These unformed tracks provide the main access to and between pastoral homesteads.

All-weather, sealed road access is provided to Olympic Dam via Woomera, connecting with the Stuart Highway at Pimba and from there to Port Augusta. Port Augusta is the hub for the national highways between Adelaide, Western Australia and the Northern Territory.

Current and predicted annual average daily traffic volumes provided by the South Australian Department of Transport for selected points within the road transport corridors between Olympic Dam, Port Augusta, Whyalla and Adelaide are presented in Table 11.3.

Table 11.3 Current and predicted annual average daily road traffic volumes

Sector	DoT Site No.	Current	2001	2011
Olympic Dam–Pimba	10006302	397	n.a.	n.a.
Pimba–Port Augusta	10000421	670	726	850
Port Augusta–Adelaide	10000470	2,750	2,735	2,705
Port Augusta–Whyalla	10000430	1,165	1,027	800

Note: Reductions in traffic volumes in 2001 and 2011 are due to the predicted use of road trains, which would reduce the absolute numbers of vehicles.
DoT = Department of Transport.
n.a. = not available
Source: Planning Division, South Australian Department of Transport.

Increases in the current commercial traffic volumes between Olympic Dam and Port Augusta are expected to be approximately proportional to the projected increases in production. From a base at current production levels, it is estimated that the Expansion Project would result in an increase of four Class 11 (double road train) equivalent truck movements per day by the year 2000, and fourteen trucks per day in the longer term. At a production rate of 350,000 t/a of copper and associated products, this would represent an increase of approximately 10% over present annual average daily traffic volumes for this class of vehicle.

The options for transport for imported copper concentrate (Section 3.7) include shipment to Whyalla and transportation by truck to Olympic Dam, and shipment to Port Pirie or Port Adelaide followed by transportation by rail to Pimba or Port Augusta and then truck to Olympic Dam. It is expected that Australian copper concentrate or other South Australian copper ore would be delivered by surface transport direct to Olympic Dam.

The option involving the importation of copper concentrates through Whyalla would involve the maximum use of road transport and necessitate an annual average of up to thirty-three Class 11 truck movements per day between Whyalla and Olympic Dam by 2004–05. These would be additional to those previously identified, representing a further increase of approximately 15% to traffic volumes for this class of vehicle within the corridor. If concentrates are imported through Port Adelaide, the predicted increase in truck movements would apply from Pimba, as rail transport would be used to this point.

Increased general traffic volumes between Olympic Dam and Port Augusta would be created by vehicles delivering construction materials and equipment to the site, by trucks carrying products from site, and by the day-to-day activities of the additional, permanent population at Olympic Dam.

Estimates of the magnitude of the likely increase in general traffic are influenced by factors that are difficult to quantify, such as the frequency at which the resident population of the region uses the road and the level of any additional tourist activity within the region. However, any increase associated with the Expansion Project would not be expected to exceed 10–15% of present annual average daily traffic volumes.

The combined traffic increases would not be expected to exceed the capacity of any roads within the existing corridors.

Road transport risk assessment

The additional risks posed by increases in heavy-vehicle traffic associated with the Expansion Project have been assessed based on data presented by Kinhill Engineers and ERA Environmental Services (1996) and statistical information relating to actual heavy-vehicle accident rates in Australia. Table 11.4 gives estimated figures for the estimated frequency of accidents, spills and fatalities owing to:

- additional heavy-vehicle movements between Port Augusta and Olympic Dam
- transport of copper concentrate from Whyalla to Olympic Dam
- transport of uranium oxide from Olympic Dam to Port Adelaide.

It should be emphasised that the frequency and severity of accidents arising from the Expansion Project would be the same as those for heavy-vehicle transport in general. The road conditions between Whyalla, Port Augusta and Olympic Dam and between Port Augusta and Adelaide are uniformly good and designed to handle heavy-vehicle traffic. In the unlikely event of a spill of uranium oxide, clean-up procedures currently in place would ensure that the risk was virtually negligible.

Table 11.4 Summary of estimated road traffic accident frequencies and consequences

Accident type	Number per year: Additional heavy-vehicle movement—Port Augusta to Olympic Dam	Transport of copper concentrate—Whyalla to Olympic Dam	Transport of uranium oxide—Olympic Dam to Port Adelaide[1]
All types[2]	0.339	1.0314	0.058
Spills[3]	–	0.314	0.018
Fatalities[4]	0.025	0.076	0.004

1 *Actual risks much lower due to additional transport precautions and degree of product containment.*

2 *Based on 0.263 accidents per million vehicle kilometres, White (1991).*

3 *Based on 0.08 spills per million vehicle kilometres, Kinhill Engineers and ERA Environmental Services (1996).*

4 *Based on 0.0195 fatalities per million vehicle kilometres, Federal Office of Road Safety data.*

The transport routes traverse large areas of low population density; consequently, interactions with town traffic would be minor, and the expected accident rate lower than predicted in the table. The additional precautions taken in the transport of uranium oxide lower the risks arising from this activity even further.

The data in Table 11.4 represent individual risks to drivers of heavy vehicles or of vehicles involved in collisions with heavy vehicles. It is not appropriate to consider societal risk in the context of road accidents. Societal risk analysis is only applied to industrial accidents.

11.3.2 Ports

Overseas export of products from Olympic Dam would continue under established arrangements through Port Adelaide.

Imported copper concentrates would be shipped through existing wharf facilities at either Whyalla or Port Adelaide. The Whyalla jetty facilities and bulk materials handling equipment can accommodate shiploads of up to 20,000 t of concentrate with a nominal moisture content of 8%. Some refurbishment of the jetty and infrastructure would be required, including:

- new concrete decking
- a new, redesigned hopper to overlie the ship in order to capture any spillage
- construction of a new concentrate storage shed of 20,000 t capacity.

Should Whyalla be used for landing concentrates, some additional employment opportunities might be created both during the refurbishment of the jetty and from the additional use of the port during the concentrate importation programme.

Maritime transport risk assessment

A detailed review of shipping volumes and accidents in the northern Spencer Gulf from 1970–71 to 1979–80 was reported by Santos Limited (1981). That assessment revealed the following:

- No ship–ship collisions occurred during the ten-year period.
- The probability of a grounding incident was in the region of 6.7×10^{-4} (1 in 1,500 ship movements).
- No grounding incidents in South Australia during that period resulted in hull damage.
- There were thirty-three ship–structure collisions that could be considered as significant, only one of which resulted in a vessel being made unseaworthy.

Ports Corporation SA has reviewed equivalent data for the period 1986–96 and reports that there have been no collisions between ships in Spencer Gulf and only one collision involving a single ship during mooring operations during that period.

The total numbers of vessel movements in the northern Spencer Gulf from 1986 to 1996 were 1,103 to Whyalla and 482 to Port Bonython, representing 3,170 movements up and down the gulf at an approximate average of less than one movement per day. At the projected maximum tonnage of concentrate of 236,000 t/a, shipping to and from Whyalla would only increase by twelve vessels per year, representing a 12% increase in shipping to that port, and an overall 8% increase in shipping in the northern Spencer Gulf.

It should be noted that the number of ship movements to Whyalla for the period 1970–80 averaged 252 per annum, compared with the current rate of 100 per annum and the additional twelve per annum at the projected maximum tonnage.

Because there have been no reported collisions between ships in Spencer Gulf in the last eleven years, prediction of the probability of such an event cannot be realistically estimated. Nevertheless, it can be regarded as extremely remote.

There have been no groundings of sea-going vessels in northern Spencer Gulf during the period 1986–96. Given this, the probability of a grounding incident may be considered to be no more than the previous estimate of 6.7×10^{-4}. Hull damage would not necessarily be expected should a grounding incident occur, as the bottom of the northern Spencer Gulf is described in hydrographic charts as sand and shell.

A review of ship–structure collisions over the period 1986–96 has indicated that there was only one incident that could be regarded as significant. Damage in this incident was minor, resulting in repair costs of less than $20,000.

Owing to the inert nature of copper concentrates, no significant adverse environmental consequences would be expected in the unlikely event that a spill occurred. Spilled concentrates could also be salvaged if necessary.

11.3.3 Airfields

Olympic Dam is serviced by a licensed airfield with a sealed, 1,591 m × 18 m all-weather runway on alignment 06/24. Other licensed airfields and authorised landing areas in the region are shown in Figure 11.1.

Before commencement of the expansion to 150,000 t/a copper, Kendall Airlines operated fourteen return flights per week between Adelaide and Olympic Dam, using either SAAB SF340 (34 seats) or Fairchild Metroliner 23 (19 seats) turbo-prop aircraft.

Additional flights were implemented in early 1997. Flights may need to be further increased, or larger aircraft provided, particularly during the peak construction phase of the Expansion Project, to cope with larger numbers of the workforce travelling to and from Adelaide. The magnitude of the increase would largely depend on the nature of individual contracts, and whether individuals chose to fly out during rest periods. Another factor is the scheduling and room management of the construction villages.

Following completion of the Expansion Project, when the construction staff have disbanded, the increased number of personnel travelling to and from the site would probably be only an incremental increase over current volumes. In that case, it would be a commercial decision by aircraft operators as to whether additional flights or larger aircraft were required.

The decision as to whether larger aircraft would be introduced has not been made. However, the use of larger aircraft may require an upgrade of the airport, including the runway length, width and pavement strength as well as terminal facilities.

11.3.4 Railways

The closest railhead to Olympic Dam is at Pimba on the Trans Australian Railway line between Port Augusta and Kalgoorlie. From Pimba, direct standard gauge rail access is available to Port Augusta, Whyalla, Adelaide, Perth and Sydney. The line to Alice Springs branches off the Trans Australian Railway at Tarcoola, to the west of Pimba.

The South Australian and Northern Territory governments have formally agreed to study the feasibility of extending the railway from Alice Springs to Darwin. Although it is a future option and is subject to a separate economic and technical review, the construction of a railway line from Pimba to Olympic Dam is not included in the current expansion proposal.

11.4 TELECOMMUNICATIONS

Olympic Dam is connected via optical fibre cable with the Adelaide – Alice Springs main trunk route. Telecommunications within the wider region are provided by the Telstra Digital Radio Concentrator System (DRCS) remote area network.

The existing service provides full STD, ISD and facsimile access through the Telstra automatic exchange in Roxby Downs. Telephone connections to Olympic Dam are also provided from pump stations PS1A in Borefield A and PS6A in Borefield B. All telephone cabling within the development area is in underground conduit.

Planning by Telstra in conjunction with WMC provides for increases to the capacity of the service in response to project demands (G. Scriven, Telstra Corporation Pty Ltd, pers. comm., November 1996).

A mobile telephone service (digital) has recently been installed by Telstra. The transmitter is located at Roxby Downs and has a range of approximately 35 km, which covers most of the Special Mining Lease, the Roxby Downs township and nearby areas.

Very high frequency (VHF) radio communications are provided in selected vehicles, with long-range high frequency (HF) radio or satellite telephone systems fitted to vehicles used in remote areas such as the borefields. Borefield A and Borefield B are monitored and controlled from Olympic Dam by a microwave radio telemetry system, with solar powered repeater towers located at approximately 40 km intervals along each pipeline. The existing PABX system within the mine and process areas is also to be upgraded to provide a higher level of service.

11.5 SOLID WASTE DISPOSAL

Solid waste and refuse are generated as a result of operations at the mine, plant, support facilities and the township. This section describes the sources of waste and methods of disposal from the township and Olympic Dam Village; that is, excluding the mine and process areas. Discussion regarding wastes from the existing and proposed mine and process areas is provided in Chapters 2 and 3.

Solid waste generated from the township and Olympic Dam Village includes:

- normal household solid wastes
- garden waste
- housing construction materials
- earth from the construction of subdivisions
- commercial waste
- industrial waste.

There are five waste disposal locations associated with the different types of waste outlined above:

- Roxby Downs township sanitary landfill
- clean fill landfill—north of the township
- clean fill landfill—south of the township
- Olympic Dam sanitary landfill
- recycling—predominantly within the industrial estate adjacent to the township.

These waste disposal areas are shown in Figure 11.5. The current and future operations of each of the above waste disposal areas are described below.

11.5.1 Roxby Downs township sanitary landfill

The council-managed Roxby Downs township sanitary landfill has been licensed by the Environment Protection Authority (EPA). Public access is available twenty-four hours a day, and the entrance to the landfill is unmanned. Disposal of the waste is via the trench method, where waste is deposited at the edge of deep excavated trenches and pushed by a front end loader into the trench on a daily basis. As a trench is filling, it is progressively covered with the excavated soil. Trenches are normally excavated in parallel. After a large area has been trenched and backfilled, it is levelled and graded to promote stormwater drainage away from the landfill areas.

At present, when the waste is deposited on the edge of the trench, wind gusts may pick up light-weight plastic and paper materials and deposit them throughout the landfill site; a portion of this light-weight rubbish is also blown beyond the perimeter of the landfill site. To overcome this problem, the council has recently designed, and has received approval from the EPA to construct, what is in essence a small transfer station on the site (Trevor Kroemer, Roxby Downs Council, pers. comm., November 1996).

This transfer station is a trafficable trenched disposal area, covered with a permanent netting. Both the public and the municipal waste collection vehicles will deposit their refuse under the netted area, within the trafficable trench. The netted enclosure has only one opening for vehicle access. The council will collect waste from this transfer area and redeposit it in trenches within the landfill proper on a daily basis. Adjacent to this area, there will also be several fenced bays designated for the disposal of heavy refuse such as car bodies.

There is evidence of waste being dumped next to the access track to the trench areas. However, no effective solution to this problem has been identified to date.

A number of completed landfill areas have now been covered with approximately 1 m of soil and graded to provide drainage. Very little vegetation grows on these areas. The reason for this is unclear, but may include:

- poor quality of soil covering
- no venting of gases from the rubbish beneath
- no revegetation programme.

There are currently no plans to vent the existing landfill areas. Approximately 10% of the designated site of the landfill has now been used.

11.5.2 Clean fill landfill north of township

A clean fill landfill is located on WMC land adjacent to the 10 ML water storage dam north of the township, and is both unfenced and unmanned. From discussions with the council, it

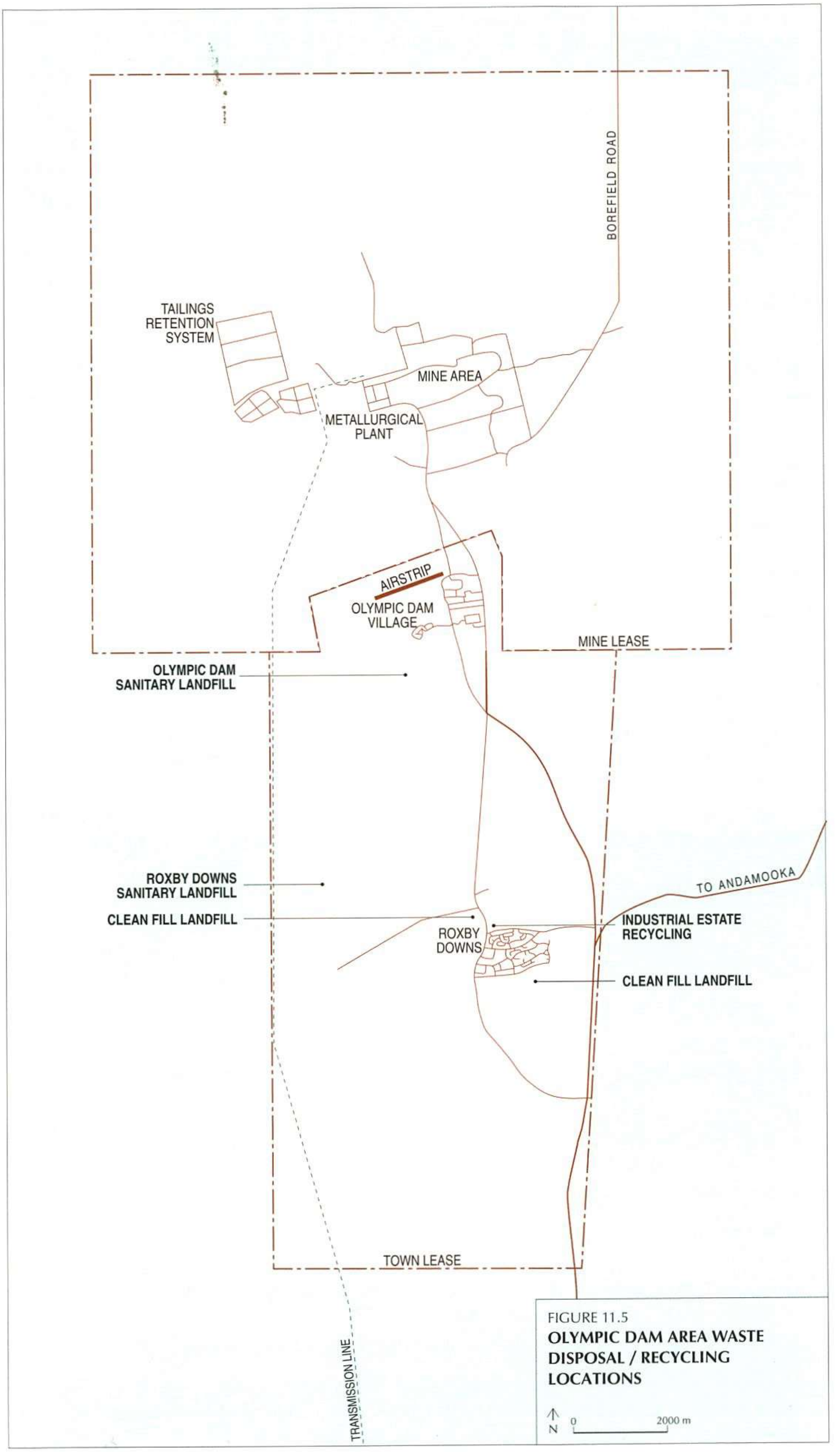


FIGURE 11.5
OLYMPIC DAM AREA WASTE DISPOSAL / RECYCLING LOCATIONS

is understood that this landfill area was designated for clean fill from subdivision construction, and also for the disposal of felled trees.

Inspection of this site reveals that, although predominantly clean soil is being dumped at this location, there is evidence of other materials being dumped, including street sweepers' refuse and small amounts of concrete, timber and other construction materials. There does not appear to be any evidence of illegal dumping of household wastes. It also appears that tree disposal no longer occurs in this location, and that felled trees are now disposed of at the council sanitary landfill where there is an area allocated for tree disposal. There are no plans by the council to change the mode of its operation.

11.5.3 Clean fill landfill south of township

A large clean fill landfill located south of the current township boundary is used for the disposal of soil from excavations at subdivision construction sites. Where subdivisions require filling, fill materials are reclaimed from this landfill. Inspection of the landfill indicates that, although predominantly clean fill is dumped in the area, there is evidence of other materials also being disposed of, including concrete and other construction materials.

There are no plans in place to alter the current use of this site. If the site became incorporated in the township expansion as proposed, remediation in terms of soil disposal and other material removal would become a council responsibility. The timing of this would depend on future expansion of the township.

11.5.4 Olympic Dam sanitary landfill

The Olympic Dam sanitary landfill is located several kilometres from the Olympic Dam Village at the end of a dedicated all-weather roadway. The entire landfill area is fenced and the gate is locked. Access to the landfill is currently only by specific request to WMC (W. Stringer, WMC, pers. comm., January 1997). All earthwork areas on site have been graded to promote drainage. It is understood that waste that would have been disposed of in this area is now being disposed of at the Roxby Downs township sanitary landfill.

11.5.5 Recycling

There are a number of recycling measures currently undertaken within the township and adjacent light industrial area.

These measures include the following:

- Paper: WMC provides green bins for the disposal of paper and cardboard around the town. Similar bins are located throughout the Olympic Dam site. WMC regularly picks up these bins and carts them to the salvage yard within the mine site for recycling/mulching of the contents. The mulch is used on gardens or around the Olympic Dam site.
- Bottles/glass/aluminium cans/batteries: These items can be disposed of at a commercial property within the light industrial area adjacent to the Roxby Downs township.
- Green waste: WMC has set up a mulcher within the light industrial area adjacent to the Roxby Downs township. Beside the mulcher are two open bays into which residents can deposit lawn clippings and tree prunings. These are available for dumping twenty-four hours a day. Mulched materials are then sold back to residents, and also used for mulching in the mine process area. The proceeds benefit the Royal Flying Doctor Service.
- Used oil: It is understood that service stations and motor mechanics make their own arrangements for collection and disposal/recycling of used oil.

11.5.6 Predicted effects of the Expansion Project

As described in Chapter 12, the population of the Roxby Downs township would be expected to increase from an estimated 2,500 in mid-1996 to approximately 3,100 by mid-2000 with the expansion to 200,000 t/a copper production. In the longer term, when the production rate reached 350,000 t/a of copper, the estimated population would reach around 4,500.

On the basis that the requirement for solid waste disposal is proportional to population, the Expansion Project would be expected to increase this requirement by about 24% and 80% at copper production of 200,000 t/a and 350,000 t/a respectively. These estimates ignore the effects of the further development of recycling measures, which would partially reduce the future requirement to dispose of solid waste.

The existing solid waste disposal facilities, as described above, have sufficient capacity to accommodate the increased rate of solid waste generation following the Expansion Project. The Roxby Downs township sanitary landfill has about a further 90% of the designated site available following approximately ten years of previous operation. Therefore, this site would be able to cater for the township's needs well into the future.

The clean fill landfills to the north and south of the township are used predominantly as temporary soil stockpile areas between periods of subdivision construction. It is not envisaged that the Expansion Project would require any significant changes to the operation of these landfills.

11.6 TOWNSHIP WATER SUPPLY AND SEWAGE DISPOSAL

11.6.1 Township water supply

Potable water is supplied to the township from a 10 ML water reservoir on the boundary of the township. The reservoir is completely covered to reduce the effects of evaporation. Water is supplied to the reservoir from a reverse osmosis desalination plant (Section 11.1). At present, potable water is supplied to the township and adjacent light industrial area from the reservoir. Chlorination is automatically controlled, with the chlorine being injected into the pipeline just upstream of the pumps. Chlorine is only injected when the flow rate exceeds 25–30 L/s.

The expansion of the township does not warrant an increase in the size of the water storage reservoir; however, it is proposed to increase the capacity of the pumping units from the reservoir, and also to augment existing pipe capacities into the town.

11.6.2 Township sewage disposal

The current township sewage treatment lagoons were designed for an equivalent population of 3,000 persons. The township expansion associated with the increase in workforce would provide an equivalent population of approximately 4,500 persons for 350,000 t/a copper production, representing a 50% increase in loading to the lagoons.

Several options for increasing the capacity of the lagoons are currently being analysed, and one of these would be implemented as part of the proposed township expansion. The options include the following:

- Construction of additional lagoons: Primary, secondary and storage lagoons. This option incorporates an increased water surface area, and hence evaporation. Recycled water would be used for irrigation of the community oval and surrounds, and the golf course.
- Increased capacity through mechanical aeration: Installation of mechanical aerators within the existing primary lagoons. This would also enable the depth of the lagoons to be increased from the current 1 m.

- Installation of a package treatment plant: A package treatment plant would treat the waste to secondary water quality standard suitable for restricted irrigation, thereby allowing the existing evaporation lagoons to be converted to storage lagoons.

The issue of providing additional storage capacity for treated effluent is critical, as over-season storage requirements (storing up treated water over the winter months for irrigation use during the summer) currently affect the operating water-levels for the lagoons. In addition, the final storage lagoons overspill into a natural surface depression. Neither of these aspects is considered desirable. Each of the treatment options being considered addresses the above problems in a different manner.

The existing lagoon system provides reclaimed water for irrigation. Prior to use, the water is chlorinated and pumped back to a number of above-ground storage tanks adjacent to the township. The reclaimed water is distributed from these tanks to either the community oval and surrounds, or the golf course. The capacity of the return line from the storage lagoon to the storage tanks is currently limited, and it is proposed to increase the size of this pipeline.

11.7 TOWNSHIP DEVELOPMENT

Detailed planning has been undertaken on a township development concept to accommodate the increased workforce associated with the Expansion Project. Overall the town population is expected to increase to about 3,100 for 200,000 t/a copper production, and 4,500 for 350,000 t/a copper production (Section 12.4).

This section describes the overall development concept for the town, the design constraints and objectives for the proposed town southern expansion, the concept design, the town expansion staging, and the construction villages to accommodate the temporary construction workforce. The related issue of municipal management is discussed in Section 12.9.

11.7.1 Overall development concept

The 1983 EIS set in place the conceptual layout of community, educational, recreational, retail, commercial, industrial and residential uses for the township of Roxby Downs. The plan provided for a core area, with a deferred residential area for future population growth around the perimeter.

To date some 699 residential dwellings have been built around the town centre, with development concentrated in the northern and eastern sectors. In addition, there are 335 single persons' quarters and 151 caravan spaces. Growth has now consumed nearly all of the land allocated in these two locations.

It is appropriate that future allotments to suit the current planned growth in mine activity be provided in the southern expansion area. Housing in this location would be sited in relatively close proximity to the town centre, allowing many residents to walk and cycle to the facilities and services that are already available.

A conceptual layout for roads, residential allotments and public reserve in this southern area is shown in Figure 11.6 and provides a framework for the future staged development of land in this part of the township.

Roxby Downs is well provided for in terms of community facilities for a town of its size. These facilities, and assessment of future needs, are discussed in Chapter 12. The most significant development planned is the construction of a medical facility by the State Government, at a cost of approximately $4 million. This facility is expected to be operational early in 1998.

FIGURE 11.6
ROXBY DOWNS TOWNSHIP SOUTHERN EXPANSION CONCEPT

11.7.2 Design constraints and objectives—southern expansion

Many of the physical constraints to subdivision in the southern part of the site have already been encountered in the northern and eastern areas. The proposed layout responds to these constraints in the manner described in Appendix H. Of particular significance in the southern area are:

- the large number of existing mature trees—particularly the western myall and native pine—that need to be retained and protected from adverse effects of development (particularly nearby excavation and altered drainage patterns);
- the extensive low-lying flood-prone areas and drainage run-offs where building must be avoided and roads need to be designed to accommodate water flows;
- a regular pattern of dune lines on an east–west alignment;
- two sites of Aboriginal significance.

The design objectives to be focused on include:

- establishment of a coherent and hierarchical pattern of roads that embodies current practices for traffic safety, including traffic management controls and the adoption of

Australian Model Code for Residential Development (AMCORD) standards where appropriate;

- suitable road linkages into the existing road network and to the town centre;
- provision of a range of allotment sizes suited to a variety of different housing types that have been derived from the current and predicted future needs of the township residents;
- design of development sites to best accommodate building design and siting for local climatic conditions;
- allocation of a suitable percentage of the total site area for recreational purposes and for potential educational and community facilities;
- retention of much of the dune system for conservation purposes and for public use and access;
- provision of safe and convenient walking and cycling trails between most of the houses and the town centre. A cross-community pathway network should also be part of the plan;
- retention and enhancement of existing significant vegetation, watercourses and other natural site features;
- protection of identified Aboriginal heritage locations;
- economic provision of services and minimal exposure to flooding. The use of natural grades and minimum earthworks would be desirable;
- flexibility in design to permit a logical and progressively staged development programme that could be effectively completed in full or in part.

11.7.3 Concept design—southern expansion

Residential allotments and house types

Residential allotments in the new area have been predominantly sited to allow an east–west alignment of the long axis of the dwelling for preferred solar conditions. Most of the dwelling designs currently used in the township tend to favour a wide frontage aspect, allowing outdoor areas to be positioned at the rear of the dwelling and at a suitable distance from neighbouring properties to provide maximum acoustic control. Since many of the allotments also back on to public open space along the retained dune ridgeline, the separation of outdoor living areas is even further enhanced with this layout and individual privacy is maintained.

The concept plan recognises that the township population is heavily weighted towards a younger than average age profile and that a high percentage of family accommodation is required. A large number of 600–700 m^2 allotments are therefore provided in the plan to meet this demand.

To address the growing demand for alternative housing types to meet the needs of single persons, couples without children, longer term residents now approaching middle age, and the elderly, it is proposed that a variety of allotments suited to cluster groups of houses be scattered throughout the more 'traditional' allotments.

In general these cluster housing sites are directed at two and three-bedroom duplex style dwellings provided as pairs, and small groups of two and three bedroom houses sited for optimum solar conditions and minimal neighbour interference between living areas. Adequate levels of resident and visitor parking would be achieved individually and within common areas, and with limited land allocated to driveways. Reduced yard space, but with more functional and shaded outdoor living areas, would allow these dwellings to cost less while also achieving other gains over the 'traditional designs' through less house and yard maintenance.

Siting these cluster sites adjacent to parklands would assist in further enhancing the attractiveness of this type of dwelling through the direct access to recreation facilities and good long-distance landscape views.

As this type of housing is relatively new to Roxby Downs, public acceptance of the product will need to be tested before commitment can be made to large numbers. The plan proposes to establish several early trial areas where new concepts could be established and evaluated.

Commercial centres and community facilities

The 1983 conceptual town plan layout provided a site within the southern expansion area for a second primary school. The need for this school was supported by the catchment area criteria established by the Education Department at that time, as well as the department's predicted percentages of school-age children. More recent changes to the Department for Education and Children's Services (DECS) catchment criteria might mean that the establishment of another primary school in this location for the short-term projected township population would not come within the criteria. However, longer term growth in the total township size is likely to warrant construction of an additional facility in the future.

Consequently sites for future educational (preschool and primary) and recreational facilities are identified within the concept layout to meet these possible needs.

The existing central location of commercial and retail facilities within the township is regarded as both convenient for a relatively mobile community and desirable to achieve critical mass. Establishment of a local centre that is removed from the town centre is therefore not included in the concept layout.

Road pattern

The conceptual layout and hierarchy of the roads incorporate:

- a main loop collector road system and a secondary series of minor collector loops to facilitate a staged growth;
- the main collector road's continuation of the Arcoona Street alignment to maintain direct road linkage into the town centre. Modifications to the Arcoona Street median would be required in the vicinity of Stuart Road to accommodate a roundabout at this four-way intersection. The inclusion of a roundabout at this point would provide an effective and safe solution to the mixing of traffic and also limit the speed of traffic on Stuart Road and on Arcoona Street and the future collector road;
- a series of local access roads designed in both loop and cul de sac formats to provide variety in living environments;
- traffic management control devices in the form of:
  - roundabouts at approximately 0.5 km spacing on the main collector road;
  - slow point treatments on the major and minor collector roads at pedestrian crossing locations;
  - protected parking lanes where high traffic flow conditions are encountered;
- wider east–west roads (mainly collector roads) with street trees to enhance safety aspects relating to early morning sun glare and improved sightlines;
- accommodation of a local community bus service.

Road design is to be in accordance with the specifications in Table 11.5.

Table 11.5 Road design specifications

Road category	Road reserve width (m)	Road carriageway size (m)	Carriageway format	Footpath
Major collector road	20	12	Two moving lanes and protected parking bays on both sides	Both sides
Minor collector road	15	8	Two wide moving lanes and parking on one side	One side
Local access road	14	7.5	Two moving lanes and parking on one side	One side only where part of a main pathway system

Design of main roads includes provision for the on-street movement of bicycles, with suitable carriageway widths for safe use.

Streetscape treatment would involve the provision of footpaths along nominated streets and the inclusion of suitable shade trees and lighting. Residents would be encouraged to complete their front yard landscaping to the kerbline through the use of reduced building setbacks on each allotment, and narrower road verge widths than currently exist. Low maintenance and attractive vegetation is recommended for street landscaping and would include hardy groundcovers and small bushes.

Open space

The 1983 plan provided for some 20% of the developed township to be allocated to open space. Retention of existing trees, dunes and low-lying land in the southern area would ensure that a significant part of the site area remained as public open space. While perhaps regarded as generous by current residential standards, this amount of parkland would be more consistent with the outback location of the township and create a more open living environment.

To complement other outdoor recreational locations in the established areas of Roxby Downs, a series of parklands suited to various levels of active and passive recreation is proposed. In particular the enhancement of existing western myall groves with sections of irrigated grassland and groundcovers could make these sites desirable picnic grounds. The addition of shaded play equipment, barbecues, tables, seating and lighting is envisaged in key locations.

Given the high percentage of children in the town, suitable play equipment should be positioned within 0.5 km walking distance of all households, and the extensive reserve areas would allow this. Shading of the play equipment and adjacent seating area would be necessary for the practical usage of these facilities, and drinking fountains are also proposed at these locations.

Opportunities for teenage recreation are planned for some of the larger pieces of parkland, where there can be good separation distances between the activity and nearby housing. Overlooking from nearby properties is also essential to minimise the incidence of undesirable behaviour.

Activities including '3-on-3' basketball courts, dual-use tennis and netball courts, netball rings, skateboard tracks and skatebowls, and BMX/mountain bike circuits are envisaged to fulfil the needs of older children. Fitness tracks could also be included in the pathway system.

Pedestrian and cyclist pathways

Apart from providing for on-road pedestrian/cyclist movement, the concept plan also establishes a comprehensive network of off-road pathway linkages between the residential areas and the town centre. Located within the dunes, in the low-lying land and in areas of established vegetation, the pathway routes would provide variety and interest for users, and in many instances would be within the more shaded parts of the site.

Intersections between pathway routes and roadways would provide identifiable and safe crossing points, with special road treatment (including median islands and carriageway deviations) and 'chicane style' barrier fencing (to prevent cyclists entering crossing points at speed) incorporated into the layout.

Safe crossing points would also need to be included at several places along Stuart Road where identified pedestrian/cyclist routes intersect with this main road. Continuation of the 2.5 m wide pedestrian/cycle path existing along the western edge of Arcoona Street (currently running from Tutop Street to the town centre and school) across Stuart Road and into the southern area for approximately 400 m would encourage cyclists to keep off the busier sections of the road network, and also direct them to a safe crossing point (via median island) adjacent to the new roundabout at the Arcoona Street and Stuart Road intersection.

Much of the pathway system within the reserves would be an integral part of the parkland development, and suitable furniture and lighting would be provided along the routes to ensure optimum levels of safety and amenity. Similarly, surface materials and grades of the path surface would be designed to meet all current requirements for non-discriminatory and convenient access.

The pedestrian/cyclist pathway system and its interrelationship with areas of open space are displayed in Figure 11.6.

House design and siting and off-road parking

A range of modifications to current practices for the design and siting of houses would be implemented in the southern expansion area. Changes would include:

- provision for a greater number of cars to be parked on each allotment with spaces for at least three to four vehicles being desirable, to reduce congestion within the road system and to allow reduced carriageway widths;
- covered car parks to be an integral part of the house shading system, particularly on western walls;
- reduced street setbacks where appropriate to limit the extent of landscaped front yard, but without restricting the opportunity for driveway parking behind cars parked undercover;
- side setbacks to provide for sound attenuation between buildings;
- air-conditioning compressors to be sited away from bedrooms or living rooms;
- pergola shade to all west-facing bedroom and living room walls and windows. Eaves blocking in identified locations for the future addition of pergolas to other parts of the building for increased shading;
- 600 mm minimum eaves overhang generally, but with canopy roof extensions or verandahs over north-facing windows (and walls where feasible);
- good relationships to be established between indoor living and outdoor entertaining areas;
- service areas to be screened from outdoor entertaining areas;

- landscaping to comprise:
  - minimal lawned areas;
  - shaping of the yard to collect stormwater for natural watering of lawn and other plantings;
  - extensive use of hardy groundcover plants within mulched areas to bind soil and to provide a more attractive appearance;
  - use of screening bushes to protect outdoor areas from hot winds and to screen views into rear yards from abutting dunes;
  - inclusion of suitable canopy trees on the side boundaries, around outdoor entertaining areas, alongside parking spaces and in other key locations for optimum climatic control;
  - use of native plants selected from a list of species that are known to perform well in the area;
- inclusion of roof insulation and mechanical ventilation to the roof spaces;
- use of high-efficiency or solar water heating units and air-conditioning/heating plant.

11.7.4 Town expansion staging

The principal proposed town developments for the Olympic Dam Expansion Project are:

- use of some of the sixty-five new dwellings on fifty-three allotments in the eastern section of the township by October 1997;
- provision of a further sixty-five dwellings on fifty-three allotments in the proposed southern development;
- provision of 100 additional allotments in the southern expansion of the township, commencing in late May 1997, and a further 100 allotments designed ready for development as required;
- expansion of the sewage treatment system, duplication of the sewage rising main to the treatment areas, upgrading of the main sewage pump station, and provision of a new sewage pump station to cater directly for the new areas;
- replacement of the six town water pumps with larger units;
- construction of a large water main in Olympic Way to service the proposed southern extension and to boost water pressures on the eastern fringe of the town;
- extension of the existing high voltage overhead line on the western side of the town to the proposed southern extension, and the provision of four new transformers within the new areas.

In addition, land has been made available to the South Australian Health Commission for the construction of a medical facility, as provided for in the Indenture. This land is on Burgoyne Street, opposite Richardson Place, and construction is expected to be completed by early 1998.

11.7.5 Construction villages

The Expansion Project would require two construction villages:

- the existing Construction Camp 1 site, which would be rebuilt and called the Olympic Dam Village No. 1 (ODV1);
- the existing Construction Camp 2 site, which would be extended, refurbished and upgraded and called the Olympic Dam Village No. 2 (ODV2).

ODV1 would cater for 900 people, with the capacity for later expansion for up to 1,300 people as required. The additional 400 rooms, if provided, would be located on land currently occupied by the Olympic Dam Village Caravan Park, which is to be vacated by the end of 1997. A new caravan park is to be established at Roxby Downs.

The construction of ODV1 would involve the provision of new transportable accommodation units arranged in 6 × 6 room clusters, refurbishment of existing buildings, and removal and disposal of redundant transportable units. The ODV1 concept plan is shown in Figure 11.7.

New village facilities would include the following permanent buildings:

- kitchen and dining area
- tavern and beer garden
- administration office, convenience store and post office
- warehousing
- games room.

Several existing buildings and facilities would be refurbished to provide the following:

- swimming pool
- tennis courts
- new grassed playing fields
- squash courts and gymnasium
- library.

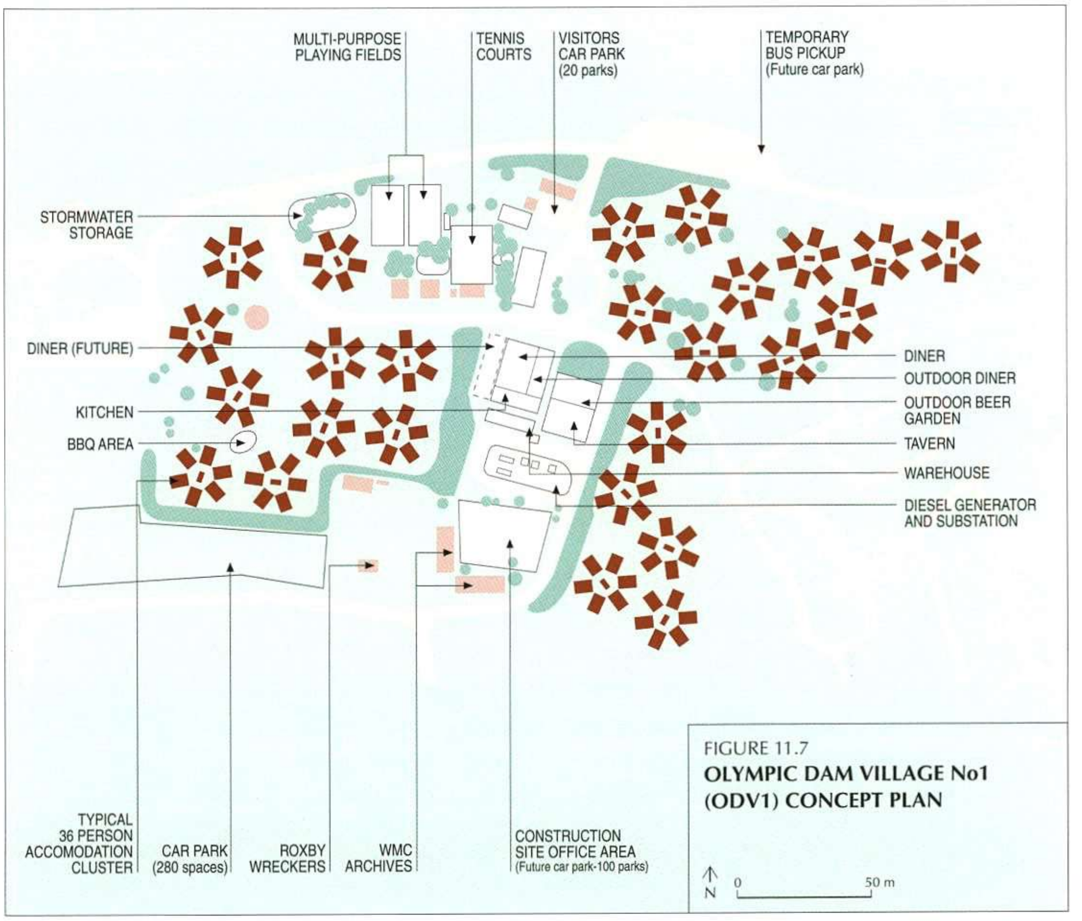


FIGURE 11.7
OLYMPIC DAM VILLAGE No1 (ODV1) CONCEPT PLAN

ODV1 would use a packaged sewage treatment plant to provide treated effluent water for landscaping irrigation. This would enable the village area to be intensively planted and mulched to create a pleasant environment.

Refurbishment of the Construction Camp 2 site would include the construction of a new kitchen and mess area, and relocation of some of the transportable buildings from the existing Construction Camp 1 site. ODV2 would be designed to accommodate 300 people, and would be used principally by construction personnel on site for periods of up to about four weeks. The ODV2 concept plan is shown in Figure 11.8.

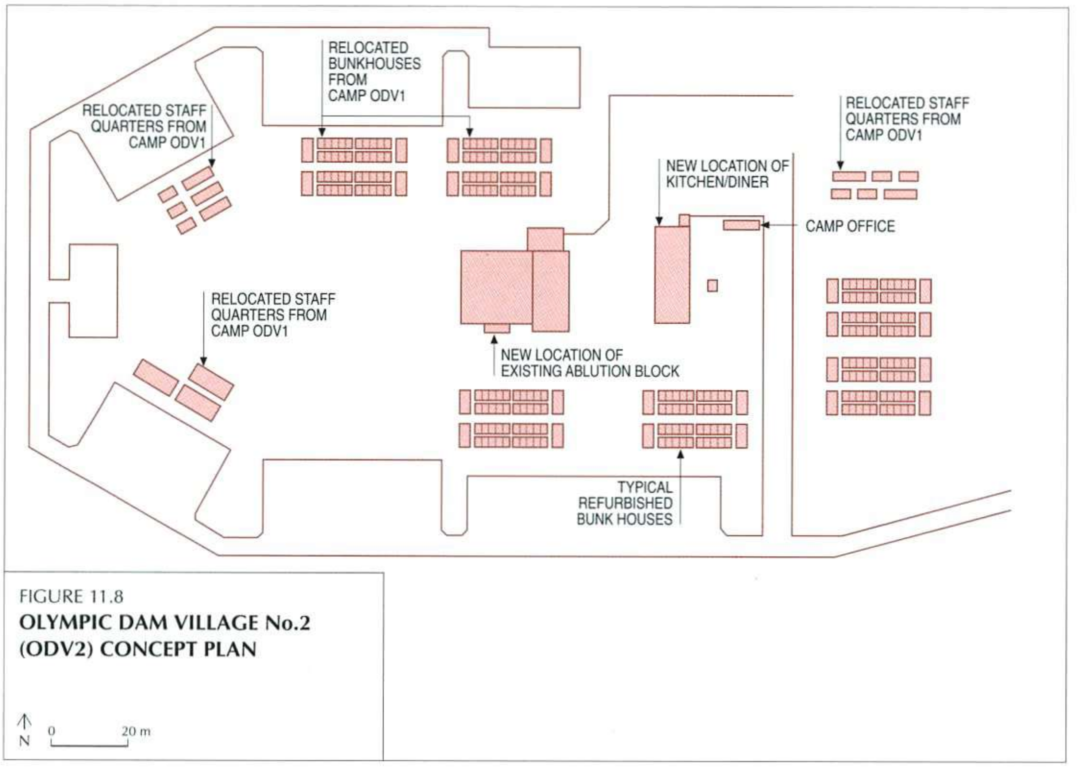


FIGURE 11.8
OLYMPIC DAM VILLAGE No.2 (ODV2) CONCEPT PLAN

CHAPTER 12

SOCIAL ENVIRONMENT

CHAPTER 12

SOCIAL ENVIRONMENT

This chapter discusses the likely social impacts resulting from the proposed expansion of Olympic Dam operations on the local township of Roxby Downs as well as on the communities of Andamooka and upper Spencer Gulf. On the basis of workforce projections, future population characteristics are forecast, with discussion of the implications for provision of accommodation and community services, and for municipal management. Issues relating to the impact on other significant communities in the region, namely pastoralists and Aboriginal people, are discussed in Chapters 5 and 6, respectively.

12.1 STUDY APPROACH

The study approach is based on detailed assessment of the existing social environment, including the existing population characteristics (Section 12.2). The current workforce characteristics and future workforce projections are also considered, including the implications of the Expansion Project for direct and indirect employment opportunities (Section 12.3).

These data have been projected forward to assess the likely future population, and its characteristics (Section 12.4), in order to provide a basis for the likely future requirements for community facilities.

In order to gain a further appreciation of the likely social effects of the Olympic Dam Expansion Project, community consultations were conducted in Roxby Downs, Andamooka and upper Spencer Gulf. The outcomes of these consultations are discussed in Section 12.5.

Sections 12.6 to 12.9 focus on the provision of accommodation, community services and commercial facilities. The issue of local governance is also discussed.

In brief, the population of Roxby Downs township would be expected to increase from an estimated 2,500 in mid-1996 to approximately 3,100 by mid-2000 with the expansion to production of 200,000 t/a of copper. For the future possible production rate of 350,000 t/a of copper, the population is estimated to reach around 4,500.

12.2 EXISTING SOCIAL ENVIRONMENT

12.2.1 Northern region

Roxby Downs is located 560 km from Adelaide in the subdivision defined by the Australian Bureau of Statistics (ABS) as the Far North of South Australia. This subdivision forms part of the Northern Statistical Division of South Australia together with Whyalla, Port Pirie and the Flinders Ranges (Figure 12.1).

As discussed in Chapter 13, the population of the Northern Statistical Division has been declining for several years, with rates of unemployment in the three regional cities of Whyalla, Port Pirie and Port Augusta being higher than the State average.

Further information on the regional social profile is provided in Chapter 5, including the regional land uses of grazing, mining, defence (Woomera), tourism and recreation, and conservation areas.

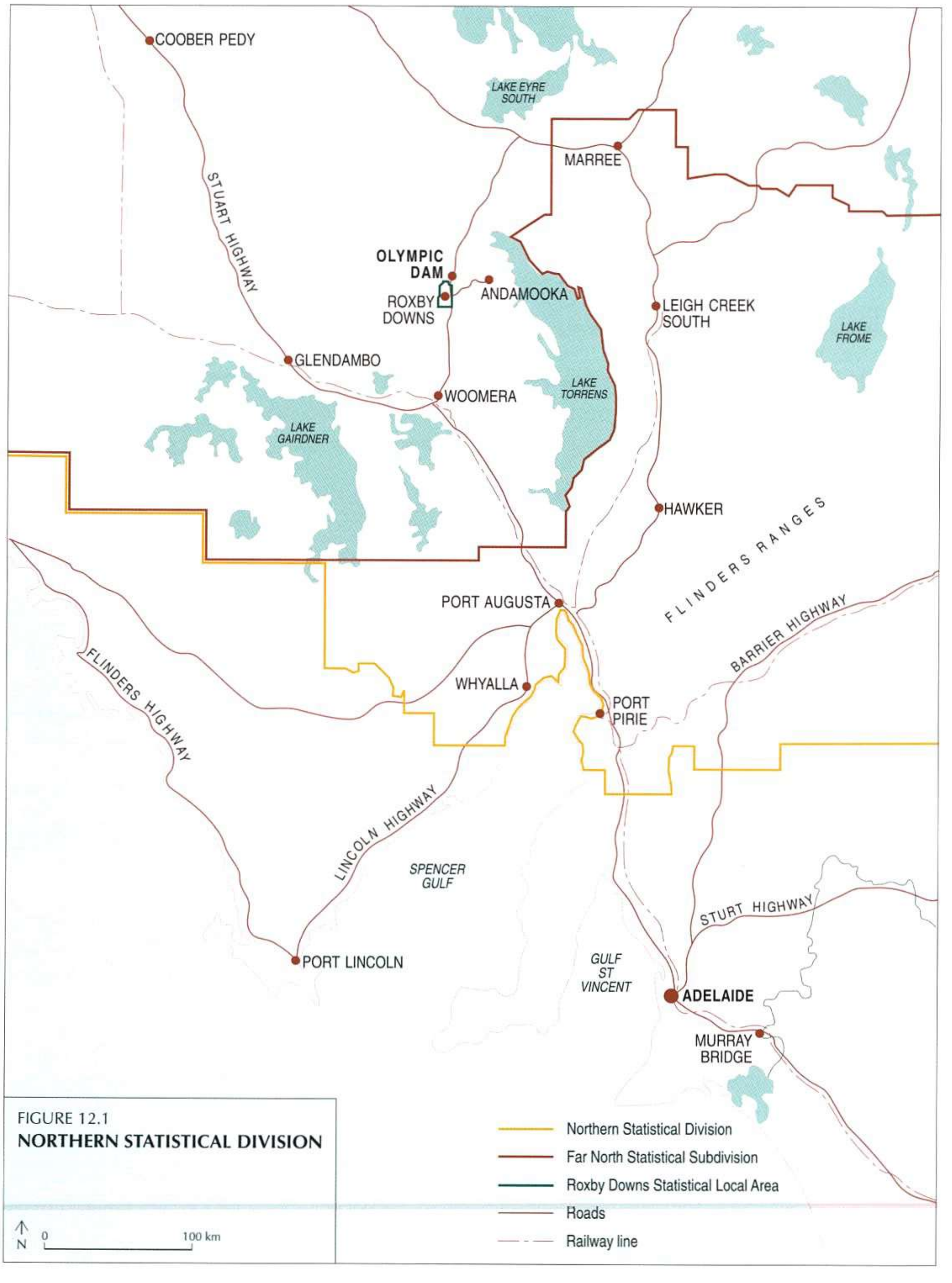


FIGURE 12.1
NORTHERN STATISTICAL DIVISION

12.2.2 Roxby Downs

Construction of the Roxby Downs township commenced in mid-1986, with the first residents moving into the town in early 1987, the majority of them from the Olympic Dam Village. Since then, the population has grown steadily, reflecting the staged completion of the mine and process plant and subsequent optimisations.

The most reliable source of data regarding population size is the Census of Population and Housing conducted every five years by the ABS, where the actual location counts on the night of the census are subsequently adjusted to take account of people's usual place of residence in order to determine an estimated resident population. The 1996 Census data results were not available at the time of writing this EIS.

An analysis of the census data from 1986 and 1991 indicates that the Statistical Local Area (SLA) of Roxby Downs, which includes the Roxby Downs township, Olympic Dam Village and surrounding countryside, had grown rapidly from 450 persons in 1986 to 2,353 in 1991 (Australian Bureau of Statistics 1996a). An estimate of the resident population in the township of Roxby Downs in 1991 is not available. However, the actual location count for the township was 1,999.

By mid-1996, the population of the Roxby Downs SLA was estimated by the ABS to have grown to 2,814 (Australian Bureau of Statistics 1996b). This represents an increase of 461 persons since the 1991 Census. Based on advice from the Manager of the South Australian Small Area Population Unit of the ABS it has been assumed that all of these additional people were resident in the township. The population of the township in mid-1996 is therefore estimated to have been in the order of 2,500.

Just over two-thirds of the population resident in Roxby Downs SLA in 1991 had moved there after 1986. The vast majority of new residents to the area migrated from within South Australia, with smaller numbers from other States (predominantly Western Australia), as well as a small number from overseas.

The 1991 age and sex structure of the township of Roxby Downs, the Northern Statistical Division (SD) of South Australia, and South Australia as a whole is shown in Figure 12.2. While the profile of the Northern SD closely approximated that for the whole of South Australia, in comparison Roxby Downs township was characterised by:

- a substantially higher proportion of children aged 0–9 years
- a correspondingly higher proportion of young adults aged 20–34 years
- a substantially lower proportion of people aged over 50 years
- a slightly smaller proportion of females.

The predominance of younger families in Roxby Downs was reflected in the relatively high average household size of 3.18, compared with 2.68 for the Northern SD and 2.63 for South Australia.

In terms of ethnicity, Roxby Downs had a higher proportion of people born in mainly English-speaking countries (95%) compared with both the Northern SD (92.3%) and South Australia (87.7%).

Very few Aborigines were registered as living in Roxby Downs, comprising only 0.8% of the population compared with 6% for the Northern SD and 1.2% for South Australia.

A comparison of key socio-economic indicators highlighted the fact that the population of Roxby Downs township as a whole was relatively affluent, having:

- higher levels of educational attainment, with 14.6% having been awarded either degrees or diplomas compared with 8% in the Northern SD and 11.6% in South Australia;
- a higher labour force participation rate (84.9% compared with 64.3% and 62.0% for the Northern SD and South Australia, respectively);
- a much lower rate of unemployment (2.5% compared with 8.4% and 7.3% for the Northern SD and South Australia, respectively);
- higher levels of household income, averaging (in 1991 dollars) $56,117 compared with $29,597 for the Northern SD and $32,345 for South Australia;
- a predominance of two-parent families (70.6%) and a correspondingly lower proportion of single-parent families (1.3%), the latter being almost negligible compared with the 12.8% and 12.9% of single-parent families in the Northern SD and South Australia, respectively.

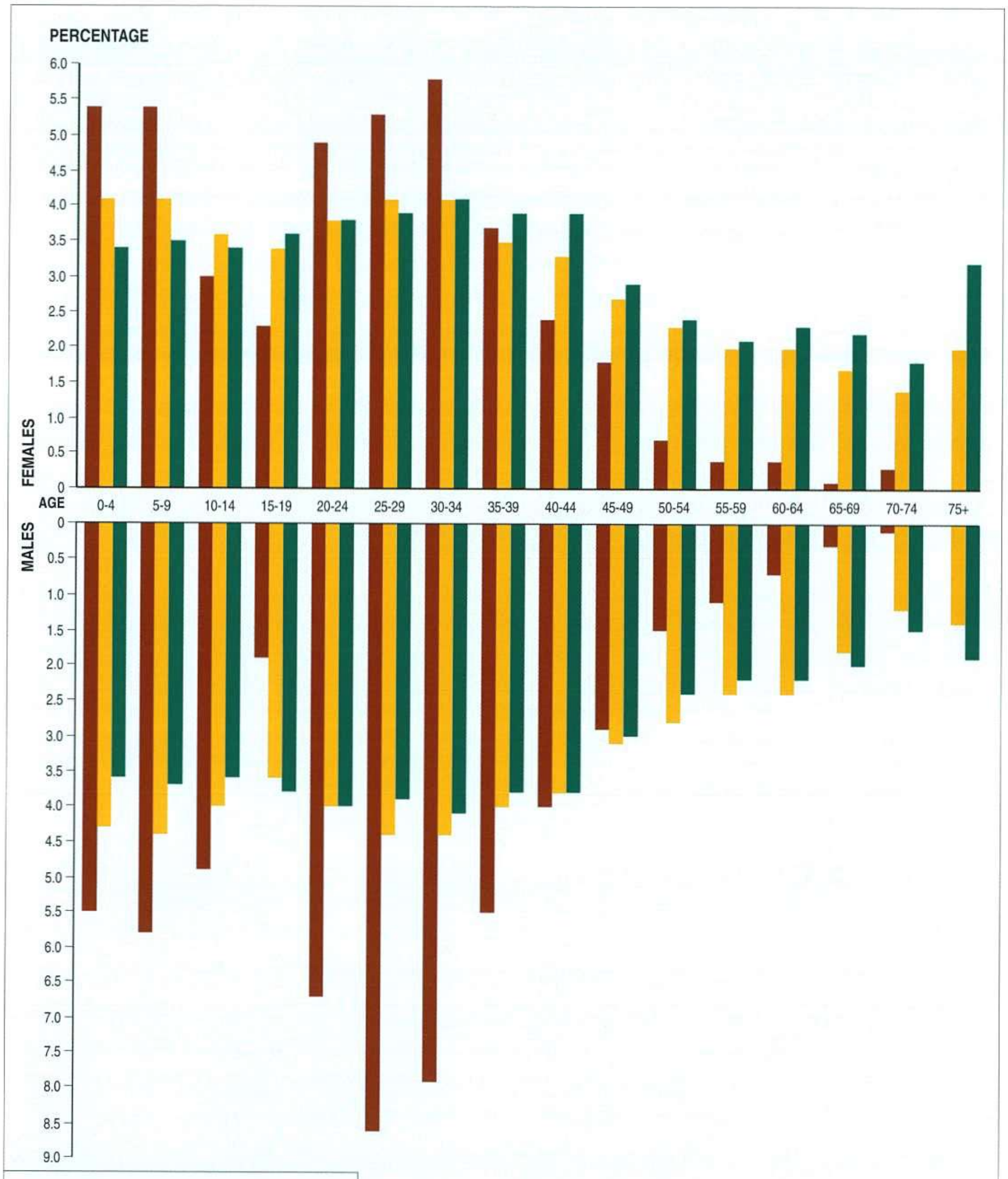


FIGURE 12.2
CURRENT AGE STRUCTURE

12.2.3 Andamooka

Andamooka is the closest town to Roxby Downs, located 32 km to the north-east. Since the discovery of opal in 1930, the number of miners attracted to the area has fluctuated over the years, with peak production and population occurring during the late 1960s.

Since then, the population has declined from an estimated 2,000 to 398 in 1986, rising slightly to 464 in 1991 (based on ABS Census of Population and Housing data for 1986 and 1991). However, anecdotal evidence suggests that the population is larger than that officially enumerated by the 1991 Census. Unofficial town estimates put the current population at between 700 to 1,100 people, fluctuating markedly in response to seasonal conditions, with people heading south during the hotter months.

Anecdotal reports do, however, accord with an analysis of the census data, which indicate an increase in the proportion of people aged over forty years, particularly those aged over sixty years. This reflects both an ageing-in-place of the population as well as an influx of retired people.

At the same time, the increase in the proportion of zero to four-year-olds evident in the 1991 Census data appears to be continuing, with anecdotal reports of more young families who have moved to the area to work at Olympic Dam choosing to live in Andamooka rather than Roxby Downs.

Andamooka is a multicultural community, with just over one-quarter of residents recorded in the 1991 Census as having been born in non-English speaking countries. Mining was still the major source of employment, accounting for 18% of the labour force.

It is estimated that approximately fifty Olympic Dam employees live in Andamooka. In the main, these workers are employed by contractors, not directly by WMC. It is unknown how many of these workers were already residents of Andamooka prior to the operations commencing. What is evident in the 1991 Census, however, is the substantially high rate of unemployment (22.2%), particularly amongst those aged forty-five to sixty-four years.

12.3 LOCAL WORKFORCE PROJECTIONS

This section discusses the number of permanent jobs likely to be generated locally as a result of the Expansion Project, in terms of both direct and indirect employment. The term 'direct' refers to employment on site, while 'indirect' applies to the non-project workforce employed by the private and public sectors to provide support services to the project, its workforce and the town.

12.3.1 Current workforce

Direct employment

Since mine production commenced in June 1988, the total workforce employed at Olympic Dam has remained relatively stable, averaging around 850 employees (the 'direct local' workforce). As shown in Table 12.1, there has been a gradual growth in the number of personnel employed directly by WMC and a decline in the number of contractors.

Table 12.1 Olympic Dam workforce statistics since commencement of production

Employee category	Number of employees[1]						
	1989	1990	1991	1992	1994	1995	1996
WMC							
Senior staff	40	43	41	37	41	34	
Staff	256	288	299	297	302	311	373[2]
Award	301	297	284	280	318	314	301[3]
Apprentices			9	14	16	16	20
Subtotal	597	628	633	628	677	675	694
CONTRACTORS							
Operating			56	51	67	66	55
Maintenance			143	134	124	126	146
Subtotal	268	206	199	185	191	192	201
TOTAL WORKFORCE	**865**	**834**	**832**	**813**	**868**	**867**	**895**

1 *As at June each year.*
2 *Includes both staff and senior staff.*
3 *All award staff have subsequently accepted staff offers (July 1996 for process plant and December 1996 for the mine).*
Source: WMC June Progress Reports, 1989 to 1996 (1993 data not available).

Table 12.2 shows the distribution of the 895 personnel employed in June 1996 to achieve a production level of 85,000 t/a of copper. The process plant accounted for 56% of the workforce with 504 employees, with 391 (44%) employed in the mine. Approximately half of the process plant personnel and two-thirds of the mine personnel were shift workers, rostered four days on and four days off.

Table 12.2 Distribution of direct local workforce at Olympic Dam, June 1996

Workforce	Mine		Process plant		**Total**	
	(No.)	(%)	(No.)	(%)	**(No.)**	**(%)**
WMC						
Staff	120	30.7	253	50.2	**373**	**41.7**
Award[1]	157	40.2	144	28.6	**301**	**33.6**
Apprentices	7	1.8	13	2.6	**20**	**2.2**
Subtotal	284	72.6	410	81.3	**694**	**77.5**
CONTRACTORS						
Operating	31	7.9	24	4.8	**55**	**6.1**
Maintenance	76	19.4	70	13.9	**146**	**16.3**
Subtotal	107	27.4	94	18.7	**201**	**22.5**
TOTAL WORKFORCE	**391**	**43.7**	**504**	**56.3**	**895**	**100.0**

1 All award staff have subsequently accepted staff offers (July 1996 for process plant and December 1996 for the mine).
Note: Percentages may not tally because of rounding.
Source: WMC June Progress Reports for the Mine and Process Plant, 1996.

Just over three-quarters of the workforce (78%) were directly employed by WMC, with the remaining 22% of contractors engaged primarily in maintenance (16%) rather than operating (6%) activities. A higher proportion of contractors was employed in the mine (27%) compared with the process plant (19%).

The workforce profile has changed over recent months with award personnel being offered staff positions. The processing plant was the first to introduce this in July 1996, and all offers were taken up. At the same time, process work was restructured to make it more satisfying and rewarding through a fundamental change in management style. This led to a slight reduction in the total number of operations and support staff required to maintain the continuing competitiveness of the Olympic Dam operation. Offers of transfer from award to staff positions were made to mine award employees in December 1996 and 98% of offers were taken up.

The profile of the December 1996 workforce is shown in Table 1.2. This also includes personnel employed in the Copper Uranium Division based in Adelaide and Melbourne, referred to as the 'direct non-local' workforce.

Indirect employment

No specific data are available to quantify the number of people living and working in Roxby Downs who are not employed in Olympic Dam operations, referred to here as the 'indirect local' workforce. However, an estimate of the direct to indirect workforce can be derived from a comparison of the June 1991 WMC workforce statistics for the Olympic Dam site and the 1991 ABS Census of Population and Housing for the township of Roxby Downs.

Table 12.3 indicates the distribution of the 1,152 employed persons by industry classification according to the 1991 Census.

Although the mining industry accounted for 497 persons, Olympic Dam employees would also have been recorded under a range of other classifications. Based on the assumption that 832 persons were employed in Olympic Dam operations as at June 1991 (as shown in Table 12.1), approximately 320 persons were engaged in non-project based (indirect) employment in Roxby Downs and Olympic Dam Village at that time.

This represents a total multiplier effect (including direct employment and induced local employment) of 1.38 which is slightly higher than the total multiplier effect of 1.3 used in the 1983 EIS to predict the indirect workforce for the third and fourth years of mining production. The latter figure was based on an assumption that the indirect workforce would comprise 22% of the total forecast workforce.

Table 12.3 Employment by industry classification

Industry class	Roxby Downs					
	Males		Females		**Total**	
	(No.)	(%)	(No.)	(%)	**(No.)**	**(%)**
Mining	418	54.0	79	20.9	**497**	**43.1**
Manufacturing	87	11.2	10	2.6	**97**	**8.4**
Construction	60	7.8	3	0.8	**63**	**5.5**
Wholesale and retail trade	52	6.7	52	13.8	**104**	**9.0**
Transport and storage	16	2.1	15	4.0	**31**	**2.7**
Communication	6	0.8	6	1.6	**12**	**1.0**
Finance, property and business services	24	3.1	39	10.3	**63**	**5.5**
Public administration and defence	6	0.8	6	1.6	**12**	**1.0**
Community services	30	3.9	66	17.5	**96**	**8.3**
Recreational, personal and other services	22	2.8	63	16.7	**85**	**7.4**
Not classifiable/not stated	53	6.8	39	10.3	**92**	**8.0**
TOTAL	**774**	**100.0**	**378**	**100.0**	**1,152**	**100.0**

Source: 1991 Census of population and housing (Australian Bureau of Statistics 1996a).

12.3.2 Projected workforce to year 2000

Construction workforce (direct)

It is expected that an average of 1,300 construction personnel including management will be located on site, over a two-year period, to expand the mining and processing facilities to enable production to reach 200,000 t/a of copper by the year 2000. In addition, between 200 and 300 personnel are likely to be required on a short-term basis from January to April 1998. Construction has already commenced to permit expanded production within the existing environmental approval of 150,000 t/a of copper.

The majority of construction employees will be accommodated in a self-contained village at Olympic Dam, approximately 9 km north of Roxby Downs, and work on a fly-in, fly-out basis. Approximately 80% will work above ground on a six-week-on, one-week-off roster. The estimated 20% working underground will work a three-week cycle of two weeks on and one off.

Both skilled and unskilled employees will be required depending on the phase of construction. Bechtel, the principal contractor, will assist subcontractors in recruiting personnel by coordinating a central project employment register for interested persons. It is expected that the majority of employees will originate from South Australia.

Operational workforce (direct)

Table 12.4 details estimates of the direct operational workforce requirements to the year 2000 to reach a production level of 200,000 t/a of copper. It is estimated that the direct operational workforce at Olympic Dam will need to increase by 181 personnel in order to expand to this level. In Adelaide, the Copper Uranium Division staffing is expected to increase from 51 (Table 1.2) to 61, resulting in an overall direct employment of 191 personnel arising from the expansion from 85,000 t/a copper to 200,000 t/a copper. In the mine, there will be a total increase of 159 comprising 120 staff and thirty-nine contractors. In the process plant, it is estimated that an additional twenty-two personnel will be required, equally distributed between staff and contractors.

Table 12.4 Estimates of direct local workforce requirements at Olympic Dam to the year 2000 (200,000 t/a copper production)

Project workforce	1996[1]	1996–97	1997–98	1998–99	1999–2000
CONSTRUCTION	–	1,300	1,300	–	–
OPERATIONAL—MINE					
Staff	277	350	362	373	397
Contractors	107	170	177	172	146
Subtotal	384	520	539	545	543
OPERATIONAL—PROCESS PLANT					
Staff	397	412	412	411	408
Contractors	94	128	116	104	105
Subtotal	491	540	469	515	513
APPRENTICES	20	20	20	20	20
Total operational workforce	**895**	**1,080**	**1,087**	**1,080**	**1,076**
TOTAL WORKFORCE	**895**	**2,380**	**2,387**	**1,080**	**1,076**

1 *Actual employment numbers in June 1996 required to produce 85,000 t/a.*

It should be noted that the workforce estimates for the mine are based on achieving workforce efficiencies by introducing an underground rail ore handling system to replace the current reliance on trucks. The 1983 EIS predicted higher workforce levels than those now projected. This is because technological improvements have resulted in workforce efficiencies in both the mine and plant.

Construction and operational workforce (indirect)

Low and high projections of the induced indirect local workforce resulting from both the construction and the expanded operational workforce have been estimated as shown in Tables 12.5 and 12.6, respectively.

Table 12.5 Estimates of indirect local workforce: low projections

Project workforce	1996[1]	1996–97	1997–98	1998–99	1999–2000
A Direct construction workforce[2]	–	1,300	1,300	–	–
B Indirect construction workforce (A × 0.1)	–	130	130	–	–
C Direct operational workforce[2]	895	1,080	1,087	1,080	1,076
D Indirect operational workforce (C × 0.3)	269	324	326	324	323
Total indirect workforce (B+D)	**269**	**454**	**456**	**324**	**323**
TOTAL LOCAL WORKFORCE	**1,164**	**2,834**	**2,843**	**1,404**	**1,399**

1 *Actual employment numbers in June 1996 required to produce 85,000 t/a.*
2 *From Table 12.4.*

Table 12.6 Estimates of indirect local workforce: high projections

Project workforce	1996[1]	1996–97	1997–98	1998–99	1999–2000
A Direct construction workforce[2]	–	1,300	1,300	–	–
B Indirect construction workforce (A × 0.2)	–	260	260	–	–
C Direct operational workforce[2]	895	1,080	1,087	1,080	1,076
D Indirect workforce (C × 0.4)	358	432	435	432	430
Total indirect workforce (B+D)	**358**	**692**	**695**	**432**	**430**
TOTAL LOCAL WORKFORCE	**1,253**	**3,072**	**3,082**	**1,512**	**1,506**

1 *Actual employment numbers in June 1996 required to produce 85,000 t/a.*
2 *From Table 12.4.*

Assumptions regarding multipliers for induced local employment have been based on previous studies of large-scale development projects in remote areas (as shown in Table 12.7).

The total multiplier for induced local employment associated with the construction workforce, including direct employment, has been assumed to be 1.1 in the low projection and 1.2 in the high projection. For the direct operational workforce, the total multiplier effect has been assumed to be 1.3 for the low projection and 1.4 for the high projection.

Table 12.7 Multipliers for induced local employment in other relevant studies

Project	Multiplier	
	Construction	Operation
1982 Olympic Dam Draft EIS	1.15	1.30
1983 Kingston Lignite Mine Draft EIS	1.40	1.40
1983 RAAF Base Tindal Draft EIS	1.2–1.4	1.2–1.4

In summary, it is estimated that between 130 and 260 indirect workforce jobs based at Olympic Dam will be required to support the two-year construction workforce of 1,300. It is expected that most of these additional indirect jobs will be casual and filled by existing residents of Roxby Downs and Andamooka. Personnel will be required to run the catering and servicing of the construction camp site, as well as carry out earthworks, electrical works, transportation and maintenance.

Based on Tables 12.5 and 12.6, it is estimated that in June 1996 there were between 269 and 358 personnel in the indirect operational workforce, which is likely to increase to between 323 and 430 by June 2000. Overall, this represents the generation of 54 to 72 indirect operational workforce positions resulting from the estimated increase of 181 personnel in the direct operational workforce.

12.3.3 Projected workforce to year 2010

No formal decision has been taken by the WMC Board at this time on the possible future expansion to 350,000 t/a copper production. However, it is assumed in this EIS for economic and water modelling purposes that a production rate of 350,000 t/a of copper will be achieved in the year 2010. Estimates of the workforce requirements at Olympic Dam to meet this rate of production are shown in Table 12.8. In Adelaide, the Copper Uranium Division staffing is expected to increase from 61 to 65, resulting in an overall direct employment of 510 personnel arising from the expansion from 200,000 t/a copper to 350,000 t/a copper. It should be noted that these depend on a number of variables including economic conditions.

Applying a total employment multiplier of 1.3 and 1.4 (including direct employment) results in an additional indirect workforce of between 152 and 202.

Table 12.8 Estimated additional workforce at Olympic Dam required to increase production from 200,000 t/a to 350,000 t/a copper

Direct operational workforce	1999–2000	2010	Increase
Mine	543	850	307
Process plant	513	712	199
Apprentices	20	20	–
TOTAL	**1,076**	**1,582**	**506**

12.3.4 Social implications of workforce structure

As will be discussed in Section 12.5, residents of Roxby Downs expressed concern about the potential impact of the influx of construction personnel on the township. It is timely to review this issue, together with other potential social implications of the forecast workforce structure, and assess any future impacts that may result from the proposed expansion of the workforce.

Impact of construction workforce

Up to 1,300 construction personnel will be required during the two-year construction period.

Residents of Roxby Downs who participated in the EIS consultation processes expressed concern about the potential impact of this influx of construction personnel on their lifestyle. In particular, they expressed concern about the possible increase in criminal and antisocial behaviour such as drink driving. They believed these concerns could be overcome by ensuring prospective workers were screened prior to employment.

These concerns are being actively addressed by senior management of the Olympic Dam Expansion Project. In order to minimise the impact on Roxby Downs township, construction personnel will be accommodated in the two single persons' quarters at Olympic Dam Village as discussed in Chapter 11. A high standard of amenities including recreation and entertainment facilities will be provided, thereby reducing the need for construction personnel to travel to Roxby Downs. While it is likely that some will still wish to frequent the townships of Roxby Downs and Andamooka, they will be expected to comply with a code of behaviour while both on and off duty.

Shiftwork

In order to operate the mine and the process plant continuously, a proportion of the workforce is rostered on a twelve-hour day or night shift for four days, followed by four days off.

While shiftwork offers substantial financial rewards and other individual benefits, it can be detrimental to the health and well-being of the shiftworker owing to disruption of circadian rhythms and sleep patterns, and resultant fatigue. However, research generally indicates that effects vary depending on individual attributes and coping mechanisms.

Research findings tend to favour a four-day-on, four-day-off roster of twelve-hour day or night shifts. These are preferred to the traditional roster of eight-hour shifts (day, then afternoon, then night) for five days followed by two days off. Studies have shown no evidence that twelve-hour shifts cause any increase in fatigue or decrease in alertness, provided that sufficient time is allowed for recreation and recuperation.

There appears to be a generally high level of acceptance of the four-day-on, four-day-off roster by Olympic Dam personnel. Employees experiencing difficulties are encouraged to seek independent counselling provided by the WMC Employee Assistance Programme. This is also available to partners and dependent children.

Health and welfare services are also available in the township, as described in Section 12.7.

The proposed expansion is not expected to result in any changes to the operational hours of the mine or process plant. Approximately the same proportion of the workforce will be rostered on shiftwork.

Employment for women

The 1983 EIS predicted that while employment for women would initially be mainly in administrative positions associated with the project, a range of opportunities in the service and public sector would expand as Roxby Downs developed.

An analysis of the 1991 Census for the Roxby Downs township shows this is in fact the case. Although just over one-fifth of positions filled by women were in the mining industry, a substantial proportion of women were engaged in the more traditional areas of female employment, namely community and recreation, and wholesale and retail services.

There was a higher rate of employment amongst females compared with both the Northern SD and the whole of South Australia. Just over half of the employed women were in part-time positions.

WMC's employment policy is one of equal opportunity for all people with appropriate skills. Although most women employed by WMC are in administrative positions, in recent years there has been an increase in the number of women in professional positions as well as in traditionally male dominated areas in the mine and process plant. This trend is expected to continue with the creation of additional jobs.

Employment for school leavers

With high rates of youth unemployment at a national level, gaining employment is even more difficult for school leavers in country towns. Roxby Downs is no exception, resulting in many young people leaving to seek employment elsewhere.

WMC is assisting in redressing this situation by providing apprenticeships for up to twenty young people at any one time.

Lower levels of educational attainment in the secondary school were identified as an issue during the consultation process. The school and WMC have considered strategies for improving the quality of education, as noted in Section 12.7.

12.4 PROJECTED POPULATION CHARACTERISTICS

12.4.1 Methodology

In order to determine the likely increase in permanent population resulting from the proposed expansion of Olympic Dam, a number of assumptions have been made based on the 1991 Census data regarding the characteristics of the projected operational workforce in terms of their marital status and family composition.

As discussed in the previous section, it is estimated that there will be a net gain in equivalent full-time staff at Olympic Dam of 181 direct personnel and between 54 and 72 indirect personnel to the year 2000.

Table 12.9 summarises the changes over the three-year period required to increase copper production from 85,000 t/a to 200,000 t/a. It should be noted that with the accelerated construction programme, the rate of change may differ from the figures given.

Table 12.9 Estimated changes in direct and indirect local workforce

Local workforce	1996–97	1997–98	1998–99	1999–2000	Total
DIRECT					
WMC	+88	+12	+10	+21	+131
Contractors	+97	–5	–17	–25	+50
TOTAL	**+185**	**+7**	**–7**	**–4**	**+181**
INDIRECT					
Low projection	+55	+2	–2	–1	+54
High projection	+74	+3	–3	–2	+72
TOTAL	**240 to 259**	**9 to 10**	**(–9 to –10)**	**(–5 to –6)**	**235 to 253**

Calculations regarding the increase in population have been based on the premise that the contractors who are no longer required after 1997 will either be absorbed into newly created jobs or leave Roxby Downs. It has also been assumed that all positions will be full-time and that the characteristics of the incoming and outgoing workforce will be the same as those of the 1991 workforce, according to the ABS Census of Population and Housing, namely that:

- 83% of full-time employees will be male and 17% female;
- of the male employees, approximately 55% will be married and living with their family in Roxby Downs and 45% will be living as a single person; of the female personnel, approximately 71% will be married and living with their family in Roxby Downs and 29% will be living as a single person;
- of those who are married, 72% will be in households with children while 28% will be couples with no children;
- there will be an average of 1.0 full-time worker in every household with children and 1.3 full-time workers in every household of a couple without offspring;
- the average size of households with children will be 4.0.

In order to test the relevance of these 1991 characteristics to the current workforce, the profile of process plant personnel employed at November 1996 was compared with the profile generated by applying these assumptions. There was a reasonably close fit between the two profiles suggesting the model is suitable for further application. In addition, the model has been confirmed in discussions with the Manager of the South Australian Small Area Population Unit of the ABS.

These assumptions have therefore been used to generate Table 12.10 which shows low and high projections of the incoming population to the years 2000 and 2010 based on:

- a net increase of 181 personnel in the direct workforce at Olympic Dam and between 54 and 72 in the indirect workforce to the year 2000;
- a net increase of 506 personnel in the direct workforce at Olympic Dam and between 152 and 202 in the indirect workforce to the year 2010. This assumes the possible future expansion to 350,000 t/a copper is approved by the WMC Board.

12.4.2 Results of forecasts

From Table 12.10, it is estimated that the net increase in the workforce of between 235 and 253 will result in a population increase of between 554 and 589 persons in Roxby Downs by the year 2000. Given an estimated population of 2,500 at mid-1996 (Section 12.2), the total population by mid-2000 is likely to have increased to around 3,100. By 2010, the population is expected to have increased to around 4,500.

Estimates have been made of the age profile of incoming dependent children 0–19 years in order to determine likely requirements for the provision of community services.

Table 12.10 Estimated profile of additional workforce and resulting population increase

Profile characteristic	Year 2000 Low projection	Year 2000 High projection	Year 2010[1] Low projection	Year 2010[1] High projection
Net increase in local workforce	235	253	658	708
SEX				
Male (83%)	195	210	546	588
Female (17%)	40	43	112	120
MARITAL STATUS				
Married male (55%)	107	115	300	323
Married female (71%)	28	31	80	85
Total married	135	146	389	408
Single male (45%)	88	94	246	265
Single female (29%)	12	12	32	35
Total single	100	106	278	300
HOUSEHOLD TYPE				
Single	100	107	278	300
Couples without offspring (1.3 workers per household)	29	31	82	88
Family (1.0 worker per household)	99	105	274	294
Total households	228	243	634	682
RESULTANT POPULATION				
Single (household type x 1)	100	107	278	300
Couples (household type x 2)	58	62	164	176
Families (household type x 4)	396	420	1096	1176
TOTAL RESULTANT POPULATION	**554**	**589**	**1538**	**1652**

1 *Assumes the possible future expansion to 350,000 t/a copper is approved by the WMC Board.*

Based on the characteristics of the population of Roxby Downs township according to the 1991 Census, it has been assumed that 90% of the children living in families will be dependent on their parents and distributed across the age cohorts as shown in Table 12.11. Given the anticipated increase of between 396 and 420 persons in families, with an average of two children per family (Table 12.10), the increase in the number of dependent children is expected to be in the order of 178 to 189 by the year 2000.

Estimated age breakdowns shown in Table 12.11 should be used with care, given the numerous assumptions on which they are based. Ongoing monitoring of the characteristics of the incoming community will be required to ensure the timely and adequate provision of community services. This is discussed further in Section 12.7.

Table 12.11 Estimated profile of incoming dependent children, 0–19 years, to the year 2000

Age	Percentage of all children[1]	Number of children: Low projection	Number of children: High projection
0–4	32	57	61
5–9	33	59	62
10–14	23	41	43
15–19	12	21	23
TOTAL	**100**	**178**	**189**

1 *1991 Census of population and housing (Australian Bureau of Statistics 1996a).*

12.5 COMMUNITY CONSULTATION PROGRAMME

In order to gain a better appreciation of the social effects of the expansion, community consultations were conducted in upper Spencer Gulf, Roxby Downs and Andamooka.

In upper Spencer Gulf, the municipal councils and economic development boards of Whyalla, Port Augusta and Port Pirie were invited to submit written comments, as were members of the local community by advertisements in local newspapers.

In Roxby Downs, the consultation process involved:

- distribution of a self-administered survey to all households and residents of both the Olympic Dam Village and Roxby Downs caravan parks;
- day and evening workshops targeted at the general community;
- interviews and a workshop with key community service providers;
- a meeting with local traders.

In Andamooka, a community workshop was organised with support from the Andamooka Opal Mining and Progress Association.

12.5.1 Upper Spencer Gulf

Between July and October 1996, WMC conducted a series of presentations regarding the operations and proposed expansion of Olympic Dam to the regional economic development boards, business communities and interested community members in the three Spencer Gulf cities.

A formal invitation was subsequently extended to the three local government authorities and their economic development boards seeking written comments regarding the benefits and any adverse effects resulting to date from Olympic Dam operations and the perceived benefits or concerns likely to emanate from the proposed expansion. Advertisements were also placed in the January 1997 issue of local newspapers in the region inviting members of the general public to comment on the expansion and any specific matters they believed should be addressed in the EIS.

Written responses were received from the City of Port Augusta, the Whyalla Economic Development Board Incorporated, the Port Pirie Regional Development Board Incorporated, the Northern Regional Development Board and the Trades and Labour Council of Port Augusta.

Generally, these organisations expressed a positive view of current Olympic Dam operations and of the proposed expansion. The mine and its associated activities are seen as a source of economic and social benefits to the State as a whole and to the local communities.

Increased opportunities for employment and apprenticeship in the provision of goods and services (e.g. engineering, construction, transport, equipment, food, entertainment, medical facilities, education and training) are envisaged for both the construction and operational phases. Commercial and industrial expansion is expected in the form of new firms, new outlets for existing businesses in Roxby Downs and improved facilities. This in turn would lead to increased disposable income and a higher standard of living, and a perception of a secure future, for the local population centres.

Some concerns were expressed by the Whyalla Economic Development Board about vegetation loss along road corridors and on industrial sites, and increased environmental emissions. However, the board noted that all participating industrial companies had environmental standards in place.

The Northern Regional Development Board and the Trades and Labour Council of Port Augusta were concerned about the increase in heavy-vehicle traffic following approval of the

Expansion Project. It was suggested that a rail link should be established so that products could be transported in sealed containers directly to Port Adelaide by standard gauge railway. It was believed that this would improve safety, efficiency and amenity.

12.5.2 Roxby Downs

During the preparation of this EIS, residents of Roxby Downs were invited to state what they liked and disliked about living in Roxby Downs, as well as express their views on the impacts of the proposed Expansion Project in terms of the opportunities it presented to improve the township. They were also invited to express any concerns and indicate how these could be dealt with.

In addition to attending a day or evening community workshop held in October 1996, residents had the opportunity to complete a simple open-ended questionnaire. In all, seventy-five people participated in the consultation process. While this number of participants is a relatively small sample of the population, there was a great deal of consistency in people's views, suggesting that they may reflect the views of the broader community.

In addition, approximately 100 Year 8 to Year 10 school children attending Roxby Downs Area School participated by recording their comments regarding what they liked or disliked about living in Roxby Downs and what improvements they would like to see.

In the main, residents liked living in Roxby Downs, referring to it as 'an oasis in the desert'. In particular, they described the town as:

- a safe place to live, especially for women and children
- relaxed, easy-going and friendly
- family oriented with a good community spirit
- visually appealing, with plenty of trees and gardens
- well designed and laid out, with good pedestrian and cycle access
- equipped with good community and recreational facilities
- situated in a bush environment
- enjoying a good climate.

Residents generally had a high level of satisfaction but were keen to see a range of specific improvements to the physical design and functioning of the town, including:

- an expansion of the commercial sector to offer greater competition and an extended variety of goods and services;
- the development of facilities and programmes for teenagers (e.g. BMX track, roller blading, drop-in centre, and a second basketball stadium);
- improvement of parks and oval maintenance, the erection of shade coverage over existing playground equipment, and installation of seats for parents supervising play;
- construction of more footpaths, and better pedestrian crossings in the main street;
- extended recycling programmes to include household paper, plastics and glass, and improvements to the condition of the town landfill facility;
- increased supply of cheaper housing and accommodation, including provision of alternative accommodation for single people and accommodation for tourists and people visiting relatives in Roxby Downs.

These issues have been taken into account in designing the southern expansion of Roxby Downs township (refer Chapter 11).

Other concerns were:

- the restricted secondary school curriculum and the high turnover of teaching staff;
- the movement of secondary students to boarding schools in Adelaide, particularly in senior years;
- the difficulty of attracting and retaining doctors;
- the lack of accountability of the municipality to ratepayers in the absence of either an elected body or active advisory committee;
- the limited frequency and high cost of both bus and plane services;
- pressures resulting from the lack of support because residents live far from close relatives.

It should be noted that these issues are common to many country areas, and in particular to mining towns in remote locations.

The primary concern of residents about the proposed expansion was the impact of the temporary construction workforce. They felt there would be a need to ensure the screening of all potential employees to minimise crime or antisocial behaviour. Increased policing may be needed to monitor public behaviour, especially in relation to additional road traffic. The integration of the construction workforce with townsfolk to prevent development of a 'them' and 'us' mentality was also viewed as important. Strategies for dealing with this issue were noted in Section 12.3.

Residents also expressed concern that an increase in the town population could overtax existing facilities, especially those providing services for children. In relation to housing, concerns varied from the possibility of a housing shortage to the potential devaluation of existing housing by the construction of new improved dwellings. The need for water conservation was also raised by a few respondents, and the need for recreational use of off-road vehicles to be controlled to minimise damage to the environment.

Young people tended to be more negative in their outlook, describing Roxby Downs as 'an adult town', with little in the way of specific activities for teenagers. Like most teenagers, they wanted fast food outlets and a range of entertainment and recreational facilities, and additional opportunities for participating in competitive sports. While they felt isolated in not being able to access facilities available to teenagers in the city, they valued the freedom and safety of country living and the lack of pollution and traffic.

Overall, apart from reservations about the influx of the temporary construction workforce, the proposed expansion is viewed positively by Roxby Downs residents, with potential benefits including:

- creation of employment opportunities with associated social and economic benefits;
- a sufficient increase in the population of Roxby Downs to enable a viable expansion of commercial facilities as well as justify an expansion of community services;
- the construction of a medical facility in accordance with the Indenture.

12.5.3 Andamooka

Discussions about the proposed expansion with residents at a community workshop, held at Andamooka in early December 1996, indicated that the development of Olympic Dam is perceived by residents to have resulted in both adverse and beneficial effects on the residents' lives. As only ten townspeople attended, the views expressed may not be fully representative of the community.

Prior to the commencement of Olympic Dam operations, long-term residents of Andamooka described the township as being a very isolated, close-knit and self-sufficient community. With the development of Roxby Downs, and the subsequent increase in the number of people living in the area, some residents perceived that Andamooka had lost some of its unique 'frontier' character.

The sealing of the road from Andamooka to Roxby Downs in September 1995 had substantially improved access of 'outsiders' to Andamooka and had, at the same time, made it easier for Andamooka residents to travel to other town centres to access a broader range of services and facilities. The relative merits of improved access vary depending on the perspective of the individual.

The better access and road conditions were reported in the consultation to have led to reduced patronage of the local supermarket, with some Andamooka residents going to Roxby Downs to shop. However, some Roxby Downs residents occasionally go to Andamooka for an outing and to shop, as an alternative to shopping in Roxby Downs.

Residents expressed concern at the change in status of the Andamooka school, once a special rural school offering both primary and secondary education, to one that now offers only primary education. Similarly, the availability of health services in Andamooka has declined since the opening of the Roxby Downs Medical Centre. Initially operating an outreach service twice a week, the medical service now visits only once a fortnight.

Andamooka receives water by water tanker, provided from the Roxby Downs potable supply, in addition to that collected in the town. Residents considered that supply of water by a pipeline would be beneficial for Andamooka. This is an issue for the State Government. The Indenture only permits supply of water to the Olympic Dam Project and Roxby Downs.

In summary, those Andamooka residents attending the community workshop voiced a desire to share in the success and wealth resulting from Olympic Dam operations, which they see being enjoyed by Roxby Downs residents. WMC's proposed expansion of Olympic Dam operations would create additional local employment opportunities.

12.6 PROVISION OF ACCOMMODATION

12.6.1 Current situation

The Indenture provides that WMC is responsible for providing accommodation to meet the needs of Olympic Dam employees and their dependants as well as using its best endeavours to assist in providing housing for people who provide services in the town.

The 1983 EIS outlined the various types of accommodation that were to be provided to meet this obligation, namely:

- a separate village at Olympic Dam to house the construction workforce
- single room accommodation or self-contained flats for single employees
- houses for married employees
- a caravan park primarily for short-term residents.

This section outlines how these various forms of accommodation have all been developed. Section 12.6.2 discusses how demands for additional accommodation resulting from the expected increase in the workforce will be met.

Accommodation supply

Table 12.12 indicates the current supply of accommodation in the Roxby Downs township as well as at the Olympic Dam Village Caravan Park, located approximately 9 km away. Temporary accommodation for contractors is also available at the two single persons' quarters located at Olympic Dam Village.

Table 12.12 Supply of accommodation in Roxby Downs and Olympic Dam Village—December 1996

Type of accommodation	Units of accommodation (number)
HOUSES	
WMC	370
Government	44
Private	139
Total houses	553
DUPLEXES	
WMC	42
Private	36
Total duplexes	78
UNITS	
WMC (1 bedroom)	12
Private	56
Total units	68
Total rateable housing properties	**699**
SINGLE PERSONS' QUARTERS, ROXBY DOWNS	335
CARAVAN PARKS	
Roxby Downs	83
Olympic Dam Village	68
Total caravans	151
TOTAL	**1,185**

Information regarding the number of houses, duplexes and units in Table 12.12 has been derived by superimposing data supplied by:

- the Roxby Downs Municipality, which indicates a total of 699 rateable housing properties;
- the WMC Roxby Downs Town Office regarding the number of allotments sold to the private sector, the mix of dwelling types constructed by WMC and the retention or sale of these over the years.

Release of additional allotments

In response to the current demand, a further 101 allotments have been developed in the eastern subdivision of Roxby Downs, allocated as shown in Table 12.13. The allotments retained by WMC will be used to construct forty-six houses and fifteen one-bedroom units, to be completed by October 1997. An additional four allotments within the existing township are also being developed by WMC.

WMC subsidised housing

All full-time WMC personnel over the age of eighteen years employed at Olympic Dam operations are eligible for subsidised housing.

Table 12.13 Allocation of eastern subdivision allotments—February 1997

Allocation	Number of allotments
WMC—Houses	46
WMC—One-bedroom units	3
Contractor companies	19
Private sale	33
TOTAL	**101**

Married employees with dependent children are allocated houses designed for family living. There is a range of internal layouts to ensure variety, with features including a family room, three or four bedrooms, and an ensuite bathroom off the main bedroom. Living and sleeping areas are separated by a buffer, ensuring quiet rest areas are available which is particularly important for shift personnel.

Most houses are on allotments of around 800 m^2, enabling the construction of large covered outdoor areas and, if desired, a swimming pool. Larger size allotments also ensure sufficient off-street car parking. External walls are mostly timber framed with a light-weight cladding such as weatherboard or stucco finish. Combined with full wall and roof insulation, this light-weight cladding ensures heat is quickly dissipated in the evening.

Single parent families and couples without children are allocated a duplex. These have been designed with the carports located between living areas to ensure minimal noise transfer. Most are on allotments of 400–450 m^2 and have two bedrooms.

Single employees are housed in the single persons' quarters (SPQ), a self-contained unit or share living in a three-bedroom house depending on availability. The SPQ, located in Roxby Downs township, has 335 single-room units, grouped in thirty-three blocks of ten units and one of five units. Each unit has a large bed–sitting area with built-in storage and an ensuite bathroom. There is a central dining room and activity hall, with a laundry available for each group of ten units.

Twelve one-bedroom units are also available, with four units located on each of three allotments integrated into the town. These feature a separate bedroom, a kitchen–dining and lounge area and a combined bathroom and laundry. These have proved very popular and additional units are planned to be constructed in the eastern subdivision.

Under an earlier home purchase policy, WMC employees living in a three-bedroom or four-bedroom house who commenced their employment with Olympic Dam Corporation before 31 August 1995 were eligible to purchase their home at a discount from the market value. Houses for executive or senior staff, as well as duplexes and one-bedroom units, were not for sale.

For this earlier home purchase policy, WMC provided a guaranteed buy-back for the first five years after settlement, on the basis of a 5% escalation per year on the purchase price plus reimbursement for any capital improvements. Within this five-year period, employees who left the company were obliged to sell back to WMC. There was a further five-year period within which WMC had the first right of refusal before employees were able to sell on the open market.

The home purchase policy is currently under review, and discussions are being held with third party property developers on potential options to improve housing availability.

Caravan park accommodation

In addition to houses, duplexes and units available for rental or purchase in the private market, accommodation is also available in the Roxby Downs and Olympic Dam Village caravan parks. The Roxby Downs Caravan Park was initially opened early in 1987 to provide accommodation for workers and their families. It is now open to anyone, regardless of employment.

The caravan park currently provides eighty-three permanent sites. In addition, six overnight vans and sites for tents and eight caravans are available for tourists or as temporary accommodation. In addition to a caravan, most permanent sites have capacity to accommodate an annex and car park. All sites have sewerage and fifty-four have their own shower and toilet.

For the last two years, the caravan park has been operating at or near full capacity. Nearly two-thirds of the permanent sites are owner-occupied with the rest being rented. Approximately one-third of the sites are occupied by single people (mainly men), another third by couples without children, and the remaining third by families. Most families have two children aged under eight years. With the exception of a small number of long-term residents, the majority have been in the park for fewer than three years. There is an annual turnover of approximately one-third of all sites.

The Olympic Dam Village Caravan Park is not open to the general public, with leases only available to people in employment at Olympic Dam. The caravan park was only envisaged as a temporary site and is scheduled for closure by the end of December 1997.

Many families prefer living in the caravan parks because of the lower cost of accommodation. In addition, the Olympic Dam Village Caravan Park is only a short distance by car to the mine and processing plant, while the Roxby Downs Caravan Park is within a short walking distance of the town's community and commercial facilities.

Owing to the ready availability of cheaper housing, the nearby town of Andamooka offers an alternative place to live. Woomera offers another alternative although it is about 100 km from the mine and processing plant; and for those employees originating from upper Spencer Gulf, commuting for the work week is another option.

12.6.2 Requirements for additional accommodation

A comprehensive study has recently been undertaken to determine the number and type of dwellings required to house the projected increase in the permanent local workforce. Applying the same assumptions regarding the characteristics of incoming personnel as those outlined in Section 12.4, Table 12.14 shows the resultant housing requirements for the projected increase in the direct workforce as well as the low and high projections for the additional indirect workforce. As shown, it has been assumed that single persons will be accommodated in either the single persons' quarters or single units, while couples will be housed in duplexes and families in houses.

In order to house the incoming workforce, WMC is embarking on a three-stage programme of making available up to 253 allotments as part of the southern expansion of the township, which is discussed in more detail in Chapter 11. In Stage 1, the first fifty-three allotments will be developed into sixty-five dwellings (fifty-three houses and twelve one-bedroom units) by approximately October 1997. Development of a further 100 allotments will commence in late May 1997 (Stage 2), while another 100 allotments will be designed ready for development as required (Stage 3).

Plans for a 150–200 berth caravan park are also under way, with construction expected to be completed by mid-1997. This will provide housing for tenants of the Olympic Dam Village Caravan Park which is scheduled to close by December 1997. It will also provide separate accommodation for tourists.

Table 12.14 Household requirements for additional workforce to year 2000

Profile characteristic[1]	Direct		Indirect	
	WMC	Contractors	Low projection	High projection
Net increase in local workforce[2]	131	50	54	72
SEX				
Male (83%)	109	41	45	60
Female (17%)	22	9	9	12
MARITAL STATUS				
Married male (55%)	60	23	25	33
Married female (71%)	16	6	6	9
Total married	76	29	31	42
Single male (45%)	49	18	20	27
Single female (29%)	6	3	3	3
Total single	55	21	23	30
HOUSEHOLD TYPE/DWELLING				
Single (SPQ, single unit)	55	21	23	30
Couples without offspring (1.3 workers per household)	16	6	7	9
Family (1.0 worker per household)	55	21	22	30
Total household type	126	48	52	69

1 *See Section 12.4.1.*
2 *From Table 12.9.*
Note: Some figures may differ from figures in Table 12.10 due to rounding.

12.7 PROVISION OF COMMUNITY SERVICES

12.7.1 Overview

For a town of its size, Roxby Downs has a relatively high standard of public infrastructure offering a wide range of community services. In the main, these are co-located in the centre of the town, adjacent to the commercial sector. Easy access to a comprehensive range of community services was one of the positive features of the township highlighted by the community during the consultation process.

With the township projected to grow by approximately 550–590 people by the year 2000, and subsequently to approximately 4,500 in the longer term when production levels reach 350,000 t/a of copper, it is important to consider the capacity of existing community services to respond to increased demands. To this end, interviews have been conducted with all key community service agencies to discuss their capacity to meet current demands, and consequently their likely requirements for the expansion of existing facilities or development of new facilities. Any additional resources would need to be determined by the relevant government departments.

Given that an extensive range of facilities and services will be provided at the Olympic Dam Village as discussed in Section 11.7, it is unlikely that construction personnel will place undue demand on community services located in the township. This section therefore focuses on the needs of the operational workforce and associated population of Roxby Downs.

Under the Indenture, the State Government is responsible for funding the provision within the town site of a police station, lock-up and court-house; child care facilities, preschools, primary and secondary schools; a ten-bed acute medical facility, and medical and dental services; local authority offices, including a library and civic auditorium; State Government offices; swimming pool complex, sporting facilities and playing fields; premises and facilities for the creative, performing and visual arts; fire services, an ambulance centre and associated equipment; parks and gardens; and garbage disposal facilities for the town. The State Government is also required to provide the necessary personnel and equipment for these facilities and services. The State Government and WMC share equally any shortfall in the Roxby Downs municipality budget (Section 12.9.1).

In broad terms, the range of community services available in Roxby Downs can be grouped into:

- child care and educational services
- community health and medical services
- community welfare and support services
- recreational and cultural facilities
- policing and emergency services.

This section considers the capacity of the existing community services to cater for the current and expected future population of Roxby Downs township for each of the above groupings, and comments on potential additional services that may be required. The detailed assessment and provision of actual service requirements is a matter for the respective State and Commonwealth governments.

In summary, it is expected that the increase in population resulting from the expansion to 200,000 t/a of copper production will have a minimal impact on existing services and facilities. However, monitoring and review of the impact on services and facilities as the composition of the population changes are necessary to anticipate future requirements and to maintain a quality standard of living.

Government community service agencies have indicated an interest in establishing a community services planning group, to include WMC's Community Liaison Officer based at Olympic Dam, to regularly review and monitor the impact of changing demographics and, in particular, to:

- identify gaps and overlaps in services
- ensure community planning is undertaken in a coordinated manner
- identify opportunities for resident participation
- assess the adequacy of the provision of community services.

12.7.2 Child care and educational services

The State Government Department for Education and Children's Services (DECS) is responsible for the provision of child care services, through either the Roxby Downs Child Care Centre or the Family Day Care programme. DECS is also responsible for providing preschool, primary, secondary and post-secondary education services.

Child care

The Roxby Downs Child Care Centre provides child care services on a full-time, part-time, casual and emergency basis. The majority of service users opt for part-time and occasional care reflecting the low participation rate of married women in full-time employment. The centre is licensed to cater for a maximum of forty places at any one time, twenty-five of which are for children aged two years to eight years and fifteen for babies six weeks to two years.

While 120 children from eighty families currently use the centre, it is operating at just under half of its licensed capacity with an average full-time utilisation figure of eighteen and a half out of the forty places. The centre is therefore considered to have sufficient capacity to accommodate the projected increase in families resulting from the expansion. It is difficult to quantify the potential increased usage given the expected continued high proportion of casual users. Continual monitoring is therefore required.

An issue is the difficulty that has been experienced by the centre in attracting trained staff to Roxby Downs. Incentives, such as subsidised housing, may be needed to attract and retain trained staff.

Family Day Care is also funded by DECS on a part-time basis as an outreach service from the Port Augusta office. This provides child care for children and babies in the homes of selected and approved care providers. Currently, the service is fully utilised with eighty-four children receiving care.

Preschool

Preschool education is available at the Roxby Downs Kindergarten. Children aged between four and five years are able to attend up to four of the nine half-day sessions. Each session is able to cater for up to thirty-five children.

After a relatively stable enrolment of around fifty to sixty children for the last few years, enrolments increased throughout 1996 to seventy-two by the start of the fourth term. Currently, an average of twenty-six children attend each session, which represents an overall utilisation rate of 74%.

Although the kindergarten has capacity to cater for a limited number of enrolments under its current licensing arrangements, it is experiencing difficulty in accommodating increasing numbers of children because of the current layout of the building. It is understood that DECS is investigating internal design changes to the current facility to achieve a 30% increase in space.

Based on the assumptions regarding the increase in population resulting from the proposed expansion to 200,000 t/a of copper production, approximately 10–15 additional four-year-olds would require preschool education. This would bring the Roxby Downs Kindergarten to near capacity, and ongoing monitoring of this would be required.

In the longer term, as the population expands to the expected long-term population of around 4,500, it may be necessary to consider development of another kindergarten to cater for families living further than the recommended 2.5 km away from the existing kindergarten. Land has been allocated in the southern expansion area for local-level community services, which could include a kindergarten, as discussed in Section 11.7. The provision of the preschool services is the responsibility of DECS.

Primary and secondary education

The Roxby Downs Area School opened in 1987, with the capacity to cater for up to 600 students from Reception to Year 12. The buildings are of solid construction, air-conditioned and connected by covered walkways. Classroom blocks are segregated from buildings offering specialist activities such as computing, open access, library and administration services. The school also provides care out of school hours.

Table 12.15 shows a relatively stable enrolment pattern over the last four years of just under 500 students at the start of each school year. However, numbers may fluctuate; for example, enrolments were 507 in November 1996, representing an increase of thirty-six students since the beginning of the school year.

Table 12.15 Roxby Downs Area School: February enrolments

Enrolment type	1993	1994	1995	1996
Primary	347	378	371	363
Secondary (FTE)[1]	120	115	120	108
TOTAL (FTE)	**467**	**493**	**491**	**471**

1 *FTE = full-time equivalent.*

Between 1997 and 2000, it is estimated that up to an extra seventy-five primary school and thirty secondary school children could move into the town, resulting in the school operating at full capacity. It is understood that DECS is currently considering ways of responding to increased enrolments.

For a long-term population of approximately 4,500, assuming the proportion of school aged children in the population remains at approximately 20%, the school would need to cater for up to 900 children. It is understood that there is likely to be sufficient land on the existing school site to expand facilities.

The Roxby Downs Area School currently has a teaching staff of thirty-three. The school has had difficulty in attracting and retaining teachers. The average length of stay by teachers is about three years. In particular there has been a high turnover in senior staff. These difficulties are not unique to the Roxby Downs township. The high turnover of professional staff is a problem shared by all educational services located in remote areas in Australia.

WMC has a company policy of providing subsidies for secondary schooling to its staff in remote mine-site locations. This results in some movement of Roxby Downs secondary students to boarding schools, particularly in the senior years. Concerns were expressed in the community consultation process that an exodus of secondary students is seen to result in reduced academic expectations at the school.

The school principal and WMC have considered strategies to address this situation and to put in place incentives to make the local senior secondary schooling more attractive than is currently the case, including the provision of funding by WMC to make computers more widely available to students.

Non-government education

Currently, all schooling in Roxby Downs is provided by the State Government. However, it is understood that the Catholic Education Office has commenced preliminary planning for a primary school.

Post-secondary education

The Roxby Downs campus of the Spencer Institute of TAFE provides post-secondary courses in relevant industry areas as well as a limited range of continuing education programmes. It provides nationally accredited TAFE award courses from entry level and certificate through to associate diploma level. It also provides a range of vocational education and training initiatives and consultancy services to meet specific industry needs. The campus works closely with the Roxby Downs school to provide vocational education and training modules.

Work-oriented and employment-enhancement programmes such as computing and business skills are the most popular courses offered by the campus. There has been little demand for leisure courses and programmes to date. Courses are scheduled to meet the needs of those on shiftwork. The ability to hold courses is reliant on part-time instructors and one full-time permanent lecturer.

With the proposed expansion of Olympic Dam, and consequent expected increase in the town population, an increase in demand for TAFE programmes and courses is expected. Use of the facility is close to capacity, especially during the first half of each year. The monitoring and review of any current and future impacts on staffing and resource allocations is a responsibility of the Department for Employment, Training and Further Education (DETAFE).

12.7.3 Community health and medical services

Health facilities and services are provided in Roxby Downs from the Roxby Downs Community Health Centre and the Roxby Downs Medical Centre. In addition, hospital services are available through the Royal Flying Doctor Service in both Port Augusta and Adelaide.

The Roxby Downs Medical Centre presently has one part-time visiting and two resident general practitioners. Services include general practice, accident and emergency services and occupational health and safety services for WMC. A fortnightly visiting service to Andamooka is also provided.

Visiting specialist and paramedical services are provided on a sessional basis, with varying frequencies, at the medical centre and community health centre. The range of allied health services which currently provide a visiting service includes a gynaecologist and obstetrician; ear, nose and throat specialist; paediatrician; optician; chiropractor; speech therapist; dietician; physiotherapist; orthodontist; and podiatrist. A private dental clinic with one dentist is also based at the medical centre.

The existing medical centre is being used to capacity and unable to provide additional room for visiting specialists. This is expected to be remedied with the construction of a new medical facility by the State Government to accommodate a ten-bed acute-care health facility as agreed under the amended Indenture. This new facility, which is expected to be opened in early 1998, will be staffed on demand and provide facilities for accident and emergency, minor surgical procedures, elective day surgery and low-risk obstetric care.

Community health services, general practice, private dental services and an imaging department are expected to be accommodated in the new facility. A number of visiting health practitioners should be able to visit at the same time, and it is expected that the range and frequency of allied health services would increase. It will continue to be necessary for Roxby Downs residents requiring more specialised medical treatment to travel to Port Augusta, Whyalla or Adelaide for consultation and treatment. This situation is not unique to Roxby Downs but common to remote areas Australia-wide.

The medical centre is expected to schedule additional clinic times to accommodate an increase in demand. It is understood that the South Australian Health Commission is assessing the immediate and longer-term staffing allocations required for the health and medical services at Roxby Downs.

Community health services

The Roxby Downs community health centre operates as an outreach service of the Port Augusta Hospital and Regional Health Services, and currently employs 1.5 full-time equivalent community health nurses. Services and programmes currently provided include counselling, health promotion and education; family planning; ante-natal classes; domicilliary care; and an immunisation clinic. There is no locally based or visiting mental health service or women's health service at present.

The current community health centre is expected to be relocated to the new medical facility. It is understood that appropriate staffing levels and the services to be offered are being reviewed and assessed by the South Australian Health Commission.

Child and Youth Health (an agency of the South Australian Health Commission) provides a weekly child health clinic four days per week and a home visiting service; a visiting service to Woomera (one day per week) and to Andamooka (one day per month); health screenings; and parent education. Post-natal follow-up, in the short term, is also provided by the community health centre's part-time domicilliary midwife. It is expected that this service will also be relocated into the new medical facility. It is understood that any increase in demand could be met by providing additional clinic sessions.

12.7.4 Community welfare and support services

The Port Augusta office of the Department for Family and Community Services (FACS) provides an outreach service to Roxby Downs, with a social worker visiting every three weeks for two to three days, or more frequently if required. The service operates from the Roxby Downs Community Health Centre, offering counselling, budget advice and financial assistance as well as fulfilling FACS statutory functions.

Support services are also provided by the Catholic, Christian Community and Lutheran church groups located in Roxby Downs.

In order to inform new residents about community services available locally and in the region, the Olympic Dam Community Liaison Officer is preparing a directory as part of a Welcome Kit, to be available in a booklet as well as on-line at the library and accessible by home computers. There was an earlier community services directory prepared by the Community Health Centre, volunteers and the Council; however the Welcome Kit will be more current.

Additional demands are likely to be made on government welfare and non-government support services as a result of the population growth. It is understood that FACS is exploring service delivery models including possible video conferencing as a way of providing extended services where this is appropriate. It is understood that FACS would monitor the need for any staffing adjustments to respond to any increase in demand for its service.

12.7.5 Recreation and cultural facilities

Indoor and outdoor recreation facilities

As in many Australian country towns, sporting activities are a major focus within the Roxby Downs community. A variety of sports are played in the town, including football, golf, basketball, netball, cricket, volleyball and baseball. The town has superior recreation facilities compared with many country towns. It has good facilities for most popular sports and is well served by a range of recreation areas, as follows:

- a swimming pool;
- an indoor recreation complex comprising a basketball and other sports stadium, three squash courts, and various meeting rooms;
- four combined tennis and netball courts;
- a main oval;
- a school oval;
- a grassed area between the ovals;
- various playgrounds;
- a bowling green;
- a partly developed golf course;
- specialist areas outside the town, e.g. motor sports and a horse racing and pony club.

The Roxby Downs Leisure Centre provides a range of programmes, and it is understood that these are well utilised. Indoor facilities include a large stadium; squash courts; an area for aerobics and a bar; and two small to medium rooms with gym equipment. Outdoor facilities include tennis courts; swimming pools; oval; and an area allocated for building another stadium.

The swimming pools are the only area that is considered to be presently under-utilised, which is due, in part, to the increase in private backyard pools in the area. The stadium area is regularly booked, and this is attributed to increased use by the school. It is understood that the gym area is considered by users to be inadequate, and that the equipment is outdated.

The increased population is expected to produce benefits for the recreation and leisure activities in Roxby Downs. Expectations include an expansion of club memberships, improvements in the standard of local sport through greater competition, and diversification of the range of sporting, cultural and entertainment activities. Demands for new sporting or entertainment facilities may also emerge.

Library services

The Roxby Downs Community Library is jointly used by the school and the community. The facility and services are well utilised by the community, students from the Roxby Downs Area School and TAFE, as well as by visitors to the area.

The original plan for the library made provision for a mezzanine. It is understood that this will be constructed in 1997 and will overcome some of the space problems currently experienced by the library.

The library's computer access facilities are expected to be expanded and improved over the next two years. With the assistance of WMC, the library is also expected to provide an outreach service by mid-1997 at Olympic Dam Village.

Cultural and entertainment facilities

Roxby Downs presently has few entertainment facilities or regular cultural activities, especially for people under eighteen. This is an issue not only for remote country areas, but also for many urban areas across Australia. The cultural and entertainment facilities available at Woomera, their variety and accessibility by a wide age group, were often referred to in public consultation, and considered to be a positive model.

Further assessment would be required to better understand the future recreational and cultural needs of the community, in order to develop recommendations that reflect the needs and long-term aspirations of the Roxby Downs community. This would be considered by either the proposed community services planning group (Section 12.7.1) or the municipal Advisory Committee (Section 12.9).

12.7.6 Policing and emergency services

Policing

Since 1987, when police officers were first stationed at Roxby Downs, the South Australian Police has operated a two-officer station. The officers work regular office hours from Monday to Friday. The main workload of the Roxby Downs police includes core policing duties and government functions which traditionally have been undertaken by police stationed in remote areas. The officers process a very high number of registration and licensing matters which impacts on the time available for core policing duties.

Over the past four years it is understood that the workload at the Roxby Downs Police Station has increased, nearly doubling in terms of reported incidents. Other government functions also diminish policing time, and attempts to reduce these have met with limited success.

It is understood that a request has been submitted for an additional police officer to be based at Roxby Downs to cater for the current demands. The Expansion Project could place additional demands on policing duties. As a result of the short-term influx of some 1,300 construction personnel, some increase in the incidence of traffic offences, disturbances and petty crimes may be expected. While it is not expected that any significant or long-lasting social disruption would occur, an increase in the police presence at Roxby Downs for at least the duration of the construction period could be necessary.

Emergency services

In addition to the Police Station, two voluntary emergency services—the Country Fire Service and the South Australian Ambulance Service—operate in Roxby Downs.

The Country Fire Service has a portable pump unit, a fire vehicle and a utility housed in temporary facilities in the township. The additional population and property development may increase demands on the fire service. Additional brigade members may be able to be recruited from the increased population to service any increased demand on services.

The local ambulance service is staffed by volunteers and operates two ambulances servicing the Roxby Downs area. It is based in temporary facilities behind the municipal offices but is expected to be relocated to the new medical facility in the near future. The ambulance service is supplemented by access to the Royal Flying Doctor Service for patient transfers to and from Adelaide.

It is understood that the South Australian Ambulance Service has capacity to meet present ambulance needs and resources are adequate for the Expansion Project. In the long term, additional staffing resources could be required to serve the increased population.

12.8 RETAIL AND COMMERCIAL FACILITIES

12.8.1 Existing facilities

The Roxby Downs township has a number of retail and commercial businesses that provide goods and services to the community. These are situated on the southern side of Richardson Place in a generally linear arrangement fronting the street. The facilities in this area and approximate floor space are listed in Table 12.16. In addition to these facilities the motel and the tavern are situated along Norman Place to the south-east of the main shopping area.

These facilities provide the majority of retail and commercial activity within Roxby Downs. In addition a monthly market is run by the kindergarten. Plans by the community club to lease part of their premises for a credit union and additional office space, while recently given planning approval, have not been implemented to date.

It is understood that there is no available floor space for expansion of any of the retail or commercial facilities should there be a demand created by either the natural increase in population or the Expansion Project.

The current retail floor space in Roxby Downs represents a reasonable standard of provision and a good range of facilities, given its relatively small population, its remote location and sparsely populated rural catchment.

12.8.2 Future requirements

It is understood that the three largest tenancies within the Roxby Downs centre (supermarket, hardware shop, and tavern) could consider expansion of their retail areas if floor space were available. The centre leasing agents also believe there are other tenancies that may wish to expand and additional office accommodation may also be needed.

Table 12.16 Roxby Downs: retail and commercial facilities

Use	Area (m^2)
SHOPPING CENTRE USE	
Bank	180
Post Office	100
Bakery	100
Jeweller	75
Photo shop	40
Supermarket	800
Newsagency	175
Video shop	100
Gift shop	60
Pharmacy	95
Fast food outlet	110
Hardware shop	175
Clothing shop	100
Hairdresser	80
Accountant	35
Restaurant	115
Butcher	100
TOTAL	**2,440**
OTHER	
Motel, 50 unit	2,600
Tavern	1,200
TOTAL	**3,800**

Source: First Pacific Davies—Centre Management.

The original town development concept provided for future expansion of the commercial area to the south, providing linkage with future housing development to the south of the city centre. The short open air mall that leads off Richardson Place could provide the focus for such an expansion. One concept is for an enclosed and air-conditioned mall with predominantly retail (rather than commercial) elements. Expansion of building development along this mall would enable more commercial and office uses to be located along Richardson Place and to provide flexibility for users to expand as demand increases.

There are some legal obligations for expansion of the supermarket in the agreement between WMC and the shopping centre owners. These relate to floor space requirements at certain population thresholds. It is expected that in accord with the Expansion Project occurring in two phases, the expansion of the retail and commercial facilities would also occur incrementally.

12.9 MUNICIPAL MANAGEMENT

12.9.1 Current situation

The township of Roxby Downs is a municipality established under the Local Government Act and in accordance with Clause 23 of the Indenture. The administration of the town is currently undertaken by an administrator, appointed by the State Government, who exercises the powers and functions of a municipal council in relation to the operation of the town.

Rates are levied on properties within the town using capital value assessments based on the Valuer General's valuations. These assist with the funding of the municipal functions, with the State Government and WMC sharing equally any shortfall, subject to prior approval of the annual budget and on lodgement of audited financial statements.

The 1983 EIS envisaged that the Town Administrator would eventually be replaced by councillors elected in the normal fashion of democratic local government. The Indenture states that the provisions of the *Local Government Act* relating to the election of councillors shall be suspended for a period of five years from the Commencement Date (defined in the Act as 1 March 1991) unless otherwise agreed by the Joint Venturers (now WMC alone) and the Minister.

As a result of discussions in the context of the amendments to the Indenture in December 1996, the State Government and WMC have agreed to maintain current arrangements until 2001.

In 1989 an Advisory Committee was established from representative members of some of the Roxby Downs community groups. The committee was formed after agreement between the Administrator, WMC and the State Government to provide a forum for liaison between the municipality and the community. Initially the membership of this committee was appointed (for a period of two years) by the Administrator. This process was later amended and the total membership increased, with four members being elected by the community at a public meeting. It is understood that this committee has not met since the early part of 1996.

During the community consultation for this EIS, several comments were made regarding the town governance. While the number of people who participated in this consultative programme was small, their comments were reasonably consistent. Concern was expressed regarding the lack of accountability of the administration to ratepayers, and the inability of members of the community to influence the decision-making process as it affects aspects of town administration, particularly for minor capital works.

The principal issue in this regard is that rate revenue is insufficient to fund the township fully, and the majority of municipal funding is provided by the State Government and WMC. Many councils receive government funding by way of special purpose grants; however, this funding avenue was examined by State Government and found to be an inappropriate funding mechanism due to the length of the potential commitment.

12.9.2 Future requirements

When Roxby Downs was first planned it was expected that a population of some 9,000 people would be living there by 1996. This has not occurred, with the current population being approximately 2,500. Current projections, as a result of completion of the expansion to 200,000 t/a copper are for a population of approximately 3,100 by the year 2000. For the second phase expansion to 350,000 t/a copper, the population is estimated to reach 4,500. These projected population increases will increase the potential rate revenue, which would have implications for municipal management.

It is widely recognised that when people share in the administration and ownership of their towns or cities there is a tendency to be more committed to the community. For remote mining towns this can also lead to feelings of belonging and an inclination to remain, rather than transitional attitudes with residents regarding themselves as short-term visitors.

It is thus important for residents to be able to influence decisions affecting the facilities and services in the town. This needs to be balanced with the town's financial position which will continue to require significant subsidies from the State Government and WMC if adequate services are to be maintained without very significant increases in rates.

The Advisory Committee is an existing mechanism that could be utilised to provide the Roxby Downs community with a greater opportunity to influence town governance. Originally established as a liaison forum, the committee's operation and membership could be reviewed so that it would be more active in advising on town services and facilities.

WMC has entered into discussions with the State Government regarding new terms of reference for the Advisory Committee, in the context of continuing to consider longer term options for municipal governance.

CHAPTER 13

ECONOMIC IMPACTS

CHAPTER 13

ECONOMIC IMPACTS

This chapter explains the projected economic impacts of the Expansion Project at Olympic Dam. Any profitable expansion at Olympic Dam will create additional jobs directly and indirectly in South Australia and perhaps other parts of Australia. Other economic impacts take the form of increases in the gross state product of South Australia, the national gross domestic product, consumption, exports, and payments to government in the form of taxes and royalties. An assessment of the economic impacts of various phases of the Expansion Project is presented.

13.1 EXISTING ECONOMIC STRUCTURE

Olympic Dam is located in the Roxby Downs Statistical Local Area, in the Northern Statistical Division, in South Australia (see Section 12.2 and Figure 12.1). The discussion in Chapter 12 illustrates that the economic structure in the local region of Roxby Downs differs from the average conditions in South Australia in that:

- the labour force participation rate is high
- the unemployment rate is low
- household income is high.

Olympic Dam has brought employment and a comfortable lifestyle to people living in the township of Roxby Downs—in fact, the township and the economic activity in the Roxby Downs Statistical Local Area exist because of the Olympic Dam operations.

To put the economic impacts of the proposed Olympic Dam expansion into a wider perspective, Tables 13.1 and 13.2 illustrate how Roxby Downs differs in its economic structure from the Northern Statistical Division and South Australia, while showing the greater similarity between the Northern Division and the State as a whole.

The Northern Statistical Division has lost population over the period 1991–1995. The unemployment rate is higher than the State level. In March 1996, the unemployment rate was high at 12.5%. There are slightly more households in the lowest income bracket, and fewer in the highest income bracket, than for South Australia as a whole.

The dominant industries providing employment in the region are community services, manufacturing, and the wholesale and retail trades. The Northern Statistical Division has a higher proportion of its population employed in the primary industries of agriculture and mining than South Australia as a whole.

The centres of Port Pirie, Port Augusta and Whyalla have all lost population and have been experiencing high rates of unemployment in the 1990s, as illustrated in Table 13.3.

The South Australian economy has experienced high rates of unemployment and fluctuating rates of growth since 1990, as shown in Table 13.4. Except for 1991, unemployment has been higher than the national average. Economic growth, measured as increases in gross state product (GSP), has generally been below the national rate of growth, measured as increases in gross domestic product (GDP), for the years 1990–91 to 1994–95.

Table 13.1 Population, employment and household income

Indicator	Roxby Downs Statistical Local Area	Northern Statistical Division	South Australia
POPULATION			
Resident population 1991	2,353	88,594	1,446,299
Resident population 1995 (est.)	2,655	83,653	1,473,966
Percentage change 1991–95	+12.0%	–5.5%	+1.9%
LABOUR FORCE (% of persons in labour force)			
Employed 1991	97.1	86.9	88.3
Unemployed 1991	2.9	13.1	11.7
Unemployed March 1996	1.5	12.5	10.1
HOUSEHOLD INCOME 1991 (% of households)			
$0 to $25,000	6.5	50.7	47.7
$25,001 to $50,000	36.6	34.2	34.2
$50,001+	56.9	15.1	18.1

Source: Australian Bureau of Statistics 1993; Department of Employment, Education, Training and Youth Affairs, various years.

Table 13.2 Employment in industries, 1991

Industry sector	Employed in labour force		
	Roxby Downs Statistical Local Area (%)	Northern Statistical Division (%)	South Australia (%)
Agriculture, forestry, fishing	0.0	9.0	5.9
Mining	46.9	5.1	0.7
Manufacturing	9.2	17.6	16.0
Electricity, gas, water	0.0	2.8	1.3
Construction	5.9	4.9	5.4
Wholesale and retail trade	9.8	15.0	20.0
Transport and storage	2.9	7.0	4.1
Communication	1.1	1.3	1.6
Finance, property and business services	5.9	5.7	10.6
Public administration and defence	1.1	3.8	5.3
Community services	9.1	21.0	21.7
Recreation, personal and other services	8.0	6.9	7.3
TOTAL	**100.0**	**100.0**	**100.0**

Source: Australian Bureau of Statistics 1993.

Table 13.3 Population and unemployment rate—major centres, Northern Statistical Division

Year	Port Pirie		Port Augusta		Whyalla	
	Population	Unemployment rate[1]	Population	Unemployment rate[1]	Population	Unemployment rate[1]
1991	15,011	11.4	15,234	9.2	26,382	10.0
1992	14,898	15.1	15,058	12.1	25,796	12.9
1993	14,830	13.1	14,759	11.0	25,017	11.6
1994	14,671	16.8	14,561	13.7	24,649	13.8
1995	14,531	11.7	14,402	9.0	24,228	9.2
1996	n.a.	19.5	n.a.	13.4	n.a.	14.2

1 *Rate at June in all years except 1996, where it is at March.*
n.a. Not available.
Source: Australian Bureau of Statistics, Department of Employment, Education, Training and Youth Affairs, various years; Kinhill Economics estimates.

Table 13.4 Economic growth and unemployment rates, South Australia and Australia

Period	Economic growth (%)		Unemployment rate (%)		
	South Australia, increase in GSP	Australia, increase in GDP	June quarter	South Australia	Australia
			1990	6.9	6.5
1990–91	1.0	2.6	1991	9.5	9.5
1991–92	1.4	2.5	1992	11.9	10.6
1992–93	4.8	4.8	1993	10.8	10.7
1993–94	5.7	5.4	1994	10.4	9.8
1994–95	3.8	5.6	1995	9.8	8.2
			1996	9.1	8.4

Source: Australian Bureau of Statistics, Department of Employment, Education, Training and Youth Affairs, various years.

The major sources of employment in South Australia, by industry sector, are community services, the wholesale and retail trades, manufacturing, and finance, property and business, each of which provides over 10% of employment (Table 13.2). Agriculture directly provides 5.9% of employment and also supports food, beverage and tobacco manufacturing.

The mining sector in 1994–95 contributed value added, or net output, of $564 million (1.9% of GSP) and employment for 3,725 persons (0.6% of the workforce). The mining industry was also important in providing resources for downstream processing which accounted for value added of $1,500 million (4.4% of GSP) and employed over 19,000 people (2.9% of the workforce) (Wittwer 1996). The mining activities at Olympic Dam are classified in the mining sector, while the processing to metals is a manufacturing activity, which contributes to economic diversification in northern South Australia.

The impacts of the Expansion Project on the economy of the Roxby Downs Statistical Local Area would include an increase in the number of people enjoying the above-average conditions of high employment and incomes. The consequences in terms of satisfaction and community services are discussed in Chapter 12.

The injection of more direct employment, and its flow-on effects, into the Northern Statistical Division could compensate for losses in population and employment experienced in recent years. However, the economic model that was used to identify the economic impacts of the Expansion Project (Section 13.2) does not enable estimates of employment for the Northern Statistical Division to be separated from the total for South Australia (refer to Appendix O).

At a minimum, the Northern Statistical Division would benefit from the direct and indirect employment supported in the Roxby Downs township, as calculated in Chapter 12. Some additional regional employment would be supported through use of electricity, transport, and services. The economic impacts of the Expansion Project at the State and national levels are modelled and discussed in the remainder of this chapter.

The stated policy of WMC for the Expansion Project is to utilise South Australian services and labour as far as is reasonably practicable. Technical and quality considerations, and the ability to deliver on time and within a tight schedule, would also be taken into account. Interstate and overseas organisations engaged on the project would be encouraged to open South Australian offices or to establish arrangements with South Australian companies.

WMC reports that more than 70% of the $1.1 billion already spent on Olympic Dam has been expended directly in South Australia. In the economic modelling, estimates of the direct expenditure were separated into three categories: within South Australia, in the rest of Australia, and imports.

13.2 MODELLING ECONOMIC IMPACTS

Economic modelling (Appendix O) was used to provide estimates of economic impacts and measures of economic benefits. A distinction needs to be made between economic impacts and net economic benefits. The economic impacts of a change such as the Expansion Project may be experienced as changes in a number of indicators of economic activity, including employment, GDP, prices, exports and imports.

Computable general equilibrium (CGE) modelling as used for this EIS is able to estimate the magnitude of change in a range of economic indicators at State and national levels, and also the distribution of changes between States. CGE modelling also takes account of linkages in the economy and allows the net impacts of changes to be predicted, which is important information for decision makers.

Measures of the net economic benefits of a project would need to take into account all its market and non-market benefits and costs. It is difficult to place dollar values on all non-market social and environmental impacts of proposals, and this is a limitation on producing a comprehensive cost–benefit analysis. The approach generally taken in environmental impact assessment is to describe impacts in their own terms, and leave it to decision makers to compare beneficial and adverse impacts.

Economic impact analysis provides a range of different measures of economic impact that may be used. If it is necessary to choose one economic measure to represent the benefit of economic activity, the chosen measure should represent the change in welfare predicted from the proposal. The value of the change in national consumption (GDP minus investment) generated using CGE modelling is proposed by some economists to be a measure of welfare (Access Economics 1996). The South Australian Centre for Economic Studies argues that the more satisfactory measure of welfare in its CGE model is change in real GDP (Appendix O). Estimates of both indicators are provided. Whichever position is correct, neither indicator comprehensively embraces all economic benefits and costs, including any non-market ones, of the project.

13.2.1 Economic model

Model methodology

For the Expansion Project, the CGE model FEDERAL–SA has been used to estimate the impacts on the South Australian and Australian economies of two expansion phases:

- first phase expansion, with construction commencing in 1997, with production increasing from 85,000 t/a of copper, plus associated products, initially to 150,000 t/a and increasing to production of 200,000 t/a of copper, plus associated products, in the year 2000.

However, it should be noted that WMC is implementing an accelerated construction programme which should shorten construction to two years;

- possible future second phase expansion, with construction commencing in 2008, increasing production from 200,000 t/a to 350,000 t/a of copper, plus associated products, in the year 2010. This assumes that the possible future expansion to 350,000 t/a copper is approved by the WMC Board.

In this model, the economic impacts of the first expansion phase are estimated by comparing the expenditure and output of the expansion modelled against a 'base case' of 1996–97. The results reported for all economic indicators are therefore the change from the base case. This is an important point to keep in mind in considering the results of the modelling. Information on revenue, expenditure and taxes paid in 1995–96 is included in Chapter 1 (Table 1.3) and current employment is detailed in Chapter 12. The base case (Table 13.5) does not differ significantly from these values. The economic impacts of the possible future expansion to 350,000 t/a are estimated as the change from a typical year of operation at 200,000 t/a.

Table 13.5 Characteristics of current Olympic Dam operations—base case estimated, 1996–97

Item	Annual value
Production of copper	85,000 t/a
REVENUE	
Annual sales (estimated)	$350 million
Annual exports (estimated)	$270 million
TAXES	
Royalties	$10 million
Payroll tax	$3.5 million
PAYE tax	$20 million
Employment[1]	946 people

1 Includes Olympic Dam workforce of 895 people and the 51 Copper Uranium Division staff in Adelaide. Excludes Olympic Dam Expansion team.
From Table 12.4.

The impacts of the construction and operational phases of the two expansion phases (to 200,000 and possible future 350,000 t/a of copper) are modelled separately. This recognises that the construction phases will be short-term and will have very different inputs and outputs from the operational phases. It is important to recognise that the construction phases require large investments, but that the resulting returns in terms of output of metals are not included in these phases. Imports are required in construction, while the operational phases produce exports. The construction phases draw upon, and have the largest impacts on, the service sectors. The operational phases produce outputs, in the form of metals, from the manufacturing sector.

The economic modelling was undertaken by the South Australian Centre for Economic Studies (SACES), using FEDERAL–SA. This model contains two 'regions', South Australia and the rest of Australia, and each region contains sixty-five individual industry sectors. CGE models trace the effects of a 'shock' (a change in inputs or outputs) on individual economic sectors and on the economy as a whole. They differ from the input–output models sometimes used in this type of analysis in that they can vary prices and constrain the productive capacity of the economy.

CGE models portray the links between sectors in terms of how inputs and outputs flow between sectors and regions. The model is also able to simulate price changes that arise because of competition for resources, or the effect of any change in exports or imports on the exchange rate.

Model results

CGE models provide information about the effect of a shock on a number of indicators, including employment, real GSP at the State level, and real GDP at the national level. An increase in GSP or GDP may signify economic growth, a positive economic impact, which has taken into account changes in price (indicated by movements in the consumer price index, or CPI) and the net impact of any contraction or expansion of individual sectors in the economy resulting from the modelled shock.

An increase in real GSP for South Australia is therefore an indication of positive economic impacts for the State. It is possible for the GSP for South Australia to increase and for the combined GSP for other States and Territories to fall. In such a case, it would be necessary to establish whether national GDP experiences a rise or a fall to determine whether the national economic impact is positive or negative.

Of the other economic indicators in CGE models, consumption, the balance of trade and government revenue have been selected for discussion in this chapter. The balance of trade indicator measures the net effect of changes in exports and imports due to the shock. The operational phase of the expansion would earn considerable export revenue but the net effect on the balance of trade may be smaller because of the increase in export revenue creating demand for more imports.

Impacts on public revenue include the taxes and royalties that accrue to government. These are represented in terms of changes in public sector borrowing requirement (PSBR), that is, the increases or decreases in government borrowings to provide the current level of services. The State Government earns royalties from WMC, payroll tax for those employed directly and indirectly because of the project, as well as other State taxes. The Commonwealth Government collects personal income tax, company tax and other Commonwealth taxes.

Information on the modelled impacts of the Expansion Project on other indicators, including private investment, returns to capital, returns to labour and the consumer price index, is included in Appendix O. These indicators provide supporting detail for the impacts represented in the changes to GSP and GDP.

Model constraints

The structure of the model allows for different assumptions (referred to as 'closures') to be made about the behaviour of key economic values. Therefore some variables (generally capital or labour, or both) can be varied within a simulation or constrained to a given total level. If a variable is constrained, the model will simulate competition for this resource, resulting in price rises that may have implications throughout the economy. In the short time period for the construction phases, the model assumes that capital is constrained. In the longer term operational phases, the capital constraint is lifted.

It is common in CGE models to treat the employment rate as fixed, allowing wages to vary. However, in periods of high unemployment, it is logical to lift the constraint, allowing employment to vary. One approach in modelling the Expansion Project has been to constrain national employment, but to lift the constraint on employment in South Australia.

The results are predicted increases in employment in South Australia for both the construction and operational phases of the expansion. Because the national increase in employment is set at zero, an increase in South Australia is at the expense of jobs in other States. These are considered to be the lowest estimates of the employment that is likely to be created.

If the national constraint is lifted, the model predicts that there will be additional jobs created in Australia. SACES advises that lifting the national constraint altogether may overestimate job creation in the operational phases, so the results are not reported here. However, a partial lifting of the national employment constraints yields some indication of how jobs would be distributed between South Australia and other States. For example, for the operational phases, SACES modelled the distribution of employment if there were 1,500 additional jobs created in Australia, and found that they would be distributed in the proportion of 1,120 in South Australia and 300 in the rest of Australia, a ratio of around 3 to 1.

SACES advises that the model results for South Australia are based on calibrating the model with empirical results from Western Australia for the responsiveness of job creation to economic growth and mining activity over the decade from 1985; the model results for the rest of Australia are not calibrated with such empirical data.

13.2.2 Investment, employment and timing

The Expansion Project plan to expand production to 200,000 t/a of copper in the first phase of the expansion requires an investment of $1.48 billion over two and a half years commencing in 1997. It is assumed that this expenditure would in the first instance be roughly split between South Australia (65%), the rest of Australia (28%) and overseas (6%). Some of the direct expenditure in South Australia or Australia could ultimately flow on to expenditure outside the State or country. The expenditure in South Australia would be on labour and materials, including prefabrication of construction requirements off site.

The investment required for the possible future expansion to 350,000 t/a production has not been specified in such detail, but has been treated as an equivalent unit cost, with some savings for increased productivity over time. For economic modelling purposes, it is assumed that this second phase of the expansion would require expenditure of approximately $900 million (present-day dollars) over twenty-seven months commencing in the year 2008. In this scenario the plant would be commissioned in the year 2010. The WMC Board has not committed to this possible future expansion at the present time.

The direct employment likely to be supported by an expansion to 200,000 t/a has been detailed in Chapter 12. The construction phase would require a workforce of up to approximately 1,300 people on site for up to two and a half years; however, WMC is implementing an accelerated construction programme which should shorten the construction period to less than two years. The construction strategy involves the maximum possible use of prefabrication off site; thus the construction workforce on site is expected to be similar for the accelerated programme. The operations phase producing 200,000 t/a would support direct employment of up to approximately 1,137 people (made up of 1,076 employees at Olympic Dam and 61 staff in Adelaide).

The potential employment generated by the possible future expansion to production of 350,000 t/a would include employment for up to 1,100 people on site over the construction period of twenty-seven months. The operations phase would be expected to support direct employment of up to approximately 1,647 people (made up of 1,582 employees at Olympic Dam and at least 65 staff in Adelaide).

13.2.3 Metals prices

Estimates of future metals prices are essential inputs to the economic modelling. A discussion of world market trends for copper and uranium is included in Chapter 1. The world demand for copper is expected to increase by around 3.1–3.3% per annum from 1996 to 2001 (Bowman 1996; Haine and Yanishet 1996). In recent years, world mine production of copper has lagged behind consumption growth, resulting in high copper prices.

In 1994, world copper metal production dropped by 1.4%. However, several major new mines, expansions of existing mines, and expansions of smelting facilities have recently come on stream or are planned. Metal production rose by 5.2% in 1995 and by 6.0% in 1996 (Haine and Roarty 1997). It is projected that world production will increase by 25% from 1995 to 2001, with over half the new production coming from new low-cost mines (Haine and Yanishet 1996).

Copper prices averaged US133 cents/lb in 1995 because of a tight market with low inventories. During 1996, prices fell to average US104 cents/lb including a low of US83 cents/lb in a volatile market (Haine and Roarty 1997). The predicted effect of further increases in supply is for continued falls in price to the end of the decade. The Australian Bureau of Agricultural and Resource Economics (ABARE) has projected a nominal price of US92 cents/lb (in 1997 prices) in 2002 (Haine and Roarty 1997). Projections by Bowman of WMC (1996) are for a fall in price to US80 cents/lb in 1998 or 1999, recovering to above US100 cents/lb in the year 2000.

Australia generally ranks in the top third of low-cost producers, behind Indonesia and Chile but ahead of the United States and Canada (Bowman 1996). The first phase expansion of the Olympic Dam operations to produce 200,000 t/a of copper would, according to WMC, result in reduced unit costs of mining and processing. The second phase expansion to 350,000 t/a copper would result in further reductions in unit costs of mining and processing. These gains have been incorporated into the CGE model.

A price of US90 cents/lb (US$2,016/t) is used in the CGE model as the estimated long-term price of copper.

The world market for uranium is undergoing a change in structure that will see greater demand for new production from mines than has been the case in recent years (as discussed in Chapter 1). Opportunities for Australia in the expanding world market for uranium exist because Australia is one of the lowest-cost producers in the world. New mines in Canada, which are expected to be lower in cost than Australia, are likely to provide substantial quantities of uranium for the world market. The effects of increased production will be a reduction in world prices. The prices used in the model reflect these forecasts.

Most uranium is sold under long-term contracts, with prices not made public; however, indicative spot market prices are published. ABARE forecasts that spot prices will increase from the low of US$7.75/lb recorded in 1992 to peak at more than US$17.00/lb in 1998, and to settle at around US$15.50/lb by the end of the decade (Stubbs and Graham 1997). A more conservative long-term price of US$15/lb (US$33.06/kg) is used in the CGE model.

The price for gold used in the modelling is US$13.40/g (US$380/oz) and the price for silver is US17 cents/g (US$5/oz).

13.2.4 Expansion phases modelled

Two phases of the Expansion Project are modelled, and separate construction and operational phases are modelled for each. The first phase is for an expansion to production of 200,000 t/a of copper and associated metals, using ore exclusively from the Olympic Dam mine. In this option, construction would begin in 1997, and copper production would be at 200,000 t/a in 2000. The impacts of the construction and operational phases are compared with the base case of 1996–97 operations.

The second phase, to which the WMC Board has not committed at the present time, is a possible future expansion to 350,000 t/a of copper and associated metals. For economic modelling purposes the proposed timing for this phase is for construction to start in 2008, and for the plant to be commissioned in 2010 and reach full production in 2011. The economic impacts of this phase are compared with a typical year at 200,000 t/a production.

The third option of utilising surplus smelter capacity after expansion to 200,000 t/a production was also considered for economic modelling. This option involves production of a further 85,000 t/a of copper and associated gold and silver (but not uranium), processed from imported concentrates, by continuing to use the existing smelter which otherwise would be closed down. The unit costs of production for this option would differ greatly from the costs for ore mined on site because of the need to purchase concentrates and transport them to the site. As this is only a possible interim arrangement, it was not modelled.

13.3 SOUTH AUSTRALIAN AND NATIONAL ECONOMIC IMPACTS

13.3.1 Expansion to 200,000 t/a of copper—construction phase

In the model for the construction phase of an expansion to 200,000 t/a of copper, capital is constrained. At the national level, additional employment may be constrained to zero (Scenario 1) or it may be unconstrained (Scenario 2). It is considered that Scenario 1 provides a low estimate of impacts and Scenario 2 portrays a high estimate. This is the only option in which the constraint on national employment is lifted, justified in this case because the construction phase is short-term and national unemployment is currently high. Detailed results are given in Appendix O.

In a typical year of the construction phase, direct employment of up to 1,300 jobs translates into between 1,750 jobs in South Australia and no additional employment nationally (Scenario 1) and 2,500 jobs in South Australia with up to an additional 3,000 jobs in other parts of Australia (Scenario 2).

Also in a typical year of the construction phase, the GSP for South Australia increases annually by between 0.4%, or about $120 million (Scenario 1) and 0.5%, or about $150 million (Scenario 2). This increase is lower than the direct investment expenditure for three reasons: firstly because other competing activity in South Australia is displaced by the Expansion Project, secondly because the price increases that this competition induces will reduce the international competitiveness of export-oriented industries, and finally because some equipment for the expansion is expected to be imported. In Scenario 1, the effect of increases in the cost of labour and capital is a decrease in combined GSP for other states of 0.03%, while the impact on GDP is negligible. For Scenario 2, there is a small increase in GSP for the other Australian States of 0.01% and an increase in GDP of 0.04%.

There is projected to be a negative effect on the balance of trade, from the import of equipment and price effects, of $326 million (Scenario 1) to $239 million (Scenario 2). This impact is net of the value of exports of metals from current levels of production continuing while the construction is occurring.

An indication of the overall size and direction of changes to output and exports of the broad sectors of the economy caused by the construction phase of the Olympic Dam expansion can be gained from Tables 13.6 and 13.7.

Because we are modelling a large investment in construction (which at this stage is not offset by expanded mining and manufacturing activity), the main positive impact is on the services sector. Agriculture and mining suffer losses in output while the results for manufacturing are mixed. The net impacts in terms of GSP and GDP, however, are positive.

Table 13.6 Broad sectoral effects, construction phase (200,000 t/a copper), Scenario 1

Industry sector	Change from base case (%)			
	South Australia		Rest of Australia	
	Output	Exports	Output	Exports
Agriculture	–0.43	–0.64	–0.30	–0.53
Mining	–0.34	–0.65	–0.23	–0.35
Manufacturing	–0.07	–0.98	–0.07	–0.71
Services	0.23	n.a.	0.02	n.a.

n.a. Not applicable.

Table 13.7 Broad sectoral effects, construction phase (200,000 t/a copper), Scenario 2

Industry sector	Change from base case (%) South Australia		Rest of Australia	
	Output	Exports	Output	Exports
Agriculture	–0.27	–0.41	–0.16	–0.30
Mining	–0.22	–0.58	–0.13	–0.23
Manufacturing	0.05	–0.60	0.01	–0.43
Services	0.29	n.a.	0.04	n.a.

n.a. *Not applicable.*

The results in terms of PSBR are different for both scenarios. For Scenario 1, the reduction in PSBR for South Australia from this construction phase is estimated at $4 million, but there are increases in the PSBR for other States ($24 million) and the Commonwealth ($98 million) which are due to CPI increases. Scenario 2 results in reduced PSBR for South Australia of $9 million and reductions in other States of $16 million, but an increase for the Commonwealth Government of $32 million.

Summary

The construction phase represents a large expenditure of capital over a short period of up to two and a half years. (The implementation of the two-year schedule would mean that short-term impacts might be marginally larger than have been modelled, but they would also be of a shorter duration.) There would be positive impacts in terms of employment generated and net increases in GSP and GDP. The net effects modelled account for the fact that some other sectors, notably agriculture and mining, may experience contraction because prices are likely to rise.

The employment that would be generated in South Australia is estimated to be between 1,750 and 2,500 jobs, contributing to up to 5,500 jobs in total in Australia. This would be a useful, though relatively short-lived, increase in employment. The estimated increase in GSP at the South Australian level would be almost 0.5%. To place this figure in some context, the annual growth rate in the South Australian economy was 1% in 1990–91 and 1.4% in 1991–92. The impact on GDP would be minor.

The South Australian Government is projected to benefit from a reduced PSBR of up to $9 million. However, if conditions modelled in Scenario 1 were to prevail, governments in other parts of Australia might need to increase their borrowings over this construction period, as would the Commonwealth Government under Scenario 2. The cumulative negative trade balance over the two and a half year construction period would be between $697 million and $815 million.

13.3.2 Expansion to 200,000 t/a of copper—operational phase

The operational phase model is based on a typical year's operation producing 200,000 t/a of copper and associated products. In this case, a typical year at full production, from the year 2001 onwards, is compared with the base case of 1996–97. While there is some annual capital investment, it is minor compared with the construction phase. The output of processed metals and their export (affecting the exchange rate) are the major sources of impacts.

Capital is not constrained and price effects are therefore less than for the construction phase. The unemployment rate is held at a constant level in the rest of Australia and unconstrained in South Australia, and the model can then identify whether a flow of people into South Australia is likely.

Total direct employment in mining and processing and in support staff in Adelaide in the operational phase is expected to be 1,137. This is 191 jobs above the number modelled in the base case. The total number of additional jobs in South Australia predicted in the model is 1,100, which includes the additional direct employees at Olympic Dam and in Adelaide, the indirect employees living in Roxby Downs (as discussed in Chapter 12) and flow-on employment in South Australia. No additional jobs are predicted for the rest of Australia because labour at the national level is constrained in the model.

The impact on GSP is an estimated increase of 0.4%, or $115 million, in value added annually to South Australia. At the national level the increase in GDP is projected at 0.1%, or $340 million. These estimates are considered to be the 'low' estimates of GSP and GDP because there may be reductions in unit cost of operation in the future for a number of reasons. However, as the proportion of national income earned from raw materials has been declining historically, continuation of this trend may offset any effects of overstating costs in the model.

The additional revenue likely to be earned from the sale of metals is about $320 million per annum. Assuming this is all export earnings, the net effect of the expansion on the balance of trade is positive at $96 million per annum (see Section O.3 and Table O.7, Appendix O). The combined effect on the broad sectors of the economy of price rises and exchange rate appreciation due to higher exports is shown in Table 13.8. In South Australia, agriculture is negatively affected by exchange rate appreciation, which decreases demand for exports, and by price changes. Commodity outputs and exports by agriculture and mining from the rest of Australia are also negatively affected by price and exchange rate impacts, dampening the net positive impacts from the operational phase.

Table 13.8 Broad sectoral effects, operational phase (200,000 t/a copper)

Industry sector	Change from base case (%)			
	South Australia		Rest of Australia	
	Output	Exports	Output	Exports
Agriculture	–0.26	–0.46	–0.26	–0.36
Mining	2.43	3.21	–0.55	–1.14
Manufacturing	0.64	1.94	0.19	1.31
Services	0.22	n.a.	0.04	n.a.

n.a. *Not applicable.*

The impacts on public revenue in South Australia include additional royalties of $12 million and payroll tax ($3 million), contributing to a total decrease in PSBR of $19 million. The PSBR of other State governments is reduced by a total of $10 million. The Commonwealth Government PSBR is reduced by $2 million.

Summary

The economic impacts of operating the mine and processing plant to produce 200,000 t/a of copper and associated metals would occur each year over the projected life of production at that level. Additional employment of 1,100 jobs in South Australia is predicted, and this is the low estimate of job creation. The impact on GSP would be almost 0.4%, which would actually mean a slight drop in GSP after the construction phase but would represent an ongoing addition to production in South Australia when compared with the base case. The negative effects on agriculture would not be large enough to reverse the increases in GSP projected for the expansion, but would need to be recognised as likely to occur.

At the national level, the operational phase of the expansion would have a small net positive effect on GDP, after losses to agriculture and mining. The annual balance of trade effect would be positive, but it could take up to eight and a half years for the deficit predicted for the construction phase to become a net positive trade balance because of the expansion.

13.3.3 Expansion to 350,000 t/a of copper—construction phase

The economic impacts reported here are the changes due to the construction phase for possible future expansion to 350,000 t/a copper from production at 200,000 t/a, which will continue during construction. In the model for this phase, capital is constrained. Only Scenario 1 for labour is modelled for the construction phase (Section 13.3.1) which assumes that additional employment is constrained to zero at the national level. This approach was chosen on the basis that expansion to 350,000 t/a occurs further into the future and unemployment might not be as high as at present. Thus, modelling Scenario 2, for unconstrained employment in the State and nationally, might not be realistic. The results should therefore be interpreted as the low estimate of employment that could be generated.

The construction phase is modelled to occur over twenty-seven months at a total investment of about $900 million. The number of jobs in South Australia is predicted to increase by 1,240, with no additional jobs in the rest of Australia. GSP in South Australia increases by 0.3%, or $87 million. There is a slight negative impact on GSP in the other States of –0.03% but, overall in Australia, GDP shows no change.

The annual balance of trade is negative at –$224 million because of the import of equipment for the expansion, as well as price effects. An indication of the overall size and direction of changes to output and exports of the broad sectors of the economy caused by further expansion to 350,000 t/a copper production at Olympic Dam is shown in Table 13.9. The service sector in South Australia expands during the construction phase, while agriculture, manufacturing and mining contract.

Table 13.9 Broad sectoral effects, construction phase (350,000 t/a copper)

Industry sector	Change from base case (%)			
	South Australia		Rest of Australia	
	Output	Exports	Output	Exports
Agriculture	–0.28	–0.42	–0.20	–0.35
Mining	–0.18	–0.20	–0.15	–0.22
Manufacturing	–0.11	–0.88	–0.04	–0.54
Services	0.16	n.a.	0.01	n.a.

n.a. *Not applicable.*

The impact on government revenue is a decrease in PSBR in South Australia of $1 million, but an increase in PSBR for other State and Territory governments of $16 million and an increase of $65 million for the Commonwealth Government.

Summary

The estimate of employment generated, of an additional 1,240 jobs, is the low estimate. The impact on South Australia's GSP would be positive and on GDP negligible, but some (albeit very small) contraction in other States may result. The predicted annual balance of trade deficit of $224 million reflects the need for equipment to be imported for the expansion. Over two and a quarter years, the total negative effect on the balance of trade could be up to $504 million.

13.3.4 Expansion to 350,000 t/a of copper—operational phase

The economic impacts reported here are those for a typical year of additional production of 150,000 t/a of copper and associated products above the 200,000 t/a level. In the model of the operational phase for the possible future expansion to 350,000 t/a, capital is not constrained. Labour is assumed to be constrained at the national level, making the results the low estimate of employment generation.

The number of additional direct jobs at Olympic Dam and in Adelaide is estimated to be 510. These are included in a total of 1,190 additional jobs in South Australia as predicted by the model for a typical year of operation producing 350,000 t/a of copper. The GSP for South Australia increases by almost 0.5% ($138 million), and GDP by 0.1% (around $468 million). Additional revenue generated from the sale of metals is approximately $400 million per annum. The net effect on the balance of trade is an improvement of $124 million.

The combined effect, on the broad sectors of the economy, of price rises and exchange rate changes due to higher exports is shown in Table 13.10. Negative impacts on agriculture occur for South Australia and the rest of Australia from price increases and appreciation of the exchange rate. Mining in the rest of Australia contracts for these same reasons.

Table 13.10 Broad sectoral effects, operational phase (350,000 t/a copper)

Industry sector	Change from base case (%)			
	South Australia		Rest of Australia	
	Output	Exports	Output	Exports
Agriculture	–0.19	–0.73	–0.16	–0.54
Mining	2.16	7.22	–0.28	–1.72
Manufacturing	0.57	4.23	0.09	2.07
Services	0.16	n.a.	0.03	n.a.

n.a. Not applicable.

For South Australia, annual royalties increase by $17 million and the State's PSBR decreases by $18 million. States in the rest of Australia reduce their combined PSBR by $19 million and the Commonwealth Government's PSBR increases by $8 million.

Summary

Operations at the level of 350,000 t/a would create at least 1,190 additional jobs and support them for the life of that production. The predicted 0.5% increase in GSP would be significant in terms of the South Australian economy. The positive balance of trade of $124 million per annum would offset the negative effect during the construction phase in about four years.

13.4 SUMMARY OF ECONOMIC IMPACTS

The Olympic Dam copper and uranium operations are a valuable component of the South Australian economy, with direct employment at June 1996 of 895 people at Olympic Dam and fifty-one in Adelaide, and an estimated indirect local employment at Roxby Downs of 269 to 358 people. By December 1996, direct employment at Roxby Downs had risen to 963 people. The additional flow-on employment in South Australia from the current operations has not been estimated. The benefits of the mine are optimised by processing the ore from this rich deposit to a higher valued metal product in the operations. Without the Olympic Dam operations, the northern region of South Australia would be experiencing even greater economic and social difficulties.

The economic impacts of the first phase of the Expansion Project to 200,000 t/a of copper would include those from the construction phase, lasting approximately two and a half years, and the operational phase, here projected to last until 2010, at which time additional production would come on stream. The predicted impacts from construction would be up to 2,500 jobs in South Australia, 5,500 jobs in Australia as a whole, and increases in the South Australian GSP of nearly 0.5%. In the operational phase, the number of additional jobs supported would be at least 1,100 (located in South Australia), and the contribution to GSP over this longer term would be 0.4%. The employment generated in South Australia would be valuable since the State is experiencing higher unemployment than the national rate. A steady addition to GSP would also be valuable. Mine operation would generate considerable export revenue and an overall positive net impact on Australia's balance of trade.

The additional impacts of increasing production from 200,000 t/a to a possible future level of 350,000 t/a, with construction commencing in 2008, have been reported. This phase of the expansion requires a smaller absolute investment and smaller investment for a typical year of construction. The construction phase therefore results in smaller increases in employment and GSP, and a smaller negative effect on the balance of trade, than the first phase of expansion. The increases in employment and GSP for the two and a quarter years are nevertheless useful contributions to the South Australian economy.

The results reported for the operational phase of the second phase of possible future expansion to 350,000 t/a are the impacts of the additional 150,000 t/a of production. This increase in production is larger than the first phase of expansion, and an increase in productivity has been projected. The employment supported in a typical year is 1,190 people in South Australia. The additional contribution to GSP of 0.5% is significant. The overall balance of trade effect is positive.

The low estimate of additional employment supported by the Expansion Project, in a typical year of operation after the year 2011 when production is 350,000 t/a, is 2,290 people in South Australia. Changes in selected indicators are summarised in Table 13.11.

Table 13.11 Selected indicators for a 'typical year'

Phase	South Australian impacts			National impacts		
	Jobs	GSP (% change)	PSBR ($ million)	GDP (% change)	Project exports ($ million)	Balance of trade ($ million)
FIRST EXPANSION PHASE TO 200,000 t/a						
Construction phase	+1,750 to 2,500	+0.4 to 0.5	–4 to –9	0 to +0.04	n.a.	–239 to –326
Operational phase	+1,100	+0.4	–19	+0.1	+320	+96
SECOND EXPANSION PHASE TO 350,000 t/a						
Construction phase	+1,240	+0.3	–1	0	n.a.	–224
Operational phase	+1,190	+0.5	–18	+0.1	+400	+124

n.a. Not applicable.

The changes in GSP (or GDP) and consumption are considered to be measures of economic benefit—although incomplete ones because they do not incorporate any changes in non-market values. The substantial additions to GSP, GDP and consumption for typical years of operational phases of the Expansion Project are shown in Table 13.12.

Table 13.12 Increases in GSP, GDP and consumption for a 'typical year' of operation

	First expansion phase to 200,000 t/a ($ million)	Second expansion phase to 350,000 t/a ($ million)
SOUTH AUSTRALIA		
Increase in GSP	115	138
Increase in consumption	50	48
AUSTRALIA		
Increase in GDP	340	468
Increase in consumption	163	218

CHAPTER 14

REHABILITATION AND DECOMMISSIONING

CHAPTER 14

REHABILITATION AND DECOMMISSIONING

This chapter discusses how progressive rehabilitation will be incorporated into operations at Olympic Dam, and provides a conceptual plan for the rehabilitation and decommissioning of the project. It is envisaged that the rehabilitation and decommissioning requirements of the Expansion Project will be met by existing procedures as described below.

14.1 OBJECTIVES

The objectives of the existing rehabilitation programme are to reinstate and revegetate disturbed areas using local indigenous plant species and to ensure the long-term viability of rehabilitated areas. Achieving these objectives involves:

- progressively rehabilitating areas disturbed by operational related activities, once they are no longer required;
- conducting a monitoring programme to quantify the effectiveness of rehabilitation and, if needed, modifying the programme.

Information gained during the ongoing rehabilitation programme and associated monitoring would be used to plan, design and implement future rehabilitation programmes and methods.

In the event of premature closure before all disturbed sites have been rehabilitated, WMC will maintain its rehabilitation programme, including monitoring, to complete all outstanding tasks in the Project Area and to establish the long-term viability of these sites.

14.2 EXISTING REHABILITATION PROCEDURES

Before land disturbance or construction can begin, a written environmental clearance form must be issued by the site Environmental Officer. The clearance sets conditions that minimise the impact of disturbance and thereby facilitate rehabilitation. The conditions may include:

- use of a WMC-endorsed work plan and methods appropriate for the task and the specific site. The plan and methods would form part of the environmental clearance;
- progressive rehabilitation as an integral part of disturbance or construction;
- completion of all rehabilitation earthworks before equipment is removed from the area;
- retention of trees or other vegetation;
- redirection of development to minimise disturbance;
- stockpiling of cleared vegetation, topsoil and, in some cases, clay overburden for reuse on disturbed areas;
- adherence to government regulations and WMC requirements on the removal of rubbish and the prevention or clean-up of any contamination.

Advice from Mines and Energy South Australia (MESA) as well as the intended final land use of the operational area are taken into account when setting rehabilitation goals.

Site categories

Operational areas that require rehabilitation include drill pads, roads, access tracks, water and power supply corridors, embankments, quarries, borrow pits, landfill sites, the tailings retention facility walls and other disturbed areas that are not expected to be used for further activities. The preferred methods are to undertake progressive rehabilitation during construction or to begin rehabilitation immediately following cessation of the disturbance; that is, as an integral part of the planning for the work undertaken.

Disturbed sites can also be placed into one of three broad landform categories: swales, dune bases and dunes. In some cases (e.g. when material has either been extracted or deposited), the rehabilitated landform is different from the original landform. In all cases, the procedure designated both for the broad landform category and for operational use is incorporated into the rehabilitation plan.

All areas disturbed in any significant, adverse way by the Expansion Project would be rehabilitated according to the rehabilitation procedures set out in the environmental clearance or procedures equivalent to those listed in Table 14.1 (at the end of this chapter), and monitored to ensure the completion criteria (i.e. performance indicators) are met before finalisation of the project.

Rehabilitation measures and monitoring

Rehabilitation planning begins before areas are disturbed and is an integral part of the environmental clearance procedures. Existing rehabilitation procedures use both passive and active methods. Passive methods essentially involve leaving the area to regenerate naturally, and are used in small areas of disturbance where nearby plants provide shelter and a source of seed for the area being rehabilitated. Active methods are used where the rehabilitation area is relatively large and requires specific earthworks as well as an additional source of seed and, in some cases, protection from wind and water erosion.

All of the seed used in rehabilitation is collected locally in order to protect the genetic integrity of the local indigenous species. The main swale species targeted is *Atriplex vesicaria*, which is a long-lived perennial plant and the dominant natural component of swale vegetation in drought years. However, seeds of all other species, including *Maireana* spp., *Sclerolaena* spp. and grasses, are collected to give greater species diversity. When an opportunity arises, seeds of species inhabiting the dunes, including *Dodonaea viscosa* subsp. *angustissima*, *Acacia* spp., *Senna* spp., and grass species, are collected.

Monitoring of rehabilitation is carried out annually in spring, and sites that have not responded to treatment are re-treated. The current monitoring programme is summarised in Chapter 15. An area is deemed to have been rehabilitated when 80% of its total vegetation cover of perennials, compared with control sites, has been restored. In addition, 80% of this cover must be provided by the dominant perennial plant species surrounding the disturbed area. After meeting these performance criteria, the area is removed from the annual rehabilitation monitoring programme. To assess long-term progress, a representative, random selection of completed rehabilitated areas is monitored every three years.

14.3 REHABILITATION CONSTRAINTS

WMC staff have identified a number of constraints on the type and extent of rehabilitation that can be successfully undertaken in the Project Area. Climate represents the largest constraint on rehabilitation, with the survival of germinating seeds and seedlings being dependent on the time of year and the amount and duration of rainfall.

Broad-scale rehabilitation based on tree planting is not an option for the site, as the indigenous tree species all require at least two years of rainfall well above average for their establishment. These circumstances occur approximately once or twice every 100 years.

Although it is possible to establish trees with drip irrigation, this is generally impracticable in a region where water is a valuable commodity and water conservation is a major concern. Therefore, irrigation is confined to relatively small areas of amenity tree planting for the purposes of screening, dust barriers, shade and/or aesthetics.

Some disturbed areas naturally have a minimal vegetation cover and require minimal rehabilitation (e.g. some borrow pits developed in gibber plains in the borefield region). In these areas, monitoring vegetation does not provide any indication of rehabilitation success. Consequently, monitoring of landform integrity and stability is required and undertaken.

Due to the acidic nature of the tailings, the type and extent of rehabilitation for the tailings storage facility will be determined by the results obtained from ongoing rehabilitation trials.

Successful rehabilitation programmes undertaken since 1984 include those on drill pad sites (Figures 14.1a, b, c and d), disused access roads and tracks, borrow pits and, most recently, the Borefield B pipeline corridor. Further development of rehabilitation procedures and the continued application of environmental codes of practice will ensure that standards of rehabilitation are either maintained or improved.

After reinstatement, stabilisation and ripping have occurred, seed is usually broadcast by hand at a rate of 5–40 kg/ha depending on a range of factors such as seed viability and site conditions. Small areas usually do not require any seeding once they have been ripped, as they are commonly surrounded by a reliable seed source, and seed blown on to the site by the wind germinates after the first effective rainfall.

During wetter years, seeds from the long-lived *Acacia* spp., including *Acacia papyrocarpa, A. aneura* and *A. ramulosa,* as well as *Callitris glaucophylla* often become available and are collected by hand. These seeds are usually transferred to a nursery for germination and later used in irrigated amenity plantings. However, seeds of these species may also be sown directly at some rehabilitation sites.

14.4 DECOMMISSIONING PLAN

There is an ongoing programme of research into the rehabilitation of operational and disturbed areas. Techniques using vegetation to stabilise and cover slopes, such as the perimeter embankment of the tailings storage facility, will be examined through trials and developed into protocols for inclusion in a decommissioning plan.

Decommissioning the areas managed by WMC will be to a best practice standard, and rehabilitation success will be measured by the development of a self-sustaining state of rehabilitated areas compared with undisturbed communities. Rehabilitated areas will have:

- stable and structurally sound landforms which are protected against accelerated erosion from water and wind;
- landforms that support pre-mining land uses and retain ecological values that, in general, are compatible with the surrounding landscape. The exception to this may be the walls of the tailings storage facility.

Site-specific rehabilitation and decommissioning procedures and completion criteria for the Expansion Project would be developed concurrently with evaluation of the ongoing rehabilitation and monitoring programme. Final rehabilitation procedures and completion criteria would be included in a decommissioning plan that would be submitted to the South Australian Government for approval prior to implementation.

The rehabilitation procedures and completion criteria contained within the decommissioning plan would generally focus on parameters such as vegetation species composition, vegetation density, vegetation cover, likely fauna species composition and abundance, water quality, erosion rates, visual quality and land capability.

A decommissioning plan for all of the Project Area has not yet been developed because of the very long operational periods involved and the desirability of including within the plan the results of ongoing research into rehabilitation procedures. However, as a minimum, on completion of the mining and processing operations, all buildings and support facilities and debris would be removed and all of the disturbed areas rehabilitated as described above. Natural drainage lines would be reinstated. Due to the cost of reclamation and the amount of disturbance required to remove them, below-ground mine installations that could not be salvaged would remain in place.

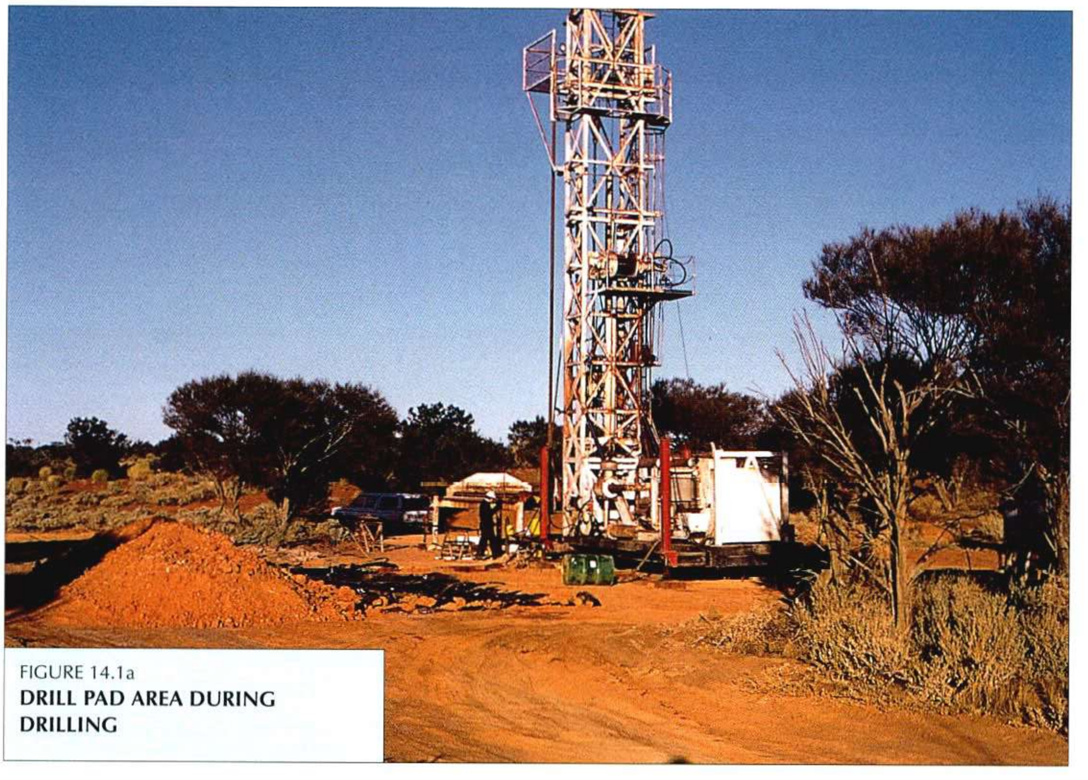


FIGURE 14.1a
DRILL PAD AREA DURING DRILLING

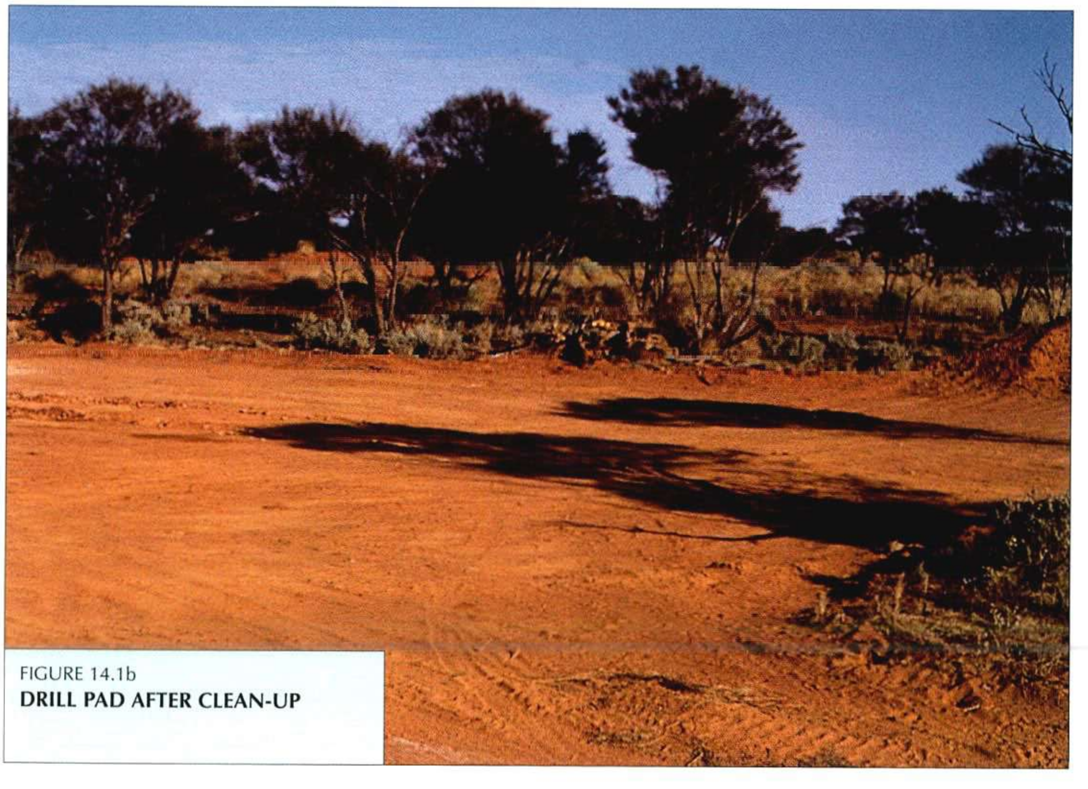


FIGURE 14.1b
DRILL PAD AFTER CLEAN-UP

FIGURE 14.1c
DRILL PAD AFTER EARTHWORKS

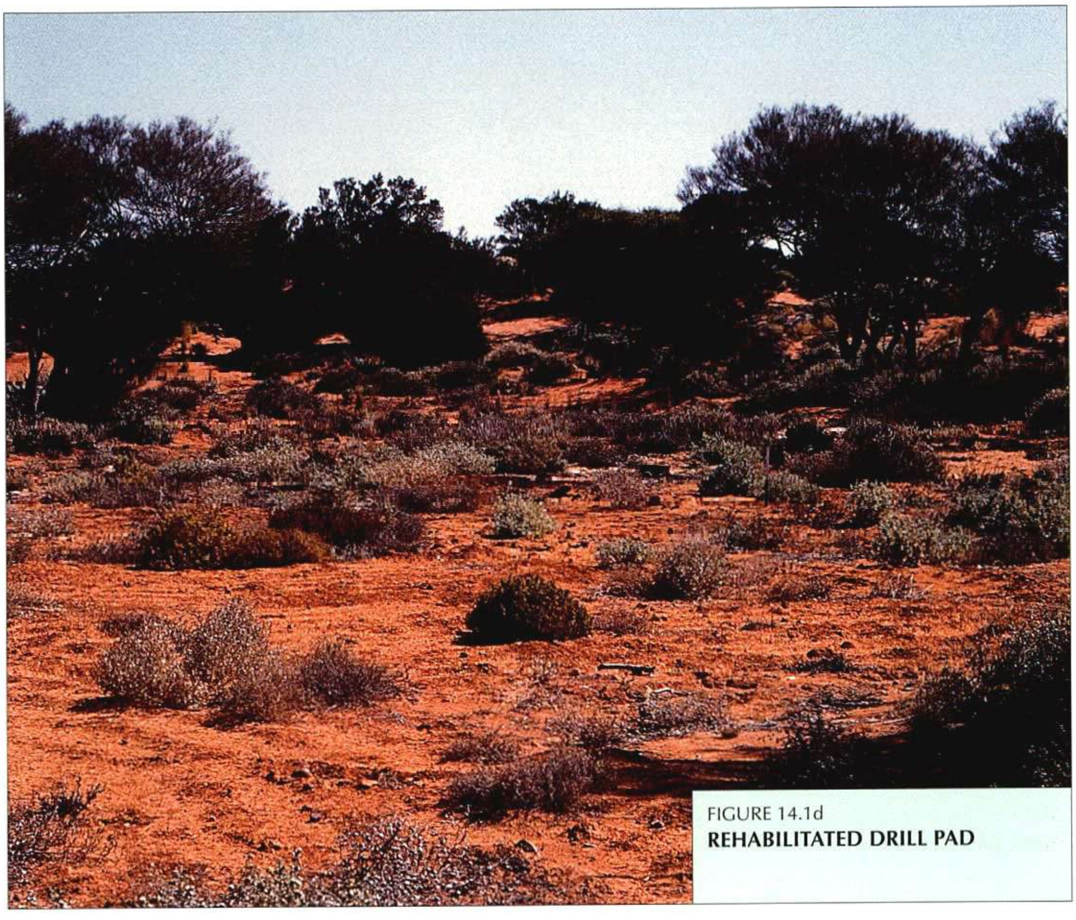


FIGURE 14.1d
REHABILITATED DRILL PAD

Table 14.1 Rehabilitation procedures

Component	Rehabilitation procedures
Swales and other flat areas	Rehabilitation method: Passive/active • Clean up site. • Reinstate contours and drainage. • Surface rip clay soils. • Seed areas that have few adjacent shrubs; in areas surrounded by relatively dense vegetation, allow windblown seed from adjacent shrubs to revegetate the area following rainfall.
Dune base	Rehabilitation method: Passive/active • Clean up site. • Reinstate contours and drainage. • If required, remove any clay or limestone rubble bases that have been placed over the sandy soils for operational activities. In general, deep rip or surface rip the area to break up any remaining hard layers. • Do not rip sandy soils unless specifically required. Note: Red duplex soils should be ripped only to the depth of the underlying limestone. In general, a grader is suitable for this task. • Sow seeds in most areas. Note: Seeding is generally not required if area is small and/or surrounded by relatively dense chenopod shrubland.
Dunes	Rehabilitation method: Active • Clean up site. • Stabilise dune cuttings where required immediately after construction of roads and tracks. • Reinstate contours and natural drainage. • If required, remove any clay or limestone rubble bases that have been placed over the sandy soils for operational activities. Alternatively, shallow rip the area to break up the hard layer. Rip deeply enough to bring up some of the underlying sand. • Do not deep rip sandy soils that do not have hard or compacted layers unless approved in the environmental clearance form. • Reseed.
Camp sites	Rehabilitation method: Passive • Clean up site; rehabilitate areas subject to significant oil or other contaminant spills by ripping and aeration, or excavation, disposal and replacement with clean fill. • Backfill rubbish and sewage pits with a minimum 1 m cover, crowned slightly to provide for water run-off and natural subsidence. • Reinstate original contours and drainage. • Unless on sand, shallow rip sites on the contour and respread any cleared topsoil and vegetation to encourage regrowth.

Objectives	Maintenance/monitoring	Reporting/auditing/review
• Reinstate to original profile. • Rehabilitate as soon as area is no longer required.	• Conduct annual vegetation monitoring until performance completion criteria are met; thereafter, triennial monitoring of a random selection of representative areas. • Control proclaimed plant species. • Carry out further work as required by the monitoring process.	• Recommend any further rehabilitation or monitoring. • Record rehabilitation on specified form and database. • Report rehabilitation in annual EMMP report.
• Reinstate to original profile. • Rehabilitate as soon as area is no longer required.	• Conduct annual vegetation monitoring until completion criteria are met; thereafter, triennial monitoring of a random selection of representative areas. • Control proclaimed plant species. • Carry out further work as required by the audit process.	• Include assessment of rehabilitation in on-site and corporate monitoring reports. • Recommend any further rehabilitation or monitoring. • Record rehabilitation on specified form and database. • Report rehabilitation in annual EMMP report.
• Reinstate to original profile. • Rehabilitate as soon as area is no longer required. • Limit erosion.	• Conduct annual vegetation monitoring until completion criteria are met; thereafter, triennial monitoring of a random selection of representative areas. • Control proclaimed plant species. • Monitor surface stability. • Carry out further work as required by the audit process.	• Recommend any further rehabilitation or monitoring. • Record rehabilitation on specified form and database. • Report rehabilitation in annual EMMP report.
• Reinstate to original profile. • Rehabilitate as soon as area is no longer required. • Loosen compacted soil. • Limit erosion.	• Conduct vegetation monitoring until completion criteria are met. • Control proclaimed plant species. • Rectify any subsidence or erosion that occurs. • Carry out further work as required.	• Recommend any further rehabilitation or monitoring. • Record rehabilitation on specified form and database. • Report rehabilitation in annual EMMP report.

Table 14.1 Rehabilitation procedures (continued)

Component	Rehabilitation procedures
Drill pads, exploration lines, pipelines, roads and access tracks	Rehabilitation method: Active
	• Clean up site. • Remove any imported material (e.g. bitumen and road base) from the drill pads, roads or access tracks. • In areas of deeply compacted material, such as limestone or clay, remove material and reduce compaction by deep ripping to a depth of 500–900 mm; if no material added or not compacted, rip to a depth of 200–300 mm. • If necessary, add a clay layer (100 mm) to the surface of older, limestone drill pads. • Backfill trenches with crown 200–300 mm high; roll; break at regular intervals to prevent ponding and longitudinal rill or gully erosion, except in sand where the original profile should be restored. • Where necessary, construct erosion control banks (e.g. level spreaders) to prevent erosion. • Plug drill holes using a concrete cone plug buried 300 mm below ground level. • Reinstate contours and drainage for all of the site. • Where practicable, respread topsoil and cleared vegetation. • Stabilise dune cuttings where required immediately after construction. • Seed with locally collected seeds.
Quarries, borrow pits and landfill sites	Rehabilitation method: Passive/active
	• Clean up the site and make it safe. • Backfill with displaced overburden. • Reshape walls ensuring slopes are 20° or less. • Respread topsoil over bare surfaces (in some cases additional soil may need to be imported). • Crown landfill sites to allow for subsidence. • Contour rip surface to a depth of 200–300 mm in clay quarries and borrow pits (some hard areas may need cross-ripping or deep ripping to 500–900 mm). • Where necessary, construct erosion control banks to minimise erosion of backfill material. • Seed large areas, particularly where topsoil and previously cleared vegetation are not available.

Objectives	Maintenance/monitoring	Reporting/auditing/review
• Reinstate to original profile. • Rehabilitate as soon as area is no longer required. • Loosen compacted soil. • Limit erosion.	• Conduct annual vegetation monitoring until completion criteria are met; thereafter, triennial monitoring of a random selection of representative areas.	• Recommend any further rehabilitation or monitoring. • Record rehabilitation on specified form and database. • Report rehabilitation in annual EMMP report.
• Rehabilitate progressively when specific areas are no longer used. • Remove compaction. • Limit erosion. • As far as practicable, design areas to shed water or be free draining. Note: Not practicable for quarries.	• Conduct annual vegetation monitoring until completion criteria are met; thereafter, triennial monitoring of a random selection of representative areas. • Control proclaimed plant species. • Rectify any subsidence or erosion that occurs. • Carry out further work as required.	• Recommend any further rehabilitation or monitoring. • Record rehabilitation on specified form and database. • Report rehabilitation in annual EMMP report.

Table 14.1 Rehabilitation procedures (continued)

Component	Rehabilitation procedures
Vehicle hard stand sites and other large, bare areas	Rehabilitation method: Active • Clean up site. • Reinstate natural drainage. • Reshape any walls (e.g. bunds) to ensure no steep batters remain and recontour any slopes. • Deep rip compacted soils. Shallow rip sandy soils. • Respread topsoil and any vegetation or gibber pebbles over bare surfaces (in some instances additional soil or clay may need to be imported). • Where necessary, construct erosion control banks. • Seed areas, particularly where topsoil and previously cleared vegetation are not available. • Stabilise to minimise wind erosion.
Tailings retention system	Rehabilitation method: Active • Clean up site. • During operation, armour the outer faces of the embankments with an adequate layer of waste rock. If practicable, final outer walls should have a slope of 20° or less. Establish suitable drainage methods and controls. • Conduct trials with various capping and surface layers of different depths. Layers should form an armouring layer against erosion and inhibit evaporation, thus reducing radon emanation. • Slightly dam and contour the clay layer cover to promote rainfall run-off and retention. • Where necessary, construct erosion control banks to prevent erosion. • Conduct rehabilitation trials on the walls of the tailings retention system using topsoil and different armouring materials at different depths. • Conduct rehabilitation trials on tailings retention system walls and surfaces using native grass and chenopod species. Trial direct seeding of the outer walls of the tailings storage facility with a range of chenopod and woodland species.
Evaporation and sewage ponds	Rehabilitation method: Active • Clean up site. • Excavate any deposited salts, synthetic liners, and contaminated clay liners and embankment materials, and place into the tailings storage facility. • Reinstate contours and natural drainage. • Spread remaining embankments evenly over the site and crown to allow for subsidence. • Rip and seed with locally collected seeds of native species.

Objectives	Maintenance/monitoring	Reporting/auditing/review
• Rehabilitate as soon as area is no longer required. • Loosen compacted soil. • Limit erosion.	• Conduct annual vegetation monitoring until completion criteria are met; thereafter, triennial monitoring of a random selection of representative areas. • Control proclaimed plant species. • Rectify any accelerated erosion. • Carry out further work as required.	• Recommend any further rehabilitation or monitoring. • Record rehabilitation on specified form and database. • Report rehabilitation in annual EMMP report.
• Progressively rehabilitate. • Minimise potential for dust and radon emissions. • Provide a permanent stable and non-eroding structure. • Provide a safe structure. • Design facility to be non-polluting, maintenance free and self-sustaining, as well as suitable for desired end land use.	• Rectify any subsidence or accelerated erosion. • Maintain a monitoring programme of groundwater and surface drainage until analytical data indicate this is no longer required. • Maintain silt traps in drainage lines downstream of the facility until no longer needed. • Control proclaimed plant species. • Carry out further work as required. • Monitor and assess the vegetation rehabilitation trials annually and eventually the final rehabilitation procedures.	• Recommend any further rehabilitation or monitoring. • Record rehabilitation on specified form and database. • Report rehabilitation in annual EMMP report.
• Reinstate to original vegetated profile. • Rehabilitate as soon as area is no longer required. • Loosen compacted soil.	• Establish monitoring sites following closure. • Conduct annual vegetation monitoring until completion criteria are met; thereafter, triennial monitoring of a random selection of representative areas. • Control proclaimed plant species. • Rectify any accelerated erosion. • Carry out further work as required.	• Recommend any further rehabilitation or monitoring. • Record rehabilitation on specified form and database. • Report rehabilitation in annual EMMP report.

CHAPTER 15

MANAGEMENT AND MONITORING—ENVIRONMENT AND WORKPLACE

CHAPTER 15 MANAGEMENT AND MONITORING—ENVIRONMENT AND WORKPLACE

This chapter summarises the 1996 Environmental Management and Monitoring Plan; discusses the modifications required to this plan as a result of the Expansion Project; lists scientific research programmes and projects that are being undertaken by WMC, or WMC employees, solely or in collaboration with others; outlines management systems, codes of practice and inductions that would be used during construction for the expansion; describes relevant aspects of occupational health and safety, and risk management and contingency planning; discusses environmental safeguards; and provides a list of the Expansion Project's key environmental commitments.

15.1 ENVIRONMENTAL MANAGEMENT AND MONITORING PLAN

Since operations began at Olympic Dam, environmental management has been guided by the implementation of two documents: the Environmental Management Programme (EMP) and the Waste Management Programme (WMP). As discussed in Chapter 2, these documents have been consolidated since February 1996 into a single Environmental Management and Monitoring Plan (EMMP) (WMC 1996).

Under the Indenture the EMMP is required to be updated every three years, involving government review and approval. It also forms one component of the environmental management system (EMS) used at Olympic Dam. Other components of the EMS include:

- a community consultation programme (described in Section 2.5);
- procedures and systems to ensure that environmental management is incorporated into site activities. These include the environmental clearance form, described in Chapter 14, and environmental codes of practice that are developed for significant construction activities;
- research programmes, described further in Section 15.3, that provide information for continuous improvement of the EMS.

Olympic Dam is currently modifying its EMS so that it is consistent with the principles of the ISO 14000 series. This programme is discussed in Section 15.7. The features of the current EMMP are described below.

15.1.1 Management processes

Environmental management at Olympic Dam is the responsibility of all employees and contractors, as set out in the site's Statement of Environmental Commitment (Section 1.1 and Appendix A). Specific personnel, however, are responsible for monitoring, auditing and reporting environmental performance as well as providing specific environmental advice to management, other employees and contractors.

The management processes used by WMC to maintain its environmental programmes and improve environmental management at Olympic Dam are set out in Table 15.1.

Table 15.1 Existing management processes

Objectives	Action
REPORTING	
• Accurately describe the environment and any positive or negative impacts brought about by operations.	• Compile statutory and site reports on time and ensure their distribution.
• Ensure that site management is correctly and promptly informed of any significant environmental incidents.	• Make available adequate resources to implement corrective action and identify preventive measures to avoid recurrence.
• Ensure that regulatory authorities are correctly and promptly informed of any significant environmental incidents.	• Report openly to all statutory agencies at a frequency dictated by Acts and Regulations.
• Produce timely, accurate and useful information, including analysis of data.	• Establish clear responsibilities to exchange information promptly and accurately with employees, local residents and the wider community on potential environmental impacts.
ENVIRONMENTAL AUDITING	
• Check the level of environmental performance against statutory requirements, WMC policies and previous commitments.	• Conduct regular audits of site activities through: – internal audits – corporate audits – third-party audits of specific topics. • Audit the EMMP process annually, using external auditors.
DATA MANAGEMENT	
• Design and maintain a comprehensive and robust data management system that provides audit trails.	• Develop a database that will clearly show trends in environmental performance.
• Securely store all data for current and future use.	• Establish and maintain an integrated filing and archiving system.
ENVIRONMENTAL TRAINING AND AWARENESS	
• Promote environmental awareness in the Olympic Dam workforce, the residents of the region, and visitors to the operation.	• Compile, update and distribute the environmental handbook, posters and environmental information brochures. Publish articles in the divisional news bulletin and local newspapers. Conduct regular community information sessions on environmental topics of local interest.
• Ensure that all employees and contractors are aware of their environmental responsibilities and are adequately trained to comply with all environmental rules and regulations.	• Provide environmental inductions for all new employees and annual refresher courses for existing employees. Provide specific environmental training to employees whose activities may be significant to the environment, environmental monitoring, or environmental management.
RESEARCH PROGRAMME	
• Understand more fully the natural and operational environments, including infrastructure developments, so that improved methods of monitoring and management of the environmental aspects of the operation can be implemented.	• Publish the results of research in scientific literature. Summarise improved monitoring methods in the EMMP annual report. Following research or monitoring, seek government approval to change the EMMP. Conduct collaborative research with appropriate organisations and individuals.
ASSESSMENT OF NEW DEVELOPMENT	
• Consider information on potential environmental impacts during the design and planning stages of new developments.	• Assess new developments or new activities in undisturbed areas with reference to appropriate internal and external bodies. Ensure that environmental factors, rehabilitation strategies and conservation of habitats, flora and fauna are integrated into new developments or activities. • Obtain an environmental clearance from the Environment Superintendent before undisturbed land is used. Obtain advisory input from the Environment Superintendent during design reviews and routine construction management meetings.

Table 15.1 Existing management processes (continued)

Objectives	Action
ASSESSMENT OF NEW DEVELOPMENT (continued)	
• Ensure that sites of cultural significance are considered in the development process, and that all interested groups are consulted.	• Consult with Aboriginal people and undertake surveys using consulting anthropologists and archaeologists. Complete sign-off procedure with Aboriginal people following surveys.
• Ensure that all appropriate approvals are obtained.	• Prepare documents for government approval for distribution to the appropriate minister.
PREPARATION FOR CLOSURE PROGRAMME	
• Determine the optimum closure and land rehabilitation programme to ensure that regulatory and community needs on these issues are considered.	• Consult with the appropriate authorities and the community in order to finalise closure criteria. Establish rehabilitation trials. Maintain a register and database of land disturbed by operations and subsequently rehabilitated.
• Ensure that all appropriate resources required for successful closure of the operation and rehabilitation of the disturbed areas concerned are available at the time of closure.	• Maintain resource requirements for the closure and rehabilitation programme. Periodically review research literature on rehabilitation and update closure plans accordingly. Progressively rehabilitate area when practicable.
ENVIRONMENTAL EMERGENCY PROCEDURES	
• Minimise the potential for accidents and incidents.	• Conduct regular risk analyses and hazard and operability (HAZOP) studies to identify methods of risk management and mitigation. Ensure employees are trained to identify and act to prevent accidents and incidents and respond appropriately in the event of their occurrence.
• Minimise the potential for reoccurrence of accidents and incidents.	• Maintain a database of incidents and accidents. Continue risk assessments and audits, and maintain management plans. Report events identified to the attention of the Environment Superintendent and other managers as appropriate. Determine and implement remedial action. Notify internal WMC officials and the relevant government agencies as appropriate.
QUALITY MANAGEMENT SYSTEMS	
• Ensure the Environmental Group activities comply with the requirements of the Quality Management System standard, AS/NZS ISO 9002:1994.	• Continue implementation of the requirements of AS/NZS ISO 9002:1994. Continue compliance with the Copper Uranium Division—Commitment to Quality and the principles of quality management systems.

15.1.2 Management programmes

Environmental management and monitoring programmes for the project include meteorology, waste management, hydrogeology, airborne emissions, environmental radiation, vegetation, rehabilitation, fauna, borefields (including the mound springs), and community consultation and heritage issues. Table 15.2 provides a summary of the objectives, strategies and monitoring for each of these areas.

Table 15.2 Existing environmental management and monitoring programmes

Objectives	Strategies and actions	Monitoring
METEOROLOGY MONITORING		
• Provide high quality data in an appropriate format.	• Monitor meteorological conditions.	• Wind speed, direction. • Stability category. • Rainfall. • Evaporation. • Solar radiation. • Humidity. • Barometric pressure.
WASTE MATERIALS MANAGEMENT		
TAILINGS STORAGE FACILITY		
• Contain solids securely.	• Provide optimum design and engineering of the structure. Provide effective plans for rehabilitation.	• Geotechnical parameters of foundations and consolidated tailings.
• Minimise seepage.	• Minimise area of supernatant pond. Maximise evaporation and consolidation by subaerial deposition in thin layers.	• Size of supernatant pond. Groundwater level and quality (see Hydrogeology—Special Mining Lease).
• Minimise dust lift-off and radon emissions.	• Minimise surface disturbance to control dust lift-off. Ensure no significant area of tailings is left to dry beyond optimum moisture levels.	• Air quality (see Airborne emissions) and radionuclide concentrations.
EVAPORATION PONDS		
• Minimise seepage and maximise evaporation.	• Provide adequate design and engineering of the structure. • Derive liquor balance.	• Specific gravity of the first and last cells, depth of solids build-up, radionuclide concentration of the first and last cells, groundwater level and quality (see Hydrogeology—Special Mining Lease).
MINE WATER DISPOSAL POND		
• Maximise water reuse.	• Use as much mine water as possible, for example, for dust suppression and mine drilling operations.	• Total water input, surface area, climatic data (see Meteorology), groundwater level and quality (see Hydrogeology—Special Mining Lease).
LANDFILL/SALVAGE AREA		
• Minimise waste.	• Minimise waste by reuse, recycling or salvaging.	
SEWAGE PONDS		
• Maximise effluent use.	• Investigate potential uses of effluent from mine and processing plant.	
HYDROGEOLOGY—SPECIAL MINING LEASE		
• Minimise the quantity of seepage of process liquors into the aquifers underlying the operation.	• Implement management tools to control the processes that might lead to seepage of process liquors. • Manage the tailings storage facility and evaporation ponds to minimise seepage. • Maintain the groundwater extraction bore network and use as required.	• Tailings retention system groundwater monitoring bores—levels and quality.
• Determine the extent of the cone of depression.	• Conduct a groundwater level monitoring programme.	• Mine cone of depression monitoring bores—levels.
AIRBORNE EMISSIONS (NON-RADIATION)		
• Comply with statutory limits.	• Maintain the management system that documents and enforces procedures for controlling discharges. • Maintain a measurement programme that provides data that can be compared with statutory limits.	• Acid plant stack—SO_3/acid mist. • Acid plant bypass stack—periods of use. • Anode furnace stack—SO_2, dust and heavy metals loading. • Anode furnace fabric filter—periods of use and bypass.

Table 15.2 Existing environmental management and monitoring programmes (continued)

Objectives	Strategies and actions	Monitoring
AIRBORNE EMISSIONS (NON-RADIATION) (continued)		
	• Document trends and the detection of instances of non-compliance with self-imposed and statutory limits. • Install and maintain dust collectors and gas scrubbers at emission source locations.	• Calciner venturi scrubber—pressure drop.
• Determine dispersion and impacts.	• Disperse residual emissions from stacks. • Direct mine ventilation outlets into a collection pit to minimise salt spray. • Employ dust suppression measures if dry ore is processed. • Control dust from unsealed roads by wetting.	• Ground level SO_2. • Salt deposition. • Total suspended particulates (high volume air sampling). • Ground-level dust deposition (dustfall).
ENVIRONMENTAL RADIATION		
• Minimise the release of radionuclides into the environment.	• Conduct a radiation measurement, analysis and dose assessment programme. • Record radiation data to detect changes that are attributable to operations.	• Olympic Dam Village, Roxby Downs township and control sites—ground-level radon decay products.
• Ensure that radiation doses to members of the public are as low as reasonably achievable and below statutory limits.	• Implement management tools to ensure controls are in place to limit the release of radionuclides to the environment and to limit the exposure of members of the public to these radionuclides. • Restrict access to authorised personnel only. • Maintain the review process of all new plant and equipment to ensure that both occupational health and safety and environmental radiation issues are addressed in the design stage. • Maintain the operation and monitoring of pollution control devices. • Maintain radioactive contamination checks of equipment before it is allowed to leave the site. • Manage facilities that have the potential to increase the concentration of radiation in the environment.	• Olympic Dam Village, Roxby Downs township and control sites—total suspended particulates (high volume sampling) and contained radionuclides. • Olympic Dam Village, Roxby Downs township and southern boundary site—ground-level dust deposition (dustfall) and contained radionuclides.
VEGETATION MANAGEMENT		
• Minimise adverse effects of operations and infrastructure development on the vegetation of the Special Mining Lease, Municipal Lease and adjacent pastoral areas. • Maximise protection of vulnerable vegetation and landscapes.	• Ensure that a written environmental clearance is obtained before any land disturbance or construction occurs. • Assess changes in vegetation from baseline conditions. • Monitor impacts of airborne emissions on vegetation. • Use environmental clearance procedures to minimise unnecessary clearance of vegetation. • Control proclaimed plant species. • Develop a rehabilitation plan when either monitoring or observations indicate that an area in the Special Mining Lease has been disturbed by mining, development or exploration-related activities, and there are no short-term development plans for the area.	• Stereo photopoints. • Species present. • Cover of each individual species. • Long-lived perennial shrub density. • Proclaimed plant species and protected/rare plant species.
REHABILITATION		
• Rehabilitate disturbed areas. • Ensure the long-term viability of rehabilitated areas.	• Ensure that a written environmental clearance is obtained before any land disturbance or construction occurs.	• Rehabilitation and control sites—cover of long-lived and short-lived perennial species and density of long-lived perennial species.

Table 15.2 Existing environmental management and monitoring programmes (continued)

Objectives	Strategies and actions	Monitoring
REHABILITATION (continued)		
• Maintain and improve monitoring programmes.	• Prepare rehabilitation plans and rehabilitate disturbed areas. Update the rehabilitation database. Conduct an assessment programme to quantify the effectiveness of rehabilitation.	
FAUNA MANAGEMENT		
TERRESTRIAL VERTEBRATES		
• Minimise any adverse impacts on terrestrial vertebrate fauna.	• Implement management actions to minimise unnecessary disturbance of fauna communities and important habitats.	• Terrestrial vertebrate pitfall sites. • Presence of rare or endangered fauna.
• Improve scientific knowledge of the fauna communities in the region.	• Conduct an assessment programme to identify changes in invertebrate fauna communities that may be attributed to operations or infrastructure development.	
• Extend knowledge of local fauna.	• Establish research programmes designed to increase scientific knowledge of fauna species and communities. • Maintain vertebrate database.	
INVERTEBRATES		
• Minimise adverse impacts on invertebrates.	• Review the assessment programme to identify changes in any populations that may be attributed to operations or infrastructure development. • Document the data and their analysis to determine long-term trends and short-term variations from normal.	• Invertebrate fauna as identified by review.
AVIFAUNA		
• Minimise adverse impacts on avifauna.	• Conduct an assessment programme to identify changes in any populations that may be attributed to operations or infrastructure development. • Document the data and their analysis to determine long-term trends and short-term variations from normal.	• Olympic Dam region—avifauna species diversity. • Avifauna transects—species abundance and mist netting.
LARGE MAMMALS		
• Minimise any adverse impacts of operations and infrastructure development on the environment.	• Measure population densities of large mammals to assess their potential impact on the environment. • Control introduced large animal species in order to minimise environmental impact.	• Densities of large mammals over set transects.
BOREFIELDS MANAGEMENT		
HYDROGEOLOGY		
• Minimise adverse effects of drawdown on springs and pastoral bores.	• Conduct an ongoing measurement programme designed to determine the extent of drawdown	Borefield A: • Bores—flow rate, temperature, pH and conductivity.
• Limit geographic extent and depth of drawdown to comply with licence conditions.	• Conduct a measurement programme designed to determine the influence of drawdown on the natural chemistry, flows and pressure of bores and springs.	Borefield B: • Bores—static water level and pumped water level. Monitored mound springs:
• Improve the understanding of the hydrogeological dynamics of the Great Artesian Basin in the borefields region.	• Implement management tools to respond to adverse changes in spring and bore flows in accordance with the terms and conditions of the Special Water Licence—(Sections 3[a] and [b]).	• Mound springs—flow, temperature, pH, conductivity and water quality.

Table 15.2 Existing environmental management and monitoring programmes (continued)

Objectives	Strategies and actions	Monitoring
BOREFIELDS MANAGEMENT (continued)		
HYDROGEOLOGY (continued)		
	• Compare measurements with previous results and predictions from modelling and note variations; investigate any substantial decrease in overall flow. If any such decrease is not directly attributable to natural causes, mitigation measures may be instigated.	
MOUND SPRING VEGETATION		
• Minimise the possible effects of drawdown on the extent and composition of the vegetation communities associated with mound springs. • Protect rare, endemic and relict species. • Increase knowledge of the natural processes of mound spring vegetation communities.	• Conduct a measurement programme designed to monitor simultaneously the condition of the vegetation communities and the hydrology of the mound springs, in order to determine any correlation between the two parameters. • Record findings in order to show long-term trends and short-term variations. • Implement management actions to minimise the effect of drawdown on vegetation communities.	• Vegetation condition in springs in the Hermit Hill region. • Presence of any proclaimed plant species. • Presence of any rare, endangered or new plant species.
MOUND SPRING FAUNA		
• Minimise possible impacts of water abstraction from the Great Artesian Basin on endemic mound spring fauna. • Further the scientific understanding of the relationships between species density/ composition and spring flow characteristics.	• Expand collaborative research programmes. • Conduct a measurement programme designed to monitor any changes in population density and species composition in endemic mound spring fauna, while simultaneously measuring water chemistry and morphology. If significant declines in microfaunal populations are observed and not attributed to natural causes, remedial measures may be required. • Record changes in population characteristics and compare with influencing factors. • Determine the number of mound springs providing habitat that supports endemic invertebrate populations. Protect important spring groups. • Prepare a contingency procedure for use if the monitoring programme shows a real or potential threat to the mound springs.	• Endemic invertebrate species abundance and aquatic habitat condition. • Presence of rare or endangered fauna.
COMMUNITY CONSULTATION AND HERITAGE MANAGEMENT		
• Maintain and improve relationships with Aboriginal groups, pastoralists, and the local and wider community. • Ensure that all groups have been adequately consulted and informed of developments. • Ensure that all relevant local knowledge is received from the groups.	• Formally consult with indigenous groups that have interests in the area of operation. • Use the procedures contained within the environmental clearance form. • Document any new Aboriginal heritage sites in accordance with the requirements of legislation, and Department of State Aboriginal Affairs guidelines on Aboriginal sites cards, and consult directly with the Department. • Distribute copies of the *Anode* bulletin (the WMC Copper Uranium Division in-house magazine) which gives updates on development, construction and other activities. • Maintain an open-door policy to requests for information.	• Regular consultation and direct feedback. • Heritage surveys. • Media reporting.

Locations of monitoring sites for vegetation, small mammals, ants and birds are provided in Figures 15.1, 15.2, 15.3 and 15.4.

15.1.3 Reporting

The reporting process that operates under the EMMP is based upon quarterly and annual reports. This section provides further detail of the key reports produced under the EMMP, based largely on the content of current reports.

The quarterly reports provide a summary review of the management and monitoring activities for the following specific topics: meteorology, waste, air emissions, hydrogeology and environmental radiation. The quarterly reports form the basis for review and discussion during the quarterly visits by State authorities.

The annual report is prepared for the Department of Mines and Energy, South Australia, which then distributes copies to other relevant government departments, including Commonwealth agencies. The report consolidates information from the quarterly reports and, in addition, provides detailed information on all environmental management and monitoring activities undertaken at Olympic Dam during the previous year. The annual report is available to the public.

15.2 MODIFICATIONS TO THE EMMP FOR THE EXPANSION PROJECT

Modifications to the EMMP would be required as a result of the expansion, with further modifications being expected as the project developed and as operations and plant process refinements were made. Modifications to environmental and radiation management and monitoring would be initiated when required, would be reported in the annual reports, and would be incorporated in the EMMP when it is submitted for government approval every three years.

Table 15.3 indicates where the EMMP would initially be modified as a result of the current understanding of the Expansion Project.

Table 15.3 Modifications required to the EMMP for the Expansion Project

Meteorology monitoring	No change required.
Waste materials management	Expand to include new tailings storage facilities and new evaporation ponds.
Special Mining Lease hydrogeology	Expand to include new tailings retention system area, and to cover the increased area of the mine cone of depression.
Airborne emissions	All significant pollution control equipment will be monitored for performance.
Environmental radiation	Review as required to accommodate any changes in national standards.
Vegetation management	Establish new vegetation monitoring and rehabilitation control sites to replace those disturbed or removed during the expansion. Investigate the use of GIS-based assessment to supplement field vegetation monitoring.
Rehabilitation	Establish review studies, trials and monitoring for rehabilitation of the tailings retention system walls and the backfill quarry. Investigate the use of GIS-based assessment to assess rehabilitation success.
Fauna management	Establish new fauna monitoring sites to replace those disturbed or removed during the expansion.
Borefield and mound spring management	Maintain existing programme. Review and update ODEX 1 model periodically and compare 1997 predictions with monitoring data. Investigate the use of GIS change mapping to assess drawdown effects.
Community consultation and heritage management	No change required.

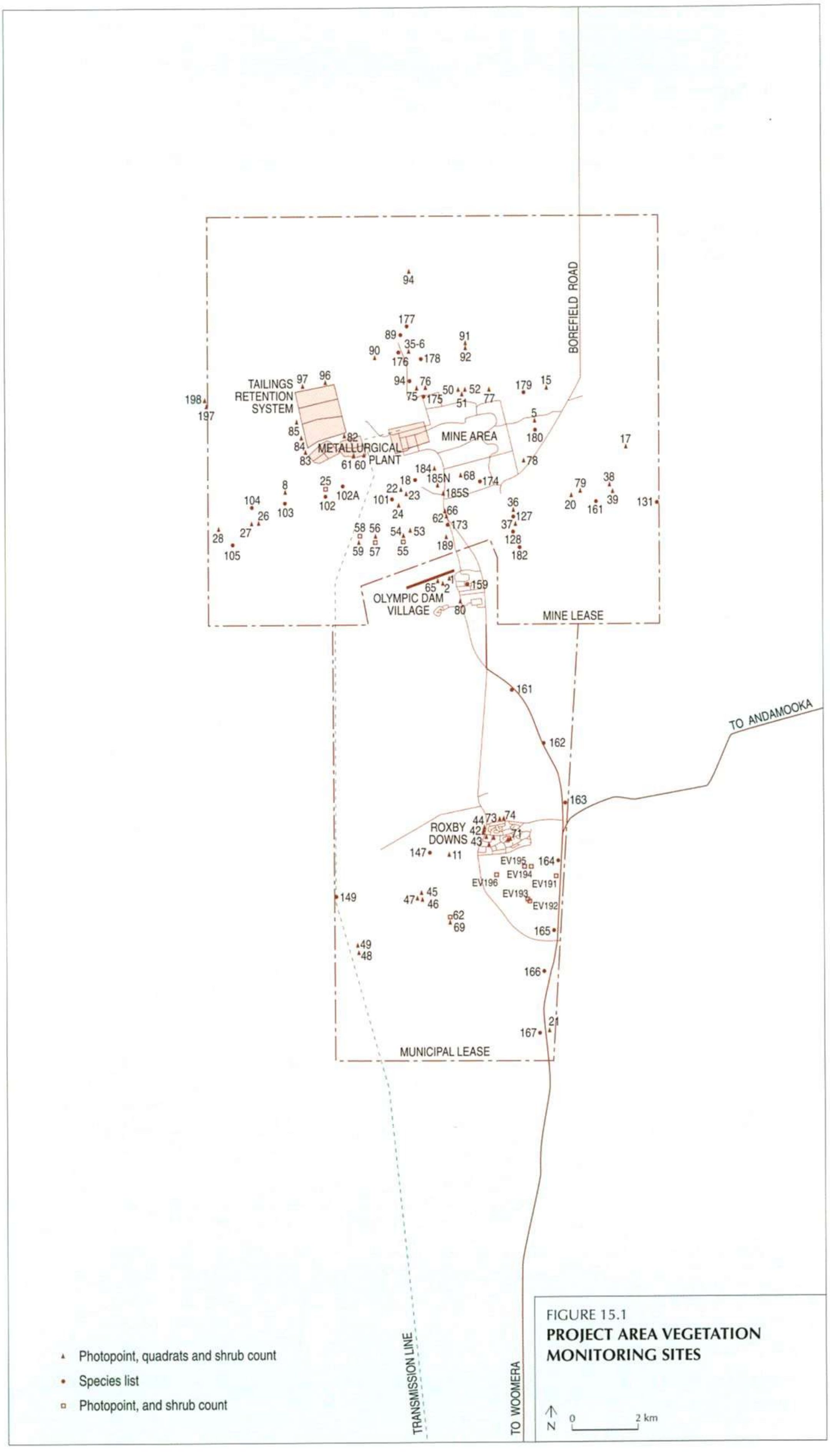


FIGURE 15.1
PROJECT AREA VEGETATION MONITORING SITES

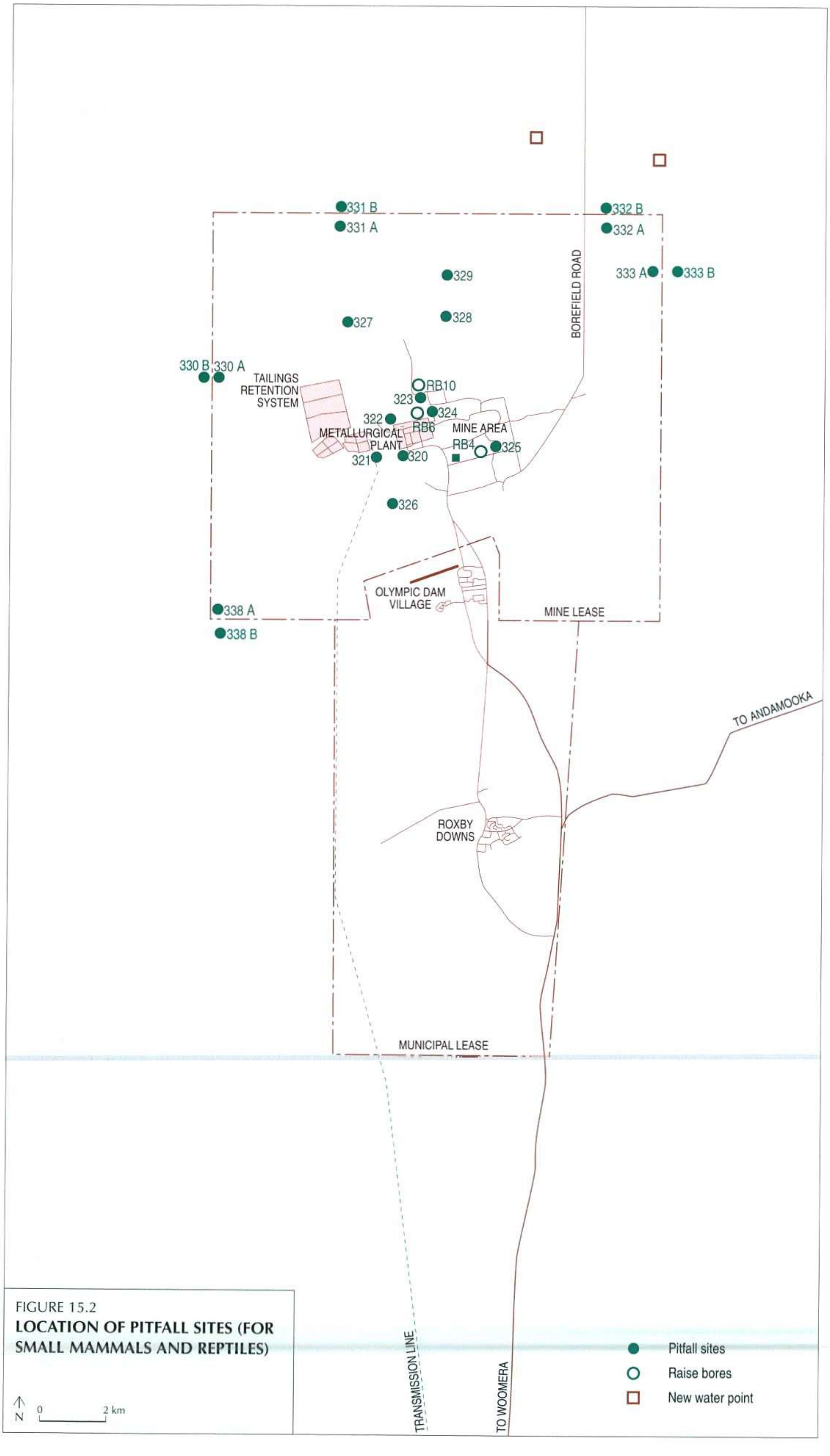


FIGURE 15.2
LOCATION OF PITFALL SITES (FOR SMALL MAMMALS AND REPTILES)

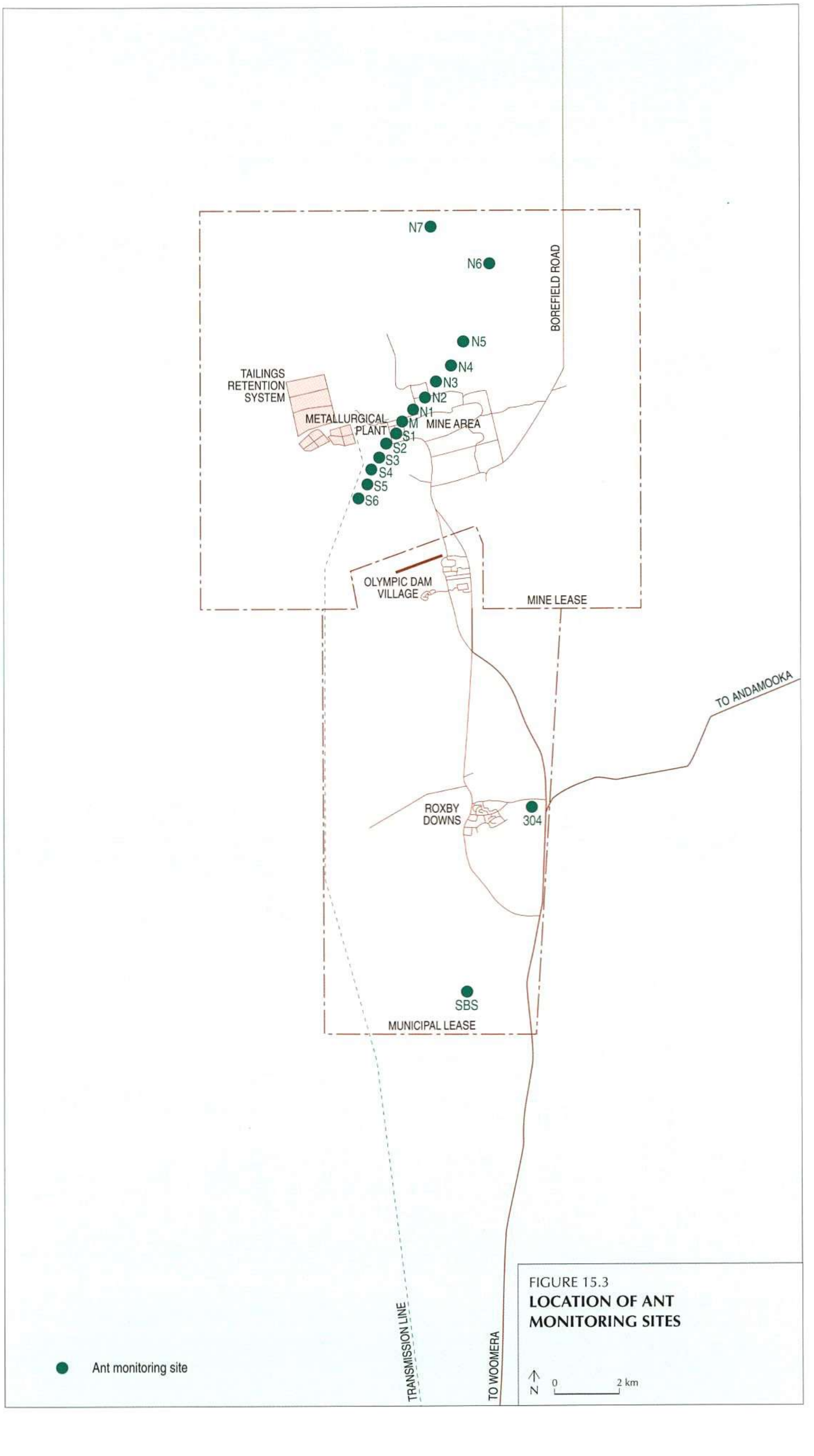


FIGURE 15.3
LOCATION OF ANT MONITORING SITES

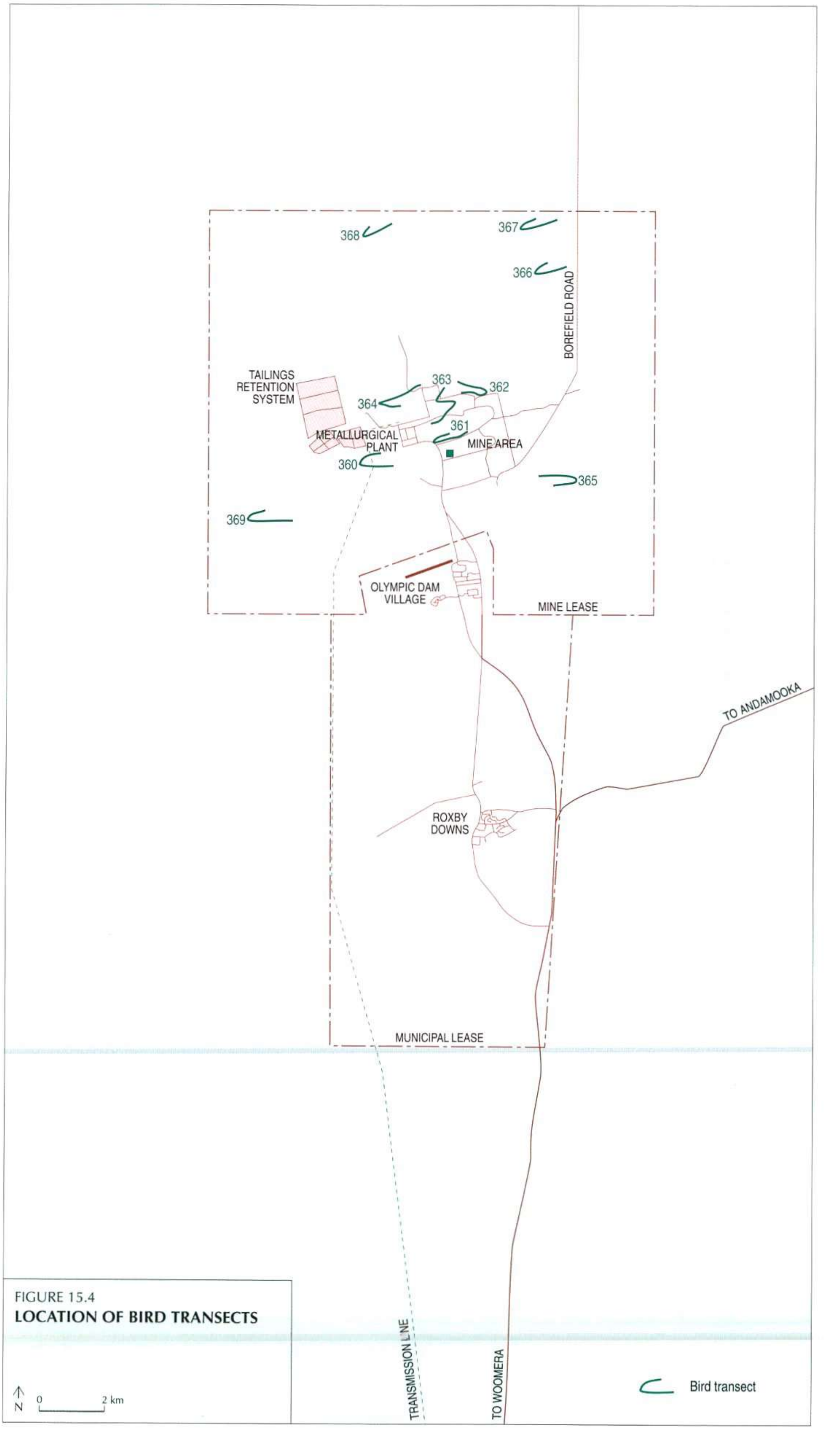


FIGURE 15.4
LOCATION OF BIRD TRANSECTS

15.3 RESEARCH AND COMMUNITY AWARENESS

To provide an ongoing process of improvement to management and monitoring programmes, WMC and its personnel are continuing and expanding research in the Olympic Dam area and its environs. The monitoring described in Table 15.2 gives an indication of the extent of operational research being undertaken in order to manage potential impacts of the project's operations.

In addition to this operational research, WMC and its personnel are undertaking, or have completed, research programmes that are increasing the knowledge of the region's environment to an exceptionally high level. These additional research programmes exceed any statutory requirements placed on WMC.

15.3.1 Research programmes and publications

Some examples of research programmes and publications involving WMC personnel are listed in Table 15.4.

Table 15.4 Research programmes and publications

Programme or publication	Reference
BIOPHYSICAL ENVIRONMENT	
Vegetation of the Lake Eyre region	Badman 1991a
Changes in the incidence of alien plant species at Olympic Dam	Badman 1995a
Plants of the Marla–Oodnadatta Soil Conservation District	Badman 1995b
Recruitment characteristics of the white cypress pine *(Callitris glaucophylla)*	Read 1995a
Ecology and biology of the rare plant *Hemichroa mesembryanthema*	Read 1992a
Influence of habitats, climate, grazing and mining on terrestrial vertebrates at Olympic Dam	Read 1992b
Ecological and toxicological effects of exposure to an acidic, radioactive tailings storage	Read and Pickering, in prep.
Birds of the Lake Eyre region	Badman 1991b
Birds of the Lake Eyre South region	Read and Owens, in prep.
Birds of the middle and lower Cooper Creek	Badman 1989
Avifauna of the Arcoona Lakes	Read and Ebdon, in prep.
Brolgas: The storks of the mound springs	Read and Niejalke 1995
Ecology of the grass owl *(Tyto capensis)* south of Lake Eyre	Read 1995b
Breeding success of the Australian pelican on Lake Eyre South	Waterman and Read 1991
Nest predation by corvids on cormorants	Dorfman and Read 1996
Gull-billed tern predation on dragons	Read 1995c
Mammals of the Lake Eyre region	Kemper and Read 1991
Mammals of the Lake Eyre South region	Owens and Read, in prep.
Ecology of the reptile *Oxyuranus microlepidotus*	Read 1994
Reptiles and amphibians of the Lake Eyre region	Read 1991
Reptiles of the Lake Eyre South region	Read and Owens, in prep.
Reptile diversity and densities in chenopod shrublands	Read 1995d; Read and Badman 1990
Status of the rare gecko *Nephrurus deleani*	Read, in prep. (a)
Life history strategies and biology of three sympatric Australian arid zone geckos	Read, in prep. (b)
Research into the use of geckos as bioindicators of air pollution	Read, in prep. (c)
Skeletal abnormalities in the trilling frog *Neobatrachus centralis* at Olympic Dam	Read and Tyler 1990; Read and Tyler 1994
Use of ants as indicators of salt spray	Read 1996
Impact of water extraction on the invertebrate fauna of artesian springs in northern South Australia	Department of Zoology, University of Adelaide, postgraduate research

Table 15.4 Research programmes and publications (continued)

Programme or publication	Reference
BIOPHYSICAL ENVIRONMENT (continued)	
Comparative life cycle, growth and secondary production in two sympatric species of hydrobiid snails *(Trochidrobia punicea* and *Fonscochlea accepta)* endemic to artesian springs.	Niejalke and Richards, in prep.
Biogeography and conservation of aquatic invertebrates endemic to artesian springs	Niejalke and Tapp, in prep.
Protecting oases in the desert: Efficient use of precious water resources from the Great Artesian Basin	Jensen et al., in press
RADIATION AND DUST	
Determination of a continuous radon daughter equilibrium factor in an operating uranium mine	Billingsley 1992
Radon daughter equilibrium factor measurements in an operating uranium mine	Warneke and Sonter 1989
Estimation of radon daughter levels for mine ventilation design	Sonter 1987a
Calculating radiation exposure and dose	Hondros 1987a
Radiation dose control in mining	Sonter 1990
Radioactive dust dose calculations	Sonter and Hondros 1987
Gamma dose rates as a function of ore grades in underground uranium mines	Sonter 1987b
Use of a natural clay based soil as an effective barrier against radionuclide migration in a uranium tailings structure	Green and Davey 1994
Respirable versus inhalable dust sampling	Hondros 1987b

15.3.2 Other research initiatives

In addition to the programmes and publications listed in Table 15.4, WMC is involved in the following research initiatives.

Australian Arid Lands Botanic Garden

As the major corporate sponsor, WMC has been involved with the Australian Arid Lands Botanic Garden project since 1989. Support for this botanic garden has included development of a master plan, major financial backing ($400,000), and technical support from WMC's arid lands expert staff at Olympic Dam.

Lake Eyre South Study

The Royal Geographical Society (SA) with support from WMC commenced the Lake Eyre South Study in 1993 in order to undertake scientific research and to document the biogeography of this region, including prehistoric, historic and contemporary aspects.

As part of the study, WMC provides infrastructure, field and staff resources and is the major corporate financial sponsor/contributor.

The study is expected to culminate in the publication in late 1997 to early 1998 of a summary book and a series of monographs on particular topics that would add considerably to the understanding of the biophysical environment in the region.

275 kV transmission line studies

As part of the construction of the 275 kV transmission line, the following studies are being undertaken:

- an assessment of the effects of construction of the 275 kV transmission line on the Pernatty knob-tailed gecko *(Nephrurus deleani)*;

- in cooperation with the South Australian Museum, a review of the taxonomy and variation in *Lerista dorsalis* and *L. bougainvillii* from the region of the 275 kV transmission line.

15.3.3 Community awareness programmes

WMC has contributed to or initiated the following recent community awareness programmes:

- Arid zone garden video—WMC was the major sponsor for the preparation of a video that describes how to plan, build and maintain an arid zone garden. Other sponsors were Imparja, Inland Nursery, Power and Water Authority, Home Hardware and Institute for Aboriginal Development.
- Primary school education pack—WMC assisted in the preparation of an education pack on all aspects of the mining industry, including environmental management. This education pack has been made available to primary schools around South Australia.
- Arid zone wildlife posters—WMC has produced posters depicting mammals, reptiles and birds common to the arid zone regions of Australia.
- Environmental education at Roxby Downs Area School—WMC staff contribute to subjects such as natural history, plant propagation and water conservation. Students also visit work sites to inspect aspects of particular interest.
- Community Mulching Programme—WMC provides and maintains a mulching machine at Roxby Downs for use by community volunteers to produce mulch from green waste obtained from the town. Mulch is sold as a fundraiser for the Royal Flying Doctor Service.
- Resources 96 Open Day—Olympic Dam operations were open to the public on 1 December 1996, with tours and inspections to most areas of the operation, including underground and the processing plant. The open day included a major focus on a display of environmental and radiation protection work at Olympic Dam. This open day was in addition to the regular public tours of the mine and plant site.

15.4 ENVIRONMENTAL MANAGEMENT DURING CONSTRUCTION

15.4.1 Environmental management systems

The environmental management systems that would be used during the construction of the Expansion Project are as follows:

- The EMMP will continue to provide the basic reference on the management and monitoring requirements for the ongoing operations.
- An environmental and workplace design criteria document has been prepared for the Expansion Project that includes information on relevant company policies, legislation, codes of practice and standards, and also guidance for consultants on WMC's design requirements for environmental and safety matters. The document is part of the overall design criteria document for the Expansion Project.
- A Safety, Health and Radiation Adviser to the Expansion Project design team has been appointed.
- An Environmental Adviser to the Expansion Project design team has been appointed.

- Two Safety and Environment Coordinators will be appointed and located on site to oversee all environmental and safety matters associated with the Expansion Project. The coordinators will have access to advice from personnel associated with the ongoing operations.
- A procedures manual will be prepared as the principal reference for project team personnel involved in the Expansion Project. The procedures manual will include specific requirements for environmental and workplace matters.

15.4.2 Environmental code of practice

An environmental code of practice has been prepared for issue to all contractors (Kinhill 1997). The environmental code of practice provides basic information describing the Expansion Project, the procedures to be followed to minimise environmental impacts associated with construction and maintenance (including the environmental clearance process), and the environmental monitoring and audit process that would be undertaken to verify compliance with the code. A similar document was used successfully for the Borefield B construction project (Kinhill 1995).

15.4.3 Contractor inductions

An induction process into environmental issues, responsibilities and management requirements for the Expansion Project would be conducted for all new personnel coming to site in conjunction with inductions into site safety procedures. The environmental code of practice will be issued to all new personnel, and will include an acknowledgement sheet to be signed by the new personnel at the completion of the induction. A similar induction process was used for the Borefield B project. The coordination of inductions would be part of the responsibilities of the Safety and Environment Coordinators.

15.5 WORKPLACE HAZARDS

Workplace hazard management at Olympic Dam has been directed by requirements under a range of government legislation and codes of practice, and in response to WMC's own policies. The operation of the existing occupational health and safety systems at Olympic Dam, which would continue to be used, are described below together with the implications for the Expansion Project.

15.5.1 Identification of workplace hazards and control measures

Workplace hazards for the existing facilities have been identified by a knowledge-based hazard identification process, which has been assisted by the familiarity and experience of operators with established plant and use of chemicals. Hazards are classified as chronic (i.e. liable to be detrimental to health following long-term exposure), or acute (i.e. capable of producing immediate traumatic injury).

Chronic hazards may be quantified in terms of airborne concentration, such as mg/m^3 of a gas or dust, or by an intensity, such as decibels, or by a dose rate, such as radiation exposure in mSv/a. Prioritisation can be made for such chronic hazards by comparison with regulatory standards and, in the most well-understood cases, by calculating quantitative risk of long-term ill health from time-integrated exposure and knowledge of dose–response function. These data are available from occupational hygiene monitoring programmes and epidemiological literature.

Acute hazards are more usually quantified by assessment of the probability of an uncontrolled event leading to injury, and the likely severity or consequence. These data are available from local injury statistics.

A summary of the identified workplace hazards and control systems for the existing plant is provided in Appendix P. The implications for the Expansion Project are given in Table 15.5.

Table 15.5 Implications of workplace hazards for the Expansion Project

Area	Implications for the Expansion Project
Mine	Over the ten years of mine operation, the significant areas requiring attention have been in relation to cooling requirements and expectations regarding underground air quality. There has also been an acceptance that air-conditioned cabins are appropriate on most large and small equipment. As part of the expansion design, traffic control requirements would be considered, in order to reduce traffic congestion in the mine. Attention would also be given to rockfall and fire prevention.
Concentrator	No major changes in approach would be necessary in this area.
Concentrate leach	No major changes in approach would be necessary in the concentrate leach area. Ongoing problem with evolution of nitrogen oxides to be addressed by nitrous and nitric acid removal from sulphuric acid in the new acid plant.
Tailings leach, countercurrent decantation and clarification	Proposed improvements over the existing plant are for the control of gas releases from the concentrate and tailings leach systems.
Uranium and copper solvent extraction	No major changes in approach would be necessary in this area.
Ammonia and diluent storage, yellowcake precipitator and calcination	Careful attention would be paid to the control of airborne uranium oxide, in the expansion design. Noise levels around the venturi scrubber would also be addressed.
Backfill plant	No major changes in approach would be necessary in this area.
Smelter	Careful design of the ventilation system would be provided, in terms of both spot fume extraction and general building air exchange rate. Careful attention would also be given to molten metal handling procedures.The waste heat boiler, electrostatic precipitator and dust recycle areas would be designed for minimal release, easy containment and rapid, easy clean-up. Attention would be given to control of noise sources.
Copper refinery and gold and silver refinery	The electrowinning circuit would be designed to minimise acid mist emissions.

15.5.2 Workplace hazard management systems

The WMC goal is to obtain the highest possible standards of occupational health and safety, and to reduce accident and illness rates. This goal is achieved through a proactive, formally structured safety management system as described below.

The overall safety management system has been shown to be effective, with a continuous improvement in lost time injury frequency rate. The rate for 1995–96 was 6.3 per million hours worked, compared with 7.5 per million hours worked in 1994–95 (Table 2.2).

Management commitment

WMC's aim is to have every member of the organisation involved and committed to the improvement of occupational health and safety in the workplace. Indicators of this commitment at the operations are:

- the managers and employee representatives have produced a site-specific Health and Safety Policy;

- managers and supervisors have safety requirements as part of their job description, and performance in these areas is assessed using safety performance indicators;
- the Du Pont (1992) Safety Training Observation Program (STOP) has been adopted;
- safety concerns must be addressed as part of the formal justification for new equipment, and these are reviewed and accepted by a safety professional before equipment is allowed to be purchased;
- a safety prevention scheme exists that takes the form of incentive payments towards community or individual safety equipment. The scheme is based around achieving a reduction in lost time and medical treatment frequency rate over a three-month period. On a monthly basis, key performance indicators are presented to management for review.

Staffing

Trained personnel are responsible for providing an advisory and auditing function with respect to all matters relating to radiation safety and industrial hygiene throughout the operation and to ensure compliance with relevant legislative requirements. These personnel implement a monitoring programme for the collection, recording and reporting of:

- radiation data
- noise data
- atmospheric contaminants (including gases and dust)
- workplace temperature and humidity
- calculation, recording and reporting of employee radiation doses
- hazardous chemicals information database and advice
- lost time and medically treated injuries.

The operations also use independent consultants to supplement in-house skills, where required.

Consultation

The aim of consultation management is to provide effective mechanisms for employee consultation.

Occupational health and safety committee meetings are held on a monthly basis. These meetings involve management and occupational health and safety representatives and are designed to advise management on occupational health and safety strategies and outstanding issues.

Task groups are set up to investigate and recommend courses of action in occupational health and safety issues. The task groups include employee involvement.

Workplace safety meetings occur on a monthly basis and are run jointly by occupational heath and safety representatives and supervisors. These meetings provide an opportunity for workers to raise formally any issues of concern.

Policies and procedures

The aim of policies and procedures management is to develop and maintain an effective and formal framework of policies and safety procedures.

Policies are developed in consultation with employees. These policies are formalised by the use of the site occupational health and safety consultative group. As noted previously, a site-specific health and safety policy has been produced.

Formal work procedures exist or are being developed for critical work practices of the operation. These work procedures include safe working requirements and are routinely audited.

A formal permit system exists and is used as a checklist to ensure that a safe working environment has been provided.

A radiation protection handbook and a safety manual outlining safety procedures, rules and policies are issued and explained to all new employees during the induction process.

Hazard management

The aim of hazard management is to act effectively to identify hazards, implement controls and evaluate remedial actions to ensure that exposure to workplace hazards is minimised. The components of hazard management are identification, quantification, control and re-evaluation.

The mechanisms for identification of hazards in the workplace include WorkCover South Australia Safety Achiever Bonus Scheme (SABS) audits, inspections by regulatory authorities, external consultants, walk-through surveys, feedback from safety meetings, and occupational hygiene and radiation protection monitoring.

Identified hazards are investigated to determine the risk. Indicators used to assess risk include audit compliance and legal requirements as a minimum.

The level of control required is a function of the results from the quantification process. The main control procedures include design, and the use of personal protective equipment. Once control measures have been taken, the hazard is re-evaluated to measure the effectiveness of the control measure and to determine if further control is required.

Training

The aim is to have the workforce effectively trained in safe work practices and occupational health issues.

The Du Pont (1992) Safety Training Observation Program (STOP) has been adopted. The aim of this programme is to train each member of line management in how to eliminate incidents and accidents by skilfully observing people as they work, talking with them to correct their unsafe actions, and encouraging their safe work practices.

Every employee commencing employment at Olympic Dam, whether an employee of WMC or a contracting company, is required to attend an induction. Inductions are designed around the requirements of the position. The standard induction covers permits, occupational health and safety, and environmental and radiation protection issues. Annual radiation re-inductions are held for designated employees.

Occupational health and safety training occurs for all personnel on site. There is a five-day course for supervisors and managers, and a four-hour course for employees.

Radiation safety

The present management mechanism for radiation safety comprises:

- formal preparation and management review of monthly radiation reports to the regulators (South Australian Health Commission, Chief Inspector of Mines and Department of Industrial Affairs);
- quarterly review meetings, including the regulators, at which the trends evidenced in the monthly reports are discussed, as well as briefings on any planned modifications. The quarterly meetings also represent a forum for considering any proposed management system changes;
- annual reporting in fulfilment of obligations set out in the Indenture and the State *Radiation Protection and Control Act 1982* LM1 licence conditions.

- site inspection by the regulators is carried out at the time of the quarterly meetings. This reporting and review mechanism has proven to be very effective in maintaining standards and as an informal prompt for the continuous improvement in the trend of annual radiation doses.

15.5.3 Hazard assessment

As described in Section 15.5.1, a knowledge-based hazard identification process has been used to identify hazards and controls that exist in the plant. This information has been used to identify the implications for the management of workplace hazards for the Expansion Project (Table 15.5).

In addition to the above process, formal hazard and operability (HAZOP) studies would be undertaken for all new major facilities associated with the Expansion Project. These HAZOP studies would be undertaken progressively during the design process, with representatives of State Government regulatory authorities given the opportunity to attend.

15.6 RISK MANAGEMENT AND CONTINGENCY PLANNING

15.6.1 Emergency response capability

WMC has a range of safeguards at Olympic Dam in relation to the control of potential major incidents, which include fire above and below ground, recovery of injured personnel from the mine and from heights above ground, vehicle recovery, casualty treatment and hazardous materials incidents (spills, leaks or escapes of hazardous substances that threaten to damage or harm personnel, equipment or the environment).

WMC provides a twenty-four-hour a day emergency response coverage for the mining and processing facilities within and outside the Special Mining Lease area—including Olympic Dam Village and the aerodrome. The area of responsibility is reported as being up to a 10 km radius of the lease, with support provided as a backup for external emergency services including Country Fire Service units and ambulance services based in the township of Roxby Downs.

The Olympic Dam Emergency Services are available to provide assistance, as required, for external emergency events, with the understanding that the mining and processing facilities have first priority for their services at all times.

The Emergency Services liaise with emergency services throughout the State in accordance with State disaster and emergency planning to ensure that support will be provided in a timely manner to deal with disasters that are beyond on-site capabilities, and outside the present operational range. External emergency service resources include:

- Royal Flying Doctor Service of Australia
- South Australian Ambulance Service
- State Emergency Service
- Country Fire Service
- South Australian Police.

Up to five trained emergency services officers provide immediate response for each twelve-hour shift, with auxiliary fire and mine rescue teams drawn from shift operators. Support is provided by the Injury Management Team, which employs two full-time occupational health nurses and two WorkCover officers. Off-shift emergency personnel can be paged and called out in an emergency.

The Emergency Services and Injury Management Team use the following facilities at the main gate and mine:

- two fully stocked medical centres
- a workshop
- breathing apparatus areas
- training rooms
- a training ground
- WorkCover offices
- a conference room.

The present location of the training ground is being reviewed in accordance with the requirements for expansion of the facility.

Main items of mobile equipment include:

- a four-wheel drive fire tender
- two four-wheel drive ambulances
- a four-wheel drive rescue tender
- two four-wheel drive passenger vehicles
- an escort truck for uranium ore convoys
- a fire trailer.

The fire tender is scheduled to be replaced to upgrade present fire-fighting capabilities and the fire trailer has recently been upgraded.

Intensive training of full-time emergency services officers is undertaken by external emergency services. All emergency personnel are trained on a yearly forecast basis, and auxiliary teams are currently trained one day per month with the full-time officers. Simulated emergencies, including external disaster events such as aircraft crashes and major road vehicle accidents, are conducted from time to time as a training aid to test and revise plans and procedures.

The Emergency Services operate in accordance with a system of policies, standard operating procedures and emergency response plans including:

- Emergency Services Standard Operating Procedures
- Site Emergency Plan
- Injury Management Policy and Procedures
- Policy and Procedure Manual for Fire Suppression Equipment
- Uranium Product Transport Emergency Response Plan
- Hazardous Substances Policy
- Olympic Dam Emergency Services Risk Plans.

Drivers and escorting personnel involved in the transport of uranium ore concentrates operate in accordance with an emergency response plan that involves notification of incidents to external organisations that include the South Australian Police and the South Australian Health Commission. The Olympic Dam Emergency Services Risk Plans identify specific site hazards; risks associated with the specific hazard, including informal consequence analyses for events; and strategies to deal with predicted outcomes (Incident Action Plan). Information to assist Emergency Services in a hazardous materials incident is derived from material safety data sheet data held as an electronic computerised database (Chemwatch) and disposal advice is also sought as required.

Plans and procedures are revised in accordance with emerging legislative requirements (particularly the Draft National Code of Practice for the Control of Major Hazard Facilities), lessons learnt from training and simulated emergencies, and technological advances.

15.6.2 Risk assessment and contingency planning

The Olympic Dam operations involve the mining and processing of ore to produce copper, uranium oxide, gold and silver. The processes used, described in Chapters 2 and 3, are typical of mineral processing facilities that operate safely throughout Australia and overseas.

In comparison with chemical industries, Olympic Dam uses and stores minor quantities of hazardous chemicals. This factor, combined with the remoteness of the site, results in negligible individual and societal risk to members of the public from toxic chemicals, fire and explosions. The risks associated with radiation are discussed in Chapter 10.

Table 15.6 provides an assessment of risk not associated with radiation at Olympic Dam together with the safeguards and contingency plans that would continue to be used to manage these risks.

Table 15.6 Risk assessment and contingency planning[1]

Event	Risk to the community	Contingency planning
Tailings discharge	None	Bunding of pipelines and other facilities to allow collection and return to containment
Failure of tailings storage facility	None	Design and operation of facilities to maintain satisfactory factors of safety for stability of perimeter containment bunds under static and seismic conditions. Regular inspections of embankments
Fire	Negligible[2]	On-site fire service as described in Section 15.6. Maintenance of roadways that also act as firebreaks
Road transport accidents	Quantified in Section 11.3	Compliance with applicable legislation and codes of practice (refer to Table 1.6)
Explosion	Negligible[2]	Compliance with applicable legislation and codes of practice (refer to Table 1.6). On-site emergency response described in Section 15.6
Loss of containment of toxic or hazardous chemicals	Negligible[2]	Compliance with applicable legislation and codes of practice (refer Table 1.6). On-site emergency response described in Section 15.6

1 *Refer to Chapter 10 for risk assessment associated with radiation.*

2 *Risk level too low to be quantified.*

15.7 ENVIRONMENTAL SAFEGUARDS

The preceding chapters have described the existing operations and the Expansion Project. They also described the extensive environmental safeguards that are already in place at Olympic Dam and their extension for the Expansion Project to mitigate potential adverse environmental impacts.

An important aspect of the environmental safeguards is the monitoring programme implemented at Olympic Dam, described in Section 15.1, which allows early identification of environmental impacts and the development of management plans that are based on an understanding of the local environmental systems.

In accordance with the Statement of Environmental Commitment (Appendix A), Olympic Dam is currently developing an environmental management system (EMS) that is consistent with the principles of the ISO 14000 series. The approach adopted in ISO 14001 requires consideration of the following activities:

- Commitment and policy:
  - gaining management commitment
  - conducting the initial environmental review
  - writing the organisation's environmental policy.
- Strategic planning:
  - identifying the organisation's environmental aspects and impacts;
  - identifying any legal and other requirements the organisation should comply with;
  - developing internal performance criteria (where external performance standards do not exist or are considered to be too low);
  - establishing environmental objectives and targets;
  - developing an environmental management programme.
- Implementation:
  - allocating human, physical and financial resources
  - aligning and integrating the EMS with the existing management system
  - establishing accountability and responsibility
  - promoting environmental awareness and motivation
  - enhancing knowledge and skills and providing training
  - communicating and reporting
  - managing EMS documentation
  - creating and using operational procedures and controls to ensure compliance
  - establishing and maintaining a system for emergency preparedness and response.
- Measurement and evaluation:
  - measuring and monitoring performance
  - undertaking corrective and preventative action
  - maintaining performance and response records
  - auditing the effectiveness of the EMS implementation against intentions.
- Review and improvement:
  - reviewing the effectiveness and adequacy of the EMS to meet its policy requirements
  - improving the system to better meet the policy requirements.

The EMS, when complete, will form the basis of the quality assurance programmes designed to ensure that environmental safeguards are being effectively applied. In addition, WMC is committed to the adoption of the Australian Minerals Industry Code for Environmental Management (Appendix A). Commitment to this code is also included in Olympic Dam's Statement of Environmental Commitment (Appendix A). This code insists on regular and audited reporting, the implementation of an EMS and the production of annual environmental reports.

Table 15.7 summarises the environmental safeguards and management measures that would be adopted for the Expansion Project. As a result of the experience gained with the existing facilities, there is a high level of confidence associated with the predictions shown in Table 15.7.

Table 15.7 Summary of environmental safeguards

Issue	Environmental safeguard	Predicted outcome
Erosion	Environmental clearance would be required prior to constructing any new works. Progressive rehabilitation would be undertaken.	Experience has shown erosion is controlled effectively by safeguards.
Vegetation disturbance	Environmental clearance would be required prior to constructing any new works. Progressive rehabilitation would be undertaken.	The Expansion Project would result in further clearing for the construction of new facilities. Some amelioration would be provided by progressive rehabilitation. Experience has shown safeguards to be effective in minimising clearance.
Bushfires and other fires	Natural safeguard is provided by characteristics of regional vegetation. Further protection is provided by roads and tracks and the site fire-fighting service.	Bushfires are not expected from site activities. There is a high level of confidence in the site fire-fighting service's ability to contain and control fires.
Changes to groundwater	Design of the tailings storage facilities and evaporation ponds has been based on ensuring seepage is minimal. As a further safety factor, the tailings retention system is also located within the cone of groundwater depression caused by dewatering of mining operations. The existing extensive groundwater monitoring system would be extended to include the new facilities.	Changes in groundwater systems under the Special Mining Lease would be dominated by dewatering of mining operations and the associated mine water disposal pond. No significant or detrimental change in groundwater quality is expected.
Air pollution	Expanded facilities would incorporate additional air cleaning equipment and higher discharge stacks. Improved ventilation of work areas would also be provided.	There would be overall improvement in ambient and workplace air quality.
Water pollution	Processing areas would be sealed and bunded to enable spillages to be collected and returned to the process.	No pollution of surface or groundwater is expected.
Exposure to radiation	A comprehensive range of safeguards is already in place. These include management of working conditions (ventilation), limitation of access, use of protective clothing and equipment, and monitoring.	No significant increases are expected in individual or combined exposure levels. Exposure levels would remain well within current guidelines. There would be a probable reduction in maximum exposure resulting from optimised smelter design.
Pollution from solid and liquid waste	Solid and liquid wastes with potential to pollute would be managed in the tailings retention system.	No significant or detrimental pollution is expected.
Noise	Noise emission limits would be specified in equipment supply contracts. Access would be controlled and hearing protection equipment provided, where required. Workplace noise monitoring would be undertaken.	No noise impacts to residential areas are expected owing to distance from site.
Economics	Expansion Project policy is to use South Australian services and labour as far as reasonably practicable, taking into account technical, quality and delivery considerations.	Olympic Dam would continue to be a significant contributor to the State economy. It would provide both short-term and long-term additional employment and revenue for governments.
Social, recreation and community considerations	Additional housing would be provided at Roxby Downs for the increased operational workforce. Construction personnel would be provided with accommodation and recreation facilities at Olympic Dam Village to minimise the need to interact with Roxby Downs. Arrangements for the provision of social infrastructure at Roxby Downs are contained in the Indenture.	Residents of Roxby Downs would continue to enjoy the benefits of high household incomes and the use of excellent social and recreational facilities.

Table 15.7 Summary of environmental safeguards (continued)

Issue	Environmental safeguard	Predicted outcome
Renewable resources (water usage)	Agreed limits on drawdown of potentiometric heads are incorporated into special water licences. Potentiometric heads would continue to be monitored in the borefields region.	Drawdown of potentiometric heads would remain within the agreed limits.
Mound springs	Agreed drawdown limits are set out in special water licences. Ongoing monitoring would be conducted in the EMMP. Enhanced monitoring of Davenport and Welcome spring groups would be undertaken.	Significant positive impact for most mound springs in Borefield A region. Minor to moderate adverse impact on some mound springs in the vicinity of Borefield B (for example, the biologically insignificant Wangianna spring group).
Surface traffic	Transport arrangements during construction would be developed in consultation with relevant authorities.	Some disruption of traffic is inevitable owing to the use of off-site fabrication and hence oversized loads. These loads would have the necessary escorts and provide frequent passing opportunities for other traffic.
Greenhouse gas emissions	WMC has committed to joining the Greenhouse Challenge. An engineer specialising in life cycle analysis has been employed to focus on energy and water use minimisation. Regular energy audits of the site have commenced.	The energy use per unit of production is expected to reduce.
Heritage sites and values	Operations are conducted in accordance with the WMC Indigenous Peoples Policy (Appendix A). Consulting archaeologists and anthropologists consult with the Aboriginal people prior to any construction activities. A Community Liaison Officer is responsible for ongoing consultation with the Aboriginal people.	Disturbance of ethnographic sites would be avoided and disturbances of archaeological sites minimised. Experience with the Borefield B pipeline and the 275 kV transmission line show disturbance of sites of significance can be avoided by careful design and route selection.
Biological diversity	Ongoing monitoring is conducted in accordance with the EMMP.	No reduction in biological diversity of the region is expected. Monitoring and research undertaken by WMC staff and consultants are providing valuable knowledge of the regional environment. WMC also actively controls feral animals and has voluntarily removed stock from previously overgrazed areas.
Design for environmental protection	Environmental design criteria are established prior to commencement of design. Preliminary designs are also reviewed by site staff with responsibility for environmental management prior to finalisation. A signed environmental clearance form is required prior to commencement of construction.	The plant and infrastructure design avoids environmentally sensitive areas wherever practicable. Construction activities are based on facilitation of rehabilitation and are also responsive to previous environmental management experience.
Employee and contractor education	Environmental codes of practice are incorporated into construction contracts. Formal inductions occur for all new employees and contractors on the site, covering safety, environmental issues and radiation management.	There is a thorough understanding of site requirements by all employees and contractors.

15.8 SUMMARY OF ENVIRONMENTAL COMMITMENTS

The preceding chapters have described the Expansion Project and the associated environmental management measures that would be implemented during construction and ongoing operations. Commitments made to achieve a prescribed level of outcome, or to undertake certain activities to mitigate adverse impacts, form an important component of the approach to environmental management. Table 15.8 provides a summary of commitments made in this EIS.

Table 15.8 Summary of key commitments relating to environmental management

Relevant EIS Section	Commitment
Chapter 1—Project objectives and background	
1.1.3	The new metallurgical plant would be designed so that any spillages of ore, concentrate or process slurries can be readily returned to the process cycle.
Chapter 2—Existing operations and environmental management	
2.3.1	The current Expansion Project will include a life cycle assessment for all major equipment items. This assessment will examine overall equipment usage over a twenty-year operational time-frame, and will focus on minimising the use of water, energy and other consumables in the expanded plant.
Chapter 3—Description of the Expansion Project	
3.3.3	Ore passes and intake shafts would be located in such a way as to minimise the induced stresses in the surrounding rock. This procedure would place the ore passes in relatively unstressed ground. It is also planned to increase the level of rock mechanics monitoring and investigation activities in order to obtain a better knowledge of rock fabric parameters and in situ stresses, as well as gauge any implications for safety management.
3.3.8	The following criteria are, and would continue to be, used for design of the ventilation system: • minimum air velocity in transport and personnel access roadways—0.5 m/s • minimum air velocity in haulage routes—1 m/s • minimum air velocity in development ends—0.5 m/s • minimum volume of air provided to development faces—25 m^3/s • maximum air velocity in intake airways where employees travel—6 m/s • maximum air velocity in service shafts—10 m/s • maximum air velocity in shafts with rope guided skips—10 m/s • maximum air residence time after contact with ore and before reaching exhaust airway—15 minutes • minimum air cooling power—135 W/m^2 • total volume of air passing through mine per million tonnes per year—300 m^3/s.
3.3.8	Detailed network simulation of the ventilation system would be undertaken on an ongoing basis when development layouts and specific ventilation requirements for each area are defined more precisely, as is current practice. The main purpose of such an analysis is to determine fan pressure requirements.
3.3.8	At the conclusion of stoping in any mine area, the area would be maintained under negative pressure to allow a nominal air flow to leak into and through it to prevent the build-up of radiation decay products.
3.6.1	WMC would require suppliers and transport companies to undertake packaging and transport of chemicals to Olympic Dam in accordance with relevant legislation and codes of practice.
3.6.1	On-site storage of chemicals would be undertaken in dedicated storage areas designed, constructed and operated in accordance with relevant legislation and codes of practice. In particular this would include, but not be restricted to: • inventory control • restriction of access • separation according to hazard classification • provision of impervious surfaces and bunding as appropriate • maintenance of a database of material safety data sheets.
3.7	At the moisture content received, dust emissions from the handling of imported copper concentrates would not be expected to be a problem. Additional dust controls would be provided as required, including water suppression sprays and the enclosure of transfer points and conveyors.
3.8.2	The existing programmes established to reduce the quantity of waste going to the on-site landfill would be maintained. These programmes include the sorting of waste and the recovery, reuse or recycling of waste where possible.
3.11	All construction materials would be transported to the site by road. The construction strategy of prefabricating as much as possible off site would necessitate some transport to site of oversize loads. The size of these loads would be restricted in order to avoid having to clear vegetation or remove infrastructure along the transport route. Each oversize load would also be subject to conditions specified in all the permits and escort provisions required by the relevant authorities.

Table 15.8 Summary of key commitments relating to environmental management

Relevant EIS Section	Commitment
Chapter 3—Description of the Expansion Project (continued)	
3.11	The policy for the Expansion Project is that South Australian services and labour would be utilised as far as is reasonable and economically practicable, taking into account technical and quality considerations, and the ability to deliver on time and within a tight project schedule.
3.11	Wherever possible, earthworks on site would be designed to balance cut and fill requirements, thereby minimising the need to dispose of surplus soil. Existing procedures that control ground disturbance and clearing would be applied to construction activities for the Expansion Project.
3.11	The effects of dust, vibration and noise generated by construction activities would be mitigated by: • watering of disturbed areas and unsealed roads to control dust; • providing restrictions on the maximum noise levels of each item of construction equipment in construction contracts; • restricting activities that may cause noticeable vibration off site to normal working hours.
Chapter 4—Water management	
4.1.1	Future rates of abstraction from the borefields will be maintained within the requirements of the special water licenses.
4.1.1	WMC will continue to research and develop methods to reduce water consumption and to use educational programmes directed at employees and other Roxby Downs residents to encourage water conservation.
4.3	The monitoring of the borefields is a condition of the special water licenses, and WMC has implemented a comprehensive monitoring programme to meet this requirement. The monitoring results will be submitted to the State Government annually as part of the company's EMMP.
4.5.5	Further hydrogeological information will be acquired from Borefield B production bores and monitoring bores and the data will enable ODEX1 to be refined to improve the accuracy of modelling predictions. Similarly, hydrogeological investigations would be carried out to identify and model an additional borefield if this proves to be necessary.
4.6.6	Stormwater management would involve: • provision of capacity in water-retaining structures, such as the tailings retention system and evaporation ponds, so that direct rainfall can be contained; • provision of impervious bunding around process equipment, enabling spillages, wash water and stormwater to be collected and returned for use as process water; • direction of stormwater from other impervious (sealed) areas of the plant to unlined sumps, where it would be allowed to infiltrate and evaporate; • direction of stormwater from other (unsealed) areas to amenity plantings or retention basins via open drains, where it would infiltrate and evaporate.
Chapter 5—Land use	
5.5.1	All mine and township developments would be conducted in accordance with the Indenture.
Chapter 6—Aboriginal heritage	
6.1	All Aboriginal groups that have expressed an interest in, or claimed traditional responsibility over, an area proposed for development would be approached by WMC prior to any development or disturbance taking place. The Department of State Aboriginal Affairs will be consulted for advice on Aboriginal groups that may have an interest in any area affected by the operations at Olympic Dam, including infrastructure corridors.
6.1	WMC has participated in the Native Title process by attending and contributing to statutory conferences and mediation meetings convened by the National Native Title Tribunal. The company will continue to participate in the Native Title process.
6.5	In general, the results of archaeological survey work have further confirmed the broad applicability of the archaeological site predictive model in this region. The model will continue to be assessed.
6.7.1	WMC is exploring the need for a further signage and fencing programme at a select number of more significant Aboriginal sites within the Olympic Dam Project Area.
6.7.1	All future proposed developments associated with Olympic Dam will continue to be subject to further Aboriginal heritage assessments.

Table 15.8 Summary of key commitments relating to environmental management (continued)

Relevant EIS Section	Commitment
Chapter 6—Aboriginal heritage (continued)	
6.7.1	It is WMC's policy to avoid all ethnographic sites. Where possible, it is also WMC's preference to avoid all archaeological sites. However, owing to the ubiquitous nature of the archaeological record at the Olympic Dam Project Area, this is not always feasible. Where conflicts between Aboriginal archaeological sites and proposed development plans do exist, WMC will follow governmental due process established by Aboriginal heritage legislation.
6.7.3	WMC has initiated discussions with Aboriginal groups in relation to community development programmes. The programmes as currently envisaged could incorporate financial or other support to assist the participating groups' attainment of their community-driven aspirations, including administrative support, education, employment and enterprise development.
6.7.4	The strategies to provide greater Aboriginal employment opportunities will include, but not be limited to: • contractual arrangements to encourage the employment of Aboriginal people • assistance for the expansion of existing Aboriginal-owned enterprises • facilitation of new enterprises and joint venture partnerships.
Chapter 7—Biological environment	
7.1.3	Future EMMPs will be consistent with the principles of the International Standards Organisation's ISO 14000 series.
7.2.4	With the proposed expansion, monitoring of introduced and proclaimed plant species would continue and would be expanded to include assessment of all new disturbance areas. Reporting of the presence, abundance and control of these species would be included in the Olympic Dam EMMP annual report. Control of proclaimed plant species would continue to be conducted in accordance with the policies of the South Australian Animal and Plant Control Commission.
7.2.5	To minimise the impact of salt emissions, all new raise bores would be fitted with salt interception devices as they become operational.
7.2.6	Land surface disturbance and vegetation clearance of any type would be kept to the minimum necessary for the expansion, and disturbed areas rehabilitated promptly.
7.2.6	A total of ten vegetation monitoring sites and two vegetation rehabilitation control sites would be displaced by the expansion in the Special Mining Lease area. The vegetation monitoring sites would be replaced with sites with similar landform and vegetation types to enable the monitoring of potential impacts on similar ecosystems. The vegetation rehabilitation control sites would also be replaced.
7.2.6	The vegetation monitoring programme would be adapted to investigate possible long-term impacts of low-concentration air emissions on vegetation cover.
7.2.7	The vegetation monitoring programme would be maintained during and following the proposed expansion. The objectives of the current and future vegetation management programme are, and would continue to be, to: • minimise the adverse impacts of operations and infrastructure development on the vegetation of the Project Area and region; • maximise the protection of vulnerable vegetation and landscapes.
7.3.2	The Olympic Dam evaporation ponds are surrounded by a 2 m high mesh fence that excludes the majority of larger and medium-sized mammals, effectively minimising the effect of the ponds on these animals. The lower 0.3 m is also covered with fine mesh to exclude smaller mammals and reptiles. The proposed extensions to the evaporation ponds would be similarly enclosed.
7.3.4	WMC would continue to use deterrents and develop new ways of discouraging birds from the ponds, especially the acid liquor evaporation ponds. To date, the following deterrents have been used with varying degrees of success: • maintaining and enhancing artificial water points as 'decoy' waterbodies • scaring birds by driving around the walls of ponds • using a bird-scare shotgun • using gas-powered sonic guns • using rotating, intermittent light beacons at night.
7.3.7	Monitoring of introduced and proclaimed animal species would continue and would be expanded to include assessment of all new disturbance areas. Reporting of the presence, abundance and control of these species, including invertebrates, would be included in the WMC EMMP annual reports.

Table 15.8 Summary of key commitments relating to environmental management (continued)

Relevant EIS Section	Commitment
Chapter 7—Biological environment (continued)	
7.3.7	The presence and efficacy of the Rabbit Calicivirus Disease would be investigated further and incorporated in the ongoing monitoring and management programme.
7.3.9	Two permanent fauna monitoring sites in the Special Mining Lease area would be directly impacted by the Expansion Project. These sites would be replaced with sites selected from nearby, similar habitats.
7.4.13	The monitoring of the presence and abundance of endemic mound springs invertebrate fauna and the species diversity of wetland invertebrate fauna will continue and, where possible, be expanded to incorporate the results of research on other species confined to the mound springs.
Chapter 8—Tailings management	
MANAGEMENT AND MONITORING	
8.1.4	Management and monitoring systems for the tailings retention system would be extended to cover the expanded facilities constructed as part of the Expansion Project.
8.1.4	In the event that loss of containment is detected in any evaporation pond cell by the liquor balance, the evaporation cell would be isolated, drained, cleared and inspected prior to any necessary repairs.
8.1.6	Sufficient, appropriately designed groundwater monitoring in and around the proposed expansion of the tailings retention system would be implemented for the proposed expansion, including the monitoring of background data prior to construction.
8.1.6	The leakage detection system using water balance calculations would continue to be used in the expansion of the tailings retention system.
PADDOCK STORAGE SYSTEM	
8.5.1	The design of the expanded tailings facilities would be largely driven by seepage minimisation considerations, including minimising the amount of supernatant liquor and maximising evaporation from the tailings surface.
8.5.2	The perimeter embankment for the new cells would be constructed using either local swale and sand dune materials, or tailings material borrowed from within the storage, and would be shaped and zoned using sand, general fill and clay in such a manner as to: • ensure stability under static and earthquake loading; • minimise seepage of acid tailings liquor through the embankment, thereby preserving embankment stability and avoiding future rehabilitation problems; • minimise erosion on the outer face. Where tailings are used for the lift, a layer of clay would separate the tailings from the downstream erosion protection layer, in order to provide a barrier to seepage and reduce radon migration.
8.5.3	The additional tailings line would be contained within the existing pipe corridor over much of its route, and thereafter within a new bunded pipe corridor.
8.5.4	To maximise supernatant water collection, the floor of the storages would be shaped by removing dunes and ridges where required, and by contouring (cut and fill) where necessary to provide a fall of about 1 in 500 towards the central decant. Temporary pumped decant facilities would be provided at any areas on the floor that were not free-draining towards the central decant facility.
8.5.4	The floor of the tailings storage would be prepared by providing a low permeability floor lining. Generally, it is intended that the floor preparation would be as follows: • The soil/limestone interface would be located by means of electromagnetic survey and shallow bores and test pits. • A low permeability clay liner would be placed over areas where the floor level would be in, or close to, sand or limestone. The clay liner would have a minimum thickness of 0.3 m. • Where the floor is on clay, the near-surface clay would be prepared, if necessary, by ripping, conditioning and compacting to a suitable depth. The preparation would remove any cracks and potential flow paths in the near-surface layer. • The floor would be proof rolled to identify any near surface dolines. Any dolines identified would be excavated and backfilled and capped with a clay seal.
8.5.4	In the event of the appearance of a doline (a fissure or solution cavity that may occur in limestones) during tailings deposition, the following approach would be adopted: • A temporary earthen embankment would be placed on the tailings surface preventing further deposition of tailings into the doline, but enabling the remainder of the tailings area to be used for deposition.

Table 15.8 Summary of key commitments relating to environmental management (continued)

Relevant EIS Section	Commitment
Chapter 8—Tailings management (continued)	
PADDOCK STORAGE SYSTEM (continued)	
	• The hole or cavern would be backfilled and an impervious seal placed over the area. • The temporary earthen embankments would be removed, and tailings deposition over the entire retention area recommenced.
8.5.5	The size of the supernatant pond would be kept to the practical minimum sufficient to ensure settling of solids from the supernatant tailings liquor. An underdrainage system would be provided to intercept and collect potential seepage below the planned maximum extent of the supernatant pond. The basin floor in the vicinity of the decant structures would also be provided with a low permeability clay layer or membrane to reduce seepage from the supernatant pond that would form adjacent to these structures.
8.5.7	Stable embankment slopes for higher storage heights would be determined using results from in situ field tests conducted prior to each raise.
CENTRAL THICKENED DISCHARGE STORAGE SYSTEM	
8.6.3	The perimeter embankment of the central thickened discharge (CTD) cell would be approximately 2–4 m high and constructed from materials removed from within the storage area. It would be zoned in a similar fashion to the starter embankment in the paddock system, to minimise seepage and radon migration through the embankment, and prevent erosion of the outer face of the embankment.
8.6.4	Special attention would be given to the stability of the tailings 'mounds', particularly in the early stages of development of the storage, when the mounds grow rapidly. It would be necessary to use several discharge points and interchange among these points to allow the tailings to dry in a manner that ensured the mound maintained stability and the drainage pattern was properly maintained.
8.6.5	As the CTD mounds grow, it might be necessary to construct and maintain a system of open drains to collect supernatant liquor that flowed off the toe of the mound.
8.6.5	Stormwater from significant rainfall events would be recycled for reuse in the process or evaporated, depending on its quality.
8.6.6	Preparation of the floor of the storage would be undertaken in areas identified as potential seepage areas. The base of the tailings storage area, including any identified dolines, would be prepared in a similar fashion to that described in Section 8.5.4. Any sand dunes would be removed and the sand stockpiled for future use.
8.6.7	A liquor balance would be carried out to size the evaporation area requirements once the optimum tailings solid content and supernatant liquor release and drainage collection are estimated using the results of the field trials.
8.6.8	Field trials would provide the data needed to design a CTD system and filling strategy that ensured the mound would be stable under all operating conditions, including extreme meteorological (rainfall and wind) and seismic conditions, and to assess the potential for dust generation from the surface.
OTHER ASPECTS	
8.7.2	The expanded tailings management system would provide for stormwater management systems. The stormwater management facilities would be designed to provide sufficient intensity and volume capacity for the design storm events. The average return interval selected for the design of each element would be determined by assessment of the hazards and consequences associated with failure of that element.
8.7.2	The CTD system would use an independent storage system, comprising a series of stormwater ponds and the perimeter embankment, to store the collected stormwater for disposal by return to the process or by evaporation. Spillways would safely discharge to the surrounding drainage system any run-off from a 1 in 500 year rainfall event that could not be stored by the stormwater ponds.
8.7.3	The new evaporation pond for the paddock system would be of similar construction to that of the two existing evaporation ponds, including a composite lining system—a lower liner of compacted clay overlain by a synthetic liner.
8.8	Specific fauna control strategies are currently used at the evaporation ponds and these would be extended to include the expanded facilities. The control strategies include: • fencing the evaporation ponds to exclude access to fauna; • using propane guns to deter visitation by birds; • at night, using another bird deterrent (developed on site) that takes advantage of birds' observed avoidance of intermittent rotating lights beamed across water surfaces.

Table 15.8 Summary of key commitments relating to environmental management (continued)

Relevant EIS Section	Commitment
Chapter 8—Tailings management (continued)	
OTHER ASPECTS (continued)	
8.10	Factors that would be taken into consideration in the design of the tailings storage facility include: • control of erosion by control of drainage patterns and provision of rock armour to external surfaces of the tailings storage facility; • selection of slopes for the perimeter embankments combined with the shear strength of consolidated tailings, so that the embankments are stable under seismic conditions.
8.10	Upon completion of rehabilitation, WMC would erect permanent markers on the rehabilitated tailings storage facility and refer its location to the relevant authorities for inclusion on mapping for the region.
Chapter 9—Air quality and noise	
9.2.1	The new smelters would be equipped with 90 m stacks.
9.2.1	Recovery of sulphur dioxide (SO_2) would be maximised in the acid plants in order to minimise SO_2 emissions and the use of imported elemental sulphur.
9.2.1	Gases leaving the acid plants would be discharged via 90 m stacks and contain no more than 2 kg SO_2 per tonne of sulphuric acid (H_2SO_4) production.
9.2.1	The yellowcake calciner gases would be cleaned by a scrubber prior to being emitted to atmosphere.
9.2.2	The acid plants would be designed to achieve stack sulphur trioxide (SO_3) emissions of not greater than 75 mg/Nm^3 of SO_3 and H_2SO_4, expressed as SO_3.
9.2.3	Nitrogen oxides produced in the gold and silver refinery acidification tank would be ducted to a caustic soda scrubber system.
9.2.9	The Expansion Project design emission limits are within the applicable SA EPA limit and the national guidelines for control of air pollutants from new stationary sources.
9.2.9	The Expansion Project design air quality criteria are less than the SA EPA criteria to provide allowance for future plant expansion. Overall levels are required to meet the SA EPA criteria.
9.3.1	If the 285,000 t/a copper production scenario were to proceed, the air pollution control on the existing anode furnaces and acid plant would be upgraded to ensure that air quality goals are met within the Special Mining Lease as well as outside it.
9.4.1	Protective measures to provide for employee safety and control of spillages would be built into new plant elements as they were for the existing plant. The aim would be to eliminate or reduce to a minimum the need for employees to wear special protective clothing or respiratory protection.
9.4.2	The equipment and techniques already in use on the site to control dust emissions during the unloading and transfer of material would continue to be employed for the Expansion Project.
9.4.2	Dust emissions at stockpile discharge conveyors would be controlled using methods such as luffing conveyors or telescoping discharge chutes, and conveyors and transfer points would be enclosed or covered as necessary.
9.4.2	The lightly trafficked secondary roads are surfaced but unsealed, and minor amounts of dust arise. These roads are used intermittently and are watered with mine water as necessary to control dust. This practice would continue following the proposed expansion.
9.5.3	The equipment contracts for the Expansion Project would include noise specifications as appropriate. Where practicable, engineering noise control would be used for reducing noise levels in key areas of the plant.
9.5.3	Occupational noise levels would continue to be at sufficient levels in some areas to require control measures. The current control measures, which include the provision of hearing protection equipment, noise monitoring, signage and employee training, would continue.
Chapter 10—Radiation	
10.2.3	The new smelter design will recirculate dust collected in the waste heat boiler and electrostatic precipitator to the flash furnace, except for a bleed stream which is passed direct to the hydrometallurgical plant. The bleed effectively controls the level of polonium-210 (^{210}Po) in the smelter blister and slag products and hence the level of any fume emitted from tapping points.
10.2.3	An improved design for the collection of fugitive emissions around tapping points will be incorporated in the design of the new smelter.

Table 15.8 Summary of key commitments relating to environmental management (continued)

Relevant EIS Section	Commitment
Chapter 10—Radiation (continued)	
10.2.3	In the new smelter, the launders will be short, without elbow bends, and covered by hoods. These will be ducted to the single air extraction system which will collect fumes from several process areas. Tapping points will also be provided with hoods connected to the air extraction system, diverting fume from the building into the collection system. Slag tapping will be automatic and the operator will be physically remote from the tapping points. An automatic mud gun will be used to plug the tapping holes.
10.2.3	The electric furnace will discharge into a launder run to the two anode furnaces, eliminating the need for hot-metal transfer by ladle. The launders will be covered and connected to the air collection system. The anode furnaces will discharge via covered launders to two casting wheels, which will also be equipped with hoods connected to the air collection system.
10.2.3	As far as possible, control rooms and control points will be enclosed in air-conditioned cabins remote from the smelter floor. Cameras will provide the necessary vision to operators. Where it is not possible to place the operator in a cabin, sealed respite cabins will be placed at strategic locations so that operators can retreat to an air-conditioned environment when they are not required on the floor.
10.2.3	A further reduction in the release of dust and fume to the building air will be achieved by improving the clean-up and maintenance services. Through-ways large enough to accommodate small front end loaders will be provided so that any spillage can be quickly and efficiently removed.
10.4.1	The Olympic Dam Expansion Project will take place in close proximity to existing production facilities which will continue in operation throughout the construction and commissioning phases of the new developments. During these phases, a programme of monitoring and assessment will be carried out separately from the routine monitoring. This programme will have two purposes. The first will be to ensure that radiation safety measures are adhered to by the contract workforce and that assessments can be made of the radiation exposure of construction and commissioning staff. The second purpose will be to verify that the new processes and equipment are operating within the design criteria established for radiation safety purposes. The frequency and types of measurements taken during construction and commissioning are usually different from those taken during routine operations. The separate monitoring and assessment programme for the construction and commissioning will be submitted for approval to the South Australian Health Commission.
10.4.2	In addition to assessing radiation doses, the current programme of actively controlling radiation exposures and limiting the resulting doses and releases of radiation to the environment will be extended to accommodate the proposed expansion at Olympic Dam.
10.4.2	A programme to implement the ALARA principle—'as low as reasonably achievable, social and economic factors being taken into account'—will form an integral part of the management of radiation safety. Annual audits will be conducted to identify issues with the potential to affect radiation exposures. The ALARA programme will incorporate the control measures outlined above.
10.4.3	In the first year of operating the new equipment associated with the Expansion Project, the number and type of research projects will increase in order to characterise the effects of the new facilities and to provide data on parameters used in dose assessments.
10.4.4	The Expansion Project will not increase the number of people required to conduct the routine environmental and safety programmes, but additional staff will be contracted as required to assist with the management of environmental and safety issues during construction and commissioning.
Chapter 11—Project infrastructure and township development	
BOREFIELD B	
11.1.2	Further assessment of selected vertebrate fauna along the Borefield B route will be carried out as part of the post-rehabilitation process.
11.1.2	The environmental code of practice for the Borefield B Stage 1 pipeline construction (Kinhill 1995) will be adapted for the Stage 2 pipeline construction. The environmental code of practice will be included in the construction contract, and will require the contractor to submit a work method statement to WMC describing proposed specific mitigation measures.
11.1.2	The construction work for the Borefield B pipeline Stage 2 construction will be subject to the issue of an environmental clearance form from WMC's Expansion Project Environment Adviser before construction starts. The environmental code of practice will also be distributed to all construction personnel as part of an induction training programme for the project, and be signed off by each recipient.
275 kV TRANSMISSION LINE CORRIDOR	
11.2.1	The requirements of the environmental code of practice for the 275 kV transmission line presently under construction have been incorporated into construction contracts, and are proposed to continue to be monitored for implementation and effectiveness, and independently audited for compliance.

Table 15.8 Summary of key commitments relating to environmental management (continued)

Relevant EIS Section	Commitment
Chapter 11—Project infrastructure and township development (continued)	
275 kV TRANSMISSION LINE CORRIDOR (continued)	
11.2.1	The environmental code of practice will be updated and used in a similar manner for the future new 275 kV transmission line, which is proposed to replace the existing 132 kV line in the future possible expansion to 350,000 t/a copper production.
11.2.2	Use of the same access track for construction and maintenance of both the 275 kV line under construction and the future new 275 kV transmission line will limit any further impact. The only additional access tracks required are those for the two minor route deviations and those to each transmission tower site. These latter tracks will also be used as fabrication areas, to minimise the extent of disturbance required.
11.2.2	At each transmission tower site an area will need to be cleared for assembly and erection of the towers. Wherever possible this activity will take place on the final section of the access track to minimise disturbance. Overall, the clearance of individual transmission tower sites is not expected to exceed an area of approximately 0.15 ha.
11.2.2	***Tablelands and plains:*** Minimising the removal of the protective gibber mantle will assist erosion control. This will be achieved by: • rolling instead of grading • limiting the extent of additional grading • ensuring that all windrows are removed from tracks and watercourse crossings • ceasing construction traffic movements after significant rain • confining all vehicles to the access or other designated tracks • limiting off-road vehicle movements during line stringing. Tower pads will not usually be graded. Where grading is unavoidable, gibbers will be stockpiled for later respreading during site rehabilitation. Towers will not be constructed in watercourses.
11.2.2	***Escarpment slopes:*** In addition to the previous mitigation measures, any necessary repairs to the existing track and the formation of tower pads in these areas will involve incorporating appropriate cross-drains and catch banks to inhibit and reduce the velocity of downslope surface flow. Sediment movement and accretion will be allowed for in the design of any drainage structures.
11.2.2	***Drainage depressions:*** Construction will be avoided to the maximum extent possible in drainage depressions and stream channels.
11.2.2	***Sand dunes and sheet sands:*** Dunes along the corridor will be crossed at, or close to, right angles to their east–west orientation wherever practicable, avoiding as far as possible the crests or flanks. Track and power line construction will be over, rather than through, the dunes. Some dune crossings will be sheeted with clay to enable trucks to cross during construction and to minimise the potential for sand dune blowouts along the corridor. Where the construction of transmission towers on dune ridges cannot be avoided, the sites will be similarly stabilised. Suitable material will be taken from borrow pits established in the dune swales, with all borrow pits being progressively rehabilitated after use. Vegetation clearance will be minimal and strictly controlled. Species such as sandhill wattle, Burkitt's wattle and narrow-leaved hopbush rapidly recolonise disturbed areas following good rainfall. Where removal of vegetation is unavoidable, these species will be removed in preference to those that grow more slowly or regenerate less successfully.
11.2.2	Vegetation clearance will be the minimum consistent with safe construction and statutory requirements, and will be controlled through implementation of the construction environmental code of practice. Limits of clearance will be clearly defined before construction begins, and ecologically significant vegetation identified by signage and protected by temporary fencing. Alignments of new access tracks will be adjusted as necessary to avoid damage to mature trees and to minimise damage to other vegetation. Vehicular access will be strictly controlled during the construction period.
11.2.2	Mitigation measures for the conservation of fauna habitats will generally accord with those for vegetation clearance and soil disturbance discussed previously.
11.2.2	Construction personnel will not be permitted to bring firearms, traps, pets or exotic animal species of any description into the area.
11.2.2	All archaeological sites in close proximity to construction sites, or assessed as being at possible risk of inadvertent disturbance during construction, will be protected by temporary fencing and/or signage. Signage will not differentiate between archaeological and other environmentally sensitive sites. Where archaeological materials occur between tower sites, particular care will be taken to minimise site disturbance during cable stringing.

Table 15.8 Summary of key commitments relating to environmental management (continued)

Relevant EIS Section	Commitment
Chapter 12—Social environment	
12.3.4	In order to minimise the impact on Roxby Downs township, construction personnel will be accommodated in the two single persons' quarters at Olympic Dam Village. A high standard of amenities including recreation and entertainment facilities will be provided, thereby reducing the need for construction personnel to travel to Roxby Downs.
Chapter 14—Rehabilitation and decommissioning	
14.1	In the event of premature closure before all disturbed sites had been rehabilitated, WMC would maintain its rehabilitation programme, including monitoring, to complete all outstanding tasks in the Project Area and to establish the long-term viability of these sites.
14.2	All areas disturbed in any significant, adverse way by the Expansion Project would be rehabilitated according to the rehabilitation procedures set out in the environmental clearance form or procedures equivalent to those listed in Table 14.1, and monitored to ensure the completion criteria (i.e. performance indicators) are met before finalisation of the project.
14.4	Decommissioning the areas managed by WMC will be to a best practice standard, and rehabilitation success will be measured by the development of a self-sustaining state of rehabilitated areas compared with undisturbed communities. Rehabilitated areas will have: • stable and structurally sound landforms that are protected against accelerated erosion from water and wind; • landforms that support pre-mining land uses and retain ecological values that, in general, are compatible with the surrounding landscape. The exception to this may be the walls of the tailings retention system; • landforms that are non-polluting and that do not compromise surrounding land uses and ecological values.
14.4	Decommissioning rehabilitation procedures and completion criteria for the Expansion Project that are site-specific would be developed concurrently with evaluation of the ongoing rehabilitation and monitoring programme. Final rehabilitation procedures and completion criteria would be included in a decommissioning plan that would be submitted to the South Australian Government for approval prior to implementation.
14.4	As a minimum, on completion of the mining and processing operations, all buildings and support facilities and debris would be removed and all of the disturbed areas rehabilitated.
Chapter 15—Environmental monitoring and management	
15.2	Modifications to environmental and radiation management and monitoring would be initiated when required and reported in the annual reports, and would be incorporated in the EMMP when it is submitted for approval every three years.
15.4.1	Two Safety and Environment Coordinators would be appointed and located on site to oversee all environmental and safety matters associated with the Expansion Project. The coordinator would have access to advice from personnel associated with the ongoing operations.
15.4.1	A procedures manual would be prepared as the principal reference for project team personnel involved in the Expansion Project. The procedures manual would include specific requirements for environmental and workplace matters.
15.4.2	Work covered by the environmental code of practice for the Expansion Project will be subject to an environmental monitoring and audit process to verify compliance.
15.4.3	An induction process into environmental management systems for the Expansion Project would continue to be conducted for all new personnel coming on site in conjunction with inductions into site safety procedures.
15.5.2	Every employee commencing employment at Olympic Dam, whether an employee of WMC or a contracting company, is required to attend an induction. The induction covers permits, occupational health and safety, and environmental and radiation protection issues. Annual radiation re-inductions are held for designated employees.
15.5.3	Formal hazard and operability (HAZOP) studies would be undertaken for all new major items of equipment associated with the Expansion Project. These HAZOP studies would be undertaken progressively during the design process, with representatives of State Government regulatory authorities given the opportunity to attend.
15.6.1	Olympic Dam Corporation Emergency Services are available to provide assistance, as required, for external emergency events, with the understanding that the mining and processing facilities have first priority for their services at all times.

APPENDIX A WMC POLICY COMMITMENTS

Safety & Health Policy

POLICY

The prime objective of WMC is to develop the culture and processes to ensure the safety and health of all employees, contractors, customers and the communities associated with our worldwide operations.

BELIEFS

In support of this we believe that:

- No business objective will take priority over safety and health
- All incidents and injuries are preventable on and off the job
- Accountability for providing a safe work environment rests with every individual
- All individuals have the responsibility and accountability to identify and eliminate or manage risks associated with their workplace
- Legal obligations will be the minimum requirements for our safety and health standards
- Individuals will be trained and equipped to have the skills and facilities to ensure an incident free workplace

HM Morgan
Chief Executive Officer
October 1996

Environment Policy

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 fulfil 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

Indigenous Peoples Policy

WMC is committed to developing relationships of mutual understanding and respect with the indigenous peoples of the areas in which we operate or propose to operate.

To fulfil this commitment, the Company will:

Establish and maintain effective, positive and frequent communication with indigenous groups.

Recognise the desire of indigenous peoples to fulfil their responsibilities within their traditional culture.

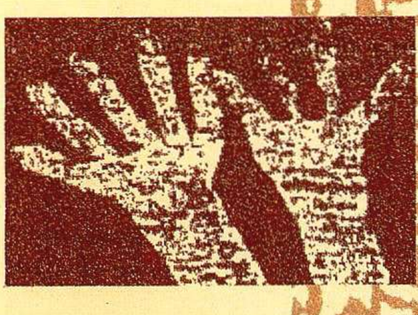
Seek to identify all indigenous interests in the area within which the Company is or intends to operate, define the basis for those interests whether derived from cultural traditions, historical association, occupation, social or economic need, and deal with those interests in accordance with the relevant government policy.

Recognise and observe all state, provincial, and federal laws relevant to indigenous and cultural matters.

Formulate and implement for appropriate Company personnel, an indigenous awareness program, pertinent to the local situation, which will engender the appropriate understanding, sensitivity and respect towards the local indigenous peoples.

Wherever reasonable and appropriate, provide local indigenous groups with the opportunity to participate directly or indirectly in employment opportunities.

Taking into account local conditions, provide the opportunity for qualified local indigenous businesses to tender for the supply of goods and services necessary for the Company's local activities.



HM Morgan

Chief Executive Officer

October 1995

Olympic Dam - Statement of Environmental Commitment

WMC (Olympic Dam Corporation) Pty Ltd and its subsidiaries are fully committed to effective management of environmental issues by applying information gained from scientific research, setting environmental objectives and targets, and regular management reviews and innovations. Environmental protection is considered to be an integral part of overall site management strategies.

WMC (Olympic Dam Corporation) Pty Ltd is committed to:

• complying with the WMC Environment and Indigenous Peoples Policies and relevant environmental legislation and regulations as a minimum environmental management standard;

• applying the Australian Minerals Industry Code for Environmental Management, and principles consistent with the ISO 14000 series of Environmental Management Systems standards;

• employing responsible, qualified persons and providing adequate resources and training to all employees;

• actively conducting appropriate environmental research, encouraging innovative environmental solutions, and applying economic environmental best practices;

• liaising with the workforce and community with respect to environmental care and land management;

• assessing, with the aim of minimising, any environmental effects that are likely to occur as a result of developments in the operation of the mine or processing plant;

• maintaining an effective and appropriate environmental monitoring programme.

At WMC (Olympic Dam Corporation) Pty Ltd, all employees and contractors are responsible for ensuring that environmental standards and rules are strictly adhered to. The Environment Section is responsible for educating the workforce on environmental issues and assessing the environmental performance and functions of the operation.

P. M. Bowman

Pearce Bowman
Executive General Manager
WMC Copper Uranium Division

Table 15.8 Summary of key commitments relating to environmental management (continued)

Relevant EIS Section	Commitment
Chapter 7—Biological environment (continued)	
7.3.7	The presence and efficacy of the Rabbit Calicivirus Disease would be investigated further and incorporated in the ongoing monitoring and management programme.
7.3.9	Two permanent fauna monitoring sites in the Special Mining Lease area would be directly impacted by the Expansion Project. These sites would be replaced with sites selected from nearby, similar habitats.
7.4.13	The monitoring of the presence and abundance of endemic mound springs invertebrate fauna and the species diversity of wetland invertebrate fauna will continue and, where possible, be expanded to incorporate the results of research on other species confined to the mound springs.
Chapter 8—Tailings management	
MANAGEMENT AND MONITORING	
8.1.4	Management and monitoring systems for the tailings retention system would be extended to cover the expanded facilities constructed as part of the Expansion Project.
8.1.4	In the event that loss of containment is detected in any evaporation pond cell by the liquor balance, the evaporation cell would be isolated, drained, cleared and inspected prior to any necessary repairs.
8.1.6	Sufficient, appropriately designed groundwater monitoring in and around the proposed expansion of the tailings retention system would be implemented for the proposed expansion, including the monitoring of background data prior to construction.
8.1.6	The leakage detection system using water balance calculations would continue to be used in the expansion of the tailings retention system.
PADDOCK STORAGE SYSTEM	
8.5.1	The design of the expanded tailings facilities would be largely driven by seepage minimisation considerations, including minimising the amount of supernatant liquor and maximising evaporation from the tailings surface.
8.5.2	The perimeter embankment for the new cells would be constructed using either local swale and sand dune materials, or tailings material borrowed from within the storage, and would be shaped and zoned using sand, general fill and clay in such a manner as to: • ensure stability under static and earthquake loading; • minimise seepage of acid tailings liquor through the embankment, thereby preserving embankment stability and avoiding future rehabilitation problems; • minimise erosion on the outer face. Where tailings are used for the lift, a layer of clay would separate the tailings from the downstream erosion protection layer, in order to provide a barrier to seepage and reduce radon migration.
8.5.3	The additional tailings line would be contained within the existing pipe corridor over much of its route, and thereafter within a new bunded pipe corridor.
8.5.4	To maximise supernatant water collection, the floor of the storages would be shaped by removing dunes and ridges where required, and by contouring (cut and fill) where necessary to provide a fall of about 1 in 500 towards the central decant. Temporary pumped decant facilities would be provided at any areas on the floor that were not free-draining towards the central decant facility.
8.5.4	The floor of the tailings storage would be prepared by providing a low permeability floor lining. Generally, it is intended that the floor preparation would be as follows: • The soil/limestone interface would be located by means of electromagnetic survey and shallow bores and test pits. • A low permeability clay liner would be placed over areas where the floor level would be in, or close to, sand or limestone. The clay liner would have a minimum thickness of 0.3 m. • Where the floor is on clay, the near-surface clay would be prepared, if necessary, by ripping, conditioning and compacting to a suitable depth. The preparation would remove any cracks and potential flow paths in the near-surface layer. • The floor would be proof rolled to identify any near surface dolines. Any dolines identified would be excavated and backfilled and capped with a clay seal.
8.5.4	In the event of the appearance of a doline (a fissure or solution cavity that may occur in limestones) during tailings deposition, the following approach would be adopted: • A temporary earthen embankment would be placed on the tailings surface preventing further deposition of tailings into the doline, but enabling the remainder of the tailings area to be used for deposition.

Table 15.8 Summary of key commitments relating to environmental management (continued)

Relevant EIS Section	Commitment
Chapter 8—Tailings management (continued)	
PADDOCK STORAGE SYSTEM (continued)	
	• The hole or cavern would be backfilled and an impervious seal placed over the area. • The temporary earthen embankments would be removed, and tailings deposition over the entire retention area recommenced.
8.5.5	The size of the supernatant pond would be kept to the practical minimum sufficient to ensure settling of solids from the supernatant tailings liquor. An underdrainage system would be provided to intercept and collect potential seepage below the planned maximum extent of the supernatant pond. The basin floor in the vicinity of the decant structures would also be provided with a low permeability clay layer or membrane to reduce seepage from the supernatant pond that would form adjacent to these structures.
8.5.7	Stable embankment slopes for higher storage heights would be determined using results from in situ field tests conducted prior to each raise.
CENTRAL THICKENED DISCHARGE STORAGE SYSTEM	
8.6.3	The perimeter embankment of the central thickened discharge (CTD) cell would be approximately 2–4 m high and constructed from materials removed from within the storage area. It would be zoned in a similar fashion to the starter embankment in the paddock system, to minimise seepage and radon migration through the embankment, and prevent erosion of the outer face of the embankment.
8.6.4	Special attention would be given to the stability of the tailings 'mounds', particularly in the early stages of development of the storage, when the mounds grow rapidly. It would be necessary to use several discharge points and interchange among these points to allow the tailings to dry in a manner that ensured the mound maintained stability and the drainage pattern was properly maintained.
8.6.5	As the CTD mounds grow, it might be necessary to construct and maintain a system of open drains to collect supernatant liquor that flowed off the toe of the mound.
8.6.5	Stormwater from significant rainfall events would be recycled for reuse in the process or evaporated, depending on its quality.
8.6.6	Preparation of the floor of the storage would be undertaken in areas identified as potential seepage areas. The base of the tailings storage area, including any identified dolines, would be prepared in a similar fashion to that described in Section 8.5.4. Any sand dunes would be removed and the sand stockpiled for future use.
8.6.7	A liquor balance would be carried out to size the evaporation area requirements once the optimum tailings solid content and supernatant liquor release and drainage collection are estimated using the results of the field trials.
8.6.8	Field trials would provide the data needed to design a CTD system and filling strategy that ensured the mound would be stable under all operating conditions, including extreme meteorological (rainfall and wind) and seismic conditions, and to assess the potential for dust generation from the surface.
OTHER ASPECTS	
8.7.2	The expanded tailings management system would provide for stormwater management systems. The stormwater management facilities would be designed to provide sufficient intensity and volume capacity for the design storm events. The average return interval selected for the design of each element would be determined by assessment of the hazards and consequences associated with failure of that element.
8.7.2	The CTD system would use an independent storage system, comprising a series of stormwater ponds and the perimeter embankment, to store the collected stormwater for disposal by return to the process or by evaporation. Spillways would safely discharge to the surrounding drainage system any run-off from a 1 in 500 year rainfall event that could not be stored by the stormwater ponds.
8.7.3	The new evaporation pond for the paddock system would be of similar construction to that of the two existing evaporation ponds, including a composite lining system—a lower liner of compacted clay overlain by a synthetic liner.
8.8	Specific fauna control strategies are currently used at the evaporation ponds and these would be extended to include the expanded facilities. The control strategies include: • fencing the evaporation ponds to exclude access to fauna; • using propane guns to deter visitation by birds; • at night, using another bird deterrent (developed on site) that takes advantage of birds' observed avoidance of intermittent rotating lights beamed across water surfaces.

Table 15.8 Summary of key commitments relating to environmental management (continued)

Relevant EIS Section	Commitment
Chapter 8—Tailings management (continued)	
OTHER ASPECTS (continued)	
8.10	Factors that would be taken into consideration in the design of the tailings storage facility include: • control of erosion by control of drainage patterns and provision of rock armour to external surfaces of the tailings storage facility; • selection of slopes for the perimeter embankments combined with the shear strength of consolidated tailings, so that the embankments are stable under seismic conditions.
8.10	Upon completion of rehabilitation, WMC would erect permanent markers on the rehabilitated tailings storage facility and refer its location to the relevant authorities for inclusion on mapping for the region.
Chapter 9—Air quality and noise	
9.2.1	The new smelters would be equipped with 90 m stacks.
9.2.1	Recovery of sulphur dioxide (SO_2) would be maximised in the acid plants in order to minimise SO_2 emissions and the use of imported elemental sulphur.
9.2.1	Gases leaving the acid plants would be discharged via 90 m stacks and contain no more than 2 kg SO_2 per tonne of sulphuric acid (H_2SO_4) production.
9.2.1	The yellowcake calciner gases would be cleaned by a scrubber prior to being emitted to atmosphere.
9.2.2	The acid plants would be designed to achieve stack sulphur trioxide (SO_3) emissions of not greater than 75 mg/Nm^3 of SO_3 and H_2SO_4, expressed as SO_3.
9.2.3	Nitrogen oxides produced in the gold and silver refinery acidification tank would be ducted to a caustic soda scrubber system.
9.2.9	The Expansion Project design emission limits are within the applicable SA EPA limit and the national guidelines for control of air pollutants from new stationary sources.
9.2.9	The Expansion Project design air quality criteria are less than the SA EPA criteria to provide allowance for future plant expansion. Overall levels are required to meet the SA EPA criteria.
9.3.1	If the 285,000 t/a copper production scenario were to proceed, the air pollution control on the existing anode furnaces and acid plant would be upgraded to ensure that air quality goals are met within the Special Mining Lease as well as outside it.
9.4.1	Protective measures to provide for employee safety and control of spillages would be built into new plant elements as they were for the existing plant. The aim would be to eliminate or reduce to a minimum the need for employees to wear special protective clothing or respiratory protection.
9.4.2	The equipment and techniques already in use on the site to control dust emissions during the unloading and transfer of material would continue to be employed for the Expansion Project.
9.4.2	Dust emissions at stockpile discharge conveyors would be controlled using methods such as luffing conveyors or telescoping discharge chutes, and conveyors and transfer points would be enclosed or covered as necessary.
9.4.2	The lightly trafficked secondary roads are surfaced but unsealed, and minor amounts of dust arise. These roads are used intermittently and are watered with mine water as necessary to control dust. This practice would continue following the proposed expansion.
9.5.3	The equipment contracts for the Expansion Project would include noise specifications as appropriate. Where practicable, engineering noise control would be used for reducing noise levels in key areas of the plant.
9.5.3	Occupational noise levels would continue to be at sufficient levels in some areas to require control measures. The current control measures, which include the provision of hearing protection equipment, noise monitoring, signage and employee training, would continue.
Chapter 10—Radiation	
10.2.3	The new smelter design will recirculate dust collected in the waste heat boiler and electrostatic precipitator to the flash furnace, except for a bleed stream which is passed direct to the hydrometallurgical plant. The bleed effectively controls the level of polonium-210 (^{210}Po) in the smelter blister and slag products and hence the level of any fume emitted from tapping points.
10.2.3	An improved design for the collection of fugitive emissions around tapping points will be incorporated in the design of the new smelter.

Table 15.8 Summary of key commitments relating to environmental management (continued)

Relevant EIS Section	Commitment
Chapter 10—Radiation (continued)	
10.2.3	In the new smelter, the launders will be short, without elbow bends, and covered by hoods. These will be ducted to the single air extraction system which will collect fumes from several process areas. Tapping points will also be provided with hoods connected to the air extraction system, diverting fume from the building into the collection system. Slag tapping will be automatic and the operator will be physically remote from the tapping points. An automatic mud gun will be used to plug the tapping holes.
10.2.3	The electric furnace will discharge into a launder run to the two anode furnaces, eliminating the need for hot-metal transfer by ladle. The launders will be covered and connected to the air collection system. The anode furnaces will discharge via covered launders to two casting wheels, which will also be equipped with hoods connected to the air collection system.
10.2.3	As far as possible, control rooms and control points will be enclosed in air-conditioned cabins remote from the smelter floor. Cameras will provide the necessary vision to operators. Where it is not possible to place the operator in a cabin, sealed respite cabins will be placed at strategic locations so that operators can retreat to an air-conditioned environment when they are not required on the floor.
10.2.3	A further reduction in the release of dust and fume to the building air will be achieved by improving the clean-up and maintenance services. Through-ways large enough to accommodate small front end loaders will be provided so that any spillage can be quickly and efficiently removed.
10.4.1	The Olympic Dam Expansion Project will take place in close proximity to existing production facilities which will continue in operation throughout the construction and commissioning phases of the new developments. During these phases, a programme of monitoring and assessment will be carried out separately from the routine monitoring. This programme will have two purposes. The first will be to ensure that radiation safety measures are adhered to by the contract workforce and that assessments can be made of the radiation exposure of construction and commissioning staff. The second purpose will be to verify that the new processes and equipment are operating within the design criteria established for radiation safety purposes. The frequency and types of measurements taken during construction and commissioning are usually different from those taken during routine operations. The separate monitoring and assessment programme for the construction and commissioning will be submitted for approval to the South Australian Health Commission.
10.4.2	In addition to assessing radiation doses, the current programme of actively controlling radiation exposures and limiting the resulting doses and releases of radiation to the environment will be extended to accommodate the proposed expansion at Olympic Dam.
10.4.2	A programme to implement the ALARA principle—'as low as reasonably achievable, social and economic factors being taken into account'—will form an integral part of the management of radiation safety. Annual audits will be conducted to identify issues with the potential to affect radiation exposures. The ALARA programme will incorporate the control measures outlined above.
10.4.3	In the first year of operating the new equipment associated with the Expansion Project, the number and type of research projects will increase in order to characterise the effects of the new facilities and to provide data on parameters used in dose assessments.
10.4.4	The Expansion Project will not increase the number of people required to conduct the routine environmental and safety programmes, but additional staff will be contracted as required to assist with the management of environmental and safety issues during construction and commissioning.
Chapter 11—Project infrastructure and township development	
BOREFIELD B	
11.1.2	Further assessment of selected vertebrate fauna along the Borefield B route will be carried out as part of the post-rehabilitation process.
11.1.2	The environmental code of practice for the Borefield B Stage 1 pipeline construction (Kinhill 1995) will be adapted for the Stage 2 pipeline construction. The environmental code of practice will be included in the construction contract, and will require the contractor to submit a work method statement to WMC describing proposed specific mitigation measures.
11.1.2	The construction work for the Borefield B pipeline Stage 2 construction will be subject to the issue of an environmental clearance form from WMC's Expansion Project Environment Adviser before construction starts. The environmental code of practice will also be distributed to all construction personnel as part of an induction training programme for the project, and be signed off by each recipient.
275 kV TRANSMISSION LINE CORRIDOR	
11.2.1	The requirements of the environmental code of practice for the 275 kV transmission line presently under construction have been incorporated into construction contracts, and are proposed to continue to be monitored for implementation and effectiveness, and independently audited for compliance.

Table 15.8 Summary of key commitments relating to environmental management (continued)

Relevant EIS Section	Commitment
Chapter 11—Project infrastructure and township development (continued)	
275 kV TRANSMISSION LINE CORRIDOR (continued)	
11.2.1	The environmental code of practice will be updated and used in a similar manner for the future new 275 kV transmission line, which is proposed to replace the existing 132 kV line in the future possible expansion to 350,000 t/a copper production.
11.2.2	Use of the same access track for construction and maintenance of both the 275 kV line under construction and the future new 275 kV transmission line will limit any further impact. The only additional access tracks required are those for the two minor route deviations and those to each transmission tower site. These latter tracks will also be used as fabrication areas, to minimise the extent of disturbance required.
11.2.2	At each transmission tower site an area will need to be cleared for assembly and erection of the towers. Wherever possible this activity will take place on the final section of the access track to minimise disturbance. Overall, the clearance of individual transmission tower sites is not expected to exceed an area of approximately 0.15 ha.
11.2.2	***Tablelands and plains:*** Minimising the removal of the protective gibber mantle will assist erosion control. This will be achieved by: • rolling instead of grading • limiting the extent of additional grading • ensuring that all windrows are removed from tracks and watercourse crossings • ceasing construction traffic movements after significant rain • confining all vehicles to the access or other designated tracks • limiting off-road vehicle movements during line stringing. Tower pads will not usually be graded. Where grading is unavoidable, gibbers will be stockpiled for later respreading during site rehabilitation. Towers will not be constructed in watercourses.
11.2.2	***Escarpment slopes:*** In addition to the previous mitigation measures, any necessary repairs to the existing track and the formation of tower pads in these areas will involve incorporating appropriate cross-drains and catch banks to inhibit and reduce the velocity of downslope surface flow. Sediment movement and accretion will be allowed for in the design of any drainage structures.
11.2.2	***Drainage depressions:*** Construction will be avoided to the maximum extent possible in drainage depressions and stream channels.
11.2.2	***Sand dunes and sheet sands:*** Dunes along the corridor will be crossed at, or close to, right angles to their east–west orientation wherever practicable, avoiding as far as possible the crests or flanks. Track and power line construction will be over, rather than through, the dunes. Some dune crossings will be sheeted with clay to enable trucks to cross during construction and to minimise the potential for sand dune blowouts along the corridor. Where the construction of transmission towers on dune ridges cannot be avoided, the sites will be similarly stabilised. Suitable material will be taken from borrow pits established in the dune swales, with all borrow pits being progressively rehabilitated after use. Vegetation clearance will be minimal and strictly controlled. Species such as sandhill wattle, Burkitt's wattle and narrow-leaved hopbush rapidly recolonise disturbed areas following good rainfall. Where removal of vegetation is unavoidable, these species will be removed in preference to those that grow more slowly or regenerate less successfully.
11.2.2	Vegetation clearance will be the minimum consistent with safe construction and statutory requirements, and will be controlled through implementation of the construction environmental code of practice. Limits of clearance will be clearly defined before construction begins, and ecologically significant vegetation identified by signage and protected by temporary fencing. Alignments of new access tracks will be adjusted as necessary to avoid damage to mature trees and to minimise damage to other vegetation. Vehicular access will be strictly controlled during the construction period.
11.2.2	Mitigation measures for the conservation of fauna habitats will generally accord with those for vegetation clearance and soil disturbance discussed previously.
11.2.2	Construction personnel will not be permitted to bring firearms, traps, pets or exotic animal species of any description into the area.
11.2.2	All archaeological sites in close proximity to construction sites, or assessed as being at possible risk of inadvertent disturbance during construction, will be protected by temporary fencing and/or signage. Signage will not differentiate between archaeological and other environmentally sensitive sites. Where archaeological materials occur between tower sites, particular care will be taken to minimise site disturbance during cable stringing.

Table 15.8 Summary of key commitments relating to environmental management (continued)

Relevant EIS Section	Commitment
Chapter 12—Social environment	
12.3.4	In order to minimise the impact on Roxby Downs township, construction personnel will be accommodated in the two single persons' quarters at Olympic Dam Village. A high standard of amenities including recreation and entertainment facilities will be provided, thereby reducing the need for construction personnel to travel to Roxby Downs.
Chapter 14—Rehabilitation and decommissioning	
14.1	In the event of premature closure before all disturbed sites had been rehabilitated, WMC would maintain its rehabilitation programme, including monitoring, to complete all outstanding tasks in the Project Area and to establish the long-term viability of these sites.
14.2	All areas disturbed in any significant, adverse way by the Expansion Project would be rehabilitated according to the rehabilitation procedures set out in the environmental clearance form or procedures equivalent to those listed in Table 14.1, and monitored to ensure the completion criteria (i.e. performance indicators) are met before finalisation of the project.
14.4	Decommissioning the areas managed by WMC will be to a best practice standard, and rehabilitation success will be measured by the development of a self-sustaining state of rehabilitated areas compared with undisturbed communities. Rehabilitated areas will have: • stable and structurally sound landforms that are protected against accelerated erosion from water and wind; • landforms that support pre-mining land uses and retain ecological values that, in general, are compatible with the surrounding landscape. The exception to this may be the walls of the tailings retention system; • landforms that are non-polluting and that do not compromise surrounding land uses and ecological values.
14.4	Decommissioning rehabilitation procedures and completion criteria for the Expansion Project that are site-specific would be developed concurrently with evaluation of the ongoing rehabilitation and monitoring programme. Final rehabilitation procedures and completion criteria would be included in a decommissioning plan that would be submitted to the South Australian Government for approval prior to implementation.
14.4	As a minimum, on completion of the mining and processing operations, all buildings and support facilities and debris would be removed and all of the disturbed areas rehabilitated.
Chapter 15—Environmental monitoring and management	
15.2	Modifications to environmental and radiation management and monitoring would be initiated when required and reported in the annual reports, and would be incorporated in the EMMP when it is submitted for approval every three years.
15.4.1	Two Safety and Environment Coordinators would be appointed and located on site to oversee all environmental and safety matters associated with the Expansion Project. The coordinator would have access to advice from personnel associated with the ongoing operations.
15.4.1	A procedures manual would be prepared as the principal reference for project team personnel involved in the Expansion Project. The procedures manual would include specific requirements for environmental and workplace matters.
15.4.2	Work covered by the environmental code of practice for the Expansion Project will be subject to an environmental monitoring and audit process to verify compliance.
15.4.3	An induction process into environmental management systems for the Expansion Project would continue to be conducted for all new personnel coming on site in conjunction with inductions into site safety procedures.
15.5.2	Every employee commencing employment at Olympic Dam, whether an employee of WMC or a contracting company, is required to attend an induction. The induction covers permits, occupational health and safety, and environmental and radiation protection issues. Annual radiation re-inductions are held for designated employees.
15.5.3	Formal hazard and operability (HAZOP) studies would be undertaken for all new major items of equipment associated with the Expansion Project. These HAZOP studies would be undertaken progressively during the design process, with representatives of State Government regulatory authorities given the opportunity to attend.
15.6.1	Olympic Dam Corporation Emergency Services are available to provide assistance, as required, for external emergency events, with the understanding that the mining and processing facilities have first priority for their services at all times.

APPENDIX A

WMC POLICY COMMITMENTS

Environment Policy

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 fulfil 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

Indigenous Peoples Policy

WMC is committed to developing relationships of mutual understanding and respect with the indigenous peoples of the areas in which we operate or propose to operate.

To fulfil this commitment, the Company will:

Establish and maintain effective, positive and frequent communication with indigenous groups.

Recognise the desire of indigenous peoples to fulfil their responsibilities within their traditional culture.

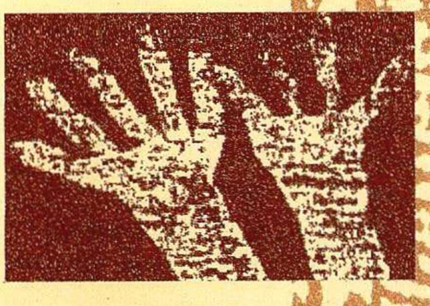
Seek to identify all indigenous interests in the area within which the Company is or intends to operate, define the basis for those interests whether derived from cultural traditions, historical association, occupation, social or economic need, and deal with those interests in accordance with the relevant government policy.

Recognise and observe all state, provincial, and federal laws relevant to indigenous and cultural matters.

Formulate and implement for appropriate Company personnel, an indigenous awareness program, pertinent to the local situation, which will engender the appropriate understanding, sensitivity and respect towards the local indigenous peoples.

Wherever reasonable and appropriate, provide local indigenous groups with the opportunity to participate directly or indirectly in employment opportunities.

Taking into account local conditions, provide the opportunity for qualified local indigenous businesses to tender for the supply of goods and services necessary for the Company's local activities.



HM Morgan

Chief Executive Officer

October 1995

Olympic Dam - Statement of Environmental Commitment

WMC (Olympic Dam Corporation) Pty Ltd and its subsidiaries are fully committed to effective management of environmental issues by applying information gained from scientific research, setting environmental objectives and targets, and regular management reviews and innovations. Environmental protection is considered to be an integral part of overall site management strategies.

WMC (Olympic Dam Corporation) Pty Ltd is committed to:

- complying with the WMC Environment and Indigenous Peoples Policies and relevant environmental legislation and regulations as a minimum environmental management standard;

- applying the Australian Minerals Industry Code for Environmental Management, and principles consistent with the ISO 14000 series of Environmental Management Systems standards;

- employing responsible, qualified persons and providing adequate resources and training to all employees;

- actively conducting appropriate environmental research, encouraging innovative environmental solutions, and applying economic environmental best practices;

- liaising with the workforce and community with respect to environmental care and land management;

- assessing, with the aim of minimising, any environmental effects that are likely to occur as a result of developments in the operation of the mine or processing plant;

- maintaining an effective and appropriate environmental monitoring programme.

At WMC (Olympic Dam Corporation) Pty Ltd, all employees and contractors are responsible for ensuring that environmental standards and rules are strictly adhered to. The Environment Section is responsible for educating the workforce on environmental issues and assessing the environmental performance and functions of the operation.

P. M. Bowman

Pearce Bowman
Executive General Manager
WMC Copper Uranium Division

Australian Minerals Industry

Code for Environmental Management

Recognising the need to achieve environmental excellence and to be open and accountable to the community, Australia's minerals industry has adopted a Code for Environmental Management. The Code is the centrepiece of a commitment to respond to community aspirations, values and concerns through consultation, demonstrated environmental performance, continual improvement and public reporting. Signatories to the Code are committed to excellence in environmental management through:

Sustainable Development
Managing activities in a manner consistent with the principles of sustainable development such that economic, environmental and social considerations are integrated into decision making and management.

Continual Improvement
Implementing management strategies to meet current and anticipated performance standards and regularly reviewing objectives in the light of changing needs and expectations.

Risk Management
Applying risk management techniques on a site specific basis to achieve acceptable environmental outcomes.

Environmentally Responsible Culture
Developing an environmentally responsible culture by demonstrating management commitment, implementing management systems, and providing the time and resources to educate and train employees and contractors.

Rehabilitation and Decommissioning
Ensuring decommissioned sites are rehabilitated and left in a safe and stable condition, taking into account beneficial uses of the site and surrounding land.

Integrated Environmental Management
Recognising environmental management as a corporate priority and integrating environmental management into all operations from exploration, through design and construction to mining, minerals processing, rehabilitation and decommissioning.

Community Partnership
Consulting the community on its concerns, aspirations and values regarding development and operational aspects of mineral projects, recognising that there are links between environmental, economic, social and cultural issues.

Performance Targets
Setting environmental performance targets not necessarily limited to legislation, licence and permit requirements.

Reporting
Demonstrating commitment to the Code's principles by reporting the company's implementation of the Code and environmental performance to governments, the community and within the company.

WMC Limited

Commits to implementation of the Australian Minerals Industry Code for Environmental Management

Hugh M Morgan, Managing Director

3/2/97 Date

APPENDIX B

GUIDELINES

Environment Australia

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

APPENDIX B

GUIDELINES

Guidelines for an environmental impact statement on the proposed expansion of the Olympic Dam operations at Roxby Downs—March 1997, issued by the Commonwealth Department of the Environment and the South Australian Department of Housing and Urban Development.

FOREWORD

The Commonwealth Department of the Environment and the South Australian Department of Housing and Urban Development are jointly assessing the environmental impacts of a proposed expansion of the WMC (Olympic Dam Corporation) Pty Ltd (WMC) Olympic Dam development to enable production to be increased from the currently approved level of 150,000 tonnes per annum (t/a) of copper and associated products, to up to 350,000 t/a of copper and associated products ('the proposed expansion'). The development is located 520 km north-north-west of Adelaide in South Australia.

The purpose of environmental impact assessment is to identify potential impacts, examine proposed mitigating strategies and—should the proposed expansion proceed—ensure that it does so in a well managed way. It is appropriate for the community to have input before governments make decisions.

WMC, the proponent, has been requested by the relevant Commonwealth and South Australian Ministers to prepare an environmental impact statement (EIS) to assist the governments in assessing the environmental impacts of the proposed expansion. An EIS is a document which describes to the Commonwealth Government, the South Australian Government and the community what the proponent wants to do, what the environmental impacts will be and how the proponent plans to manage the project.

The Commonwealth Department of the Environment and the South Australian Department of Housing and Urban Development jointly prepared draft Guidelines for the EIS. These draft Guidelines, which identified the issues the governments expect the proponent, WMC, to address in the EIS, were placed on public exhibition for a period of four weeks (18 November–11 December 1996), and comments invited from the community. The Guidelines were subsequently amended to take into account those issues raised in public and government agency submissions which lay within the scope of the Guidelines.

The existing operations at Olympic Dam (the operations) are currently wholly owned and operated by WMC. The operations have been in production since August 1988 and at present process approximately 3 million t/a of ore, for the recovery of some 84,000 t/a refined copper, 1,500 t/a of uranium oxide, 850 kg/a of gold and 13,000 kg/a of silver.

The legal framework for the terms and conditions of project development and operation was set by the 1982 Indenture between the South Australian Government (the State) and the then Joint Venturers (Western Mining Corporation, Roxby Mining Corporation, BP Australia Ltd., and BP Petroleum Development Ltd.), and was ratified by the State Parliament through the *Roxby Downs (Indenture Ratification) Act 1982* and updated by the *Roxby Downs (Indenture Ratification) (Amendment of Indenture) Amendment Act 1996*. The original Indenture provides for the development of a project recovering 150,000 t/a of copper metal, and associated products, and defines the obligations of the State and the then Joint Venturers.

In addition to the conditions laid down in the Indenture, WMC is obliged to comply with relevant State and Commonwealth legislation and Codes of Practice relating to environmental issues and to comply with the requirements of the Commonwealth *Customs (Prohibited Exports)* Regulations.

For the existing operations a comprehensive environmental assessment process was undertaken. Guidelines for the preparation of a Draft EIS were jointly agreed between the State and Commonwealth governments in consultation with the Joint Venturers in 1981. The Draft EIS was submitted to the State and Commonwealth governments in October 1982 and after public review of the Draft EIS, the Supplement was submitted in April 1983. The Draft EIS and the Supplement together with the State Assessment Report comprised the final EIS. The Commonwealth Government also produced an Environmental Assessment Report which also assessed the adequacy of the EIS in terms of the Administrative Procedures under the *Environment Protection (Impact of Proposals) Act 1974.*

The State and Commonwealth government environmental and planning approvals for the proposal were granted in June and August of 1983 to permit the mining and processing at Olympic Dam of approximately 6.5 Mt/a of ore, and the recovery of 150,000 t/a of copper metal, and associated products (including 3,000 t/a uranium oxide, 3,400 kg/a gold and 23,000 kg/a silver). These approvals were confirmed by the Commonwealth and State governments in an Environmental Review of the original EIS, completed in January 1996.

WMC now proposes to expand its Olympic Dam development to enable production of up to 350,000 t/a copper and associated products. In 1996 the Indenture was amended by the *Roxby Downs (Indenture Ratification) (Amendment of Indenture) Amendment Act* to potentially allow increased production and processing to be undertaken at Olympic Dam; however, a second EIS is required to enable environmental, social and economic impacts of the proposed expansion to be assessed.

It has been agreed that the scope of the new EIS shall encompass those issues clearly related to the proposed expansion of the Olympic Dam development and the potential impacts upon the region. These issues include, among others, the construction, operation and rehabilitation of the mine site and associated infrastructure, milling operations and disposal of tailings and transport of the uranium within Australia for export. The scope of the assessment will not include broader issues relating to the use of exported uranium in the nuclear fuel cycle. Issues related to the use of exported uranium in the nuclear fuel cycle are beyond the control of the proponent and it would be impractical for WMC to address these issues in the EIS. Issues relating to the use of exported uranium will be considered separately within the overall Commonwealth assessment of the proposal.

Public comments

Community and other interest groups and individuals were invited to comment on the draft guidelines. Written submissions were sent to:

The Manager
EIA Branch
Department of Housing and Urban Development
Level 5, 136 North Terrace
ADELAIDE SA 5000

Attention: Mr Peter Body

Comments were received until 5 pm Wednesday 11 December 1996.

A further opportunity for public comment will occur through the release of a draft EIS. Advertisements will be placed indicating the availability of the draft and the length of the public consultation period.

A INTRODUCTION

1 Background

The existing operations at Olympic Dam (the operations) are currently wholly owned and operated by WMC (Olympic Dam Corporation) Pty Ltd. The operations have been in production since August 1988 and at present process approximately 3 million t/a of ore, for the recovery of some 84,000 t/a refined copper, 1,500 t/a of uranium oxide, 850 kg/a of gold and 13,000 kg/a of silver.

The legal framework for the terms and conditions of project development and operation was set by the Indenture between the South Australian Government (the State) and the then Joint Venturers (Western Mining Corporation, Roxby Mining Corporation, BP Australia Ltd., and BP Petroleum Development Ltd.). The Indenture, as ratified by the State Parliament through the *Roxby Downs (Indenture Ratification) Act 1982,* provided for the development of a project recovering 150,000 t/a of copper metal, and associated products, and defines the obligations of the State and the then Joint Venturers. In addition to the conditions laid down in the Indenture, WMC is obliged to comply with relevant State and Commonwealth legislation and Codes of Practice relating to environmental issues.

For the existing operations a comprehensive environmental assessment process was undertaken. Guidelines for the preparation of a Draft EIS were jointly agreed between the State and Commonwealth governments in consultation with the Joint Venturers in 1981. The Draft EIS was submitted to the State and Commonwealth governments in October 1982 and after public review of the Draft EIS, the Supplement was submitted in April 1983. The Draft EIS and the Supplement together with the State Assessment Report comprise the final EIS. The Commonwealth Government also assessed the adequacy of the EIS in terms of the Administrative Procedures under the *Environment Protection (Impact of Proposals) Act 1974.*

The State and Commonwealth government approvals for the proposal were granted in June and August of 1983 to permit the mining and processing at Olympic Dam of approximately 6.5 Mt/a of ore, and the recovery of 150,000 t/a of copper metal, and associated products (including 3,000 t/a uranium oxide, 3,400 kg/a gold and 23,000 kg/a silver). These approvals were confirmed by the Commonwealth and State governments in an Environmental Review of the original EIS, completed in January 1996.

WMC now proposes to expand its Olympic Dam development to enable production of up to 350,000 t/a copper and associated products. In 1996 the Indenture was amended by the *Roxby Downs (Indenture Ratification) (Amendment of Indenture) Amendment Act* to potentially allow increased production and processing to be undertaken at Olympic Dam; however, a second EIS is required to enable environmental, social and economic impacts of the proposed expansion to be assessed.

2 Joint environmental impact assessment process

These Guidelines are based on the requirements of paragraphs 4.1 and 4.3 of the Administrative Procedures under the Commonwealth *Environment Protection (Impact of Proposals) Act 1974* (EPIP Act). The Guidelines are also based on the procedures of the *South Australian Development Act 1993.*

The South Australian Minister for Housing, Urban Development and Local Government Relations directed an EIS for the proposal.

The Commonwealth Minister for Resources and Energy has designated WMC as the proponent. The Commonwealth Minister for the Environment, Sport and Territories has determined, in accordance with Administrative Procedures under the *Environment Protection (Impact of Proposals) Act 1974,* that an EIS should be prepared for the proposed expansion of the Olympic Dam operations.

The object is to ensure that matters affecting the environment to a significant extent are fully examined and taken into account in decisions by the Commonwealth Government and the South Australian Government.

In accordance with the principles contained in the Intergovernmental Agreement on the Environment, and the Australian and New Zealand Environment and Conservation Council (ANZECC) 'Basis for a National Agreement on Environmental Impact Assessment' and to satisfy the environmental requirements of both governments, it has been agreed that a single process will be undertaken in the form of a Joint Commonwealth/South Australian EIS. The Environmental Impact Assessment Branch of the South Australian Department of Housing and Urban Development will take the lead role in the joint assessment process in full consultation with the Commonwealth Department of the Environment, Sport and Territories.

The South Australian and Commonwealth environmental impact assessment processes are broadly similar but differ in a number of minor details. The Commonwealth Department of the Environment (which is responsible for administering the *Environment Protection (Impact of Proposals) Act 1974* and the Environmental Impact Assessment Branch of the South Australian Department of Housing and Urban Development, have agreed on a joint process with the following key stages:

- Decisions that an EIS is required.
- Draft Guidelines prepared, placed on public exhibition and written submissions invited.
- Guidelines finalised.
- Proponent prepares the EIS document.
- Public exhibition of the EIS document (eight weeks) in accordance with the specific requirements of each jurisdiction. Written submissions are invited. Public meetings may be held in Roxby Downs and Adelaide during the exhibition period to assist people in the preparation of their submissions. Submissions are provided to the proponent.
- Proponent responds to public and government submissions and any other matters that may be required by the Ministers, by the preparation of a response document or Supplement.
- Independent assessment and preparation of assessment reports to Ministers with consultation between the appropriate Commonwealth and State agencies.
- For the Commonwealth, the Minister for Environment, Sport and Territories may make comments, suggestions or recommendations to the Action Minister (in this case, the Commonwealth Minister for Resources and Energy) on the environmental aspects of the proposal. The Action Minister is required to take into account such comments, suggestions or recommendations in making a decision on the proposal.
- For South Australia, copies of the EIS, response document and Assessment Report are sent to the Minister for Housing, Urban Development and Local Government Relations who may make comments, suggestions or recommendations to the Minister for Mines and Energy with whom rests the ultimate decision-making power for the proposal, under Clause 7 of the *Roxby Downs (Indenture Ratification) Act 1982*.

Copies of the EIS, response document or Supplement and assessment reports will be publicly available for inspection or purchase at places notified in public advertisements.

3 Outline of proposed expansion

Under the proposed expansion the basic mining and mineral processing methods used in the Olympic Dam operations will remain essentially the same except that improvements in technology and pollution control will be incorporated into the design of new plant and equipment. The new plant will be designed so that any spillage of ore, concentrate or process slurries can be readily returned to the process, as for the existing plant.

Underground open stoping will continue to be the principal mining method employed at the operations, with an increase in the number of stopes from about ten to about thirty. A stope is an excavation from which ore has been (or is being) extracted. Rock for backfill will continue to be a mixture of deslimed mill tailings and mullock or quarry rock, and cement and pulverised fuel ash. Mullock is waste rock (generally unmineralised) which is extracted during mine development and production.

Should the expansion proceed, additional processing facilities will include a further autogenous mill, a second tailings leach module, a new blister furnace with associated acid plant and oxygen plant, and expansion of the refinery. Additional tailings, liquor and minewater storage facilities and electrical and water supply infrastructure will also be provided. An autogenous mill uses the coarse feed (incoming material) as the grinding agent.

Pursuant to amendments to the Indenture ratified by the State Parliament through the *Roxby Downs (Indenture Ratification) (Amendment to Indenture) Amendment Act 1996*, it is also proposed to process concentrates and ore at Olympic Dam from material not mined from within the Special Mining Lease granted pursuant to the Indenture. At all times such production would come within the annual limit set for the purposes of environmental approvals, and is planned to maximise utilisation of available smelting capacity.

At Roxby Downs, additional housing will be provided. A second caravan park will be built, and water, electricity supply and sewerage services will also be upgraded.

4 Scope of EIS

The objective of both the environmental impact assessment provisions of the South Australian and the Commonwealth governments is to ensure that matters affecting the environment to a significant extent are fully examined and taken into account in decisions by the governments. The terms 'environment' and 'environmental' as used herein refer to all aspects of the surroundings of human beings, whether affecting human beings as individuals or in social groupings, and including the natural environment, the built environment (present and historic), and economic and social aspects of our surroundings. This definition covers such factors as air, water, soils, vegetation, fauna, buildings, roads, employment, housing and recreation facilities.

In preparing an EIS the proponent should bear in mind the following aims of the EIS and public review process:

- to provide a source of information from which interested individuals and groups may gain an understanding of the proposed expansion, the need for the expansion, the alternatives, the environment which it would affect, the impacts that may occur and the measures to be taken to minimise these impacts;
- to provide a forum for public consultation and informed comment on the proposed expansion;
- to provide a framework in which decision-makers may consider the environmental aspects of the expansion in parallel with economic, technical and other factors.

The proponent should ensure that the EIS demonstrates compliance with the goals, objectives and guiding principles of ecologically sustainable development as set out in the National Strategy for Ecologically Sustainable Development.

In particular the new EIS, in considering the proposed expansion of the Olympic Dam operations beyond 150,000 t/a of copper and associated products, should make specific reference to the following documents:

- Olympic Dam Project Draft Environmental Impact Statement, Roxby Management Services Pty Ltd, October 1982.
- Olympic Dam Project Supplement to the Draft Environmental Impact Statement, Roxby Management Services Pty Ltd, released in April 1983.
- Olympic Dam Project Assessment of the Environmental Impact, South Australian Department of Environment and Planning, November 1983.
- Environmental Assessment Report Olympic Dam Copper-Uranium-Gold Project, Commonwealth Department of Home Affairs and the Environment, May 1983.
- Survey and Assessment Report Supplementary Environmental Studies for the Borefield B Development, WMC Copper Uranium Division WMC (Olympic Dam Corporation) Pty Ltd, August 1995.
- Assessment Report of the Olympic Dam Operations Survey and Assessment Report for Borefield B, Department of Housing and Urban Development, November 1995.
- Environmental Review of the Olympic Dam Operations, WMC Copper Uranium Division WMC (Olympic Dam Corporation) Pty Ltd (following designation of the development under the Commonwealth *Environmental Protection (Impact of Proposals) Act 1995.*
- Assessment Report of the Olympic Dam Operations Environmental Review, Department of Housing and Urban Development, January 1996.
- Roxby Downs Water Leakage, Environment, Resources and Development Committee, 19th Report to the Parliament of South Australia, April 1996.

The document should also make specific reference to Environment Management Plans prepared under the Roxby Downs and Stuart Shelf Indenture, Clause 11 (Protection and Management of the Environment). Sub clause 1 of Clause 11 requires the Joint Venturers to submit triennial programmes for the protection, management and rehabilitation (if appropriate) of the environment. These Environment Management Plans have been prepared by WMC since 1986. Environmental Management Programme Annual Reports have also been prepared by WMC and together with the Environment Management Plans have been released as public documents since 1990.

The scope of this assessment shall encompass those issues directly related to the expansion of the Olympic Dam development, potential impacts upon the region, and alternatives to proceeding with the proposed expansion. The EIS will not address policy issues about the appropriateness of uranium mining. The scope of the EIS will also not include broader issues relating to the use of exported uranium in the nuclear fuel cycle. Issues relating to the use of exported uranium will be considered by the Commonwealth Government separately to this EIS.

The detailed scope of the EIS is set out in Section B of these Guidelines.

5 General content, format and style of EIS

The document should place emphasis on the major environmental issues associated with the proposed expansion. Matters dealt with in previous EIS and Reviews should be considered and dealt with to the extent that they are relevant to the proposed expansion from 150,000 t/a to 350,000 t/a. Matters of lesser concern should be dealt with only to the extent required to demonstrate that they have been considered.

It is envisaged that the EIS will be based on the results of available research, studies and data as appropriate, with further studies being conducted where necessary and practicable. The extent to which the limitations, if any, of available information may influence the conclusions of the environmental assessment should be discussed.

In these Guidelines the terms 'description' and 'discussion' should be taken to include both quantitative and qualitative materials as practicable and meaningful. Similarly, adverse and beneficial effects should be presented in quantitative and/or qualitative terms as appropriate.

The main text of the EIS should be written in a clear, concise style that is easily understood by the general reader. Technical jargon should be avoided wherever possible. Detailed technical information necessary to support the main text should be included as appendices issued with the EIS so that the EIS is complete and self-contained. Where appendices include results of studies conducted in preparing the proposal, the public availability of the studies should be indicated.

The documentation should include references and a list of individuals and organisations consulted. Relevant maps and illustrations should also be included. The cost of the EIS to the public should be minimised.

While every attempt has been made to ensure that these Guidelines address all of the major issues associated with this proposed expansion, they are not necessarily exhaustive and should not be interpreted as excluding from consideration matters deemed to be significant but not incorporated in them or matters (currently unforeseen) that emerge as important or significant from environmental studies or otherwise during the course of preparation of the EIS.

B CONTENTS OF THE EIS

1 Summary

As prescribed by paragraph 5.2 of the Administrative Procedures under the *Environment Protection (Impact of Proposals) Act*, the EIS must include a concise summary of the matters discussed in the main body of the document, to allow the reader to quickly obtain a clear understanding of the proposed expansion and its environmental implications. The summary should include:

- the title of the expansion;
- the name and address of the proponent;
- a brief discussion of the background to and need for the expansion;
- a brief discussion of the alternatives, and reasons for selecting the preferred option;
- a brief description of the expansion;
- a brief description of the existing environment;
- a description of the principal environmental impacts (both adverse and beneficial);
- a statement of the environmental protection measures, mitigation, safeguards and monitoring procedures proposed;
- a brief description of the proposed plans for decommissioning and rehabilitation.

2 Introduction

The main body of the EIS should be introduced with a clear definition of the objectives of the proposed expansion. A brief explanation of the scope and legislative basis for the EIS should be provided, including the role of the EIS in the governments' decision-making processes. The study area and regional setting for the expansion should be described. A description of the study area and regional setting for the proposal, including land use, tenure and the potential for application of the *Native Title Act 1993*, should be provided.

The introduction should briefly describe the studies/surveys/consultations that have been conducted in developing the proposed expansion and preparing the EIS. Results of studies and detailed comments resulting from the consultation should be included as appendices. The structure of the document should be briefly explained.

3 Background

The EIS should discuss the background to the proposed expansion, covering, for example, the following points:

- the existing development;
- the scope and major outcomes of the 1982 EIS, 1995 Survey and Assessment Report for Borefield B and the 1995 Environmental Review for the existing development, and a discussion of the effectiveness of environmental management measures adopted;
- outline of environmental studies subsequent to the 1982 EIS including studies, surveys and consultations conducted in developing the expansion and preparing the current EIS, and, where appropriate, results of these studies included as appendix items;
- a response to the findings of the South Australian Government inquiry into leakage from the tailings retention system, including a description of remediation measures taken to prevent future leaks;
- the framework of existing approval mechanisms for Olympic Dam operations;
- a review of planning, and design of on-site works which have been undertaken;
- planning considerations, regulations, standards etc. governing the design and operation of the expansion, including the legislative position under which the application of the *Environment Protection Act 1993* to the original project and the expansion in relation to the provisions of the Indenture;
- the current status of the expansion to 150,000 t/a, the approvals required in order for the expansion beyond 150,000 t/a to proceed, and approval legislation.

4 Need for the proposed expansion

The EIS should provide a comprehensive explanation of the need for, and justification of, the proposed expansion, including:

- the specific objectives the expansion is intended to meet including market requirements and trends;
- a comparative analysis of expected regional, State or national benefits and costs (including those that cannot be adequately described in monetary or physical terms, for example effects on cultural environment);
- a summary of environmental, economic and social arguments to support the expansion.

5 Description of the proposed expansion

All components of the proposed expansion (including the mine site, processing site, copper concentrate transportation, product transportation, transport corridors, etc.) should be described in detail from initial installation to the long-term horizon. Alternatives to various components of the expansion should be outlined. Emphasis should be given to those components with the most potential for significant short and long-term environmental impacts. Where appropriate, technical information should be supported by maps, figures and diagrams. Detailed technical information should be included in the appendices. Underlying assumptions and forecast reliability should be discussed.

The description should include (where relevant):

- Location, site, layout and project description including ancillary sites, transport corridors, etc.;

- Description of the physical requirements for the proposed expansion including:
  - types, total quantities, sources and availability of major construction materials;
  - additional infrastructure requirements, including transport of copper concentrate;
  - off-site infrastructure requirements, community developments and emergency response procedures required to support the safe transportation of raw materials and products, including ship loading.
- Description of the construction works required, including:
  - timing of work programme, duration of construction phase including lead times;
  - size of construction workforce and any additional accommodation requirements;
  - extent of earthmoving, building demolition/relocation, vegetation clearance and other site preparatory works including arrangements to minimise unnecessary clearance and disturbance;
  - construction standards, techniques and site management arrangements;
  - arrangements for disposal of construction wastes during and following construction;
  - arrangements for erosion control and rehabilitation of construction sites.
- Procedures/processes/technologies to be utilised, and the major plant components associated with various expanded operations, including:
  - mine programs/plans, estimated mine life, additional mine dewatering requirements and expansions, mining expansion and ground stabilisation, ore crushing and stockpiling, reclamation and transfer facilities;
  - Tailings Retention System, design and operation, including any variation from the existing system, safeguards to minimise leakage, implications of any staged commissioning or operational limitations relating to physical properties of the tailings (e.g. size distribution, density);
  - nature, quantities and sources of supply of raw materials for mineral processing imported into the existing process area;
  - milling and processing of the ore;
  - expanded onsite storage facilities for raw materials and products (location, capacity and design);
  - gas cleaning systems associated with all aspects of the metallurgical plant.
- Resultant increase of products and waste including:
  - the nature and quantities of processed mineral wastes generated by the expansion;
  - origins, quantities and nature (physical, chemical) of solid wastes produced for disposal (waste dumps, tailings storage facility etc.) including the capacity of the proposed expanded disposal sites;
  - origins, volumes and composition of liquid wastes associated with the expansion;
  - origins, quantities and composition of increased gaseous emissions from project operations (include chemical and particulate emissions, provide estimates of both total emissions and ground level concentrations and discuss predicted emission plume formation and dispersal including from mine exhausts);
  - any modifications required to address waste and hazardous substances contingency plans for spills, accidental release and pollution;
  - any modifications required to address predicted levels of noise (on-site and at site boundaries) generated by individual plant components and the project overall;

- any increased quantity of heat released to the environment via flaring and cooling operations, and modes of heat transfer;
- sources, pathways and potential doses of radiation exposure for employees, members of the public and the surrounding environment, including: radon gas and its decay products, radioactive particles in dust or water, gamma radiation, including exposure from ore transfer and processing, the tailings retention area, and transportation and storage of processed uranium;
- sources, pathways and potential exposures to non-radioactive contaminants for employees and members of the public.

- Water supplies, including:
  - requirements in terms of quantity and quality for expanded industrial operations, workforce consumption on site, domestic consumption by project workers and their families;
  - provision of and limits to supplies including, existing Special Water Licence, existing pipelines from borefields; and the proposed infrastructure and arrangements for maintenance of water quality; and
  - proposed recycling and water minimisation techniques.
- Energy supplies, including:
  - expanded requirements for industrial and workforce domestic purposes, types of energy which can be utilised, proportions of proposed energy supply mix;
  - sources of energy supplies and transmission modes (including placement of power lines) required for the expansion;
  - identification and adoption of measures to minimise energy requirements including use of renewable energy sources where feasible.
- Transport, including:
  - transport of copper concentrates and processed product to port, loading, and shipping within Australian waters, including transfer equipment (proposals for upgraded or additional road/rail links, pipelines, conveyors etc.), selection of the transport route, interim storage sites, transfer and loading of material and decommissioning of transportation and storage sites.
- Other Resource Requirements, including:
  - options available for the supply of resources;
  - infrastructure and public facilities required.
- Required workforce, its establishment and maintenance, including:
  - expanded numbers in various categories of skilled and unskilled workers required at various stages of project development, numbers of part-time, full-time and casual workers and the expected source of labour forces including references to regional availability;
  - workforce expansion and maintenance including predicted increase in total population numbers resulting from direct employment on the project;
  - any proposed expansion of accommodation, provision of accommodation by the proponent, provision by government;
  - expansion of other services and facilities to support the project workforce and families (health care, social services, education, recreation, retail outlets etc.), the adequacy of provision made by the South Australian Government and the contribution, if any, of the proponent;

- any requirements to expand health and safety services, including project site safety and medical facilities.

- Landscaping.
- Anticipated costs and feasibility, including:
  - the importance of uranium mining and processing to the economic viability of the proposed expansion.
- Community liaison and consultation, including:
  - identification of, and ongoing consultation and negotiations with, Aboriginal communities and pastoralists at all stages of the project, ensuring the full range of community viewpoints are sought.
- Economic Impacts:
  - Regional
  - State
  - National.

6 Alternatives

The EIS should describe any prudent and feasible alternatives to carrying out the proposed expansion. These alternatives, including the 'no go' option, should be discussed in sufficient detail to make clear the reasons for preferring certain options and rejecting others. The choice of the preferred option(s) should be explained, including a comparison of the adverse and beneficial effects (direct and indirect) used as the basis for selection, and compliance with the principles and objectives of ecologically sustainable development.

The alternatives to be discussed should include:

- not proceeding with the proposed expansion;
- other key alternatives to the project configuration.

Discussion should include:

- adverse and beneficial effects of alternatives at national, State, regional, and local level;
- the comparison of short, medium and long-term advantages and disadvantages of the options; and the criteria and their relative importance in comparing options.

7 Existing environment

A description of the existing and anticipated future environments within the Indenture area (i.e. including those areas likely to be affected by mine, processing and transport operations) is required to serve as a baseline against which the impact of the expansion and alternatives can be assessed. Where appropriate a description of the existing environment beyond the Indenture area should be included. The extent of the discussion and description should be guided by the general principles set out in Section A.2 above. Consideration should be given to changes to the environment that have occurred due to existing mining operations.

- Aspects of the physical environment:
  - geology, geomorphology, seismic stability, soil types;
  - topography;
  - hydrology (surface and groundwater systems, catchments, flow and discharge rates, water quality, other water users and water requirements to maintain mound spring integrity);

  - relevant climate and atmospheric conditions including precipitation and evaporation rates, winds, and temperature, seasonal variability;
  - probability of extreme storm events;
  - existing ambient noise levels;
  - existing air quality;
  - regional landscape.
- Biological environment:
  - describe the habitats, communities and vegetation/fauna species within them, noting local, regional and any other significance of the biological diversity (as per the Convention on Biological Diversity), and current condition;
  - ecological relationships, including the conservation status of species or associations to be disturbed by the expansion (including species and communities listed under the *Commonwealth Endangered Species Protection Act 1992)*;
  - other sensitive environments or areas of special significance, in particular wetlands significant in maintaining biological diversity and providing habitat for fauna species of conservation significance;
  - introduced vegetation and fauna;
  - areas of natural environment with identified special values.
- Aspects of the social and economic environment:
  - demographic characteristics;
  - social factors;
  - economic factors;
  - employment levels and characteristics;
  - existing primary, secondary and service industries in the area together with estimates of the adequacy of existing services and any unused capacity to provide for population increases associated with the expansion;
  - an overview of the history of land use in the region;
  - regional and bioregional planning strategies and frameworks;
  - land tenure;
  - existing and proposed land uses including government land, water resources, power supply, infrastructure corridors, rural, tourism, industrial, residential and commercial;
  - other physical infrastructure that could be affected by mine expansion.
- Aspects of the cultural environment:
  - Aboriginal and pastoral use of the land;
  - Aboriginal heritage (archaeology and anthropology) including reference to *Native Title Act*;
  - areas listed on the Register of the National Estate. The national estate consists of those places, being components of the natural environment of Australia or the cultural environment of Australia, that have aesthetic, historic, scientific or social significance or other special value for future generations as well as for the present community, and
  - European heritage.

- Existing legislation including provisions of the *Roxby Downs (Indenture Ratification) (Amendment of Indenture) Act* and other relevant State and Commonwealth legislation (including *Aboriginal Heritage Act, Native Title Act, Heritage Commission Act).*

8 Environmental impacts

The EIS should discuss the environmental impacts expected to result from the proposed expansion and to the extent appropriate, alternatives. The discussion should cover effects on the natural and socio-economic environment in the study area, at a local, regional, State and national level as appropriate. Consideration should be given to the effects during the construction phase and the ongoing operations of the mine. Generally the discussion should use the same indicators and descriptors used to describe the existing environment (Section 7).

Direct and indirect, short-term and long-term, temporary and irreversible, adverse and beneficial effects should be described and, where possible, quantified. The reliability and validity of forecasts and predictions, confidence limits and margins of error should be indicated as appropriate. Underlying data and assumptions should be accessible. Interactions between impacts on biophysical and socio-economic environments, individually and collectively, should be covered.

The following sections illustrate the types of impacts that need to be considered.

Impacts during construction phase

The impact of construction works associated with the expansion including Tailings Retention System, Mine, Process Plant and associated areas (roads) should be described as far as practicable, including:

- effects and extent of earthworks, including potential soil erosion;
- effects of dust, vibration, noise;
- transport of materials and disposal of construction wastes;
- any additional changes to hydrology, e.g. drainage patterns, aquifers and effects of water table and water quality;
- extent and significance of clearance and/or other disturbance of native vegetation and effects on native fauna, especially rare or endangered species or significant habitats;
- impacts of construction on regional and local communities including effects on employment and the local and regional economy;
- visual and aesthetic impacts of construction works;
- impacts of construction on sites of archaeological or cultural significance.

Impacts during operational phase

The impacts of the expansion both within and beyond the boundaries of the Indenture land (where appropriate), should be described, as far as is practicable, from initial operation to the proposed production ceiling of 350,000 t/a copper and associated products, including:

- water extraction and delivery to site;
- mine dewatering, recycling and storage of water;
- residue (tailings and waste rock) and process water and seepage (including additional impacts at the existing site);
- dust from stockpiles, transported loads and other mining operations;

Monitoring Plan to manage the impacts identified in the EIS should be discussed and any necessary changes identified. Monitoring and quality assurance programs designed to ensure safeguards are being effectively applied and to identify and measure any differences between predicted and actual impacts, should be described.

Reference should be made to relevant legislation, standards and procedures and any relevant international codes of practice. The bodies responsible for implementing each of the various safeguards and monitoring programs should be identified, and their roles explained. Details of proposed arrangements for making public the environmental management plans and monitoring results should be provided (while there is provision in the Indenture for WMC and the State Government to protect the confidentiality of information when considered necessary, particularly in relation to commercial issues, a significant amount of environmental information is made available publicly on a regular basis through the annual Environmental Management Report, the annual Environmental Radiation Report and the triennial Environmental Management Program).

Environmental safeguards

Safeguards to avoid and mitigate effects on the environment should be discussed, including measures to ensure timely responses:

- to control erosion;
- to minimise vegetation disturbance;
- to control bushfires and other fires;
- to control/mitigate changes to groundwater;
- to control air and water pollution;
- to control exposure to radiation including releases of radioactive substances from tailings, waste rock, mine dewatering and air emissions;
- to control pollution from solid and liquid waste including options for reuse and recycling;
- to mitigate noise and noise impacts;
- to mitigate any deleterious effects on economic, social, recreational, conservation, cultural, and community activities and resources (in particular, renewable resources);
- to minimise disruption to surface traffic during construction and disturbance and loss of amenity due to increases in surface traffic to and from the site;
- to minimise 'greenhouse' gas emissions and maximise energy efficiency;
- to avoid, control or minimise impacts on sites and values of environmental or heritage significance;
- to control and minimise impacts upon biological diversity;
- to incorporate environmental protection into the design, siting, layout and landscaping of facilities and associated works (e.g. to minimise visual impact);
- to educate contract and WMC personnel and their families (resident in the Roxby Downs township) in relation to their environmental protection obligations (e.g. through the incorporation of appropriate clauses in construction contracts) including appropriate management of pets;
- to provide for adequate insurance arrangements in the event of adverse impacts that may require compensation associated with remediation;
- to ensure efficient water usage.

Monitoring programmes and procedures

Comprehensive monitoring programmes to ensure the above measures are applied effectively should be outlined. Mechanisms for handling pollution incidents related to the mine, processing, tailings storage and transportation activities, including necessary management arrangements, should be discussed. Those individuals or groups responsible for monitoring programs should be identified and arrangements for making use of outside expertise should be described. There should also be a statement of the procedures that are in place for reporting on monitoring programmes, and an indication of how these reports will be distributed.

Baseline data collected as part of the description of the existing environment, and any studies proposed to identify changes as the result of the proposed development, should be included. The design of these studies should take into account the methodology of previous studies and any difficulties encountered to ensure that the results can be meaningfully compared to the baseline data and predictions of the EIS.

There should be a description of any provisions made in project planning for response mechanisms and further remedial action if monitoring indicates that the project is causing unexpected environmental degradation. Examples of the matters that should be addressed in the proposed monitoring programme are as follows:

- monitoring the effectiveness of pollution control measures (water, air and solid waste) during construction and operational phases;
- monitoring of safety and health procedures including monitoring of employee health;
- monitoring of noise levels;
- monitoring of air quality;
- monitoring of water quality and hydrology;
- monitoring of the surrounding environment potentially impacted by the expansion, including vegetation and fauna and the spread of introduced species;
- a monitoring of the adequacy of emergency procedures developed to deal with accidental release of hazardous substances, fire, radiation exposure, etc.;
- provision for liaison/consultation with relevant authorities, community and user groups.

Oversight of environmental protection strategies

The EIS should include a description of arrangements for independent oversight of monitoring, safeguards and environmental management strategies. This should identify linkages and compliance with the requirements of relevant regulations. A list and brief description of legislation relevant to the environmental management of the site should be provided.

Contingency planning

A description and outline of contingency and emergency plans, and resources and procedures to address all potential incidents both during and after the project should be included.

10 Rehabilitation and decommissioning

This section should address the rehabilitation and decommissioning objectives and goals for the whole project including both progressive and final rehabilitation processes and standards. This section should also address the constraints that may influence the type and extent of rehabilitation throughout the whole project. The success and problems encountered with rehabilitation to date should be outlined, as they relate to techniques to be used for the expansion.

Apart from specific project details listed in table form, general information which should also be addressed includes:

- strategies for the involvement of the Aboriginal communities and pastoralists, in determining the rehabilitation goals and objectives;
- integration of the rehabilitation programme with mine design and operation;
- stability and erosion control measures including stability of tailings disposal storage structures for the duration of risk to the surrounding environment;
- long-term monitoring and management of surface and sub surface drainage and subsidence;
- rehabilitation strategies to minimise radiation emission from the site after completion of the development;
- revegetation programme.

11 Consultation and studies

Describe research and investigation undertaken in the course of evaluating the need, feasibility and design of the expansion including baseline studies undertaken. Cite any sources of information used in preparing the EIS.

Describe any consultations undertaken with Commonwealth/State agencies, local government, relevant Aboriginal groups and the wider community over the expansion and the way in which concerns raised will be, or have been, addressed. Describe any further studies, investigations and consultations, either proceeding or intended to be made in regard to the design and potential impacts of the expansion.

12 Appendix A

Matters to be dealt with by environmental impact statements*

Contents of environmental impact statement:

4.1 To the extent appropriate in the circumstances of the case, an environmental impact statement shall:

(a) state the objective of the proposed action;

(b) analyse the need for the proposed action;

(c) indicate the consequences of not taking the proposed action;

(d) contain a description of the proposed action;

(e) include information and technical data adequate to permit a careful assessment of the impact on the environment of the proposed action;

(f) examine any feasible and prudent alternative to the proposed action;

(g) describe the environment that is likely to be affected by the proposed action and by any feasible alternative to the proposed action;

(h) assess the potential impact on the environment of the proposed action and of any feasible and prudent alternative to the proposed action, including, in particular, the primary, secondary, short-term, long-term, adverse and beneficial effects on the environment of the proposed action and of any feasible and prudent alternative to the proposed action;

(i) outline the reasons for the choice of the proposed action;

(j) describe, and assess the effectiveness of, any safeguards or standard for the protection of the environment intended to be adopted or applied in respect of the proposed action, including the means of implementing, and the monitoring arrangements to be adopted in respect of, such safeguards or standards;

(k) cite any sources of information relied upon in, and outline any consultations during, the preparation of the environmental impact statement.

* *Extract from the Administrative Procedures under the* Environment Protection (Impact of Proposals) Act 1974.

Graben	An elongate, relatively depressed crustal unit that is bounded by faults along its long sides. Also known as a rift valley.
Great Artesian Basin	A groundwater basin covering about one-fifth of Australia that includes an artesian aquifer whose potentiometric surface is above the land surface in topographically lower parts of the area.
Grizzly	A heavy grid used for the screening of large rocks.
Gross domestic product (GDP)	The total money value of all final goods and services produced in the national economy over a one-year period.
Gross state product (GSP)	The total money value of all final goods and services produced in a State economy over a one-year period.
Groundwater	Underground water contained within a saturated zone or rock (aquifer (q.v.)).
Gypcrete	A gypsum-cemented crust or rock found in some playa (q.v.) lake beachrock environments in arid climates.
HAZOP	A HAZOP (hazards and operability) study identifies potential hazards and operability problems in industrial plant. The concept involves investigating how the plant might deviate from the design intent under all possible operating conditions.
Hydraulic gradient	The change in static head or hydraulic potential per unit of distance in a given direction.
Hydrocyclone	A conically shaped device which uses centrifugal force to separate particles by density or size. The coarse or heavy material is collected at the bottom of the cone (underflow), while lighter material passes through the top of the cone (overflow).
Hydrogeology	The science dealing with groundwater and with related geological aspects of surface water.
Hydrostatic head	The water pressure at the bottom of a vertical column of water of a specified height above an assumed surface used as a reference surface for the measurement of reduced levels.
Hydrothermal	Descriptive of rocks altered by the reaction of hot aqueous solutions.
Incline	An underground opening usually inclined at about 1 in 10 driven from the bottom up, commonly used to access drill drives and other ancillary development from the main access underground.
Input–output analysis	A technique of economic analysis describing the interaction of sectors of the economy, and allowing estimation of the effect of change in one sector on other sectors.
Intrusive rocks	Rocks formed by intrusion of magma into pre-existing rocks.

Epiclastic	Descriptive of mechanically deposited sediments consisting of weathered products of older rocks.
Evapotranspiration	The total water loss by evaporation from a particular area, being the sum of evaporation from the soil and transpiration from vegetation.
Extrusive rocks	Rocks formed by the consolidation of lava on the surface of the ground.
Feed Buhler	A drag conveyor used to transport feed from the surge bins to the concentrate burner on the flash furnace.
Felsic	A term applied to light-coloured igneous rocks containing an abundance of feldspar and silica.
Filtercake	The layer of precipitate that builds up on a filter during pressure filtration.
Flotation	The process of mineral separation by addition of reagents (collectors) in an aerated agitated slurry. The collectors attach to sulphide minerals and render the surfaces hydrophobic. Sulphide particles therefore 'attach' to air bubbles which float to the top of the flotation tank, thus effecting a separation between the non-valuable and valuable minerals.
Flow-on effects	The effects on other areas of an economy as a result of a change in activity in a particular industry sector.
Flux	Intentionally added component of a slag which lowers its melting point or viscosity, or modifies its chemical properties.
Forb	Any herb other than a grass.
Freeboard	In mining, the vertical distance between the design water-level and the top of the containing structure.
Gamma radiation	A form of electromagnetic radiation similar to light or X-rays, distinguished by its high energy and penetrating power. Gamma radiation is emitted after nuclear reactions, or by radioactive atoms when the nucleus is left in an excited state after the emission of an alpha or beta particle.
Gangue	Non-valuable minerals associated with an ore deposit.
Geosyncline	A large, generally linear trough, which has subsided deeply over a long time interval and in which thick sequences of sedimentary and volcanic rocks have accumulated.
Gibbers	Fragments of stone on the surface of tableland, formed by weathering of the top layer of rock.
Gilgai	The microrelief of soils produced by expansion and contraction with changes in moisture, found in soils that contain large amounts of clay. It is characterised by a markedly undulating surface with mounds and depressions.

Decline	An underground opening usually inclined at about 1 in 10 driven from the top down, and commonly used for access to underground workings from the surface.
Deflation	The removal of sand from dunes through wind action.
Desliming	The removal of very fine particles from an ore pulp, or the classification of it into relatively coarse and fine fractions.
Dog Fence	A dingo-proof fence in the Australian outback, extending from the Great Australian Bight to the east coast of Australia.
Doline	A funnel-shaped cavity, created by the dissolution of carbonate rock by water, which connects with the underground drainage system in a limestone region.
Dolomitic limestone	A limestone with a high proportion of the mineral dolomite ($CaMg(CO_3)_2$).
Doré metal	A mixture of gold and silver.
Dose	The radiation energy absorbed in a unit mass of material.
Dose equivalent	The mathematical product of the absorbed dose, the quality factor, and any other specified modifying factors. The quality factor accounts for the effectiveness of energy transfer of the ionising radiation in producing a biological detriment. Modifying factors are those which may act to modify the effect of the energy imparted to the matter.
Drawdown	The fall of water-level in a natural reservoir such as an aquifer due to pumping or artesian flow.
Drill drive	An underground opening, usually horizontal, from which blastholes are drilled.
Drive (or drift)	A horizontal underground opening, usually running above the strike of the orebody.
Dyke	A tabular body of igneous rock that cuts across the structure of adjacent rocks.
Ecotype	A recognisable local form of a plant species which has become genetically adapted to certain environmental conditions.
Electrophoretic	Descriptive of the motion of charged particles under an electrical field in a fluid—positive groups to the cathode, and negative groups to the anode.
Electrorefining	The process of dissolving a metal from an impure anode and depositing it in a more pure state at the cathode.
Electrostatic precipitator (ESP)	An air pollution control device used to remove fine particulate matter from industrial waste gases. In the device, a very high voltage is imparted between sets of electrodes. One set of electrodes induces a charge on the particles which are attracted to and collected on the other set of electrodes.
Electrowinning	The recovery of a metal from a solution of its salts by electrolysis, the metal depositing on the cathode.

Central thickened discharge (CTD) method	A tailings storage method that involves further thickening of the tailings slurry, followed by discharge through central risers to form a final tailings profile resembling a series of intersecting flat cones.
Chalcopyrite	The mineral also known as copper pyrites ($CuFeS_2$).
Chenopod	A member of a family of mostly herbaceous plants and shrubs, mainly of saline and semi-arid regions. Includes bluebushes, saltbushes and samphires.
Class A pan	A standard pan used for measuring rates of evaporation.
Clastic	Descriptive of a rock or sediment composed principally of broken fragments derived from pre-existing rocks or minerals.
Comminution	The reduction of the size of ore by breaking, crushing or grinding.
Competent rock	Rock which is capable of sustaining relatively large underground openings with minimal support apart from pillars and walls left during mining.
Computable general equilibrium (CGE) model	Models of economies (regional, State, national) which portray the links between sectors of the economy in terms of how inputs and outputs flow and which are able to simulate the effects of price changes and resource constraints.
Cone of depression	A cone-shaped depression in a water table caused by pumping.
Consumer price index (CPI)	Index comparing the cost over time of a standard basket of goods.
Countercurrent decantation (CCD)	The clarification of washery water and the concentration of tailings by the use of several thickeners in series. The water flows in the opposite direction from the solids. The final products are slurry (which is removed as fluid mud) and clarified water (which may be reused in the circuit).
Craton	A part of a continent that has attained crustal stability.
Cretaceous	The final, third period of the Mesozoic Era. It spanned the geological time between 65 million and 135 million years ago.
Crib room	A lunch room in a mine or on site.
Crown pillar	That block of rock (commonly ore) at the top of a stoping region, usually left intact to eliminate surface damage through subsidence, or because ore at the top of the orebody is frequently oxidised and difficult to process.
Cyanidation	The process of extracting gold and silver from ore by treatment with dilute solutions of sodium or potassium cyanide.
Decay product	The product of the spontaneous radioactive decay of a nuclide (q.v.). A nuclide such as uranium-238 decays through a sequence of steps and has associated with it a number of successive decay products in a decay series.

Becquerel (Bq)	The SI unit of measurement of radioactive activity defined as one radioactive disintegration per second.
Beta emitter	A radioisotope that emits a beta particle (q.v.) when it decays.
Beta particle	An electron or positron emitted by the nucleus of a radionuclide during radioactive decay. Beta particles will pass through paper but are stopped by a thin sheet of metal.
Blister copper	Unrefined copper, prepared from ore by a smelting or converting process, containing approximately 1% sulphur and 1% other impurities.
Blowout	A term used for the saucer-shaped hollows formed by wind erosion on sand ridges and sand sheets.
Borrow pits	Excavations that provide extra soil, rock, gravel, clay or sand for construction activity.
Breccia	A coarse-grained clastic (q.v.) rock, composed principally of angular broken rock fragments (derived from pre-existing rocks or minerals that have been mechanically transported), held together either by a mineral cement or in a fine-grained matrix.
Bund	An earth, rock or concrete wall constructed to prevent the inflow or outflow of liquids.
Cable bolt	A type of rockbolt installation in which steel cable is used instead of steel rod. Cable bolts are usually longer than rockbolts (q.v.)—commonly up to 50 m—and can be tensioned (with a hydraulic jack) or untensioned. Cable bolt holes are commonly filled with cement grout after installation.
Cage	A conveyance in a vertical mine shaft used for transporting personnel and materials.
Calcine	The residue derived from heating a mineral substance to drive off the chemically combined volatile portion of the substance and convert the non-volatile mineral to an oxide.
Calcrete	Friable to hard calcareous material of secondary accumulation found near or on the surface, and composed largely of crusts of soluble calcium salts intermixed with gravel, sand, salt and clay.
Cambrian	The earliest period of the Palaeozoic Era. It spanned the geological time between 500 million and 570 million years ago.
Cataclastic	Descriptive of a rock that has been deformed through fracture and rotation of mineral grains or aggregates without chemical reconstitution.
Catalyst	A substance capable of increasing the rate of a reaction without itself undergoing any chemical change.

APPENDIX C

GLOSSARY

A weighted sound level (dBA)	A logarithmic measurement scale in which each increase of about 3 dBA represents a two-fold increase in sound intensity.
Adelaidean	The period in which the Precambrian rocks of the Adelaidean System of South Australia were deposited. It spanned geological time between 570 million and (about) 850 million years ago.
Aeolian	Descriptive of soil deposited by wind.
Alluvial	Descriptive of soil deposited by river or flood water.
Alpha emitter	A radioisotope that emits an alpha particle (q.v.) when it decays.
Alpha particle	A positively charged particle containing two protons and two neutrons which is emitted by certain radioisotopes. It is the least penetrating of the three main forms of radiation (alpha, beta and gamma), in that it may be stopped by a sheet of paper.
Anode furnace	A copper refining furnace in which blister copper (q.v.) is refined.
Aquifer	A permeable rock formation that stores and transmits sufficient groundwater to yield economically significant quantities of water to wells, bores or springs.
Aquitard	A confining bed that retards, but does not prevent, the water flow to or from an adjacent aquifer.
Artesian water	Groundwater under sufficient hydrostatic pressure to rise above the level at which it is encountered by a well.
Autogenous grinding mill	A mill in which a given material is ground without the assistance of balls or bars by tumbling it in a rotating cylinder.
Backfill	The process of refilling a mine opening, or the waste material (sand, rock, dirt, etc.) used for that purpose.
Ball mill	A mill in which a given material is ground with steel or ceramic balls in a rotating horizontal cylinder.
Barren liquor	A solution from which the valuable mineral component(s) has been removed. (*See also* pregnant liquor).
Barren rock	In geology, a succession of rocks within a mineralised zone that do not contain recoverable or valuable minerals.
Batter	The slope from bottom to top of the face of a retaining wall or pier.

APPENDIX C

GLOSSARY

Ionising radiation	Radiation which interacts with matter to add or to remove electrons from (i.e. to ionise) the atoms of the material absorbing it, producing electrically charged (positive or negative) atoms called ions.
Irradiation	Subjection to ionising radiation.
Isotope	One of two or more forms of a chemical element having the same number of protons but a different number of neutrons. All isotopes of the same element have the same chemical properties and therefore cannot be separated by chemical means.
Jumbo drill	A vehicle on which are mounted two or more rock drills.
Jurassic	The second period of the Mesozoic Era. It spanned the geological time between 135 million and 190 million years ago.
Kaolinitic	Descriptive of a group of clay minerals containing kaolin, or hydrated aluminium silicate ($Al_2Si_2O_5(OH)_4$).
Karstic	Descriptive of uneven limestone topography, characterised by depressions, fissures, etc., created by percolating waters.
Knapping floors	Dense concentrations of flaked material associated with stone artefact manufacture.
Lagooning	The use of artificial shallow pools for the treatment of effluent.
Launder	An inclined channel, lined with refractory material, for conveying molten metal from the furnace taphole.
Mafic	Descriptive of an igneous rock composed mainly of one or more dark-coloured, chiefly ferromagnesium, minerals.
Matte copper	A mixture of sulphides of copper (and other metals) formed in the liquid state as a homogeneous solution.
Mineral resource	An identified *in situ* mineral occurrence from which valuable or useful minerals may be recovered.
Motherplate	A stainless steel plate used as a cathode in electrorefining.
Mullock	Waste rock (generally unmineralised) which is extracted during mine development and production.
Multiplier	Indicator of the size of flow-on effects (q.v.) in economic modelling.
Net present value (NPV)	Discounted cash flow over time.
Nuclide	An atom of a particular element distinguished by the number of protons and neutrons in its nucleus.
Off-gases	Gases liberated during metallurgical treatment processes.
Ore reserve	That part of a mineral resource which could be mined, inclusive of dilution, and from which valuable or useful minerals could be recovered economically under conditions realistically assumed at the time of reporting.

Pan factor	A conversion factor applied to the evaporation rate measured in a Class A pan (q.v.) to account for the reduced evaporation rate from larger bodies of water.
Pasquill stability classes	Classes of atmospheric stability which are indicators of the degree of turbulent mixing in the atmosphere varying from Class A (the most unstable condition, with rapid mixing) to Class F (the most stable, with very limited mixing).
Perched water table	Unconfined groundwater separated from an underlying main body of groundwater by an unsaturated zone.
Permeability	The capacity of a porous rock for transmitting a fluid.
Photopoint	A designated point on the ground from which photographic records of progress of vegetation changes are made, usually on a six-monthly or yearly basis.
Piezometer	An instrument for measuring the magnitude or direction of pressure.
Pillar	A block of ore between two stopes (q.v.), usually left for purposes of stability. Pillars are commonly removed after the adjacent stopes have been backfilled.
Pilot plant	A small version of a planned industrial plant, built to gain operational experience and determine performance characteristics.
Playa	A flat area or basin at the lowest part of an undrained desert basin, underlain by clays, silts, sands and commonly by soluble salts.
Pore volume	The pores in a rock or soil considered collectively, expressed as a fraction or percentage of the total rock or soil volume.
Potentiometric surface	A hypothetical water surface representing the total head of groundwater for a particular locality, and defined by the level to which water will rise in a well.
Precambrian	The geological period of time encompassing the Proterozoic and Archaean eras between 570 million and 4,600 million years ago, equivalent to some 90% of the Earth's geological history.
Pregnant liquor	A solution containing valuable mineral component(s) in any of the steps in a mineral leaching and recovery operation.
Proterozoic	The geological period of time between 570 million and 2,500 million years ago. It is the more recent of the two great divisions of the Precambrian.
Province	In geology, part of a region that is isolated and defined by its geological history and development, and where the source, age and distribution of its minerals are unified.
Pyrolusite	The principal ore of manganese, used as an oxidant. It consists largely of manganese dioxide (MnO_2).

Quadrat	In botany, a designated measured area, usually rectangular, in which individual plants are counted and measured, usually on a six-monthly or yearly basis.
Quality factor	A numerical factor used in radiation protection to allow the biological effects of different radiations to be compared.
Radionuclide	Any nuclide (isotope of an element) which is unstable and undergoes natural radioactive decay.
Radon	Radon is the heaviest of the 'noble' or inert gases. The predominant isotope, radon-222, is the decay product of radium-226. It has a half-life of 3.82 days and decays to polonium-218 by the emission of an alpha particle.
Raffinate	The aqueous leaching solution remaining after a valuable mineral, such as copper or uranium, has been removed by solvent extraction.
Raise	A more or less vertical underground opening developed upwards from a level below. At Olympic Dam nearly all raises are developed by boring.
Rare earth elements	A group of metallic elements (the lanthanide elements), ranging from lanthanum (atomic number 57) through to lutetium (71). Yttrium (39) and scandium (21), while not strictly rare earths, are generally grouped with them. Despite their name, rare earth elements are not especially uncommon. They have very similar chemical and physical properties, making separation of individual elements difficult.
Reverse osmosis	Purification of water by forcing it under pressure through a membrane that is not permeable to the impurities to be removed.
Ripping	Breaking, with a tractor-drawn ripper or a long-angled steel tooth, compacted soils or rock into pieces small enough to be economically excavated or moved by other equipment.
Rip-rap	A layer of coarse rock used to line or protect earthen embankments from erosion.
Rockbolt	A steel rod, usually about 2 m long, inserted into a drill hole, anchored at the bottom, and tensioned by tightening a nut at the collar. It is used to improve the stability of underground openings.
Rougher and scavenger cells	Cells in which froth flotation of ores is performed. Rougher cells remove the bulk of the concentrates from the ore, and scavenger cells remove the remainder.
Run-of-mine	The raw ore as it is delivered by conveyors or skips, before treatment of any sort.

Secular equilibrium	A condition which occurs when the activity of radioactive decay products is equal to that of the parent in a material. It may arise when a radioactive parent is long lived compared with its decay products and none of the decay products are removed from the material.
Sedimentary	Descriptive of rocks formed by deposition by wind, water or ice, by chemical precipitation, or by secretion by organisms.
Shotcrete	Fine concrete applied with a pressure gun.
Sievert (Sv)	The SI unit of measurement of effective dose. One sievert is equal to the product of the absorbed dose by the quality factor (q.v.) and any modifying factor(s). It allows a comparison of the relatively greater biological damage caused by some particles such as alpha particles and fast neutrons. For most beta and gamma radiation, one sievert is equal to an absorbed dose of one joule per kilogram of biological matter.
Sigma theta	The value of the standard deviation of the wind direction over a selected time interval.
Silcrete	Surficial sand cemented into a hard mass by silica.
Siliceous	Descriptive of a rock or other substance containing abundant silica, especially as free silica rather than silicates.
Skip	A container attached to the winder rope used for carrying rock in a shaft.
Slag	Material resulting from the interaction of flux (q.v.) and impurities in the smelting and refining of metals.
Slimes	Particles of crushed ore which are of such a small size that they settle very slowly in water. Primary slimes are naturally weathered ores, or associated clays. Secondary slimes are produced during comminution (q.v.).
Slurry	A thin paste produced by mixing certain materials with water, sufficiently fluid to flow viscously.
Solution cavities	Cavities formed in certain rocks, such as limestones, where portions have been dissolved by percolating waters.
Solvent extraction	A separation process in which two immiscible solvents (water-based and organic-based) are brought into contact for the transfer or recovery of a component. At Olympic Dam, the term refers to transfer and recovery of copper and uranium. The process is usually carried out in multiple-staged countercurrent flow vessels to obtain maximum efficiency of extraction.
Stope	An underground opening from which ore is extracted.
Stoping	The excavation of ore from a reef, vein or lode.
Strandline	A cobble or shelly ridge at the upper limit of a beach.

Subaerial	Descriptive of a process that takes place in the open air on the land surface rather than under water or underground.
Subaqueous	Descriptive of a process that takes place under water.
Supernatant	Descriptive of the liquid above settled solids.
Swale	The area lying between sand ridges.
Syeno-granite	A felsic (q.v.) igneous intrusive rock intermediate between granite and syenite.
Tailings	The waste material remaining after the processing of finely ground ore.
Tailings dam	A dam, usually made from earth, and possibly with clay or other liners, used to retain tailings.
Tramming drive	A drive (q.v.) along which ore or waste is transported underground.
Transmissivity	The rate at which groundwater is transmitted through rock of a specific dimension and at a specified hydraulic gradient (q.v.).
Triassic	The first period of the Mesozoic Era. It spanned the geological time between 190 million and 225 million years ago.
Tuyere	A nozzle through which air is forced into a furnace.
Uranium (decay) series	A series of radionuclides produced in the decay of radioactive uranium to stable lead. The most important steps of this series are uranium-238 to uranium-234 to thorium-230 to radium-226 to radon-222 (and its decay products) to lead-210 and finally to lead-206, the stable non-radioactive end-product.
Understorey	The vegetative cover beneath taller trees and shrubs.
Venturi scrubber	An air pollution control device used to remove fine particulate matter or pollutant gases from industrial waste gases. In the device, water (or scrubbing solution) is injected into the throat of a venturi (a narrowed section in a length of ductwork).
Winder	A large winch used to raise and lower skips and cages in a shaft.
Yellowcake	Historically, the name 'yellowcake' was given to the bright yellow substance ammonium diuranate (ADU). In Australia, ADU is usually calcined at high temperature to produce a mixture of uranium oxides, principally U_3O_8, which is dark green in colour and is also called uranium oxide concentrate (UOC). Colloquially UOC is sometimes (incorrectly) referred to as 'yellowcake'.

APPENDIX D

ABBREVIATIONS

APPENDIX D

ABBREVIATIONS

MEASUREMENTS

Technical units of measurement in this report are based on the International System of Units (SI) wherever possible. These technical units may be broadly grouped as prefixes and measurements. A prefix applies to the unit of measurement that immediately follows it—for example, milligram is abbreviated as mg. Superscripts ^{2} and ^{3} following a linear unit indicate area and volume respectively—for example, m^2 (square metres) and m^3 (cubic metres). Different units are combined by a full stop (.) to differentiate units of the same exponential sign, and a solidus (/) to indicate 'per'. For example, kilometres per hour is abbreviated as km/h, while megalitres per day per square kilometre is $ML/d.km^2$.

PREFIXES

G	giga	1,000,000,000
M	mega	1,000,000
k	kilo	1,000
m	milli	0.001
µ	micro	0.000001
n	nano	0.000000001

UNITS OF MEASUREMENT

a	year (annum)
Bq	becquerel
c	cent
d	day
dBA	decibel, network A frequency weighting
g	gram
Gy	gray
h	hour
ha	hectare
J	joule
kg	kilogram
km	kilometre
kV	kilovolt
kW	kilowatt
L	litre
lb	pound
m	metre
m^2	square metre(s)
m^3	cubic metre(s)
ML/d	megalitre(s) per day
mm	millimetre
m/s	metre(s) per second
MW	megawatt
Nm^3	normal cubic metre(s) (gas volume at 0°C and 1 atmosphere)
oz	ounce
pH	degree of alkalinity/acidity

p.p.m.	parts per million	t/d	tonne(s) per day
s	second	V	volt
Sv	sievert	W	watt
t	tonne	$	dollar
t/a	tonne(s) per annum	%	per cent

CHEMICAL SYMBOLS AND FORMULAE

ADU	ammonium diuranate	PAH	polynuclear aromatic hydrocarbons
^{214}Bi	bismuth-214	^{234}Pa	protactinium-234
Cl_2	chlorine	^{206}Pb	lead-206
CO	carbon monoxide	^{210}Pb	lead-210
CO_2	carbon dioxide	^{210}Po	polonium-210
HCl	hydrochloric acid	^{226}Ra	radium-226
H_2S	hydrogen sulphide	^{222}Rn	radon-222
H_2SO_4	sulphuric acid	SO_2	sulphur dioxide
HF	hydrogen fluoride	SO_3	sulphur trioxide
NaOH	sodium hydroxide	^{230}Th	thorium-230
NH_3	ammonia	^{234}Th	thorium-234
NO_x	nitrogen oxides	U_3O_8	uranium oxide
NO_2	nitrogen dioxide	^{234}U	uranium-234
N_2	nitrogen	^{235}U	uranium-235
O_2	oxygen	^{238}U	uranium-238

GENERAL

AADT	annual average daily traffic
ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
ACP	air cooling power
AFFF	aqueous film-forming foam
AGC	Australian Groundwater Consultants
AGPS	Australian Government Publishing Service
AGSO	Australian Geological Survey Organisation
AHD	Australian Height Datum
ALARA	as low as reasonably achievable (social and economic factors being taken into account)
ALC	Andamooka Land Council

AMAD	activity median aerodynamic diameter
AMCORD	Australian Model Code for Residential Development
ANC	acid neutralising capacity
ANCA	Australian Nature Conservation Agency
ANFO	ammonium nitrate/fuel oil (mixture)
ANSTO	Australian Nuclear Science and Technology Organisation
AS	Australian Standard
AWA	Alcoa World Alumina and Chemicals
BEIR V	(The National Research Council's) Fifth Committee on the Biological Effects of Ionising Radiation
BRS	Bureau of Resource Sciences
CAF	cemented aggregate fill
CAMBA	China–Australia Migratory Birds Agreement 1986
CCD	countercurrent decantation
CGE	computable general equilibrium
CONCAWE	The oil companies' international study group for Conservation of Clean Air and Water—Europe (Den Haag)
CPI	consumer price index
CRO	Community Relations Officer
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CTD	central thickened discharge
DAC	derived air concentration
DCF	dose conversion factor
DDREF	dose and dose rate effectiveness factor
DECS	Department for Education and Children's Services (South Australia)
DEETYA	Department of Employment, Education, Training and Youth Affairs (Commonwealth)
DENR	Department of Environment and Natural Resources (South Australia)
DHUD	Department of Housing and Urban Development (South Australia)
DoSAA	Department of State Aboriginal Affairs (South Australia)
DoT	Department of Transport (South Australia)
Draft EIS	draft environmental impact statement
DRCS	digital radio concentrator system
DSE	dry sheep equivalent
ECP	environmental code of practice
EIP	environment improvement programme

EIS	environmental impact statement
ELCB	electric leakage circuit breaker
EMMP	environmental management and monitoring plan
EMP	environmental management programme
EMS	environmental management system
EP	evaporation pond
EPA	Environment Protection Authority (South Australia)
ESD	ecologically sustainable development
ESP	electrostatic precipitator
ETSA	the former Electricity Trust of South Australia, now ETSA Corporation
FACS	(Department for) Family and Community Services (South Australia)
GAB	Great Artesian Basin
GDP	gross domestic product
GIS	geographical information system
GLC	ground-level concentration
GSP	gross state product
HAZOP	hazards and operability study
HDPE	high-density polyethylene
HF	high frequency
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
ISO	International Standards Organisation
IUCN	International Union for Conservation of Nature and Natural Resources
JAMBA	Japan–Australia Migratory Birds Agreement 1974
KPC	Kokotha People's Committee
LHD	load haul dump
LPG	liquefied petroleum gas
MESA	Mines and Energy South Australia (Department of Mines and Energy)
MDL	minimum detection limit
MSFMP	Mound Spring Invertebrate Fauna Monitoring Programme
n.a.	not available
n.d.	no data
n.e.c.	not elsewhere classified
NHMRC	National Health and Medical Research Council

NNTT	National Native Title Tribunal
NOHSC	National Occupational Health and Safety Commission
NPV	net present value
NPWS	National Parks and Wildlife Service (South Australia)
n.r.	not recorded
NZS	New Zealand Standard
ODO	Olympic Dam Operations
ODV	Olympic Dam Village
OH&S	occupational health and safety
pers. comm.	personal communication
PLOD	person, location, occupation, description
PN	Project Notice
PS	pump station
PSA	pressure swing absorption
PSBR	public sector borrowing requirement
RGSSA	Royal Geographical Society of South Australia
RL	reduced level
ROM	run-of-mine
SACES	South Australian Centre for Economic Studies
SAEI	South Australian Exploration Initiative
SARDI	South Australian Research and Development Institute
SATC	South Australian Tourism Commission
SCADA	system control and data acquisition
SES	supplementary environmental studies
SD	statistical division
SI	International System of Units
SLA	statistical local area
SPQ	single persons' quarters (Roxby Downs)
STEL	short-term exposure limit
SX	solvent extraction
TDS	total dissolved solids
TLD	thermo-luminescent dosimeter
TRS	tailings retention system
TSF	tailings storage facility
TSP	total suspended particulates

TWA	time-weighted average
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
UOC	uranium oxide concentrate
VHF	very high frequency
WMC	WMC Limited
WMP	waste management programme
wt	weight

APPENDIX E

REFERENCES

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REFERENCES

CHAPTER 1

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APPENDIX F

AGENCIES CONSULTED DURING EIS PREPARATION

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AGENCIES CONSULTED DURING EIS PREPARATION

AGENCIES

Andamooka Land Council

Andamooka Progress Association

Animal and Plant Control Commission, Primary Industries, South Australia

Australian and New Zealand Rabbit Calicivirus Disease Program

Australian Geological Survey Organisation

Australian Heritage Commission

Barngala Consultative Committee

Biodiversity Group, Environment Australia

City of Port Pirie Council

Conservation Council of South Australia

Corporation of the City of Port Augusta

Corporation of the City of Whyalla

Defence Support Centre Woomera

Department of Environment and Heritage (Queensland)

Department of Environment and Natural Resources (SA)

Department of Land and Water Conservation (NSW)

Department of Lands, Planning and Environment (NT)

Department of Natural Resources (Queensland)

Department of State Aboriginal Affairs (SA)

Department of Transport (SA)

Environment Australia

ETSA Corporation

Kendell Airlines

Kokotha People's Committee

Kuyani Association Inc.

Mines and Energy South Australia

Municipal Council of Roxby Downs

National Parks and Wildlife Service (NSW)

Northern Region Development Board

Northern Territory Botanic Gardens

Northern Territory Herbarium

Northern Territory Museum

Nukunu Heritage Committee

P&O Catering

Pastoral Management Branch, Department of Environment and Natural Resources (SA)

Port Pirie Regional Development Board Inc.

Ports Corp. SA

Santos Limited

South Australian Health Commission

South Australian Museum

South Australian Small Area Population Unit, Australian Bureau of Statistics

Telstra Corporation Pty Ltd

University of Adelaide

Whyalla Economic Development Board Inc.

Woodward-Clyde Pty Ltd

PROVIDERS OF HUMAN SERVICES AT ROXBY DOWNS

Child and Youth Health, Roxby Downs

Department for Family and Community Services, Port Augusta

Family Day Care, Roxby Downs

Roxby Downs Area School

Roxby Downs Child Care Centre

Roxby Downs Christian Community Church

Roxby Downs Community Health Centre

Roxby Downs Community Library

Roxby Downs Kindergarten

Roxby Downs Leisure Centre

Roxby Downs Medical Services

Roxby Downs Police Station

Sisters of Our Lady of the Sacred Heart

Spencer Institute of TAFE, Roxby Downs Campus

TRADERS AT ROXBY DOWNS

Blockbuster Video, Roxby Downs

Bond, Stuppos & Associates, Roxby Downs

Endless Possibilities (Licensed Post Office), Roxby Downs

Flossy's Gifts, Roxby Downs

Milhinch Jewellers, Roxby Downs

National Australia Bank, Roxby Downs

Olympic Dam Tours

RJ's Restaurant, Roxby Downs

Roxby Bakery

Roxby Downs Motor Inn

Roxby Fast Photos

Roxby Foodland

Roxby Meat Supply

Roxby Downs Newsagency

Roxby Downs Pharmacy

Roxby Takeaway

Roxby Downs Tavern

Roxby Traders

Tandales Hair Salon, Roxby Downs

The Wardrobe Shop, Roxby Downs

PASTORALISTS AND LANDCARE GROUPS

Arcoona Station—Greg Campbell

Billa Kalina Station—Keith Greenfield

Callanna Station—George and Anne Morphett

Clayton Station—Shane and Debbie Oldfield

Dulkaninna Station—Daryl and Sharon Bell

Far North Consultative Committee (Department of Environment and Natural Resources)

Kingoonya Soil Conservation Board

Marree Soil Conservation Board

Muloorina Station—Malcolm and Colleen Mitchell; Trevor and Cindy Mitchell

Stuart Creek Station—Bobby and Debbie Hunter

APPENDIX G STUDY TEAM

K.R. Patterson	Town design
M.J. Pivovaroff	Infrastructure
A. Sharley	Demographics and social infrastructure
G.C. Ward	Librarian
M.L. Waters	Hydrogeology
M.S. Wilson	Librarian
D.J. Yeo	Economics review

Document production

K.E. Disney	Project Editor
E. Eager	Editor
J.L. Finlay	Editor
J.C. Greig	Editor
C. Jellett	Editor
P.G. Macdonald	Editor
G.B. Morgan	Editor
S.C. Pearce	Editor
S.H. Cook	Word processor operator
A.L. Shillingford	Word processor operator

Graphics

J.A. Cecere	Project graphic designer
J.M. Hamilton	Graphic designer
A. Hromniak	Graphic designer
A. Millard	Graphic designer
I.E. Piescikowska	Graphic designer
J.C. Poole	Graphic designer
M.L. Becker	Typesetter
P.R. Roberts	Typesetter
R. Stunden	Typesetter
L. Wyatt	Typesetter

Subconsultants to Kinhill

Fugro Survey	Site surveys
Golder Associates Pty Ltd	Regional groundwater
Holmes Air Sciences	Air quality
Vipac Engineers & Scientists Ltd	Noise

South Australian Centre for Economic Studies	Economic modelling

Individual consultants

Dr T.J. Fatchen	Technical review, flora
Dr L. Hercus	Technical review, Aboriginal environment
Dr W. Ponder, National Museum of Australia	Technical review, mound springs biology
M. Sonter	Technical review, radiation
Dr L. Townley, CSIRO	Technical review, tailings management
Professor K. Walker, University of Adelaide	Technical review, biological environment
Professor W. Williams	Technical review, terrestrial environment
W. Zeidler, South Australian Museum	Technical review, mound springs biology

WMC LIMITED

V. Farrington	EIS Coordinator

Copper Uranium Division, Adelaide

V. Absolon	Materials usage and production
L. Barr	Project Secretary
P. Bowman	Executive review
T. Dwyer	Community liaison
R. English	Legal review
J. Gower	Librarian
G. Hill	Energy, greenhouse issues
C. Lewis	Uranium market
D. Marshall	Technical review
H. Muller	Metallurgical processing
A. Pickford	Economics review
J. Reynolds	Geology review
K. Reynolds	Hydrometallurgy review
R. Spalding	Metals market
D. Stokes	Aboriginal consultation
B. Strong	Librarian
R. Whittington	Transportation review
P. Wilson	Copper market
R. Yeeles	Corporate review

Olympic Dam Expansion Group

G. Baldwin	Mining services
B. Clarke	Mine ventilation
B. Day	Smelter review
H. Dodds	Water balance
V. Eggern	Plant layout
C. Fearon	Mine materials handling
J. Folwell	Tailings containment design
G. Hewson	Radiation, OH&S review
C. Jones	Smelter design
P. Massee	Air pollution control
A. Mounas	Town design
C. Rigg	Town infrastructure
D. Rugari	Operations infrastructure
R. Scherrer	Project management
J. Sedlak	Stack configuration
M. Softley	Engineering review
J. Weir	Refinery operations review
C. Wheeler	Power supply
A. Willis	Mine design, backfill operations

Olympic Dam Operations

F. Badman	Flora, terrain, land use
Z. Bowen	Rehabilitation review
M. Evans	Groundwater monitoring data
S. Green	Environmental review
R. Izakovic	Employment statistics
G. Marks	Water usage
M. Milazzo	Mining review
P. Mu	Meteorological, radiation data
D. Niejalke	Mound springs
J. Read	Fauna
J. Sale	Information retrieval
J. Warneke	Radiation, OH&S review
R. Watsford	Processing operations
C. Willetts	Air emissions
J. Zwar	Environmental review

WMC Resources Limited

K. Berry	Hydrogeology
N. Green	Aboriginal heritage
W. Tacey	Corporate review

Subconsultants to WMC Limited

D. Armstrong (Lisdon Associates)	Hydrogeological modelling
Dr P. Hughes (Kinhill)	Aboriginal archaeology
Dr B. Sommer (Co-ordata Research)	Aboriginal anthropology (275 kV line)