MAGNESIUM
METAL PROJECT

Concept Study

BASS RESOURCES NL

Registrar of Mines

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MAGNESIUM METAL PROJECT

CONCEPT STUDY

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1. EXECUTIVE SUMMARY

Bass Resources NL (Bass) plans to develop a magnesium metal refinery at Bell Bay, Tasmania, to produce 80,000 tonnes per year of magnesium metal by an electrolytic process. The project will be based upon the high grade magnesite resource on Main Creek, near Savage River, on Tasmania's west coast.

This study outlines the project and surveys background information on the magnesium industry, largely obtained in the public domain.

Although a newcomer to the magnesium industry, Bass is building the project upon the work and results of existing players:-

- Bass is in negotiations for an option agreement with the leaseholder of the Main Creek magnesite leases
- Bass has a formal option agreement with Golden Triangle Resources NL (GTR) to purchase rights to the geological exploration results and interpretation on the Main Creek lease
- Through the option agreement with GTR Bass has access to pre-feasibility work undertaken on the chlorine leach electrolytic magnesium plant by Bateman Australia Pty Ltd

Bass is determined to develop a plant which combines world's best environmental practice, lowest quartile metal production cost, and which earns widespread community support in Tasmania.

2. INTRODUCTION

2.1 Background

Golden Triangle Resources Ltd. (GTR) has been exploring the magnesite resource in the catchment of the Savage River, North-West Tasmania. GTR had an agreement with the leaseholder, Savage Resources Ltd., now fully owned by Pasminco Limited, to purchase the rights to the lease over a two year period.

Bass has an option agreement with GTR which will gives access under a confidentiality agreement to most of GTR's resource exploration and process investigation results. Bass is also in negotiation under a signed confidentiality agreement with Pasminco with regards to an option agreement which will give Bass effective control of the magnesite leases.

Bass plans to continue with GTR's progress towards development of the resource. GTR's intentions as of July 1999 are set out in a paper presented at the July, 1999, Australian Magnesium Conference in Sydney, of which a copy is included in Attachment 12. Whereas GTR had announced earlier in 1999 that a Victorian site was preferred for their processing plant, Bass plans to produce magnesium metal from the magnesite at Bell Bay in Tasmania, using the chlorine leach electrolytic process.

Bass has prepared this report to introduce the project and to describe the mine, transport, refinery and infrastructure involved.

2.2 Project summary

The project proposed by Bass comprises:-

- Underground mining, initially at Main Creek, later at Bowry Creek
- Refinery location in the major industrial zone at Bell Bay
- Road and rail transportation between mine and smelter
- Magnesium metal refining using the chloride leach/Alcan electrolysis process

In later sections of this report each of these components of the project is outlined at a concept level.

2.3 Selection of project components

This report surveys that information obtained without recourse to the confidential information available to Bass from GTR under the confidentiality agreement. The components of the project which are described in this report have therefore been selected without the benefit of a pre-feasibility study.

Following completion of this concept study, Bass will proceed to study the confidential information available from GTR regarding the resource, and the pre-feasibility work on the refinery undertaken by Bateman Australia, and to complete a full pre-feasibility study for the project. With the results of that full pre-feasibility study, there may be reason to change some of the project components outlined in this report.

The refinery process elements described later are those selected by GTR as being available to the project through licensing arrangements and being consistent with cost goals. The selection process is outlined later in the section of the report dealing with the refinery process.

Bell Bay has been selected as the most suitable locality for the refinery in Tasmania, for reasons outlined later. A broad site selection process undertaken by SKM for the government in 1998 identified two sites in Bell Bay, along with Port Latta, Hampshire and Railton, as meeting some of the requirements for a magnesium refinery. At this stage Bass has selected one of these sites, between Big Bay and Dirty Bay, as its preferred refinery site, and will commence a more detailed site review process following examination of GTR's refinery pre-feasibility work.

3. PROJECT FINANCE

Bass is seeking project finance for this project. A magnesium metal off-take agreement is considered essential if project finance is to be secured. Two pre-requisites for an off-take agreement will be:-

- Production costs within the lowest quartile of world manufacturers
- A plant design and operation which complies with world's best environmental practices. No automobile manufacturer will associate with a dirty plant

It is recognised that "world's best environmental practices" and "lowest quartile costs" may at times conflict. Bass proposed to identify these difficult areas in an open manner and is optimistic that the project will be able to fully realise both goals. Among the issues to be considered and resolved to achieve these two goals will be:-

- ***Mine...***Strict grade control to minimise refinery capital and operating costs. Careful attention to wilderness values in the world heritage area surrounding the mine site *Very wrong*
- ***Transport...***Optimisation of the whole of the ore transport leg. Minimisation of that portion of the transport task using trucks on public roads
- ***Refinery construction...***Within time and budget, using a maximum of local resources. Community support generated through extensive consultation with stakeholders and maintained with fair and transparent procedures

- ***Energy...*** World competitive energy pricing. Use of natural gas or renewable energy sources to minimise greenhouse effects
- ***Emissions*** Understood through research, minimised by design and controlled using worlds best practice systems to beyond strict legal requirements by an environmentally-sensitised workforce
- ***Waste materials...*** Handled economically and responsibly within local and international environmental guidelines
- ***Transport to market...*** Via a short road stage and the nearby international Port of Launceston

4. ECONOMIC AND SOCIAL BENEFITS OF THE PROJECT

4.1 General

The development of the project will have a positive economic and social impact on a local, regional and State scale. The project will provide a number of economic and social benefits as described below.

4.1.1 Local and Regional Employment

The anticipated employment requirements for the project are 42 full time employees at the mine and some hundreds at the refinery. There will also be employment opportunities associated with the transport operations to and from the site. There will also be an increase in the demand for the provision of services to both operations. Based on a multiplier of 2.2, it can be expected that total new employment generated by the project will be in the order of 1,000.

Additional employment opportunities will also be generated during the construction period, which is expected to extend over perhaps two years.

4.1.2 Diversified mining and metals sector

Given the fluctuations which occur in commodity prices, a diversified economic base is an important part of the success of small economies in particular. The proposed development will provide an important new element of the Tasmanian economy to further strengthen and diversify the financial base of the metals and mining sector.

4.1.3 Capital Investment

The proposed refinery, mine and associated infrstructure will involve an investment of approximately $800M following approval to commence construction. This will include building construction and associated infrastructure on the site itself, and the transport links from the site.

4.1.4 Value Added processing

The magnesium refinery provides a significant value adding opportunity for magnesite mining operation, which could otherwise be exported from the State for down stream processing. Further value adding manufacturing operations will be sought in component manufacture associated with the automobile and other industries.

4.1.5 Export Opportunity

The magnesium refinery establishes another significant development in Australia to supply the export market for magnesium metal which, as discussed later, is continuing to grow.

4.1.6 Annual Expenditure

The development will also involve a further financial benefit to each region through on-going expenditure from the day to day operation of the mine, transport and refinery in such areas as salaries, power and consumables and maintenance.

4.1.7 Community Perception of the Proposal

The local and general community will be made well aware of the project both prior to, and during, the approval process through the community press, and specific consultation with key stakeholders. It is hoped through this process to establish a community perception of the project which is positive and supportive.

4.2 Community consultation process

Consultation with the community will be a key component of this project, and is considered an essential element by Bass. The statutory approvals process provides a number of opportunities for input by interested parties, including providing comment on the draft DPEMP guidelines prepared by the Board, and on the DPEMP itself, prepared by the proponent.

In addition to these formal avenues, the key stakeholders and other interested members of the community will be encouraged to participate in the project. This will involve a number of avenues throughout the approval process including;

- Early identification of parties with an interest in the project;
- Identification of the major issues of concern and incorporating solutions into the planning stages of the project;
- Meetings with individuals and groups as required;
- Press releases at appropriate stages of the project;
- Preparation and distribution of information bulletins to interested parties as required.

It is considered that with these opportunities in place that anyone with an interest or concern in the project will be well informed throughout the planning and development stages of the project.

5. MAGNESIUM

5.1 Introduction

Magnesium is the earth's eighth most abundant elements but does not occur in the native (metallic) state. Geologically it amounts to about 2.5% of the earth's crust, occurring mainly as magnesite – $MgCO_3$ – and as dolomite – $(Ca, Mg)CO_3$. Both of these minerals are important sources of magnesia – MgO – as well as the metal itself. Magnesium is also the third most abundant element in seawater, each cubic metre containing approximately 1.3 kg magnesium.

Magnesium compounds have a number of applications in the agricultural and manufacturing industries as well as being a major source of magnesium metal. Bass is considering only the production of magnesium metal and downstream manufacturing opportunities such as diecasting.

5.2 Physical and chemical properties of magnesium metal

In many respects the chemical and physical properties of magnesium metal resemble those of aluminium metal. It has a number of advantages over aluminium, particularly in terms of physical properties, with many applications similar to those of aluminium. It is these advantages that are leading to the substantial world-wide increase in demand.

Magnesium metal's properties can be summarised as follows:

- Lightweight (two thirds that of aluminium) with a low specific gravity.
- High strength, similar to that of aluminium on a volume-for-volume basis and a higher than aluminium on a weight-for-weight basis.
- High resistance to stress and low flex, having twice the stiffness of aluminium.
- High damping capacity, about 25 times that of aluminium.
- Good fatigue resistance so that it is a good structural metal.
- Can be cast to near net-shape and is very easy to machine. The low heat content per unit volume permits die-casting rates 150% of those for aluminium.
- Excellent corrosion resistance – Better than carbon steel and many aluminium alloys.
- High chemical reactivity as a reductant.
- Recyclable.
- Soluble in aluminium to produce a range of aluminium - magnesium alloys.

There are various grades of magnesium metal, as determined by the range and level of impurities. Standard specifications are set by the American Society for Testing and Materials (ASTM).

5.3 Current and Future Uses

The world magnesium market totals approximately 350,000 tonnes, most of which is spread among three applications:-

- Aluminium alloys. A major example is drink cans, the aluminium for which contains approximately 3% magnesium. Consumption in this fairly mature market segment is static in the range 140,000 to 160,000 tonnes per year
- Desulphurisation in the steel industry. This is a rapidly growing market currently 50,000 tonnes per year and expected to grow to perhaps 100,000 tonnes per year over the next few years
- Die casting, over 80% for the automobile industry. Magnesium metal is used with aluminium in diecastings to reduce weight without sacrificing strength. Some forecasters see magnesium content per vehicle produced rising to 50 kg in the next decade. 1998 consumption was 110,000 tonnes per year, 140,000 is forecast for 2000, and further growth could be rapid with pressure from environmental targets for greater fuel economy in new automobiles

5.4 Automobile manufacturer participation in magnesium production

Most motor manufacturers anticipate a rapid increase in the demand for magnesium as an effective means to reduced vehicle weight and thereby fuel consumption, and have been adopting a variety of strategies to assure a supply of magnesium at reasonable prices in the future. Examples are:-

- General Motors has signed a long-term contract with Norsk Hydro and Solikamsk whereby GM will purchase the metal and supply to its diecaster suppliers
- Ford has invested heavily in the planned refinery project under development by the Australian Magnesium Corporation
- Volkswagen owns a large share in the Dead Sea Magnesium operation in Israel

A manufacturer with an equity stake in a magnesium supplier disconnects their manufacturing operation from variable world magnesium prices and secures their magnesium supplies into the foreseeable future. Bass hopes to interest one of the other major manufacturers in this project.

6. RESOURCE

6.1 Location

The resource is located in the valleys of Main Rivulet (commonly referred to as Main Creek) and Bowry Creek, both tributaries of the Savage River, approximately 6 km south-west of the former Savage River township.

See Attachment 4 for location maps and aerial photographs.

6.2 Leases

6.2.1 Mining leases

Bass is negotiating for an option over a total of seven mining leases held by Savage Resources in the area of the resource, as follows:-

- Road leases 3W/94 and 4W/94 which cover access roads between the mining leases and the Corinna Road. Total area 72 Ha
- 2M/99 which is the primary magnesite lease, area 520 Ha
- 3M/99 and 4M/99 which are shallow leases within the boundary of 2M/99, issued for the mining of pigment. Rights to magnesite beneath the pigment rests with 2M/99. Combined area 21 Ha
- 5M/99 which adjoins 2M99 for magnetite. 55Ha
- RL 8802 which is a retention lease, 400 Ha

A total of $100,000 rehabilitation bond is held by Mineral Resources Tasmania (MRT) for the mining leases and $7,300 for the road leases.

All of the tenements are in good standing and may be operated subject to development approval from the Waratah/Wynyard Council.

Certain of the leases have been subject to caveats lodged by GTR, some of which, it is understood, have been withdrawn and others are expected to be withdrawn. It is not expected that magnesite mining will be allowed to alienate or dissipate the pigment resources which have been identified.

See Attachment 1 for plans of the leases The magnesite mining lease has a currency of 20 years. Other expiry dates are shown in the Attachment.

Transfer of the leases upon exercising of the option need not be a long process. Bonds will need to be replaced or, in case of any significant change in direction of use, reassessed.

6.2.2 Conservation status

All of the leases fall within the Tarkine Wilderness Area, an interim listing with the Australian Heritage Commission (AHC). Attachment 2 shows the approximate relationship between the leases, the boundaries of the Tarkine Wilderness Area and the nearby Savage River Mining lease. Attachment 6 is the web page from the AHC website concerning the Tarkine Wilderness Area.

The Commonwealth, by virtue of the interim listing, may be involved in the development assessment processes. We understand that, in some cases, the AHC has taken part in the assessment of interim listed properties as if they were fully listed.

When GTR first announced their intention to proceed with their magnesium project based upon the Main Creek deposit, there was considerable public support and approval of the Main Creek proposals by local caving and conservation interests. To what extent this approval was simply a contrast with the public concern by those same groups with the public proposals for exploitation of the Arthur/Lyons magnesite deposits is not clear.

Irrespective of public concern or otherwise, it will be necessary to evaluate the impact of the project on all of the significant values of the Tarkine Wilderness Area which have been registered with the AHC.

6.3 Access

The lease is accessible from the Corinna Road either 46 km from the North via Waratah and Savage River, or from the South through Zeehan and the punt across the Pieman River at Corinna. A mine access road runs several kilometres from the Corinna Road to the lease area from which exploration tracks have been pushed to specific drill sites.

The Corinna Road is an all weather tourist road. At present the mine access is suitable for 4-wheel drives in all weather. Exploration tracks are trafficable in a 4-wheel drive to varying extents depending upon rain in the previous week.

It is understood that a haul road was planned to the lease from the Savage River Mines lease to the north. Savage Resources had negotiated with the operator (then Savage River Mines) a location for a pigment treatment plant within the SRM site.

6.4 Geology

A summary report on regional geology with emphasis on the Arthur Lineament carbonates is included later.

Further description of the geology of the area is expected to be available from reports of geological investigations prepared by Savage Resources and later by GTR.

Additional information specifically related to Karst features, related conservation values and fauna is contained within the reports of investigations prepared in 1998 and 1999 for the State Government. This work was part of the state government's preparation for magnesite mining in the North-West.

6.5 Resource description

6.5.1 Deposits

Deposits identified as part of GRT's exploration activity to date have been advised as follows:

Main Creek (2M/99, RL 8802)

Location	*Status*	*Quantity (Mt)*	*Grade % MgO*	*Source*
Main Creek	Estimated	130 - 260		CSIRO
Main Creek	Inferred	24.3	44.03	
	Indicated	23.8	44.03	GTR
Main Creek - D lens	Indicated	11.82	44.08	GTR
Main Creek - D1 lens	Indicated	2.31	45.25	GTR
Bowry Creek	Inferred	23.1	42.64	GTR

Note that pure magnesite contains 47.8% magnesia or 28.8% magnesium metal.

See Attachment 8 for a pictorial cross-section representative of the Main Creek deposits.

6.5.2 Exploration

Full exploration reports are available for inspection by Bass under their confidentiality agreement with GTR.

Drill core is at present held in the premises of Newnham Mining and Exploration Services at Zeehan and will be transferred in due course to Bass's new exploration premises.

Activities to be commenced shortly include:-

- A summer infill drilling program, developed after a review of GTR's exploration reports
- Winning a 1,000 tonne bulk sample for storage at Bell Bay for use in testwork for magnesium production. Any road upgrading and the removal of the bulk sample will require approval from the Wynyard/Waratah Council under the terms of the lease

7. SUMMARY PROJECT DESCRIPTION

7.1 Mine

Open cut and underground operations will be reviewed during the pre-feasibility study. Pending that study, the outline below and the description later discusses the likely features of an underground mine.

A portal above flood level gives access to a haulage decline. On the surface are:-

- Run-of mine (ROM) storage pad
- Crusher
- Conveyor system elevating crushed ore to a crushed ore stockpile further up the escarpment
- Buildings and workshops
- Storage for consumables - fuel, lubricants, explosives
- Waste water treatment and storage system

It is expected that the mine will operate on a continuous shift basis producing 400,000 tonnes per year of high grade magnesite ore with a complement of approximately 40 employees, resident at Waratah and commuting by bus and private car.

7.2 Transportation chain

The proposed transport chain is as follows:-

- Long haul road transport using highway legal semi-trailers from the fine ore stockpile at the mine via Corinna and Waratah Roads to the railhead at Guildford Junction
- Rail on existing trackage from Guildford Junction to Bell Bay, possible extension rail spur to smelter site

7.3 Refinery

7.3.1 Process route

The refinery process will be a conventional leach chloride electrolysis route. It is planned to use to seek access to the advanced low energy cell developed by and provided under license by Alcan. Magnesium chloride dehydration will be by the advanced Alcan enhanced Nalco methanol route.

7.3.2 Main inputs and outputs

The primary raw material is high purity magnesite with smaller requirements of magnesia for neutralising the leach liquor and precipitating iron and nickel. At full production approximately 400,000 tonnes magnesite will be required per year.

Natural gas is cracked to produce hydrogen as a primary feed. The hydrogen is burnt with chlorine from the process to form the hydrochloric acid used to leach the magnesite.

At rated production 80,000 tpy of magnesium metal will be produced.

The major discharges are carbon dioxide, released from the leaching process, and solid waste in the order of 25% of the magnesite feed, which will be stored permanently in a tailings dam.

7.3.3 Energy

The single dominant operating cost for magnesium production is energy cost, expressed both as the cost of electricity for the electrolysis process, and the cost of natural gas (for hydrogen) used in the chlorine cycle within the process.

The synergy between smelter location and sources of both electricity and gas are explored in the the section dealing with the refinery site. Refer also to the separate section of this report dedicated to energy supply and costs.

7.3.4 Risk analysis

As part of the pre-feasibility study and later, a full risk study will be undertaken to examine the vulnerability of each aspect of the project to unusual or unintended contingencies. The risk study will examine risks which directly affect the commercial success of the project, for example contingencies which will reduce production or result in metal of lower quality than expected.

Another category of risk covers those contingencies which may effect the safety of individuals or communities. Clearly these risks also effect the commercial viability of the project but require treatment commensurate with the potential harm to humans.

Some of the risks which will be reviewed in the risk analysis and for which risk reduction and management strategies are to be developed in later work include:-

- Gaseous emissions. Gaseous pollutants characteristic of modern chloride leach magnesium plants include dioxins, furans and other CHC's, sulphur hexafluoride or sulphur dioxide, chlorine and hydrogen chloride. Gaseous emissions may come from process plant itself or elsewhere, e.g. from tailings in the tailings dam

- Explosion risks associated with the handling and casting of molten metal
- Catastrophic release of chlorine or hydrogen chloride

8. GEOLOGY

The Proterozoic rocks in northwestern Tasmania host significant mineral deposits such as gold, iron ore, silica, magnesite and ochre. The Rocky Cape Element, which is a major stratotectonic element in northwestern Tasmania, is composed of rock sequences of Mesoproterozoic and Neoproterozoic age (see Fig.1 - Attachment 7). The oldest of these sequences is the Rocky Cape Group and correlatives, with a depositional age similar to that of the Tyennan Element of the central Tasmania, i.e. 1100-1150 Ma (Turner et al. (1992). The Rocky Cape Group consists mainly of shale, siltstone, quartz sandstone and minor dolomite, deposited in a shallow marine shelf environment (Gee, 1971).

The Rocky Cape Group is unconformably overlain by the Neoproterozoic Togari Group (Everard et al., 1996). The Togari Group consists of a lower clastic-carbonate shallow marine shelf and basaltic-volcaniclastic rift sequences and an upper shallow marine dolomite unit.

The Rocky Cape Element is crossed by a major northeast-trending tectonic feature referred to as the Arthur Lineament (Gee, 1967), which contains an assemblage of metasediments and amphibolite called the Arthur Metamorphic Complex (AMC, Fig. 1). The lineament is from 8 to 15 km wide and stretches 115 km north-northeast from the southwest coast to the north coast (Frost, 1982). The metamorphism in the AMC reached blueschist facies (Bottrill et al., 1998), and is considered to have occurred at ~500 Ma (Turner et al., 1992; 1994).

The Arthur Lineament is bordered in the east by a Neoproterozoic sequence of less-varied sandy turbidite-facies quartzwacke-mudstone of the Burnie Formation, which is considered to be coeval with the Oonah Formation (Turner, 1989). The K-Ar dating of detrital muscovite from the upper part of the Oonah Formation has given a age of 708±6 Ma (Turner, 1993). The Oonah Formation is overlain by the Success Creek Group. It has been suggested that the Oonah and Burnie Formations may represent a link between Neoproterozoic, mainly shallow-marine sedimentation in the Rocky Cape Element, and the commencement of Neoproterozoic-Late Cambrian, mainly deeper marine sedimentation in the Dundas Element (Bottrill et al., 1998).

The Success Creek Group consists of an about 1 km thick shallow shelf sequence of siliciclastic and carbonate facies. The Success Creek Group is conformably overlain by the thick (~5km) sequence of siliciclastic, carbonate and mafic-volcaniclastic rocks of the Crimson Creek Formation. Brown (1986) suggested a Neoproterozoic age for the Success Creek Group and the Crimson Creek Formation based on radiometric age dating and lithological and chemical correlation with the sequence in the Smithton Basin. Carbon isotope chemostratigraphy, using global compilation carbon isotope curves, supports the Neoproterozoic age of about 570-820 Ma for the Crimson Creek Formation and the Success Creek Group respectively (Adabi, 1997). Extensive Devonian granites, such as Meredith and Heemskirk Granites, lies east and south of the Arthur Lineament.

8.1 Arthur Metamorphic Complex

The Arthur Metamorphic Complex has been mapped by Turner et al (1991). Rocks of the AMC are probably metamorphosed equivalents of sedimentary and volcanic rocks to the west. Boundaries between the units of the AMC are mainly structural and the application of lithostratigraphic terms such as formation are probably inappropriate. The mappable units in the AMC were grouped into the Whyte Schist and the Bowry Formation. The Whyte Schist consists of muscovitic and quartz phyllites and schists with minor layers of amphibolite, metaquartz arenite and boudinaged quartz feldspar porphyry.

8.2 The Bowry 'Formation'

The Bowry 'Formation' consists of chloritic phyllite and schist, some amphibolites, with layers of magnetite and lenses of magnesite with subordinate dolomite. It is older than 770 Ma.

8.3 Mineralisation

Most of the Proterozoic mineralisation in Tasmania occurs in the Arthur Lineament. The Bowry Formation hosts many industrial minerals such as iron ore (Savage River), silica flour (Corinna) and large magnesite deposits (in Main Creek, Lyons and Arthur River areas), with associated ochre and umber pigments. Gold occurs in hard rock and alluvial deposits in the area and a few small base-metal deposits (mostly copper) are also known. The origin of both the Savage River iron ore deposit and the magnesite deposits of the Bowry Formation remain controversial.

8.4 Magnesite deposits

Five major magnesite deposits occur within the Bowry Formation (Fig 2 - Attachment 7) in the Arthur River and Lyons River areas some 40 km NNE of the Savage River (Dickson, 1990), to the east of the northern part of Savage River (Frost and Matzat, 1984), at Main Creek, 5.5 km SW of Savage River (Frost, 1982), and at Bowry Creek, a few kilometers to the south of the Main Creek deposit (Frost and Matzat, 1984). The magnesite appears to be replacement deposits, probably of dolomite, with the Mg sourced from mafics or ultramafics.

8.5 Arthur River (Crest Magnesium N.L.)

In the Arthur River area, the magnesite is associated with dolomite. Minor quartz, pyrite, talc and chlorite are associated with the dolomite. The Arthur River deposits contain at least 30Mt of high grade (>40% MgO, >24% Mg) magnesite. The average analyses of magnesite samples show that the magnesites contain ~2% Fe_2O_3, 2.2% CaO and 6.3% SiO_2 (Dickson, 1990). In the Arthur River area, quartz is the main impurity in the magnesite. Crest Magnesium N.L. estimated that, in the Arthur River areas, magnesite contains between 42.8% MgO (25.8% Mg) to 43.4% MgO (26.2% Mg).

8.6 Lyons River (Crest Magnesium N.L.)

The Lyons River deposit is 4 km south of the Arthur River magnesite areas. The magnesite body is up to 400m thick over a strike distance of at least 2000m (Dickson, 1990). Turner (1990) suggested that at Lyons River the zone of magnesite is 200 to 400 m wide, over 1000m long and at least 270m deep. The body grades to dolomite to the south and pinches out to the north under Tertiary basalt cover. The Lyons River deposit contains at least 30 Mt of high grade (>40% MgO, >24% Mg) magnesite, with impurity levels of ~1% Fe_2O_3, 3.4% CaO and 7.2% SiO_2 (Dickson, 1990). In the Lyons River, most samples consist of mixtures of magnesite and dolomite with minor quartz, pyrite and occasional silicate minerals such as talc and chlorite. Magnesite commonly constitutes 70% of the orebodies and is usually creamy white, having five different textures (Dickson, 1990). All five different rock textures are overprinted by recrystallisation.

8.7 Main Creek (Golden Triangle/Bass Resources)

The magnesite at Main Creek, a tributary of Savage River, is associated with dolomite and talc-chlorite schist and reserves most likely exceed 40Mt of magnesite (Frost, 1982). At Main Creek, the magnesite zone is over 200m thick and at least 1000m long. The creek is entrenched to a depth of more than 3 m in magnesite in some places but, away from the creek, the exposures generally are poor. To the west of Main Creek a lens of magnesite about 60 by 20 m crops out on the hillside 5-30 m above the creek bed. Irregular lenses of magnesite are also exposed in the upper reaches of Main Creek over a distance of about 300 m (Threader, 1976).

Golden Triangle Resources N.L. estimated that at Main Creek, MgO contents in magnesite range between 44 (26.5% Mg) to 45.25% (27.3% Mg).

The average of four magnesite analyses by Threader at Main Creek shows that MgO contents in magnesite is 43.27% (26% Mg). The major impurities are CaO (2.4%), Fe_2O_3 (2.4%) and SiO_2 (3%). Al_2O_3 (0.47%) and MnO (0.13%) are present in minor amounts.

Frost (1982) using magnesite analyses from Diamond Drill Hole M.C.1, showed that average MgO contents in the magnesite is 45.21% (27.3 % Mg), CaO (0.11), FeO (2%, Fe

~1.6%) and MnO (0.12%). He also suggested that the major impurities in the magnesite ore at Main Creek are quartz (as small irregular blebs or thin veins) and dolomite (each 5-10%), and $FeCO_3$ which decreases from about 3% at the surface to less than 1% at depth of about 305 m. Boron content is very low. Frost and Matzat (1984) have found that at Main Creek the Fe and Mn content of magnesite fall steadily toward the west.

At Main Creek the most common variety of magnesite is a light grey, weathering to a pinkish colour. Magnesite is usually very uniform in composition across individual grains, although small areas showing rhythmic zoining (Frost, 1982). It is massive and fine grained with recrystallised seams and joints giving a pseudo-bedded appearance. Less commonly, the magnesite is very white and coarse grained. The magnesite is often mottled by grey dolomite. Magnesite in the eastern contact zone is banded, (up to 10 m thick) with parallel layers of silica up to 13 mm in width, and is generally associated with a talc alteration zone (Threader, 1976). The rocks dip vertically or steeply to the east.

Frost (1982) suggested that metasomatism of original dolomite by solutions containing $MgCl_2$ is more likely than a sedimentary origin for the magnesite at Main Creek. Rock textures indicating replacement of dolomite by magnesite are common, particularly in the upper part of the deposit.

8.8 Bowry Creek (Golden Triangle/Bass Resources)

A deposit similar to that exposed in Main Creek, occurs in Bowry Creek in the Long Plains South Brown Plains area. Dissection by Bowry Creek has exposed pinkish white cryptocrystalline magnesite over a width of 90 m. Magnesite is exposed over a depth of 3 m in some creek sections, thus in this area, a possible 300,000 tonnes is inferred for an area roughly 180 m square (Threader, 1976). It has been suggested that the Bowry Creek and the Main Creek are a single continuous larger deposit, concordant with the enclosing schist (Frost and Matzat, 1984). Drill holes south of Bowry Creek show that the magnesite is associated with the schist, a thin lens of amphibolite, and 30 m thick lenses of magnetite (Frost and Matzat, 1984).

Magnesite analysis by Threader at Bowry Creek shows that MgO is 42.90% (25.87% Mg). The major impurities are CaO (1.94%), Fe_2O_3 (2.17%). Silica (SiO_2) is present in minor amounts (0.51%). Golden Triangle Resources N.L. estimated that at Bowry Creek MgO contents in magnesite is 42.64% (25.7% Mg).

8.9 Savage River (Australian Bulk Minerals)

The Savage River magnesite deposit, 7 km to the north along the general strike of the Arthur Lineament schists, is found totally within a series of amphibolites (Frost and Matzat, 1984). These amphibolites form a lens over 2 km wide and 10 km long which includes the central and northern magnesite deposits. The magnesite occurs as a series of nearly vertical dipping lenses, some of which reach a width of over 60 m (Frost and Matzat, 1984).

The Savage River deposits often contain a high proportion of relatively Fe-rich magnesite compared with the Main Creek deposits which show a marked trend toward magnesite containing less $FeCO_3$ at depth (Frost, 1982). Talc is found more frequently within magnesite-rich zones at Savage River (Frost and Matzat, 1984), whereas at Main Creek, talc is rare and quartz more common.

9. MINING

9.1 Discussion

The preliminary understanding we have of the deposits, prior to review of GTR's reports, suggests that the deposits form a series of lenses, some exposed and others at depth, dipping steeply and, within the lenses, varying significantly in grade, vein width and impurity species. Highly selective underground mining may be appropriate.

Drilling in the Main Creek area is understood to have shown that the deposits are generally competent with relatively infrequent caves, mud holes or strong water ingress. This accords with informal opinions expressed in discussion on the North-West Coast that there is little caving potential in the Main Creek/Bowery Creek area.

The smaller surface manifestation (pit, waste dumps) of underground mining compared with open cut mining also favours an underground approach given the situation within an interim listed AHC property. Underground mining will also minimise the amount of mine water by avoiding collection of direct rainfall and undiverted surface runoff. It will almost certainly obviate the need to consider major creek diversion works.

9.2 Mine Description

The mine, buildings and associated infrastructure will be located adjacent to Main Creek on lease 2M/99 (Figure 2).

The mine is planned to comprise:-

- Single underground mine for all of the Main Creek deposits with decline access.
- Decline portal and ventilation upcasts away from stream sides and above flood levels.
- Waste rock generally with little or no acid generation tendency, to be used for road and mine site construction works, including construction of the run of mill stockpile area. Suitable waste rock may also be used in the construction of the crushed ore stockpiling area. Excess and/or unsuitable material will be placed in an appropriately designed waste rock dump.

- Mine haul trucks working from stopes via a decline and surface haul road to run of mine (ROM) pad (constructed from non-acid forming waste rock).
- Natural fall from ROM pad to in feed of primary crusher, worked by bucket loader.
- Primary crushed ore conveyed by two conveyors to crushed ore stockpile on pad, also constructed from non-acid forming waste rock.
- Crushed ore feeder located beneath crushed ore stockpile feeding onto secondary crusher in feed conveyor, worked by a bucket loader.
- Secondary crusher to <150mm lump size.
- Fine ore elevating conveyor (one or two conveyors depending upon location) raising product to fine ore stockpile in a location accessible to public road trucks.

Buildings will be concentrated in a single location at the mine on the ROM stockpile slab (except for the magazine) and will comprise:-

- Mobile equipment maintenance workshop suitably sized for underground equipment (drills, loaders, mine haul trucks) and with basic fixed equipment, for the use of the equipment maintenance contractor. Includes wash bay, refuelling and lubrication bay and daily fuel/lube storage.
- Maintenance workshop suitable for use by fixed equipment maintenance contractors for minimum site-based work.
- Mine office comprising all office accommodation, change house, production stores, first aid and security

The magazine will be located at a suitable location away from the main operating area for safety reasons and will consist of a secure shed, surrounded by security fencing. An access road will be constructed, with a lockable boom gate located at the head of this road, adjacent to the mines main operating area.

Refer to Attachment 9 for a concept flowsheet and layout for mine surface works. The flowsheet and layout assume a simpler plant than that described above, with single stage crushing only. The choice between one or two stages of crushing will depend upon a number of related investigations to take place in the pre-feasibility and feasibility stages of the project.

9.3 Establishment

The mine is expected to be a continuous shift operation with a small permanent staff and a high degree of contracting of service provision.

A total permanent staff of approximately 42 is anticipated as follows:-

Manager	1
Security/watchman/first aid/stores	2

Production supervision	3
Maintenance planning, supervision and records	2
Mine operations and planning	4
Geologists	2
Admin/HR/IR/IT/financial	3
Safety coordination	1
Environmental coordination, laboratory	1
Miscellaneous	2
Production	20
Logistics coordination	1
Total	**42**

Staff will be expected to live locally and to make their own way to site each day. A commercial operator will be encouraged to operate a daily bus service to the site.

9.4 Infrastructure

9.4.1 Hydraulics

While water is required for drilling underground, the surface crushing operation will be a dry process. Water required on the surface will therefore be that which is required for domestic purposes, within the workshop and for washing of vehicles. Water for fire fighting purposes will also be required.

9.4.1.1 Potable Water

Potable water will be supplied to galvanised iron water tanks from the rooves of the various buildings on the site via gutters and downpipes. This water will be used for domestic purposes and for use within the workshop and stores. During dry periods potable water will be trucked into the site. From the tanks the potable water will be reticulated to the various buildings and fittings via a domestic pressure water supply pumping arrangement.

9.4.1.2 Fire water, Mine supplies and Washwater

A 200,000 litre concrete storage tank will be constructed up slope of the main operations area, at an elevation of at least 60metres above the other buildings. Water will be pumped into this tank from an inlet structure and a pressure pumping station to be constructed at Main Rivulet. The tank will be fitted with level sensors, from which the pressure pumping system will be controlled.

A 150mm PVC rising main will direct flows into this tank from the pump station. This supply main will also be cross connected into a ring main which will provide a reticulated network of hose reels and hydrants around the mine entrance, explosives store, conveyors, crusher and buildings.

A high level off take will allow water from the tank to be used for wash water. This off take will be positioned to allow at least 144 m3 of water to remain in the tank. This volume of water is required to provide four hydrants with 10 l/s of flow for an hour in the event of fire. Although the pump will also be able to provide water to the reticulation system, a storage and gravity feed is required in case of a power outage.

9.4.1.3 Domestic Wastewater

Domestic wastewater emanating from site will be directed to a septic tank and absorption trench treatment and disposal system. This system will be designed and installed in accordance with the Australian Institute of Health Surveyors (Tasmanian Division) Code of Practice *'Site Assessment for Septic Tank Absorption Trenches'*.

If a suitable site for such a system cannot be found then a wastewater package treatment plant and disinfection system will be installed. This treatment plant will discharge treated effluent directly into Main Rivulet in accordance with the Tasmanian Environment Protection (Water Pollution) Regulations of 1974.

9.4.1.4 Stormwater Runoff

Surface water runoff from the crushed ore stockpile, ROM stockpile pad, buildings area and mine haul road will be directed to a stormwater retention pond via open channel drainage. The stormwater retention pond will be designed to settle out sediments from the collected flow prior to discharge into Main Rivulet. This dam will be cleaned out periodically if required. Regular monitoring of the quality of water discharged from this dam into Main Rivulet will be undertaken.

9.4.2 Power Supply

Total demand at the site is expected to be in the range 2 - 3.5 MVA and will be brought to site by a 22kV overhead line from the sub-station at Savage River. To avoid overloading the feeder to Savage River and to eliminate voltage variation to the existing user (ABM) care will be required in design of all starting equipment. Such expedients as soft starting, sequenced starting on medium or large drives, and power factor correction may be undertaken to minimise total current drawn.

10. TRANSPORT

10.1 Road

10.1.1 Existing roads and tracks on the lease

The mine access road runs several kilometres from Corinna Road to the lease area from which exploration tracks have been pushed to specific drill sites. At present this access is suitable for 4-wheel drives in all weather. Exploration tracks are trafficable in 4-wheel drive vehicles to varying extents depending upon rain in the previous week.

A track more or less connects the exploration areas to the Savage River Mines lease to the North, running largely along the ridge between Main Rivulet and the Savage River.

The drill sites are at an altitude between 100 and 150 m ASL whereas the higher access routes typical of the track to the Savage River lease or the Corinna Road are more than 300 m ASL, the change in level occurring in less than a kilometre

10.1.2 Road to Waratah or to Guildford Junction

The Corinna Road is an all weather gravel surfaced tourist road running 26 km from Savage River to Corinna on the Pieman River.

The 46 km long section of the Waratah Road from Savage River to the intersection with the Murchison Highway is a flush seal pavement road serving the township of Waratah and tourist traffic.

10.1.3 Road data

Road	Paved width M	Shoulders M	Traffic Veh/day	Traffic split Note 1	Roughness
Corinna Rd	5.4	Nil	90	100/0/0	No data
Waratah Rd	6.0	1.0	350	71/19/10	Class1/2
Hampshire Lk Rd	6.2	1.3	900 - 1,300	58/27/15	Class 1

Note 1: Traffic split indicates percentages car, rigid trucks or buses and semi trailers.
Semi trailers are typically 3 - 6 axle articulated or rigid truck and trailer.

Road upgrading

Based on a 400,000 tonne per year, vehicle movements would increase by some 64 semi trailer truck movements/day. The use of existing carriageways between the mine and

Waratah or the Murchison intersection, would be subject to environmental, social and engineering scrutiny.

The recommended lane width for rural roads, with traffic volumes in the range 500 to 1,000 units (or greater) is 3.5 metres. This may be reduced to 3.0 metres on lower volume roads. Recommended shoulder widths for such volumes are in the order of 1.5 to 2.5 metres. 1.0 metre wide shoulders may be used if provision is made for vehicles to stop clear of the traffic lanes wherever possible.

The existing lane widths are approximately 3.0 metres for the majority of the proposed haul route to the railhead, whether at Waratah or at Guildford Junction and may therefore be adequate as far as width is concerned. It can be expected that upon closer scrutiny a fairly major upgrading will be required at least for Corinna Road section, as a project cost, were this the preferred route. It will be argued that any upgrading on the Waratah Road should be met by the roads authority, except possibly for the provision of an overpass for haul trucks at the Murchison Highway intersection.

Sections of the existing road between Waratah and Savage River are narrow, steep and windy, and upgrading of these sections can be expected to very expensive.

10.2 Rail

10.2.1 Existing rail system

Tasrail operate a rail service between Burnie and mines at Hellyer and Rosebery, and connect with a truck shuttle from Queenstown at Melba Flats. There is an existing rail formation from Guildford Junction, on the existing rail, to Waratah, a distance of approximately 17 km. From Burnie, regular rail services connect with Bell Bay via Western Junction, south of Launceston.

Rail transport of ore from Guildford Junction to Bell Bay is simply an expansion of existing services and the only new works required to initiate the service are a storage and rail loading facility at Guildford Junction, a passing loop or loops at selected locations and means of unloading and a spur line at Bell Bay.

Existing rail track imposes a load limitation on rolling stock with the result that wagon payload is restricted to 42 tonnes. Rakes of 18 wagons with two locos carry a total ore load of 760 tonnes. Because of easier grades north of Guildford Junction trains of more than 18 wagons may be practicable.

10.2.2 Proposed rail transport system for project

Approximately 2 rakes of 760 tonnes payload per day will be required to handle the total expected mine production. The rail transport cost before consideration of associated capital expenditure can be expected to be in the order of $16/tonne.

The rail terminus at the mine end of the system will comprise an outdoor stockpile area and a rail siding. Bucket loaders will load wagons directly from the stockpile.

At Bell Bay, a new rail siding will be required to link the incoming main line with the smelter site. Wagons will bottom dump to an underground hopper. A feeder will discharge to hopper to an elevating conveyor discharging to a outdoor stockpile.

10.3 Summary - road/rail system

Three transport modes are anticipated:-

- Mine haul trucks either from open cut or from decline
- Road haul trucks from ROM storage to railhead
- Rail to Bell Bay

Questions to be resolved in the pre-feasibility stage are:-

Regarding rail:-
- Should rail be extended to Waratah?
- Should rail be extended beyond Waratah?

Regarding road:-

- Road route from the mine to Savage River?
- Where should the road haul leg commence?

Brief consideration is given to each of these questions below.

10.3.1 Extension of rail

A notional capital cost of $17 million has been indicated for the re-instatement of rail on the existing formation between Guildford Junction and Waratah. An indicative cost for the upgrading of the road to accept the additional haul traffic might be between $2 million and $4 million. The difference in capital cost is therefore expected to be no less than $13 million.

At the simplest level, the marginal road transport cost for this 17 km leg can be expected to cost approximately $1.70/tonne, and the marginal rail transport cost for the same distance in the order of $0.34/tonne. The difference of say $1.36/tonne will result in a saving in the order of $550,000 per year, which is unlikely to justify the capital cost of the rail extension.

Extension of the rail to Waratah may however be attractive for broader reasons of public interest which may provide avenues for shared funding.

Whereas extension of rail to Waratah is relatively inexpensive because of the existing rail formation, beyond Waratah the additional cost of construction of a formation will be required. Using similar logic, extension of the rail beyond Waratah is unlikely to be attractive on purely financial grounds at the limited annual production rate of 400,000 tonnes proposed.

10.3.2 Route from mine to Savage River

The main choice here will be between relatively easy grades and country through which the Corinna Road runs and the generally heavy forest country of the northern route from the mining areas direct to Savage River.

The tourist values of the Corinna Road over this section may be a factor which favours a separate haul road over the northern route. On the other hand, minimising the development footprint within the Tarkine Wilderness Area (AHC interim listed) may favour upgrading of the existing road.

Location of crushing, and the length of a crusher discharge conveyor are factors here. It may be cost-effective to extend the conveyor to a stockpile location at considerably higher elevation and avoid road haulage over the steepest country. A notional route and long section for a possible new road is shown in Attachment 4.

10.4 Why is a slurry pipeline not being considered?

Transport of ore to Port Latta in the form of a slurry, using either a separate pipeline running in the existing pipeline reserve, or possibly even sharing the existing pipeline, has received preliminary consideration.

Slurry transport would be attractive for a Port Latta refinery location, but not attractive in conjunction with a Bell Bay refinery location, as discussed below. As the Port Latta smelter site is not being considered further, the discussion below is included for background only and to explain why it receives no further attention.

For a Bell Bay refinery, a pipeline would somewhat reduce the rail leg and greatly reduce or completely eliminate the road leg. On the other hand, unless the slurry were dried after filtration, adding a considerable processing cost, it would increase the total tonnage to be transported by rail, and the wet fine ore would be considerably more difficult to handle into and out of the wagons.

A further consideration is that while the rail formation extends from Burnie to the vicinity of Port Latta, the re-instatement of the line represents a capital cost which would have to be borne by the project either directly or indirectly.

If use were made of the existing pipeline, there is a gap of a few kilometres between the existing pipeline terminus at Port Latta and the nearest section of the rail. This would have to be filled either by a road transport stage or by extension of the rail, both of which would be costly additions to the total transport cost.

For these reasons it is not proposed to consider slurry transport further in conjunction with the preferred Bell Bay refinery location.

11. REFINERY SITE

11.1 Bell Bay Heavy Industrial Zone

Bell Bay is the state's premier major industrial zone, shown diagrammatically in Attachment 3. Also in Attachment 3 is a section from Tasmap's 1:25,000 topographic map of the area. The zone comprises 2,300 Ha south of Georgetown on the Tamar River. The entire zone is zoned "heavy industrial" and is well buffered from residential areas. General features making the zone suitable for the smelter include:-

- Deep-water port adjacent
- Rail access to the site
- Good highway access to the North-West and South
- Local (Georgetown) population of 7,000. Regional population of 120,000
- Synergy from the cluster of industries already in the area including manufacturing of aluminium, aluminium powder ferro alloys and meduim density fibreboard

Energy costs are seen as being optimised for the smelter at Bell Bay because of:-

- Proximity to the Bell Bay power station
- Strength of the regional HV electricity supplies associated with Comalco and Temco as well as at the Bell Bay power station
- Electricity in future from the Basslink cable for which Bell Bay is one of the alternative landing sites under consideration

- Gas supply - Bell Bay is the favoured landing for Duke Energy's proposed Victoria to Tasmania gas pipeline

11.2 Site selection

The State Government commissioned engineering consultant SKM in 1998 to undertake a broad-brush site selection for a magnesium refinery. The criteria for the study focussed on land use and availability and did not consider in any detail important factors including for example gaseous emissions and the capacity of an airshed to absorb pollutants.

After an initial pre-selection a short list of sites was agreed for more detailed review by the consultant: Main Creek, Port Latta, Hampshire, Railton, and two sites at Bell Bay. The section of the report dealing with the two Bell Bay sites is included as Attachment 11. For clarity SKM's sites 5 and 6 are referred to as sites 1 and 2 in this study.

Of the two Bell Bay sites Bass has selected site 1, between Big Bay and Dirty Bay, for further study in the pre-feasibility stage. The site is preferred for its proximity to the Bell Bay power station, and, of sites 1 and 2, may be better located for atmospheric dispersion of gaseous emissions.

Confirmation of this selection for the actual refinery site within the Heavy Industrial Zone will be based on a detailed assessment of the commercial, community, environmental and government requirements. These will include such issues as;

- Availability of approximately 50 hectares of relatively flat land plus buffer zone and suitable nearby tailings dam site
- Located to minimise community concerns regarding the on-going operation of the refinery
- Compliance with the George Town Council planning requirements;
- Minimisation of infrastructure costs for road and rail access;
- Sufficiently remote from residential and industrial uses to meet risk assessment requirements;
- Located in an area with good air dispersion characteristics;
- Site to present minimal opportunities for emissions to surface and groundwater; and
- Located to minimise noise and visual impacts.

The site is adjacent to or may encroach the Four Mile Creek Wildlife Sanctuary which is listed on the register of the national estate and as such the Commonwealth will have an interest in the development assessment process. The development and operation of the refinery will take into consideration the flora and fauna values of the site, which have resulted in the listing of the area. A copy of the web page dealing with the Four Mile Creek Wildlife Sanctuary is included in Attachment 6.

Following this confirmation, in the pre-feasibility study phase of the project, the site and the reasons for its suitability will be described in detail in the Development Proposal and Environmental Management Plan (DPEMP), required as part of the formal planning and environmental approval process.

11.3 Comalco

Comalco will consider the potential sale of land from within their buffer zone for the smelter, subject to a number of conditions, including:-

- Approval of the Comalco board
- Local and state government planning and environmental approvals
- Comalco's satisfaction on environmental grounds. Generally, Comalco will need to be satisfied that emissions from the smelter would not interfere in any way with Comalco's demonstrating their own emissions performance
- Agreement on price. Generally, Comalco is not seeking to profit from the sale, and a price which covers government valuation plus costs of sale could probably be expected

12. ENERGY AVAILABILITY

12.1 Introduction

Preliminary discussions for supply of electricity and natural gas have commenced with Duke Energy International (DEI) under a yet to be determined confidentiality agreement, based upon the project described in this report.

Contact has also been made with Aurora Energy and the HEC for electricity supply.

The cost of energy is perhaps the most difficult and critical factor in the viability of a project, gas and electricity input costs being expected to comprise approximately 40% of the metal output price.

12.2 Electricity and gas supply

In order for a supplier to offer pricing, quite detailed information regarding the supply required by the refinery will be needed.

Generally this information will only become available from work to be undertaken as part of the pre-feasibility study. Nevertheless there is an ongoing process of exchange of information between purchaser and supplier, at whatever level of detail it is available, which allows mutual confidence to grow. From this ongoing exchange it is expected that DEI will be able to bracket probable high and low pricing outcomes.

Preliminary information at the level available to us prior to gaining access to GTR's engineering studies is set out below.

For electricity	***Metal production rate: 80,000 tpy***
Supply reliability rate	Minimum 98%
Maximum downtime	Max 2 hrs in any 24 hour period [Note 1]
Quantity	1,750,000 MWh
Quality	
"Firm" or "non-firm" backup?	Firm
Supply commencement date	June 2003
Indicative ramp-up time	12 months
Period for off-take agreement	20 years
For gas	
Supply reliability rate	Minimum 98%
Maximum downtime	Max 2 hrs in any 24 hour period [Note 2]
Quantity	1,750,000 GJ
Quality	
"Firm" or "non-firm" backup?	Firm
Supply commencement date	June 2003
Indicative ramp-up time	12 months
Period for off-take agreement	20 years

Note 1... Assumes standby power supply will be available for safety requirements and maintaining cells at above electrolyte freezing temperature

Note 2... Assumes that sufficient gas will be stored in the vicinity to allow immediate commencement of operations upon restoration of supply

13. GOVERNMENT AND APPROVALS

13.1 Department of State Development

The Department of State Development (DSD) has indicated both in writing and by their actions a keen desire to assist the gaining of a magnesium metal project for Tasmania. Meetings with other state agencies have been facilitated and ongoing support provided in coordination of state agencies and advice on aspects of state policy where appropriate.

DSD may be able to facilitate access to funds for feasibility studies from Invest Australia, a joint state and federal government funding route.

13.2 The approvals process

A coordinated approvals process is mandated by the state government for projects meeting certain threshold criteria. Two processes are available, one of which, Level 3, is appropriate for large projects involving major public interest transactions and in which government intervention is expected to be required. Projects approved under the Level 3 process are referred to as Projects of State Significance (POSS).

Flow charts for the two processes are included as Attachment 5.

Both the mine and the refinery are Level 2 processes under the definition of the Environmental Management and Pollution Control Act. The Level 2 process is appropriate for a project such as this, and involves selected state agencies and the appropriate local council, and may involve federal agencies. Bass will seek approvals through the processes set out in the Act, through a process which may go further in terms of public consultation which is required by legislation. The process will include the following activities:-.

- Prepare the project description for the mine, transport and processing plant.
- Review of background information already obtained from previous investigations.
- Initial meetings with Councils, Department of Primary Industry Water and the Environment (DPIWE), and other key agencies and key stake holders to determine issues of concern.
- Submit Development Applications for each development to the respective councils.
- Identify the additional investigations required, prepare sub consultant briefs, engage preferred sub consultants and supervise the investigations.
- Describe in detail the proposed mine, transport and processing plant operations.
- Detailed and on-going liaison with DPIWE, DSD and other State Government agencies.
- Detailed liaison with Waratah-Wynyard Council and George Town Council.
- Detailed communication with key stake holder groups throughout the project.
- Overall management of the community consultation program.
- Prepare the draft development plan and environmental management plan (DPEMP) in accordance with the detailed guidelines prepared by the Board of Environmental Management and Pollution Control.
- Submit the draft documents to DPIWE and other key agencies for initial comment.
- Review of comments received from these agencies.
- Prepare the final DPEMP and submit to the two Councils.

14. ENVIRONMENTAL ASPECTS

14.1 Development Proposal and Environmental Management Plan (DPEMP)

Both mine and refinery will be operated in accordance with the requirements of the State Legislation including the Environmental Management and Pollution Control Act 1994 and associated regulations and State Policies.

DPEMP's will be prepared for each of the mine and refinery, and will describe in detail;

- Existing environmental conditions around the site, including the results of any baseline environmental studies;
- Actual and potential emission sources
- The nature of the emissions including mass emission data
- Modelling of these emissions where appropriate
- Proposed emission minimisation and control measures to be incorporated into the design and operation.

The nature, quantity and source (liquid, solid or gaseous) of potential emissions will depend on the specific operations and process technologies used, and the particular emission control technologies and environmental management regimes utilised. For example, the major potential source of dioxins will be the electrolytic cells, with the quantities generated dependent on such factors as the quality and type of the anodes used and the contamination levels in the chlorine in feed to the leaching stage. The process and environmental control technologies which will be selected for the refinery during the pre-feasibility phase will reflect worlds best practice.

Location of the mine within the Tarkine area will require additional environmental control measures and procedures to ensure that the values of the area are not compromised.

The major potential environmental issues will include, for the refinery:-

- Air emissions including, greenhouse gases;
- Wastewater management;
- Noise impacts;
- Management of solid wastes;
- Surface and groundwater impacts;
- Chemical management;
- Risk assessment in terms of the initial site selection, and the possible uncontrolled emissions during plant upset conditions.

..and for the mine:-

- The impact on conservation values;
- Surface and ground water quality during mine development, operation and decommissioning;
- Archaeological and culture heritage impacts;
- Flora and Fauna;
- Impact on karst features;
- Noise impacts;
- Overburden and waste rock management including acid generating material;
- Rehabilitation of disturbed areas both during mine operations and following mine closure; and
- Transport of ore from the mine (including noise traffic numbers, safety issues, road/rail upgrading issues and general amenity).

In order to assess these potential impacts there is likely to be a need for baseline environmental studies for both sites which may include, for the refinery:-

- Air surveys to establish existing conditions along with modelling of the likely plant emissions
- Surface and groundwater quality
- Flora and fauna surveys of refinery area
- Archaeological and cultural heritage surveys

..and for the mine:-

- Surface water hydrology and biological surveys (vertebrates and invertebrates)
- Groundwater quality and karst hydrology
- Flora and fauna surveys of mine area (including karst)
- Archaeological and cultural heritage surveys

All of these issues will be addressed in accordance with the detailed guidelines for the DPEMP prepared by the Board of Environmental Management and Pollution Control.

14.2 Refinery - gaseous emissions

14.2.1 Tamar airshed model

Characteristics of the airshed in the Tamar valley in the vicinity of Bell Bay were studied extensively early in the 1990's and as a result the effects of specific emissions can be modelled reasonably accurately, when used in conjunction with a site modelling package such as "Auspuff".

Features of air movements relevant to the gaseous emissions limits which will be required include:-

- Temperature inversions which capture emissions in a ground level b layer below the inversion unless the combination of stack height and discharge velocity can "punch" through the inversion layer
- Building lee effect during Easterly weather for sites close behind the Tippogoree Hills
- Sea breeze fumigation effects

Generally speaking, no previous work prejudices the possibility of a magnesium smelter or even two smelters operating within the Bell Bay heavy industrial zone.

14.2.2 Dioxins and other atmospheric emissions

In some plants it is expected that measurable quantities of dioxins will be discharged with tailings, and for volatilisation of those dioxins to be a significant source of atmospheric emissions. Remedial measures of acceptable cost are reputed to have been developed to remove the contaminant before discharge.

Hydrochloric acid mist and other organochlorines are likely to be of concern.

Sulphur hexafluoride SF_6, which has been commonly used to prevent oxidation of magnesium during casting, has an extraordinarily high greenhouse effect. Sulphur dioxide has been used in the past but has not to our knowledge been proven suitable for the high metal purity now required..

14.2.3 Australian guidelines

Representatives from the Tasmanian Department of primary Industry, Water and the Environment (DPIWE) visited a number of leach/chloride magnesium smelters, regulatory authorities and environmental groups worldwide earlier in 1999 in order that Tasmania would be in a position to deal intelligently and promptly with any proposal for a magnesium smelter.

We understand that Environment Australia is proposing to facilitate a workshop of State and Federal agencies (with inputs from national and international experts) later this year to develop national performance objectives for magnesium metal plants, and in particular for dioxin and furan emissions.

15. PRE-FEASIBILITY STUDY TEAM

15.1 Geology and exploration

Newnham Mining and Exploration Services (NMES) will be approached with a view to their retention for the continued exploration program which they had undertaken under contract to GTR. Lindsay Newnham, the principle of NMES former chief geologist at Renison and Mt. Lyell, is currently running the exploration program for Allegiance Mining NL at Zeehan.

15.2 Environmental - mine

SEMF Holdings (SEMF) will prepare the DPEMP for the mining operation. SEMF has considerable experience examining the environmental, engineering and planning aspects of various developments and in particular, integrating each of these aspects into a comprehensive assessment process, including greenfield site assessment.

Two significant recent approvals achieved include:-

- The $60M UMT milk processing plant on a greenfield site at Spreyton which required an extensive comparison of alternative sites, public consultations and rezoning of the site finally selected. The site spanned the boundary of two local councils which added complexity to the process, the whole of which took place within a demanding project schedule driven by the need for production to occur within a tight seasonal window for milk supply
- A heavy mineral extraction operation from coastal sands at Naracoopa on King Island for Australian Titanium Minerals. A full range of environmental investigations and background monitoring undertaken for the DPEMP. The approval required achieving agreement for the reservation of a portion of the mining lease which is a migratory staging ground for the orange bellied parrot, an endangered species.

15.3 Environmental - smelter

SEMF will submit the project description using data obtained from the process engineers and stay with the process until the DPEMP guidelines have been formally issued. During this time it is expected that a number of baseline studies will have been initiated.

Following finalisation of the guidelines a suitable environmental consultant with experience in projects of this scale and type will be selected. SEMF will ensure that this approval process is integrated with the mining operation, and would provide appropriate support to this consultant in the DPEMP process.

15.4 Engineering - process

Process Technologies Australia Pty. Ltd. will be retained and Dr. John Canterford of that company will act as process advisor to Bass. Dr. Canterford has long experience with the development of the processes used in magnesium metal extraction, working initially for CSIRO, then Minproc Engineers, and more lately in consultancy with Mt. Grace Resources.

Bateman Engineering Pty. Ltd. (Bateman) will act as process engineers for the study phase. In November 1998, Bateman were contracted by GTR to conduct a comparative scoping study on magnesium production from the Main Creek Project and the chrysotile asbestos/serpentinite tailings based Woodstreet Project in New South Wales. For both projects, the study focused on a conceptual process flowsheet involving the application of concentrated HCl leaching, $MgCl_2$ solution purification, $MgCl_2$ dehydration and ultimately electrolysis to recover 80,000 tonnes per annum of Mg metal.

The principle aim of the study was to produce capital and operating cost estimates for the two projects. Capital costs were estimated to +/- 30% accuracy whilst operating costs have been estimated to +/- 25% accuracy. The study, which was completed in March 1999, identified the principal process risks and a report which was submitted to GTR contained recommendations for future work, including an outline of the testwork and piloting programmes required for demonstration of the process flowsheet/technologies.

Whilst the scoping study itself focused primarily on technology and process-related issues, Bateman were also involved, subsequent to the completion of the study, in a financial modeling exercise on behalf of GTR. This exercise incorporated a sensitivity analysis in a number areas specific to the Main Creek Project such that they are aware of the key issues involved in the potential development of the project.

Bateman was also deeply involved in the design and construction of Dead Sea Magnesium Works in Israel.

A copy of a paper presented by Bateman at the July, 1999, Australian Magnesium Copnference in Sydney, is included in Attachment 12.

15.5 Engineering - infrastructure and transport

SEMF is Tasmania's largest engineering consulting firm and brings to this project the skills and experience in the areas of water, civil and electrical engineering to undertake the studies of surface all works including roads and waste rock disposal, and the provision of electricity supplies, water supply and waste water treatment and disposal.

In addition to these skills in the infrastructure area, SEMF is expert in the general field of bulk materials handling including conveyors, stackers and reclaimers, and consults widely in the optimisation and interfacing of mechanical plant, road and rail transport modes.

16. OVERVIEW - MAGNESIUM PRODUCTION

16.1 Magnesite

16.1.1 Occurrence and properties

Magnesite, with theoretical Mg and MgO contents of 28.8% and 47.6%, respectively, rarely occurs as the pure mineral. In nature it shows a significant variability in impurity content, crystallite size and bulk density. These chemical and physical properties play a crucial role in the type and extent of its use as an industrial, non-metallic mineral. It is mined in over 20 countries from more than 60 deposits.

16.1.2 Beneficiation

Although some magnesites can be used directly after crushing and grinding, the vast bulk of applications require both forms of magnesite to undergo some form of beneficiation.

Magnesite ore processing normally begins with crushing, screening and washing. In some localities hand sorting may be used, while there is now an increasing tendency to use optical sorting where there are sharp colour differences between the magnesite and the gangue (waste) minerals. In certain cases no further processing is required either before direct use or prior to thermal treatment to produce magnesia. This is normal in the case of agricultural grades of magnesite and caustic magnesia, and for general maintenance and lower quality refractory grades of dead burned magnesia. However, the quality of the ore may be such that higher quality grades of magnesia, namely industrial grades of caustic and regular quality brick making grades of dead burned magnesia, can be produced without further processing, although such deposits are relatively rare.

In general, a range of other processing methods, particularly heavy media separation, magnetic separation and flotation are used to remove the physically discrete impurities from the magnesite. The principal impurities tend to be combinations of dolomite, quartz, talc, chlorite, serpentine, mica, pyrites, magnetite and graphite. In general beneficiation methods do not remove impurities that are present as lattice substituents within the magnesite crystal structure.

Depending on the type of feed and the desired and product, the physical beneficiation techniques may be used singly or in combination on all of the ore or only certain fractions. When flotation is used it tis necessary to fine grind the ore to usually less than 100 micron, float, thicken, filter, dry, and briquette before dead burning. This procedure is necessary to obtain the required density and structure in the final product. Depending upon the nature of the impurities present, most flotation circuits involve the flotation of the impurity, leaving the upgraded magnesite as the tailing. Provided adequate mineral liberation is achieved during grinding, it is possible to achieve rejection of greater than 90% of the impurities with an overall magnesite recovery of greater than 85%. As would be expected, the type and extent of beneficiation must be optimised for each deposit and product specification.

The beneficiation steps all have the aim of producing a product, or more generally a range of products, that have high magnesia content, low silica, calcium, iron and aluminium levels, and low trace metal impurities.

The Main Creek magnesite, with careful selective mining, is believed to be of sufficient purity that no beneficiation will be required.

16.2 Survey of magnesium production processes

16.2.1 Introduction

Production of magnesium metal is an energy intensive process. The ideal process would be to directly electrowin magnesium metal from high purity magnesium oxide (magnesia) dissolved in a suitable fused salt (equivalent to the production of aluminium metal from alumina dissolved in a cryolite melt). A viable option has yet to be developed.

At the present time there are two major commercially proven production routes:

- High temperature reduction of dolomite.
- Electrowinning from a magnesium chloride electrolyte.

Both of these routes suffer from a number of inherent metallurgical and engineering-related problems that affect capital and operating costs, as well as product quality. In addition to the current producers, a number of research groups are involved in attempts to improve current flowsheets and equipment, as well as develop alternative, innovative options. Only those that cannot be described as "laboratory curiosities" are noted in this section.

16.2.2 Metallothermic reduction

Magnesium oxide has a high degree of chemical stability and can only be directly reduced to the metallic state using a limited range of reductants at a high temperature or low pressure or a combination of both. Metallic aluminium, calcium, silicon, their ferroalloys or carbides can, under appropriate conditions, reduce magnesium oxide. The cost of the reductant is a significant economic penalty.

Up to the present time, the principal reductant used on a commercial basis has been ferrosilicon, FeSi. With the first versions, known as the Pidgeon process, the basic reaction can be represented as follows.

$$2(CaO, MgO) + FeSi = 2Mg + Ca_2SiO_4 + Fe$$

The Pidgeon process has now been replaced to some extent by the Magnatherm process. Here the reaction mixture is supplemented with alumina, together with a small amount of magnesia. The principal reaction is as follows:

$$2(CaO, MgO) + FeSi + nAl_2O_3 = 2CaO, SiO2.nAl_2O_3 + 2Mg + Fe$$

The reaction is carried out in an electric furnace, on a batch basis. Modern Magnatherm furnaces are capable of producing about 15 tonnes of product per day. Because of the high temperature (1,550°C), productivity is higher than in the older Pidgeon process.

A major disadvantage of the Magnatherm process is the quality of the product, typically containing 0.2% Si, 0.1% Mn and 0.2% Ca. Further high temperature refining is required for it to meet the ASTM specifications.

As noted above, a major problem with the Pidgeon and Magnatherm processes is that they are operated on a batch basis. Moreover, there are significant problems with heat balance, while with the Magnatherm process, there is a high level of refractory corrosion. Another feature of the metallothermic reduction route is the very high operating temperature required for magnesium metal vapour transport. This has led to an interest in the use of plasma-arc furnaces.

16.2.3 Carbothermic process

Rather than using ferrosilicon as the reductant, there are a number of potential advantages when carbon, in the form of coke, is used – the so-called carbothermic process. A major problem is that the reaction

$$MgO + C = Mg + CO$$

is reversible at the operating temperature (about 1,800°C). For the product yield to be acceptable, the magnesium metal vapour has to be quenched (cooled) very rapidly. Quenching by liquid metal spraying is a possible option.

16.2.4 Electrowinning from fused salts

Theoretically it is possible to directly electrowin magnesium metal from molten anhydrous magnesium chloride.

- At the cathode: $MgCl_2 = Mg^{2+} + 2Cl$
- At the anode: $2Cl^- = Cl_2$

However, because of the high melting point of anhydrous magnesium chloride (987°C) and its low electrical conductivity, this is impractical. Moreover, the solubility of magnesium metal in magnesium chloride is high enough to cause a significant reduction in current efficiency. To overcome these problems, the magnesium chloride is dissolved in a supporting electrolyte which is made up of other chlorides. The more important include lithium, sodium, potassium and calcium chlorides.

There are two basic approaches to the design and operation of magnesium metal electrowinning cells.

- The Dow process uses molten partly dehydrated magnesium chloride ($MgCl_2.1.5H_2O$)
- The I.G. Farben process uses anhydrous magnesium chloride.

Modifications to the basic design of the I.G. Farben cell have been developed by Alcan, Norsk Hydro, Osaka Aluminium and Showa Denko. These are all characterised by much higher productivities and current efficiencies than the original I.G. Farben design. For example, the Alcan multi-polar cell is claimed to have extremely low electrode consumption, a current efficiency of 90-93%, and a power consumption of 8.5-11 kWh/Kg Mg. By comparison the Farben cell has a power consumption of 12-14 kWh/Kg Mg.

The Alcan cell, which has been developed in part through collaboration with the Osaka Titanium Company, operates at a relatively low temperature (670-700°C) so as to maintain a relatively viscous electrolyte. Magnesium is formed at the cathode as a continuous film undisturbed by convective flows in the electrolyte. The metal rises slowly into inverted steel troughs positioned above each cathode. These divert the metal into the collection chamber.

16.3 Reasons for the particular process selection

While the process selection will require full confirmation in the pre-feasibility study, the following steps illustrate the basis upon which the process selected for the Bass project has been selected.

16.3.1 Thermal or electrolytic?

The major metallothermic process in current use, Magnatherm, is unable to meet current standards of metal purity and has significantly higher operating costs and metal costs than modern electrolytic plants.

Metallothermic processes under development, based upon plasma arc furnaces, are still unproven and are not expected to be available for commercial use for some years

The chloride leach electrolytic process is therefore the only commercial technology with low production costs and acceptable metal purity. It is recognised that improvements are needed especially in the area of control of dioxins, furans and other chlorohydrocarbons

16.3.2 Which cell technology?

While there is a suggestion that the Dow cell technology is now able to match the energy efficiency of the Alcan cell technology, the latter is readily available under license from Alcan. With the Alcan process, attention and development of anode technology may be required to reduce organochlorine generation

16.3.3 Which dehydration technology?

CSIRO's development of the Nalco/St Joe process is understood to be not yet available to plants other than the Australian Magnesium Corporation. The process to be used at Noranda's Magnola plant, still under construction, is also unavailable until some time after successful commissioning of that plant.

The Alcan development of the Nalco/St Joe process appears to offer some reduction in organochlorine generation compared with Magnola. Use of this process will require a license agreement with Alcan and participation with other users in a development program.

17. PROCESS DESCRIPTION

17.1 Process Overview

The refinery will be designed in order that it can be operated in accordance with best practice environmental management, with the production of 80,000 tonnes per year of magnesium metal.

Elements of the process which are described in more detail below are:-

- Feed preparation
- Acid preparation
- Leaching
- Solution purification
- Dehydration
- Electrolysis
- Casting

Proprietory processes to be licensed from Alcan are to be used for both dehydration and electrolysis.

A general discussion of organochlorines associated with the process is included.

A summary of inputs and outputs associated with each section of the process (neglecting stormwater runoff and exchanges between sections) is given.

17.2 Feed preparation

The primary raw material is high purity magnesite. At full production approximately 400,000 tonnes of magnesite will be required per year. The magnesite, having been crushed at the mine to <150 mm, is received by rail in bottom dump wagons.

A rake of loaded wagons will be advanced over an unload station by a remotely controlled cable operated wagon indexing system. The wagons will dump into a below-ground hopper with feeder discharging onto an elevating conveyor which in turn discharges onto a conical feed stockpile with a total capacity of approximately 5,000 tonnes.

Three reclaim openings beneath the stockpile discharge onto a reclaim conveyor which in turn discharges to a feed preparation area. Feed preparation will comprise a feed bin, full-flow comminution, or screening and comminution of oversize, depending upon the detailed comminution characteristics of the ore and its leaching characteristics. Crushing or dry milling will be considered for comminution. Details of feed preparation will be optimised with the leaching process in testwork.

At this stage it is not expected that further beneficiation is cost-effective. Beneficiation, using physical separation processes such as flotation can remove only impurities which are not bound into the crystal lattice of the magnesite.

17.3 Acid preparation

17.3.1 Hydrogen

Natural gas is reformed in a proprietory packaged plant to produce hydrogen for the synthesis of hydrochloric acid. The packaged plant would incorporate the following unit processes:-

- Feed gas conditioning
- Desulphurisation. Sulphur is the major cause of odours
- Steam reformation using nickel catalyst, producing hydrogen and carbon monoxide
- Shift conversion, oxidising the carbon monoxide with the production of further hydrogen

- Gas cooling
- Hydrogen purification using PSA (pressure swing absorbtion)

The overall reactions are endothermic. The net heat input required is obtained by combustion of natural gas.

Serious risks are associated with the manufacture and storage of hydrogen, and will be given close attention in risk analysis studies.

17.3.2 Chlorine

Chlorine is continuously extracted under a slight negative pressure from the electrolysis cells and cleaned for use in acid synthesis.

Chlorine losses in the form of chloride (liquid) wastes may be as high as 5% or more of the circulating chlorine load resulting in a requirement for makeup chlorine in the order of 10,000 tonnes per year at a magnesium production rate of 80,000 tonnes per year.

At this annual consumption rate it is possible that generation of chlorine on the plant is cost-effective by comparison with purchase of liquid chlorine gas. At this stage however it is planned that either hydgrogen chloride or chlorine gas will be purchased from a third party supplier.

17.3.3 Hydrogen chloride - hydrochloric acid

The hydrogen and chlorine are burnt to form the hydrogen chloride in a synthesis unit designed to ensure full combustion. The combustion chamber has a high temperature capable, acid resistant lining. Tramp oxygen combines in the same reaction vessel with excess hydrogen. The synthesis reaction is exothermic and will be used for steam raising for use within the refinery.

Hydrogen chloride gas is contacted with process water recycled from the tailings dam to produce concentrated hydrochloric acid.

17.4 Leaching

Leaching with concentrated hydrochloric acid will either occur in a top-fed counter-current leaching column (as described below) or a three or four unit train of agitated leach tanks. The nominal 3 hour leach period takes place at between 60° and 90°C and the temperature of the leach is controlled using process steam. Leach liquor concentration is approximately 30% $MgCl_2$.

The leach liquor contains fine particles of unreacted magnesite and any gangue (waste) mineral. With a column leach solids overflow the top of the column through a launder

system, and columns are fitted with appropriate facilities for controlling any froth generated. The slurry overflowing from the leach column flows to a conventional stirred tank where magnesite leaching is completed.
The solid waste from leaching is then filtered and the cake further washed to recover the maximum amount of magnesium chloride. The washed cake is predominantly unreacted magnesite and gangue minerals. The quantity generated will depend upon the final combination of comminution and leaching parameters selected and on the purity of the feed magnesite.

Solid wastes will be pumped to a tailings dam and water from the dam recycled for process use. It is expected that because of the evaporation taking place during dehydration of the magnesium chloride, the overall water balance of the plant will be negative and that there will be no need to discharge process water from the plant to maintain the balance.

Off-gas from leaching is carbon dioxide with water vapour and carry-over chlorides. Off-gases are wet scrubbed in a packed tower before discharge of saturated carbon dioxide to atmosphere. If shown to be necessary during testing of the leach process, off-gases will be cooled before scrubbing to remove the bulk of the chlorides.

Variations to be examined during testwork include:-

- Multiple stage leaching which may result in less dissolution of impurities
- Feed size and size distribution
- Temperature
- Dosing with concentrated sulphuric acid to remove calcium during leaching

17.5 Solution purification

Calcined magnesite (magnesia) is produced on site by calcination of a portion of the magnesite feed. A rotary furnace will probably used for this process.

Magnesia is progressively added to the leachate to raise the pH above 8, but below about 10, during which most of the nickel and iron precipitate as their respective hydroxides. Excess magnesia and/or magnesium hydroxide must be avoided in order to prevent the precipitation of a magnesium chloride – magnesium hydroxide material known as Sorel cement

The amount of impurity dissolution and hence the complexity of the impurity removal stages will be affected by the quality of the magnesite feedstock. The high quality Main Creek magnesite feedstock, with low levels of gangue minerals such as reactive clays, iron oxides and dolomite, is expected to minimise the complexity of the purification required to achieve acceptable purity of the $MgCl_2$ solution.

Most of the significant impurities, including the heavy metals, are precipitated at this stage. In practice two or three stages of precipitation may be required to ensure adequate removal of the impurities. The precipitate is removed by thickening then filtration and the final liquor clarified to remove any suspended solids.

If the boron content of the final liquor is above a predetermined level, it may be necessary to remove it by passage through an ion exchange resin column. A number of other impurities will require elimination in this stage. The need and the required processes will be determined during testwork.

Wastes from solution purification are expected to report to the leaching solid residues. If addition of purification residues would make the leaching residues unsuitable for use as landfill, separate disposal may be preferred.

There will be a significant liquid bleed from the purification stage, predominantly chlorides. The liquid bleeds are expected to be innocuous as marine discharges, but if this proves in testing not to be the case, evaporation and disposal as solid wastes will be required.

17.6 Dehydration

17.6.1 Licensing

Electrolysis of fused magnesium chloride by selected technology, the Alcan multipolar cell (MPC), requires that the magnesium chloride be completely anhydrous.

The first step in dehydration is to remove all of the water of solution, by a combination of conventional techniques such multi-stage evaporation, spray drying and crystallisation, to produce either a strong brine or solid magnesium chloride, mostly as the hexahydrate.

Dehydration of magnesium chloride hexahydrate is expected to take place by a modification of the process originally developed by Nalco/St. Joe. In this process:-

- Ethylene glycol is used to extract both surplus solution water and water of crystallisation.
- Anhydrous ammonia is then sparged through the ethylene glycol solution, precipitating solid $MgCl_2.6NH_3$
- Removal of the complexed ammonia by two calcination stages

Alcan has modified the original Nalco/St Joe process at laboratory scale and patented the new process, in which ethylene glycol is replaced by methanol. Benefits of the modified process include operation at ambient temperatures and pressures, few and relatively mild reactants, more ready recycling of the reactants, higher yield and lower levels of hydrolysis in the product.

The conclusion of a license agreement with Alcan will be necessary, and possibly with other licensed users. Successful completion of pilot scale testwork will be required before this process can be considered commercially proven.

17.6.2 Process

The magnesium chloride hexahydrate is contacted with methanol recycled from the ammonia/alcohol recovery system later in the process, allowing alcohol insoluble impurities remaining in the feed to be removed.

In a crystalliser, anhydrous ammonia is sparged through the solution and crystals of a magnesium chloride/ammonia complex $MgCl_2.6NH_3$ form. A tendency to precipitate magnesium hydroxide is restrained by maintaining an appropriate concentration of ammonium chloride hydroxide in the circuit. When crystals are sufficiently large they are removed by centrifuging a bleed stream in the crystalliser circuit.

Centrifuged product is washed in ammonia saturated methanol, then dried to a minimum alcohol content using hot ammonia gas from the subsequent calcination stage. Recovered ammonia and alcohol are recycled as described earlier. Leaving this process the magnesium chloride will be present as both a hexa-ammoniate and a tetra-ammoniate.

The dried cake is then calcined in a fluidised bed to produce the anhydrous magnesium chloride. Heat is recovered from the calcine firstly by ammonia for the fluidised bed, then from partly cooled calcine to provide heat for the alcohol and ammonia recovery stages.

Magnesium chloride leaves calcination in solid form, is melted in a separate melting furnace and transported in molten form to the electrolysis cells under argon. Any contact with atmospheric moisture would result in the formation of magnesium oxide, a major contaminant in electrolysis.

17.7 Electrolysis

17.7.1 Purity of magnesium metal

Product purity and electrowinning efficiency are largely determined by the level of impurities in the anhydrous magnesium chloride feedstock, together with highly efficient separation of the magnesium metal and the chlorine by-product. Overall loss of current efficiency can occur via a number of mechanisms.

- Parasitic reactions involving simultaneous discharge of ions (impurities) whose deposition potential is not as negative as that of magnesium. These include the heavy metals such as nickel and iron.
- Redox reactions involving multivalent ions such as iron, manganese and titanium.
- Direct and indirect combination of the products.
- Failure of magnesium droplets to coalesce so that the metal disperses in the electrolyte, reacts with impurities, and finally sinks to the bottom of the cell to become entrapped in the sludge. Magnesium borides, formed between the boron in the electrolyte and the metallic magnesium, are believed to be major cause of coalescence impairment, as well as forming a cathode-passivating film.
- Burning of magnesium metal in the collection compartment where it contacts air. The MgO so formed is found in the sludge and may even be entrapped in the metal itself.

Impurities in the electrolyte arise directly from the feed itself as well as from reactions between the cell components (electrodes, cell walls) and the electrolyte. As would be expected, some of the current developments in cell design are aimed at reducing impurity generation through the use of less reactive materials of construction.

17.7.2 The Alcan multi polar cell (MPC)

Alcan licenses the fully developed MPC system which is reputed to give the highest energy efficiency of any current technology, consistent with the high purity required in the magnesium metal product.

The electrolysis plant is physically organised in a manner similar to that for aluminium recovery. A number of cells form a line, electrically in series, so that the total DC voltage available for the line dictates the number of cells, each one of which has a voltage drop of approximately 7V.

The electrolyte will comprise a relatively low proportion of magnesium chloride, the balance being mostly sodium chloride, with other metal chlorides, including lithium, calcium and potassium.

Magnesium metal is recovered from a metal collection chamber in each cell and transported in a sealed container to the casting area. Chlorine is collected under a slightly negative pressure to a chlorine recovery duct which runs the length of the cell line. Sludge collects in the bottom of the metal collection chamber and is tapped periodically.

18. CASTING

18.1 Process

Magnesium metal is stored in gas fired holding furnaces during purification and alloying prior to casting. Some impurities can be removed at this stage by addition of a flux which draws the impurity into a dross on the surface of the molten metal. Alloying metals are added according to customer requirements.

The casting technique will depend upon the ingot size or sizes required by customers, with either batch casting or machine casting depending on ingot size and length of production run before changing.

All operations with molten metal require gas blanketing with a gas which is inert to the molten metal surface. Sulphur hexafluoride is commonly used but as escaping gas has an extremely intense greenhouse gas effect, nearly 25,000 times more severe than CO_2, more benign alternatives will be sought as a matter of urgency. Sulphur dioxide has been proposed and will be studied.

18.2 Dioxins

18.2.1 Sources

18.2.1.1 Electrolysis

The chlorine stream from the cell line contains all gaseous contaminants generated during electrolysis, including any dioxins (a term used generically in this report to cover any chlorohydrocarbons including among others dioxins and furans).

It is surmised that the dioxins are generated at the anode, which is conventionally manufactured either from a carbon/pitch mixture or from graphite, and that there is a significant range in the amounts of dioxins generated by electrodes of different materials and quality. Some information may be available when access is gained to detailed operational knowledge, either through a licensing agreement with Alcan or through GTR's pre-feasibility work.

It is understood that a ceramic anode which will eliminate dioxin generation at this source is under development, but will not be commercially available for some years.

18.2.1.2 Hydrogen chloride synthesis

Graphite is sometimes used as the acid and temperature resistant lining for the hydrogen chloride synthesis chamber. The juxtaposition of carbon, chlorine and high temperatures gives rise to dioxin generation, although the relative significance of this as a source compared with electrolysis is unknown at this stage.

Some of the dioxins generated in electrolysis and in hydrogen chloride synthesis will be destroyed in the hydrogen chloride synthesis process, others will report in the tail gas. Further destruction can be expected in the hot hydrochloric acid of the leaching process.

18.2.1.3 Superchlorinator

It is understood that the superchlorinator in the dehydration process at the Magnola plant is regarded as a significant source of dioxins. The Alcan development of the Nalco/St Joe process does not involve a superchlorinator or any similar process.

18.2.2 Sinks

All of the dioxins characteristic of both sources (electrolysis and HCl synthesis) are present in the HCl synthesis tail gas stream, and this would appear to be one opportunity for their interception. After the tail gas is contacted with water, some dioxins will remain in the spent gas (presumably nitrogen and hydrogen) and the balance will report to the concentrated acid stream.

Solid residues from leaching will carry a proportion of dioxins present in the leach acid to the tailings dam. The process and environmental control technologies which will be selected during the pre-feasibility phase to manage these emissions will reflect world's best practice.

18.3 Process inputs and outputs

Inputs		
Magnesite ore	800,000 tpy	Rail
Natural gas		For reformation and combustion for process heat - piped to site by gas supplier (Duke)
Chlorine gas		Delivered in liquid form in rail tankers by third party supplier
Concentrated sulphuric acid		Received in small quantities by rail from Hobart

Inputs (cont'd)		
Reagents		Flocculants and filter aids, purification reagents not yet selected, Sodium, potassium and calcium chlorides for electrolyte makeup, methanol, anhydrous ammonia, fluxes for electrolysis and casting
Carbon anodes		For electrolysis
Blanketting gas		SF_6 or preferably a substitute because of the extreme activity of SF_6 as a greenhouse gas
Outputs		
Runoff		Stormwater runoff from plant areas will be treated in the site waste water management system.
Sulphur compounds		(Unknown) from desulphurisation of natural gas
Waste nickel catalyst		From reformation of natural gas
Carbon dioxide		From natural gas reformation and leaching. May have traces of contaminants such as carbon monoxide and sulphur compounds
Chlorine gas		No discharge under normal operating conditions. Risk of accidental escape from the process or catastrophic escape from bulk storage or tanker will be studied
Water		Normally no process water discharged from site except those which meet normal environmental requirements for chemical content, temperature etc..
Hydrogen chloride gas		No release of hydrogen chloride under normal operating conditions. Risk of accidental releases due to plant failure will be studied. Hydrogen chloride gas will not be accumulated or stored in the process
Solid wastes		Washed solid waste containing some unreacted magnesite and most of the contaminants present in the magnesite. Will be discharged to a tailings dam. Water from dam recycled for process use.
Ammonia and alcohol		Small quantities will escape from the process. Risk of accidental releases due to plant failure will be studied
Spent anode		Waste carbon and solidified electrolyte from spent anodes

Outputs (cont'd)		
Solidified electrolyte		Comprising predominantly sodium and magnesium chlorides
Losses of blanketing gas		
Dross from casting		Predominantly impure magnesium oxide with some chloride
Dioxins		Also furans and other chlorohydrocarbons

19. ATTACHMENTS

1. Mining lease plans
2. Map showing approximate boundaries of mining leases and Tarkine Wilderness Area
3. Diagram of the Bell Bay heavy industrial zone. Section of Tasmap 1:25,000 map
4. Maps (1:250,000, 1:25,000), aerial photographs of the Main Creek site and long section of alternative road access to mine.
5. Approval processes - flow charts for Level 2 and Level 3 (POSS)
6. AHC website description of the Tarkine Wilderness Area
7. Figures and references - regional geology section of study
8. Pictorial cross-section representative of the Main Creek deposits
9. Concept flowsheet and layout for mine surface works
10. Concept layout - Refinery
11. Extracts from SKM preliminary site study
12. Papers from the Australian Magnesium Conference, Sydney, July 1999

ATTACHMENT 1
Mining Lease Plans

SEMF

Tasmania

MINERAL RESOURCES TASMANIA

A Division of DEPARTMENT *of* INFRASTRUCTURE, ENERGY *and* RESOURCES

500058

Copy Malcolm Bendall

RECEIVED 28 SEP 1999

Enquiries: Dennis Burgess
Phone: (03) 6233 8341
Our File: 9DRB214:DS

27 September 1999

Mr Malcolm Bendall
Level 3, 65 Murray Street
HOBART TAS 7000

Dear Mr Bendall

SAVAGE RIVER MAGNESITE PROJECT

Further to our meeting on Friday, 24 September 1999, details relating to tenements held by Savage Resources Limited are as follows.

Tenement	Area	Product	Expiry Date
RL 8802	4 km^2	Category I	23/05/2003
3W/94	42 ha	Road	01/02/2005
4W/94	30 ha	Road	01/02/2005
2M/99	520 ha	Magnesite	25/03/2020
3M/99	15 ha	Ochre	25/03/2004
4M/99	6 ha	Umber	25/03/2004
5M/99	55 ha	Magnetite	25/03/2004

As mentioned during the meeting, all of the above tenements are in good standing and may be operated subject to development approval from the Waratah/Wynyard Council.

Leases 4M/99 and 5M/99 are subject to caveats lodged by Golden Triangle Resources (GTR). We have been advised that the caveats are likely to be withdrawn following confirmation from GTR.

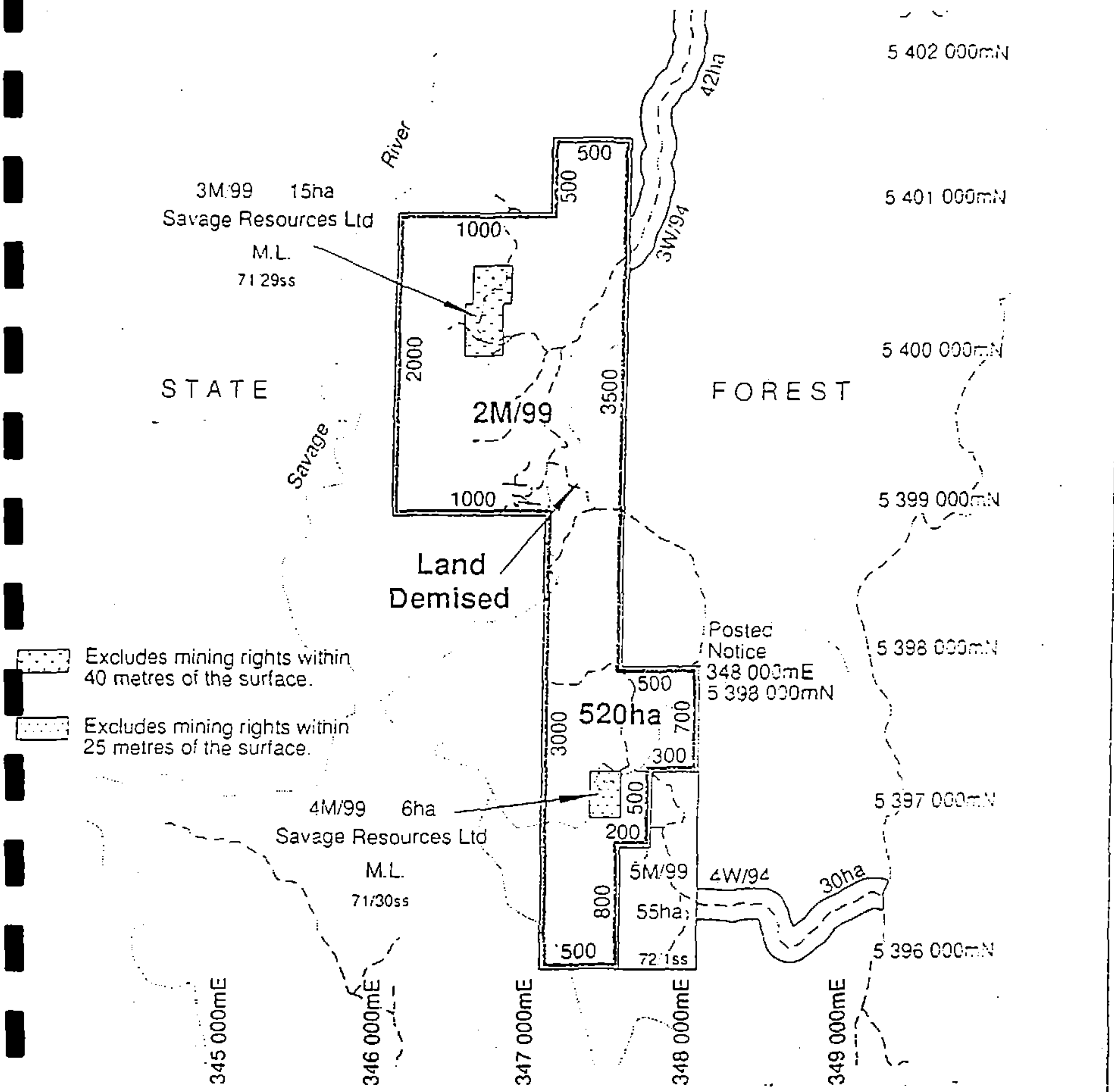
Attached are copies of tenement documents and a location plan.

Yours sincerely

Dennis Burgess
REGISTRAR OF MINES

PLAN-SUBJECT TO SURVEY

500059

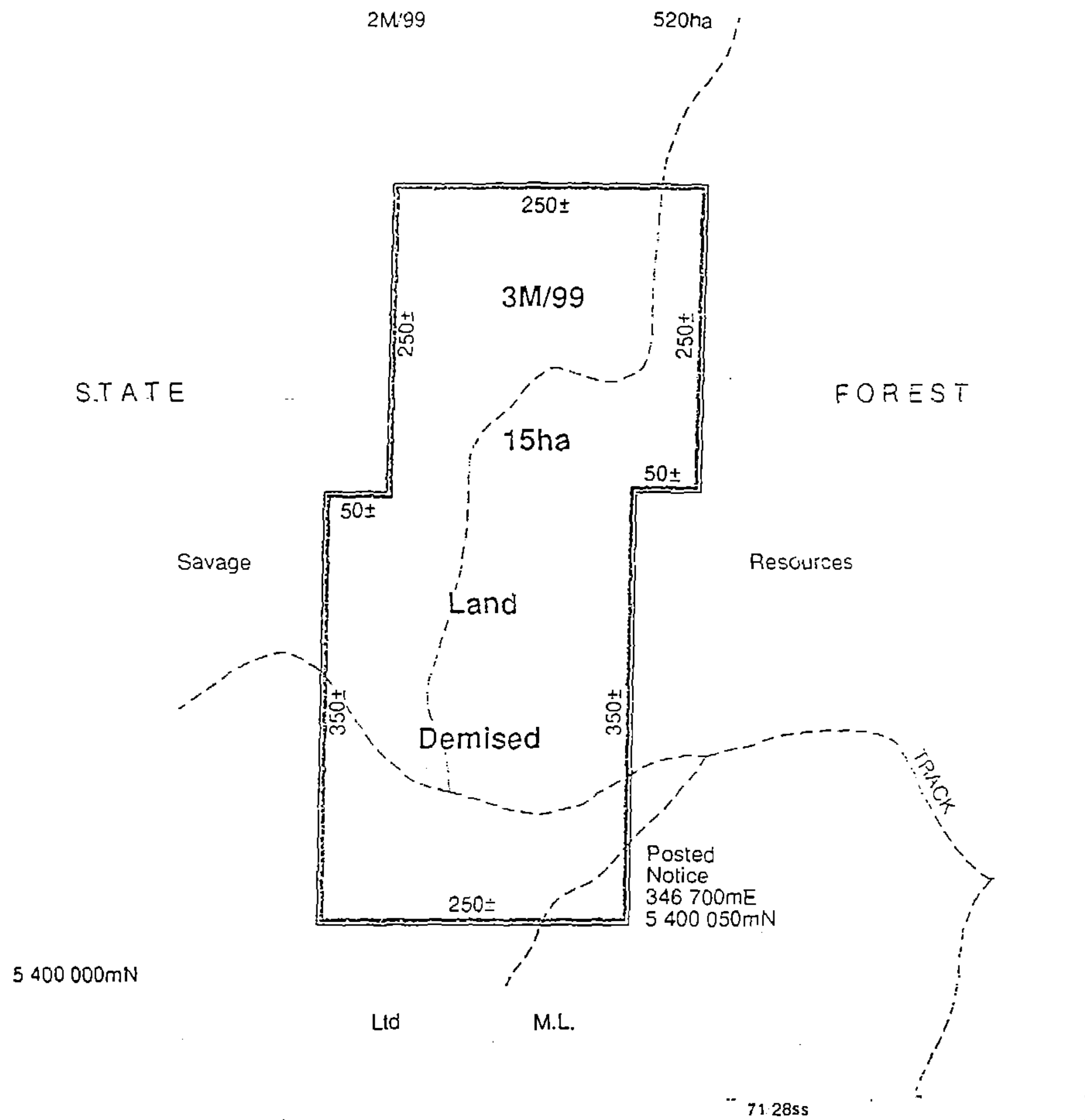


AND DISTRICT RUSSELL		VICINITY BOWRY CREEK, SAVAGE RIVER	
UNICIPALITY WARATAH/WYNYARD	MAP CORINNA 1:50000	SCALE 1:40000	
PPLICATION NO. 2M/99	AREA 520ha		MINERAL RESOURCES TASMANIA
PPLICANT	SAVAGE RESOURCES LTD		
	5 cm		Tasmania
RAWN *A. Ploughman*	EXAMINED *[signature]*	DATE *10.3.99*	
PPROVED *[signature]*	DIRECTOR OF MINES	DATE *10.3.99*	VOL. 71 / FOLIO 28

MINERAL RESOURCES TASMANIA - DATA MANAGEMENT GROUP

PLAN-SUBJECT TO SURVEY

500060

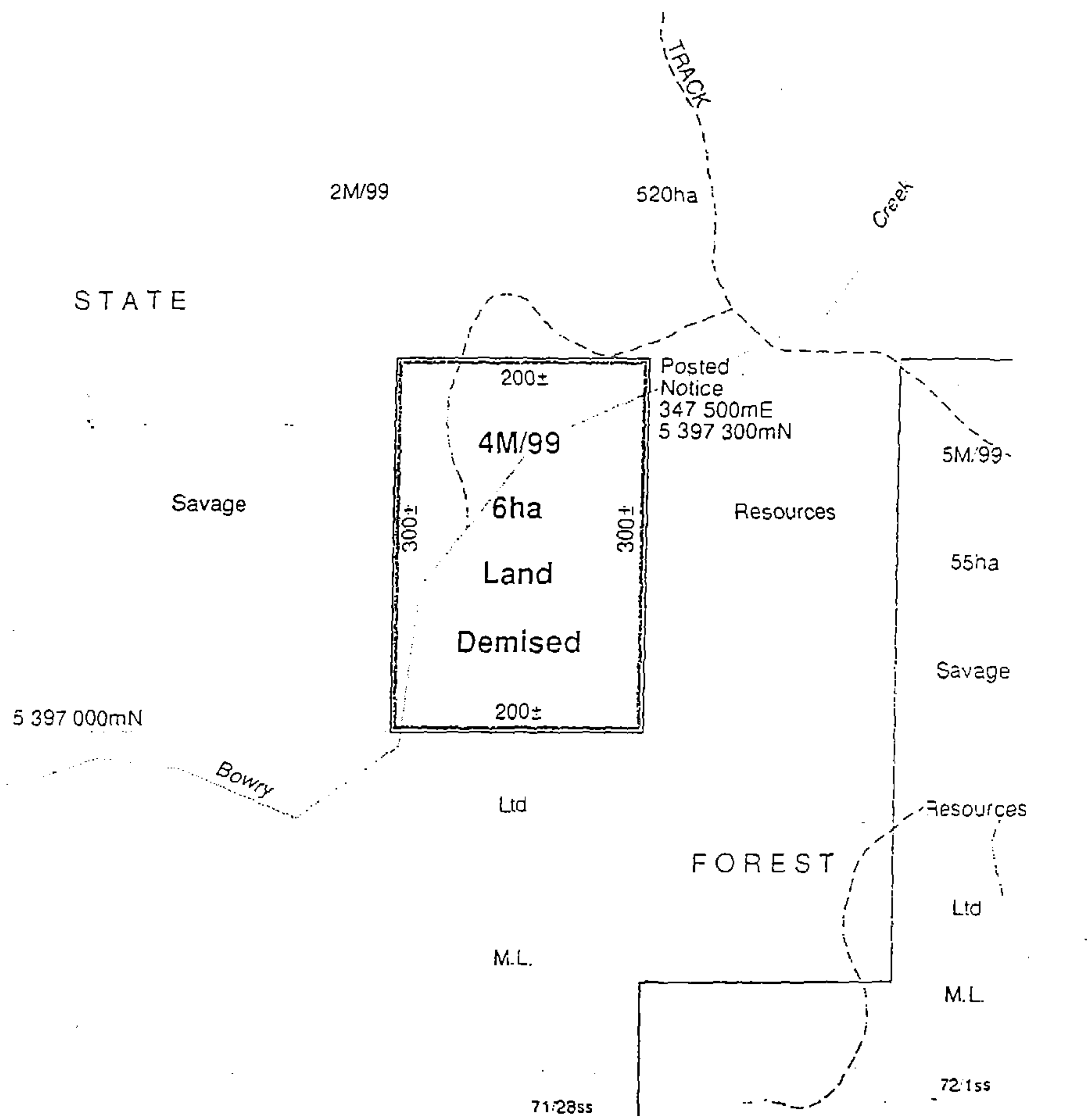


LAND DISTRICT RUSSELL		VICINITY SAVAGE RIVER	
MUNICIPALITY WARATAH/WYNYARD	MAP SAVAGE RIVER 1:25000	SCALE 1:5000	
APPLICATION NO. 3M/99	AREA 15ha		MINERAL RESOURCES TASMANIA
APPLICANT SAVAGE RESOURCES LTD			
5 cm			Tasmania
DRAWN A. Ploughman	EXAMINED [signature]	DATE 10 5 99	
APPROVED DIRECTOR OF MINES		DATE	VOL. 71 / FOLIO 29

MINERAL RESOURCES TASMANIA - DATA MANAGEMENT GROUP

PLAN-SUBJECT TO SURVEY

500061

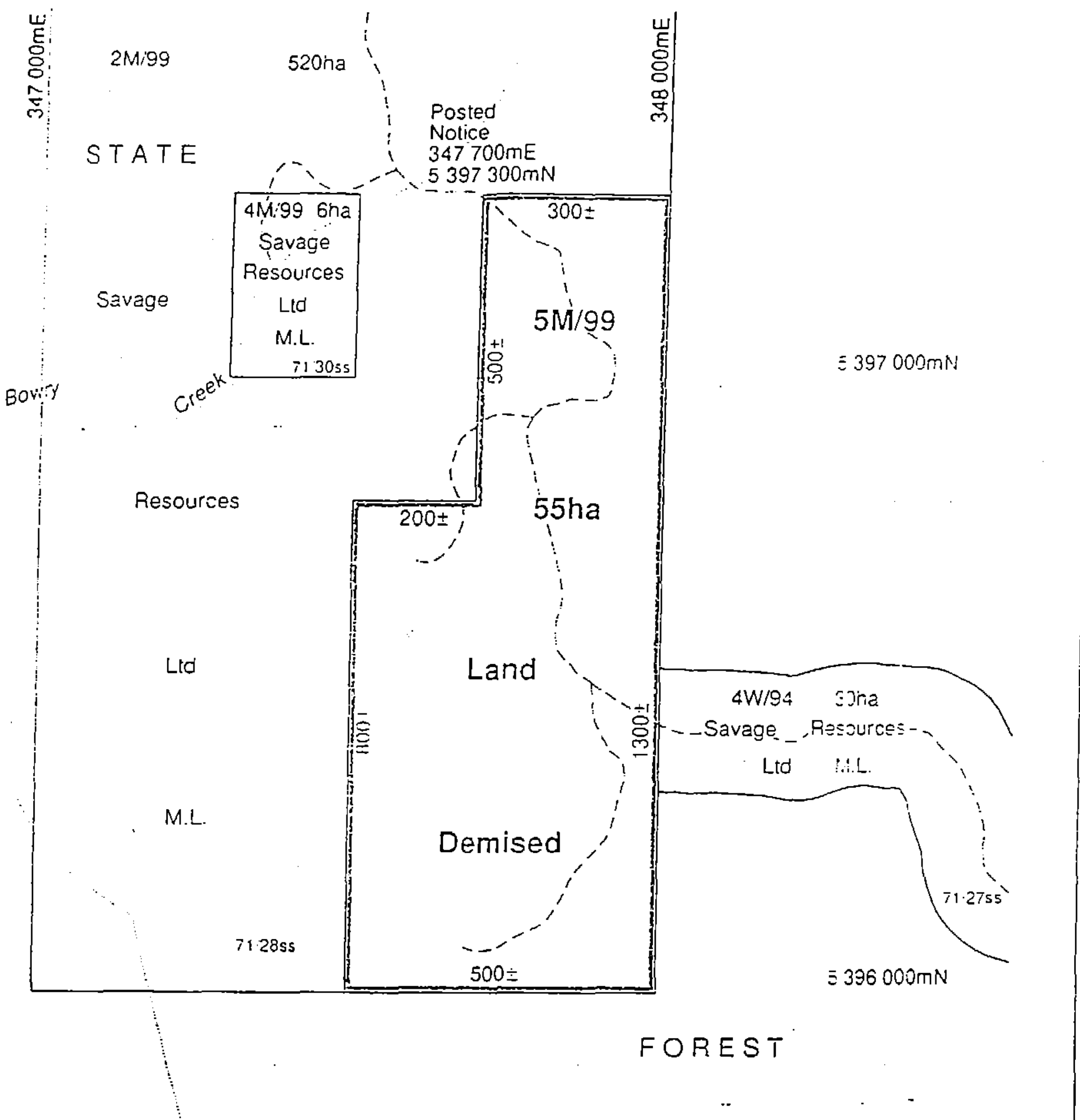


LAND DISTRICT RUSSELL		VICINITY BOWRY CREEK, SAVAGE RIVER	
MUNICIPALITY WARATAH/WYNYARD	MAP CORINNA 1:50000	SCALE 1:5000	
APPLICATION NO. 4M/99	AREA 6ha		MINERAL RESOURCES TASMANIA
APPLICANT SAVAGE RESOURCES LTD			
5 cm			Tasmania
DRAWN *A. Ploughman*	EXAMINED	DATE 10.3.99	
APPROVED [signature] A/DIRECTOR OF MINES		DATE 10.3.99	VOL. 71 / FOLIO 30

MINERAL RESOURCES TASMANIA - DATA MANAGEMENT GROUP

PLAN-SUBJECT TO SURVEY

500062



LAND DISTRICT RUSSELL	VICINITY BOWRY CREEK, SAVAGE RIVER
MUNICIPALITY WARATAH/WYNYARD	MAP CORINNA 1:50000 — SCALE 1:10000
APPLICATION NO. 5M/99	AREA 55ha
APPLICANT	SAVAGE RESOURCES LTD

5 cm

MINERAL RESOURCES TASMANIA

Tasmania

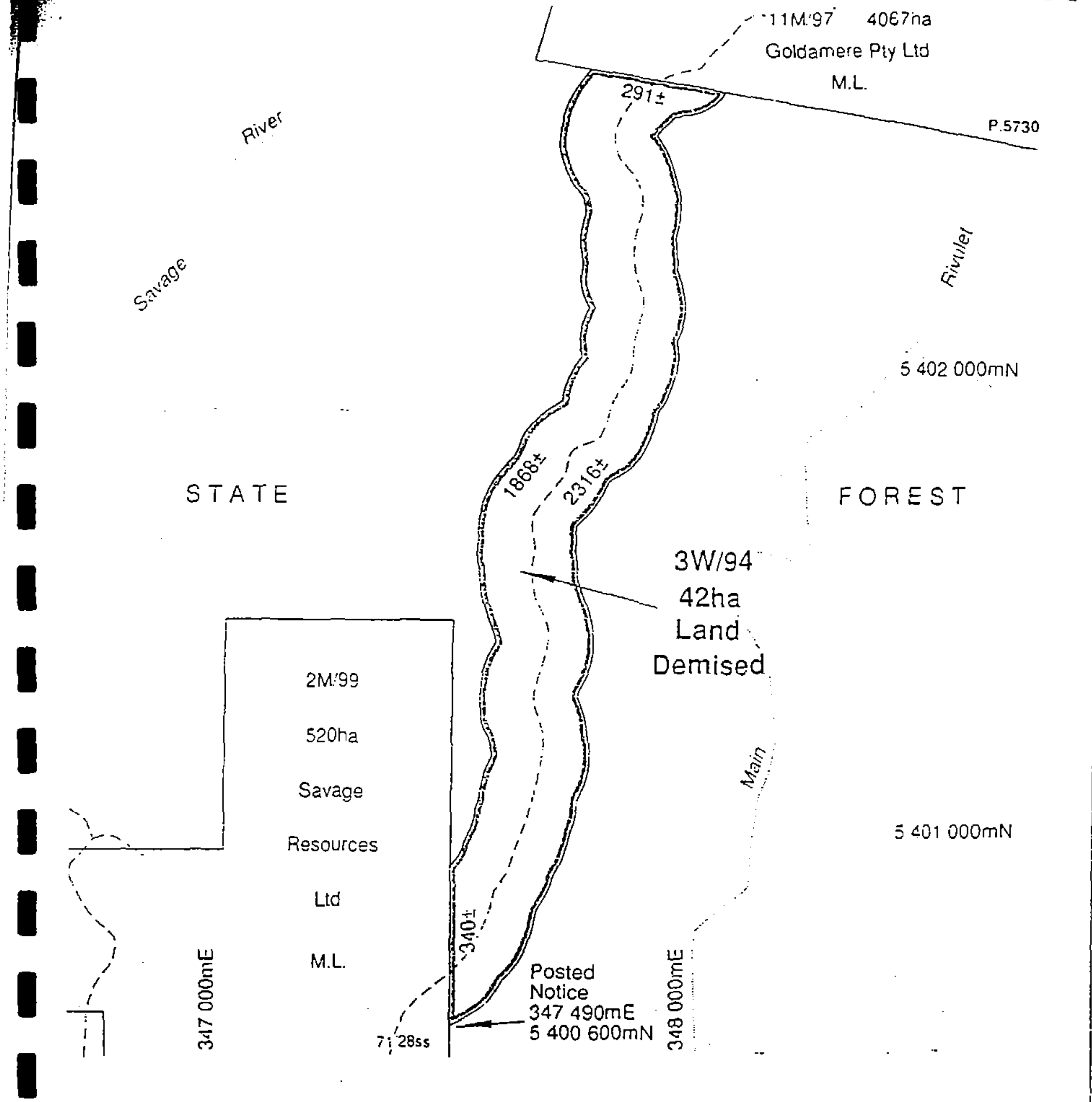
DRAWN *A. Ploughman*	EXAMINED *[signature]*	DATE 10.3.99
APPROVED *[signature]* A/DIRECTOR OF MINES		DATE 10.3.99

VOL.	FOLIO
72	1

MINERAL RESOURCES TASMANIA - DATA MANAGEMENT GROUP

PLAN-SUBJECT TO SURVEY

500063

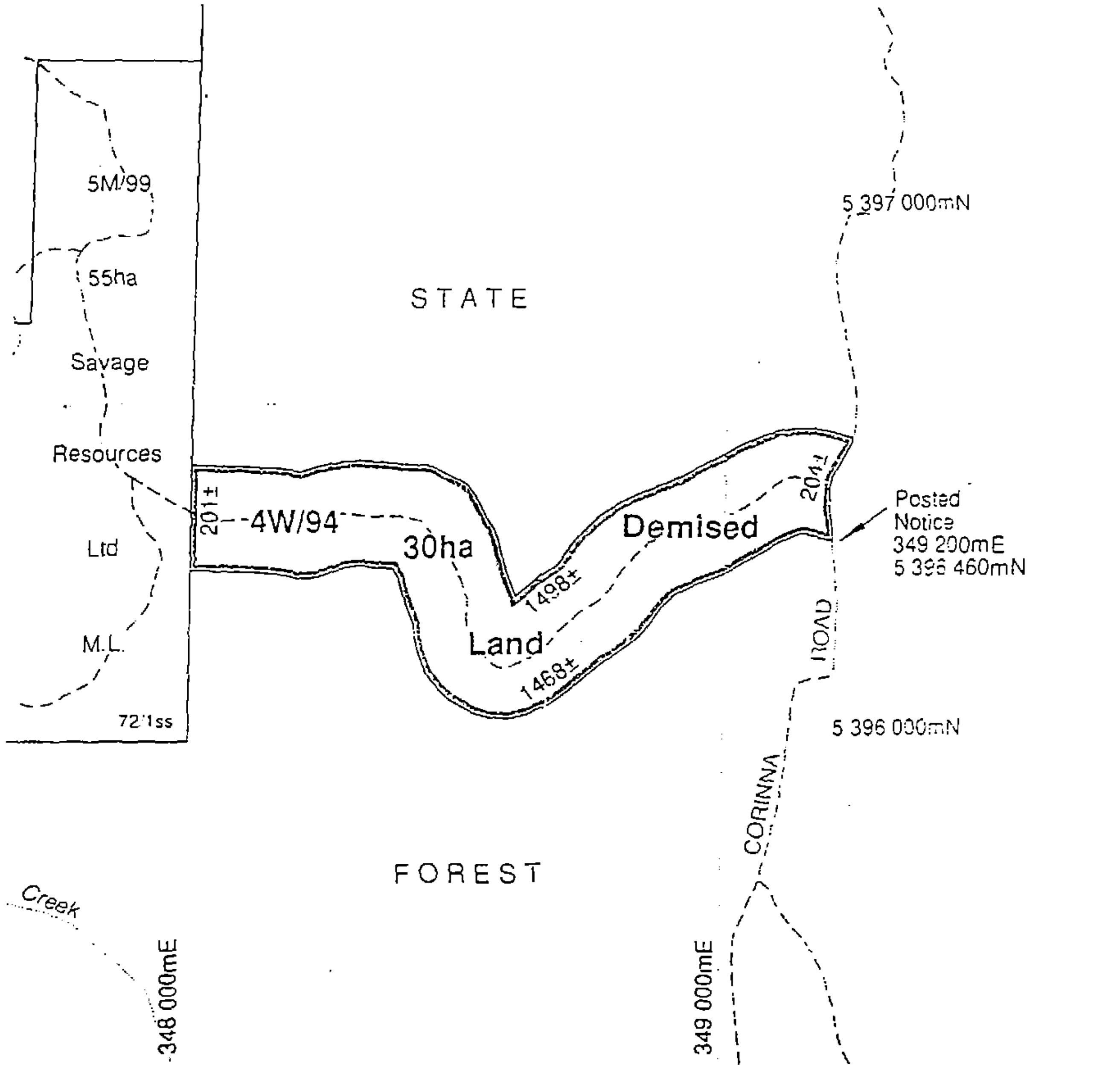


LAND DISTRICT RUSSELL		VICINITY SAVAGE RIVER	
MUNICIPALITY WARATAH/WYNYARD	MAP SAVAGE RIVER 1:25000	SCALE 1:12500	
APPLICATION NO. 3W/94	AREA 42ha		MINERAL RESOURCES TASMANIA
APPLICANT	SAVAGE RESOURCES LTD		
	5 cm		Tasmania
DRAWN *A. Ploughman*	EXAMINED	DATE 10 3 99	
APPROVED [signature] DIRECTOR OF MINES		DATE 10·3·99	VOL. 71 / FOLIO 25

MINERAL RESOURCES TASMANIA - DATA MANAGEMENT GROUP

PLAN-SUBJECT TO SURVEY

500064

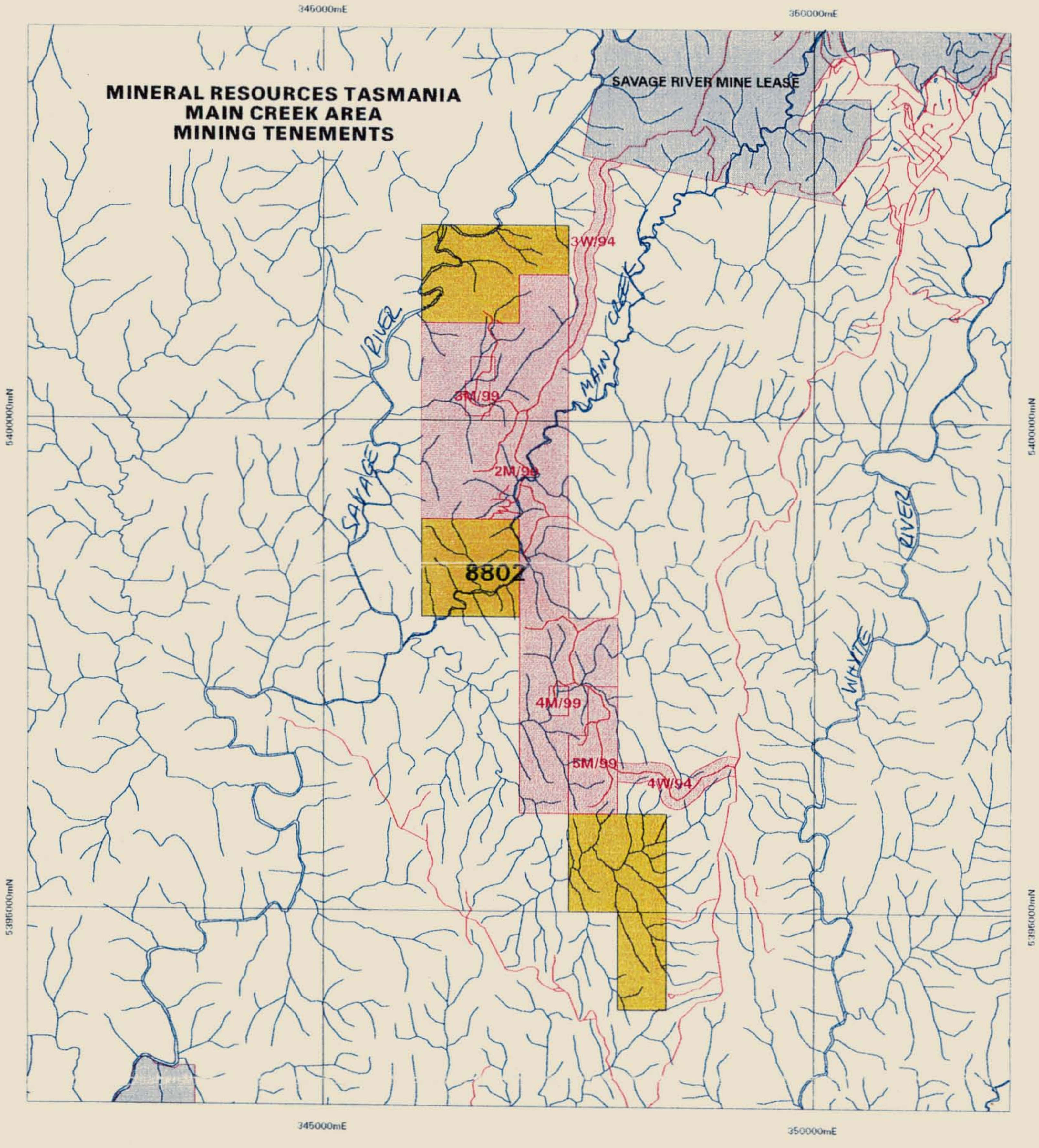


LAND DISTRICT RUSSELL	VICINITY CORINNA ROAD		
MUNICIPALITY WARATAH/WYNYARD	MAP CORINNA 1:50000	SCALE 1:12500	
APPLICATION NO. 4W/94	AREA 30ha		MINERAL RESOURCES TASMANIA
APPLICANT	SAVAGE RESOURCES LTD		
	5 cm		Tasmania
DRAWN *A. Ploughman*	EXAMINED	DATE 10.3.99	
APPROVED	DIRECTOR OF MINES	DATE 10.3.99	VOL. 71 / FOLIO 27

MINERAL RESOURCES TASMANIA - DATA MANAGEMENT GROUP

ATTACHMENT 2

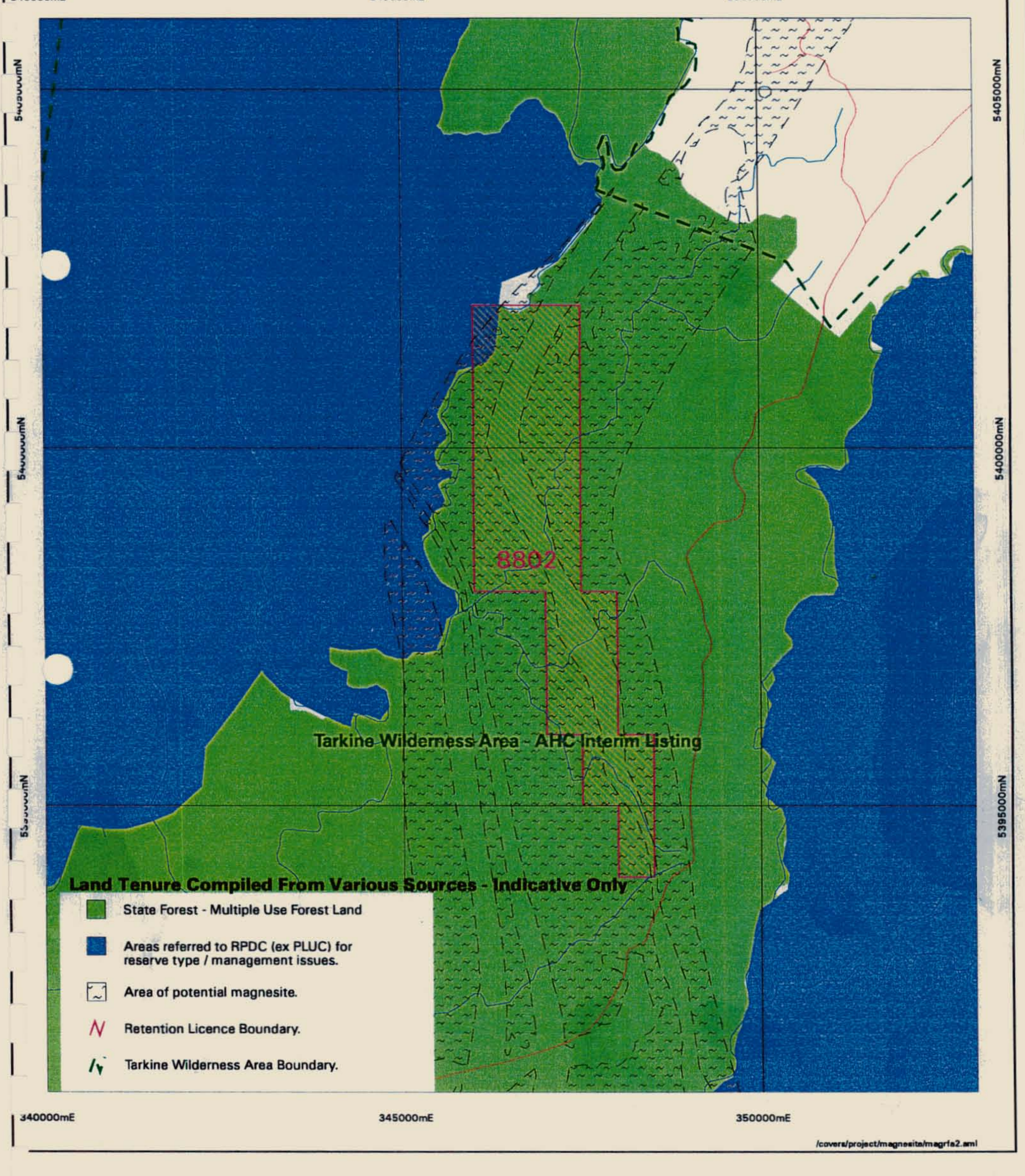
Approximate Boundaries of Mining Leases and Tarkine Wilderness Area



345000mE
350000mE
MINERAL RESOURCES TASMANIA
MAIN CREEK AREA
MINING TENEMENTS
SAVAGE RIVER MINE LEASE
3W/94
SAVAGE RIVER
MAIN CREEK
2M/99
8802
4M/99
5M/99
4W/94
WHYTE RIVER
5400000mN
5395000mN
345000mE
350000mE

500066

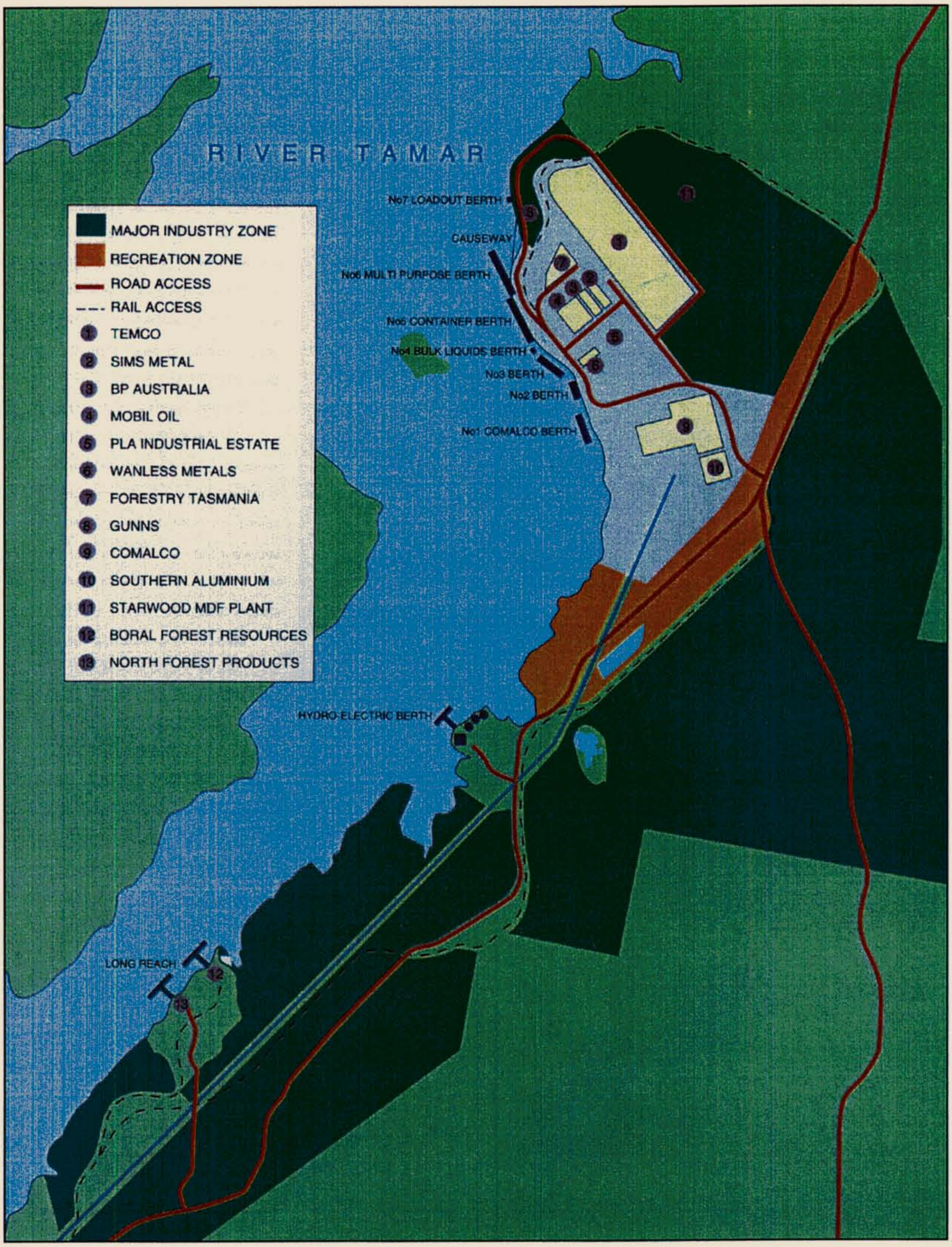
MINERAL RESOURCES TASMANIA
LAND CLASSIFICATION - RFA
MAIN CREEK MAGNESITE RETENTION LICENCE



ATTACHMENT 3

Bell Bay Heavy Industrial Zone

BELL BAY INDUSTRY ZONE AND PORT FACILITIES



Source: Port of Launceston Authority, Annual Report

EAST
TAMAR
HIGHWAY
A8
BRIDPORT
ROAD
Four
Mile
Creek
HEC
sub-station
Lauriston Reservoir
George Town Golf Course
Howell Reservoir
BELL
BAY
Note: All islands in the River Tamar are included in the Municipality of Beaconsfield.
Donovans Bay
oil tanks
HEC
Bell Bay Thermal Power Station
Middle Point
Big Bay
RIVER
FOUR
MILE
CREEK
Dirty Bay
Wilmores Bluff
Long
Reach
TAM
BELL
WILDLIFE
BROOKES ROAD
WESTWOODS ROAD
ROWELL
Chartley
Bayswater
woodchip plant
stockpile
tanks

500070

500071

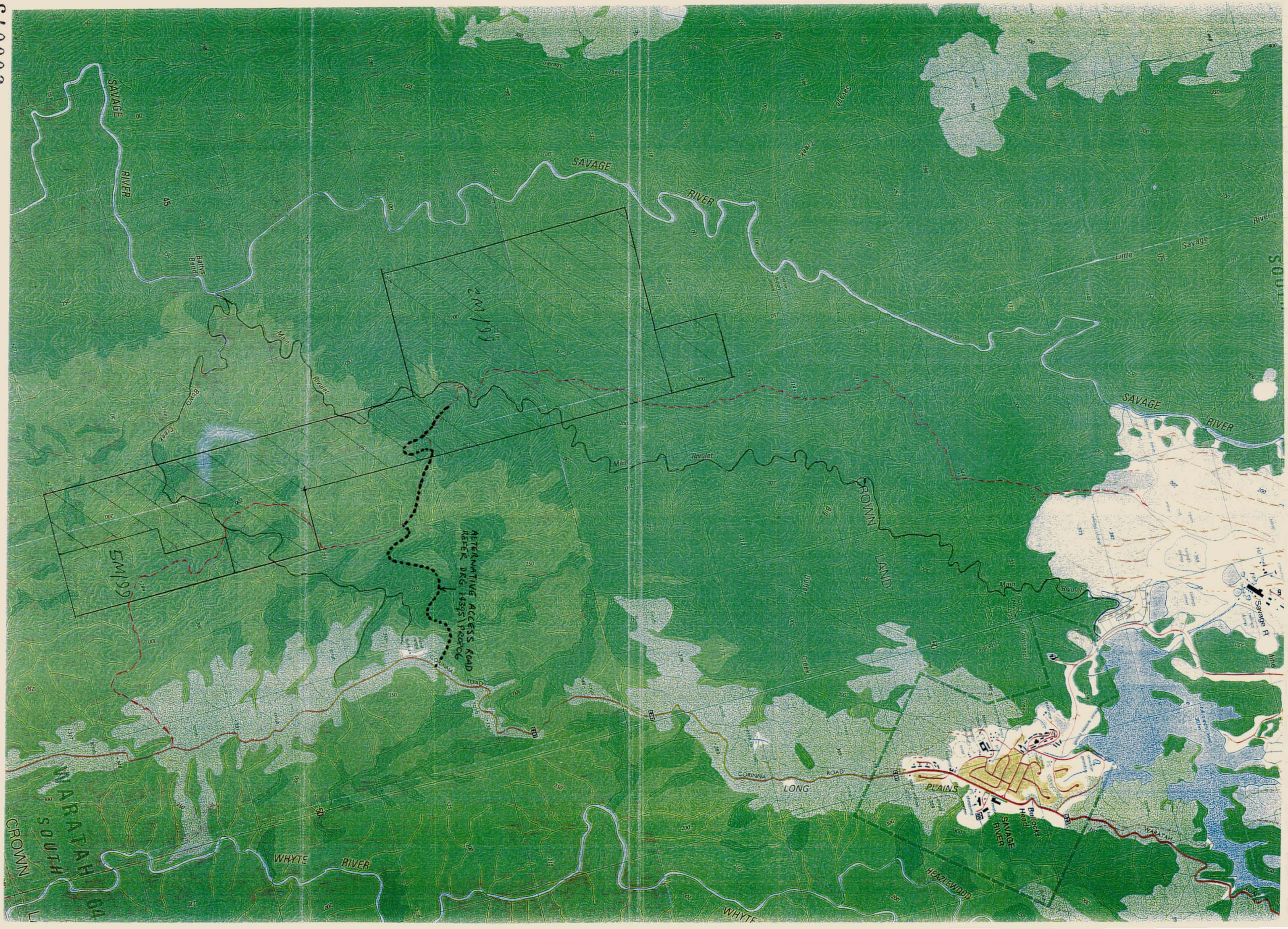
ATTACHMENT 4

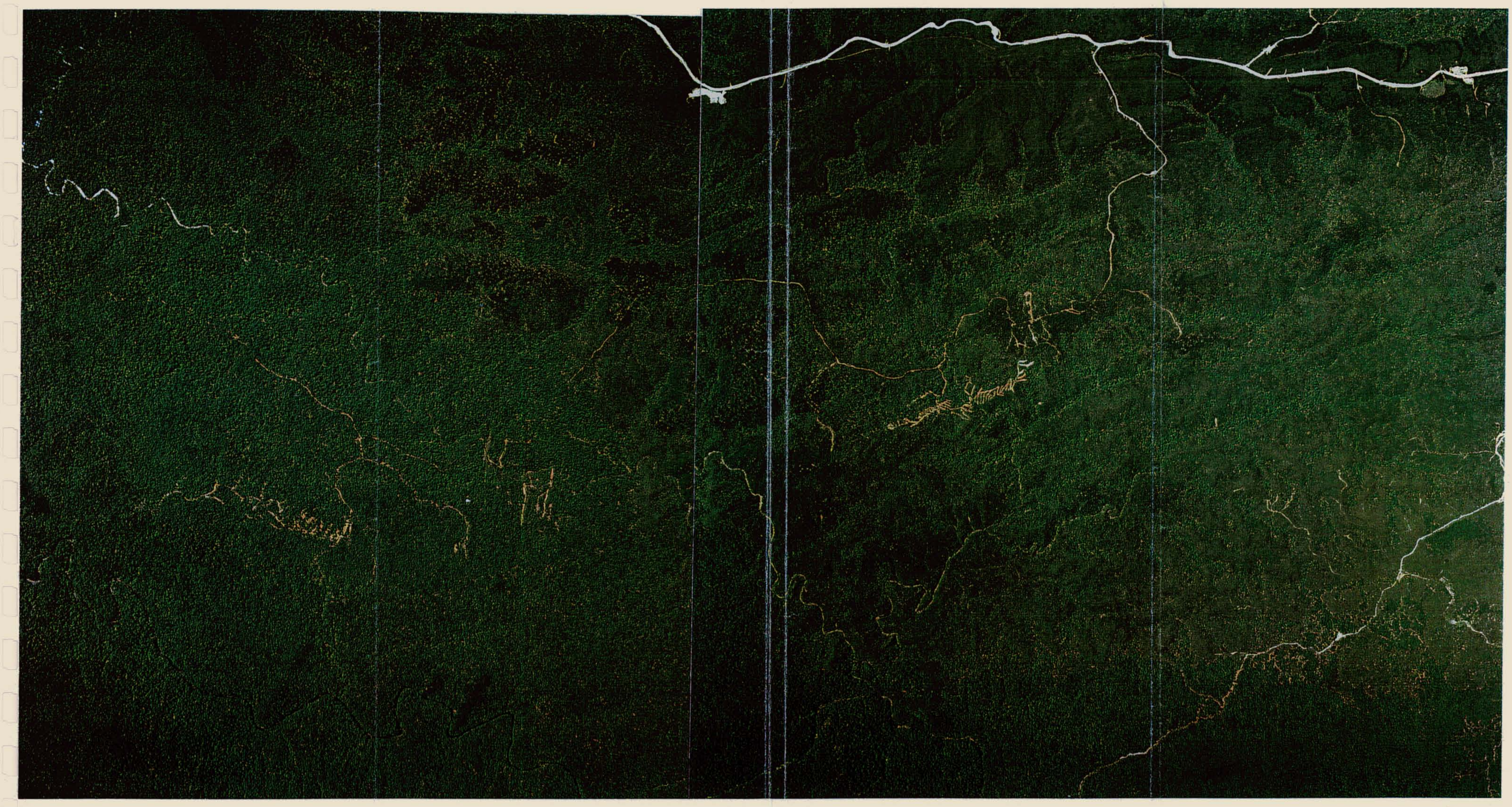
Maps
1:250,000
1:25,000
Aerial Photographs of the Main Creek Site and Long Section of Possible Alternative Road Access to Mine.

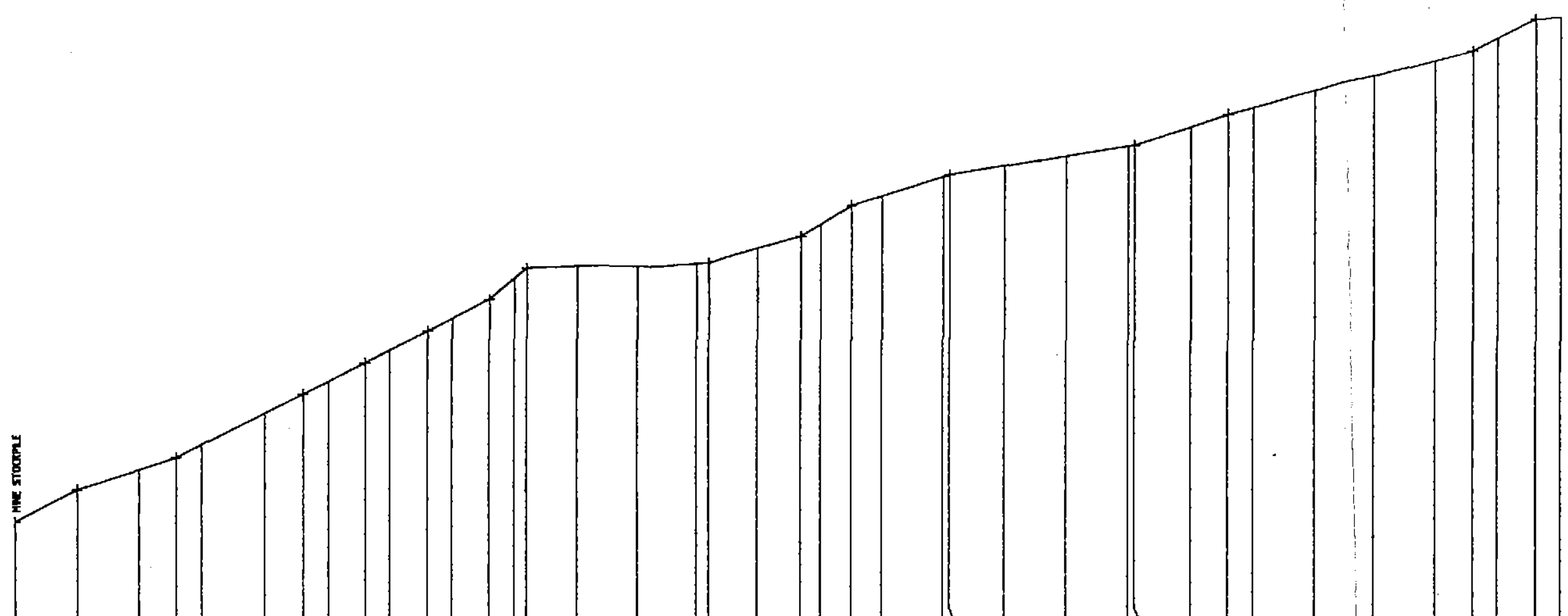
SEMF


500072
5 cm
SCALE 1:500,000
LEASES
SOUTHERN
Arthur Pieman Protected Area
CRADLE MOUNTAIN
LAKE ST CLAIR
NATIONAL PARK
CENTRAL PLATEAU
PROTECTED AREA (CPPA)
BURNIE
DEVONPORT
Wynyard
Somerset
Penguin
Ulverstone
Latrobe
Deloraine
Westbury
Beaconsfield
Beauty Point
Zeehan
Rosebery
Queenstown
Strahan
Waratah
Tullah
Savage River
Luina
Smithton
Stanley
Marrawah
Arthur River
Corinna
Granville Harbour
ASBESTOS RANGE
NATIONAL PARK
ROCKY CAPE
NATIONAL PARK
Hellyer Gorge
State Reserve
Pieman River
State Reserve
Table Cape
WALLS OF JERUSALEM
Sheffield
Railton
Mole Creek

500073


SAVAGE RIVER
SAVAGE RIVER
Little Savage River
SAVAGE RIVER
Main Rivulet
CROWN LAND
EM/99
EM/99
ALTERNATIVE ACCESS ROAD
REFER DRG 1435/5\R0P06
CORINNA ROAD
LONG PLAINS
SAVAGE RIVER
WHYTE RIVER
WHYTE
HEAZLEWOOD
WARATAH
WARATAH 64
SOUTH
CROWN



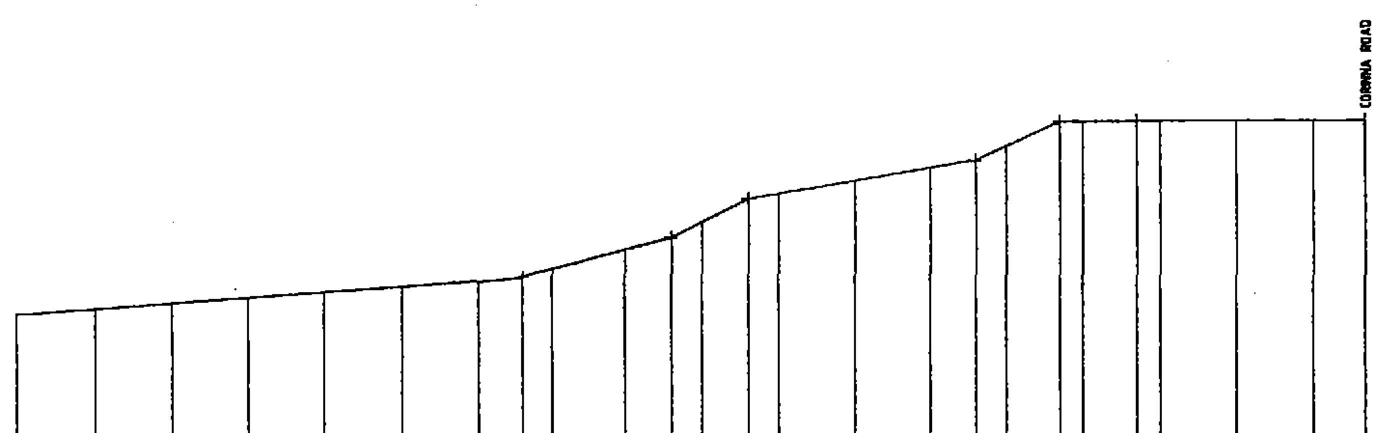


DATUM RL 110

EXISTING NATURAL SURFACE GRADE: 10% | 6.25% | 10% | 10% | 10% | 10% | 16.67% | 1.67% | 5.33% | 12.5% | 6.25% | 3.33% | 6.67% | 5% | 10% | 1.43%

CHAINAGE	EXISTING NATURAL SURFACE LEVEL
0	150
100	160
200	166.25
260	170
300	174
400	184
460	190
500	194
560	200
600	204
660	210
700	214
760	220
800	226.667
820	230
900	230.533
1000	231.2
1110	231.867
1120	232
1200	236.267
1270	241
1300	243.75
1350	250
1400	253.125
1500	259.375
1510	260
1600	263
1700	266.333
1800	269.667
1810	270
1900	276
1960	280
2000	282
2100	287
2200	292
2300	297
2360	301
2400	304
2460	310
2500	310.571

LONGITUDINAL SECTION
HORIZONTAL SCALE 1:5000
VERTICAL SCALE 1:1000



DATUM RL 270

EXISTING NATURAL SURFACE GRADE: 1.43% | 5% | 10% | 3.33% | 9.09% | 0% | 0%

CHAINAGE	EXISTING NATURAL SURFACE LEVEL
2510	311.571
2600	312
2700	313.429
2800	314.857
2900	316.286
3000	317.714
3100	319.143
3160	320
3200	322
3300	327
3360	330
3400	334
3460	340
3510	341.333
3610	344.667
3710	348
3760	350
3800	353.636
3870	360
3900	360
3970	360
4000	360
4100	360
4200	360
4270	360

LONGITUDINAL SECTION (CONTINUED)
HORIZONTAL SCALE 1:5000
VERTICAL SCALE 1:1000

5 cm

REV.	DATE	DESCRIPTION
A	25.10.99	PRELIMINARY ONLY

DRAWING CHECK: DRAWN (DO); DESIGNED (ENG); CHECKED (SUP. ED); APPROVED BY (PM)
CO-ORDINATION CHECK: STRUCTURAL (RE); MECHANICAL (RE); ELECTRICAL (RE); CIVIL/ENV. (RE)

SEMF — SCIENTISTS ENGINEERS MANAGERS & FACILITATORS

BASS RESOURCES NL

MAGNESIUM METAL PROJECT-CONCEPT STUDY
ALTERNATIVE ACCESS ROAD
LONGITUDINAL SECTION ALONG PROPOSED ROUTE

SCALE: AS SHOWN — DIMENSIONS IN MILLIMETRES — A1
CAD FILE NO. & PLOT SCALE: 14395\PROP07 1:5000
DRG. No. 14395\PROP07 REV. A

ATTACHMENT 5

Level II and Level III Assessment Process

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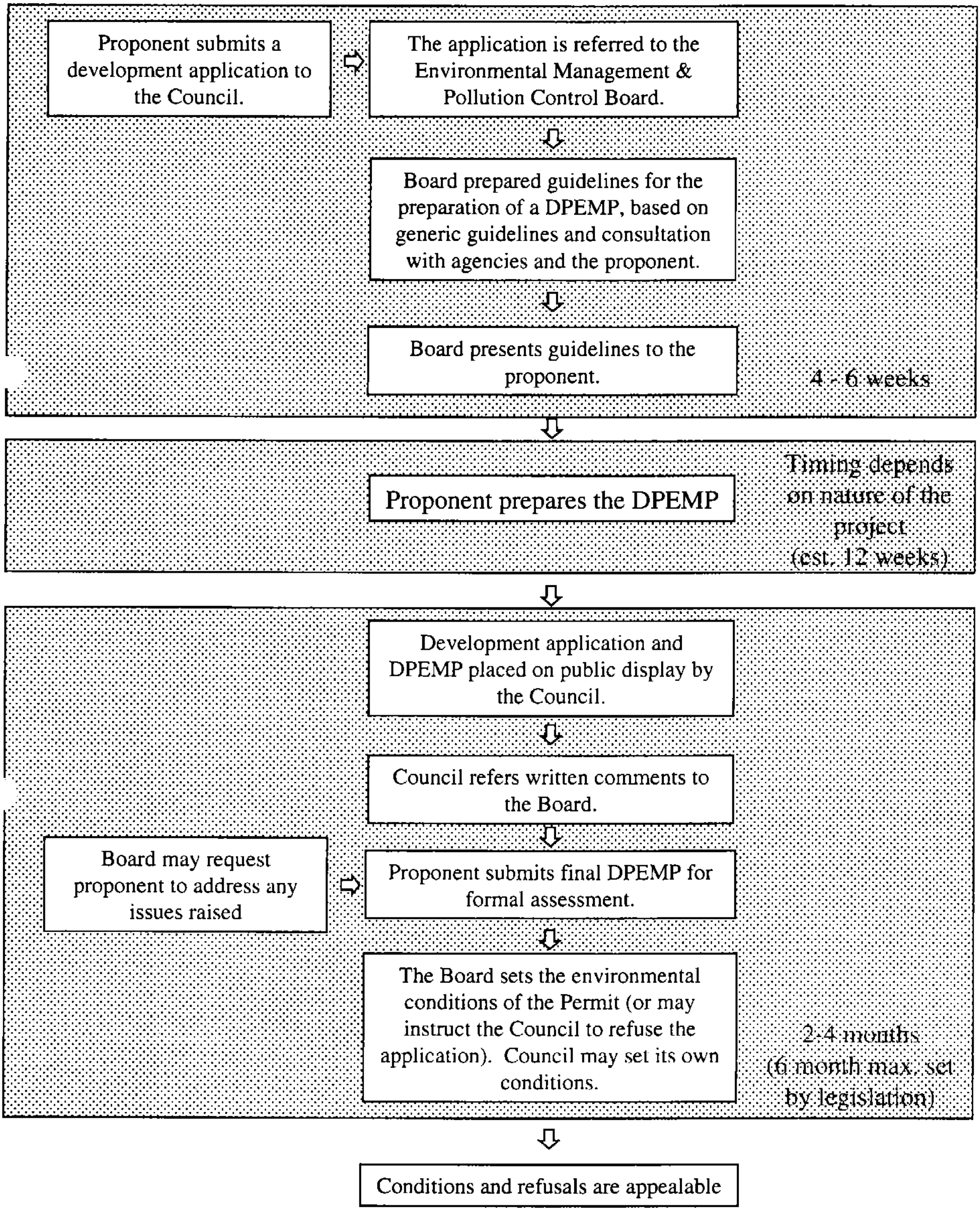
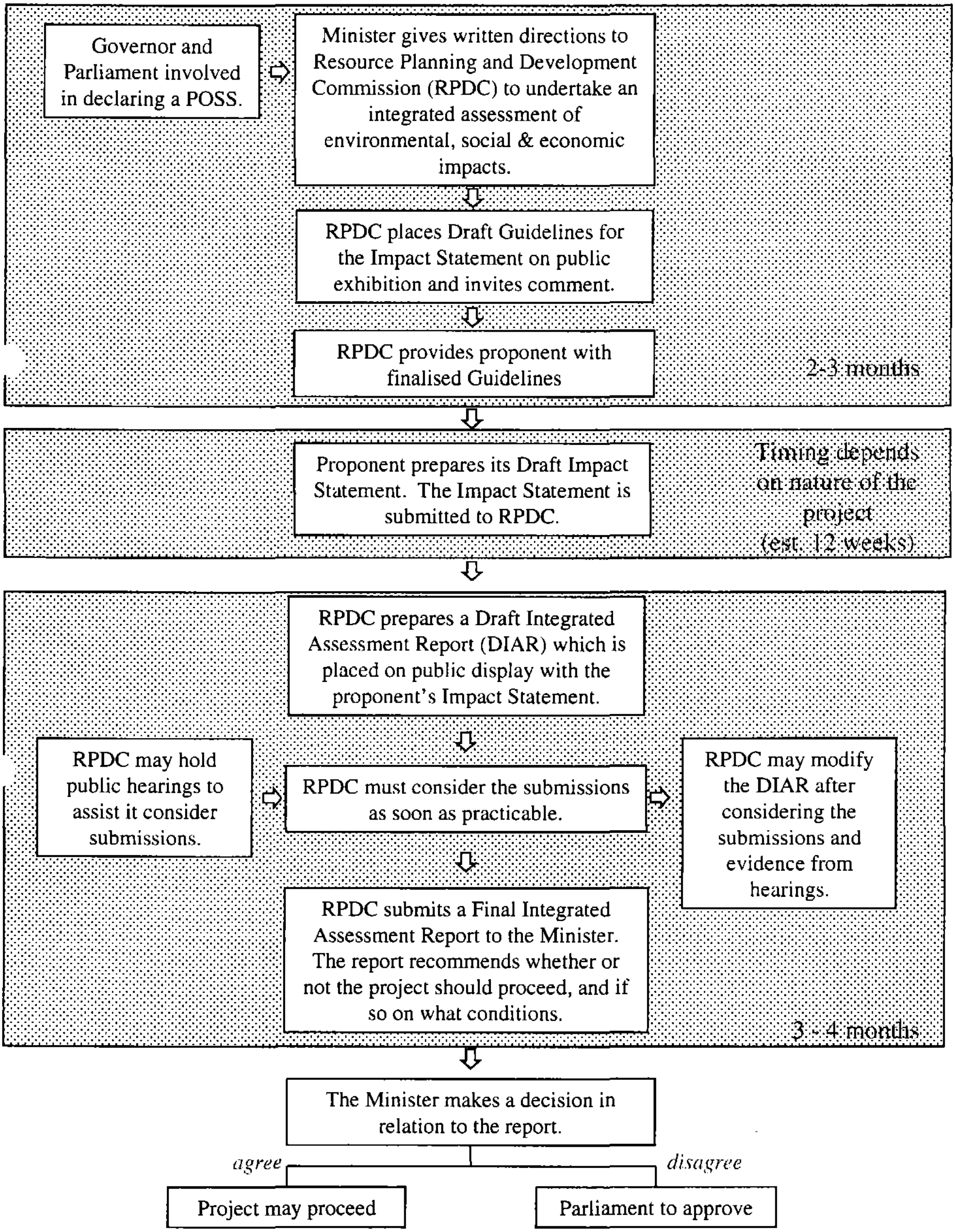
Level II Assessment Process



Integrated Assessment of a Project of State Significance - Level III Assessment



ATTACHMENT 6

Extracts from Register of the National Estate Database

500080

AUSTRALIAN HERITAGE COMMISSION

Register of the National Estate Database

Tarkine Wilderness Area , Savage River TAS

Class: Natural
Legal Status: Interim List

Database Number: 017747
File Number: 6/02/031/0052

Statement of Significance: The Tarkine is one of the most significant wilderness-areas in Australia, containing Australia's largest contiguous area of temperate rainforest. The Tarkine contains important populations of a number of species with strong links to Pangaean, Gondwanan and Antarctic floral and / or faunal assemblages. These species are very significant in understanding the evolution of the Australian flora and fauna. Rainforest and freshwater habitats are the most important for these species. Some taxa in the area have distributions which indicate that they are relicts of an ancient Pangaean fauna that was widespread during the Cretaceous or earlier, before the separation of Gondwana from Laurasia. The best examples are in the crangonyctoid amphipod crustaceans (families Paramelitidae and Neoniphargidae). At least one endemic parastacid engaeus lengana has its major distribution in the area. Another member of the family, the world's largest freshwater crayfish, astacopsis GOULDI, has its most secure population in the area a number of disjunct species, or species at the limit of their range are found in the Tarkine, the most notable being LAGAROSTROBOS FRANKLINII (Huon pine). The Tarkine Region contains a number of earth science features that are regarded as significant in the evolution of the landscape at a State, National or International level. The most notable of these are the Huskisson syncline, the Meredith Range, the coastal benches and platforms, and the magnesite karst system of the Arthur Lineament. The Tarkine is of outstanding significance for the maintenance of ecosystem processes containing a number of catchments and sub- catchments in excellent condition. Examples include the Pedder, Thornton, Wild Wave and Interview rivers on the coast, and the Upper Savage and Upper Rapid Rivers inland. The area contains the largest contiguous area of rainforest in Australia and over 2000 hectares of tall oldgrowth eucalypt forest. The area is vital as a trans-Bassian migratory corridor for many species and as such it maintains feeding, breeding and loafing sites for endemic migratory breeding species, and allows for vagrants and other species to disperse or recolonise Tasmania. Significant examples of these species are: the Swift Parrot (LATHAMUS DISCOLOR), the Orange-bellied Parrot (NEOPHEMA CHRYSOGASTER) and the Eastern Ground Parrot (PEZOPORUS WALLICUS WALLICUS). The successional relationship between moorland and forest communities involving fire is one of the most significant processes occurring in the Tarkine with areas showing both the retreat and advance of climax vegetation. The area has a good example of the successional relationship between grassland and rainforest. The Netherby plains area in the Tarkine is one of the few areas in Tasmania where this relationship is maintained. The Tarkine is important for the maintenance of processes which allow the formation of peat soils. The moorland vegetation of these soils is significantly different from that occurring elsewhere in Tasmania. This region is geologically, floristically and faunistically rich and contains a high diversity of plant communities, with examples of most of the broad vegetation types found in Tasmania, the only major absence being alpine communities. Moorland communities in the region and elsewhere are noted for their floristic richness. In addition "oldgrowth" (long unburnt) moorlands in the Tarkine have been shown to contain a comparatively diverse terrestrial vertebrate fauna. The Tarkine contains the major Tasmanian expression of wilderness, outside of south western Tasmania. It is particularly important as a large rainforest wilderness. The area is the habitat for a number of animal species that are uncommon or threatened. These are the Swift Parrot (LATHAMUS DISCOLOR), the Orange-bellied Parrot (NEOPHEMA CHRYSOGASTER), the Eastern Ground

500081

Parrot (PEZOPORUS WALLICUS WALLICUS), the Hooded Plover (CHARADRIUS RUBRICOLLIS), the Tasmanian Wedge-tailed Eagle (AQUILA AUDAX FLEAYI), the Broad-toothed Rat (MASTACOMYS FUSCUS FUSCUS) and the Giant Freshwater Lobster (astacopsis GOULDI). Two rare buttongrass moorland communities, Sedgy Austral Cord-rush and North Western Dense buttongrass moorland, occur in the area. Several buttongrass moorland communities are the habitat for the rare heath species, EPACRIS CURTISIAE. The Tarkine is the habitat for 24 plant species that are nationally listed as rare or have been recently recommended for listing as rare, and/or are listed in Tasmania. The magnesite karst in the Savage River area is a very rare formation on a global scale. The basalt plateau in the north east of the region and its soils represent the most extensive basalt plateau in Tasmania which still retains a natural vegetation. This is now a rare phenomenon. The whole area is of significance as benchmark because of its remoteness and integrity. One example is the use of a large area of burnt, but otherwise undisturbed, early successional rainforest between the Savage River Rd and the Pieman which is being used to study successional processes in burnt rainforest. Another is that living and buried logs of the conifers LAGAROSTROBOS FRANKLINII (Huon pine) and PHYLLOCLADUS ASPLENIIFOLIUS (Celery-top pine) in the Stanley River area have yielded a dendrochronological sequence of importance in the determination of climate trends. Coastal benches and platforms also provide an important record of sea level during Tertiary and Quaternary times, and the Savage River pipeline road area is an important benchmark forest invertebrate site and the type locality for a number of invertebrate species. The Tarkine is very significant for the large number of representative areas of plant communities present in the region. The area is particularly significant for the representation of rainforest ,wet eucalypt and moorland communities but contains representative examples of sphagnum communities and a grassland community as well. The area is the major stronghold for the wet forest avifauna in Tasmania and as such is important for the representation of this suite of species. The Tarkine is held in high regard for its aesthetic qualities and parts of the area have been assessed as having high and or outstanding landscape quality.

Description : Geology: the known geology of the Tarkine is in many ways a microcosm of Tasmanian geology as a whole, containing as it does features representative of most major stages in the geological development of Tasmania. The oldest rocks in the area are siltstones and quartzites which were deposited on a quiet shallow marine shelf. With the later development of a deep water trough in the eastern half of the area, slaty mudstones and greywacke sandstones were deposited while possibly contemporaneous dolomites and volcanic rocks were deposited in the region of the Arthur Lineament, which may represent both the approximate shoreline at the time and a zone of volcanism. Earth movements then deformed parts of these rock sequences in a narrow "hinge" zone, forming the metamorphic complex of the Arthur Lineament.
The area can be broadly divided into three physiographic regions:
Western Ranges-In this region the topography largely reflects the major structural trends of the underlying folded rocks. The main physiographic anomaly is the massive highland area of the Meredith Range. The geomorphology of the Meredith Range is dominated by a rectilinear pattern of stream courses and ridges whose trends are controlled by major joint fractures. The joint control on physiography is strongly evident at both outcrop and areal scales, and shows consistent trend directions over the whole range. The Meredith Range is an outstanding example of joint-controlled topography on granitic rocks.
North-West Plateau-The effect of underlying fold structures on topography is less evident in this region, although it is recognisable in places. In the western parts this appears to be a result of the relatively monotonous lithologies which have fewer resistant beds to form ridges. In the eastern part the folded rocks are overlain by thick basalt flows. Rolling hilly topographies and steeply dissected plateaux have formed on these rock types.
Western Coastal Platform-An undulating to flat coastal platform topography has formed on uniform sequences of folded Precambrian rocks. The monadnocks of the Norfolk Range are the main physiographic anomaly in this region, although the range may be best regarded as a western extension of the Western Ranges physiographic region. The range provides a major and striking focus in an area of otherwise low relief topography.

Geomorphology: the drainage patterns of the Tarkine have been characterised as a trellised pattern reflecting the structural control of the underlying folded rocks. However, this is only true at a general level. In detail, many rivers and streams in the area are controlled by jointing and faulting structures, or exhibit dendritic or parallel drainage patterns in areas where structural control is less

significant. The first order river channels, particularly the Pieman and Arthur Rivers, are essentially discordant with underlying geological structures, and are superimposed channels which probably originated in non-folded cover rocks which have now been eroded off. Large areas of potential karst substrate (carbonate rocks) exist in the region, but apart from the sinkhole-riddled Black River Dolomite, relatively few karst features, and no decorated caves, are known. Known features include a river arch and gorge, underground stream, sinkholes and sinkhole lakes, karst springs, small undecorated caves and sub-surface (drilled) cavities. Large glaciers occupied the Pieman Valley during at least five Cainozoic glaciations. However, no evidence of glacial ice action has been identified in the highland parts of the area. This may be an artefact of the lack of detailed examination, and not reflect a lack of ice action.
The coastline is broadly linear. A number of coastal benches and platforms are considered to record a history of changing sea levels during Tertiary and Quaternary times. Extensive Quaternary coastal sand dunes constitute a partially stabilised transgressive dune system.

Soils: the soils of the Tarkine, other than the recently deposited calcareous coastal sands, tend to be moderately to strongly leached and acid. The surface layers of the soils are generally high in organic matter. The extensive peat soil blanket bogs of western Tasmania, which are represented in the area are almost without parallel globally. The vegetation occurring on these soils in the area is significantly different from that found in the Tasmanian Wilderness World Heritage Area. In a broad sense, the major inland parts of the area support yellow podsolic soils (mainly with gradational profiles), with strongly leached kraznozems on the extensive Tertiary basalt plateaux. Skeletal soils and moor podsol peats are widespread along the coastal platform west of the Norfolk Range, while groundwater podsols and podsols occur along the narrow coastal strip, on marine and aeolian sands. The kraznozem soils on Tertiary basalt plateaux in the Arthur Lineament region of the area are of particular interest, since they represent the largest area of basalt soils in Tasmania which have not been exploited for agricultural purposes, and which still support undisturbed natural vegetation communities.

Vegetation: the cool wet climate of Tasmania's north-west region is unusual in Australia. The nature of the vegetation of the Tarkine in consequence has as much in common with cool temperate regions of South America and New Zealand as with the rest of Australia. The intricately varying geology, soil, topographic relief and fire frequency have created a rich tapestry of colour, texture, and form in the vegetative landscape. The closed forest (temperate rainforest), open forest (eucalypt forest) and buttongrass moorland occur in a mosaic of Antarctic and Australian elements of the flora. The Antarctic element consists of species descended from the super-continent Gondwana. For example, the cool temperate rainforest communities of the area contain the best representation of these ancient taxa. The more recently evolved plants of the Australian element of the flora dominate the sclerophyll communities of the area. The area contains a number of higher plant species (many endemic to Tasmania) listed as rare or threatened. The area is also correspondingly important for the conservation of lower plant species. Preliminary studies of lichens and bryophytes have already revealed the presence of new endemic taxa. Two hundred and thirty- nine bryophyte species representing 93 mosses and 146 liverworts have been identified in the area. The area contains the largest tract of pristine rainforest in Australia and together with the rainforests of the Tasmanian Wilderness World Heritage Area represents the greatest range in floristic and structural variation of these forests in cooltemperate Australia. The area contains at least 15 of the 34 temperate rainforest communities identified in Tasmania, in addition Five of the seven Huon pine rainforest communities recognised in Tasmania occur in the area. Sixteen of the 65 previously recognised Tasmanian wet eucalypt forest communities, some of which are found mainly in the area occur along with at least one new community not known to occur anywhere else in Tasmania. The area contains 14 of the 25 buttongrass moorland communities identified in Tasmania, some of which are almost entirely confined to the area. Seven of the 51 wetland communities distinguished in Tasmania are found in the area. Two of the 8 Tasmanian sphagnum communities occur in the area, although further work is required on these within the area. At least 5 of the 37 grassland and grassy woodland communities identified in Tasmania have been located in the area. In addition there are communities within the area for which comprehensive surveys have not yet been undertaken or are as yet are incomplete. These include significant areas of coastal vegetation, dry eucalypt forest, and wet and dry scrub communities.
The Tarkine is of major significance for the representation of Callidendrous, Thamnic, Implicate, and intermediate Callidendrous / Thamnic rainforest communities. Eleven out of a possible fourteen communities found in the area are good representative examples.
Eight representative wet eucalypt forest communities have been identified for the area. These are

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dominated by EUCALYPTUS OBLIQUA, E. DELEGATENSIS, E. NITIDA, E. AMYGDALINA and E. BROOKERIANA. Included in these communities is approximately 2000 ha of tall (>41m) forest.
The west coast has a wide range of plant communities peculiar to salt marsh, coastal sand dunes and sea bird breeding colonies. These offer specialised niches for rare and restricted endemic plants. Serpentine, limestone and dolomite substrates are also important habitats for restricted endemic plant species.

Fauna: of the 31 mammal species known to be present, 4 species and 13 of the recognised subspecies are endemic to Tasmania, including the Tasmanian devil (SARCOPHILUS HARRISII), the world's largest extant carnivorous marsupial if the thylacine is extinct. One hundred bird species are present, including 9 of the 11 Tasmanian endemics, plus two migratory bird species that breed only in Tasmania: the endangered Orange- bellied parrot (NEOPHEMA CHRYSOGASTER), one of Australia's rarest birds and the threatened Swift parrot (LATHAMUS DISCOLOR). There are11 reptile species, of which one is endemic.
Eight of Tasmania's eleven amphibian species have been recorded in the area, including Tasmania's three species of froglets, two species of marsh frog and three species of tree frogs. Three of the four species in Tasmania with restricted distributions, are present in the area, including the brown-striped or Peron's marsh frog which is restricted to marshes along the north west coast, and the green and gold tree frog, which is thought to occur only in the eastern half and coastal areas of northern Tasmania. Two endemic species are present in the area: the Brilliant green Tasmanian tree frog (LITORIA burrowsi) and the Tasmanian froglet (ranidella TASMANIENSIS).
There are 13 species of freshwater fish found in the area.
The wet forest invertebrate fauna is diverse and includes many groups of Gondwanan descent. Talitrid amphipods have undergone great adaptive radiation in Tasmanian forests. At least eight species are present in the area, one of the richest centres of diversity in the world. Rotting logs, moss-covered substrates and leaf litter are important microhabitats for many endemic archaic invertebrate groups in the area. Land snails, flatworms, onychophorans, spiders, centipedes, millipedes, collembola and beetles have been found to be well represented in these environments. Bird species recorded in wet forest habitats in the area include all 22 species regarded as common and regular Tasmanian rainforest species, and all 6 species dependent on wet forest: the Grey Goshawk, Brush Bronzewing, Pink Robin, Whites Thrush, Tasmanian Thornbill and Scrubtit. The large tracts of rainforest found in the area are regarded as making the area the most important refuge for wet forest avifauna in Tasmania. The endangered Tasmanian wedge-tailed eagle (AQUILA AUDAX FLEAYI) and the white form of the Grey goshawk (ACCIPITER NOVAEHOLLANDIAE) nest in tall eucalypt and rainforest trees.
Scrub, heath and moorland are widespread and important habitats occupied by animals with many interesting adaptations. Moorland dominated by buttongrass is inhabited by the endangered Orange-bellied parrot (NEOPHEMA CHRYSOGASTER), the threatened endemic subspecies of Swamp ANTECHINUS (ANTECHINUS MINIMUS MINIMUS) and the rare Broad toothed mouse (MASTACOMYS FUSCUS). Freshwater crayfish such as the endemic parastacoides TASMANICUS live in burrows under the buttongrass tussocks despite the highly acidic groundwaters that are produced in such environments.

Aquatic: the high annual rainfall experienced in the area helps form in diverse aquatic habitats in rivers, coastal lagoons, streams, and estuaries. The freshwater crustaceans are of world significance as many groups such as amphipods, isopods and crayfish are relicts of the Gondwanan fauna or remnants from even earlier eras. The Arthur River catchment is the only river system that does not drain into Bass Strait containing the giant Freshwater crayfish (astacopsis GOULDI).

Indigenous values are known to exist in this area. As yet these have not been identified, documented or assessed for national estate significance by the Commission.

Condition and Integrity : Most of the Tarkine is in very good condition as is attested to by its wilderness values. Limited areas have been subjected to intensive forestry operations, small scale mining and mineral exploration and cattle grazing on the coastal strip. Off road vehicle use is increasing, particularly in the coastal zone. (Condition statement written 1994.)

Location : About 350,000ha, around Savage River township, comprising the area bounded by a line commencing at Low Water Mark at the most south- western corner of Pieman River State Reserve (approximate AMG point (Zone 55G): CP269834), then directly to LWM on the most southerly point of Pieman Head (268849), then northerly via LWM to the mouth of Possum Creek (CQ081289), then upstream via the middle thread of that creek to the Balfour Track (093288), then easterly via the southern side of that track to AMG easting: 321400mE (214290), then directly to AMG point: 244279, then directly to 250285,then directly to the middle thread of the Frankland River at AMG easting: 325400mE (approximate AMG point: 254310), then downstream via that middle thread to the Arthur River, then upstream via the middle thread of the Arthur River to easting: 323600mE (236460), then directly to the middle thread of the Blackwater Rivulet at AMG northing: 5444400mN (252444), then upstream via the middle thread of that rivulet and a tributary to northing: 5439800mN and approximate easting: 326000mE, then via straight lines joining the latter point and following AMG points consecutively: 270406, 272428, 292452 and 304457, then directly to Sumac River Road at the southern end of the Kanunnah Bridge, then easterly via the southern side of that road to a creek at AMG northing: 5442100mN (345421), then upstream via the middle thread of that creek to AMG northing: 5440600mN (359406), then directly to the middle thread of the Sumac Rivulet at northing: 5439900mN (373399), then upstream via the middle thread of that creek to northing: 5437000mN (347370), then directly to AMG point: 352361, then directly to Sumac Road at easting: 335900mE (359365), then easterly via the southern side of that road to Mount Bertha Road, then easterly via the southern side of that road to easting: 341900mE (419382), then directly to AMG point: 418352, then directly to the middle thread of a creek at easting: 339500mE and approximate northing: 5433900mN, then downstream via the middle thread of that creek to Trias Creek, then up stream via the middle thread of that creek to northing: 5428400mN (415284), then directly to the middle thread of the Horton River at northing: 5427500mN (369275), then downstream via the middle thread of that river to easting: 332400mE (324316), then directly to the confluence of the Leigh and Lindsay Rivers, then upstream via the middle thread of the Lindsay River to easting: 5426700mN (303267), then directly to the Leigh River at easting: 332300mE (323277), then upstream via the middle thread of that river and a tributary to easting: 340000mE (400195), then directly to the middle thread of the Boulder Rivulet at its confluence with the Horton River, then upstream via the middle thread of Boulder Rivulet to easting: 344000mE (440205), then via straight lines joining the latter point and following AMG points consecutively: 447237,433279, 437322, 448363, 466376, 470386, 484390, 498382, 518388, 532382, 566387 and 578383, then directly to the iron ore pipeline at northing: 5439800mN (580398), then northerly via the eastern side of that pipeline to northing: 5442100mN (574421), then directly to Neasey Creek (or a tributary thereof) at easting: 5457600mE (576437), then down stream via the middle thread of that creek to the Arthur River, then easterly via the middle thread of that river to a creek at about AMG point: 687405, then upstream via the middle thread of that creek to Farquhars Road, then directly to AMG point: 696387, then directly to the Arthur River at easting: 370600mE (706395), then upstream via the middle thread of that river to Halfway Creek, then upstream via the middle thread of that creek to northing: 5433900mN (727339), then directly to a creek at easting: 372800mE and approximate northing: 5433600mN, then downstream via the middle thread of that creek to the Arthur River, then upstream via the middle thread of that river to a creek at about AMG point: 750309, then upstream via the middle thread of that creek to easting: 374000mE (740303), then directly to another creek at northing: 5430100mN and approximate easting: 373800mE, then downstream via the middle thread of that creek to the Arthur River, then upstream via the middle thread of that river to Horizontal Creek, then upstream via the middle thread of that creek to easting: 373600mE (736174), then directly to another creek at easting: 373500mE and approximate northing: 5416500mN, then downstream via the middle thread of that creek to the Arthur River, then upstream via the middle thread of that river and Magnet Creek to northing: 5410500mN (703105), then via straight lines joining the latter point and following AMG points consecutively: 686085, 664087, 644084, 659106 and 654110, then directly to a track at easting: 364400mE (644104), then westerly via the northern side of that track to Mount Cleveland Road, then southerly via the western side of that road to northing: 5407800mN, then via straight lines joining the latter point and following AMG points consecutively: 587078, 544081, 536065, 519069 and 510091, then directly to Broderick Creek at northing: 5407800mN (498078), then downstream via the middle thread of that creek and the Savage River to northing: 5403600mN (477036), then via straight lines joining the latter point and following AMG points consecutively: 504026, 510017, 534042, 544062, 562072, 577072, 598064, 635076, 633065,

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645061, 645055, 637054, 640044, 650045, 656051, 660071, 695071, 694064, 703066, 722055, 740057, 747050, 781065, 789081, 817086, 820077, 812062 and 819046, then directly to a stream at northing: 5404400mN and approximate easting: 381400mE, then downstream via the middle thread of that stream, the Hatfield River and the Huskisson River to northing: 5383400mN (CP701834), then directly to a stream at northing: 5381900mN and approximate easting: 371800mE, then downstream via the middle thread of that stream to the Huskisson River, then upstream via the middle thread of that river to northing: 5378100mN (704781), then directly to AMG point: 691781, then directly to the Pieman Road at easting: 367400mE (674792), then westerly via the southern side of that road to easting: 364800mE, then via straight lines joining the latter point and following AMG points consecutively: 600802, 570760, 508777, 505787, 494782, 483793 and 472782, then directly to the Pieman River State Reserve eastern boundary at its most southerly corner point, then via the southern and western boundaries of the reserve to a track at about AMG point: 443793, then westerly via the northern side of that track and Wilson Road to the western boundary of land parcel 33-1327, then northerly and westerly via the boundaries of parcels: 1327, 1323, 1322, 1324, 1325, 1326, 1328 and 1329, so that they are all excluded, to Top Farm Track (about AMG point: 337783), then southerly via the western side of that track to an intersection at about AMG point: 335776, then dir ectly to AMG point: 324777, then directly to a track as it crosses Newdegate Creek (32057865), then northerly via the eastern side of that track, taking the most easterly of any alternative tracks, to the southern boundary of land parcel: 331398, then westerly via that boundary to the eastern boundary of Pieman River State Reserve, then southerly via that boundary to the commencement point.

Report produced : 4/10/1999
RNEDB URL : http://www.environment.gov.au/heritage/register/database.html

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AUSTRALIAN HERITAGE COMMISSION

Register of the National Estate Database

Four Mile Creek Wildlife Sanctuary , George Town TAS

Class: Natural
Legal Status: Registered

Database Number: 012610
File Number: 6/03/053/0005

Statement of Significance: Four Mile Creek is an area adjacent to the Tamar River, and provides a refuge for wildlife dependent upon the river. It is a wildlife sanctuary, and is an example of the original vegetation lining the Tamar River.

Description : The Four Mile Creek Wildlife Sanctuary lies adjacent to the Tamar River in the vicinity of Long Beach. The topography of the reserve rises fairly steeply from the Tamar River for the first hundred metres generally, then flattens to a plateau for the rest of the sanctuary area to the east.
The reserve includes areas of industrial development: Bell Bay coal- fired power station, and two woodchip mills are situated within the wildlife sanctuary. The ecology of the big bay area in the north of the reserve has been studied (Ritz et al, 1980) and serves as a guide to the ecology of the remaining area of the reserve which is of similar associations but exists in much poorer condition.
The following vegetation associations are described in the study: the environment of areas such as headlands is characterised by exposure and good drainage resulting in an overall dryness that has made it particularly susceptible to intense fires. This is reflected in its floristics, which contain large numbers of the fire seres CASUARINA STRICTA and PTERIDIUM ESCULENTUM. The foreshore community is a low exposed grassy verge at the shoreline, with GAHNIA FILUM and DISTICHLIS disticophylla occuring in densley packed clumps. inland, small specimens of ACACIA DEALBATA and E. VIMINALIS occur as dominants with a dry understorey of P. ESCULENTUM forming most of the ground-cover. In sites such as protected gully areas, a thick wet sclerophyll association forms. Low in the gully MELALEUCA ERICIFOLIA, POMADERRIS APETALA and PROSTANTHERA LASIANTHOS were the major species. The valley slopes support smaller shrubs such as CORREA LAWRENCII, ACACIA MYRTIFOLIA, CYATHODES sp. and the monocotyledons GAHNIA RADULA and DIANELLA REVOLUTA. The predominant association of the area is characteristic coastal dry sclerophyl. An open canopy with low understorey is typical. The canopy is formed by E. AMYGDALINA and E. VIMINALIS and occasionally by larger individuals of A. DEALBATA. Occasionally large shrubs occur such as ACACIA RICEANA and C. STRICTA, PULTENAEA DAPHNOIDES and A. DEALBATA. Forming most of the ground cover are the smaller shrubs PIMELEA HUMILIS, COPROSMA QUADRIFIDA, EPACRIS IMPRESSA, the monocotyledons GAHNIA RADULA, POA POIFORMIS and the bracken fern P. ESCULENTUM. The density of the understorey varies with fire incidence. Mudflats are extensive in the intertidal zone. Apart from a few isolated specimens of algae, ZOSTERA MUELLERI (Short) appears to the only plant in this zone. Predominantly, however, the intertidal zone is bare mudflats, and less commonly rocky.

Condition and Integrity : Four Mile Creek wildlife sanctuary includes areas of intensive industrial development. Bell Bay power station is located at the northern edge of the reserve, and two woodchip mills are situated within the reserve. The area has a high fire frequency, and vegetation near the woodchip mills has been recently burned. The primary importance of the sanctuary appears to be for its landscape value.

Location : About 607ha, 4km south-east of George Town, adjacent to the east bank of the Tamar river, generally west of east Tamar Highway and extending from Bell Bay to Fourteen Mile Creek.

The Register of the National Estate has been compiled since 1976. The Commission is in the process of developing and/or upgrading official statements of significance for places listed prior to 1991.

Report produced : 20/10/1999
RNEDB URL : http://www.environment.gov.au/heritage/register/easydatabase/database.html

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ATTACHMENT 7

Figures and References - Regional Geology Section Of Study

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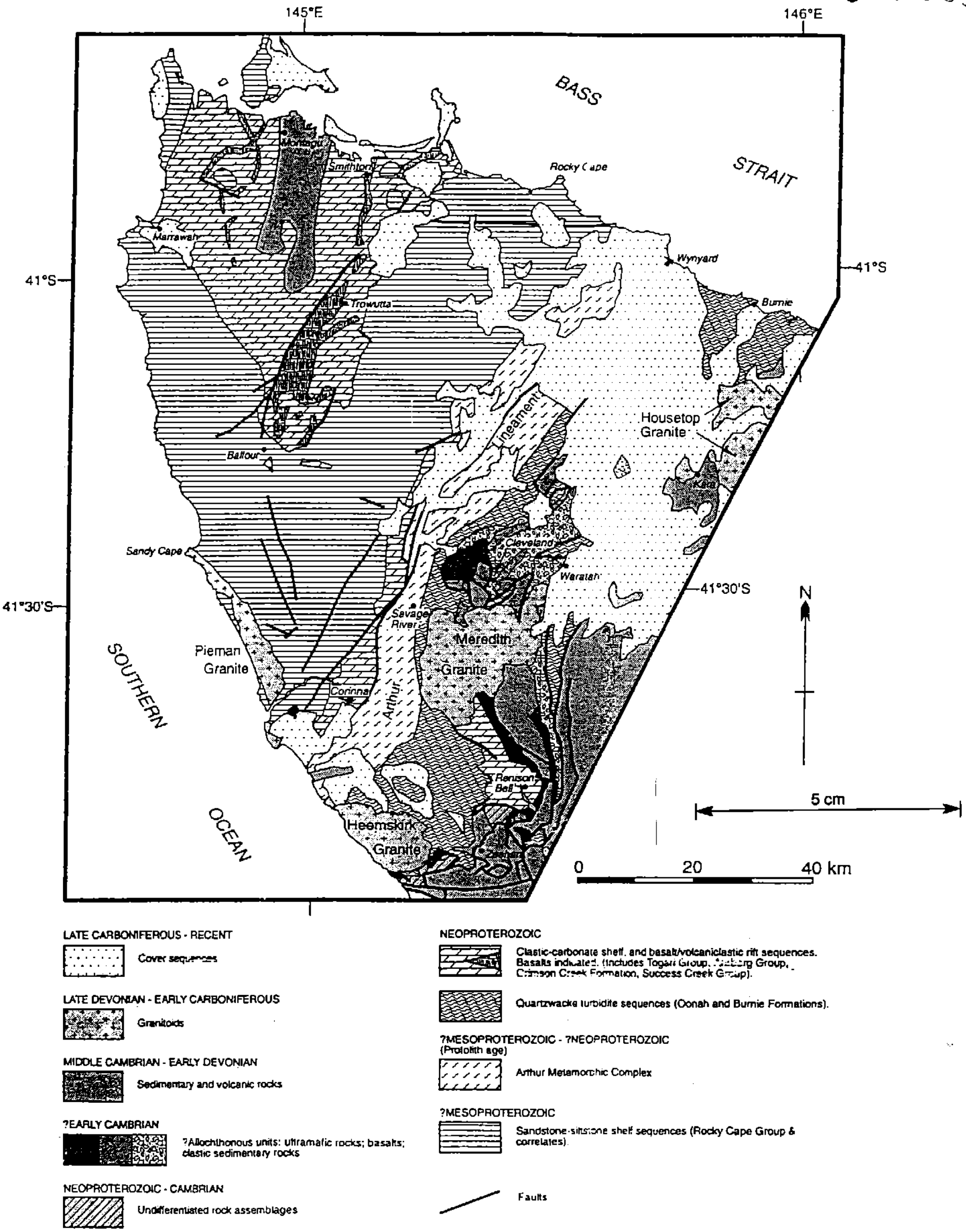

Figure 1. Summary geological map of northwestern Tasmania showing main Proterozoic rock units (after Bottrill et al, 1998).

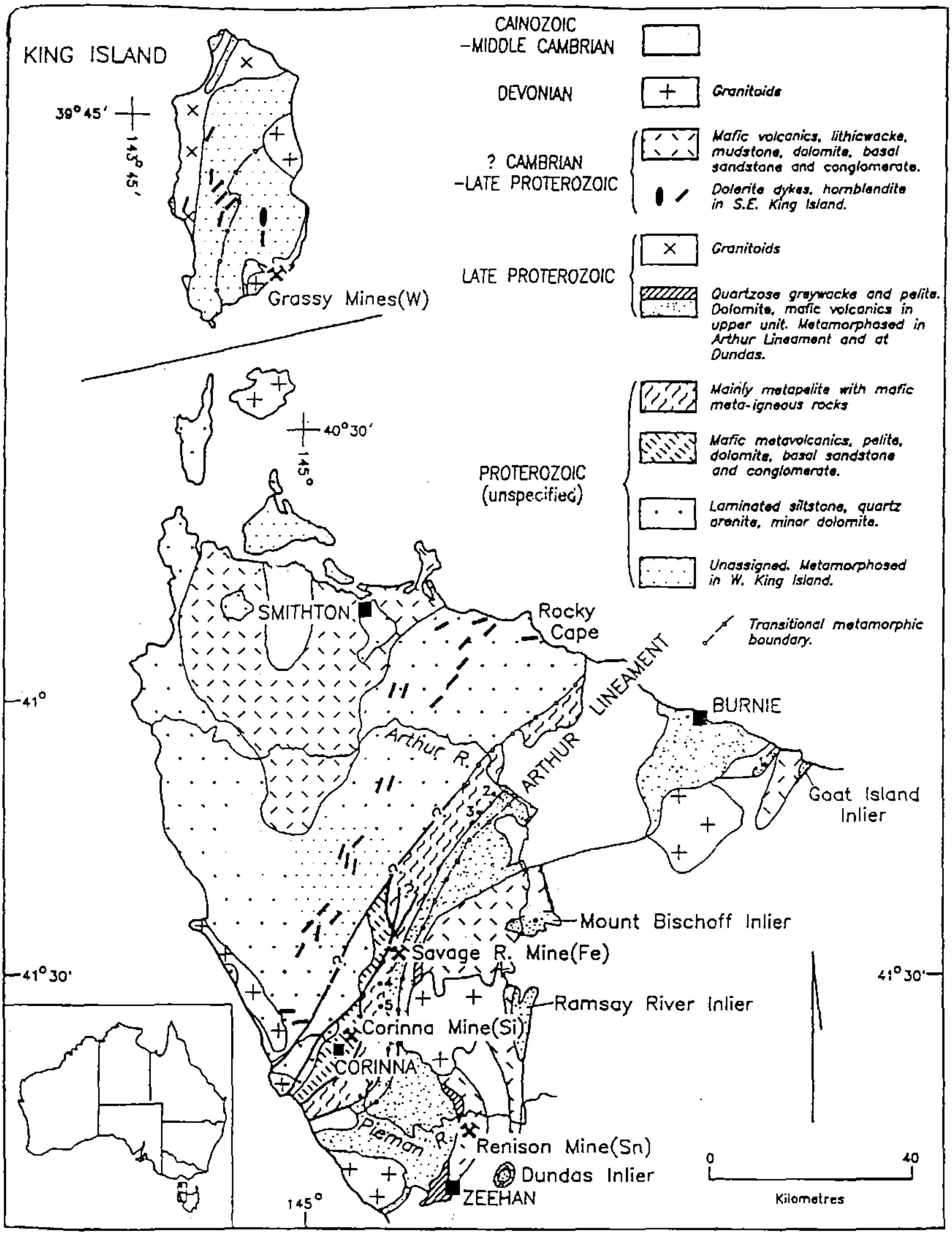

Figure 2. Proterozoic-?Cambrian geological map of the Rock Cape region, nearby inliers and King Island. Mine areas are shown by mine symbols. Other deposits include magnesite-pyrite-chalcopyrite at Keith River-Arthur River (S from 2). Long Plains South (5). Also magnesite at Keith River-Arthur River, Lyons River (3), Savage River mine and Main Creek (4, after Turner 1990).

5 cm

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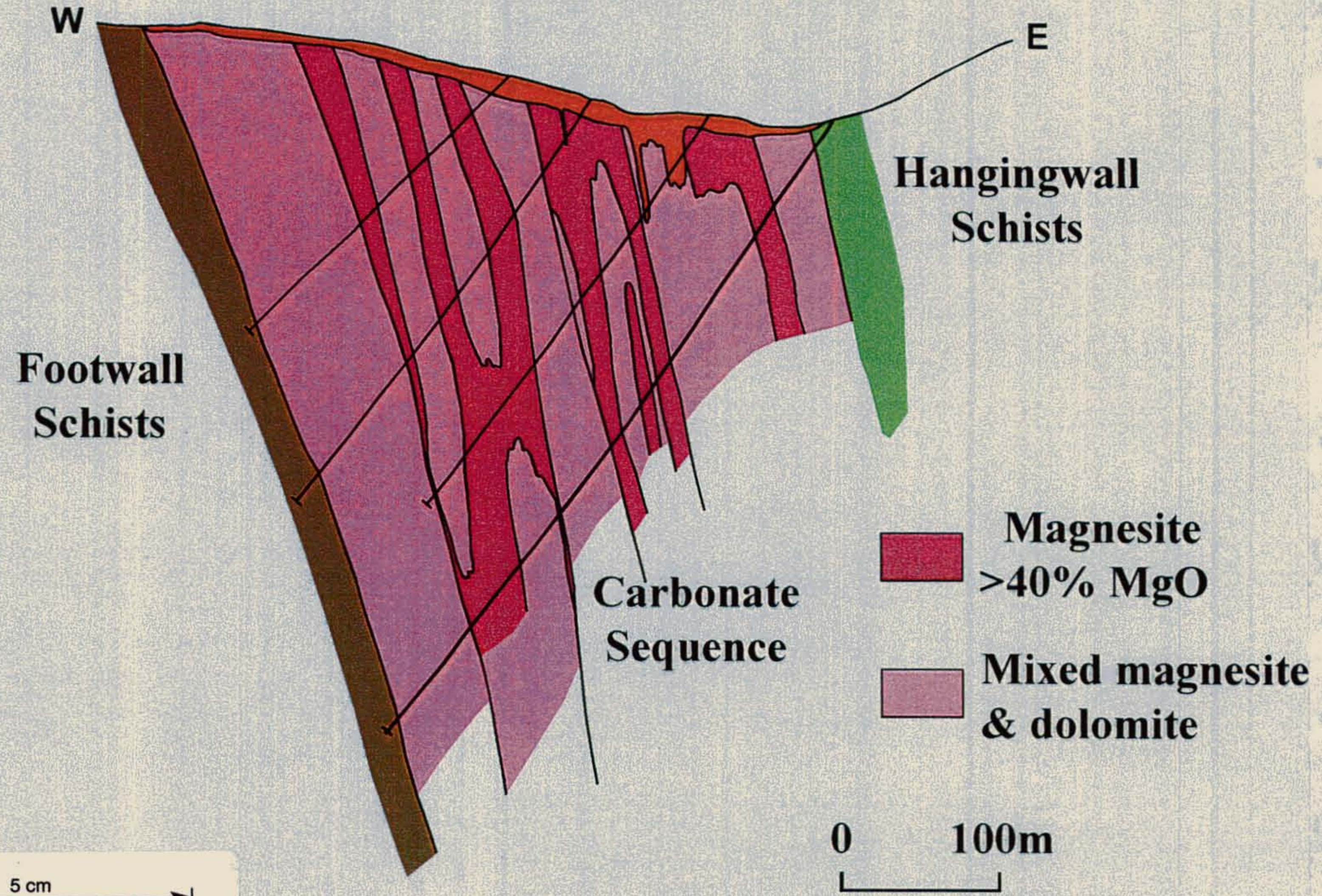
ATTACHMENT 8

Main Creek Cross Section

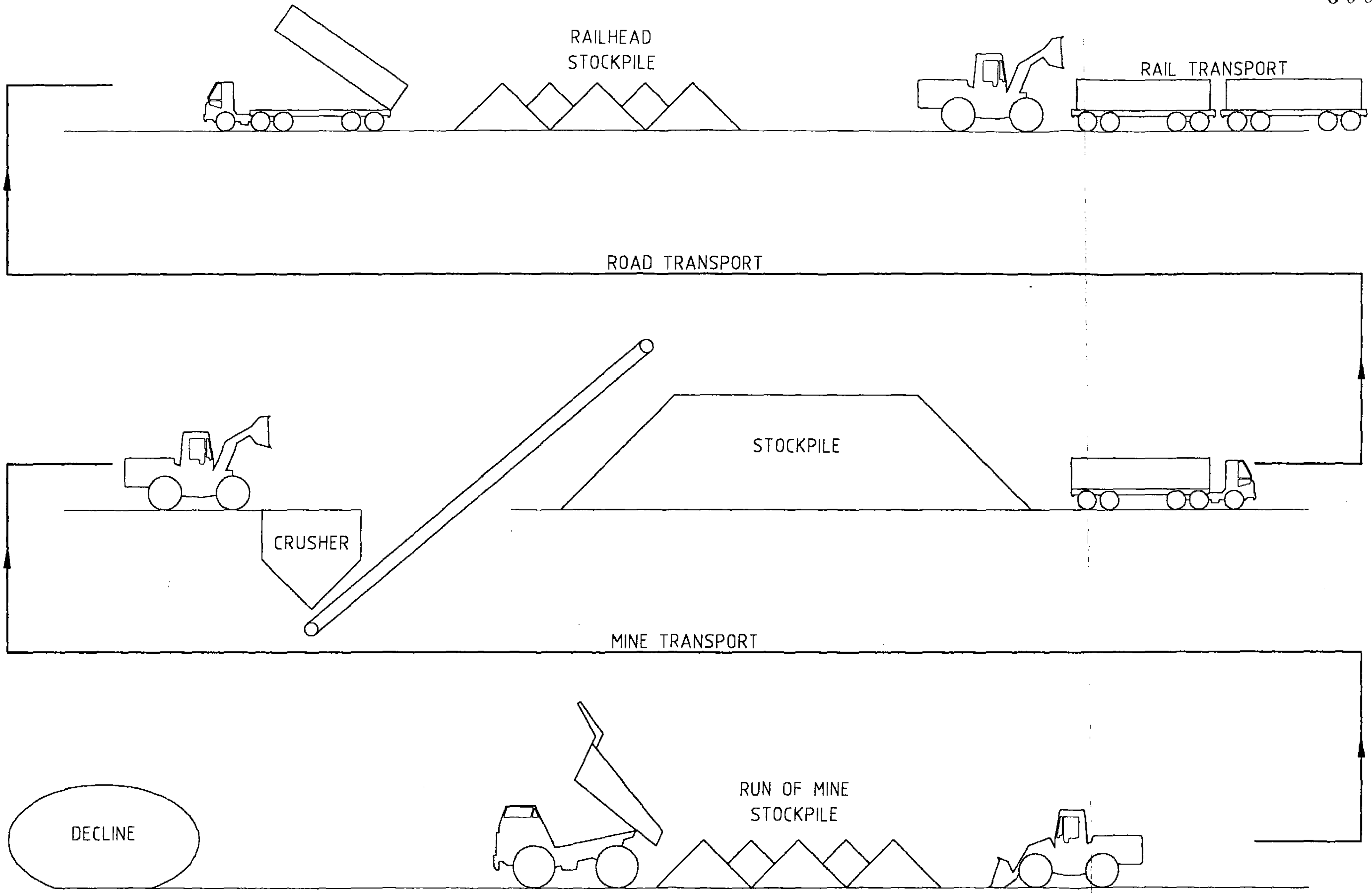
SEMF

Main Creek Cross Section



ATTACHMENT 9

Concept Flowsheet and Layout of Mine Surface Works



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DESIGNED (ENG.):			MECHANICAL (RE)		
CHECKED (SUP. DO):			ELECTRICAL (RE)		
APPROVED BY (PM):			CIVIL/ENV. (RE)		

SEMF SCIENTISTS ENGINEERS MANAGERS & FACILITATORS

BASS RESOURCES NL

MAGNESIUM METAL PROJECT-CONCEPT STUDY
PROPOSED TRANSPORT SYSTEM

SCALE: N.T.S.	DIMENSIONS IN MILLIMETRES
CAD FILE NO. & PLOT SCALE	14395\PROP04.....1:1
DRG. No. 14395\PROP04	REV. a

A3

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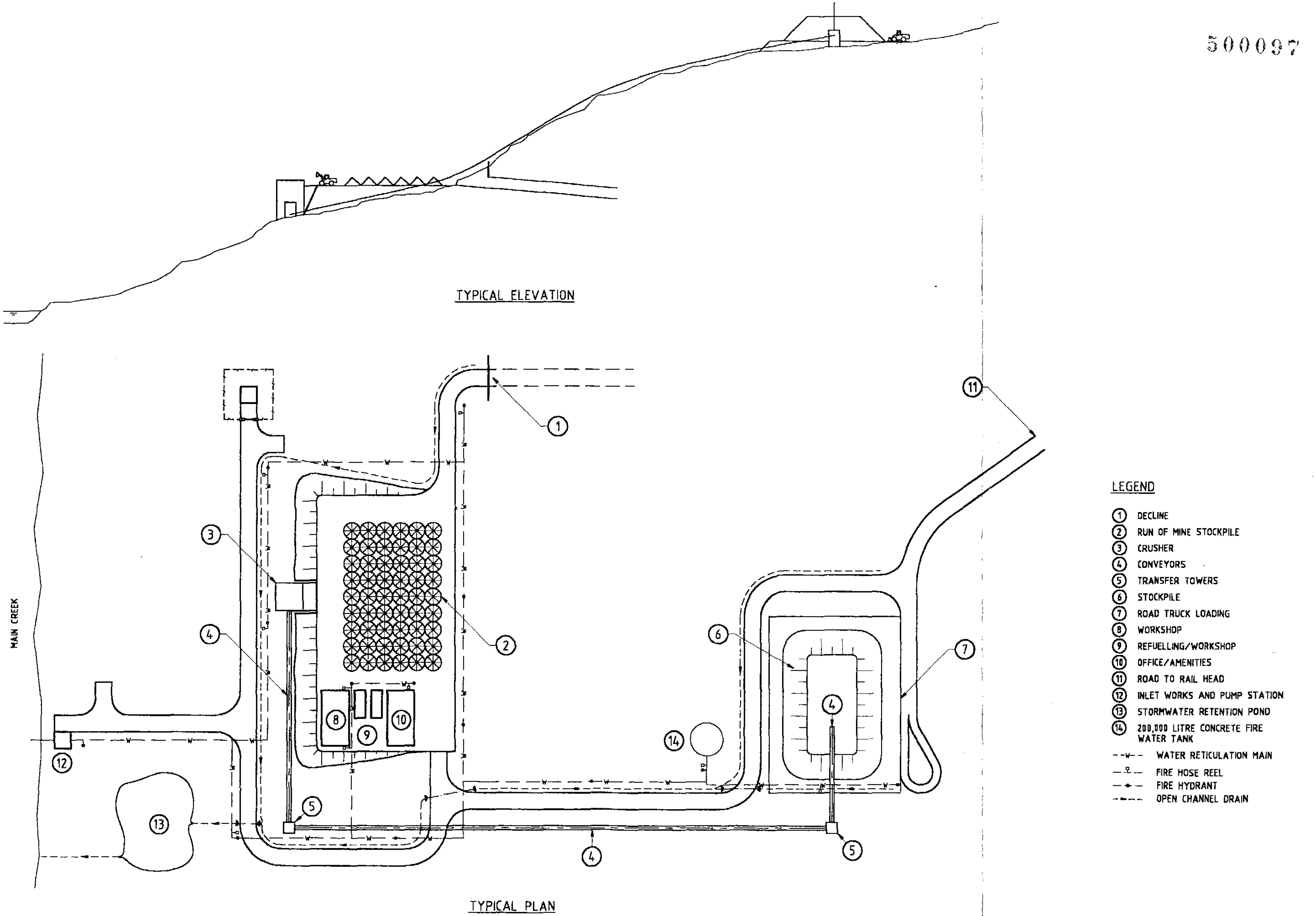

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DESIGNED (ENG.):			MECHANICAL (RE)		
CHECKED (SUP. DO):			ELECTRICAL (RE)		
APPROVED BY (PM):			CIVIL/ENV. (RE)		

SEMF SCIENTISTS ENGINEERS MANAGERS & FACILITATORS

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MAGNESIUM METAL PROJECT-CONCEPT STUDY

TYPICAL MINE SITE ARRANGEMENT

A1

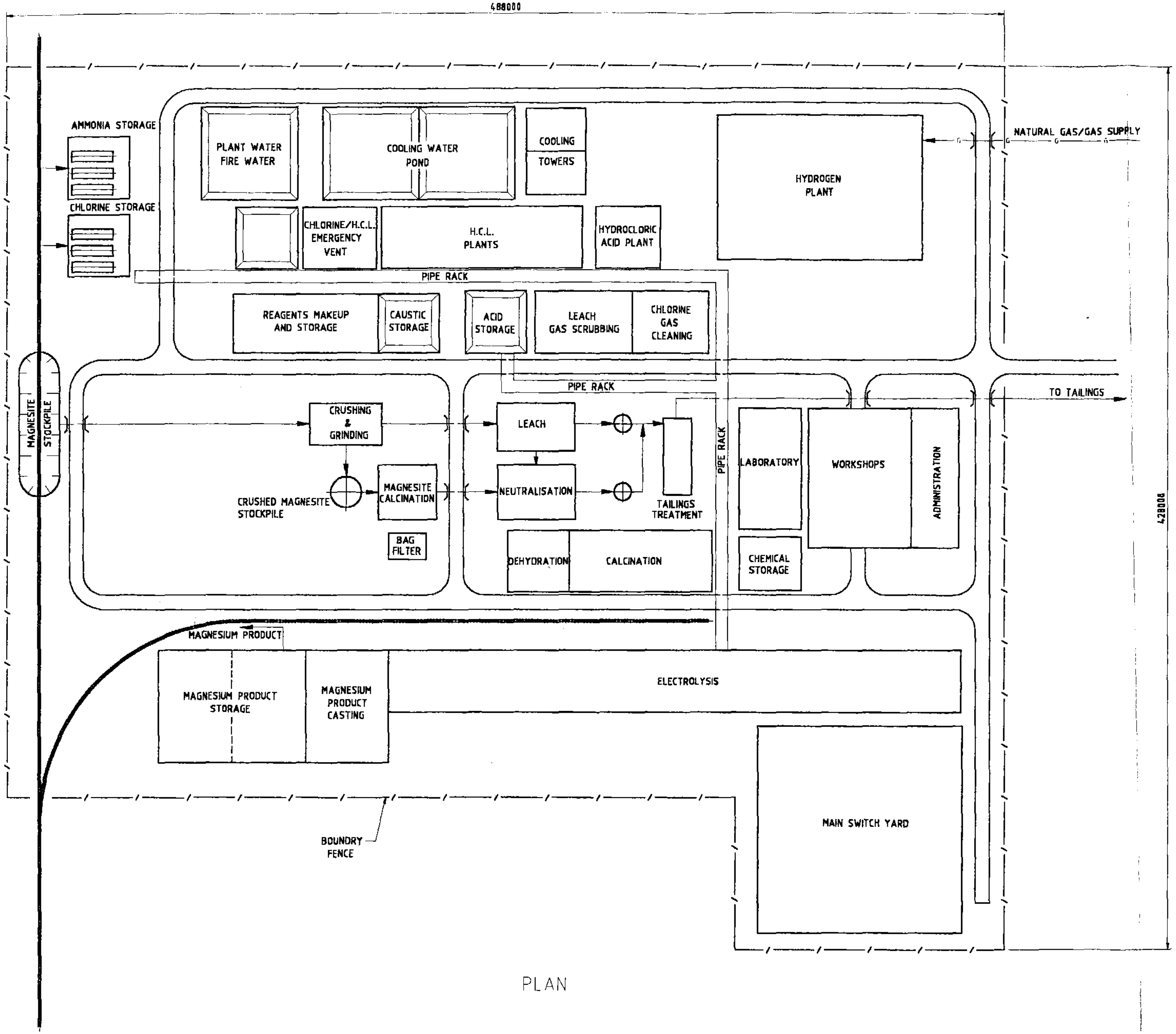
SCALE: N.T.S.

CAD FILE NO. & PLOT SCALE: 14395\PROP05

DRG. No. 14395\PROP05 REV. A

ATTACHMENT 10

Concept Layout – Refinery



PLAN

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REV.	DATE	DESCRIPTION	TM
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A	13/10	ISSUED FOR CLIENT REVIEW	A.W.

DRAWING CHECK	SIGNATURE	DATE
DRAWN (DD):	A. W.	13/10/99
DESIGNED (ENG.):		
CHECKED (SUP. DD):		
APPROVED BY (PM):		

CO-ORDINATION CHECK	SIGNATURE	DATE
STRUCTURAL (RE)		
MECHANICAL (RE)		
ELECTRICAL (RE)		
CIVIL/ENV. (RE)		

SEMF
SCIENTISTS ENGINEERS MANAGERS & FACILITATORS

BASS RESOURCES NL

MAGNESIUM METAL PROJECT-CONCEPT STUDY

GENERAL PLANT LAYOUT

A1

SCALE 1:1000 | DIMENSIONS IN MILLIMETRES

CAD FILE NO. & PLOT SCALE: Eba916-08-PROP06.....1:1

DRG. No. 14395\PROP06 REV. B

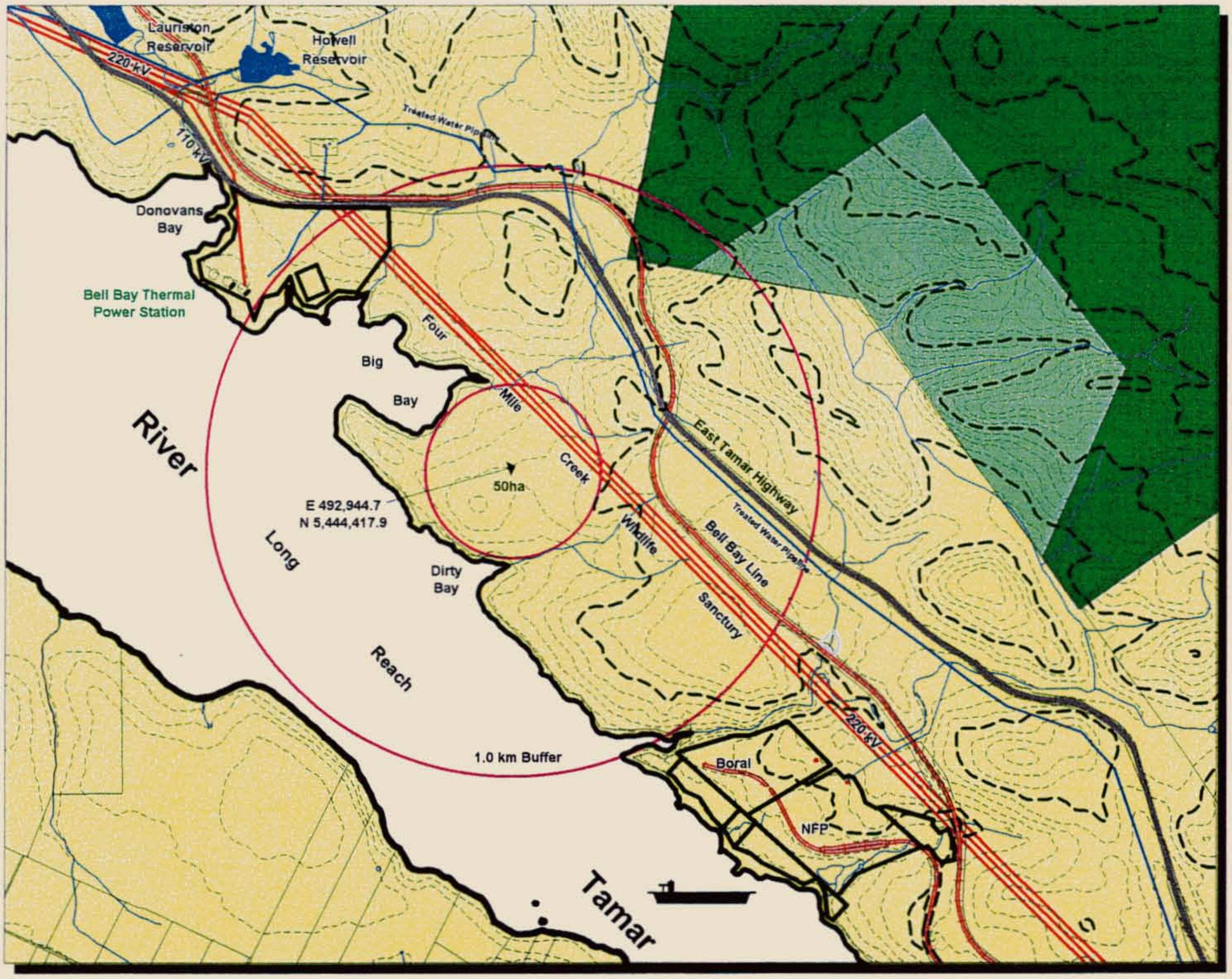
ATTACHMENT 11

Extracts from SKM Preliminary Site Study

SEMF

Table 5.5: Description of Site 5 - Big Bay

SITE FEATURE	DESCRIPTION
Location	
Approximate Co-ordinates	E492,945; N5,444,418
Distance from Urban Centre	Approximately 9km south-east of George Town.
Land Tenure	Private. Land owned by Comalco.
Distance to Nearest Sensitive Receptor	1.1 km to properties on Wilmores Bluff on the west side of the Tamar River.
Planning Details	
Municipality	George Town Council.
Planning Instrument	George Town Planning Scheme 1991.
Zoning	Bell Bay Major Industrial.
Use Status	Permitted (Heavy and Noxious Industry).
Topography	Approximately AHD 30m. On a raised site, falling approximately 20m in all directions. River frontage around half the site. Adjacent to Four Mile Creek Wildlife Sanctuary. Medium density forest.
Climate	Mild with a mean annual rainfall of around 900mm.
Geotechnical Features	Site underlain by Jurassic dolerite.
Proximity to Mine	Approximately 192km from the mine via the Murchison Hwy, Bass Hwy, Frankford Main Road, Batman Bridge and the East Tamar Hwy.
Proximity to Rail	Bell Bay rail line runs approximately 400m east of the site.
Proximity to Road	East Tamar Hwy runs approximately 400m east of the site.
Ease of Gas Supply	Gas could come to shore at the Bell Bay thermal power station about 800m north of the site.
Water Supply	There is currently 1200 ML/yr of untreated water available via a 900mm pipeline from Curries River Dam. There is also approximately 1900 ML/yr available of treated water via a 375mm pipeline from Chimney Saddle and Distillery Creek treatment plants. Supply to the plant would be met by managing the supply from both sources. New infrastructure would comprise a reservoir and pumping station adjacent to the site for treated water and a 4km long rising main from Bridport Road to supply untreated water. Esk RWA controls the water supply in this region. To supply future demand, a pumping station at Pipers River and rising main to Curries River Dam would be required. This scheme has been proposed for over 20 years.
Proximity to Port	A wharf exists at the power station. Several berths also exist at Bell Bay, approximately 4 km north of the site. Bell Bay has adequate facilities for the handling and export of 95,000 tpa of product. Access to port would be by road or rail.
Power Transmission Infrastructure	3 x 220kV lines run through the site. Major transmission upgrade from Palmerston would most probably be required unless refiring the thermal power station with gas was undertaken. Detailed energy supply assessment is being done by Crest and is beyond the scope of this study.
Communications	Optical fibre available at George Town. Mobile phone coverage OK.



SITE 1

Site 5
Big Bay

LAND TENURE
(Existing Coverage)

N

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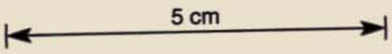


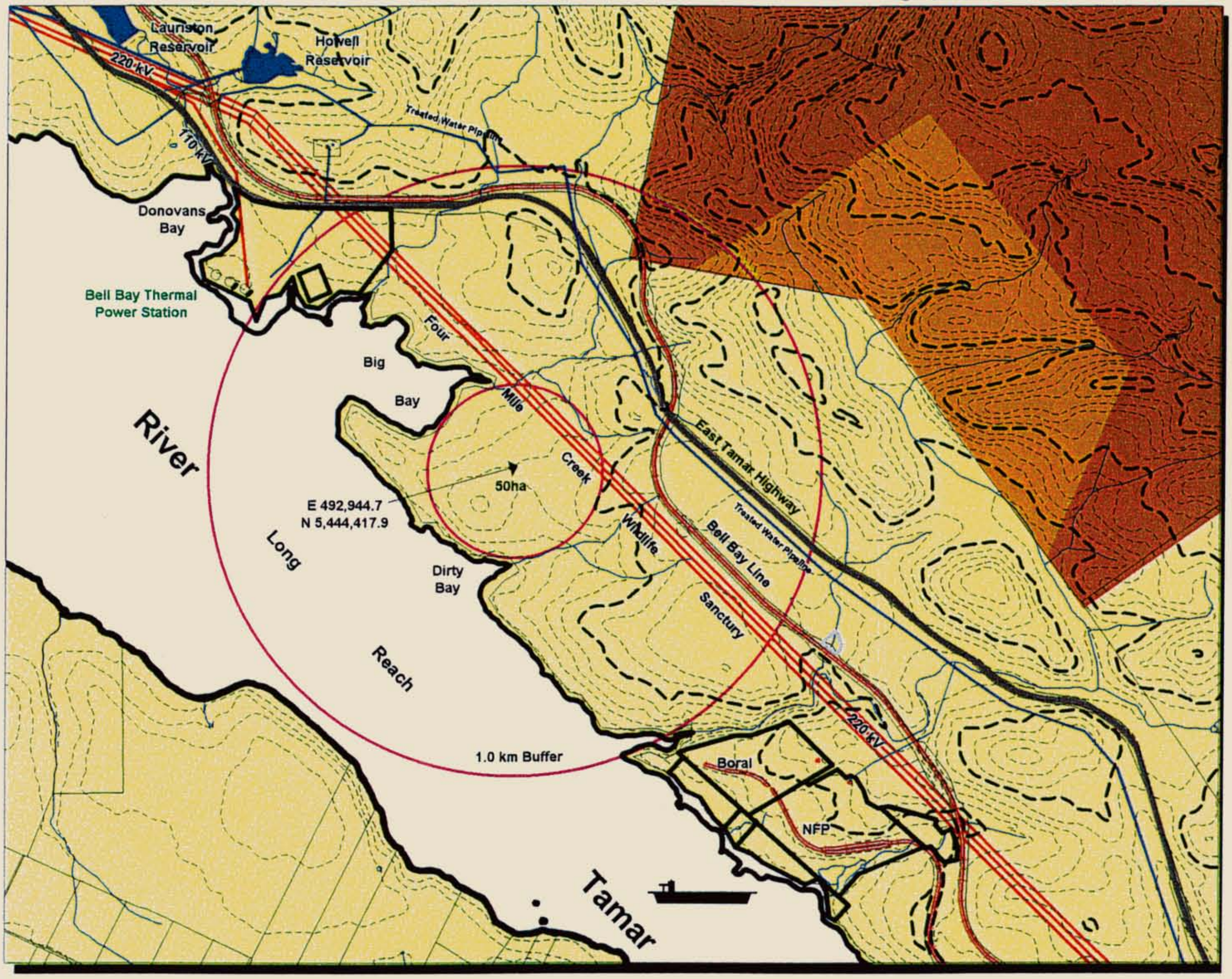
Magnesite Processing
Plant Site
Selection Study

SINCLAIR KNIGHT MERZ

LANDINFO

500103

Figure 1



Site 5
Big Bay

LAND TENURE
(Proposed)

SITE 1

N

5 cm

1:30000

Legend (Proposed Tenure based on Regional Forestry Agreement)

- Proposed Site
- Existing Formal Reserve
- Existing Informal Reserve
- Dams/Rivers
- Private
- Other State Land
- Highways
- Streets / Roads
- Rail
- Drainage
- Contours
- Index Contours (10m interval)

Magnesite Processing Plant Site Selection Study

SINCLAIR KNIGHT MERZ

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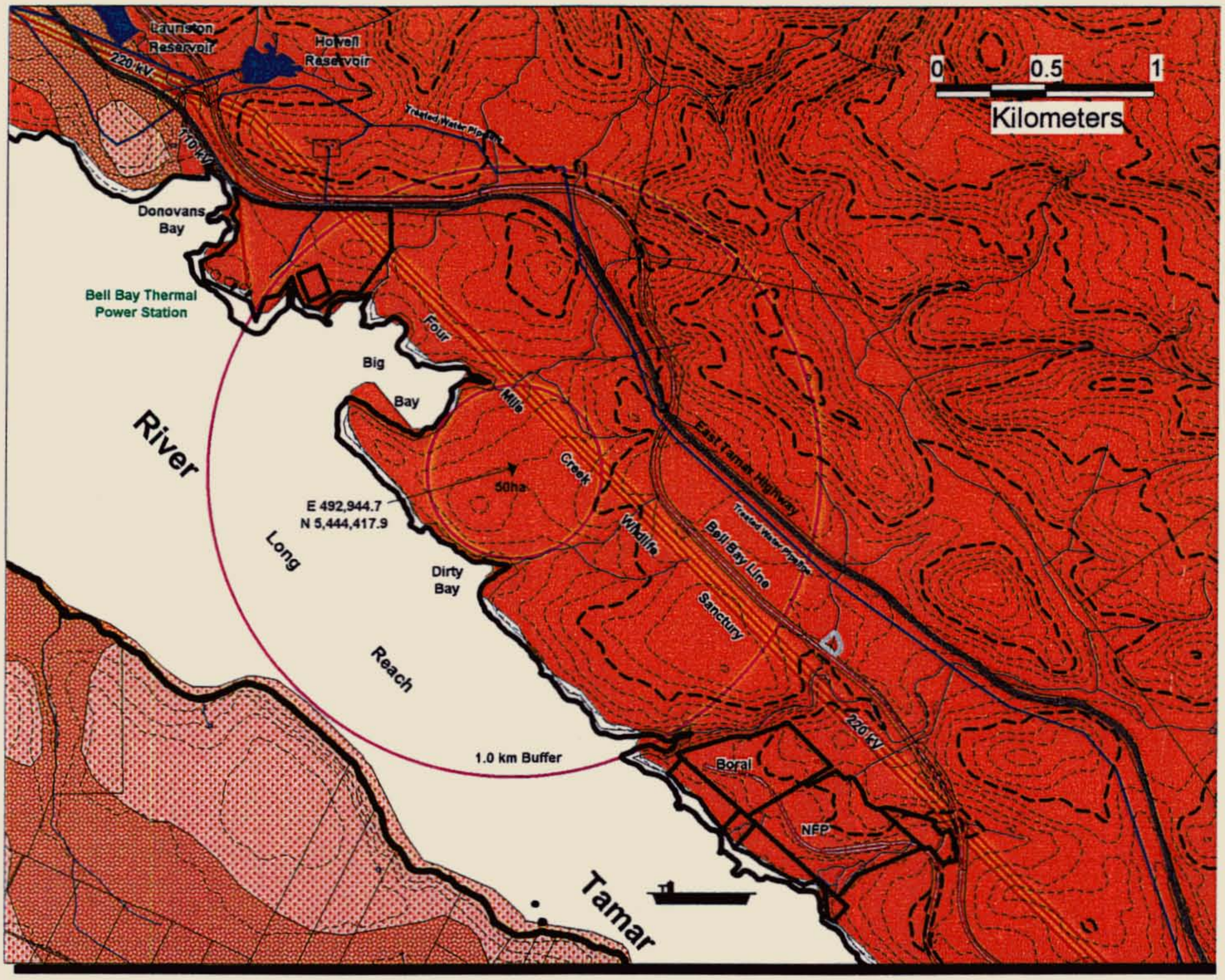

SITE 1

5 cm

Legend

- Proposed Site
- Basalt and related igneous and pyroclastic rocks
- Dominantly non-marine sequences of gravel, sand, silt, clay and regolith
- Dolerite with locally developed granophyre
- Highways
- Streets / Roads
- Rail
- Drainage
- Contours
- Index Contours (10m interval)

Site 5
Big Bay

GEOLOGY

N

1:30000

Magnesite Processi
Plant Site
Selection Study

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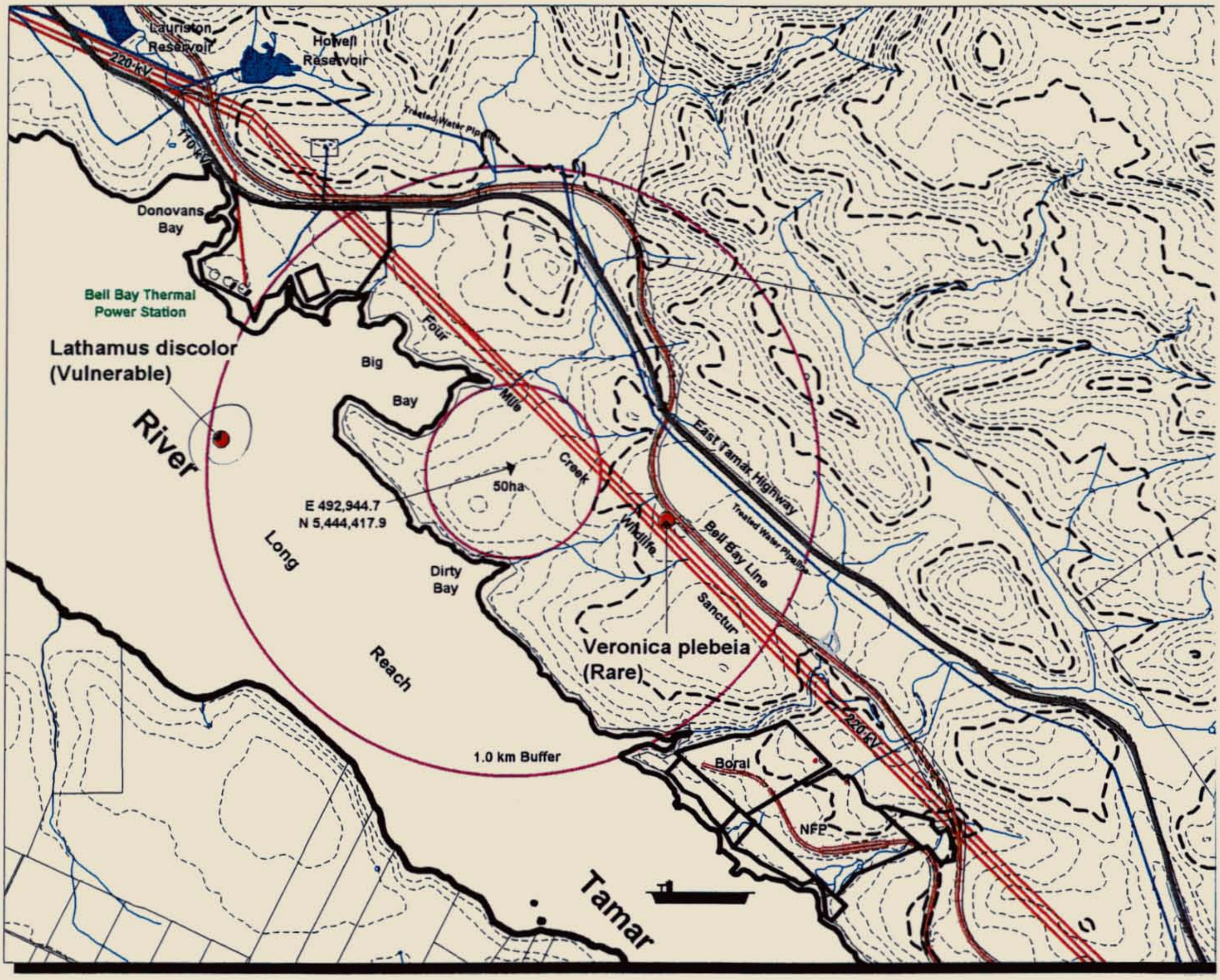

* Drafting error

SITE 1

Site 5
Big Bay

THREATENED SPECIES SITES

N

1:30000

5 cm

Legend

- Proposed Site
- Threatened Species
- Highways
- Streets / Roads
- Rail
- Drainage
- Contours
- Index Contours (10m interval)

Magnesite Processing Plant Site Selection Study

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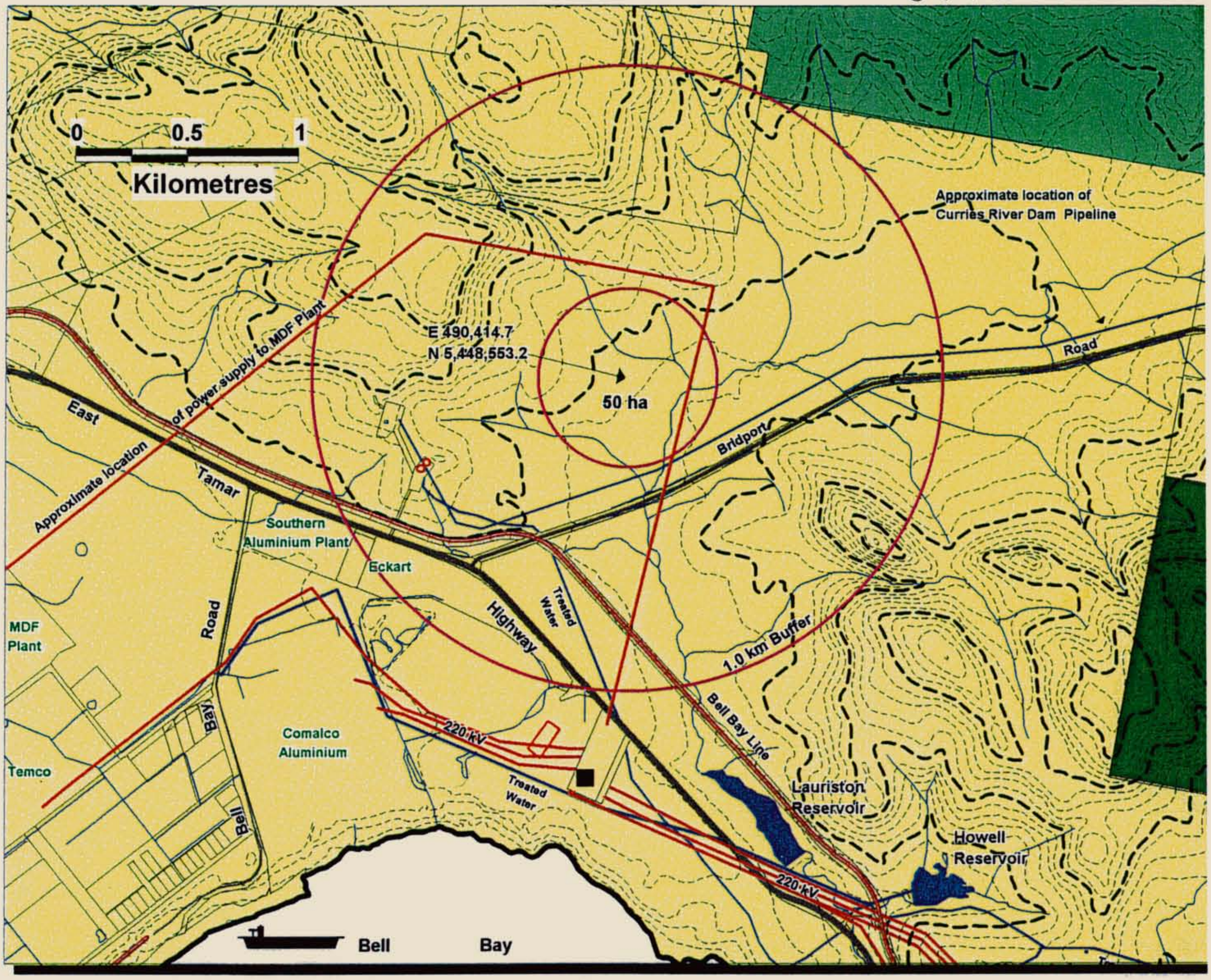
Table 5.6: Description of Site 6 - Bell Bay

SITE FEATURE	DESCRIPTION
Location	
Approximate Co-ordinates	E490,415; N5,448,553
Distance from Urban Centre	Approximately 4km east of George Town.
Land Tenure	Private. Land owned by Comalco.
Distance to Nearest Sensitive Receptor	4km to George Town.
Planning Details	
Municipality	George Town Council.
Planning Instrument	George Town Planning Scheme 1991.
Zoning	Bell Bay Major Industrial.
Use Status	Permitted (Heavy and Noxious Industry).
Topography	Approximately AHD 40m. Flat site. Medium density scrub and forest. Minor creek tributaries course through site. Land rises steeply to the north-west.
Climate	Mild with a mean annual rainfall of around 900mm.
Geotechnical Features	West of site underlain by Jurassic dolerite while eastern end of site underlain by glacial sediments and deposits.
Proximity to Mine	Approximately 197km from the mine via the Murchison Hwy, Bass Hwy, Frankford Main Road, Batman Bridge and the East Tamar Hwy.
Proximity to Rail	Bell Bay rail line runs approximately 400m south of the site.
Proximity to Road	Bridport Road immediately south of the site.
Ease of Gas Supply	Gas could come to shore at the Bell Bay thermal power station about 3km south of the site.
Water Supply	There is currently 1200 ML/yr of untreated water available via a 900mm pipeline from Curries River Dam. There is also approximately 1900 ML/yr available of treated water via a 375mm pipeline from Chimney Saddle and Distillery Creek treatment plants. Supply to the plant would be met by managing the supply from both sources. New infrastructure would comprise a reservoir and 500m long rising main to the site for treated water and a reservoir and pump station adjacent to the site for untreated water. Esk RWA controls the water supply in this region. To supply future demand, a pumping station at Pipers River and rising main to Curries River Dam would be required. This scheme has been proposed for over 20 years.
Proximity to Port	A wharf exists at the power station. Several berths also exist at Bell Bay, approximately 2.5km from the site. Bell Bay has adequate facilities for the handling and export of 95,000 tpa of product. Access to port would be by road or rail.
Power Transmission Infrastructure	3 x 220kV lines run into Comalco via a sub-station west of the site. An above ground power supply to the Starwood plant also runs through the site. Major transmission upgrade from Palmerston would most probably be required unless refiring the thermal power station with gas was undertaken. Detailed energy supply assessment is being done by Crest and is beyond the scope of this study.
Communications	Optical fibre available at George Town. Mobile phone coverage OK.



SITE 2

5 cm

Legend

	Proposed Site		Dams/Rivers
	State Forest		Highways
	Forest Reserve		Streets / Roads
	Private Freehold		Rail
			Drainage
			Contours
			Index Contours (10m interval)

Site 6
Bell Bay

LAND TENURE
(Existing Coverage)

N

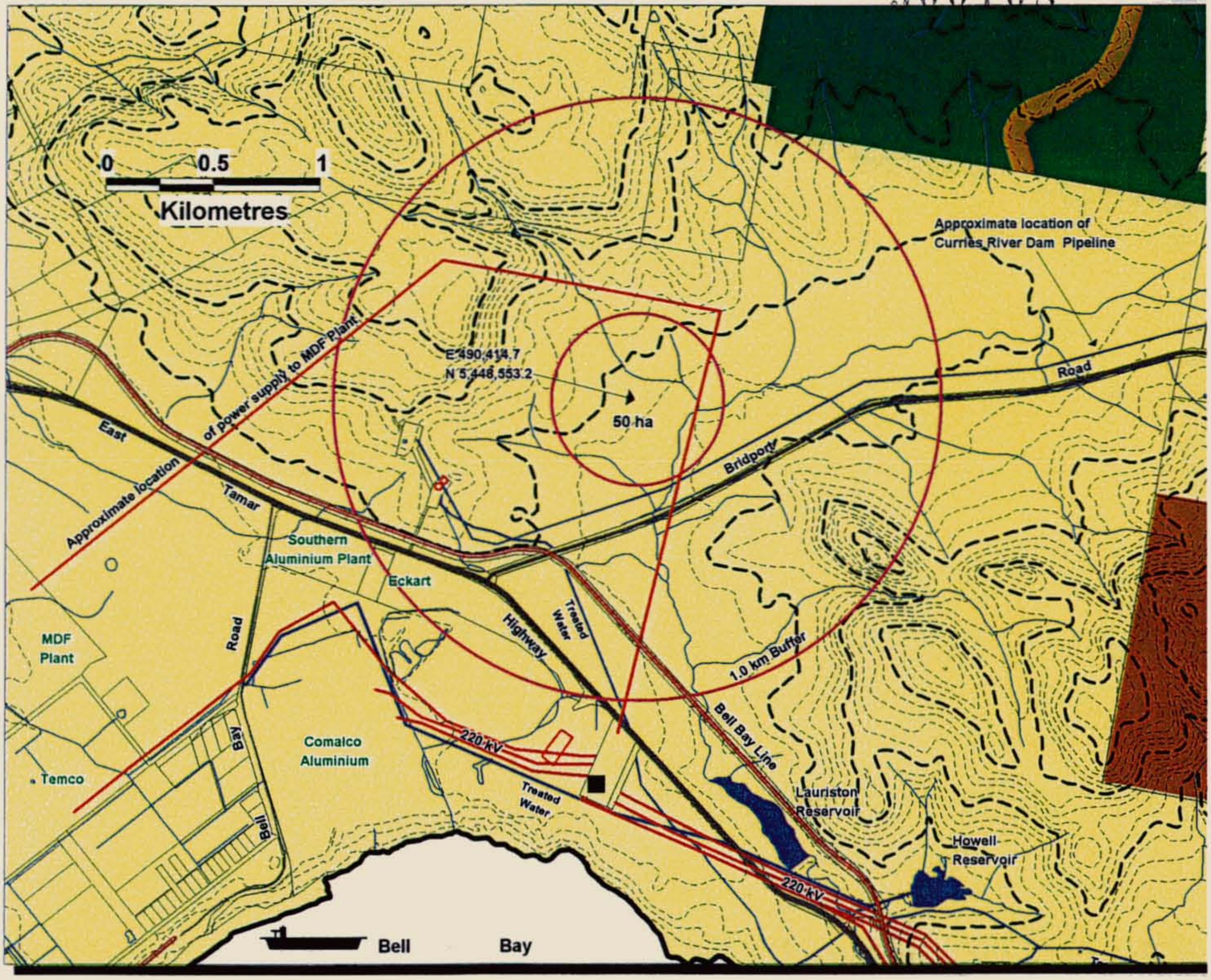
1:30000

Magnesite Processing Plant Site Selection Study

SINCLAIR KNIGHT MERZ

LANDINFO

500108 **Figure**



SITE 2

5 cm

Legend

(Proposed Tenure based on Regional Forestry Agreement)

- Proposed Site
- Private Tenure
- Dams
- Existing Formal ReserveTenure
- Existing Informal Reserve Tenure
- State Forest Tenure
- Rail
- Highways
- Ports
- Streets / Roads
- Drainage
- Transmission
- Contours
- Index Contours (10m interval)

Site 6
Bell Bay

LAND TENURE
(Proposed)

N

1:30000

Magnesite Processing Plant Site Selection Study

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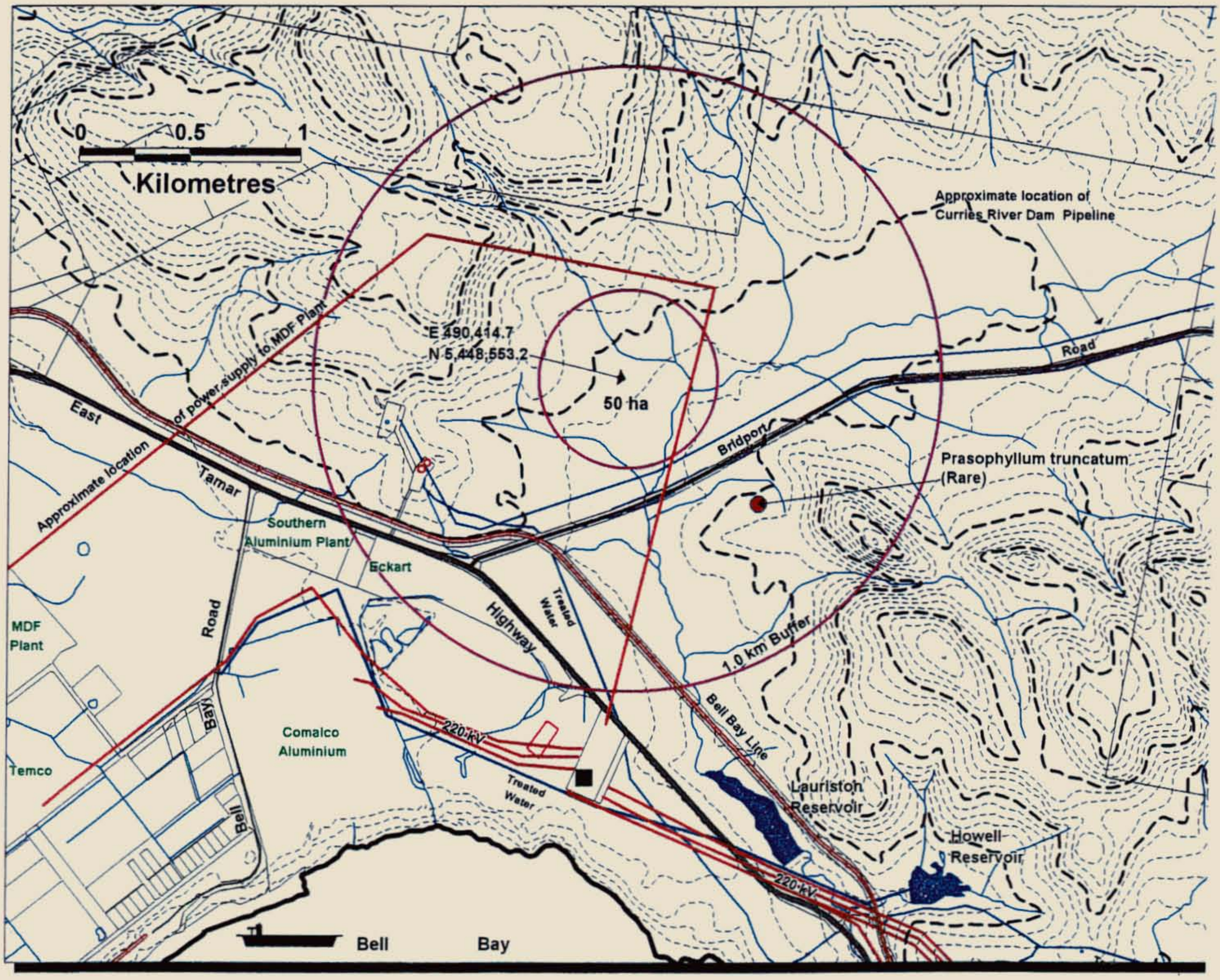
500109 **Figure 1**



SITE 2

Site 6

Bell Bay

THREATENED SPECIES SITES

N

5 cm

1:30000

Legend

○	Proposed Site		Rail
●	Threatened Species		Drainage
			Contours
	Highways		Index Contours (10m interval)
	Streets / Roads		

Magnesite Processing Plant Site Selection Study

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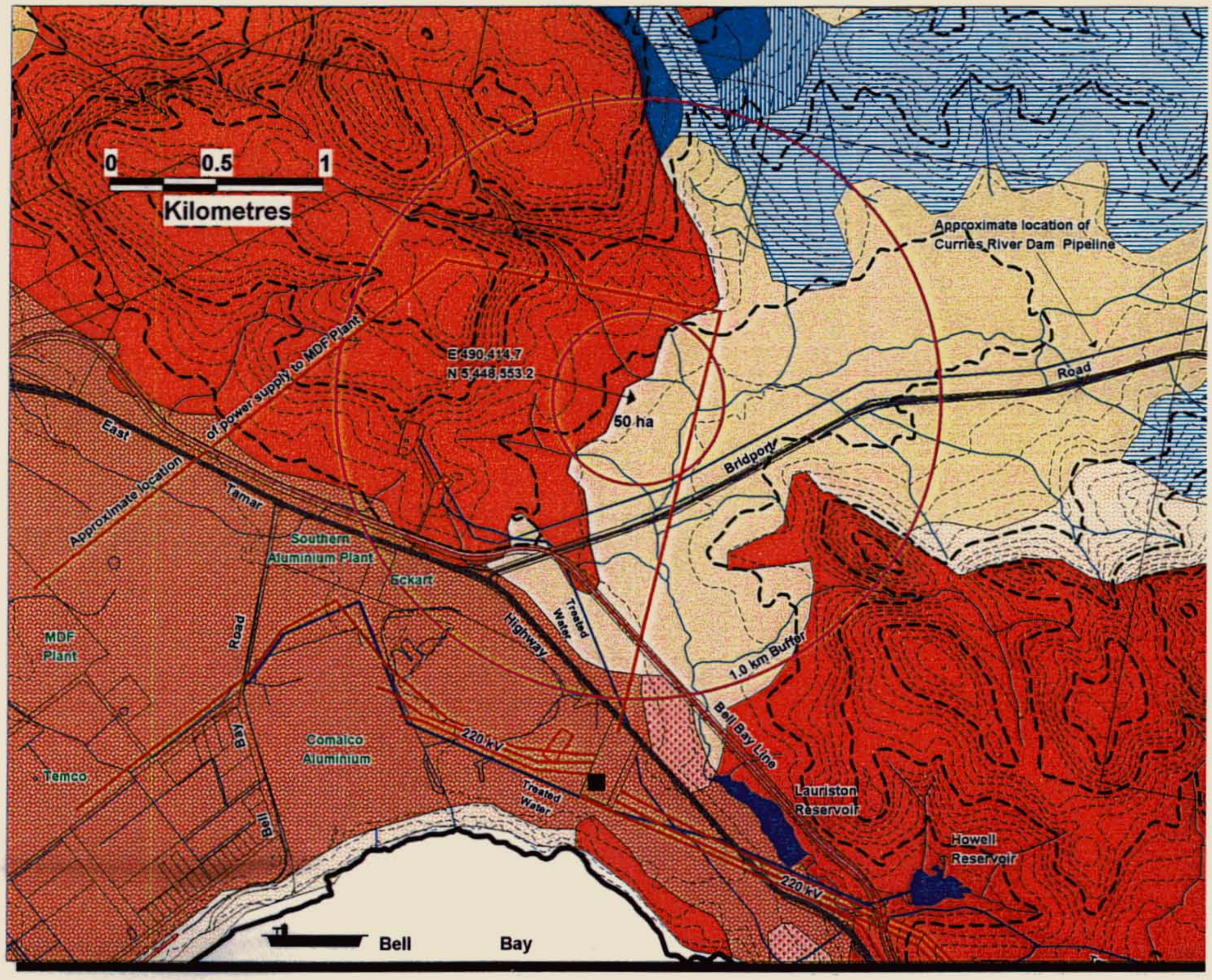


SITE 2

Site 6
Bell Bay

GEOLOGY

5 cm

N

1:30000

Legend

Proposed Site	Freshwater sandstone with coal measures
Dolerite with locally developed granophyre	Dominantly non-marine sequences of gravel, sand, silt, clay and regolith
Talus, vegetated and active	Streets / Roads
Dominantly quatz sandstone	Drainage
Upper glaciomarine sequences of pebbly mudstone pebbly sandstone and limestone	Transmission
	Contours
Glacial, periglacial and fluvioglacial sediments including till and interglacial deposits and limestone	Index Contours (10m interval)
Basalt and related igneous and pyroclastic rocks	Rail
	Highways
	Ports

Magnesite Processi[ng]
Plant Site
Selection Study

SINCLAIR KNIGHT MERZ

LANDINFO

ATTACHMENT 12

Papers from the Australian Magnesium Conference, Sydney, July 1999

500112

MAGNESITE AND SERPENTINITE GOLDEN TRIANGLE'S FEEDSTOCKS FOR MAGNESIUM METAL PRODUCTION

Presented by:

Chris Laughton
General Manager
Golden Triangle Resources NL

AJM
AUSTRALIAN JOURNAL OF MINING

Magnesium

Golden Triangle Resources N.L.

globally competitive

MAGNESIUM

PROJECTS

GTR

500113

Magnesium

Electrolytic Magnesium Producers
Current & Proposed

Location	Plant	Capacity	Operating Cost* ¢/lb(US)	Capital Cost* US$Million
USA	Magcorp	45,000	94	
** USA	Dow	60,000	91	
Norway	Norsk Hydro	44,000	85	
Israel	Dead Sea	55,000	81	460
Canada	Norsk Hydro	68,000	74	
Australia	SAMAG	52,000	71 (60 – 65)	420
Canada	Magnola	58,000	66	515
Australia	QMC	90,000	66	520
Australia	Crest	95,000	65	561
Australia	GTR (Main Creek)	80,000	62	421
Australia	GTR (Woodsreef)	80,000	57	423

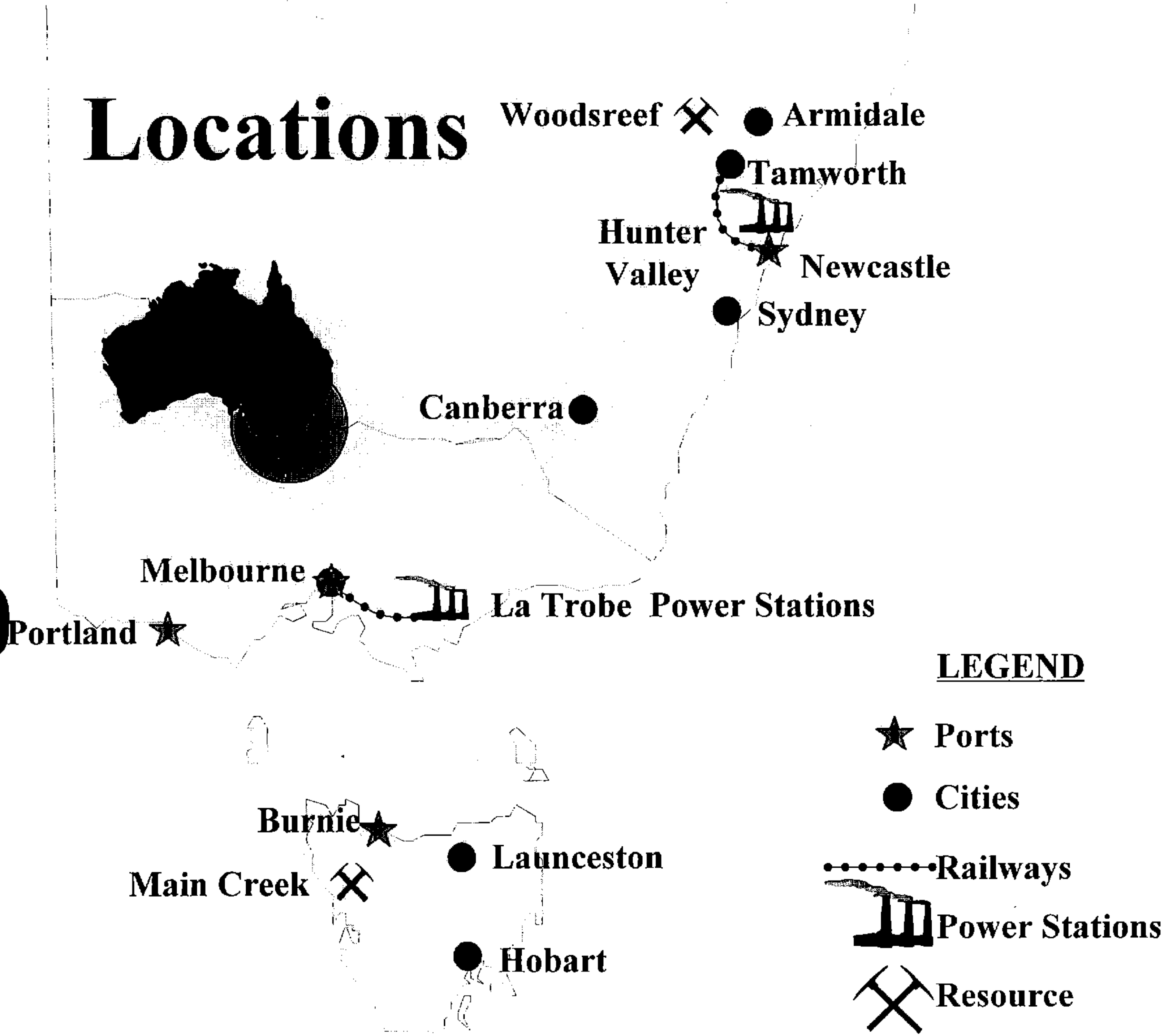
* Derived from a variety of sources

** Now closed

GTR

500114

Magnesium



500115

Raw Material for Magnesium Production

Source	Composition	(%Mg)
Magnesite	**$MgCO_3$**	**28.8**
Serpentinite	**$3MgO.2SiO_2.2H_2O$**	**26.3**
Dolomite	$MgCO_3$, $CaCO_3$	13.2
Carnallite	$MgCl_2$, $KCl/6H_2O$	8.8
Lake brines	$MgCl_2$, $MgSO_4$	0.80
Seawater	$MgCl_2$, $MgSO_4$	0.15

Magnesium

Golden Triangle's Magnesium Projects

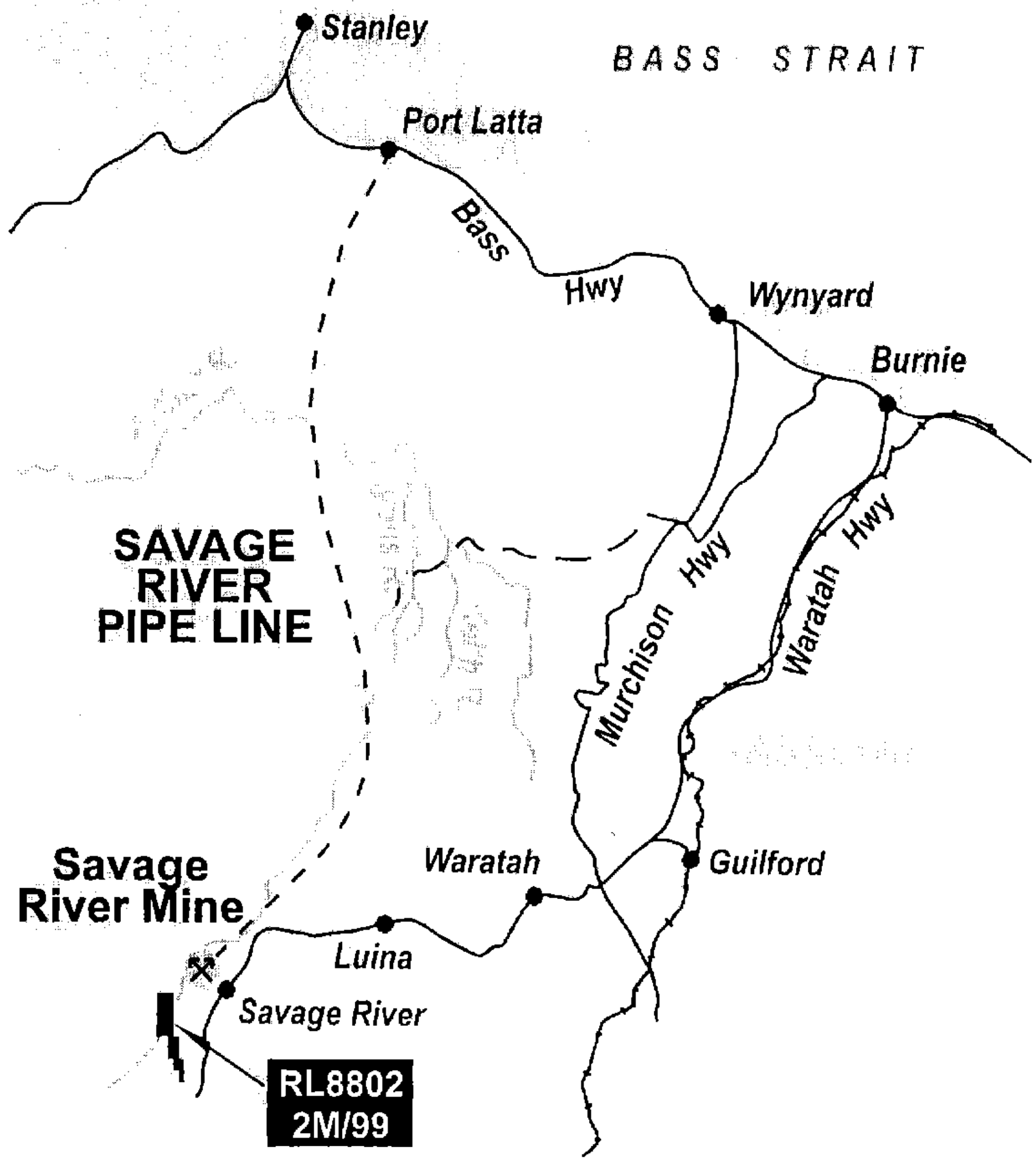
Main Creek, Tasmania

- 47Mt magnesite @ 43.4% MgO
- Inferred resource defined
- Preliminary mine design
- Testwork well advanced
- Feasibility study in progress based on refinery located in La Trobe Valley

GTR

Magnesium

Main Creek Project



N

0 25km

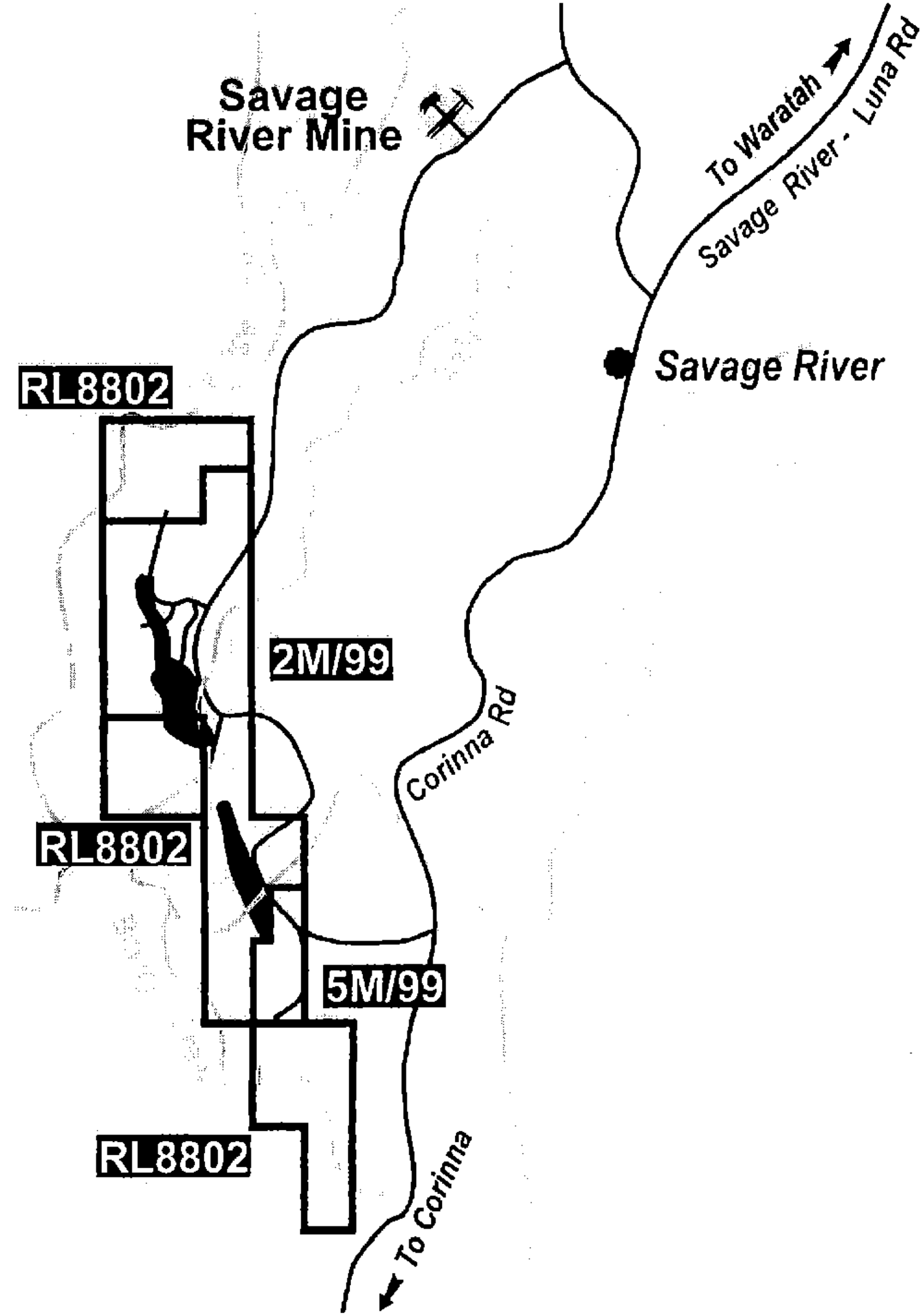
5 cm

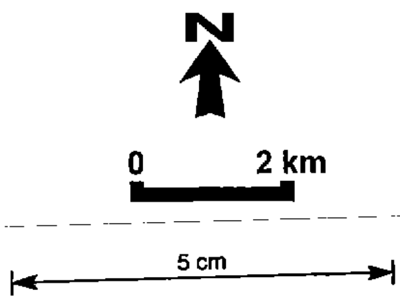
GTP

500118

Magnesium

Main Creek Tenements



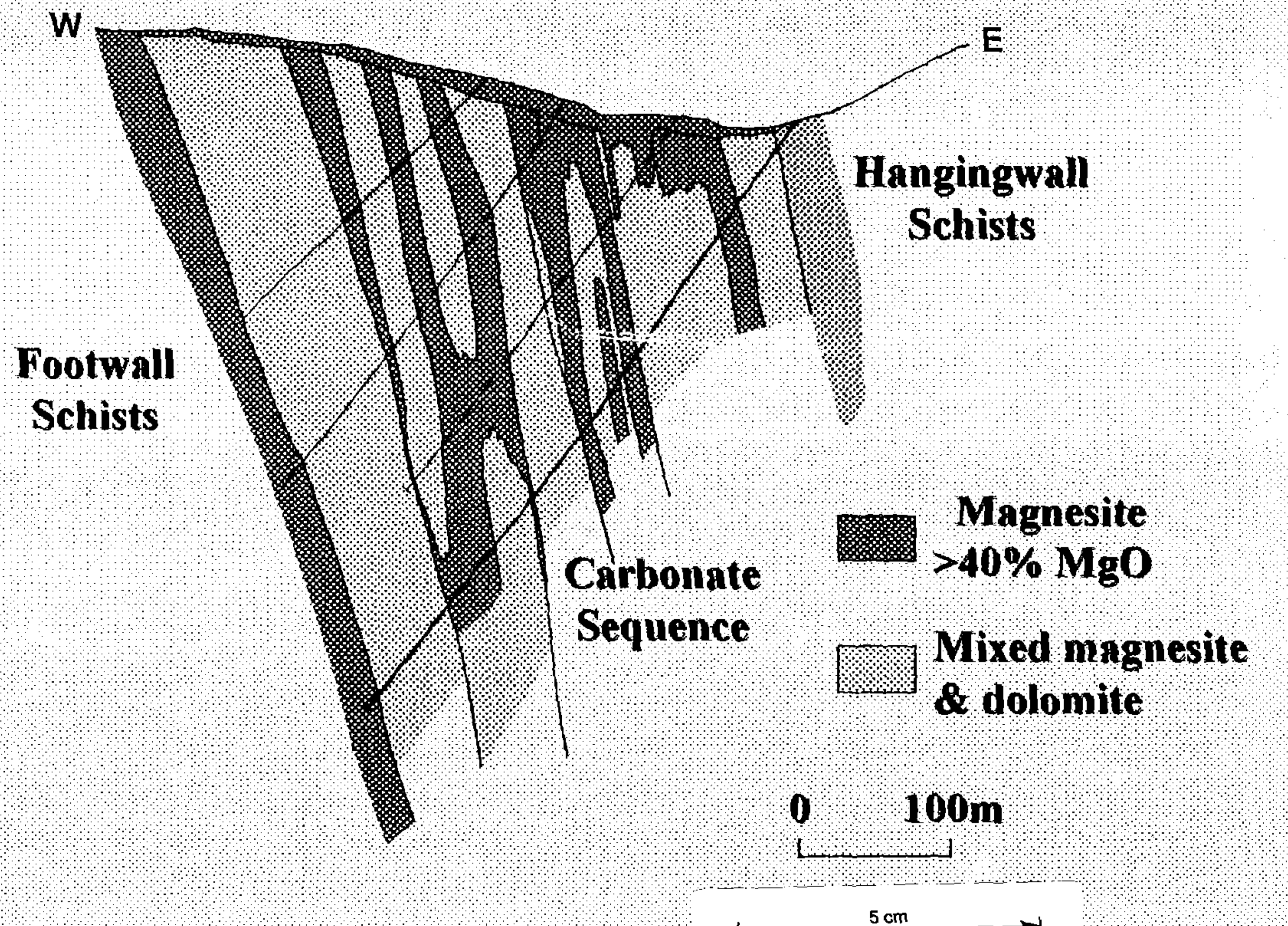


GTR

600119

Magnesium

Main Creek Cross Section



GTR

500120

Magnesium

Golden Triangle's Magnesium Projects

Woodsreef, NSW

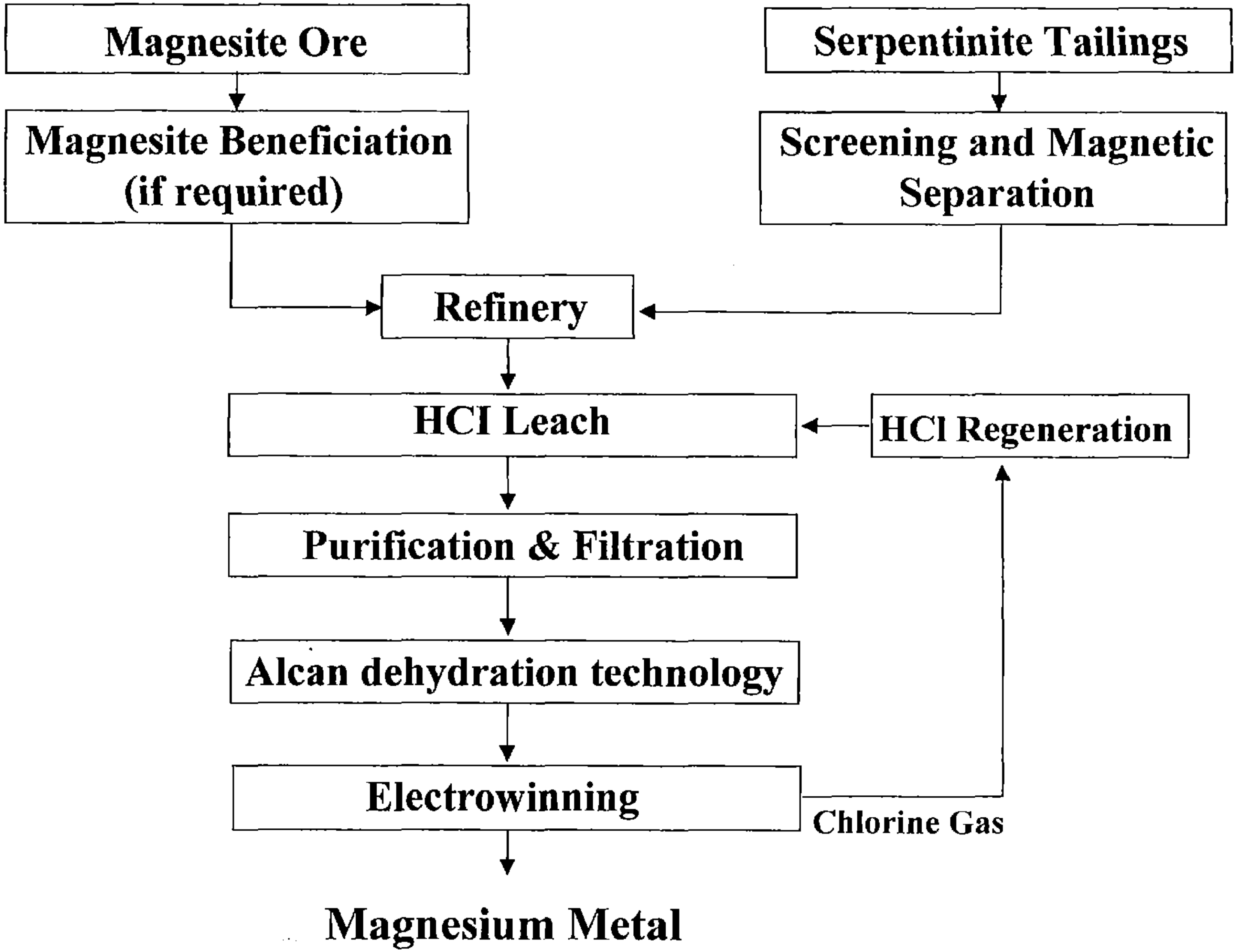
- 24Mt serpentinite tailings @ 38.3% MgO
- Material already mined and crushed
- Testwork initiated
- Favourable location and infrastructure
- Noranda currently building magnesium project utilising similar feedstock

GTP

500121

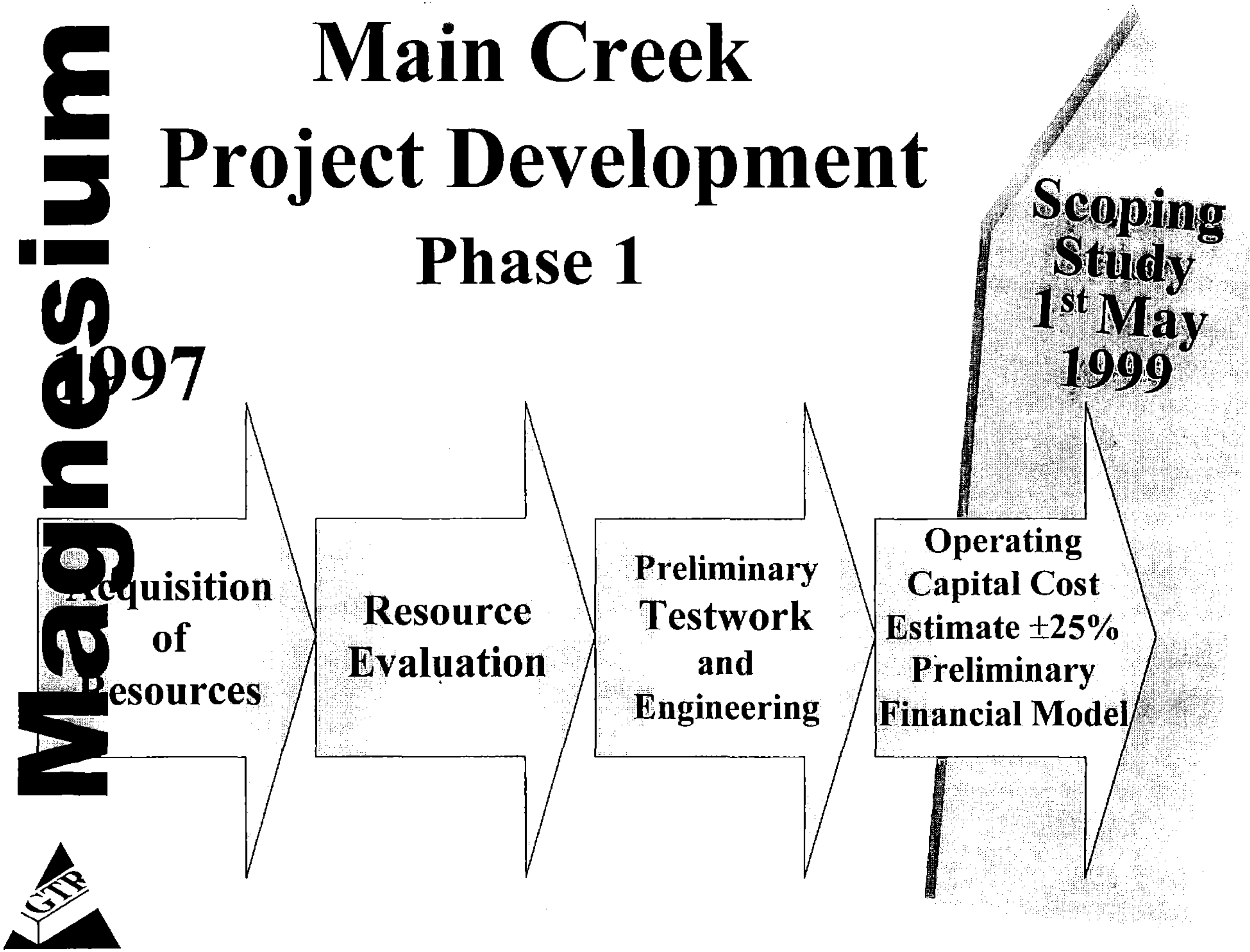
Magnesium

Magnesium Metal Flow Chart



Main Creek Project Development

Phase 1



500123

Magnesium

Main Creek
Project Development

May 1999

Phase 2

Feasibility Study Dec. 1999

1. Resource Definition/ Mine Plan Development
2. Infrastructure and Power Study
3. Detailed Continuous Testwork
4. Detailed Engineering & Pilot Plant Design
5. Operating Capital Cost Estimate ±15% Detailed Financial Analysis

GTR

500124

Main Creek
Project Development
Phase 3

Magnesium

Dec. 1999

- First Plant Testwork & Final Design
- Draft Power Supply Contracts Draft Offtake Contracts
- Draft EPCM Contracts
- Project Management Finalised
- Full Project Documentation

Bankable Feasibility Dec. 2001

GTR

500125

Magnesium

Project Development

Phase 1:

Resource Acquisition - Preliminary evaluation:

Scoping Study

COMPLETED

Phase 2:

Detailed Testwork and Engineering Studies:

FeasibilityStudy

Phase 3:

Pilot Plant Testwork - Final Design - Financing:

Bankable Feasibility Study

Phase 4:

Construction - Commissioning - Optimising

Project Complete

Magnesium

Advantages of Golden Triangle's Projects

- Large, accessible high-grade resources
- Golden Triangle ownership 100%
- Preliminary Resource Definition drilling and testwork successful
- State and Federal Government support for both projects
- Top engineering and process research companies engaged
- Bateman, Brown & Root Scoping Study indicates capital and operating costs in lowest quartile
- No major environmental or land title issues are anticipated

GTP

500128

AN ENGINEERING PERSPECTIVE ON TECHNOLOGY SELECTION FOR THE AUSTRALIAN MAGNESIUM INDUSTRY

Presented by:

Michael Anderson
Business Development Manager
Bateman Brown & Root

AJM
AUSTRALIAN JOURNAL OF MINING

An engineering perspective on technology selection for the Australian Magnesium Industry

By

Eric Craig, Jim Smith

Bateman Brown & Root, Asia-Pacific

Presented at

The Inaugural

Australian Magnesium Conference

1st July 1999

Wentworth Hotel, Sydney, Australia

Introduction

All projects undertaken by an engineering contractor involve risks for both the engineering contractor and the client. Obviously unidentified risks cannot be managed or controlled throughout the life of the project. Risk identification is therefore, the vital first stage of any risk management program. As the project risks are identified, it is essential that the magnitude of these risks be quantified.

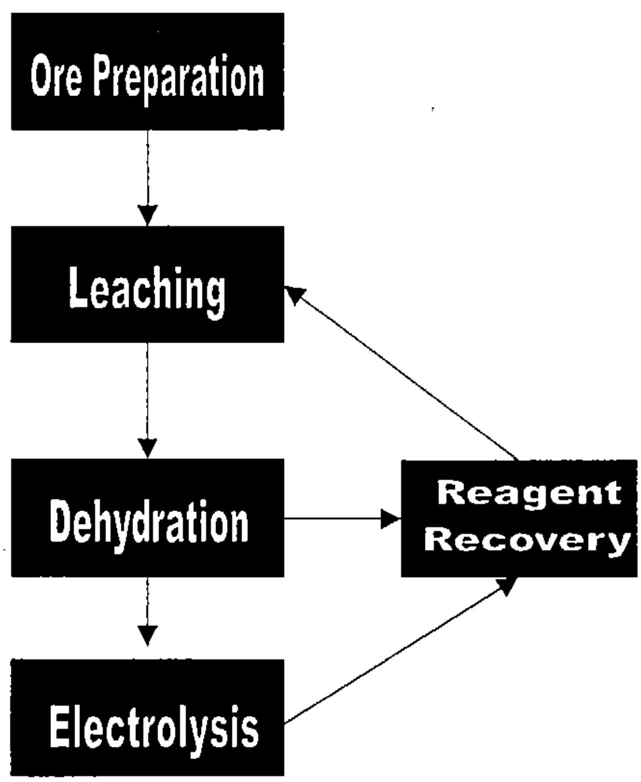
From an engineering perspective the risk can be either a project cost overrun, project schedule overrun, failure to achieve the projected operating cost or a combination of any of these, all of which would influence profitability of the executed project. From a client's perspective the risk can be operating cost overrun, capital cost overrun, a process that does not meet the design criteria, or a combination which effects the overall return on the project.

This paper briefly describes the selected flowsheet for Golden Triangle Resources' Main Creek magnesite project. The key technical risks for this flowsheet are identified and the implication on the project viability is discussed. A summary of the testwork program for the next stage of the project, which has been designed to mitigate certain aspects of the process risk, is outlined, together with some technology licence implications.

Flowsheet selected for the Main Creek Project

The flow sheet selected for the Main Creek Project can be divided into six discrete sections

- Ore preparation
- Acid leaching and neutralisation
- Purification
- Dehydration
- Magnesium metal recovery
- Reagent recovery and acid production



The following is a broad outline of the process flow sheet selected. The dehydration process is of greater importance and is detailed appropriately.

Ore Preparation

Magnesite ore is crushed in a closed circuit and transferred to a dry milling circuit with the coarse particles being re-circulated to the mill via an air classifier system. A portion of the milled magnesite is calcined to produce sufficient calcined magnesium oxide for the neutralization step after leach. The calcination reaction can be described by the equation:

$$MgCO_3\ (s) + Heat \Rightarrow MgO\ (s) + CO_2\ (g)$$

The balance of the magnesite is conveyed to the leach plant for dissolution.

Acid Leaching, Neutralisation and Impurity Removal

The crushed and milled magnesite is dissolved in concentrated hydrochloric acid, The main leaching reaction is detailed below: -

$$MgCO_3\ (s) + 2HCl\ (aq) \Rightarrow MgCl_2\ (aq) + H_2O\ (aq) + CO_2\ (g)$$

A parallel / competing reaction between the hydrochloric acid and the minor quantities of calcium carbonate that may be present in the feed material is;

$$CaCO_3\ (s) + 2HCl\ (aq) \Rightarrow CaCl_2\ (aq) + H_2O\ (aq) + CO_2\ (g)$$

The calcium content of the feed ore in this instance is however, low such that minimal hydrochloric acid is consumed by this reaction.

The carbon dioxide released during the dissolution is vented through demisters on each reactor and scrubbed.

Calcined magnesite is introduced to the neutralization reactors and, with careful pH adjustment, the majority of the calcium and iron are precipitated together with a significant portion of metal impurities.

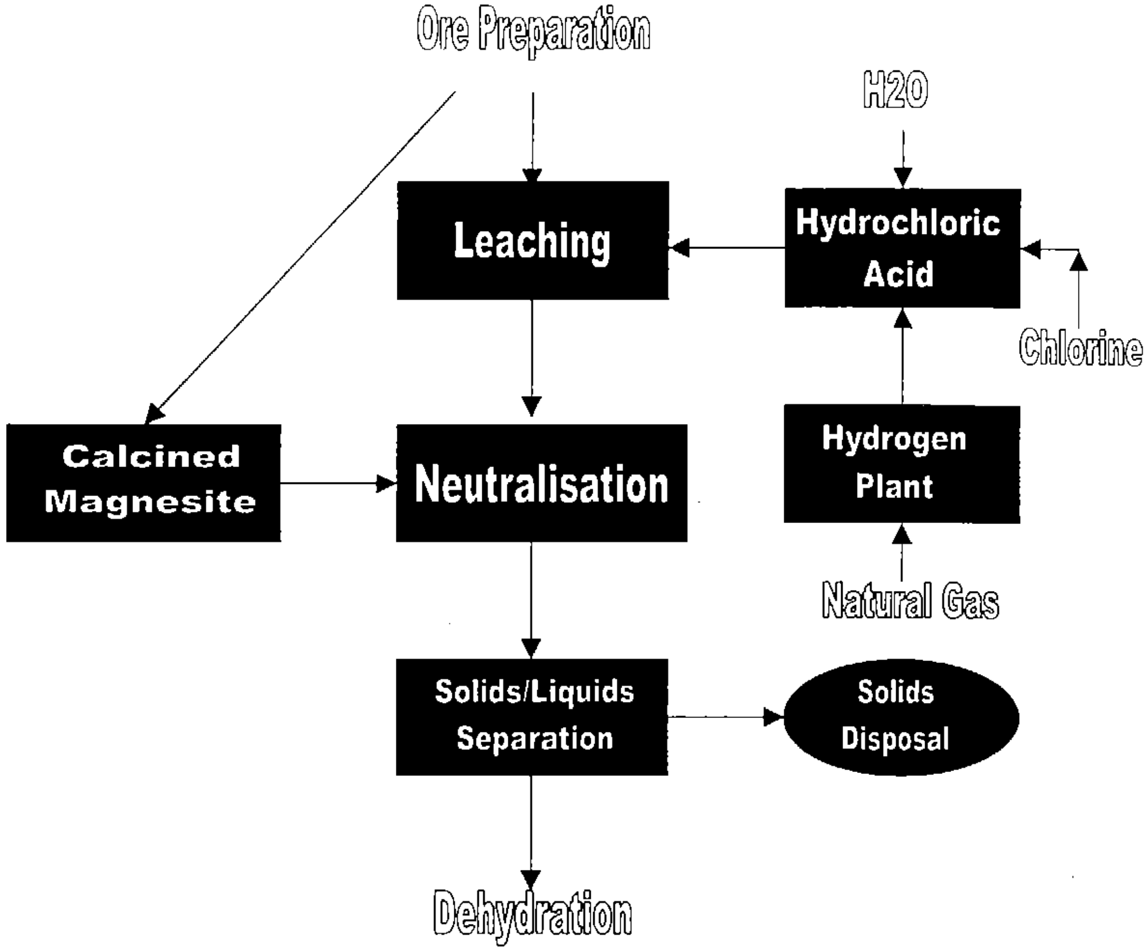
The neutralisation reaction can be described as follows;

$$MgO\ (s) + 2HCl\ (aq) \Rightarrow MgCl_2\ (aq) + H_2O\ (aq)$$

The final neutralized slurry from the neutralization reactors is thickened and filtered where non-reacted material is washed and de-watered. The residue solids filter removes the non-reacted material together with the precipitated impurities and enables the magnesium chloride solution present in the voids of these solids to be washed and recovered.

Purification

Additional purification stages on streams within this circuit are currently being investigated. Unfortunately, however, the details cannot be included in this description.



Dehydration

Modern electrolytic cell technology requires the virtual elimination of all water of hydration and any other oxygen bearing species from the feed entering the cell. The basis of the Alcan and Nalco / St Joe technologies is the affinity for water of certain short chain alcohols.

Evaporation or flash drying removes excess water and, depending on how the process is run, leaves a concentrated brine or solid magnesium chloride hydrate.

This magnesium chloride hydrate is contacted with alcohols recycled from the ammonia /alcohol recovery system. Alcohol insoluble impurities from the feed can be removed at this stage.

Alcohol present in the dissolution vessels has a high affinity for the water associated with the magnesium chloride hydrate. In the Nalco / St. Joe process, the water is removed from the magnesium chloride at this stage by distillation. In the Alcan process, the water is carried through to the next stage. Anhydrous ammonia is then sparged through the solution. The reaction of magnesium chloride with ammonia results in $MgCl_2.6NH_3$ crystals precipitating.

$$MgCl_2 + 6NH_3 \Rightarrow MgCl_2.6NH_3\ (s)$$

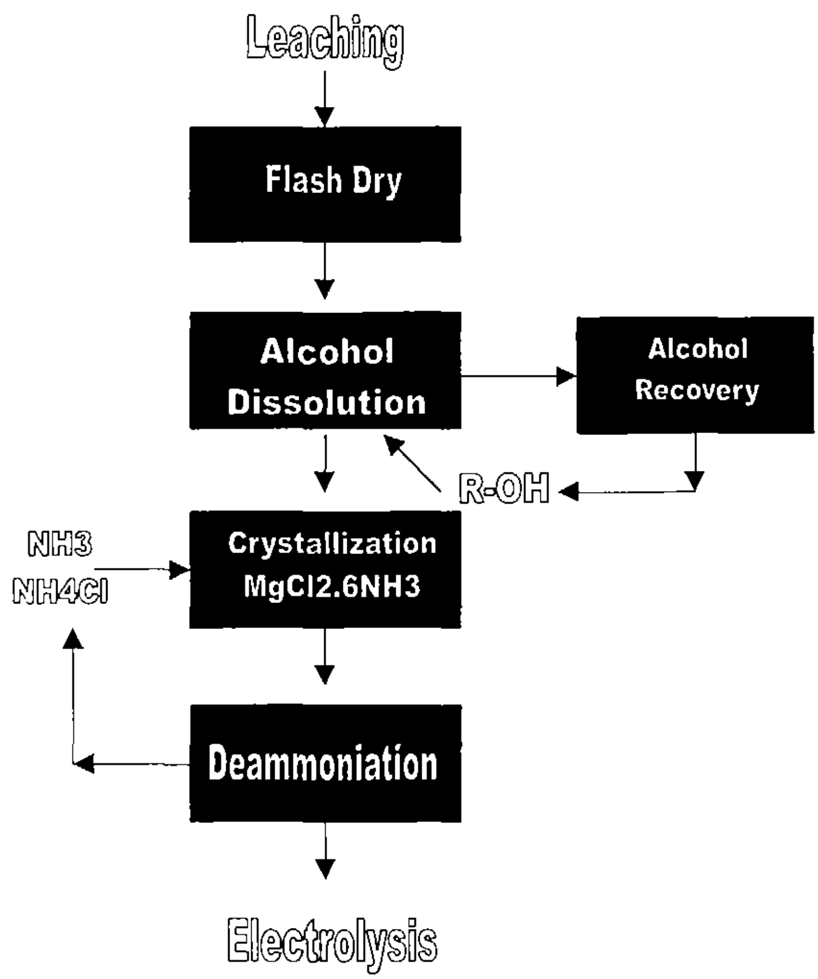
In the crystalliser coarse crystals are grown or formed by agglomeration of fine particles of $MgCl_2.6NH_3$. The $MgCl_2.6NH_3$ cake is washed with ammonia saturated methanol. In the presence of water a competing reaction can occur.

$$MgCl_2\,(aq) + 2H_2O\,(aq) + 2NH_3 \Rightarrow Mg(OH)_2\,(s) + 2NH_4Cl\,(aq)$$

The second reaction is undesirable as it produces MgO after calcination and contaminates the desired product, anhydrous $MgCl_2$. Because the water is carried into the crystallizer in the Alcan process this reaction is controlled by the addition of ammonium chloride which forces the equilibrium of the reaction to the left.

The cake is discharged (filtered or centrifuged) and dried to a minimal alcohol content using hot ammonia gas originating from the subsequent calcination stage. The alcohol and the ammonia are recovered and recycled back to the dissolution process.

During the drying the magnesium chloride will be partly calcined from hexa-ammoniate to tetra-ammoniate. The dried cake is then calcined in a fluidised bed to the anhydrous magnesium chloride. The hot solids from the calciner will be used to preheat the ammonia fluidising media to the calciner. The residual heat after drying will be used for the ammonia and alcohol recovery circuits to provide the majority of the energy requirements (Ref.5). The process can be summarised as follows.



Magnesium Metal Recovery

The $MgCl_2$ is transported under argon to the cellroom and injected into the electrolytic cell which operates at temperatures in excess of 670°C

It is important for the feed to avoid contact with moist air as the salt hydrolyses forming hydrochloric acid and magnesium oxide (sludge component):

$$MgCl_2 + H_20 \Rightarrow Mg0 + 2HCl$$

In the electrolytic cell Alcan Multipolar technology is proposed. This cell is constructed with a chamber for electrolysis and a chamber for metal collection. The bipolar electrode is an electrically conductive plate where one side is anodic and the other side cathodic. The chlorine produced at the anode surface produces a re-circulating flow of electrolyte in the cell. This is used to sweep the metal into the metal collection chamber. Sludge is also transported to the metal chamber where it settles on the bottom. The heating, melting and electrolysing of the magnesium chloride produces molten magnesium metal, which is cast into ingots, and chlorine gas, which is recycled.

Reagent Recovery and Acid Production

Chlorine gas is continuously extracted from the cells under a small negative pressure and is collected in ducts running the length of the electrolysis building to the chlorine cleaning plant.

In the hydrochloric acid plant, chlorine and hydrogen enter the top of the synthesis unit and are burnt in a specific burner designed to ensure complete combustion. The vigorous reaction of hydrogen and chlorine is controlled and releases large amounts of heat which can be utilised in to raise process steam.

$$Cl_2\,(g) + H_2\,(g) \Rightarrow 2HCl\,(g) + 2500\text{ MJ/t Heat Evolved}$$

The hydrogen plant uses natural gas as the hydrocarbon feed stock. The standard package plant will typically comprise the following sections; feed treatment, hydro - desulphurisation, reforming, shift conversion, process gas cooling, pressure swing absorption hydrogen purification and waste heat recovery.

The de-sulphurised feed is mixed with superheated steam and fed to the catalyst tubes filled with nickel catalyst in a reformer vessel. The following reaction occurs: -

$$C_rH_m\,(g) + n\,H_20\,(g) \Rightarrow r\,CO(g) + (m+n)\,H_2\,(g)$$

$$CO\,(g) + H_20\,(g) \Rightarrow CO_2\,(g) + H_2\,(g)$$

The first reaction is the reforming reaction and the second reaction is the shift conversion. Both are equilibrium limited, based on the outlet temperature and pressure. The overall reaction is endothermic, requiring heat supplied by a natural gas burner.

Risks Associated with the selected Flowsheet

A simplified approach could consider two broad categories of risk namely commercial and technical. Ultimately, the latter technical risk will have commercial implications. This paper is primarily concerned with technical or process risk, and the identification and mitigation of certain aspects of such technical risk for this stage of the project.

The confidence and knowledge of the chosen process flowsheet, and the specific unit operations involved in each section, are the main factors to be considered. The risks involved in the following sections of the process flowsheet;

- Ore preparation.
- Acid leaching, neutralisation and impurity removal.
- Dehydration.
- Magnesium metal recovery.
- Reagent recovery and acid production.

are briefly described below.

Ore Preparation

Closed circuit crushing and dry milling is not considered a difficult unit operation. An opportunity exists to optimise the comminution circuit with milling models developed in house by Bateman Brown & Root Asia-Pacific using the relevant testwork data. The required particle size is dictated by the leaching operation. Therefore, the technical risk associated with the milling operation is essentially associated with i) the selected sample being representative of the ore feed, and ii) the integrity of the crushing, milling and leaching testwork.

Similarly the technical risk associated with that portion of the milled magnesite calcined to produce magnesia is also associated with i) the selected sample of the milled product being representative, and ii) the integrity of the calcination testwork. The choice of calcination equipment, e.g. rotary kiln or fluid bed, is a trade-off between operating cost versus capital cost. The above issues are discussed in greater detail in the section detailing the testwork for the project.

The project capital costs for these areas are relatively low when taken in the context of the overall project. Consequently, the potential impact of an overrun in this area on overall project expenditure is limited.

Acid Leaching, Neutralisation and Impurity Removal

The principal risks associated with the dissolution of the crushed and milled magnesite in concentrated hydrochloric acid can be defined as; -

- Choice of materials of construction for highly corrosive hydrochloric acid systems.
- Hydrochloric acid spillage / hydrogen chloride gaseous emission.
- Integrity of the leach test-work.
- Integrity of the neutralisation / precipitation / impurity removal test-work.
- Solids liquids separation post leach and neutralisation.
- Disposal of liquid / solids.
- The number of leach residue washing stages (washing efficiency) versus evaporation costs.

A key risk associated with the leaching and neutralisation operation is also testwork related, however, materials of construction and reagent loss are equally important in the process design. Related experience from the platinum refining industry in South Africa and from Bateman's involvement in the Dead Sea Works Magnesium Project in Israel has been useful in understanding the issues relating to materials of construction for this project.

The project capital costs for these areas are also relatively low compared to the project as a whole, such that overrun risk on overall project expenditure for this area is moderately low.

The effect on the project operating cost is, however, significant with respect to consumption of hydrochloric acid. The overall leach efficiency has an even more significant effect on project economics hence the criticality of the testwork referred to previously.

Dehydration

Various technologies have been developed, or are in the process of being developed, for the production of dehydrated magnesium chloride both by existing magnesium producers and potentially new producers. For the Main Creek magnesite project a conceptual dehydration flowsheet has been developed to bench-scale utilising the patented Alcan magnesium chloride dehydration process.

It is clear that some of the more significant risks for the project as a whole are associated with this flowsheet. These risks will be addressed by piloting of the dehydration process. Specific risk areas that have been identified at this stage of the project are.

- Choice of materials of construction.
- Volatile reagent vapour release / spillage.
- Magnesium chloride dissolution in alcohol test-work.
- Solids / liquids separation of residues and treatment of these residues.
- Crystallisation of the magnesium chloride hexa-ammoniate.
- Separation of $MgCl_2.6NH_3$ precipitate.
- Removal of the complexed ammonia.

Clearly there are a number of areas requiring testwork to quantify the risk. Currently a testwork program is being developed to address the leach and dehydration areas. This program, which will be conducted in close collaboration with the technology provider, has been prioritised to ensure the successful progress of the project.

Magnesium Metal Recovery

Alcan's Multipolar Cell technology is proposed for the electrolysis section of the flowsheet. From an engineering perspective, the established nature of this process unit operation allows a low technology risk to be assumed.

Risks from a process design perspective would include.

- *Choice of materials of construction for the electrolysis building*
- Chlorine hazardous release within the building environment
- Handling of the anhydrous magnesium chloride product
- Handling of the anhydrous magnesium product
- Quality /Engineering specifications

Again a close alliance with the technology provider is important to clarify areas of responsibility.

Reagent Recovery and Acid Production

The processes for the production of hydrogen and hydrochloric acid are well established and both are considered to represent a low process risk. Capital costs and input into the operating cost estimates for the production facilities for both the hydrogen and hydrochloric acid have been developed by the suppliers of these facilities. These international companies have an established record supplying similar facilities locally and overseas.

Some of the process risks, which will nevertheless require consideration in the detailed engineering phase, are;

- Hydrogen release
- Hydrochloric acid spillage / hydrogen chloride gaseous emission to the environment
- Chlorine gaseous emission/ emergency vent systems
- Hazardous limitations to chlorine makeup storage
- Interface with the chlorine recovery system, leach plant and hydrogen and acid plant

The chlorine recovery, gas cleaning systems and emergency vent systems from the magnesium electrolysis are well understood by Bateman. A key project objective will therefore be the effective transfer of this experience, standards and procedures to this project.

Examples of Common Process Risks and Their Management

The following examples are presented for more detailed discussion.

1 Choice of materials of construction
2 Hazardous liquid spillage / gaseous release
3 Waste treatment / discharge to the environment
4 Reliability of equipment for any extreme duties
5 Integrity of the test-work
6 Licensing appropriate technology

Items 1and 2 clearly fall within the responsibility of the engineering contractor and are generally dependent on experience from similar types of projects.

An engineering contractor's related experience with the materials of construction suitable for chlorine, hydrogen chloride, hydrochloric acid, volatile alcohols and ammonia is important for managing these risks.

Use of Hazop Analysis Techniques in the detailed stages of the project will enable the sources of spillage and gaseous emissions to be identified and managed.

For item 3, identifying and defining the main waste solid, liquid and gaseous effluent streams early in the conceptual stages of the project is a prerequisite. This will include: -

- Development of an effluent treatment strategy early in the conceptual stages of the project
- Addressing likely environmental obligations for the life of the project.
- Understanding capital and operating cost implications
- The areas of responsibility and the environmental standards applied for the project life must be clearly defined and agreed between the permitting authorities, owner and the engineer as early as practical in the project.

Testwork is normally implemented to define and quantify risk within a process. It is a necessary part of evolving the process design, removing any guesswork or assumptions and, enabling equipment to be specified more accurately. Typically pilot plant testwork is a requirement for bankability / financing. The process areas mentioned above vary from known, established processes requiring little or no confirmatory testwork such as the hydrochloric acid plant, to a unique process such as the dehydration of magnesium chloride.

Item 4 will be investigated within the pilot plant program. For example solid-liquid separation for selection of equipment will include specific investigation of equipment reliability. A Pilot plant is considered fundamental to the success of this project and for this reason is discussed in more detail in the following section.

The licensing of appropriate technology imparts a degree of process risk to the technology supplier. The commercial risk carried by the technology supplier is typically limited to the services provided by the technology supplier. The selection of the licensed dehydration technology is discussed separately.

Testwork Requirements for the Project

Summary outline of project test program

The selection of properly representative samples for all the testwork is critical to the success of the whole project and sample selection is a carefully planned exercise involving the geologist, metallurgist and mining engineer. For practical and economic reasons, an ore body consisting of tens of millions of tonnes is finally represented by drill core. Knowledge of the composition and variability of the ore body will be used in selecting the testwork samples.

It has been mentioned previously that testwork will be fundamental to this project's success. Understandably some areas of the program remain confidential and will not be discussed in detail, however, a description of some of the key components of the program is given below.

Comminution – Specific Testwork Requirements

The selection of the appropriate flow sheet for the comminution section of the plant is dependent on the variability and the competency of the orebody. Detailed below is a typical list of the standard comminution testwork procedures proposed for this project.

- Unconfined Compressive Strength (UCS)
- Bond Crushing Work Index (BCWI)
- Bond Rod Mill Work Index (BRWI)
- Bond Ball Mill Work Index (BBWI)
- Abrasion Index

The determination of these parameters will provide comminution energy requirements and the relevant design data. Not all of the above comminution work will be necessary and judgement may be used based on knowledge of the orebody, experience and data when it becomes available.

Leaching Neutralisation / Purification Solid- Liquid Separation Bench Scale

To enable optimisation of the recovery leach kinetics, batch laboratory leaching tests will be conducted in order to;

1. Investigate the effect of multi stage leaching and co-current verses counter current leaching on acid utilisation and recovery
2. Determine the effect of solids particle size magnesium leaching kinetics, impurity solubilisation, foaming and effluent gas displacement of the charge.
3. Determine the effect of solids density on the magnesium leaching kinetics and impurity solubilisation, foaming and effluent gas displacement of the charge.
4. Determine effect of temperature on the magnesium leaching kinetics and impurity leaching kinetics, foaming and effluent gas displacement of the charge.
5. Investigate the effect of oxidising leaching versus reductive leaching on acid utilisation and recovery and impurity solubilisation
6. Determine effect of impurity build-up in the leach liquor recycle stream on the leaching kinetics.

From the information generated in the batch tests, the parameters for a continuous leaching train will be specified. A continuous leach train, run at a steady state, will confirm leaching efficiencies. In addition, solution for downstream neutralisation and impurity removal testwork will be generated.

For batch neutralisation and impurity removal bench-scale testwork the following will be considered.

1. Determine the solid / liquid separation characteristics at the optimum conditions identified by the previous leaching testwork.
2. Liquid and solid samples will be taken to quantify metal precipitation as well as associated magnesium losses;
3. Liquid and solid samples will be taken and analysed to examine impurity deportment; the solution produced will be tested to determine filtration characteristics (for polishing); the crystalline and chemical characteristics of the deposit will be examined and quantified for magnesium content.
4. Batch laboratory filtration tests will be conducted in consultation with the equipment suppliers.

The results will be used to define the process flowsheet for these areas, set the operating parameters and complete a more detailed mass balance.

Dehydration

The technology provider has implemented preliminary testwork and modelling, the details of which are confidential. Some confirmatory testwork will be required using the solutions generated from the abovementioned leach testwork. This testwork will typically be implemented in close consultation with the technology supplier.

Three discrete phases are envisaged for the testwork program namely;

1. A confirmatory batch bench / laboratory scale test-work program investigating the effects of the specific solutions generated from the leaching operation.
2. A detailed continuous bench/ laboratory scale test-work program test-work to optimise recycles etc. for the dehydration process.
3. A detailed design phase to determine the pilot plant requirement.

Pilot Plant and Economic Modelling

The revised mass balances for the leaching and dehydration areas can be completed based on information generated during this bench-scale testwork. Revised estimates of capital and operating costs for the plant will be updated accordingly. An economic model developed by Bateman Brown & Root for the project will be updated and used to monitor and compare the project economics for the project.

Thus data generated will also form a basis for the pilot plant design. The definition of the integrated pilot plant process flowsheet will be undertaken during the testwork program.

Technology License Implications

Various technologies have been licensed or developed for the production of dehydrated magnesium chloride by existing magnesium producers and potentially new producers.

A few of the more important alternative technologies include: -

- The Russian National Aluminium and Magnesium Institute and the Ukrainian Titanium Institute (VAMI / UTI) carnallite dehydration process. This technology is currently the subject of an exclusive license arrangement in Australia. Bateman Brown & Root, Asia-Pacific through Bateman Israel have first hand experience of the stringent engineering procedures required for the VAMI / UTI carnallite technology guarantees. (Ref. 3)

- Noranda's Magnola Process, developed to treat serpentinite tailings in Canada. Development is being conducted by Ontario-based Lakefield Research. It is understood that Noranda will not consider making this technology available for license until their 58,000 tpa plant has been commissioned. (Ref. 1)

- The Nalco / St Joe process proposed by Australian Magnesium Corporation for its full-scale plant in Gladstone. It is understood to be an ethylene glycol and anhydrous ammonia based process. (Ref. 2)

The complexity of these processes varies, however, the availability of the Alcan alcohol / ammonia dehydration technology (ref 5, 6), coupled with a flowsheet requiring fewer reagents to recycle and relatively low energy requirements favoured its incorporation into the flowsheet for the Main Creek magnesite project.

The Alcan multipolar electrolysis technology will also be fully compatible with the chosen dehydration technology and is itself recognised as requiring a low specific energy input per tonne of magnesium product (ref 7).

Conclusions

A combination of potentially low capital cost and the potentially lower energy cost for generic alcohol / ammonia based processes, in conjunction with multipolar electrolytic technology, has motivated the choice of this technology.

The key technical risks for the selected flow sheet have been identified. The majority of these risks are highlighted in this paper and are currently being addressed via the testwork program as described.

At this early stage of the project, it is not possible to mitigate all aspects of the process risks as outlined. However, combining the experience of the chosen research / testwork facilities and that of the project managers, together with the appropriate licensed technology, provides a degree of cover on the process risk for the project and a clear understanding of the way forward to the successful commercialisation of this technology.

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