PRE-FEASIBILITY STUDY
NT EVAPORITES PROJECT

30th July, 1992
# TABLE OF CONTENTS

## SECTION 1: MARKET & COMMERCIAL ASSESSMENT

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>SUMMARY CONCLUSIONS</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>COMMODITY ANALYSIS</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>POTASSIUM CHLORIDE (KCl)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>SODIUM CHLORIDE (NaCl)</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>POTASSIUM SULPHATE (K2SO4)</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>SODIUM SULPHATE (Na2SO4)</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>MAGNESIUM SULPHATE (MgSO4)</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>MAGNESIUM OXIDE (MgO)</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>POTASSIUM NITRATE (KNO3)</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>BROMINE (Br2) &amp; SODIUM BROMIDE (NaBr)</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>AMMONIUM CHLORIDE (NH4Cl)</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>AMMONIUM SULPHATE ([NH4]2SO4)</td>
<td>48</td>
</tr>
<tr>
<td>4</td>
<td>FINANCIAL ANALYSIS</td>
<td>50</td>
</tr>
<tr>
<td>5</td>
<td>RECOMMENDATIONS</td>
<td>51</td>
</tr>
<tr>
<td>6</td>
<td>DISCLAIMER</td>
<td>52</td>
</tr>
</tbody>
</table>

## SECTION 2: CONCEPTUAL PROCESS ENGINEERING STUDY

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SUMMARY</td>
<td>1-1</td>
</tr>
<tr>
<td>2</td>
<td>INTRODUCTION</td>
<td>2-1</td>
</tr>
<tr>
<td>3</td>
<td>SCOPE OF WORK</td>
<td>3-1</td>
</tr>
<tr>
<td>4</td>
<td>REVIEW OF EXISTING DATA</td>
<td>4-1</td>
</tr>
<tr>
<td>5</td>
<td>CRITICAL PROCESS ISSUES</td>
<td>5-1</td>
</tr>
<tr>
<td>6</td>
<td>DESIGN CRITERIA</td>
<td>6-1</td>
</tr>
<tr>
<td>7</td>
<td>DISCUSSION</td>
<td>7-1</td>
</tr>
<tr>
<td>8</td>
<td>BUDGET CAPITAL ESTIMATE</td>
<td>8-1</td>
</tr>
<tr>
<td>9</td>
<td>OPERATING ESTIMATE</td>
<td>9-1</td>
</tr>
<tr>
<td>10</td>
<td>EQUIPMENT LIST</td>
<td>10-1</td>
</tr>
<tr>
<td>11</td>
<td>PROJECT IMPLEMENTATION SCHEDULE</td>
<td>11-1</td>
</tr>
<tr>
<td></td>
<td>DISBURSEMENT SCHEDULE</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>REFERENCES</td>
<td>12-1</td>
</tr>
<tr>
<td>13</td>
<td>APPENDIX - GLOSSARY</td>
<td>13-1</td>
</tr>
</tbody>
</table>
PRE-FEASIBILITY STUDY

SECTION I:
MARKET & COMMERCIAL ASSESSMENT

NT EVAPORITES PROJECT

20th July, 1992
SECTION 1:
MARKET & COMMERCIAL ASSESSMENT
# TABLE OF CONTENTS

1. INTRODUCTION ........................................................................................................... 1
2. SUMMARY CONCLUSIONS ...................................................................................... 2
3. COMMODITY MARKET ANALYSIS ............................................................................ 3

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>POTASSIUM CHLORIDE</td>
<td>3</td>
</tr>
<tr>
<td>SODIUM CHLORIDE</td>
<td>8</td>
</tr>
<tr>
<td>POTASSIUM SULPHATE</td>
<td>17</td>
</tr>
<tr>
<td>SODIUM SULPHATE</td>
<td>21</td>
</tr>
<tr>
<td>MAGNESIUM SULPHATE</td>
<td>30</td>
</tr>
<tr>
<td>MAGNESIUM OXIDE</td>
<td>30</td>
</tr>
<tr>
<td>POTASSIUM NITRATE</td>
<td>30</td>
</tr>
<tr>
<td>BROMINE &amp; SODIUM BROMIDE</td>
<td>42</td>
</tr>
<tr>
<td>AMMONIUM CHLORIDE</td>
<td>45</td>
</tr>
<tr>
<td>AMMONIUM SULPHATE</td>
<td>48</td>
</tr>
</tbody>
</table>

4. FINANCIAL ANALYSIS ................................................................................................ 50
1. INTRODUCTION
|                | Sodium | Potassium | Magnesium | Ammonium | Sulphate | Chloride | Potassium | Magnesium | Ammonium | Sulphate | Chloride |
|----------------|--------|-----------|-----------|----------|----------|----------|-----------|-----------|----------|----------|----------|----------|
| Sodium chloride |        |           |           |          |          |          |            |           |          |          |          |          |
| Potassium chloride |     |          |           |          |          |          |            |           |          |          |          |          |
| Magnesium carbonate |   |          |           |          |          |          |            |           |          |          |          |          |
| Ammonium sulphate |       |          |           |          |          |          |            |           |          |          |          |          |
| Bromine         |        |           |           |          |          |          |            |           |          |          |          |          |
1. INTRODUCTION

Status Resources Australia was commissioned by the Northern Territory Department of Industries & Development to undertake a Pre-Feasibility Study on behalf of NT Evaporites (NTE) to assess the possibility of developing commercially the extensive brine resources which NTE had delineated and assayed on mining tenements held by them SW of Alice Springs, Northern Territory, Australia.

Status Resources has undertaken the marketing and commercial analysis for this project, which comprises Section I of this Report, and BHP Engineering was commissioned to undertake the conceptual process engineering segment of the Study, which forms Section II of the Report.

The project is fully described in Section II.

In the first instance it was decided to evaluate the commercial potential of a series of 12 products which could be derived from the NT brines. They are:

- Sodium sulphate (Na₂SO₄)
- Magnesium sulphate (MgSO₄)
- Potassium sulphate (K₂SO₄)
- Potassium chloride (KCl)
- Magnesium carbonate (MgCO₃)
- Magnesium oxide (MgO)
- Sodium chloride (NaCl)
- Sodium Bromide (NaBr)
- Bromine (Br₂)
- Ammonium sulphate ([NH₄]₂SO₄)
- Ammonium chloride (NH₄Cl)
- Potassium nitrate (KNO₃)

Each of these commodities has been analysed from an Australian and Pacific region market perspective, with a considerable degree of detail in respect to domestic Australian markets. Details of industry structure in respect to competitive sources of supply have been covered in some detail. Where possible, regional export market opportunities have also been analysed, however it was soon realised that the production levels from the proposed NT operation which became the parameters of this Study were such as to be able to be well within Australian domestic demand for each of the chemicals being assessed.

In an attempt to bring a degree of focus to the project it was decided that a plant should be designed to produce three basic brine derivatives, all of which had been shown to have commercial potential. These were thenardite (Na₂SO₄), potassium sulphate (K₂SO₄), potassium chloride (KCl), with halite (NaCl) as either a waste by-product or a saleable one. Each of the eight remaining commodities listed above have also been assessed as potential future products, of which some have potential, namely magnesium sulphate, sodium bromide/bromine, and potassium nitrate. Each of these could return additional revenue to the project, depending upon future market developments, further brine characterisation and suitable process design.

All revenue streams in the COMMODITY MARKET ANALYSIS are based on ex-plant unit selling prices which have been derived after taking into account likely transport costs to the respective market locations of the end-users.
2. SUMMARY CONCLUSIONS
Main Products

$Na_2SO_4 \rightarrow$ detergents, glass, pulp & paper
40000 tpa @ $1.15 = $4.6 m

$K_2SO_4 \rightarrow$ fertiliser
3000 tpa @ $3.60 = $1.1 m

$KCl \rightarrow$ oil & gas, fertiliser
3000 tpa @ $2.90 = $890

$NaCl \rightarrow$ roads, stockfeeds, oil & gas, food
40000 tpa @ $0.50 = $2.0 m

Sales revenue $10.8 m
Capital cost $11.9 m
Operating cost $2.44 m

\[ \frac{\text{Sales revenue} - \text{Capital cost}}{\text{Operating cost}} > 15\% \]
2. SUMMARY CONCLUSIONS

The key markets into which the proposed products need to be sold are:

Sodium sulphate: Powder detergent, glass and pulp & paper
Potassium sulphate: Fertiliser
Potassium chloride: Oil & gas, fertiliser
Sodium chloride: Swimming pool, stockfeed additives, oil & gas, food processing

With the exception of salt, each of the other chemicals would be import replacements. All are relatively inexpensive commodities, and therefore are highly transport sensitive. Transport considerations therefore have been addressed in this Study, as to a lesser extent have been handling and packaging.

The Study has established that sales could possibly be generated of the following order of magnitude:

<table>
<thead>
<tr>
<th>Product</th>
<th>Sales (tpa) @ ex-plant price</th>
<th>Revenue (p.a.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium sulphate</td>
<td>40,000</td>
<td>$6,600,000</td>
</tr>
<tr>
<td>Potassium sulphate</td>
<td>3,800</td>
<td>$1,368,000</td>
</tr>
<tr>
<td>Potassium chloride</td>
<td>3,000</td>
<td>$870,000</td>
</tr>
<tr>
<td>Sodium chloride</td>
<td>&lt; 40,000</td>
<td>$2,000,000</td>
</tr>
</tbody>
</table>

These sales volumes are based on current Australian domestic demand only, and fall within the planned production capacity of the project as it is, at this stage, conceived. As the chapter on Sodium Sulphate indicates, detergent demand for this chemical may decrease in Australia during the end of this decade, and to supplement this there is an equivalent sized market in New Zealand's pulp and paper industry for sodium sulphate which is currently imported and could be addressed from the NT project.

With the exception of bromine chemicals, and possibly the three potassium salts, Asian export markets are likely to be difficult to enter, due to local regional competition. However, there is a real possibility of establishing additional sales for potassium chloride and potassium nitrate into agricultural and oil and gas markets in New Guinea, New Zealand and in ASEAN countries which could provide the project with significant incremental sales opportunities should brine resources adequate for such production be shown to exist.

Thus, a sales revenue up to $10.8M per annum is possible within the parameters of this Study, based on domestic sales, or one of $8.8M if the halite salt is regarded as a waste product. Sales valued at least at an additional $13M could be addressed with the production of magnesium sulphate, potassium nitrate, bromine and with some penetration into regional export markets.

Budget capital costs have been identified as being $11.91M, and operating costs are shown to be $2.44M p.a. In the financial analysis provision has been made for some road construction as well as for bulker bag handling of products, although it is anticipated that the greater tonnage of the three main products will be sold in bulk.

A series of Net Present Value calculations and sensitivities has been undertaken and appears in the Appendix. They show that the project will provide suitable returns through a range of discount rates, levels of sales and capital expenditure. The Base Case A shows an NPV surplus after tax of $4.88M at a 15% discount rate, $8.35M @ 12%, and an $11.22M NPV surplus @ 10% discount over a 15 year operation.

Such a result provides a significant measure of confidence in the project, and indicates that further funding allocation is warranted to provide additional assessment of the resource and the commercial opportunities on which its development is based.
3. COMMODITY MARKET ANALYSIS
3. COMMODITY ANALYSIS

POTASSIUM CHLORIDE (KCl)

World Production: 46M tpa

(a) Industry Applications

Fertilisers: Source of potassium, especially in Qld. sugar industry. Known as muriate of potash. The muriate or chloride form is the cheapest source of potassium for fertilisers. Pasture and forage crop regrowth is faster with adequate potassium supplements, as are lucerne and grass-legume pastures. The sugar industry is a major user.

Oil drilling muds, oil & gas fraccing: KCl is the major clay stabiliser used in the oil drilling industry. Clay stabilisers are routinely added to aqueous stimulation and completion fluids to prevent damage to the formation. These clay stabilisers can be of either a temporary or permanent type, and are often used in combination. Temporary clay stabilisers are materials such as KCl, NH₄Cl, CaCl₂ and NaCl which, when added to fresh water, prevent the injected fluid from swelling or dispersing clays.

Permanent clay stabilisers, such as zirconium salts and certain polymers, are usually applied using a carrier fluid containing a temporary stabiliser, such as KCl, to prevent the carrier from damaging the formation.

Of the the temporary clay stabilisers, KCl is the product most commonly used. It is quite effective and is routinely added to aqueous fracturing fluids at concentrations of 1% to 3%. Other salts, such as NH₄Cl, CaCl₂ and NaCl, have also occasionally been used. Recently, some organic compounds have also been proposed for this application. However there is little likelihood of KCl's well entrenched position in these applications being usurped to any significant degree in the foreseeable future. It has been concluded in industry research¹ that some proposed KCl substitutes are not as effective as ordinary KCl. Apart from its use in drilling muds and well completion fluids, to a lesser extent KCl is also used in the hydrofraccing of tight formations.

There is some concern in respect to potential environmental impact. Esso in Bass Strait was using up to 10%-12% concentrations. This has been reduced to 2%-3%. KCl is typically used at concentrations of 6%-8% and is widely used in Australia, PNG, NZ and SE Asia.

(b) Australian End-Users

Fertilisers

This industry is the major user of KCl. Major users include Incitec - Brisbane, Cairns, Newcastle, as well as Pivot and other fertiliser companies and distributors. A stockfeed and fertiliser distributor, Natcorp Marketing, as an example of a medium size distributor, purchase 250 tpa from Incitec's warehouse in Newcastle.

Oil & Gas Industry Service Companies

This is a subsidiary use in terms of tonnage, but an important market for NTE to address. The major users are:
M-I Australia (Dresser/Halliburton - US): WA, Qld & Timor 500 tpa in a low demand year, 1,000 - 1,500 tpa in a good year @ $400-$500 per tonne.
Baroid Australia (NL Inds Inc - US)
Milpark (Baker Hughes International)
Dowell Schlumberger: Hydro-fracking, clients tend to purchase their own requirements. Purchased some tech grade from Top Fertilisers in Brisbane @ $400/t
Halliburton Australia: Their use for hydrofracking together with that of Dowell Schlumberger's, is currently in the order of 120 tpa in Australia.

Oil & Gas Producers
Esso-BHP - Bass Strait, Timor Sea
Santos - Cooper-Eromanga Basins & Roma: 520 tpa ag. grade @ $320/t ex Adelaide, 400 tpa tech. grade @ just over $400/t. 1990 level of use: 950tpa ag. grade, 500tpa tech. grade.
WAPET - Barrow Is., WA
AGL - Qld.
Bridge Oil - Roma, Qld
Hartogen
Ampol

(2) Australian Producers
None, nor are there any in the region at present, with the notable exception for major potash production in Thailand (Refer below)

Minable marine potash deposits have not as yet been discovered in Australia although occurrences of potash minerals are known in the Adavale Basin in Queensland. Potash production was scheduled by Texada to begin in 1973 from the brines of Lake McLeod in WA (Refer Section on Salt elsewhere in this Report). The brines occur in porous halite and gypsum sediments approximately 20 cm below the dry lake surface. The brines were to be concentrated by solar evaporation and then processed to yield a synthetic langbeinite product ($K_2SO_4 \cdot 2MgSO_4$). The programme was curtailed in 1974, and in 1978 Texada was acquired by Dampier Salt Co. Ltd. In 1981, construction of test crystallisers and pilot plant tests commenced with production scheduled by 1985. This development was also subsequently suspended. However the writer has had several indications during the preparation of this Report that Dampier Salt has recently been exploring the potential for production of evaporite salts other than halite from this source.

(3) Australian Importers
Incitec, Pivot Fertilisers, Bisley & Co. Incitec imports 80,000 - 90,000 tpa, all from Canpotex, in Canada.

(4) Overseas Production & Trade
Canpotex of Canada: This is a marketing cartel of producers comprising Potash Corp. of America, Potash Corp. of Saskatchewan (PCS) and others. PCS is currently producing around 4M tpa.

Israel & Jordan are other major potash producers. Arab Potash (Jordan) will invest an estimated US$106M to raise KCl capacity by 400,000 tpa from 1.4M tpa at present. The planned cold crystallisation process refinery is expected to be in production 1994-95. Jordan exported 842,000 tonnes of potash in 1990.

Argentina, Brazil, Paraguay and Uruguay have entered into a trade pact under which tariffs on most products will be abolished. This trade accord will eliminate tariffs on fertiliser chemicals, which had been imported from Europe & Canada. The new common market could result in increased chemical production for the member
nations. Compania Minera TEA (Argentina) will spend up to US$60M to develop a potassium mine in Argentina that would enable the company to make KCl for fertiliser applications. Minera TEA hopes to extract enough raw materials to produce 250,000 tpa of KCl by 1994. If it can develop the rest of the deposit in Neuquen province, yields could be much larger. Argentina's demand for potassium chloride totals about 30,000 tpa. Brazil has an annual demand in the order of 2.5MT. Supply to this could be augmented should the Minsal project in Chile proceed. It was planned to start up in 1994-95, with an output of about 530,000 tpa of KCl and 270,000 tpa of potassium sulphate.

In 1990 Japan imported 944,000t of which Canada was the major supplier with 587,3000 tonnes. The USSR supplied 182,800 tonnes to Japan.

Discussions have commenced in Israel between Chinese representatives and two Israeli companies, Dead Sea Works, and the Eisenberg Group, on setting up a potash plant in China. The proposed 800,000 tpa plant would be located at a salt lake in NW China at a cost of US$300M, of which US$70M would be for engineering services & equipment from Israel. The plant would use the cold crystallisation process in use at Dead Sea Works. The Israelis would have a 25% interest in the project. China currently imports all of its potash requirements of around 2MTpa.

There is a development in Thailand which could impact upon the current supply/demand dynamics in the region. This is the ASIAN Industrial Project (AIP) which plans to develop potash reserves at Bannmet Narong in Chaiyaphum province in northeastern Thailand. These potash reserves are among the largest in the world, covering an area of 2,468 acres. Geological reserves are estimated at 570MT, producing 30MT of mineable reserves. The project is to be operated by a joint venture company under the name ASIAN Potash Mining Holding Company Limited to supply potash fertilisers in the region. The shareholders comprise Thailand 71% (of which 20% is held by the government and 51% by private companies), Indonesia 13%, Malaysia 13%, Philippines 1%, Singapore 1%, and Brunei 1%, with a total investment approximating A$385 million.

The project comprises two sub-projects, a potash mining project and a potash fertiliser project. Production is scheduled to commence in 1996 and it is planned to produce 1MT of potash annually. The aim is to save in foreign exchange payments, saving about A$36m by replacing imports, and allowing a potential improvement of A$120m in exports of domestic market surplus.

Apart from the Thai project detailed above, there is no other KCl production in ASEAN countries.

(5) Product Requirements & Specifications
Agricultural Grade: KCl 96.3%, & Technical Grade: KCl 99.1%. 3-5mm granules are supplied by Incitec from Newcastle. With KCl, as with many fertilisers, there are two main size gradings, a coarse grade for spreading, and a fine grade for soluble fertilisers. Although the lower purity "agricultural" grade can be used in drilling muds, the trend is to use the purer (more soluble) grade. This must be used in completion fluids. The oil industry buys in 25kg bags.

(6) Current & Forecast Levels of Demand
Oil & Gas Industry - (Australia): 4,500 tpa - 7,500 tpa (currently both grades)
- (PNG, NZ, ASEAN & NE Asia): approx. 40,000 tpa
Fertiliser Industry (Australia): 100,000 tpa +
1991 Australian Imports

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<tr>
<td>WA</td>
<td>23,000</td>
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<tr>
<td>Qld</td>
<td>80,000</td>
</tr>
<tr>
<td>SA</td>
<td>7,000</td>
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</table>

(7) Commercial Determinants of Demand

FERTILISER INDUSTRY: Agricultural demand, especially sugar-cane in Qld.

OIL & GAS INDUSTRY: Levels of exploration activity. The recent announcement (July, 16, 1992) that $7 billion is likely to be spent over the next seven years on additional development of the North West Shelf oil & gas project indicates good growth potential for oilfield servicing products. The Wandoon oil discovery is much larger than was expected and the Cossack/Wanaraa fields are now likely to be brought into production by mid-1995. These projects are all being underpinned by the strong overseas growth in LNG demand, and therefore this will be reflected in increased demand for KCl in Australia.

(b) Potential Impediments to Demand

Longer term environmental pressures against an increase in Cl ion excesses in the environment.

(8) Domestic & Import Prices

Agricultural Grade Domestic prices - @ $274/t ex Pivot warehouses Adelaide & Geelong. Natcorp Marketing, located at Charbon, near Lithgow, NSW, pays $400/t bulk KCl in 25 tonne loads ex Incitec, Newcastle. Technical Grade Domestic Prices - @ $400/t - $500/t FIS. Both are packed in 25kg bags or 1 tonne bulker bags, although some deliveries of ag-grade into the rural industry may be bulk.

In order to supply the oil & gas industry off-shore Darwin, technical grade KCl would need to be landed in Darwin at somewhat under A$400 per tonne, in the order of $375 per tonne.

(9) Supply - Demand Dynamics

Australia is wholly import dependant. World fertiliser demand and overseas plant capacity are major determinants of the imported price into Australia.

(10) Transport, Shipping & Logistics

Major KCl fertiliser markets are in Queensland, with current road transport rates being quoted at $105/t. However fertiliser markets closer to the NT plant in SA, Vic & NSW account for over 20,000 tpa which alone is several times more than NTE's initially planned output. Demand for Tech. Grade KCl in the oil & gas industry is increasing, and focuses upon SA, Darwin, NW Shelf & Vic, with freight rates, in the case of SA, being no more than $30/t with Vic & NSW rates less than $80/tonne.

Sixty per cent of oil & gas demand for KCl is from Timor (Darwin) and Karratha - NW Shelf (Dampier), the rest divided between Roma Qld), SA & Sale (Vic). This pricing structure would translate to an ex-plant Alice Springs bagged price for technical grade in the order of $290 per tonne, and for agricultural grade at $240 per tonne.

(11) Future Market Trends & Alternative Products

Trends for oil exploration and rural demand in the medium to long term will be definitely characterised by growth. There are some environmental concerns re high concentrations of Cl- into our soils and drainage systems, but these are relatively low key, and are not likely to be expressed commercially. There do exist some patented synthetic weighting fluids that are used by Dowell Schlumberger in a very limited extent in completion wells instead of KCl, but costs are prohibitive for a significant usage of these in the oil & gas industry.
(12) Likely Domestic Market Share Addressable by NTE
Planned production by NTE of 3,000 tpa of KCl represents only about 3% of Australian demand. If NTE were to concentrate in producing the 99% KCl tech. grade largely for the oil & gas industry, in Australia, the market for which fluctuates between 2,500 tpa and 5,000 tpa, selling any surplus into the fertiliser industry, it would have a guaranteed growth market.

(13) Likely Export Market Share Addressable by NTE
If a viable large scale supply of potassium rich brine could be established by NTE then export markets for this commodity in the SE Asian & N.E. Asian region could be secured totalling 20,000tpa for the oil & gas industry alone.

In order to confirm previous estimates of demand for KCl in the oil & gas industry in S.E. Asia, contact was made with Baroid, the US drilling services company based in Singapore. Their Singapore office is responsible for all of Asia, (excluding Australia, New Guinea, Indonesia and New Zealand). Singapore is the major centre of supply for goods and services into the SE Asian oil & gas industry. Chemical trading companies such as International Chemicals import large tonnages of bulk KCl both as fertiliser and as technical grade for the oil & gas industry. Their warehousing operations often include bagging facilities for local distribution. Such are the vagaries of international supply that earlier this year Baroid supplied 2,000 tonnes of KCl from Singapore into a Middle East oil project, because the material was obtained ex Singapore at internationally attractive prices. Mitsubishi is a major supplier of KCl into the oil & gas industry in the region, and Status is advised that this material originates in Japan, although at present we have no other data confirming any Japanese production, other than that Japan is a net importer. Baroid in Singapore often purchases from Mitsubishi as Mitsubishi is the most competitive and aggressive supplier. KCl costs between US$7.00 and US$8.00 per 50kg sack ($US$140 - $160/tonne). Baroid has purchased 10,000 sacks in the last 5 months - excluding purchase for the Middle East, which translates to 1,200 tpa. This is just Baroid’s requirement, which we are advised is 20% of the regional demand - i.e. 6,000 tpa. This figure, however, does not take into account material used in fracturing, which is likely to be a further 1,000 tpa. Demand by the oil & gas industry in Indonesia is approximately the equivalent of this.

It should be stressed that current exploration and demand for oil in the region is considerably lower than usual - this has been a very lean year for the industry, and in more normal years, demand is more than double the figures quoted above. Thus the demand for technical grade KCl in ASEAN fluctuates between 14,000 tpa and 25,000 tpa, depending upon levels of activity. In order to compete in this market the NTE project would need to be able to land technical grade KCl in Singapore for around US$150 (A$200) per tonne. Assuming this meant an ex-plant cost of A$100 per tonne for export orders (less than half the domestic price) an incremental revenue stream of $500,000 ex plant would be generated per each 5,000 tonne shipment.

Fertiliser demand for KCl in the region is of the order of 2Mtpa.

(14) Revenue Streams
3,000 tpa x $290 = $870,000

2. Mr. Keith Steel, General Manager of Baroid, Singapore
**SODIUM CHLORIDE (NaCl)**

**World Production**
World salt (halite) production in 1990 totalled an estimated 190.5MT, an increase of 6MT over 1989 production.

(1) **Industry Applications**
By far the most important consumer of salt is the chemicals industry, in particularly the chloralkali sector which accounts for about 60% of total production, followed by human consumption (20%), road de-icing in Europe and North America (10%), agriculture (5%).

**SALT FOR CHEMICAL INDUSTRY:** In the inorganic chemicals industry salt is used in the electrolytic production of chlorine, caustic soda, hydrogen, etc. It is also used for the production of sodium sulphate, hydrochloric acid, titanium dioxide pigments, etc. In chloralkali manufacture calcium and magnesium must be precipitated and hence there is a price penalty on salt which does not reach a 96% NaCl grade. Insolubles, on the other hand, do not present a problem in halite for chloralkali production since in any wet process they can be floated off.

**INDUSTRIAL SALT:** This is supplied as either undried or as dried salt (sieved and unsieved), granular, and either in bags or in bulk. User categories comprise the following industries:

- **Agriculture:** For fertilising and ensilage and for stockfeed additives
- **Fishing:** For fish curing and preserving
- **Oil & Gas:** For well drilling fluids
- **Textiles:** For dying processes
- **Leather:** For tanning & salting of hides
- **Recreation:** For municipal, resort & domestic salt water swimming pools & spas
- **Miscellaneous:** Wood products, Paper, Metal processing

**DE-ICING SALT**
(ROAD SALT):
For de-icing roads and footpaths in cold climates.

**CONSUMPTION SALT:**
- **Food & beverages:** sieved salt for the preservation of vegetables & meat, for meat processing and dairy processes
- **Household:** Table and cooking salt

**COMPACTED SALT:**
- **Agriculture:** In salt licks for the supplemental feeding of cattle and other livestock
- **Industry:** For the regeneration of water softeners, and a range of other industrial uses
- **Household:** For the regeneration of water softeners
- **Retail:**

**CHEMICALLY PURE SALT:** For pharmaceutical & medical application, saline drips
(b) **Australian End-Users**

A cross section of Australian salt consumers are listed in the following table. The list is by no means meant to be all inclusive, but it presents some picture as to the diversity of application and end-user in the domestic market.

<table>
<thead>
<tr>
<th>COMPANY</th>
<th>USE</th>
<th>LOCATION</th>
<th>APPROX. tpa</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICI Australia</td>
<td>Caustic soda prodn.</td>
<td>Sydney, Melbourne</td>
<td></td>
</tr>
<tr>
<td>Penrice Soda</td>
<td>Chlorine prodn.</td>
<td>Osborne, SA</td>
<td></td>
</tr>
<tr>
<td>APPM</td>
<td>Caustic soda, Cl₂</td>
<td>Burnie, Tas</td>
<td></td>
</tr>
<tr>
<td>Amcor</td>
<td>Caustic soda, Cl₂</td>
<td>Maryville, Morwell, Vic</td>
<td></td>
</tr>
<tr>
<td>SCM Chem Co.</td>
<td>Ti pigment</td>
<td>Kemerton, Kwinana, WA</td>
<td></td>
</tr>
<tr>
<td>Tioxide</td>
<td>Ti pigment</td>
<td>Whyalla, SA (Planned)</td>
<td></td>
</tr>
<tr>
<td>CSBP Farmers Ltd</td>
<td>Caustic soda, Cl₂</td>
<td>Kwinana, WA</td>
<td></td>
</tr>
<tr>
<td>Minproc</td>
<td>Sodium cyanide</td>
<td>Kwinana, WA</td>
<td></td>
</tr>
<tr>
<td>NuFarm</td>
<td>Chlorkalkali plant</td>
<td>Bunbury, WA</td>
<td></td>
</tr>
<tr>
<td>Santos</td>
<td>Oil &amp; gas drilling</td>
<td>Moomba, SA</td>
<td>1,000</td>
</tr>
<tr>
<td>M-I Aust.</td>
<td>Oil &amp; gas drilling</td>
<td>Pt. Hedland, WA</td>
<td>150</td>
</tr>
<tr>
<td>Baroid Aust.</td>
<td>Oil &amp; gas drilling</td>
<td>Darwin, various</td>
<td>150</td>
</tr>
<tr>
<td>Esso</td>
<td>Oil &amp; gas drilling</td>
<td>Bass Strait</td>
<td></td>
</tr>
<tr>
<td>Milpark</td>
<td>Oil &amp; gas drilling</td>
<td>WA, NT</td>
<td>150</td>
</tr>
<tr>
<td>Various pool shops</td>
<td>Swimming pools</td>
<td>All states</td>
<td>35,000</td>
</tr>
</tbody>
</table>

Other users, with current prices, are set out in the following table:

<table>
<thead>
<tr>
<th>User</th>
<th>Location</th>
<th>Supplier</th>
<th>Deliv. S/t</th>
<th>Pckging/type</th>
<th>tpa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Centre Pools</td>
<td>Alice Springs</td>
<td>Pacific</td>
<td>$153.60</td>
<td>25kg bags</td>
<td>15</td>
</tr>
<tr>
<td>Airlite Pool &amp; Spa</td>
<td>Alice Springs</td>
<td>Pacific</td>
<td>$180.00</td>
<td>25kg bags</td>
<td>20</td>
</tr>
<tr>
<td>Pooland</td>
<td>Darwin</td>
<td>NT Salt</td>
<td>$240.00</td>
<td>25kg bags</td>
<td>30</td>
</tr>
<tr>
<td>Delaneys Produce</td>
<td>Darwin</td>
<td>NT Salt</td>
<td>$240.00</td>
<td>25kg bags</td>
<td>30</td>
</tr>
<tr>
<td>Viking Fibreglass</td>
<td>Darwin</td>
<td>NT Salt</td>
<td>$296.00</td>
<td>25kg bags</td>
<td>30</td>
</tr>
<tr>
<td>Figleaf Pool</td>
<td>Darwin</td>
<td>NT Salt</td>
<td>$300.00</td>
<td>25kg bags</td>
<td>30</td>
</tr>
<tr>
<td>Maurice's Pool Shop</td>
<td>Darwin</td>
<td>NT Salt</td>
<td>$300.00</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Olympic Dam</td>
<td>Roxby D, SA</td>
<td>Pacific</td>
<td>$200.00</td>
<td>crse refnd,bgs</td>
<td>13</td>
</tr>
<tr>
<td>Goodman Fielder</td>
<td>Sydney, NSW</td>
<td>Cheetham</td>
<td>$200 +</td>
<td>&quot;flossy&quot; food grd,</td>
<td>60</td>
</tr>
<tr>
<td>Santos</td>
<td>Whyalla, SA</td>
<td>Pacific</td>
<td>$190</td>
<td>&quot;flossy&quot;, bgs</td>
<td>1,000</td>
</tr>
<tr>
<td>Vella Stockfeeds</td>
<td>Riverst'n NSW</td>
<td>Pacific</td>
<td>$150-200</td>
<td>&quot;flossy&quot; salt</td>
<td>24</td>
</tr>
<tr>
<td>Young Stockfeed</td>
<td>Young, NSW</td>
<td>Cheetham</td>
<td>$127</td>
<td>&quot;Feed Grade #2&quot;</td>
<td>100</td>
</tr>
<tr>
<td>Colborn Dawes</td>
<td>Wagga, NSW.</td>
<td>Cheet/Dia</td>
<td>$140</td>
<td>&quot;A-Mix&quot;</td>
<td>300</td>
</tr>
<tr>
<td>Natcom Mktng</td>
<td>Charbon, NSW</td>
<td>Hattah Salt</td>
<td>$120</td>
<td>1tonne b.bags</td>
<td>1,000</td>
</tr>
<tr>
<td>Manildra Stk Feeds</td>
<td>Orange, NSW</td>
<td>Pacific</td>
<td>$130</td>
<td>Swim pool, bags</td>
<td>50</td>
</tr>
<tr>
<td>Coffs Hrbr Produce</td>
<td>Coffs H. NSW</td>
<td>Ch'tham*</td>
<td>$2080</td>
<td>Swmmg Pool</td>
<td></td>
</tr>
<tr>
<td>Coffs Hrbr Produce</td>
<td>Coffs H. NSW</td>
<td>Ch'tham*</td>
<td>$240-2800</td>
<td>Table salt</td>
<td></td>
</tr>
<tr>
<td>Coffs Hrbr Produce</td>
<td>Coffs H. NSW</td>
<td>Ch'tham*</td>
<td>$240-2800</td>
<td>Flossey</td>
<td></td>
</tr>
<tr>
<td>Coffs Hrbr Produce</td>
<td>Coffs H. NSW</td>
<td>Ch'tham*</td>
<td>$200-2800</td>
<td>coarse</td>
<td></td>
</tr>
<tr>
<td>Arnotts Biscuits</td>
<td>Sydney, NSW</td>
<td>Cheetham</td>
<td>$210-2200</td>
<td>&quot;household&quot;</td>
<td>250</td>
</tr>
<tr>
<td>Arnotts Biscuits</td>
<td>Sydney, NSW</td>
<td>Cheetham</td>
<td>$210-2200</td>
<td>&quot;table&quot;</td>
<td>67</td>
</tr>
<tr>
<td>Arnotts Biscuits</td>
<td>Sydney, NSW</td>
<td>Cheetham</td>
<td>$210-2200</td>
<td>Super-fine</td>
<td>13</td>
</tr>
<tr>
<td>Arnotts Biscuits</td>
<td>Sydney, NSW</td>
<td>Cheetham</td>
<td>$210-2200</td>
<td>Dairy &amp; cheese</td>
<td>22</td>
</tr>
<tr>
<td>Arnotts Biscuits</td>
<td>Brisbane</td>
<td>Cheetham</td>
<td>$270</td>
<td>Dairy</td>
<td>276</td>
</tr>
<tr>
<td>Arnotts Biscuits</td>
<td>Vic &amp; SA</td>
<td>Cheetham</td>
<td>$220</td>
<td>Various</td>
<td></td>
</tr>
<tr>
<td>Melcann</td>
<td>Adelaide</td>
<td>Cheetham</td>
<td>$113-120</td>
<td>Swim-pool</td>
<td>30</td>
</tr>
</tbody>
</table>

* Wholesalers for Cheetham, ♦ wholesale prices from Coffs Hbr. Produce to retailers. Swimming Pool Grade salt into Northern NSW comes only from South Australia, as Bajool (Qld) material allegedly has river water impurities in it which makes it unsuitable for salt pools.
Other large food industry users (significantly larger than Arnotts) include:

- Unilever - margarine, soups, tomato sauce
- Heinz - canning
- Edgells
- Campbells - soups
- Amatil - "Smiths" chips
- Pepsi - "FriLay"
- Eta Foods, White Wings
- Kraft - cheese
- Plumrose - cheese

Smallgoods producers - salami, preserved meats, bacon & ham producers - very large.
Fish co-op - prawns

It should be noted that neither Arnotts, nor any of the companies listed above, are subsidiaries of either National Foods, nor Goodman Fielder Wattie, who have equity links with Cheetham and Diamond Salt.

(2) Australian Producers

Salt is one of Australia's major mineral export commodities. Annual production is around 7.8 Mt, of which about 6.5 Mt is exported. Exports of salt from Australia were worth A$170m in 1990.

There are eight major producers with an installed capacity of almost 9m tpa. Production from WA is of high quality, low cost mineral suitable for export and accounts for 80% of national salt exports. Most producers are increasing their capacity to meet increased future demand from the chloralkali industry, which is expected to grow, particularly in North Asia, S.E. Asia and in the Indian Ocean Region, and to combat increasing competition from other salt producing countries, such as Mexico which is expanding production from 5m to 7m tpa. Production from the eastern states (Qld, SA, & Vic) although well established, serves mainly domestic markets.

The requirements for a solar salt field include high evaporation rate, low rainfall, and for export markets, short haulage distance from the production site to a deepwater port. Currently Australian salt for export is priced at about US$15-20 per tonne bulk FOB and as it is clear that the proposed production site in the vicinity of Alice Springs with a freight rate of A$30 to the Port of Adelaide, there can be no consideration of salt being produced for the general export market from this operation. The WA salt fields generally are able to comply with all these conditions. Their main drawback, however is the cyclone season which has in the past severely dislocated production.

All Australian salt is produced by solar evaporation, mainly of seawater, but also from brine lakes and underwater brines.

DAMPIER SALT LTD.

This is a CRA subsidiary, CRA 64.9%, Marubeni 20.5%, Nissho Iwai 10.1%, C. Itoh 4.5%. Dampier is Australia's largest salt producer operating two fields at Dampier and Lake MacLeod on the north west coast of WA.

The Dampier salt field is located about 1,300km north of Perth near the town of Karratha. An expansion was recently completed near the town of Dampier which

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Much of the data in Section (2) describing the Australian salt industry is from an article on "Australian Minerals" by Joyce Griffith in "Industrial Minerals", June, 1992
increased production capacity to 3m tpa. Production is based on a continuous process of seawater evaporation. After harvesting and washing in a 1,000 tph capacity plant the salt is conveyed to a stockpile where it drains for about two months. Salt is then reclaimed by front-end loaders into road trains for transportation 16km over a causeway to a dry stockpile at the company's ship loading facility at Mistaken Island. The berth can accommodate vessels up to 75,000dwt but has been designed to allow further dredging for vessels up to 100,000dwt.

The Lake MacLeod salt field 65km north of Carnarvon uses naturally occurring concentrated sub-surface brine which does not require primary concentrating ponds. The brine occurs as an aquifer in halite and underlying gipsite layers in a coastal lake separated from the Indian Ocean by coastal dunes and rock outcrops. The lake is 110km long and 40km across its widest section. Natural underground caverns provide a constant input of seawater to two ponds at the northern end of the lake. To recover brine from Lake MacLeod a 6.5km collection ditch 4 metres deep has been cut into the halite layer near the southern end of the lake. The brine is pumped from there to a collection point before being pumped to crystallisers. The brine remains in the crystalliser for about eight months before being hauled 24km by road trains to a stockpile at Cape Cuvier to await shipment. Reclamation for shiploading is effected by dozers pushing over a 30 metre cliff to a hopper which feeds a ship loader conveyor. The company has also installed equipment to incorporate additives such as free-flowing agents, to meet customer requirements.

Dampier Salt has steadily increased production in recent years and in 1991 shipped 4.1m tonnes of salt. The chloralkali market takes 90% of Dampier's output, largely to Japan taking 70%. Other important markets are Taiwan, Indonesia, Korea and the Philippines. Outside Asia, Dampier has supplied salt to the USA, Brazil, Saudi Arabia, Nigeria and South Africa.

Dampier Salt accounts for 23% of world seaborne salt trade, and ranks just behind the world's biggest exporter, Exportadora de Sal, a joint venture between Mitsubishi and the Mexican Government. Dampier Salt's sales in 1991 were nearly $90m, and it contributed 12.9M to CRA's group profit, which would indicate that Dampier's total profit for the year was around $19.8M.

LESLIE SALT (CARGILL AUSTRALIA LTD)
The company is wholly owned by Cargill Inc. of the USA, one of the world's largest private agricultural commodity traders and processors. The company is Australia's second largest producer from a single solar salt operation at Port Hedland in WA. The plant has a capacity of 2.25m tpa.

The operation is based on seawater from the Indian Ocean which is pumped to a concentrator pond system, 30km west of Port Hedland where it is evaporated to 95% NaCl concentration. The brine is then pumped 22km along a ditch to the crystallisers. From there road trains transport the salt to the washing plant and then a further 8km to the port where it is stockpiled for eventual ship loading. Cargill has commenced work to increase output by a further 500,000 tpa. This additional production is planned to be available in 1994. Japan is its major consumer, taking about 1m tpa, followed by Korea (400-450,000 tpa), and Taiwan (300,000 tpa), with Indonesia and the Philippines taking the balance. In addition about 1,000 - 2,000 tpa is sold to the domestic meat industry. Sales to Japan are made through Toshoku, Mitsui and Cargill Japan Ltd.

NT Salt Pty Ltd is a business recently formed in Katherine NT which road freights salt from Port Hedland into the NT market. Basically a transport & salt marketing operation, the operator is at present benefiting by transporting barite to Port Hedland, WA from Darwin for M-I Australia for oil drilling use, and back-loading salt on the return trip.
SHARK BAY SALT JOINT VENTURE
WA's third largest producer is the Shark Bay Salt Joint Venture, a joint venture between AMP (35%), Mitsui Salt Pty. Ltd. (30%), and Shark Bay Resources Trust (SBRT). Clough Resources owns 92% of SBRT. This operates at Useless Loop and has a current capacity of about 0.7m tpa.

Feedstock for the operation is seawater which is concentrated in primary concentrator ponds from where the brine is moved by pumping and gravity flow about 20km to secondary concentrator ponds at Useless Loop. The salt is transported to the washing plant and port at Shark Bay by company owned road trains. Salt is shipped from the company's private port at Useless Loop which can accommodate vessels to about 25,000 dwt. Production facilities are being upgraded to 750-800,000 tpa, to be completed by 1996. Salt from Shark Bay, which grades 99.7% NaCl on a dry basis, is all exported, principally to Japan, Taiwan, Korea, Malaysia, Singapore and Indonesia.

WESTERN SALT REFINERY PTY. LTD.
This is a joint venture between WA Salt Supply Pty. Ltd. and Cheetham Salt Ltd. The company produces 20,000 tpa of salt at Pink Lake, Esperance from a coastal lagoon.

WA SALT SUPPLY PTY. LTD.
This company in its own right produces about 80,000 tpa from a salt lake, Lake Deborah, near Koolanobbing. There are believed to be plans to increase production capacity to 180,000 tpa. The salt is transferred by rail to Western Salt Refinery's Coogee refinery south of Fremantle. From here most of the salt has traditionally been sold bagged or packaged for domestic use with limited quantities in bulk for the small local chloralkali industry. However recently some shipments have been made overseas. The first exports were made in 1987 supplying 1,800 to the UK chemical industry, followed in 1989 with contracts for 1,000 tpa to Papua New Guinea and 4,000 tpa to Singapore. The company is also hoping to be successful in exporting to Indonesia.

The company's strength is as a salt refiner and packer rather than a bulk supplier, with grades priced at almost ten times the value of the bulk product. It can produce up to 20 grades totalling 88,000 tpa, of which 14 (80,000 tpa) are used in industry and 6 (8,000 tpa) supply the whole of Western Australia's domestic market. WA Salt Supply has had to increase its salt production in recent years to keep level with expanded domestic industrial demand. Recent projects in WA supplied by the company include SCM's and Tiwest's titanium dioxide pigment plants at Kemerton and Kwinana, and Nufarm, CSBP's chloralkali plant at Kwinana.

GULF HOLDINGS PTY. LTD.
Gulf Holdings is investigating the potential for a 1-2m tpa capacity plant south of Onslow on the east coast of the Exmouth Gulf, WA. This project was first promoted over 20 years ago in conjunction with Toyo Menka Kaisha Ltd. It is not certain whether Toyo Menka is still involved, however in 1989 Gulf Holdings revived the project and so far environmental surveys have been undertaken. Wesfarmers Ltd, holds a 50% interest in the company sponsoring the project. The project is in the early stages of detailed evaluation and the Asian chemicals market is being assessed before a decision to proceed is made.

SALT EXPORTERS AUSTRALIA LTD.
Salt Exporters owns tenements containing potential salt resources in the north of WA and in the Northern Territory. The company is investigating the possibility of a solution mining and solar evaporation process with shipments through the Port of Wyndham.

PENRICE SODA PRODUCTS PTY. LTD.
Penrice was established in 1989 with the purchase of the ICI Australia Ltd's salt plant at Dry Creek and soda ash (Na₂CO₃) plant at Osborne, both in South Australia.
Salt production from the 400,000 tpa operation began in 1940 specifically to supply the Australian soda ash market. Seawater is pumped from St. Vincent Gulf for evaporation. Harvesting takes place seasonally and salt is loaded onto a mobile conveyor located in the ponds. The salt is then stockpiled on the pond levee banks from where it is dissolved as required and pumped as brine to the Osborne plant across the river for the manufacture of 400,000 tpa of soda ash.

RIDLEY CORPORATION LTD./CHEETHAM SALT LTD.
The ownership of Cheetham salt has changed several times in recent years, and events in June 1992 have resulted in a considerable concentration of the ownership of Australia's domestic salt producers. Those events have led to the major Australian food groups, Goodman Fielder Wattie Ltd. and National Foods Ltd. through rationalising their ownership of stockfeed mill Ridley Corp. now controlling Cheetham Salt, & Diamond Salt. This brings under the one ownership the 10 salt operations of Cheetham (most of which were separate businesses acquired by Cheetham over the past 20 years), as well as Diamond Salt's two operations, providing a total production capacity in the order of 1,025,000 tpa, most of which supplies the domestic market.

Cheetham operates salt fields in Victoria, SA and Queensland. It also has an interest by joint venture in a WA operation and operates the Port Alma plant in Queensland on behalf of ICI. Cheetham produced a total of 350,000 tonnes of bulk and refined grades in 1990.

Cheetham has three salt operations in Victoria, two of which are based on seawater at Port Phillip Bay and Corio Bay, and the third at Lake Tyrrell is a lake-brine operation. Each of the seawater operations has a capacity of 25,000 tpa. The Lake Tyrrell salt lake is located 350km north-west of Melbourne. Most of the salt for this operation is obtained by crystalising brine formed in the lake after winter rainfall and by pumping brine from below the lake surface. Some salt is also produced from the surface. Cheetham has installed a mill and drier at Lake Tyrrell which will allow the closure of the company's drying, crushing and bagging facility at Lake Boga which was purchased from Sunray Salt in 1985. Capacity at Lake Tyrrell is believed to be 150,000 tpa with output closer to 100,000 tpa.

In other States Cheetham's salt production is won by wholly-owned subsidiaries.

Oscall Pty. Ltd. and sister company ASC Ltd. operating in South Australia, were acquired in 1971. Oscall works a salt field at Price, based on seawater, with a production capacity of 130,000 tpa. Bulk salt is transported by road to the port of Ardrossan, about 20km south of Price, where BHP's facilities are used for shiploading. Most of the product goes to Cheetham's salt refinery for packaging.

ASC's operation consists of a salt lake, Lake Bumbunga at Lochiel. A ponding system enables rainfall run-off to dissolve the lake surface and serve as brine feed. Harvesting is conducted only every two or three years producing an annual output of 20,25,000 tonnes. The plant has washing and crushing facilities to produce salt grades for stockfeed, water softening and swimming pool use and also for tanning.

Queensland Salt Pty. Ltd., acquired by Cheetham in 1981, produces seawater salt at Bowen in Queensland. The capacity is about 10,000 tpa of which a proportion is sold in bulk to local mining operations. A small refinery supplies salt blocks for salt licks.

Central Queensland Salt Industries Ltd. was also acquired by Cheetham in 1981 and has operated since 1958. The salt field at Bajool is fed by seawater and underground brine. Production capacity is 70,000 tpa and output around 60,000 tpa. About 50% of the output is sold in bulk while the remainder is transferred to the company's refinery for bagging in a variety of grades.
Diamond Salt Pty. Ltd. is a newly formed company in the Ridley Corporation. Diamond has constructed a modern 100,000 tpa capacity refinery at Geelong in Victoria. Salt is purchased from Boral Gypsum's SA plant (refer below) and shipped to Corio Bay from Thevenard. A range of bagged grades are produced at the refinery. Currently sales amount to about 50,000 tpa. Diamond has also built a small washing and bagging plant at Lake MacDonnell which supplies some 40,000 tpa of bagged salt into local South Australian markets.

BORAL LTD.
Boral's Waratah Gypsum division processes salt as a co-product of its gypsum operation at Lake MacDonnell, SA. The Lake MacDonnell operation is a solar pond system with a capacity of around 150,000 tpa salt. It is believed that all of Boral's output is sold to Diamond Salt.

PACIFIC SALT PTY. LTD.
BHP began production of salt from seawater at Whyalla in SA in 1951. The 80,000 tpa capacity plant takes its feed from Spencer Gulf. In 1979 Pacific Salt constructed a refinery at Whyalla taking all BHP's production. Subsequently, in 1988, BHP sold the salt field to Pacific. The refinery produces a range of bagged and packaged salt for local markets as well as supplying into the eastern states. It is understood that Pacific Salt is also constructing a small plant at Bajool adjacent to the Cheetham and ICI facilities.

AUSTRALIAN SOLAR PONDS (COLLFRED PTY. LTD.)
This is a small scale operation producing intermittently several hundred tonnes from a salt pan about 250km south of Alice Springs.

Australian Importers
Only a small quantity of specialised BP (pharmaceutical) grade is imported.

Overseas Producers
Salt is produced in over 110 countries, but world production is dominated by the USA (19%), China (12%), the CIS (8%), Germany (7.3%), & Canada (5.7%). Worldwide 21 countries produce individually over 1m tpa and together account for 90% of total world output. Australia is the eighth largest producer (1991: 7.5m tpa) accounting for 3.5% of world production.

Akzo Salt & Basic Chemicals BV of the Netherlands is the world's largest salt producer with an annual production capacity of over 15m tpa of which roughly 10m tpa is located in the USA. Akzo does not have any halite salt interests in Australia but in recent years has acquired the Pacific Chemicals operations in Sydney, which produces magnesium sulphate. The salt and basic chemical division of Akzo produces three types of salt: - PURE EVAPORATED VACUUM SALT is produced in Netherlands, Germany, Denmark and by Akzo's US division, International Salt Company.
- SOLAR SALT is produced by Antilles International Salt
- ROCK SALT is produced by the International Salt Company (USA).

Deutsche Solvay -Werke, Solingen, Germany

North American Salt Co. (NAMSCO) is the third largest salt producer in North America with an output of over 6.5m tpa.

Great Salt Lake Minerals (GSLM) is a subsidiary of NAMSCO and is also a significant salt producer in the USA.

Whittaker Corp, Heico Chemicals Div, PA, USA

Kaiser Chemicals, Cleveland, Ohio, USA
Mallinckrodt Inc, Mo, USA
Canadian Salt Co. Ltd, Mississauga, Ontario, Canada
Industrial del Alcali SA, Monterrey, Mexico
Productos Quimicos Monterrey SA, Monterrey, Mexico
Sulfato de Viesca, SA Mexico City, Mexico
Dead Sea Works Ltd, Israel
Dov Chemicals, Haifa, Israel

Naruto Engyo KK, Naruto City, Tokushima

India: There are 6 producers in India. Japan has recently invested in a 300,000 tpa salt producing operation in India which is expected to provide in the region of 100,000 tpa into Japan's domestic market.

Product Requirements & Specifications
The application of all three types listed in the Section above depends upon purity or composition and particle size. The following table provides typical analyses of Australian salt, on a wet basis.

<table>
<thead>
<tr>
<th>PRODUCER</th>
<th>Dampier Salt</th>
<th>Leslie Salt</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaCl (wt)</td>
<td>96.5-97.5%</td>
<td>96.75-97.25%</td>
</tr>
<tr>
<td>H2O</td>
<td>1.5-2.6%</td>
<td>2.1-2.65%</td>
</tr>
<tr>
<td>Ca</td>
<td>0.03-0.05%</td>
<td>0.035-0.042%</td>
</tr>
<tr>
<td>Mg</td>
<td>0.02-0.04%</td>
<td>0.022-0.03%</td>
</tr>
<tr>
<td>SO4</td>
<td>0.10-0.15%</td>
<td>0.12-0.15%</td>
</tr>
<tr>
<td>K</td>
<td>0.01-0.02%</td>
<td>0.01-0.02%</td>
</tr>
<tr>
<td>Insol.</td>
<td>0.01-0.03%</td>
<td>0.008-0.01%</td>
</tr>
<tr>
<td>NaCl (dry)</td>
<td>99.7-99.8%</td>
<td>99.7%</td>
</tr>
</tbody>
</table>

Current & Forecast Levels of Demand
Current domestic demand for all grades of salt is in the vicinity of 1,000,000 tpa. It is likely that there will be growth at around 1.0% pa once the economy recovers. This is the equivalent of 10,000 tpa being added to demand. Whereas it seems that there may be some slight over-capacity in Australian salt production at present, this would amount to less than 100,000 tpa, and some of this, if it does truly exist, could be diverted into export markets. It is true that there is some continuing plant expansion, such as that at Western Salt Refinery, but it is likely that the company's expansion is focused upon export markets.

Commercial Determinants of Demand
In the short term it is likely that salt demand from Australia's markets will soften, and the domestic market will also feel the effects of the current recession. The Japanese market began to weaken last year and salt sales are likely to have diminished by 3-4%. However it is likely that growth in the chloralkali industry in several ASEAN countries and in China will lead to greater demand of industrial salt. Australia's domestic demand may increase with planned expansion in titanium dioxide pigment production, and possibly in the paper and other industries. Food processing demand will increase if Australia is successful in significantly expanding this industry to cater for growing Asian demands. It should be noted,
that some of Australia’s food majors, have access to “in-house” salt supplies through subsidiaries such as Cheetham.

(8) Domestic Prices
(Refer Section 1 in this NaCl Section for details) Current prices on the domestic market range from $180/t - $280/t delivered into various mainland centres:

(9) Supply - Demand Dynamics
The supply demand structure in the domestic market is more or less in a state of equilibrium. However, with ownership of domestic suppliers being more concentrated, into two main players, if the proper market strategies are put in place an operation from NT should be able to gain a small market share based on a tonnage which although small in industry terms is significant in terms of incremental revenues as a co-product from the NT operation.

(10) Transport, Shipping & Logistics
It is feasible for road or rail freight from Alice Springs to be utilised to transport the product to SA and into eastern states markets.

(11) Likely Domestic Market Share Addressable by NTE
2.5 - 5.0% of a national market of 1,000,000 tpa is between 25,000 and 50,000 tpa. Over a 2 year market growth from date of market entry a market of 40,000 tpa could be addressed, selling at an average price of $50.00 per tonne bulk ex plant, NT.

(12) Likely Export Market Share Addressable by NTE
None

(14) Revenue Streams
40,000 t X $50.00 = $2,000,000 pa
POTASSIUM SULPHATE (K₂SO₄)

World Production
Demand is forecast to rise from approx. 2.8M tpa currently to over 3.5MT by 2000. Production is between 2M tpa and 3 M tpa.

(1) Industry Applications
Potassium sulphate's main use is as a fertiliser, especially for tobacco, pineapples, crops, vines & citrus fruits. Potassium is an essential constituent of all living cells. Deficiencies in soils and stock feed require to be rectified for viable rural industries. Potassium is therefore one of the three primary plant nutrients, and about 95% of current potash production is used in the manufacture of fertilisers. The remainder is used in soaps, glass & ceramics, drugs and a variety of chemical processes. The low chlorine content and lower solubility of potassium sulphate fertiliser products makes them desirable for certain crops and soil conditions. Products with higher potash grades (K₂O) and coarser particles are usually the most acceptable in the market.

Potassium sulphate is used in potassium deficient areas with a chloride problem. It also finds application in special purpose food processing crops where a low chloride fertiliser is required. Pastures in coastal regions in Australia often require potassium sulphate supplements in topdressing.

(b) Australian End-Users
Major fertiliser manufacturers, including Incitec & Pivot, CSBP Wesfarmers

(2) Australian Producers
None. CSBP Wesfarmers commenced production of potassium sulphate in WA as a small stand-alone operation several years ago, but found it to be uneconomic, and resumed importing its requirements.

(3) Australian Importers
Incitec, Pivot, CSBP Wesfarmers. Incitec import 4,000 - 5,000 tpa of granular (2.00mm -3.00mm) material from the USA, and somewhat less than 1,000 tpa of finer grade (0.85mm).

(4) Overseas Producers
There is no production at present in ASEAN countries. However reference should be made to details of planned potash production in Thailand detailed in the Potassium Chloride section of this Report.

Potash ores containing K₂SO₄ occur in Canada, USA, CIS & Mexico, as a salt or as brines.

Capacity:

<table>
<thead>
<tr>
<th>Company</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climax Chemical, Grantsville, Utah, USA:</td>
<td>50,000 tpa</td>
</tr>
<tr>
<td>Great Salt Lake, Ogden, Utah, USA:</td>
<td>215,000 tpa</td>
</tr>
<tr>
<td>Great Salt Lake, Trona, California, USA:</td>
<td>55,000 tpa</td>
</tr>
<tr>
<td>IMC Fertilizer, Carlsbad, New Mexico:</td>
<td>700,000 tpa</td>
</tr>
<tr>
<td>Western Ag-Minerals, Carlsbad, N. Mex, USA</td>
<td>450,000 tpa</td>
</tr>
<tr>
<td>Canpotex, Canada</td>
<td></td>
</tr>
</tbody>
</table>
Kalie Chemie AG, Hanover, Germany
Holland, Belgium
Societa Italia Sali Alcalim SpA (Italkali) 550,000 tpa
Dead Sea Works, Israel
Arab Potash Company, Jordan
Jeil Moolsan Co Inc., Seoul, Korea
Thailand
S.E. Soda, Taiwan
Coop Chemical, Japan
Chisso, Tagi Chemical, Nihon Kasei and Nissan Chemical - all of Japan
CIS (USSR) {Australian importers have had "painful" experiences importing from this source}

Great Salt Lake Minerals & Chemicals Corp. restarted its Ogden, Utah potassium sulphate plant in February, 1989, and will expand capacity there to about 400,000 tonnes by mid 1993. IMC's capacity is about 2:5 potassium sulphate to potassium/magnesium sulphate. Western Ag-Mineral produces only potassium/magnesium sulphate. US demand for sulphate of potash is expected to increase at the rate of 3% to 4% pa till 1995. Exports to Canada and to overseas markets from the US have more than doubled since 1988.

Coop Chemical of Japan in 1991 brought on-stream a 20,000 tpa potassium sulphate plant in Niigata, Higashiko. Some 8,000 tpa of production will be consumed by the company, with the remainder to be bought by another chemical company. The plant, the company's fifth, will use the Mannheim process.

(5) Product Requirements & Specifications
Fertiliser grade sulphate of potash: \( K_2SO_4 \) - 97% min., \( K_2O \) - 50% Min., Cl < 1.0%, 41.5% K, 17% S. KCl is cheaper, contains 9-10% more K, and is generally preferred to \( K_2SO_4 \) in general fertiliser applications. However for some horticultural and vegetable crops, sulphate of potash is preferred particularly where the crop is used for processing or grown in saline conditions.

Potassium sulphate is usually white but may grade towards pink. It is produced in a number of different particle sizes. Coarser granular grade is 3mm. Typical finer grade is a topsize of 0.5mm grading to 0.15mm. Finer particle sizes are more suitable for application as a solution in irrigation water while coarse grades are best suited for solid application.

It should be noted that Incitec has experienced many quality problems with Canadian material, largely due to an unacceptable dust content of 15%.

Potash Corp. of Saskatchewan produces two"Big Quill" brand-name grades \( K_2SO_4 \) with low Cl levels of 0.05% and 0.02% Cl.

(6) Current & Forecast Levels of Demand
Demand varies widely from year to year in Australia, depending on the state of the rural economy. The rural industry in Queensland is a major user and the Ord River region in the NW of WA has increasing demand. Imports over the past 10 years have ranged from a low of 8,000 tonnes in 1983-84 to current Australian consumption at present around 25,000 tpa. Incitec management states that the product has not been promoted due to quality problems, and believes that there is considerable growth potential in Australian domestic fertiliser markets, with Incitec's demand increasing from the current level of 3,000 tpa to 10,000 in the next decade.

Pivot currently imports 4,000 tpa at a cost landed Geelong of between A$200-A$230 per tonne bulk. A purchaser located in WA has recently requested two orders in the past 6 months each of 1,720 tonnes with an import price requirement to be in the
order of A$390/tonne CIF Fremantle. CSBP Wesfarmers in Perth currently use around 2,000 tpa.

Current import levels into Australia are as follows:

<table>
<thead>
<tr>
<th>State</th>
<th>Qld</th>
<th>SA</th>
<th>Tas</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSW:</td>
<td>4,800</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vic:</td>
<td>9,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WA:</td>
<td>2,300</td>
<td></td>
<td>200</td>
</tr>
</tbody>
</table>

(7) Commercial Determinants of Demand
The rural economy. If the Australian processed food industry successfully positions itself to develop markets in Asia for certain food commodities, this should mean an increased demand for potassic fertilisers in the medium to long term.

(b) Potential Impediments to Demand.
Because of its higher price compared to that of KCl, farm use of potash of sulphate and potassium/magnesium sulphate in the US (and in Australia) has been limited largely to situations where non-chloride potash fertiliser is required to avoid crop damage.

As tobacco production in Australia declines, this will be reflected in a decrease in demand from this crop for potassium sulphate.

(8) Domestic & Import Prices
CIF Fremantle in 1 tonne bulk bags - A$390 per tonne
Pivot's 1991 wholesale price in 50kg bags ex Adelaide and Geelong was $510 per tonne. Its current July 1992 price for bulk ex Adelaide and Geelong is $463 per tonne.
PCS (Canada) price for high sulphate/low Cl grade CIF Sydney, in 25kg bags in 20t container lots in 1991 was US$ 565/tonne for 0.05% Cl and US$625/tonne for 0.02% Cl grade.

(9) Supply - Demand Dynamics
Virtually all potassium sulphate is imported from North America, and Incitec has indicated that with the establishment of a source of good quality supply, the domestic market could be expanded.

(10) Transport, Shipping & Logistics
S.A. demand for sulphate of potash fertiliser historically been fairly constant at 3,000 tpa. This alone would represent 79% of NTE's possible annual production of 3,800 tpa $2SO_4. Victoria's additional 9,000 tpa market would more than take up the balance.

(11) Future Market Trends
This is a growing market in Australia and in the ASEAN region and in China, where there is a drive to produce high-value cash crops to generate hard currency. In the US, potassium sulphate's growth has been most pronounced in non-farm fertiliser markets, such as on golf courses and other turf applications. Future Australian demand could also be developed from these trends, especially with the proliferation of new golf courses associated with the growth in Japanese and other Asian tourism in Australia.
(12) **Likely Domestic Market Share Addressable by NTE**

There is little doubt that NTE could address a large proportion of Australian domestic demand for fertiliser grade potassium sulphate from an Alice Springs based plant. Initial planned production of 3,800 tpa only represents 15% of the national market. One would expect that as an economically significant import replacement, market penetration would be reasonably swift.

(13) **Likely Export Market Share Addressable by NTE**

For the short to mid-term, it is likely that NTE would not need to address any export markets due to the large domestic market which it can address. (Large compared to its likely production capacity). South Korea and Taiwan are significant exporters. However more than half of Indonesia's fertiliser's imports come from Middle East countries, such as Iraq, Jordan and Tunisia. Indonesia's fertiliser trade statistics show that in 1989 Tunisia was the prime supplier of fertiliser to Indonesia, supplying 130,946 tons, valued at US$ 25.3M or US$ 193 per ton (or A$ 253 per ton). The USSR (CIS) is a source for Indonesia's potassium sulphate requirements.

In 1989 China imported 153,647 tons of potassium sulphate, largely from Canada, although Jordan is also exporting increasing quantities.

In 1990 Japan imported 176,000 tonnes of potassium sulphate, of which the major suppliers were Belgium and Germany.

(14) **Revenue Streams**

3,800 tpa x $370 per tonne ex plant = $1,400,000
SODIUM SULPHATE (Na₂SO₄)

World Production:
Natural: 2Mtpa, Synthetic: 2Mtpa

(1) **Industry Applications**
Detergent powder formulations, in textile treatment process and in glass manufacture, (flat glass, container glass and fibre glass).

(b) **Australian End-Users**
Australia's eight largest users and their current demand is set out hereunder:

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Colgate</td>
<td>9,730* - 13,000</td>
</tr>
<tr>
<td>ACI - AGM</td>
<td>3,358</td>
</tr>
<tr>
<td>Pilkington</td>
<td>1,005</td>
</tr>
<tr>
<td>Unilever</td>
<td>10,590</td>
</tr>
<tr>
<td>Robert Bryce</td>
<td>3,051</td>
</tr>
<tr>
<td>Ajax Chemicals</td>
<td>4,200</td>
</tr>
<tr>
<td>Kiwi</td>
<td>665</td>
</tr>
<tr>
<td>Deltrex</td>
<td>750</td>
</tr>
<tr>
<td>Others</td>
<td>4,453</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>37,802</strong></td>
</tr>
</tbody>
</table>

*Colgate states that its current demand is in the order of 13,000 tpa in NSW & QLD.

Locations of consumption on a state by state basis is:

<table>
<thead>
<tr>
<th>State</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSW</td>
<td>25,161</td>
</tr>
<tr>
<td>Vic</td>
<td>6,814</td>
</tr>
<tr>
<td>Qld</td>
<td>4,738</td>
</tr>
<tr>
<td>WA</td>
<td>400</td>
</tr>
<tr>
<td>SA</td>
<td>689</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>37,802</strong></td>
</tr>
</tbody>
</table>

(2) **Australian Producers**
None

(3) **Australian Importers**
The dominant supplier is Akzo Chemicals through Sydney, Newcastle, Melbourne and Brisbane ports. Akzo imports largely from the US company National Chemicals, from the US West Coast. This company is part of the old Kerr-McGee Chemical Corp., the largest US producer of sodium sulphate.

Gardner Smith Pty. Ltd of Sydney has been the agent for Ozark - Mahoning Co. of the USA. This firm is currently importing at levels of 12,000 tonnes annually, which costs CIF Sydney US$195-200 per tonne in bulk (A$260). They import three times a year in shipments of 4,000 tonnes each.

The total import volume approaches 40,000 tpa. Other chemical trading companies import at most 10,000-15,000 tpa, largely from China, through Port Kembla. The importation from China up until two years ago was supported mainly by Colgate, but Chinese sources proved unsatisfactory due to inconsistency of availability and inconsistency of quality. This is still the case, and Colgate has reverted to US sources.
(4) **Overseas Producers**

Mexico, Spain, Turkey, Argentina, Chile, Canada, USA, Japan & CIS are producers of natural sodium sulphate.

(Natural Na₂SO₄ Producing Companies)  

<table>
<thead>
<tr>
<th>Company</th>
<th>Annual Capacity ('000 tpa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Great Salt Lake Minerals &amp; Chemicals Corp., Utah, USA</td>
<td>100</td>
</tr>
<tr>
<td>Ozark-Mahoning Co, USA</td>
<td>70</td>
</tr>
<tr>
<td>Kerr-McKee Chemical Corp., California, USA</td>
<td>240</td>
</tr>
<tr>
<td>Saskatchewan Minerals, Canada</td>
<td>300</td>
</tr>
<tr>
<td>Agassiz Resources Ltd, Canada</td>
<td>160</td>
</tr>
<tr>
<td>Quimica del Rey, Mexico</td>
<td>510</td>
</tr>
<tr>
<td>Sociedad Quimica Minera de Chile SA (SQM), Chile</td>
<td>70</td>
</tr>
<tr>
<td>Alkim Alkali Kiimya, Turkey</td>
<td>100</td>
</tr>
</tbody>
</table>

**Synthetic Producers**

Japan, CIS, USA, ECC, China, Korea, India, Thailand & Taiwan produce synthetic Na₂SO₄.

<table>
<thead>
<tr>
<th>Company</th>
<th>Production (%) of Domestic Japanese Market</th>
<th>Annual Capacity ('000 tpa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asahi Glass, Japan</td>
<td>(40% of domestic Japanese market)</td>
<td>100</td>
</tr>
<tr>
<td>Central Glass, Japan</td>
<td>(20% of domestic Japanese market)</td>
<td>50</td>
</tr>
<tr>
<td>Tosoh Corp. Japan</td>
<td>(20% of domestic Japanese market)</td>
<td>50</td>
</tr>
<tr>
<td>Tokuyama Soda, Japan</td>
<td>(20% of domestic Japanese market)</td>
<td>50</td>
</tr>
<tr>
<td>Akzo Salt &amp; Basic Chemicals, Netherlands</td>
<td></td>
<td>20</td>
</tr>
</tbody>
</table>

(5) **Product Requirements & Specifications**

Kerr-McGee sodium sulphate (used in Australia) is produced as TRONA anhydrous sodium sulphate, minimum 99.0% Na₂SO₄ in fine, standard and coarse and special coarse granulations. It is sold in the US in bulk hopper cars and trucks, or in 50 & 100 lb net multiwall paper bags.

Chinese sodium sulphate used for glass manufacture in Indonesia is 98% min. Na₂SO₄, 0.05% max Fe₂O₃, and moisture 0.1%, packed in 50kg bags.

**Detergents:** Detergent manufacturers require a technical grade, anhydrous material of minimum 98% purity, supplied in a fine granular form.

**Glass Industry:** The glass industry uses 98%+ pure Na₂SO₄ in a 200# granular form, 20kg per 3 tonnes of glass furnace raw materials. Both natural and synthetic saltcake can be used in glass, providing that the Fe₂O₃ content is less than 0.15%. There are no commercial viable alternatives likely to supercede the use of sodium sulphate in the glass industry, although calcium sulphate, sodium sulphite and soda ash provide technical alternatives.

**Paper Manufacture:** The sulphate process for the conversion of wood into paper pulp requires the use of sodium sulphate. In this digestion process the sulphate is not actually used as such, but is first converted into sodium sulphide. The consumption of sodium sulphate varies with the type of wood used, and the quality of pulp required. In Australia sulphate use in the Kraft process is limited to Amcor’s Maryville Mill in Victoria. Sodium sulphate is actually a by-product of the Kraft process, and usage of purchased material is for a 10% supplement that is required.
(6) **Current & Forecast Levels of Demand**

Detergent and soap manufacturers make up by far the largest component of Australian demand, with the three main users, Colgate, Unilever (Rexona) & Ajax between them accounting for 24,520 tpa, or 64% of Australian use.

Rexona, located on Sydney's outskirts, at Minto has had a recent history of sodium sulphate use of between 8,000 and 11,000 tpa. Demand depends on their product formulation philosophy. This will remain unchanged over the next five years or so, but could undergo changes after that which would affect sodium sulphate consumption. Rexona purchase from Akzo.

ACI also purchases its sodium sulphate requirements through Akzo (the Netherlands based largest salt producing company in the world) ACI buys in either 40kg paper sacks or in 1 tonne to 1.5 tonne bulker bags, at levels of 3,000 tpa. ACI used to purchase through Kerr-McGee, but has now shifted its purchases to Azko.

Total domestic demand, currently, is between 37,000 tpa and 40,000 tpa. This could decrease to between 25,000 and 28,000 tpa in the 5 years 1996-2000.

(7) **Commercial Determinants of Demand**

The chemical, glass and detergent industries have an ongoing demand for sodium sulphate manufacture. Australian demand in the soap, detergent and glass industries is mature, although growing wine export market inroads by Australian wine companies will underpin some small growth in glass container demand. This will tend to balance the slightly decreasing demand in mature glass markets due to competition from plastics and cardboard packaging, as well as from glass recycling, and new technologies producing lighter glass containers. Sodium sulphate is an essential glass raw material, and is not likely to be displaced by a substitute.

**Detergents:** In the detergent industry, however, its use is likely to reduce, with little or no detrimental effect on performance. Its use in powder detergents is that of a low cost, white, inert filler. Although larger users in detergent manufacture tend to increase volumes of filler as the demands in difficult economic conditions favour sales of relatively lower cost domestic detergent products, there is the possibility that a significant product sector of the detergent industry could reformulate in about 5 years time, if markets in Australia follow some European and North American product trends. In Australia this would be more as a result of market education and new product introduction, partly as a result of the environmental lobby.

Powder detergents in Australia in the main are bulked up by sodium sulphate filler, providing a density up to 40% more than a detergent without the filler loading. Consumer perceptions in the household market will need to be changed from the existing view that bulk equals washing capacity. The bulk in fact is inert bulk sulphate, that does not make the detergent last any longer or do more washes. In the US and in several European markets, powder detergent concentrates, with little or no sodium sulphate filler have a much larger market acceptance and share than they do in Australia. In Australia, concentrate powders have been available for some years, and have made little market impact, being lucky to achieve a 10% market share. Now, however, new companies, and new brands are entering the Australian market place as a result of which the local industry is in a state of flux regarding formulations for the future.

One of these is a leading Japanese maker of household products, Kao Corp, which announced last month that it is to commence selling detergent in Australia. Kao, which has already been marketing its detergent in SE Asian countries, such as Taiwan, Hong Kong and Singapore, will begin selling its detergent "Bio-zet" in Australia from the beginning of August. It will market its product through Sydney-based Kao (Australia) Marketing Pty. Ltd., which was established earlier this year.
All the detergent will come from its manufacturing plant in Taiwan. Kao hopes to take about a 10% share of the Australian market, which it estimates to be about A$310M a year.

Among the arguments in favour of detergents containing less sulphate filler is that concentrates can be sold in smaller packages, using less packaging, and it follows less wood pulp and less energy to produce. However against such "green" pressure it must be said that in Australia economic and market factors are different than those in North America and there are market forces here that could mean that the pressure for filler-free detergents here will be less successful.

Marketing and technical comment within the soap industry⁴ is that a reduction in demand for sodium sulphate by local detergent manufacturers is probably likely, will be no more than 50% of current levels of use, probably less, and would not take place for at least 4 to 5 years. The maximum reduction, probably the worst possible scenario at the highest level of a 50% reduction in demand of sodium sulphate, would be of the order of 12,000 tpa.

Paper Manufacture: Should the proposed paper mill be constructed at Maryville by Amcor, then demand for sodium sulphate will increase by around 1,460 tonnes annually, based on the requirement of 10kg of Na₂SO₄ per tonne of dried pulp at 400 tonnes of pulp per day, 365 days per year.

(8) Domestic & Import Prices
US West Coast export prices are around US$90/t FOB. The larger users (Colgate & Unilever) contract bulk supply in Sydney and Brisbane at around A$250/tonne FIS. Other significant volume users pay A$350-500/tonne packed in 25kg bags.

Chinese sodium sulphate is available FOB China @ US$30-US$40 per tonne in bags and at $US 150 - 160/tonne CIF Sydney. This translates to a cost of around A$220 - A$250/ tonne into store. Chinese material delivered FIS Jakarta costs in the order of A$230/tonne.

ACI will not reveal its local Australian cost, however it is known that in 1991 the then Smorgon owned container glass plant at Penrith, (Sydney), now owned by ACI, was purchasing its sodium sulphate from Azko at $260 per tonne. Sodium sulphate for Colgate/Rexona is being delivered Minto in bulk tankers @ between A$240 - $260 per tonne. It is likely that the higher figure is closer to the actual price being paid. This is to increase by $5.00 per tonne next year.

(9) Supply - Demand Dynamics
On the basis that NTE can establish an effective production and distribution base in Australia for Na₂SO₄ then an Australian supply/demand balance is achievable. As the economies of the developing countries in ASEAN require more chemical raw materials, any surplus production capacity from the NTE project could address this growing demand.

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Morris Fidler - Technical Director: Colgate Palmolive, Sydney - personal communication
(10) Transport, Shipping & Logistics

Akzo ships from the US West Coast bulk into Newcastle and then trucks it to its Camellia (Sydney) plant where it screens and dries the sodium sulphate in a dryer. The hygroscopic nature of the sulphate means that it tends to take up moisture and become caked on the surface during shipment. Both Colgate and Unilever have their sulphate delivered bulk in pneumatic discharge tankers. Colgate in Sydney has Aztec (a Boral operated transport company) contract its tankered deliveries of sulphate into Colgate’s Villawood plant.

Road freight costs to Sydney from Alice Springs are expected to be in the order of $85 per tonne. In order to compete with a bulk delivered price of Azko material into Rexona in Sydney of about $250, an ex-plant price of $165 would need to be established. The requirement for tankered delivery by Colgate and Unilever will need to be examined in a cost effective manner.

(11) Future Market Trends

It is possible that Australian demand for sodium sulphate will decrease in the latter half of the 1990s.

(12) Likely Domestic Market Share Addressable by NTE

There is no apparent commercial reason why NTE would not be able to supplant current imports of sodium sulphate with a current value of around $7 million, as long as it is able to produce a high quality material at competitive prices. However in order to achieve this, it will need to be able to set up effective bulk transport and distribution systems in order to compete with imported bulk chemicals currently sold by Akzo. On this basis NTE could obtain about 85 - 90% of Australian demand - i.e. about 35,000 tpa. Should demand for sodium sulphate by detergent manufacturers decrease from around 1997 as is indicated, then a reduction to levels of around 24,000 tpa could be expected near the year 2000, unless alternative domestic (or export) markets can be developed.

(13) Likely Export Market Share Addressable by NTE

Sodium sulphate is not produced in ASEAN countries, with the possible exception of Thailand. Japan is the largest consumer in Asia, with a peak use in 1986 of 344,000 tonnes of sodium sulphate, of which 96,000 tonnes was imported from China, USA, Mexico and Taiwan. About 57% of this consumption was by detergent manufacturers. The Japanese glass industry has its own captive production (refer (4) above). Japan's pulp & paper industry is now recycling bi-product sodium sulphate.

NZ has a demand ranging from 8,000tpa to 15,000tpa, a very large part of which goes into the paper & pulp industry. Some of this material has been supplied by Gardner Smith of Sydney from the US West Coast, and more recently US Gulf Coast. The recession in America has resulted in weakening demand for sodium sulphate and therefore at present there exists a state of surplus supply. Indonesia also has an increasing demand, but this is supplied from China.

Nippon Glass use 50,000 tpa which they source from a local Japanese producer. In Indonesia, ACI subsidiary glass maker, PT Kangar Consolidated Industries, purchases 400 tpa of Chinese sodium sulphate through a local importer, PT Panca Kusuma Aneka Kimia. This costs 355,000 Rupiah per tonne, the A$ equivalent of which is A$230/tonne.

It is feasible that 5,000 - 10,000 tpa could initially be sold from Australia into the NZ or ASEAN markets.

(14) Revenue Streams

40,000 tpa x $165 = $6,600,000
MAGNESIUM SULPHATE (MgSO₄)

(1) Industry Applications

Fertilisers
This is almost wholly utilised in the rural industry as a fertiliser. Mg fertiliser does not command the same high level of demand in the fertiliser industry worldwide as do potassic fertilisers, but it is a commodity with some perceived growth potential.

In most soils magnesium is normally present in adequate quantities, and predominates in the subsoil of most Australian soils. Deficiencies of Mg is most frequent on coarse textured soils in humid regions, and more generally on the light, sandy acid soils of higher rainfall areas, usually occurring mainly in coastal and some tableland areas. Mg deficiencies occur mainly with citrus crops, rarely with pastures, which is the underlying reason for the relatively small scale use of Mg fertilisers compared with potassic ones. Potassium - magnesium sulphate fertilisers are widely used on citrus crops for their multi-nutrient value. In the US the fertiliser chemical company, Western Ag-Minerals, produces potassium/magnesium sulphate in a combined form.

Stockfeed Supplements
In Australia the more soluble form of Mg in caustic calcined magnesia (MgO) or the cheaper naturally occurring dolomite (CaCO₃/MgCO₃) is used for this application.

Oxy/Sulphate Cements
Magnesium oxychloride cements are prepared by mixing calcined magnesia (MgO) and MgCl₂, and, dependent on final product requirements, sodium hexametaphosphate, magnesium sulphate and other materials. This cement, known as Sorel cement, or magnesite cement, has many properties superior to those of Portland cement. However there have been certain application problems with this material regarding instability in water, and these are being examined. Other versions of magnesium cement are magnesium oxysulphate cements made from magnesium sulphate heptahydrate, which can be prepared by reacting calcined magnesia with sulphuric acid or by reaction grinding with gypsum (calcium sulphate). A typical application for oxysulphate cement is in the manufacture of light-weight, fireproof insulation boards, particle boards and the like. Queensland Metals Corp. is examining these downstream cement options in conjunction with Queensland Cement Ltd.

Detergents
Detergent manufacturers incorporate magnesium sulphate in their formulations to stabilise peroxy bleaches in powder detergents.

Pharmaceuticals
Pharmaceutical uses are well known (Epsom Salts) and utilise the product’s laxative effect.

(b) Australian End-Users
Fertiliser producers - Incitec, Growforce, Pivot, W. Paton, Merco Bros.,
Chemical importers - Robert Bryce.

A summary of major users by state is as follows:
### NSW

**Technical: heptahydrate**

<table>
<thead>
<tr>
<th>Company</th>
<th>tpa</th>
</tr>
</thead>
<tbody>
<tr>
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<td>250</td>
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<tr>
<td>Maytex</td>
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<tr>
<td>Yates</td>
<td>40</td>
</tr>
<tr>
<td>Stockmans Rural</td>
<td>25</td>
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<tr>
<td>Heat Containment</td>
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<tr>
<td>Other</td>
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<td><strong>TOTAL</strong></td>
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**BP: Heptahydrate**

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<tbody>
<tr>
<td>Carlton United</td>
<td>25</td>
</tr>
<tr>
<td>Reckitt &amp; Colman</td>
<td>30</td>
</tr>
<tr>
<td>EOI</td>
<td>30</td>
</tr>
<tr>
<td>Others</td>
<td>45</td>
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<tr>
<td><strong>TOTAL</strong></td>
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**Excicated BP**

<table>
<thead>
<tr>
<th>Company</th>
<th>tpa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procter &amp; Gamble</td>
<td>60</td>
</tr>
<tr>
<td>Harcros</td>
<td>10</td>
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<tr>
<td><strong>TOTAL</strong></td>
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**NSW TOTAL**

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### VIC

**Technical: heptahydrate**

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<tr>
<td>1C1 Operations</td>
<td>70</td>
</tr>
<tr>
<td>Deltrex</td>
<td>80</td>
</tr>
<tr>
<td>Aust Forest Inds</td>
<td>50</td>
</tr>
<tr>
<td>Phosphate Corp (Pivot)</td>
<td>75</td>
</tr>
<tr>
<td>Dalgety Farmers</td>
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<tr>
<td>E E Muir</td>
<td>35</td>
</tr>
<tr>
<td>DGO Distributors</td>
<td>25</td>
</tr>
<tr>
<td>Cattlecare</td>
<td>20</td>
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<tr>
<td>Consolidated Chemicals</td>
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<td>Others</td>
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**BP Heptahydrate**

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**Excicated BP**

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**VIC TOTAL**

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### QLD

**Technical: Heptahydrate**

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<td>750</td>
</tr>
<tr>
<td>Growforce</td>
<td>260</td>
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<tr>
<td>World Search</td>
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<td>Agtech</td>
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<tr>
<td>Primac</td>
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<tr>
<td>Barmac</td>
<td>25</td>
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<tr>
<td>Globe Trading</td>
<td>25</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td>1,220</td>
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**BP: Heptahydrate**

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<thead>
<tr>
<th>Company</th>
<th>tpa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other</td>
<td>20</td>
</tr>
</tbody>
</table>

**QLD TOTAL**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1,240</td>
</tr>
</tbody>
</table>
(2) **Australian Producers**

Akzo Chemicals is the sole Australian producer, with its plant located in Sydney. The Australian market of around 3,500 tpa is almost solely supplied by Akzo. Management of the Australian subsidiary of this Netherlands based company considers there is unlikely to be any significant additional domestic market opportunities for MgSO₄.

The Australian magnesium industry until this year has been in its infancy. The commissioning of the Kunwarara magnesite project by Queensland Metals Corp. in joint venture with Pancontinental Mining, brings Australia into the league of being an international producer of Mg downstream products. A second project, the historically small scale magnesite operation now controlled by the Devex group, located near Young, is also planning downstream materials development, in conjunction with Toyota of Japan. The significance of the QMC operations to the potential for the production of Mg compounds by NTE is that QMC and Devex is each examining a range of options in respect not only to the committed production of MgO in both caustic calcined and dead burned forms, but are also considering production of various downstream products including MgSO₄. To date some 5,000 tonnes of calcined MgO has been delivered to stockpiles in Gladstone, and/or transported to Brisbane, where the material is further processed, ground and bagged in facilities owned by Incitec Ltd, under a two year toll-processing contract. Several products are being developed by ICI, of which Incitec is a subsidiary, for waste water and other environmental applications.

(3) **Australian Importers**

Imports only amount to several hundred tonnes per annum, mainly from China.

(4) **Overseas Producers**

Western Ag-Minerals, Carlsbad, New Mexico, USA: 450,000 tpa capacity of Mg/K sulphate

IMC Fertiliser, Carlsbad, New Mexico, USA: 500,000 tpa capacity of Mg/K sulphate.

China: The largest Chinese plant for the production of MgSO₄ is in Laizhou City, in Shandong province. Locally produced magnesite and sulphuric acid will be used by the 10,000 tpa factory. Japan and Korea also have plants producing magnesium sulphate.

(5) **Product Requirements & Specifications**

The heptahydrate grade is available in Australia as a technical quality as well as material of BP (British Pharmaceutical) standard. A 10.5% Mg content is an average minimum acceptable level.
Fertiliser manufacturers would be able to use a blended magnesium/potassium sulphate, should such a mixed brine product be produced.

(6) Current & Forecast Levels of Demand
Static

(7) Commercial Determinants of Demand
The state of the Australian rural economy, and should oxysulphate cement demand become established, the levels of operation and acceptance of the product within the construction industry, will be the major demand determinants.

(8) Domestic & Import Prices
The current Australian domestic wholesale price for magnesium sulphate, heptahydrate grade is A$400 - $450 per tonne, subject to size of order based upon FOT Sydney deliveries to other states. The BP Heptahydrate is normally more expensive at A$480 - 500/tonne, but the largest user, Faulding buys in bulk at A$390/tonne ex Sydney. The BP Excicated grade is purchased generally at around A$1,600 per tonne. US West Coast domestic price of bulk heptahydrate grade is in the order of US$300 per tonne.

(9) Supply - Demand Dynamics
With Akzo & possibly QMC/Incitec or QMC/QCL coming into the market as producers of MgSO4, the supply situation may be the predominant factor in the Australian market. Market development by the Queensland groups however could stimulate demand and acceptance for a wider range of magnesium sulphate products than now exist.

(10) Transport, Shipping & Logistics
Queensland is the state in which there is the largest consumption of magnesium sulphate. High road freight rate charges of $105 per tonne from Alice Springs to Brisbane is an obstacle to a competitive base needing to compete with the potential of local Queensland production from Incitec, which virtually has its own captive fertiliser market in that State.

(11) Future Market Trends
(Refer (9)). Pressure on pricing is a potential trend since recent ICI interest in magnesia production with its JV with QMC in Queensland has caused its subsidiary, Incitec to consider production for its own captive fertiliser manufacture.

(12) Likely Domestic Market Share Addressable by NTE
2,000 tpa expanding to 3,000 tpa, the majority of which could be marketed as a compound Mg/K sulphate fertiliser.

(13) Likely Export Market Share Addressable by NTE
Not any at this stage.

(14) Revenue Streams
2,000 tpa x $320 = $640,000, expanding to 3,000 tpa x $320 = $960,000. It should be noted that in this preliminary study, capital costs have not been allocated for production of magnesium sulphate.
MAGNESIUM OXIDE (MgO)
MAGNESIUM CARBONATE (MgCO₃)

These two minerals are presented together as much of their production is linked and derives as co-products from the same companies.

World Production
Magnesia (MgO) - derived from Magnesite: 8.5 M tpa
Synthetic Magnesia - from brines & seawater 2.3 M tpa
Crude Beneficiated Magnesite (MgCO₃): 23.0 M tpa

(1) Industry Applications
Although untreated magnesite in a fine milled form has some commercial uses, such as in fertiliser, glass & ceramics, rubber additive and as an industrial filler especially in paper and plastics (where it generally has significant competition from more readily available CaCO₃), its main use is as a feedstock for the manufacture of caustic calcined magnesia, deadburned magnesia, electrofused magnesia and magnesium metal.

CAUSTIC MAGNESIA:
Caustic calcined or light burned magnesia is produced by heating magnesite in a kiln at temperatures between 700° and 1,000°C. In this form it is quite chemically reactive, and can be used in paper and rubber manufacture, as an additive in neutralising acids and in lubricating oils, as an electrical insulator, a component in oxychloride and oxy sulphate cements, a filler for plastics and paints, a cosmetic and pharmaceutical base, an additive for flue gas desulphurisation, as fertiliser, stockfood supplement, in water clarification and in pollution control.

The agricultural sector of the market for magnesia products in some ways is the easiest to enter as its basic product requirements are relatively undemanding. 80% MgO for fertilisers and 85% MgO for stockfeeds, with no precise minimum levels set on calcia, silica, iron oxide or alumina. As a bulk, low cost item it therefore occupies the bottom end of the market in terms of pricing.

DEADBURNED MAGNESIA
When magnesite or caustic calcined magnesia is calcined to higher temperatures, above 1,500°C, the material adopts the structure of periclase, a white relatively non-reactive solid which exhibits exceptional dimensional stability and strength at high temperatures. In this state magnesia is variously known as deadburned, clinker or sintered magnesia, and accounts for approximately 90% of the world's output of magnesia. It is used almost exclusively for refractory applications in the form of basic brick and granular or monolithic refractories.

MgO has the highest melting point of all refractory oxides and is the most suitable heat containment material for high temperature processes in the steel industry, which accounts for at least 70% of the world's output.

ELECTROFUSED MAGNESIA
Electrofused Magnesia is produced by the electric arc melting of caustic or deadburned magnesia at temperatures above 2,750°C. It is superior to deadburned magnesia in strength, abrasion resistance and chemical stability. Crushed fused magnesia is used as an insulating material in heating elements for industrial electric furnaces and in domestic appliances. It is also used in the manufacture of premium quality refractories including those used in nuclear reactors, rocket nozzles and in the most corrosive areas of high temperature furnaces.
VERY HIGH PURITY MAGNESIAS

A variety of chemical processes to produce very high grade magnesia have been developed, which react magnesium carbonate or magnesium oxide with a range of reagents such as hydrochloric, nitric, sulphuric and acetic acids and carbon dioxide gas. A number of such chemical plants have been constructed in the USSR (CIS), Yugoslavia, Czechoslovakia, India and Austria. Energy consumed in these processes ranges up to 1,200 kg heavy fuel oil equivalent per tonne of product.

Ultra high purity magnesia (+99.99%) is also produced, in limited quantities, by burning magnesium metal in an oxygen enriched atmosphere. The resulting product, whilst extremely pure, commands a commensurate price.

MAGNESIUM METAL

Magnesite and its derivatives represent concentrated sources of Mg ions as feedstock for the production of magnesium metal. Mg metal is extremely light, with a very high strength to weight ratio. It is used in the production of other rare metals, i.e. zirconium and titanium, and is extensively used in castings, either alone or as an alloy. It has growing electronic, motor vehicle and aerospace applications.

(b) Synthetic Magnesia vs. Magnesite Beneficiation

MAGNESITE ORE

Depending on the ore type, as well as contained magnesite and impurities, processing of raw magnesite entails a number of beneficiation steps prior to the production of "kiln feed" i.e. raw magnesite of sufficient purity to be calcined to magnesia.

Magnesite ore processing typically involves crushing, screening and washing, with or without ore sorting, depending on the deposit. In certain cases no further processing is required before the burning process to convert the carbonate to the oxide. This is normally so in the production of agricultural grades of calcined magnesia and for "general maintenance" and lower quality refractory grades of deadburned magnesia.

However the quality of the ore may be such that higher grades namely industrial grades of calcined, and regular quality refractory brickmaking grades of deadburned magnesia, can be produced without further processing, although such deposits are rare. It is understood that the Kunwarara deposit is one such deposit. In general, a range of other processing methods, most frequently heavy media separation, magnetic separation and flotation, are employed to remove the impurities from magnesite ores. When flotation is required, it is necessary to fine grind the ore, flotate, thicken, filter, dry, calcine and briquette (pelletise) the product before deadburning. Beneficiation may also be undertaken on calcined magnesia, including selective crushing, screening, hydration and high intensity magnetic separation.

These beneficiation techniques all have one aim - to produce a product, or a range of products, that have high magnesia content, low silica, calcium, iron and aluminium levels and low trace metal impurities. Generally cryptocrystalline magnesite, such as exists in the QMAG deposit, can be readily processed to produce the required pure and high density material. Often macrocrystalline magnesites, which are much more common as commercial deposits, have significantly higher processing costs.

SYNTHETIC MAGNESIA

It is generally considered within the industrial minerals industry that the process of obtaining magnesia from seawater and brine is decidedly more complex than the relatively simple calcination of natural magnesite to magnesia. The comparison is
essentially between a quarrying or mining and clinker operation and that of a chemical processing plant. Magnesia production from seawater involves the extraction of dissolved magnesium - values typically 1.3 gm/litre - and the reaction of magnesium chloride with lime (CaO) or dolime (CaO.MgO) to produce magnesium hydroxide precipitate.

Brines and bitterns are more concentrated salt solutions where the magnesium values can range between 3 to 40 times those of seawater. For instance the Dead Sea brine contains about 41 g/litre magnesium. The brines tested so far on the NTE leases have magnesium contents ranging from 1.36 g/litre at Lake 62, 4.5 g/litre at Karinga to 12.07 g/litre at Curtis Springs. Generally, after extraction of the magnesium and conversion to magnesium hydroxide, the precipitated material is washed, thickened, dewatered and converted to oxide at high temperature.

It is argued that production of magnesia from brines is more energy consumptive than calcining a high purity magnesite, when the energy costs of producing the lime from limestone or dolomite to precipitate Mg(OH)₂ is taken into account.

(c) **Australian Demand**

In recent years apparent consumption in Australia of raw magnesite equivalent has been in the order of 80,000 - 90,000 tpa, but has decreased over the past two years due to lower steel production levels. There have been some imports of both deadburned magnesia ranging between 10,000 tpa and 17,000 tpa, mainly from Japan. Typically, several hundred tonnes per year of electofused magnesia have also been imported, also largely from Japan. It is likely that the QMAG operation in Queensland (refer next Section) will now replace these imports by its local production.

The major markets for deadburned and electofused magnesia will remain offshore. It is likely that additional markets for caustic magnesia will be developed in the waste water and associated pollution control service industries.

(2) **Australian Producers**

**QUEENSLAND MAGNESIA PROJECT (QMAG)**

(Refer also to "Magnesium Sulphate" chapter, Section 2)

QMAG is owned 50% by *Queensland Metals Corp. Ltd.*, 40% by *Pancontinental Mining Ltd.* (the operator), and 10% by the Austrian refractory group, *Radex Heraklithe Industrie AG*. QMAG extracts cryptocrystalline magnesite from a deposit extending over an area of 63 sq. km. at Kunwarara in Queensland. In an international context, this resource represents a world class deposit of exceptionally high quality. It contains 1.2 billion tonnes of magnesite in-situ, and is by far the largest deposit of cryptocrystalline magnesite in the world. Furthermore it is located close to relatively cheap coal and natural gas energy resources, as well being 160km NW of the Port of Gladstone.

CSIRO testing of the QMAG magnesite as mined reveals minor mineral impurities present in the nodules being dolomite, quartz, iron, clay silicates and manganese. These minor contaminants tend to be concentrated on the surface of the magnesite nodules, and are reported as being easily removed by standard mineral beneficiating processes. A beneficiation plant on site produces feedstock for the company's Parkhurst burning and electrofusion plants, 55km to the south east.

The plant has been commissioned over the past nine months and is now in production. When all facilities come on stream, investment in the project will be $215 million. MIM Holdings is contract mining to the venture. To date some 600,000 tonnes of ore have been mined and stockpiled and some of this has been processed and exported to Europe.
The initial phase of the calcining plant at Parkhurst has an installed capacity of 100,000 tpa of deadburned and 15,000 tpa of electrofused magnesia. The second phase will add a further 50,000 tpa deadburned capacity and 10,000 tpa electrofused magnesia. Maximum putput is planned to be reached by 1995. QMAG has planned production of three deadburned magnesia grades with bulk high density greater than 3.4 g/cm³-MgO contents of 96% minimum and boron levels below 50 ppm. It is planned that the highest grade will have a mean crystal size of 140 μm.

The local BHP Steel magnesia refractory demand, especially for furnace linings, as well as other local industries using refractories, produced by the handful of Australian refractory manufacturers will constitute the main Australian outlets. Much more significant are the international export markets of Japan, Korea, Taiwan, USA, and Europe.

As well as the QMAG project, Queensland Metals Corp is investigating a wide range of magnesia products and applications in joint venture with other firms from a technical and marketing perspective. These include the ENVIRONMAG project, a joint venture with ICI and CSIRO, to promote the use of Queensland magnesia for pollution control applications (Refer also to "Magnesium Sulphate" chapter, Section I). Other joint magnesia product development joint ventures are CEMAG, in conjunction with Queensland Cement Ltd and CSIRO, FLAMEMAG (flame retardant plastic filler) in conjunction with CSIRO, and MAGMETAL (magnesium metal project) with MIM and UBE Corp. The CSIRO is also undertaking a programme of generative research, GENMAG, aimed at developing and optimising low cost processing techniques to produce ultra high purity magnesia and specially formulated magnesium hydroxide.

DEVEX LTD.
Devex, a minerals company which is emerging with a portfolio of Australian minerals projects, which include fused alumina in Perth, as well as gas and gold, has acquired the Causmag calcined magnesite company which has been operating for many years at Young, NSW, producing, at an annual capacity of 10,000 tpa, lower grades of caustic calcined magnesia for the domestic market. The magnesite ore, on which the operation has been based is mined at Thuddungra, 44 km from Young.

Causmag produces a range of caustic grades - Standard grades (typically 96.5-97% MgO), SGW (98% MgO), and Pexu (98.5-99% MgO). The company's 10,000 tpa capacity, deadburned magnesia plant, located at Fifield, NSW, has been on care and maintenance basis since February, 1991. However Causmag plans to implement a major expansion at Thuddungra which will include new caustic facilities plus the installation of some dead burning and fused magnesia capacity. Discussions are well advanced with Toyota to investigate the production of magnesium metal in Australia based on this resource.

COMMERCIAL MINERALS LTD.
In addition to being the Australian agent for Qmag's deadburned and fused magnesia, Commercial Minerals Ltd, part of the Poseidon Mining group, produces small quantities of magnesite at Myrtle Springs, 600 km north of Adelaide. The magnesite beds, ranging up to 3 metres in thickness, are mined selectively on a contract basis, with milling taking place at CM's Gillman plant in Adelaide, and products are sold in local markets for use in welding electrodes (Lincoln Electric), stockfeed and fertilisers. Production is generally less than 2,000 tpa.

UNDEVELOPED DEPOSITS
Both CRA and Savage Resources have extensive magnesite tenements in Tasmania, however both companies have decided that they will not attempt to develop them in the foreseeable future, due to market, mineralogical and logistic considerations.
In the Northern Territory, a magnesite resource is known to be associated with the Woodcutters base metal mine operated by Nicron Resources and controlled by Aztec Mining Co. At one stage the Norwegian minerals group Norsk Hydro, major producers of seawater magnesia and magnesium metal, was evaluating the commercial potential of the deposit as feedstock for an Mg metal plant. At the date of this Report there is no evidence of any ongoing activities in respect to the further development of this deposit.

In Queensland, in 1987 Peabody Australia, a subsidiary of the US resources group, led a joint venture with local interests associated with the potential development of an oil shale resource at Yamba. Associated with the oil shale deposit was a magnesite ore body on which a preliminary assessment was undertaken. For the present, any development of this project has been shelved.

(3) **Australian Importers**

Certain grades of magnesia, until the recent QMAG start-up, have been imported by BHP Refractories, South Coast Refractories and Heat Containment (an Australian subsidiary of the UK based Morgan Crucible Co). Each of these companies is based either in Newcastle or Port Kembla. The local chemical industry also uses small tonnages annually.

(4) **Overseas Producers**

**RAW MAGNESITE**

<table>
<thead>
<tr>
<th>Major Producing Countries</th>
<th>1988 prod'n (crude ore '000 tpa)</th>
</tr>
</thead>
<tbody>
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</tr>
<tr>
<td>China</td>
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<td>North Korea</td>
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<td>Australia</td>
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* Estimates

**MAGNESIA**

**NORTH AMERICA:** Six companies account for 815,000 tpa deadburned and caustic calcined magnesia in the USA. Two of these are old established small speciality magnesium chemical companies which also supply caustic calcined magnesia to US markets. The three Michigan brine magnesia producers have a combined 485,000 tpa capacity of calcined magnesia and account for 60% of the nation's total magnesia capability situated within several miles of each other on the shores of Lake Michigan. At Manistee, Martin Marietta Magnesium Specialities Inc. has its 250,000 tpa brine operation as does Morton International with its smaller speciality caustic magnesia brine operation. With a capacity of 10,000 tpa Morton produces a range of caustic magnesias for direct sale as well as magnesium hydroxide and carbonate. Markets include rubber, plastics, pharmaceuticals, and food markets. Dresser Industries subsidiary, Harbison-Walker Refractories Co., operates nearby and is one of the world's leading refractory manufacturing technology companies. Dow Chemical operates a brine plant, using its magnesia production to produce a variety of magnesium based chemicals.
In Delaware Barcroft operates a small seawater magnesia plant for the production of a range of magnesium chemicals, excluding oxide products, primarily for use by Rhône-Poulenc.

The three US seawater brine producers have a combined operational capacity of 230,000 tpa of magnesia products. They comprise National Refractories in California, American Premier Corp. in Florida, and Marine Magnesium Co. in California. As well as these plants, American Premier Corp operates the only natural magnesite plant in the US in Nevada, with 100,000 tpa capacity for deadburned and caustic grades.

In Canada, capacity is 160,000 tpa, and is produced by Baymag and Dresser Industries.

In Mexico, Industria Penoles operates twin seawater and brine plants with capacity of 160,000 tpa.

SOUTH AMERICA: Brazil has 200,000 tpa of deadburned and 45,000 tpa of caustic calcined magnesia capacity, produced by two companies, namely Magnesita SA, (140,000 tpa DB) and Industrias Brasileiras de Artigas Refractarios (60,000 tpa DB), both produced from naturally mined magnesite.

EUROPE: In Western Europe, producers have a combined magnesia production capacity of around 3,000,000 tpa. Major companies supplying this output are:

<table>
<thead>
<tr>
<th>Country</th>
<th>Company</th>
<th>Capacity (tpa)</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ireland</td>
<td>Premier Periclase</td>
<td>100,000</td>
<td>SW/DB</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Billiton Refractories</td>
<td>100,000</td>
<td>BR/DB</td>
</tr>
<tr>
<td>Norway</td>
<td>Norsk Hydro</td>
<td>105,000</td>
<td>SW/CC</td>
</tr>
<tr>
<td>UK</td>
<td>Steetley</td>
<td>200,000</td>
<td>SW/DB+CC</td>
</tr>
<tr>
<td>Austria</td>
<td>Radex</td>
<td>80,000</td>
<td>N/DB</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>45,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>12,000</td>
</tr>
<tr>
<td>Czechoslovakia</td>
<td>Veitcher Magnesitwerke</td>
<td>75,000</td>
<td>N/DB</td>
</tr>
<tr>
<td>CIS - Russia</td>
<td>Slovenske Magnezitova</td>
<td>726,000</td>
<td>N/DB</td>
</tr>
<tr>
<td>CIS - Ukraine</td>
<td>Grecian Magnesite</td>
<td>2,205,000</td>
<td>N/DB</td>
</tr>
<tr>
<td>Greece</td>
<td>Magnomin Gen'l Mining</td>
<td>1,345,000</td>
<td>N/DB</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>180,000</td>
</tr>
<tr>
<td>Israel</td>
<td>Dead Sea Periclase</td>
<td>30,000</td>
<td>N/DB</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>30,000</td>
</tr>
<tr>
<td>Italy</td>
<td>Sardamag</td>
<td>60,000</td>
<td>SW/DB</td>
</tr>
<tr>
<td></td>
<td>Nuova Sardamag</td>
<td>65,000</td>
<td>SW/DB</td>
</tr>
<tr>
<td>Spain</td>
<td>Magnesitas Navarras</td>
<td>70,000</td>
<td>N/DB</td>
</tr>
<tr>
<td></td>
<td>Magnesitas de Rubian</td>
<td>60,000</td>
<td>N/CC</td>
</tr>
<tr>
<td>Turkey</td>
<td>Various</td>
<td>75,000</td>
<td>N/CC</td>
</tr>
<tr>
<td>Yugoslavica</td>
<td></td>
<td>300,000</td>
<td>N/DB+CC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>200,000</td>
<td>N/DB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40,000</td>
<td>N/CC</td>
</tr>
</tbody>
</table>

N: Natural magnesite, SW: Seawater, BR: Brine, DB: Deadburned, CC: Caustic Calcined

THE CIS has a magnesia capacity in the order of 5,750,000 tpa.

ASIA produces in the vicinity of 4 million tpa of magnesia. The plants are in India, Nepal, China, North Korea, South Korea, and Japan.
Ube Chemical Industries Co. Ltd. is Japan's and the world's leading seawater magnesia producer accounting for just over three-quarters (450,000 tpa) of the country's 590,000 tpa installed deadburned magnesia capacity. Shin Nihon Chemical Industry Co Ltd. (owned by Asahi Chemical Industry Co. Ltd.) accounts for a further 120,000 tpa deadburned capacity. The remaining 20,000 tpa capacity is provided by Asahi Glass Co. Ltd. Approximately 60,000 tpa of caustic magnesia capacity is also held by Ube and Asahi Glass. Even with this large capability, Japan is a major importer of magnesia principally from China.

A summary table of production from Asia is provided hereunder:

<table>
<thead>
<tr>
<th>Country</th>
<th>Company</th>
<th>Capacity (tpa)</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>Liaoning Magnesite</td>
<td>850,000</td>
<td>N/DB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>200,000</td>
<td>N/CC</td>
</tr>
<tr>
<td>India</td>
<td>various</td>
<td>228,000</td>
<td>N/DB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30,000</td>
<td>N/CC</td>
</tr>
<tr>
<td>Japan</td>
<td>Asahi Glass</td>
<td>20,000</td>
<td>SW/DB</td>
</tr>
<tr>
<td></td>
<td>Shin Nihon Chem. Ind</td>
<td>120,000</td>
<td>SW/DB</td>
</tr>
<tr>
<td></td>
<td>Ube Chemical Inds. Co.</td>
<td>450,000</td>
<td>SW/DB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50,000</td>
<td>SW/CC</td>
</tr>
<tr>
<td>Nepal</td>
<td>Nepal Orind Magnesite</td>
<td>50,000</td>
<td>N/DB</td>
</tr>
<tr>
<td>North Korea</td>
<td>Korean Magnesite</td>
<td>2,000,000</td>
<td>N/DB+CC</td>
</tr>
<tr>
<td>South Korea</td>
<td>Sam Wha Chemical Co.</td>
<td>50,000</td>
<td>SW/DB+CC</td>
</tr>
</tbody>
</table>

N: Natural magnesite, SW: Seawater, BR: Brine, DB: Deadburned, CC: Caustic Calcined

(5) **Product Requirements & Specifications**

(Also refer Section 2)

The following are typical analyses and specifications for deadburned magnesias:

- **Class LCA1 Magnesia:** 97%+ MgO, C:S (CaO:SiO₂ ratio) over 4.1, 3.43 + Bulk Density, over 110μ crystal size
- **Class A1 Magnesia:** 97%+ MgO, C:S over 3:1, 3.4 plus BD
- **Class B1 Magnesia:** 96%+ MgO, C:S over 2:1, 3.33 plus BD
- **Class B2 Magnesia:** 95%+ MgO, C:S under 2:1, 3.25+ BD
- **Class C1 Magnesia:** 90% +MgO, C:S under 2:1, 3.1 plus BD
- **Class FE Magnesia:** 85% + MgO, C:S over 2:1, 3.2 plus DB, over 4.0% Fe₂O₃

<table>
<thead>
<tr>
<th>Class LCA1</th>
<th>Premier Periclase</th>
<th>MgO</th>
<th>CaO</th>
<th>SiO₂</th>
<th>Fe₂O₃</th>
<th>Al₂O₃</th>
<th>B₂O₃</th>
<th>C:S</th>
<th>BD</th>
<th>Crystal μ</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>97.2</td>
<td>2.10</td>
<td>0.25</td>
<td>0.20</td>
<td>0.07</td>
<td>0.01</td>
<td>8.4</td>
<td>3.43</td>
<td>150</td>
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</table>

<table>
<thead>
<tr>
<th>Class A1:</th>
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<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Ube Chemical</td>
<td></td>
<td>98.1</td>
<td>1.3</td>
<td>0.35</td>
<td>0.07</td>
<td>0.07</td>
<td>0.04</td>
<td>3.7</td>
<td>3.45</td>
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<tr>
<td>Dead Sea Periclase</td>
<td></td>
<td>99.2</td>
<td>0.70</td>
<td>0.02</td>
<td>0.03</td>
<td>0.01</td>
<td>0.00</td>
<td>35.0</td>
<td>3.44</td>
<td>100</td>
</tr>
<tr>
<td>Billiton</td>
<td></td>
<td>98.5</td>
<td>0.69</td>
<td>0.13</td>
<td>0.48</td>
<td>0.06</td>
<td>0.01</td>
<td>5.3</td>
<td>3.43</td>
<td>80</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class B1:</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Liaoning</td>
<td></td>
<td>98.05</td>
<td>1.0</td>
<td>0.25</td>
<td>0.7</td>
<td>0.3</td>
<td>-</td>
<td>4.0</td>
<td>3.36</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class B2:</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ube Chemical</td>
<td></td>
<td>99.52</td>
<td>0.20</td>
<td>0.15</td>
<td>0.06</td>
<td>0.06</td>
<td>0.003</td>
<td>1.3</td>
<td>3.43</td>
<td></td>
</tr>
</tbody>
</table>
Class C1:
Liaoning 92.5 1.5 3.5 0.9 1.7 - 0.4 3.25

Class C2:
Steetley 90.7 3.10 2.25 3.10 0.70 0.18 1.4 3.20

Synthetic processes account for the purer, higher technical quality products under the A1 and B1 categories. However, natural magnesite sources are represented at the top quality end of the spectrum and synthetic sources are also present at the lower quality end in categories B2 and C1.

The trend towards higher crystal size has grown over the past several years and it is now accepted that a minimum 120μm periclase crystal size is required for top performing refractory grades.

(6) Current & Forecast Levels of Demand
Demand for magnesia in Australia has been commented on in section 1(c) above, as being in the order of 80,000 tpa. In fact demand currently is not likely to be over 50,000 tpa. Australian demand will increase only if our industrial process industries significantly expand production. The industries that utilise refractory magnesia are the metallurgical processing industries, led by raw steel producers, other metal smelting industries, glass manufacturers, and cement producers, to name the major ones. The major metal producers in the region are Japan, China, Korea and Taiwan, and in the mid to long term, magnesia demand will increase in the Asia/Pacific region as construction materials, motor vehicle production and infrastructure projects in the region continue to expand.

Demand for caustic calcined material will increase and will find relatively smaller niche markets in the environmental control sector. It is impossible within the scope of this study to attempt to quantify such future demand.

(7) Commercial Determinants of Demand
(refer previous comments)

(8) Domestic & Import Prices
International prices for most grades of deadburned magnesia have been eroded considerably in the last year or two. Reports of prices as low as US$100 FOB for Chinese material has the effect of placing a cap on achievable prices in some magnesia markets. It has been reported in "Industrial Minerals" that in March this year a cargo of high grade deadburned magnesia from Japan entered a European Mediterranean port at US$348/tonne CIF. Towards the end of 1991 prices for European deadburned magnesia dropped to below £250/tonne CIF.

Caustic calcined magnesia (97% MgO, Ca 1.5% max, 0.5 - 2.5mm grain) from Devex on domestic Australian markets is currently supplied at A$500/tonne delivered to Pivot in Geelong in 1 tonne bulked bags.

(9) Supply - Demand Dynamics
World magnesia markets are currently depressed, with prices severely low when compared with levels at the end of the 1980s. Permanent or temporary plant closures are common, in an effort to reduce non-operating capacity, and bring it more in line with reduced demand. With international magnesia demand around the 10.8 million tpa level, and 4.00 million tonnes of production capacity existing in NE Asia, the supply/demand ratio in our region will remain in a state of instability for some time. QMAG has entered this difficult market with its 100,000 tpa deadburned capacity just commissioned with plans to expand that to 150,000 tpa within the next few years. China has also demonstrated its ability to dump at low prices onto European markets, and even though much of this was reportedly
inferior grade material it was finding markets, and it is also believed that China is now achieving high quality products. In the caustic magnesia market China and North Korea have by far the largest caustic magnesia production levels in Asia, and both are major exporters. In this scenario Australian capacity for the production of caustic calcined magnesia is to increase four fold from what it was a year ago, with the commissioning of QMAG's 30,000 tpa to add to Causmag's present 10,000 tpa operation.

(10) Transport, Shipping & Logistics
These are similar for production of magnesia as for those detailed in the Sections of the Report covering the marketing of potassium salts, and sodium sulphate.

(11) Future Market Trends
In the medium to long term as environmental and additional industrial end-uses for MgO become established, demand is likely to increase. [refer (9) above]

(12) Likely Domestic Market Share Addressable by NTE
In the short term it would be not advisable for NTE to consider the production of magnesia (MgO) or magnesium carbonate, due to the current and at least mid-term oversupply situation in this market. Should historical high demand markets for magnesia remain depressed, the already perceivable trend will increase of existing suppliers concentrating the focus of their market and product development strategies into newly developing environmental and other smaller tonnage/higher value areas. It is likely to be a highly competitive market for some time with considerable impediments to a successful market entry by NTE.

(13) Likely Export Market Share Addressable by NTE
Nil, for the reasons outlined above.

(14) Revenue Streams
Nil.
POTASSIUM NITRATE (KNO₃)

World Production
Approximately 500,000 tpa.

(1) Industry Applications
Nitrogen is one of the three primary plant nutrients, along with potassium and phosphorus. Thus its combination with potassium in naturally occurring mineral deposits in Chile, and by chemical conversion elsewhere, provide an ideal fertiliser, as well as a source of nitrogen for chemical industry application. However as a source of nitrogen for industry, the use of KNO₃ has been eclipsed by the production of synthetic ammonia originally by the Claude-Haber process.

Potassium nitrate is utilised as a source of potassium in potassium fertilisers, with specialised market applications particularly for vegetable crops and for tobacco. It tends to increase a soil's pH. The damage to crop by a high concentration of soluble salts is lessened when potassium nitrate is applied rather than potassium chloride. As a source of nitrogen in other fertiliser applications other fertilisers are generally preferred, such as ammonium nitrate, ammonium sulphate, urea and blood and bone.

If environmental concerns in respect to the effects of excessive use of potassium chloride become more widespread, demand for potassium nitrate will gain increased momentum.

(b) Australian End-Users
Tobacco and banana growers are increasingly using potassium nitrate, as are cotton growers. However tobacco demand is diminishing.

(2) Australian Producers
None

(3) Australian Importers
Incitec is the major importer, all from Israel and Chile. The quality of the prilled Chilean product was described to the writer as being "shocking". It is shipped in containers. In bulk the Chilean material tends to clump together, and will not flow. To be able to successfully market KNO₃, the product must freely flow. With these problems with the Chilean material, Incitec went back to purchasing its requirements from Haifa Chemicals Ltd.

Grow Force in Queensland, Pivot in Victoria and Patons in NSW are the other major importers.

(4) Overseas Producers
Chile is the world's largest producer and exporter of sodium and potassium nitrates, produced by the one company, Soquimich, with a total nitrate production of around 800,000 tpa in 1988. Their main product is sodium nitrate, both fertiliser and industrial grade. In an attempt to diversify, Soquimich has entered into the production of potassium nitrate, installing a plant with a capacity of 250,000 tpa. In addition to this, there are two large projects which could bring about an increase in the production of nitrates: Pampa Pissis - Nebraska (Soquimich) with a projected capacity of 30,000 tpa, as well as iodine, and Yolanda - Taltal (a joint venture of North Lily Mining Co) and other parties who are planning to produce 250,000 tpa of
potassium nitrate, iodine and sodium sulphate. However the future of these projects is not certain. It is believed that improvements will be required in present nitrate technology before they become economically attractive.

Minera del Norte is planning a US$69M iodine-potassium production complex in Chile. The company already has two plants on site (Pozo Almonte). The new plant would add a further 200,000 tpa KNO₃ capacity.

SQM last year also announced plans to expand its Chilean nitrates capacity at its Marie Elena mine to 1.1M tpa. Modifications to the crystallisation process will allow greater production flexibility between sodium nitrate and potassium nitrate production, as a result of which potassium nitrate output could rise to 430,000 tpa from the current level of 230,000 tpa.

SQM has several subsidiary companies with nitrate plants in Europe. One of these, Nitrate Sales International, is planning to establish specialty NPK plants (Nitrogen-Phosphorous-K (potassium)) in Spain and Belgium. These include a 12,000 - 15,000 tpa KNO₃ plant in Spain. The Belgian plant will be located in Antwerp and will be capable of producing 15,000 tpa of highly soluble compound fertilisers.

Sociedad Chilena del Litio (SCL) produces 35,000 tpa of KCl, based on the flotation of the sylvinite obtained in the production of lithium salts. This production is sold to Soquimich and is used for manufacturing potassium nitrate. Nearly 130,000 tpa of potassium chloride were imported in 1989, mostly from Canada, and larger quantities will be required to service the increase in potassium nitrate production. Chile in 1988 exported US$32.4M of KNO₃.

Israel is the other major producer, the world's largest. It was recently announced that Haifa Chemicals plans to set up a KNO₃ plant at Mishor Rotem in the Negev Desert, Israel, at an estimated cost of US$50M. It is thought that the process for this is based on solvent extraction from Dead Sea potassium chloride brine feedstock. Initial capacity of the plant will be 100,000 tpa, with expansion possible to 200,000 tpa when additional infrastructure is completed. If the plan goes ahead, production could commence in 1994. Haifa Chemical's President has stated that the company should have no problem selling more than its current 300,000 tpa capacity, since world demand, is growing between 5%-9% per year. This could grow even faster should Chinese demand increase, as is considered likely.

Most of the KNO₃ in the USA is chemically produced and is based on the reaction of potassium chloride with nitric acid, producing chlorine as a co-product. Such synthetic processes have largely eclipsed the use of naturally occurring nitrates (the Chilean caliche) as a source of nitrogen for the chemical industry, now supplying less than 0.3% of the world's nitrogen needs.

(5) **Product Requirements & Specifications**

Fertiliser grades of potassium nitrate contain a minimum of 36.5% K and 13% N with a maximum of 0.1% Cl. The fertilizer must be free flowing or it cannot be applied in bulk. The Chilean material has been giving Incitec many problems in this regard. Prilled KNO₃ (2mm-4mm prills) is imported in bulk, whereas the fines (0.5mm) are imported in bags. The fertilizer needs to be extremely water soluble.

(6) **Current & Forecast Levels of Demand**

Recent import statistics indicate the following demand on a state by state basis:

- NSW 250 tpa
- QLD 4,500 tpa
- VIC 400 tpa
- SA 600 tpa
- WA 700 tpa
The 6,450 tonnes of demand listed above, in the eastern states is largely imported and distributed by Incitec and Pivot. Pivot currently merchandise 2,000 tpa of prilled nitrate, supplied to them in bulk, and a further 1,000 tpa of fine crystalline potassium nitrate (0.5mm). The 700 tonnes demand into WA is imported by CSBP Wesfarmers.

(7) Commercial Determinants of Demand
The possible trend away from the use of KCl in certain crops will provide market growth for this product. The fines product is especially in demand. Incitec is keen on promoting the use of potassium nitrate. Its use is increasing by banana and tobacco growers, and NSW farmers are moving away from the use of ammonium sulphate towards increased use of KNO₃.

Demand in Australia will largely be determined by the buoyancy of specific sectors of the rural industry, especially those of cotton, tobacco and bananas and general horticultural use. Incitec is developing its use in the cotton industry, and its prospects are looking good. Compared to the user price of KCl at $400 per tonne, KNO₃ is around twice the cost, and therefore requires an "educative" marketing campaign to promote its use. Price sensitivity analyses of the potential markets have yet to be undertaken by the product manager for Incitec in this regard.

(8) Domestic & Import Prices
The cost to Incitec for KNO₃ delivered into store is around $600 per tonne. The cost to North Queensland growers is in the region of $800 per tonne. Pivot Fertilisers also sells on the Sydney market at around $800 per tonne.

BP (pharmaceutical and food) grade costs around $1,000 per tonne in Australia.

(9) Supply - Demand Dynamics
Should the planned plant expansions in Chile and Israel take place there will be several hundred thousand tonnes additional production available for world markets. In international terms Australian demand is an insignificant 0.1% of world output.

(10) Transport, Shipping & Logistics
(Refer other sections)

(11) Future Market Trends
Increases in the domestic market are most likely.

(12) Likely Domestic Market Share Addressable by NTE
Should it prove feasible in the future for the NTE project to produce potassium nitrate, then as an import replacement, local production could address an expanding Australian market of over 6,000 tpa at ex-plant selling prices of around $450 per tonne, providing an incremental annual sales revenue of $2.7M.

(13) Likely Export Market Share Addressable by NTE
Unknown at this stage.

(14) Revenue Streams
None at present within the current project parameters. However future production could address a domestic market of 6,000 tpa.

6,000 tpa @ $450 = $2,700,000
BROMINE (Br₂) & SODIUM BROMIDE (NaBr)

World Production
Bromine: 460,000 tpa

(1) (a) Industry Applications
The alkali-metal bromides, particularly those of sodium, potassium and lithium are important industrial chemicals. The manufacture of each of these compounds is by the reaction of the hydroxide or carbonate with hydrogen bromide (HBr) or with bromine and a reducing agent, such as ammonia, formic acid or carbon. Concentration, filtration and drying produces crystalline materials, whereas spray-drying results in a powder.

The main uses for elemental bromine is in the production of bromine compounds that have chemical or biological reactivity, or fire retarding and extinguishing qualities. Gasoline additives, retardants, agricultural preparations, sanitisers, bleaching agents, dyes and sundry pharmaceutical formulations - pharmaceutical (BP) grade NaBr is prescribed for its sedative properties - are the specific applications for bromine/bromide compounds.

The largest use of bromine is in the manufacture of ethylene dibromide (EDB), a lead scavenger used in petrol to reduce engine knocking. However this demand has dropped as the lead content has been reduced in most petrols. Similarly the use of EDB as a fumigant in agriculture is also declining (in the US and possibly elsewhere) due to environmental focused government legislation.

The high density characteristics of bromine compounds are advantageously applied to hydraulic fluids, ore flotation and drilling fluids - mainly as calcium bromide, but this seems to have been largely supereceded by KCl.

There is a growing use in engineering plastics.

Sodium bromide is also used for the preparation of light-sensitive silver bromide for photographic application. It is also used as a treatment in swimming pools, hot tubs and industrial water. NaBr solutions can be used in the petroleum industry as completion and workover fluids (refer Section on KCl), especially in formations with high levels of carbonate rocks.

(b) Australian End-Users
Kodak in Melbourne uses 50-60 tpa of sodium bromide in various photographic processes and in the manufacture of film. The required quality is for a very high purity, and Kodak Chemicals division in the USA supplies the local company's requirements.

(2) Australian Producers
None

(3) Australian Importers
Kodak, Nufarm, Consolidated Chemicals

(4) Overseas Producers
Israel (Dead Sea Bromine - 25% of world production)
USA (Dow Chemical, Morton Chemical, Great Lakes Chemical Corp., Ethyl Corp
Kerr-McGee - all produced from lake or underground brines)
CIS
UK  (Associated Octel - seawater)
France  (Octel Kuhlmann SA - seawater,
(Mines de Potasse d'Alsace - bi-product of potash production)
Italy  (SAIBI SpA - seawater)
Spain  (Union Salinera de Espana - seawater)
Japan  (Toyo Soda Mfg. Co - seawater)
(Ginkai Chemicals - 1,100 tpa Br- bittern bi-product from salt prod'n)
Germany  (Kali & Salz - bi-product of potash production)

Most bromine is produced from seawater, in which reserves are very large indeed.

5) Product Requirements & Specifications
Sodium bromide is a hygroscopic white solid. It can be isolated as an anhydrous compound from an aqueous solution above 50.7°C. The solid product is available in 25 kg plastic lined bags.

All marketable bromine in the US contains less than 100ppm of impurities and is therefore 99.99% pure. The extremely hazardous nature of bromine due to its very high volatility, and extreme characteristics as an irritant to the eyes, nose, throat and skin means that great care must be taken in its production and handling.

6) Current & Forecast Levels of Demand
Only 19 tonnes of sodium bromide were imported into Australia last year. Kodak's usage of 50-60 tpa considerably exceeds this. In recent years imports for bromides in general have been between 200 and 300 tpa. Bromine demand is expected to increase.

7) Commercial Determinants of Demand
The chemical industry - especially in the manufacture of fire retardants, photographic film manufacture, and biocide manufacture for water treatment applications are the main determinants for levels of demand of bromine compounds in Australia. The use of bromine internationally as a slime and biocidal control product in water treatment increased nearly 25% in 1990.

8) Domestic & Import Prices
Domestic prices for sodium bromide in Australia are A$3 - A$4/kg.
US domestic prices for bromine are between US$0.50 and US$0.55/lb.

9) Supply - Demand Dynamics
Dead Sea Bromine is increasing its bromine production capacity from 135,000 tpa to 170,000 tpa. Plant expansion is expected to be completed by mid-1993. The company expects to reach a capacity of 200,000 tpa by 1996-1997.

10) Transport, Shipping & Logistics
For such a relatively highly priced product, transport sensitivity is not such a relevant issue.

11) Future Market Trends
Up. In the Australian market region the growth in demand will follow increases in GNP growth in neighbouring ASEAN countries, Japan, Korea and Taiwan. The use of bromine will continue to grow in the sanitary preparation market as it is an area where the product has been found to be safer than its substitutes.

12) Likely Domestic Market Share Addressable by NTE
Should it prove feasible in the future for the NTE project to produce bromine/sodium bromide, then as an import replacement, local production could
address an expanding Australian market of around 100 tpa at selling prices of $3,500 per tonne, providing incremental annual sales revenue of $350,000.

(13) **Likely Export Market Share Addressable by NTE**
The development of an export market of 500 tpa represents approximately 1% of international demand. Were NTE able to produce NaBr then incremental sales revenue for such an export market of $1,750,000 would be achieved.

(14) **Revenue Streams**
None at present within the current project parameters. However revenue from bromide sales of 600 tpa would produce sales of $2,100,000.
AMMONIUM CHLORIDE (NH₄Cl)

World Production
Over 1M tpa

(1) Industry Applications
Initially ammonium chloride was produced almost solely as a fertiliser, but now it has a wide range of uses.

As a source of nitrogen, which is the major requirement of nitrogenous fertilisers, ammonium chloride is of only minor importance compared to ammonium nitrate, sodium nitrate, potassium nitrate, ammonium sulphate and urea. It is, however, an effective fertiliser for paddy, upland rice, wheat and other crops in Japan, China and SE Asia. Most of the annual production in Japan is used as high grade compound fertilisers such as chloro-ammonium phosphate, chloro-potash-ammonium phosphate, etc. Other fertiliser uses for ammonium chloride are limited by its acidity and high chlorine content.

Industrial uses of technical grade ammonium chloride are, in order of importance:

- solid electrolytes in dry-cell batteries
- component in quarry explosives
- hardeners for formaldehyde based adhesives
- one of several components of etching solutions in production of printed circuit boards
- component of fluxes in tin and zinc plating
- photographic rapid fixer additive
- textile printing

Recently the addition of ammonium chloride to tiles and bricks prior to firing has been proposed. It serves to control product porosity and to accelerate the firing process. High purity ammonium chloride is used in food production, and in some pharmaceutical uses.

(2) Australian End-Users
Current imports into Australia are in the order of 5,305 tpa, and on a state by state basis are as follows:

<table>
<thead>
<tr>
<th>State</th>
<th>Tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSW</td>
<td>900</td>
</tr>
<tr>
<td>QLD</td>
<td>40</td>
</tr>
<tr>
<td>SA</td>
<td>545</td>
</tr>
<tr>
<td>VIC</td>
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<td>WA</td>
<td>3,120</td>
</tr>
<tr>
<td>TAS</td>
<td>100</td>
</tr>
</tbody>
</table>

Hardman Chemicals onsell into the galvanizing industry. Smaller fertiliser manufacturers, such as Morco Bros. in WA are significant users. Australian usage in previous years has been higher, up to 10,000 tpa.

(2) Australian Producers
None

(3) Australian Importers
Hardman Chemicals, Sydney. This is all imported from China, Japan and the USA

(4) Overseas Producers
Ammonium chloride can be produced by three main processes:
(1) The modified Solvay process, or ammonia-soda ash process, (ASAP)
(2) The direct reaction between HCl and ammonia
(3) The reaction of reciprocal pairs of salts.

This third process is no longer economic. The most suitable salt pair is \((\text{NH}_4)_2\text{SO}_4 + 2\text{KCl} \rightarrow 2\text{NH}_4\text{Cl} + \text{K}_2\text{SO}_4\). Basic problems with this approach are impure products and highly polluting waste streams.  

(1) BASF originally developed the ASAP process in which ammonium chloride is the primary product, a 97% purity fertiliser grade.

The Asahi Glass process is based on the use of raw salt. The pollution problems associated with this process, however, are not critical, and production of wastewater streams can be almost entirely eliminated, but due to high ammonia levels, any wastewater produced needs treatment.

(2) The synthesis of ammonium chloride from hydrochloric acid (HCl) and ammonia is becoming increasingly important for two reasons:

i) The increasing availability of inexpensive corrosion resistant construction materials

ii) The tendency to further process a potential pollutant such as hydrochloric acid.

The central factor in an economic comparison between the direct processes and the modified Solvay process is the feedstock cost. In addition, the cost involved when production is based on byproducts from other processes must also be considered. A Brazilian company, Engeclor is using this process. The latest data available showed this plant in the 1980's was producing 50,000 tpa of ammonium chloride via the HCl-ammonia process.

In the Asian/Pacific region India, China, Japan, Korea are producers. In Indonesia the Sahid Group, in partnership with PT Pupuk Kaltim, will set up the country's first synthetic soda ash plant, which will produce ammonium chloride as a co-product. In India Tuticorin Alkali Chemicals & Fertilisers Ltd. in a new plant with a capacity to produce 66,000 tpa each of soda ash and ammonium chloride. That plant is based on technology from Hitachi Zosen Corporation of Japan.

(5) Product Requirements & Specifications

Annual world production of ammonium chloride via the modified Solvay process is over one million tpa, most of the capacity for which is in Asia, where a granulated product containing 97%+ pure NH\(_4\)Cl is usually produced. The ammonia/nitrogen content of this fertiliser grade always exceeds 25% by weight. However if the production of ammonium chloride is the prime requirement, the process can be modified as to give purities exceeding 99.7% NH\(_4\)Cl with < 0.25 %NaCl and < 3ppm Fe, a quality adequate for most industrial purposes. Reagent grade NH\(_4\)Cl can be produced on a large scale with special operating techniques but without additional processing steps. This ammonium chloride contains < 0.01% NaCl and corresponds to the ACS specification.

Ammonium chloride is corrosive, whether as a gas, a solid or in solution. Equipment made from iron, aluminium, lead or non-ferrous metals is especially prone to

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5 Ullman's *Encyclopaedia of Industrial Chemistry* - Germany, 1985 Vol 2A, p 257
6 American Chemical Society
stress corrosion cracking. Today special steels, including low carbon steel, or plastics are used, but these are expensive.

Ammonium chloride has a tendency to cake and is therefore usually sold bagged.

(6) **Current & Forecast Levels of Demand**

Australian demand is 5,300 tpa, which is down on previous years' imports of up to 10,000 tpa. It is not likely to be a product with much growth potential.

(7) **Commercial Determinants of Demand**

There are several restrictions as to the use of ammonium chloride beginning to appear. In Germany and Holland over the last two years changes in environmental legislation has stopped the use of an ammonium chloride based chemical as a thickening agent in fabric conditioners.

Fertiliser applications for ammonium chloride that have been identified by Status Resources are extremely limited, and it is not listed as a fertiliser component on any of the major fertiliser manufacturers' product lists.

(8) **Domestic & Import Prices**

There are several grades ranging in price on the domestic market between $500 and $800 per tonne.

(9) **Supply - Demand Dynamics**

There is considerable capacity in the region, far larger than Australian demand.

(10) **Transport, Shipping & Logistics**

If the manufacture of ammonium chloride by NTE depended on the purchase and transportation of a cheap source of ammonia to the proposed Alice Springs plant, the cost of this feedstock movement would need to be assessed and compared with the shipping of competitive imported ammonium chloride from China or Japan. This is especially the case when the major demand is in WA, into which transport costs from the NT are high, compared to shipping costs from Asian suppliers.

(11) **Future Market Trends**

This commodity has only been given a preliminary analysis in this study, but indications are against significant growth in use.

(12) **Likely Domestic Market Share Addressable by NTE**

Nil, in the short to medium term

(13) **Likely Export Market Share Addressable by NTE**

Nil, in the short to medium term

(14) **Revenue Streams**

Nil, in the short to medium term
AMMONIUM SULPHATE (\((\text{NH}_4\)\)_\text{2}\text{SO}_4\))

**World Production**
3.8M tpa

(1) **Industry Applications**
Ammonium sulphate, previously thought to be a nitrogen only fertiliser, is now being considered for its 24% sulphur content, with the introduction of better granulation systems. There is also now a greater worldwide awareness of sulphur deficiencies in soil.

(b) **Australian End-Users**
Incitec uses its own production in-house. Pivot uses around 30,000 tpa.

(2) **Australian Producers**
BHP Steel produces ammonium sulphate as a waste bi-product from steel making. Incitec produces some 200,000 tpa from its plants in Brisbane and Newcastle using the ammonia and sulphuric acid process. It supplies the Australian market as well as exports to New Zealand. CSBP also produce ammonium sulphate in WA.

(3) **Australian Importers**
Only negligible amounts imported.

(4) **Overseas Producers**
In 1989, when world ammonium sulphate consumption was 2.67MT of contained nitrogen, with 3.77MT nitrogen ammonium sulphate was being produced, compared to 3.78MT nitrogen in 1985, when world consumption was 2.88 MT. Eastern Europe was traditionally the largest ammonium sulphate producer, 1.1MT in 1989. Asia, in particular, which produced 942,800 tonnes N ammonium sulphate in 1989, and which produces 70-75% of its output artificially, is expected to expand capacity in the next few years, and will become the world's leading regional producer.

Overseas producers include Mexico (2.31M tpa capacity), which exports surplus production to the US, Brazil (157,000 tpa), India and Czechoslovakia.

(5) **Product Requirements & Specifications**
There are two fertiliser grades of ammonium sulphate, prilled and fine. One is a 2-4 mm crystalline, but hygroscopic material. This is what BHP produces and it can only be used for soluble fertilisers. Incitec produces a granular material coated with an aluminium compound which stops it being so hygroscopic.

Technical grade requirements in Australia total around 2,000 tpa. Product consists of 98% ammonium sulphate, 0.1% moisture max.

(6) **Current & Forecast Levels of Demand**
230,000 tpa for the Australian market.
By comparison Japanese demand is 1M tpa, with production of 1.8M tpa, much of which is bi-product from steel making.

(7) **Commercial Determinants of Demand**
Largely the fertiliser industry.
8) **Domestic & Import Prices**
Domestic wholesale prices for standard ammonium sulphate from Pivot is $225 per tonne, bulk in Adelaide, and for granular grade, $235 per tonne.

9) **Supply - Demand Dynamics**
The market for fertilisers containing sulphur is expected to grow from the current global deficit of 10 MT, with 5MT possibly supplied by the year 2000 with effective promotion and marketing, largely accounted for by new materials. World consumption of plant nutrient sulphur in fertilisers reached 11.5MT in 1984, with Latin America accounting for 14%, or 1.64 MT, and Asia 22%, or 2.35MT. The Latin American sulphur fertiliser market reached 2.25MT in 1987.

10) **Transport, Shipping & Logistics**
Same as for other commodities dealt with in this report.

11) **Future Market Trends**
Steady & increased demand based on agricultural use.

12) ** Likely Domestic Market Share Addressable by NTE**
Nil

13) **Likely Export Market Share Addressable by NTE**
Asian demand is at present consuming 800,000 tpa of ammonium sulphate, and producing 940,000 tpa. There is considerable production capacity in ASEAN countries. Indonesia has a cheap source of nitrogen in its inexpensively produced urea, and is not likely to require imported ammonium sulphate to supplement this. The chances of export markets being developed for this commodity by NTE are very small indeed.

14) **Revenue Streams**
Nil.
4. FINANCIAL ANALYSIS
4. **FINANCIAL ANALYSIS**

The foregoing commodity market analysis indicates the revenue streams possible from each of the three commodities, potassium chloride, potassium sulphate and sodium sulphate.

The capital and operating costs provided by BHP Engineering in Section II of this Report have been the basis of this analysis.

A *Base Case (Case A)* together with 7 sensitivity analyses (*Cases B - H*) have been presented. It will be seen that in Years 1 and 2 a gradual increase of sales has been provided with full capacity being reached not till Year 4 or 5 and thereafter maintained at those levels for the operation over a 15 years period. The total operating costs in those first years have been reduced to an appropriate level accordingly. This is a most conservative approach and should maximum sales be achieved within a shorter time frame, the returns from the project will be very much greater. The *Base Case A* has built into it an immediate additional development cost factor of $330,000, which is an estimated cost for additional drilling and brine assessment required in the vicinity of Lake Callata.

*Case A* provides an additional scenario, with the full capital cost of roadworks, shown as an extra by BHPE, being provided as an alternative. *Case B* provides a project value with a 10% across the board reduction in sales revenue, and *Case C* shows the *Base Case* scenario with both a 20% reduction and a 20% increase in the capital costs. *Case D* provides for a sales value decrease of 20%, and *Case E* shows NPVs with capital variation of ±30%. *Case F* provides for total development costs of $1M added to the base capital requirement. *Case G* provides for ±30% capital cost variation superimposed onto the *Case F* scenario. Finally *Case H* provides 4 scenarios of capital variation set against sales variations of ±20%.

Although each of these analyses produce quite dramatic variations to the NPV of the project, they also demonstrate its quite sound base, given the range of assumptions that has been made.

The NPV analysis provides a present value of a series of future cash flows generated from a business, discounted at various percentage rates, which take into account both interest rates and a certain amount of business risk. The rates chosen in this analysis cover the range 15% down to 8%. In current economic conditions, the mid range of 10% - 12% after tax is a reasonable basis, and in the *Base Case A* provides a net present value of $11.22 million and $8.35 million respectively, surplus to the $12.36 million cost of the project. With the additional capital cost of $2.35M added in for the fully constructed roadworks from the evaporite pond area to the processing plant, as is provided in the adjunct scenario in Case A, the NPV's thus generated are still particularly high values of $8.6 million and $5.7m million at 10% and 12% discount rates respectively.

*Tables 1 & 2* in the following pages provides the forecast sales revenues, operating and estimated overhead costs and net cash revenues thereby generated after tax on which the *Base Case A* has been formulated. The NPV's based on this and the several sensitivity analyses follow in Tables 3, 4, 5 and 6.
<table>
<thead>
<tr>
<th>Base Case A</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
<th>Year 6</th>
<th>Year 7</th>
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<td>Na₂SO₄ Sales (tpa)</td>
<td>7,500</td>
<td>15,000</td>
<td>25,000</td>
<td>35,000</td>
<td>40,000</td>
<td>40,000</td>
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<tr>
<td>@ $/tonne *</td>
<td>165</td>
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<td>4,125,000</td>
<td>5,775,000</td>
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<tr>
<td>KCl Sales (tpa)</td>
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<td>3,000</td>
<td>3,000</td>
<td>3,000</td>
<td>3,000</td>
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<tr>
<td>@ $/tonne</td>
<td>290</td>
<td>290</td>
<td>290</td>
<td>290</td>
<td>290</td>
<td>290</td>
<td>290</td>
</tr>
<tr>
<td>Sales Revenue</td>
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<td>870,000</td>
<td>870,000</td>
<td>870,000</td>
<td>870,000</td>
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<td>K₂SO₄ Sales (tpa)</td>
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<td>3,800</td>
<td>3,800</td>
<td>3,800</td>
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<tr>
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<td>1,368,000</td>
<td>1,368,000</td>
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<tr>
<td>TOTAL REVENUE</td>
<td>2,247,500</td>
<td>4,713,000</td>
<td>6,363,000</td>
<td>8,013,000</td>
<td>8,838,000</td>
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</tr>
</tbody>
</table>

**Fixed costs**

| Project Dvlpmnt    | 330,000 |
| Cap Costs ($M)     | 12,030,000 |
| Plant & Staff      | 926,000  | 1,082,000 | 1,082,000 | 1,082,000 | 1,082,000 | 1,082,000 |
| Oheads             | 350,000  | 380,000   | 380,000   | 380,000   | 380,000   | 380,000   |

**Variable Costs**

| Operators          | 500,000  | 608,000   | 608,000   | 608,000   | 608,000   | 608,000   |
| Consumables        | 50,000   | 101,000   | 101,000   | 101,000   | 101,000   | 101,000   |
| Reagents           | 93,000   | 186,000   | 186,000   | 186,000   | 186,000   | 186,000   |
| Fuel               | 400,000  | 464,320   | 464,320   | 464,320   | 464,320   | 464,320   |
| Total Costs        | 2,319,000 | 2,821,320 | 2,821,320 | 2,821,320 | 2,821,320 | 2,821,320 |
| Profit (pre-tax)   | -71,500  | 1,891,680 | 3,541,680 | 5,191,680 | 6,016,680 | 6,016,680 |
| Plant Depreciation** | -1,467,000 | -1,467,000 | -1,467,000 | -1,467,000 | -1,467,000 | -1,467,000 |
| Taxation           | 0       | 0        | 374,735   | 1,452,825 | 1,774,375 | 1,774,375 |
| Tax Credits (Cumulative) | -1,538,500 | -1,113,820 | 960,860   | 0         | 0         | 0         |
| Net Cash Revenues  | ($71,500) | 1,891,680 | 3,166,945 | 3,739,055 | 4,242,305 | 4,242,305 |

* All sales revenues are ex-plant

**Plant depreciation is based on plant value of $9.78m @ 15% p.a. depreciation.

STATUS RESOURCES AUSTRALIA  (NPV TABLE 1)
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<th></th>
<th>Year 8</th>
<th>Year 9</th>
<th>Year 10</th>
<th>Year 11</th>
<th>Year 12</th>
<th>Year 13</th>
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<tbody>
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<td>Base Case A</td>
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<td>TOTAL REVENUE</td>
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<td>Plant &amp; Staff</td>
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<td>Oe喵s</td>
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STATUS RESOURCES AUSTRALIA [NPV TABLE 2]
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<td>$14,947,975</td>
<td></td>
</tr>
<tr>
<td>Period</td>
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<td>15 years</td>
<td></td>
</tr>
<tr>
<td>Discount Rate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15.00%</td>
<td>$4,886,130</td>
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<td>$8,351,098</td>
<td>$5,763,123</td>
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<td>10.00%</td>
<td>$11,227,179</td>
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<td>$12,101,146</td>
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<table>
<thead>
<tr>
<th>CASE B</th>
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<th>Base Case</th>
<th>Base+Full Road</th>
</tr>
</thead>
<tbody>
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<td>SALES -10%</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Capital</td>
<td>$12,360,000</td>
<td>$14,947,975</td>
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</tr>
<tr>
<td>Period</td>
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<table>
<thead>
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<th>CASE C</th>
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</tr>
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<td>CAPITAL</td>
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<td></td>
</tr>
<tr>
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<td>15 years</td>
<td></td>
</tr>
<tr>
<td>Discount Rate</td>
<td></td>
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<td>$2,414,130</td>
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STATUS RESOURCES AUSTRALIA (NPV TABLE 3)
### CASE D

<table>
<thead>
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<th>Sales</th>
<th>NET PRESENT VALUES</th>
<th>Base Case</th>
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<tbody>
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<td>Capital</td>
<td>$12,360,000</td>
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</tr>
<tr>
<td>Period 15 years</td>
<td>15 years</td>
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<tr>
<td>Discount Rate</td>
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### CASE E

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>Period 15 years</td>
<td>15 years</td>
<td>15 years</td>
<td></td>
</tr>
<tr>
<td>Discount Rate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15.00%</td>
<td>$1,178,130</td>
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<td>10.00%</td>
<td>$7,519,179</td>
<td>$14,935,179</td>
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<tr>
<td>8.00%</td>
<td>$10,981,121</td>
<td>$18,397,121</td>
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### CASE F: Base Case Net Present Values

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<th>Capital + $1m dev costs</th>
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<td>Base Case + $1m</td>
<td>Base + $1m + Road</td>
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<table>
<thead>
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### CASE G: Capital ±30% Net Present Values

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<td>Capital Period</td>
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<td>10.00%</td>
<td>$6,648,179</td>
<td>$14,466,179</td>
</tr>
<tr>
<td>8.00%</td>
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<td>$17,926,121</td>
</tr>
<tr>
<td>CASE H</td>
<td>NET PRESENT VALUES</td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>--------------------</td>
<td></td>
</tr>
<tr>
<td>CAPITAL ±30%</td>
<td>CAPITAL +30%</td>
<td>CAPITAL -30%</td>
</tr>
<tr>
<td>SALES ±20%</td>
<td>SALES +20%</td>
<td>SALES -20%</td>
</tr>
<tr>
<td>Capital Period</td>
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</tr>
<tr>
<td>15 years</td>
<td>15 years</td>
<td>15 years</td>
</tr>
<tr>
<td>Discount Rate</td>
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<tr>
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<td>10.00%</td>
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<td>8.00%</td>
<td>$17,889,253</td>
<td>$25,707,253</td>
</tr>
</tbody>
</table>
5. RECOMMENDATIONS
5. RECOMMENDATIONS

The result of this Pre-feasibility Study as stated in the SUMMARY CONCLUSIONS in Section 2 of this Report is that:

(1) The brine resources as so far identified, are likely to provide viable market products that can be competitive with existing sources of supply.

(2) As such they are likely to provide adequate financial returns on the necessary level of investment and identified costs of production.

However the FINANCIAL ANALYSIS indicates considerable sensitivity of the project to costs and revenue stream variations, which although are expected and within the levels of acceptability of a pre-feasibility study, requires that many of the assumptions on which the present Study has relied, need to be clarified and subjected to much closer analysis, in order to fully and accurately assess the project's feasibility. Such results should form the basis of a Final Feasibility Study for the brines project.

In broad terms further testwork should be undertaken to establish a final design concept so that more detailed project evaluation can be made. Further brine resource delineation, quantification and characterisation is required as part of this task. The Study has established that in the case of the three potassium salts, namely chloride, sulphate and nitrate, as well as in the case of sodium bromide, potential markets exist, both domestic and export, which could be addressed by production on a larger scale than that on which this Study has been based. Therefore the potential for the discovery of significantly larger brine reserves ought to be fully assessed by NT Evaporites.

Specific tasks to be addressed are detailed in the body of the ENGINEERING Study (CRITICAL PROJECT ISSUES p 5-1, 5-2), and in the COMMERCIAL Study and include:

- Additional brine resource drilling, sampling and analysis
- The conceptual process designed by BHP Engineering should be proven at pilot plant stage prior to further plant design development. This will also provide sample products for market evaluation.
- Aboriginal & other community acceptance
- Energy supply
- Final plant location & infrastructure considerations
- Detailed end-user testing & product acceptance of pilot plant products
- Commercial supply commitments addressed
- Transport & product distribution options analysed

It is therefore recommended that NT Evaporites obtain an estimate budget costing to undertake a Final Feasibility Study and then arrange funding adequate to develop the project to the Final Feasibility stage.
6. DISCLAIMER
6. DISCLAIMER

This Pre-feasibility Study has been prepared by Status Resources Australia (Status) at the request of the Northern Territory Department of Industries & Development as well as by the Directors of NT Evaporites. It has been prepared solely for the purpose of information and analysis and does not constitute an offer or invitation to any person to buy or sell any asset or shares in any company, or to deposit monies with any person.

All information, forecasts, projections, estimates and opinions contained in this Study have been arrived at on the basis of information available at the date hereof. However no responsibility is taken and no representations, undertakings nor warranties, expressed or implied, are made by Status. Status disclaims any liability in contract, tort or any other liability to any person or corporation with respect to the completeness or accuracy of any statements, opinions, projections, forecasts and any other information contained herein or in any subsequent Study provided by it.

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N. T. EVAPORITES
NORTHERN TERRITORY DEPARTMENT OF INDUSTRIES DEVELOPMENT

NORTHERN TERRITORY EVAPORITE MINERALS
SECTION II
CONCEPTUAL PROCESS ENGINEERING STUDY

Issue No. : 
Issue Date : 
BHPE Ref : 
Doc. Reg. No. : PS0075

Prepared By:
BHP Engineering Pty Ltd
(A.C.N.008 630 500)
Australia

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North Sydney  NSW  2059

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Facsimile: 923 3590
CONTENTS

1. SUMMARY
2. INTRODUCTION
3. SCOPE OF WORK
4. REVIEW OF EXISTING DATA
5. CRITICAL PROCESS ISSUES
6. DESIGN CRITERIA
7. DISCUSSION
8. BUDGET CAPITAL ESTIMATE
9. OPERATING ESTIMATE
10. EQUIPMENT LIST
11. PROJECT IMPLEMENTATION SCHEDULE AND DISBURSEMENT SCHEDULE
12. REFERENCES
13. APPENDIX – GLOSSARY
# ENGINEERING DOCUMENT

**DOCUMENT TYPE:** PREFEASIBILITY STUDY

**DOCUMENT REGISTRATION NO:** G250-469-P-0183

**TITLE:**

NORTHERN TERRITORY EVAPORITE MINERALS

CONCEPTUAL PROCESS ENGINEERING STUDY

**GENERAL DESCRIPTION:**

**REFERENCED DOCUMENTS:**

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<th>POSITION</th>
<th>SIGNED</th>
<th>DATE</th>
</tr>
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<tr>
<td>ORIGINATOR</td>
<td>PHILLIP CRISAFTILI</td>
<td>PROCESS ENGINEER</td>
<td>22/07/92</td>
<td></td>
</tr>
<tr>
<td>CHECKED</td>
<td>GEORGE FURMANSKI</td>
<td>SEN. PROCESS ENGR.</td>
<td>02/09/92</td>
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<tr>
<td>APPROVED</td>
<td>ALLAN MOORE</td>
<td>PROCESS TECH. MGR.</td>
<td>22/07/92</td>
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## REVISIONS

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1. SUMMARY
SUMMARY

Status Resources Australia and BHP Engineering Pty Ltd were engaged by the Northern Territory Department of Development and N.T. Evaporites to examine the potential market for salt products and the technical processing issues involved in development of N.T Evaporites playa lake salt resources in Central Australia.

The purpose of this study is to enable N T Evaporites to assess the justification for further work to fully delineate and characterise the resource and to verify process design concepts by pilot plant testing.

This section of the Report documents BHP Engineering work on the Study. A companion section documents Status Resources market study.

This study indicates that on-site production of thenardite appears technically feasible and that the resultant spent liquor provides a rich source of other extractable minerals.

Status Resources market evaluation has identified thenardite (sodium sulphate), sylvite (potassium chloride) and potassium sulphate as the marketable products available from this brine. Consequently, this report addresses the on-site processing of these products. Additionally, the harvesting of halite from the pond area has also been reviewed and can provide additional revenue dependent on market and quality issues.

The potential viability of this project however, depends on the product quality, quantity and market values, figures which can vary significantly with time. BHP Engineering has established a conceptual mass flow diagram, process flowsheets, layout diagrams, equipment list and budget capital and operating costs.

The following budget capital and operating costs have been prepared on the basis of a site assumed to be established at Calata or Erlidunda for the production of thenardite, sylvite and potassium sulphate at a rate of up to 40,000 tpa, 2 970 tpa and 3 800 tpa respectively.

<table>
<thead>
<tr>
<th>Budget Cost</th>
<th>$M</th>
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</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>Operating</td>
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</tr>
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</table>

Additional costs of a roadway to an alternative site location and also for a packing plant have also been presented.

Further testwork has been recommended to establish a final design concept for detailed evaluation and to confirm the mining reserves.
2. INTRODUCTION
INTRODUCTION

N. T. Evaporites is a Northern Territory company that holds a number of exploration licences located in the Amadeus Basin. The exploration licences cover access to potential valuable industrial mineral resources associated with a salt lake system in the area.

N. T. Evaporites has identified industrial minerals on these license areas, with the main groups being sulphate and chloride salts of sodium, magnesium and potassium. These can be recovered from the highly concentrated ground water solutions.

Following encouraging result of brine quality obtained from exploration programmes discussions were held with the Northern Territory Department of Industries Development (DID) regarding the possibility of undertaking a technical feasibility of commercial production of salts from the brines in the licence area.

Approval was subsequently received for the study. Status Resources Australia and BHP Engineering were selected as the consultants to undertake the pre-feasibility study for the N. T. Evaporites Project.
3. SCOPE OF WORK
SCOPE OF WORK

The following lists the specific issues to be addressed by BHPE in the study.

1. "Broad Brush" Review of Existing Data, Previous Studies and Testwork including:
   - Potential Sites for Stage I and Stage II
   - Resource Data and Reserve Estimates
   - Meteorological Data
   - Chemical and Physical characterisation of the resource
   - Preliminary analytical and process testwork
   - Literature review of potential technologies
   - Desired Product slate and specifications
   - Transport and infrastructure constraints
   - Regulatory and environmental constraints
   - Community acceptance (including Aboriginal communities)

2. Identification of any potential critical project issues or "showstoppers"
   - Assessment of adequacy of current data to address those issues
   - Recommendation of further testwork or data generation to redress any inadequacies

3. Confirmation of conceptual project parameters
   - Mine Life
   - Desired products
   - Stage I plant production capacity
   - Stage II plant production capacity
   - Start-up target and production ramp-up schedules
   - Potential sites for Stage I and Stage II plants

4. Preliminary Screening of Potential Processes and Recommendation of preferred processing concept to fit the project parameters and constraints.


7. Prepare major equipment list and obtain vendor budget prices.
8. Prepare preliminary site layout drawings.

9. List basic infrastructure requirements.

10. Prepare capital cost estimate ±30% order of accuracy from vendor data and BHPE cost data base.

11. Recommend a range of project capital contingency allowances considered appropriate for the quality of project data and the inherent technical and commercial uncertainties involved. These would be applied to financial modelling and sensitivity studies (by others).

12. Prepare a list of project operating consumables including labour and maintenance and recommend a range of prices for financial modelling and sensitivity studies. Recommend appropriate range of contingency allowance for sensitivity studies.

13. Prepare a preliminary project implementation schedule and an estimated schedule of capital disbursement for use in financial modelling.


15. Publish twenty copies of report including hard covers, drawings and coloured photographs or illustrations to a standard suitable for inclusion in the project "Bankable Document".
4. REVIEW OF EXISTING DATA
REVIEW OF EXISTING DATA

4.1 POTENTIAL SITES AND PROCESSING CONCEPTS

N.T. Evaporites' initial concept was for two stages of processing to final product. The primary stage was envisaged to be performed close to the salt resource to produce a raw brine (or brines) for further value-added processing at Port Augusta in South Australia.

The rationale was to overcome the following perceived constraints:

a) the cost of energy in remote Central Australia

b) the potential ability to obtain economies of scale by also exploiting previously delineated salt lake resources at Port Augusta.

Following the initial BHPE review of project data, N.T. Evaporites agreed to alter the plant concept to a single site at or within 30 km of any one of three potential salt well fields within the Erldunda-Karinga Creek region, identified by Dr Aro Arakel as suitably characterized and of size adequate to supply 2500m³/day of brine for at least 15 years.

In making this recommendation, BHPE considered the following:

a) Although the total resource is not fully delineated and characterized, N.T. Evaporites was confident that the exploration and test work performed on its behalf by Dr Arakel clearly demonstrated sufficient resource in each of at least three areas within the Karinga Creek-Erldunda region to justify a development based on extraction at 2500m³/day of brine.

b) Fuel for processing and electrical power generation was relatively accessible to the Karinga Creek-Erldunda region either as LNG from the Energy Equity plant at Alice Springs, or as light Mereenie crude from Palm Valley. Such fuel could be trucked relatively cheaply from Alice Springs via main highways to the potential plant sites in Central Australia.

c) Indicative freight costs to Port Augusta of the order of $50 per tonne make the cartage of water in semi-processed brines prohibitively expensive. Thus, only solid finished product should be trucked.

d) Labour for processing of the brines is available from Alice Springs on a "bus in-bus out" cycle with site accommodation at a base camp at (say) Erldunda station.
e) Development of the Port Augusta salt lakes should be examined separately from this study since this project concept has sufficient salt resources within N.T. Evaporites central Australian exploration leases.

4.2 RESOURCE DATA AND RESERVE ESTIMATES

Resource data, reserve estimates, meteorological data, chemical and physical characterisation, preliminary analytical and process test work were all provided to BHPE by Dr Aro Arakel of Geoprocessors Pty Ltd who has been engaged by N.T. Evaporites over two years to explore and test the exploration leases. Although much more delineation work is necessary to fully quantify and characterize the resource, BHP Engineering has based its design on Dr Arakel's estimates that more than sufficient salt reserves are available for the relatively modest scale of development adopted for this study.

The design criteria assumed for this study, based on Dr Arakel's recommendations, are detailed in Section 6.

4.3 PRELIMINARY LITERATURE REVIEW

A literature review was conducted and relevant references are appended. Generally salt production processes are specific to each resource and its potential market. All make use of natural meteorological conditions to minimise fuel use to obtain pure products. Since the Karinga Springs salt resource and potentially marketable products therefrom differs in many respects from other commercial salt developments, it is not appropriate to transfer a single proven process technology although many similar unit operations can be employed. Thus, a specific process must be developed for Karinga Springs and the process concept has been developed in consultation and based on test work of Dr Arakel. Such a concept (Section 7, figure 2) should be proven at pilot plant stage prior to further development.

4.4 DESIRED PRODUCT SLATE

The desired product slate (Section 6) has been advised by Status Resources Australia from a market study conducted concurrently with this study. Thenadite (Na₂SO₄) is indicated, to be a suitable base product from a Karinga Springs type resource and sylvite (KCl) and potassium sulphate (K₂SO₄) together with common salt (NaCl) are potentially saleable byproducts. Thus the flowsheet has been designed to optimize their production.
4.5 TRANSPORT AND INFRASTRUCTURE CONSTRAINTS

4.5.1 Transport

Potential transport options for a salt production development in Central Australia are limited to road freight either to Port Augusta in South Australia or Darwin or to rail head at Alice Springs.

Status Resources has obtained indicative freight rates for various options of product transport and have advised that road freight to port or to Australian markets on the East Coast currently appear to be the most economical options.

The three currently identified extractable resources in the Karinga Creek-Erdunda area each have two major N.T. all weather highways, the Stuart and the Lasseter Highways within 30 km.

4.5.2 Infrastructure

The only infrastructure currently available to the potential plant sites in the Karinga Creek region are the two major highways mentioned previously. Although the potential mine sites are within 30 km of the highways provision must be made for gravel roads to the minesite. Processing plants could be either located at the minesite; in which case suitable roads for road trains would be required from the highway; or located at the highway in which case a 30 km pipeline would be required for the transfer of preconcentrated brine.

Power must be generated at site using either light crude oil or LNG fuelled generator sets. Some fresh water springs are available although condensation/desalination from the brines is also a potential fresh water source for the conceptual process plant.

There is some development at Erdunda Station and this must be considered as one potential plant site and/or accommodation base camp.

Labour would mainly be recruited from Alice Springs residents and the concept assumes that four operating crews would be bussed in on (say) a two weeks on/two weeks off type roster. The two crews on site would work a 12 hour shift.

4.6 REGULATORY AND ENVIRONMENTAL CONSTRAINTS

No unusual environmental or regulatory issues are anticipated for the project concept of this study.

Disposal of residual salty brines after processing will require careful management, however this problem can be overcome relatively simply by
REVIEW OF EXISTING DATA

recycling discarded brine solution back to the salt lake source. Thus impact on the existing environment would be minimal.

4.7 ABORIGINAL COMMUNITY

N.T. Evaporites and Dr Arakel, in their exploration activities have already demonstrated an understanding and sensitivity to Aboriginal issues within the region. The final mine and process plant site would only be established after consultation with the Aboriginal community within the region.
5. CRITICAL PROJECT ISSUES
After reviewing the current data from N.T. Evaporites, and Geo-Processors Pty Ltd, BHP Engineering has listed the following issues to be resolved by more work, prior to N.T Evaporites making a major commitment to development of the conceptual project.

5.1 RESOURCE DELINEATION AND CHARACTERISATION

Further drilling and analyses of samples is recommended particularly within the three target areas in Karinga Creek - Calata - Eldunda nominated by Dr Arakel. This will confirm the reserve estimates and focus initial development to the most promising resource.

5.2 PROCESS PILOT PLANT

Once the initial minesite is selected and the chemical characteristics of the resource is confirmed, the conceptual process should be verified at pilot scale and product produced for market acceptance testing of product quality.

5.3 MARKET ACCESSIBILITY

Accessibility of N.T Evaporites products to markets identified in the companion report of this Study, should be ensured by Sales Contracts, Letters of Intent or other suitable commercial strategies.

5.4 ABORIGINAL AND OTHER COMMUNITY ACCEPTANCE

As previously discussed the community acceptance issue is critical to implementation of the conceptual project.

5.5 ENERGY SUPPLY

Given the limited options for fuel for the conceptual project supply contracts should be negotiated at an early stage.

5.6 RECOMMENDATIONS

The process design and equipment selection in this report is based on preliminary testwork carried out by Geoprocessors. As a result, the design work is conceptual only and subject to confirmation. Consequently, the following recommendations are proposed by BHP Engineering in establishing a final process design for detailed evaluation. The list is in the required order of performance.

- Carry out further drilling to identify a singular source of brine suitable to make the project stand alone.
- Perform laboratory and site testwork on the identified brine including:
  - Uniformity of brine
CRITICAL PROJECT ISSUES

- Product content in brine and potential product yield.
- Pilot evaporation rates (summer and winter) at various concentration levels.
- Suitability of unlined pond base for initial concentration of brines.
- Energy required to cool concentrated brine 40° Celsius for mirabilite production.
- Suitability of mirabilite for "halite replacement" using available brines.
- Energy required to heat bittern.
- Suitability of brine for sylvite recovery by froth flotation.
- Conversion of KCl to K₂SO₄ using available brines.
- Product dewatering testwork using such items as screens, centrifuges, vacuum belt filters etc. Obtainable moisture levels need to be reported.
- Energy required to dry final product.
- Flow characteristics of products in silos, chutes etc.
- Evaluation of products in respect to market specification.

Establish a pilot scale processing plant to verify the process design and for market evaluation of products.
6. DESIGN CRITERIA
DESIGN CRITERIA

This design criteria is based on information provided to BHP Engineering.

1. **Feed Brine Characteristics**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Rate</td>
<td>2,500 m³/day</td>
</tr>
<tr>
<td>Solution Density</td>
<td>1.15</td>
</tr>
<tr>
<td>Mineral Salts Content</td>
<td>250 g/l (625 t/d)</td>
</tr>
<tr>
<td>Operating Days/year</td>
<td>330</td>
</tr>
</tbody>
</table>

2. **Pre-Concentration of Brine to S. G. 1.265**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method of Concentration</td>
<td>Evaporation</td>
</tr>
<tr>
<td>Volume Retained After Evaporation</td>
<td>625 m³</td>
</tr>
<tr>
<td>Volume To Be Evaporated</td>
<td>1875 m³/batch</td>
</tr>
<tr>
<td>Anticipated Halite Precipitated</td>
<td>350 t/d</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Summer Operation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Days</td>
<td>230</td>
</tr>
<tr>
<td>Average Evaporation Rate</td>
<td>6.5 mm/day</td>
</tr>
<tr>
<td>Pond Cycle Time/Batch</td>
<td>7 Days</td>
</tr>
<tr>
<td>Pond Area Required/Batch</td>
<td>45,000 m²</td>
</tr>
<tr>
<td>Pond Depth</td>
<td>60 mm</td>
</tr>
</tbody>
</table>
Winter Operation

<table>
<thead>
<tr>
<th>Days</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Evaporation Rate</td>
<td>2 mm/day</td>
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<tr>
<td>Pond Cycle Time/Batch</td>
<td>21 days</td>
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<td>Pond Area Required/Batch</td>
<td>45,000 m²</td>
</tr>
<tr>
<td>Pond Depth</td>
<td>60 mm</td>
</tr>
</tbody>
</table>

3. Primary Products

Thenardite (Na₂SO₄) 22–40,000 TPA

Bittern (Conc. Brine) 300–420 m³/day

As indicated by Dr. Arakel, thenardite (Na₂SO₄) yields will vary depending on brine source and the amount of mirabilite (raw thenardite) used in the production of potassium sulphate. The process plant however, has been sized to produce the anticipated 40,000 tpa of thenardite. This figure will need confirmation by further testwork and pilot scale production.

4. Secondary Products

Potassium Chloride KCl 2970 TPA

Potassium Sulphate K₂SO₄ 3,800 TPA

In addition, an anticipated 10,000 TPA of Halite (Salt) is expected by Status Resources, to be sold commercially.
7. DISCUSSION
LOCATION

The location of the project area is shown on Figure 1.

The project area covers parts of the Pastoral Leases. Cattle breeding is the main land use.

The project area does not have a permanent population. Aboriginal tribes of significance are known.

Access to the general area is via two sealed highways (Stuart Highway and Lasseter Highway). The site is approximately 1300 km from Port Augusta and 200 km from Alice Springs.

The study addresses a strategy of development in processing the brine to produce marketable grade Thenardite (Na$_2$SO$_4$), Potassium Chloride and Potassium Sulphate.

CLIMATE

The climate in the area is arid; mean average rainfall varies between 226 mm (Alice Springs) and 333 mm (Ayers Rock). The mean monthly maximum temperature is 33°C in January and 20°C in July. On site monitoring of climate parameters during the past three years indicate that daily temperature ranges from -6°C–27°C during the winter months (May to July). Such extreme seasonal and diurnal temperature variations (including significant temperature variation between exposed and sheltered conditions) are considered suitable for natural harvesting and processing evaporites.

BRINE QUALITY

The brine quality is reported by Dr. A. Arakel, to be variable according to location within the playa system; geochemistry of the particular lake and in relation with neighbouring calcrete and dunal sand aquifers.

Significant climatic variation does effect on the chemistry of the shallow ground waters, however ground water levels seem to fluctuate insignificantly on a yearly basis.

An average ground water quality is shown on Table 1.

Compared with seawater; Na, K and Cl are generally concentrated 4–6 times, Ca and CO$_3$ is nearly depleted, SO$_4$ is 8–10 times the concentration and Mg 2–3 times.
Figure 1 - Map showing the distribution of Exploration Licence areas held by NT Evaporites in the Central Australian Groundwater Discharge Zone, Northern Territory.
TABLE 1 Chemical Analysis of Playa Brines*

<table>
<thead>
<tr>
<th>ELEMENT</th>
<th>MEAN ASSAY**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium Na</td>
<td>93000</td>
</tr>
<tr>
<td>Potassium K</td>
<td>5700</td>
</tr>
<tr>
<td>Calcium Ca</td>
<td>400</td>
</tr>
<tr>
<td>Magnesium Mg</td>
<td>8000</td>
</tr>
<tr>
<td>Bicarbonate HCO₃</td>
<td>120</td>
</tr>
<tr>
<td>Chloride Cl</td>
<td>157000</td>
</tr>
<tr>
<td>Sulphate SO₄</td>
<td>43,000</td>
</tr>
<tr>
<td>Nitrate NO₃</td>
<td>400</td>
</tr>
</tbody>
</table>

Total Dissolve Solids TDS 313 000


** Reported as ppm

PROCESS DESCRIPTION

General

A conceptual process has been developed for the treatment of the mineral rich ground water, associated with the salt lake deposit under investigation. The basis of this process is the mass flow block diagram, Figure 2, developed by BHP Engineering based on information provided by Dr. Arakel.

A market evaluation by Status Resources has identified thenardite (Na₂SO₄), potassium sulphate (K₂SO₄) and potassium chloride (KCl) as the current marketable products available from this brine. Preliminary testwork has identified evaporation and cooling as the main basis of thenardite production with the resultant bittern suitable for the extraction of K₂SO₄ and KCl by mineral and chemical processing methods.
Thenardite production is envisaged as an on-site operation. Consequently, with the production levels of K₂SO₄ and KCl regarded as low but economical, this report investigated the on-site processing of these three products with future provision for the potential production of magnesia and bromide.

Preconcentration of Brine

Refer to Drawing No. NTE-001-M-1-001.

Two submersible pumps built of marine grade stainless steel and sized to fit down a 250 mm dia borewell have been selected to bring the brine to the surface for treatment. The brine will be pumped to 50 000 m² surface area ponds for concentration by evaporation.

The pond sizes have been selected to maximise evaporation and consequently, product recovery. As a result of the size of the ponds, lining has been restricted to the bank walls only of the 8 major ponds (summer ponds). This will however need confirmation by testwork on the permeability of the natural clays.

During the winter months, when the evaporation rates are lower, the number of ponds required to maintain the summer production levels is 21.

Upon reaching a required brine concentration of SG 1.26, the brine is pumped to a "Mirabilite" pond for further processing. It is proposed to pump this concentrated brine a distance of 25 km to the Mirabilite ponds which will be located adjacent to the processing plant. The pumping is anticipated to be in 5 stages using a combination of pump energy and gravity flow. All field pumps will be diesel (or crude oil) powered either directly or through a generator and fitted with auto-transformer soft-starters.

Once the concentrated brine is removed for processing, some 350 tonnes of Halite, precipitated out during evaporation, will remain at the bottom of each pond. This material can be harvested for commercial use or simply, form the base material in the evaporation of the subsequent fresh brine. Harvesting may be restricted in some areas due to accessability.

Process Plant

The process plant is where the concentrated brine is received and further processed. The sequence of processing is given on the attached block diagrams.

The plant could be located near the highway either at Calata or Erldunda for ease of transport and have all associated infrastructure including office, accommodation, canteen etc. located nearby.
50,000 m³ CONCENTRATION PONDS EACH SIZED TO RECEIVE 2500m³ OF BRINE AND CONCENTRATE IT TO SG 1.265 (APPROX 600m³) BY EVAPORATION.

ONE POND TO BE FILLED EACH DAY
ONE POND TO BE HARVESTED EACH DAY

EACH POND HAS BEEN SIZED TO REACH THE REQUIRED CONCENTRATION FOR "HARVESTING" EVERY 7 DAYS IN SUMMER (21 DAYS IN WINTER)

DURING BRINE CONCENTRATION APPROX 360 TONES OF GYPSUM & HALITE IS EXPECTED TO PRECIPITATE TO BOTTOM OF POND. THIS IS NOT PRODUCT & CONSEQUENTLY IT IS TO REMAIN THERE. FRESH BRINE TO BE INTRODUCED ON TOP.

NO. OF PONDS
SUMMER: 8 (7 OPERATING, 1 STANDBY)
WINTER: 24

LINING:
DUE TO SIZE OF PONDS, LINING RESTRICTED TO BANK WALLS OF SUMMER PONDS ONLY. SUBJECT TO FURTHER TESTWORK.

4 "OFF" MIRABLITE PONDS
EACH 15m x 15m x 3m HIGH & 625m³ CAPACITY BRINE PUMPED THROUGH CHILLER UNIT AS TO COOL TO BELOW 0°C UPON WHICH MIRABLITE CRYSTALS WILL FORM

WINTER

2 "OFF" 50m x 100m x 1m MIRABLITE PONDS CYCLED NIGHT HARVEST
OPERATION CONSISTING OF:
1. PUMP SPENT LIQUOR OUT AT DAWN, FOLLOWED BY
2. PUMP FRESH CONC. BRINE IN TO PROTECT UNDERLYING MIRABLITE CRYSTALS DURING THE DAY.
3. NATURAL NIGHT TIME COOLING OF BRINE TO BELOW 0°C ASSISTED BY SPRAY COOLING VIA PUMPS.
A FRESH LAYER OF MIRABLITE CRYSTALS WILL FORM ON TOP FOR PREVIOUS NIGHTS LAYER
4. CHANGE POND OF OPERATION AFTER 7 DAYS LEAVING A FRESH LAYER OF CONC. BRINE SOLUTION ON TOP FOR HALITE REPLACEMENT.
5. REMOVE MIRABLITE/THERMADITE FROM FILLED POND.

NO. OF PONDS
SUMMER: 8 (7 OPERATING, 1 STANDBY)
WINTER: 24

LINING
PONDS FULLY LINED

TIME OF OPERATION: 24HRS/DAY, 7 DAYS/WEEK, 330 DAYS/YEAR

DRAWING
NTE-001-P-1-001

N.T. EVAPORATES
PROPOSED SALINE TREATMENT PLANT - EVAPORATION AREA
CONCEPTUAL FLOW DIAGRAM
THENARDITE

BRINE
2500 m³/day

EVAPORATION
TO S.G. = 1.265
IN A POND

COOLING
TO - 5°C IN A POND

MIRABILITE
SLURRY TRANSFER

SOLID - LIQUID
SEPARATION

WASHING LIQUOR

MIRABILITE CRYSTALS
WASHING

BITTERN FOR FURTHER
PROCESSING

DEWATERING

WASHING LIQUID
RETURN TO PONDS

DRYING

THENARDITE
Na₂SO₄
POTASSIUM CHLORIDE

BITTERN FROM THENARDITE PRODUCTION

EVAPORATION TO S.G = 1.36

CARNALITE CRYSTALS IN NaCl BASE SOLUTION

FLOTATION CONDITIONING

ROUGH FLOTATION

CLEANER FLOTATION

LIQUID-SOLID SEPARATION (CENTRIFUGE)

DRYING

POTASSIUM CHLORIDE KCI

TAILINGS

RETURN TO PONDS

FILTRATE

FOR POTASSIUM SULPHATE PRODUCTION

FROOTHER

DESLIMING AGENT

COLLECTOR

FROTH MODIFIER
Thenardite (Na$_2$ SO$_4$) Production

By cooling the concentrated brine to below 0°C glauber salt (mirabilite) is precipitated. Based on local meteorological data, the required cooling conditions for mirabilite formation are obtainable naturally during most winter nights.

Mirabilite formation is a necessary step in the production of thenardite. Consequently, to take advantage of the winter night conditions, separate winter and a summer mirabilite production operation has been investigated.

The summer operation involves the cooling of concentrated brine in deep (3 m) ponds by pumping the liquor through a skid mounted refrigeration package. Due to the size of the system, air cooling is not considered practical consequently, a fibreglass cooling tower has been included in the system. A chiller unit has been sized to cool the brine to the required temperature in 12–24 hours.

The winter evaporation involves the use of shallow ponds with a continuous cooling spray. Up to 7 days brine production is treated in turn through these ponds using the following sequence:

1. Pump spent liquor out at dawn
2. Immediately pump fresh concentrated brine into the pond to protect the underlaying mirabilite crystals during the day
3. Natural night time cooling of brine assisted by spray cooling to form a fresh layer of mirabilite crystals overlaying the previous nights layer.
4. Repeat cycle until sufficient mirabilite is acquired.

The resultant mirabilite will contain halite impurities. This halite may be replaced by introducing a mixture of glauberite and residual brine to produce a higher grade of mirabilite (Na$_2$ SO$_4$ - 10 H$_2$O). The mirabilite is then dried to form Thenardite (Na$_2$ SO$_4$).

Subsequent Treatment of Brine

Upon precipitation of mirabilite by cooling, the composition of the residual brine is such that sylvite (KCl) may be recovered from solution. However, this sylvite will contain significant levels of impurity. Based on overseas operations and subject to further testwork, it is assumed that Sylvite of a marketable grade can be obtained by further brine concentration through evaporation followed by froth flotation. Refer to Drawing No. NTE-001-M-1-002.
The froth liquor containing purified sylvite is pumped to storage tanks from which it can be dewatered, dried and sold as KCl product or, blended with a mirabilite solution and chemically treated to produce potassium sulphate.

**Product Handling**

Refer to Drawing No. NTE-001-M-1-003.

In order to utilise a single drier, the 3 products will be dried in individual batches through a single fluidised bed dryer. The resultant products will be conveyed and stored in their respective storage bins ready for transport.

Due to the relatively high production levels and the plant's remote location, the transportation of product in bulk containers appears to be the most practical option at this stage. However, the cost of a bagging plant has been provided as an additional capital cost item.

The bagging plant will consist of a dump hopper, located outside the plant building, from which product is conveyed to either of two storage bins, one bin for the bagging of product into 25 kg bags, and the other for bagging into 1-2 tonne bulk bags. A bag palletiser plant has also been included with the 25 kg bagging plant. The equipment has been designed on a bagging rate of 20 tonnes/hr. The bagging plant will be in a 10 m x 20 m building.

An additional 3 operators will be required for the bagging plant. Neither their cost nor the cost of bag supplies have been included in plant operating cost.

**Halite Production**

When halite (salt) is harvested, it is proposed to dry the material in the ponds and then stockpile it outside, near the process plant for storage. From here, the salt can be transferred straight into bulk transport trucks using a front-end loader, or if the bagging plant is installed, it can be sold in bags. Although the proposed plant can treat up to 40,000 tpa of halite, it is envisaged that the proposed labour levels may only be sufficient for harvesting up to 10 000 TPA of the salt.

**PLANT SERVICES AND INFRASTRUCTURE**

Refer to Drawing No. NTE-001-M-1-004.

**General**

Plant services and infrastructure are those services outside the ponds and process plant areas. These services include all work associated with:

- Roads
DISCUSSION

- Water
- Communications
- Power Supply
- Site Buildings
- Fire Protection

These facilities are required to support plant operations and to provide a complete operating site.

**Roads**

General Plant access roads will be provided around the process plant. The alternative cost of providing up to 25 km of roadway for locating the plant closer to the ponds has also been provided.

The roads will be crushed rock surfaced (300mm thick) and suitably drained to prevent water build-up during wet weather periods. It is assumed that all crushed rock will be imported and that water will be available during construction for roadway compaction. The roadway to the ponds would be suitable for up to 20 tonne haulage trucks.

**Water**

The fresh and potable water will be distributed through the process plant for emergency wash facilities and drinking.

If potable water needs to be transported to site, additional capital and operating cost will be necessary but cannot be estimated until the actual site is confirmed.

**Communications**

A PABX system would be installed as part of the treatment plant.

**Power Supply**

Power Supply will be provided by means of generators. Mereenie crude and LNG are two possible fuel sources.

**Site Buildings**

A number of site buildings are included in the treatment plant study. These include:

- administration office which includes the foreman's office and the laboratory.
- sleeping quarters and meals area
• amenities
• workshop and stores
• canteen

It is considered these the buildings will be adequate for the plant operation. Hence, no additional plant support buildings are included in this study. Switchrooms and control/operating rooms are included as part of plant building costs.

Fire Protection

The process water supply will service a fire fighting system in and around the plant site. A ring main will direct water to a series of hydrants in the plant area in accordance with the provisions of AS 2419 and the relevant authorities governing the site.

No provision has been made for fire/smoke detection systems, fire sprinklers or gas extinguishing systems.

Mobile Equipment

The following mobile equipment is expected to be used in the treatment of brine:

• Bulldozer - 1 off
  - for the formation of ponds and access into ponds over the 1m bank walls
• Front-end Loaders - 2 off
  - each of approximately 4m³ capacity for:
    i) loading halite into trucks in pond area
    ii) general loading in the process plant area of product into dump hoppers or transport trucks.
• Truck - 1 off
  - of 12 tonne capacity for general transport of products etc.
• Forklift - 1 off
  - for general lifting of goods received including reagents and, in the case of bagging of products, the transfer of product bags into transport trucks or storage areas.
• Minibus - 1 off
  - for transportation of workers to and from site.
• Utes - 3 off
- for general use.

- Cars - 2 off
  - for general use.

The total anticipated cost for this equipment has been presented separately in our Capital Cost estimate since it can be treated either as capital or as operating (lease basis) cost.
8. BUDGET CAPITAL ESTIMATE
BUDGET ESTIMATE

The estimated budget capital cost for the design, supply, fabrication, installation and commissioning of the proposed brine treatment plant (base case) is $11.91M. This estimate has an accuracy of ±30%. A break-down of this cost is as follows:

Preparation of Ponds

The supply and installation of pumps, lining, chiller units, power etc associated with the pond areas.

$2,746,860

Pipeline to Plant

The supply and installation of 25 km feed line to plant using a combination of pump energy and gravity flow.

$1,772,025

Product Processing and Storage Plant

The fabrication, supply and installation of processing buildings, mechanical equipment, piping, storage silos, drier and power for the processing, drying and storage of products ready for transportation

$4,073,900

Infrastructure

The installation of offices, workshops, stores, roads and communication facilities associated with such a project

$1,060,150

Engineering/Project Management

The costs associated with the engineering, procurement, preparation of drawing and project management in establishing this operation

$2,257,065

Financial Modelling Contingency

An additional 15-30% contingency range on the cost of the project, is recommended by BHP Engineering for financial modelling, to reflect the current degree of definition of the project.
Additional Costs

Additional costs may be associated with further or alternative on-site processing of products. Some of these costs can be summarised as follows:

1. Roadway to Ponds

The preparation and supply of 25 km of compacted crushed rock roadway to the pond area.

- Cost of roadway $4,360,000
- Less Cost of pipework included in base estimate $1,772,025
- Additional Cost $2,587,975

Alternatively, a budget cost estimate for 8 km of crushed rock roadway and 17 km of level track is $1.6M. Subject to site, this figure would allow some access to pond area for halite retrieval and for servicing of pipeline.

2. On Site Bagging Plant

The design, supply and fabrication of a 20 tph bagging plant suitable for either 25 kg bag sizes or 1-2 tonne bulk bags including; dump hopper, transfer conveyors, storage bins, $2,169,200

20 m x 10 m bagging and storage building

Alternatively, bulk bagging only of the 3 main products (thenardite potassium chloride and potassium sulphate), can be achieved in our "base case" plant at the rate of up to 10 tph, for an estimated additional cost of $120,000.

Mobile Equipment

The anticipated capital cost in the purchase of new mobile equipment as described in our discussion, is $774,000. This cost has been included in our capital cost estimate.
9. OPERATING ESTIMATE
Operating Costs

A summary of operating costs is given in Table 2. The basis of these figures is summarised below:

- Estimated Power Consumption as given in Table 3.

  Power is locally available in the form of LNG, Mereenie crude oil, diesel etc. The current cost of Mereenie crude is anticipated to be approximately $6/GJ. This energy cost however could rise to near $12/GJ if LNG is preferred.

- Estimated Manning levels as summarised in Table 4. The table gives a range of anticipated operator earnings and costs associated with accommodation, meals, transport to and from site etc.

  The labour proposed is on a two/12 hour shifts on-site and two shifts resting at Alice Springs swapping every two weeks. Buses will be used to transport labour to and from site (every two weeks) and to and from the plant. Accommodation and meal allowance has only been calculated for the on-site personnel only.

- Maintenance is expected to range between 2 and 3 percent of capital costs.

- An allowance has been included in the operating cost estimate for insurance and license fees. The final figure will of course depend on such factors as size of mining lease, insurance costs etc.
<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>UNIT COST $</th>
<th>AREA</th>
<th>TOTAL ($/year)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Ponds</td>
<td>Rehab</td>
</tr>
<tr>
<td>Mine Manager/Foreman 1 off</td>
<td>80,000/yr</td>
<td></td>
<td></td>
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<tr>
<td>Office Staff 1 off</td>
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<td>Metallurgist/Chemist 1 off</td>
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<td>Operators 19 off</td>
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<tr>
<td>Cook/caretaker 4 off</td>
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<tr>
<td>Driver/Cleaner 2 off</td>
<td>28,000/yr</td>
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<tr>
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<td>Allowance</td>
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<tr>
<td>Accommodation/Meals</td>
<td>25/man/day</td>
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<tr>
<td>Fuel</td>
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<tr>
<td>Insurance and Licence</td>
<td>150,000/yr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reagents</td>
<td>1kg/tonne</td>
<td>1.80/kg</td>
<td>156,816</td>
</tr>
<tr>
<td>Mobile Equipment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rego &amp; Service</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>$/yr</td>
<td>708,450</td>
<td>77,000</td>
</tr>
</tbody>
</table>
### OPERATING ESTIMATE

#### POWER CONSUMPTION

**TABLE 3**

**ESTIMATED POWER CONSUMPTION**

<table>
<thead>
<tr>
<th>Item</th>
<th>Installed Power KW</th>
<th>Consumed Power GJ/Week</th>
<th>Efficiency Allowance %</th>
<th>Total Power Consumed GJ/Week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant</td>
<td>620</td>
<td>211.7</td>
<td>70</td>
<td>302.4</td>
</tr>
<tr>
<td>Brine Pumps</td>
<td>60</td>
<td>17.3</td>
<td>70</td>
<td>12.1</td>
</tr>
<tr>
<td>Conc. Brine Pumps</td>
<td>425</td>
<td>25.5</td>
<td>70</td>
<td>36.6</td>
</tr>
<tr>
<td>Dryer</td>
<td></td>
<td>245</td>
<td>65</td>
<td>377</td>
</tr>
<tr>
<td>Brine Chiller</td>
<td>350</td>
<td>176.4</td>
<td>70</td>
<td>252</td>
</tr>
<tr>
<td>Heat Bittern</td>
<td>200</td>
<td>200</td>
<td>70</td>
<td>284.9</td>
</tr>
</tbody>
</table>

**TOTAL** 1265

These figures are preliminary only subject to further investigation at the detailed design stage and are based on the following criteria:

- Plant power consumption to peak at 470 kW and average at 350 kW on a daily basis.
- Brine pumps to operate 89 hours/week.
- Concentrate brine pumps to operate 21 hours/week.
- Dryer to operate 40 hours/week with energy requirements of 238 kJ/kg.
- Brine chiller to operate 168 hours/week.
- Heat bittern based on 50% of required energy generated by “waste” steam utilisation.
OPERATING ESTIMATE

MANNING SCHEDULE

<table>
<thead>
<tr>
<th></th>
<th>Shifts/Day</th>
<th>No/Shift</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Ponds</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Scraper Operator</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>• Operator</td>
<td>4</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td><strong>2. Plant</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Operators</td>
<td>2</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>• Dryer Operators/Day Gang</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td><strong>3. Staff and Administration</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• General Manager/Foreman</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>• Shift boss/Tradesman</td>
<td>1</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>• Chemist</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>• Office Staff</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>4. Utilities</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Storeman</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>• Lab Analyst/Rehabilitation</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>5. Catering</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Cook/Caretaker</td>
<td>4</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>• Driver/Caretaker</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td>32</td>
</tr>
</tbody>
</table>

The basis of manning schedule is as follows:

- The pond area will utilise the day time evaporation rates and consequently, most pumping will be performed at night time. Therefore, a 24 hours/day, 330 days a year operation has been proposed with the scraper only in use during one shift.

- The plant can be divided into 2 sections:
  - The bittern treatment (flotation) plant which follows on from the daily heating/cooling sequence in the pond area. Consequently, as to provide a 7 days/week operation, two 35 hours/week shifts have been allocated.
- The dryer area, which will batch process the dewatered products, has been proposed as a one shift, 5 days/week operation.

- A review of staff and administration has in place one tradesman in every shift. The tradesman will also act as shift supervisor.

A plant manager/foreman, chemist and a girl friday have also been allocated in staff and administration.

- Utilities has a storemen and a general plant assistant.

- To cater for the operators, four general cooks/caretakers have been allocated in the sleeping/dining quarters and two drivers/caretakers to transport workers to and from work.
10. EQUIPMENT LIST
EQUIPMENT LIST

This list of mechanical items is provisional only used in obtaining a budget estimate of ±30% accuracy.

1. Brine Feed Pumps
   SUPPLIER: Grundfos or equivalent
   NO. OFF: 2
   DUTY: 100 m³/hr at 65 m head
   SIZE: SP124
   MATERIAL: 316 S/Steel (Marine Grade)
   MOTOR: 30 kW each
   COMMENTS: Require soft starter device

2. Brine Feed Pump Generator
   SUPPLIER: Advanced Power or equivalent
   FUEL: Diesel or Crude
   CAPACITY: 103 kVA
   COMMENTS: Portable

3. Brine Pumps Support Frames

4. Feed Brine Head Tank
   DIAMETER: 1.2 m
   CAPACITY: 1.2 m³
   MATERIAL: Mild Steel
   LINING: Rubber

5. Skid and Head Tank Support Frame
6. Concentration Ponds
   NO. OFF: 24, 8 for Summer
   SURFACE AREA: 50,000 m² each
   DEPTH: Approx. 1 metre
   CAPACITY: 250,000 m³
   LINING: Banks of Summer Ponds only

7. Concentrated Brine Feed Pumps
   SUPPLIER: Warman or equivalent
   NO. 5
   TYPE: 6/4-AH
   DUTY: 250 m³/hr at 75 m head
   MATERIAL: Rubber Lined
   MOTOR: 75 kW Diesel

8. Mirabilite Summer Ponds
   NO. 4
   SURFACE AREA: 225 m²
   DEPTH: 3 metres
   LINING: 1.5 mm HDPE Sheeting

9. Mirabilite Winter Ponds
   NO. 2
   SURFACE AREA: 6000 m²
   DEPTH: 1 metre
   LINING: 1.5 mm HDPE Sheeting
10. Brine Chiller Unit

SUPPLIER: Gordon Brothers or similar
COOL VOLUME: 600 m³ in 24 hours
TEMP COOL: 40°C
MOTOR: 350 kW Compressor
4 kW Cooling Tower
22 kW Pump

11. Chiller Unit Feed Pump

Included above.

12. Bittern Feed Pump

SUPPLIER: Warman or equivalent
NO. OFF 4 (2 operating)
TYPE: 4/3-AH
DUTY: 140 m³/hr at 22 m head
MATERIAL: Rubber Lined
MOTOR: 30 kW

13. Bittern Ponds

NO. OFF 24 (8 Summer)
SURFACE AREA: 3000 m² each
DEPTH: Approx. 1 metre
CAPACITY: 420 m³
LINING: Summer Ponds Only
14. Concentrated Bittern Feed Pumps
   SUPPLIER: Warman or equivalent
   NO. OFF: 4 (1 operating)
   TYPE: 4/3-AH
   DUTY: 75 m³/hr at 23 m head
   MATERIAL: Rubber Lined
   MOTOR: 15 kW

15. Bittern Heating Ponds
   NO. OFF: 2
   SURFACE AREA: 225 m²
   DEPTH: 1.8
   CAPACITY: 300 m³
   LINING: 1.5 mm HDPE Sheeting

16. Flotation Plant Feed Pump
   SUPPLIER: Warman or equivalent
   NO. OFF: 2
   TYPE: 3/2-AH
   DUTY: 46 m³/hr at 37 m head
   MATERIAL: Rubber Lined
   MOTOR: 15 kW
17. **Halite Removal Screen**
   - **SUPPLIER:** Honert Vibration Technic or equivalent
   - **TYPE:** U25X
   - **SIZE:** 1200 x 2400 mm
   - **MATERIAL:** Rubber Lined M. Steel
   - **ALTERNATIVE:** Static Sieve Bend
   - **MOTOR:** 2 x 1.5 kW

18. **Rougher Flotation Feed Hopper**
   - **CAPACITY:** 2 m³
   - **MATERIAL:** Mild Steel
   - **LINING:** Rubber
   - **COMMENTS:** Conditioning Tank

19. **Rougher Flotation Feed Pump**
   - **SUPPLIER:** Warman or equivalent
   - **TYPE:** 3/2-AH
   - **DUTY:** 35 m³/hr @ 15 m head
   - **MATERIAL:** Rubber Lined
   - **MOTOR:** 4 kW

20. **Rougher Flotation Cells**
   - **SUPPLIER:** Supaflo, Denver or equivalent
   - **CELL SIZE:** 5 or 8 m³
   - **NO. OF CELLS:** 2
   - **MATERIAL:** Rubber Lined M. Steel
   - **MOTOR:** 2 x 22 kW
21. Rougher Froth Sump/Pump
   SUPPLIER: Warman or equivalent
   DUTY: 10 m³/hr at 14 m head
   FROTH FACTOR: 8 allowed
   MATERIAL: Rubber Lined
   MOTOR: 5.5 kW

22. Cleaner Flotation Cells
   SUPPLIER: Supaflo, Denver or equivalent
   CELL SIZE: 3 m³
   NO. OF CELLS: 2
   MATERIAL: Rubber Lined M. Steel
   MOTOR: 2 x 11 kW

23. Air Blower
   SUPPLIER: Fitzpatrick Eng. or equivalent
   DUTY: 22 m³/min at 20 kPa
   MATERIAL: Mild Steel
   MOTOR: 22 kW, 2920 rpm

24. Froth Product Sump/Pump
   SUPPLIER: Warman or equivalent
   DUTY: 10 m³/hr at 14 m head
   FROTH FACTOR: 8 allowed
   MATERIAL: Rubber Lined
   MOTOR: 5.5 kW
<table>
<thead>
<tr>
<th></th>
<th>EQUIPMENT LIST</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>KCl Guard Screen</td>
</tr>
<tr>
<td>25.</td>
<td>SUPPLIER: Warman or equivalent</td>
</tr>
<tr>
<td></td>
<td>DUTY: 10 m³/hr, 0.5 mm Ap.</td>
</tr>
<tr>
<td></td>
<td>SIZE: Kason K-30</td>
</tr>
<tr>
<td></td>
<td>MATERIAL: Rubber Deck, Rubber Lined</td>
</tr>
<tr>
<td></td>
<td>MOTOR: 0.75 kW</td>
</tr>
</tbody>
</table>

|   | Flotation Tailings Pump Hopper |
| 26. | SUPPLIER: Warman or equivalent |
|   | SIZE: 4/3 |
|   | MATERIAL: Rubber Lined M. Steel |

|   | Flotation Tailings Discharge Pump |
| 27. | SUPPLIER: Warman or equivalent |
|   | TYPE: 3/2 AH |
|   | DUTY: 22 m³/hr at 40 m head |
|   | MATERIAL: Rubber Lined |
|   | MOTOR: 11 |

|   | Heat Exchanger |
| 28. | SUPPLIER: HEA or equivalent |
|   | TYPE: Shell and Tube |
|   | MATERIAL: 316 S. Steel Provisional |
29. **Steam Trap**
   SUPPLIER: Spirax Sarco or equivalent

30. **Hot Water Tank**
   MATERIAL: Mild Steel
   DIAMETER: 4 m
   CAPACITY: 60 m³
   COMMENTS: Insulated

31. **Hot Water Pump**
   SUPPLIER: Kelair or equivalent
   DUTY: 6 m³/hr at 20 m Head
   MOTOR: 4 kW

32. **Sump Pump**
   SUPPLIER: Warman or equivalent
   DUTY: 20 m³/hr at 30 m head
   TYPE: 40 PV-GPS
   MOTOR: 7.5 kW

40. **Mirabilite Pump**
   SUPPLIER: Warman or equivalent
   TYPE: 6/4-AH
   DUTY: 216 m³/hr at 12 m head
   MATERIAL: Rubber Lined
   MOTOR: 15 kW
41. C. D. Tank/Wash Vessel
   CAPACITY: 7 m³
   MATERIAL: Mild Steel
   LINING: Rubber

42. Mirabilite Feed Pump
   SUPPLIER: Warman or equivalent
   TYPE: 6/4-AH
   DUTY: 200 m³/hr at 33 m Head
   MATERIAL: Rubber Lined
   MOTOR: 45 kW

43. Dewatering Classifier
   Details to be established during design

44. Pond Return Hopper No.1
   SUPPLIER: Warman or equivalent
   SIZE: 8/6
   MATERIAL: Rubber Lined M. Steel

45. Pond Return Pump No. 1
   SUPPLIER: Warman or equivalent
   TYPE: 6/4-AH
   DUTY: 136 m³/hr at 15 m Head
   MATERIAL: Rubber Lined
   MOTOR: 15 kW
46. **Thenardite Screw Feeder**
   - SUPPLIER: Jacmor or equivalent
   - SIZE: 300 mm dia
   - LENGTH: 16 m
   - MATERIAL: Rubber Lined M. Steel
   - DRIVE: 7.5 kW

47. **Thenardite Feed Hopper**
   - CAPACITY: 8 m³
   - MATERIAL: Rubber Lined M. Steel

48. **Sylvite Solution Storage Tank**
   - TOTAL CAPACITY: 600 m³
   - NO. OF TANKS: 5
   - MATERIAL: Mild Steel
   - LINING: Fibreglass spray (provisional)

49. **Agitators**
   - SUPPLIER: Lightnin or equivalent
   - NO. OF: 5
   - MODEL: 75Q15
   - MATERIAL: Rubber Lined M. Steel
   - MOTOR: 11 kW each
50. Sylvite Solution Feed Pump

SUPPLIER: Warman or equivalent

TYPE: 4/3-AH

DUTY: 100 m³/hr at 13 m head

MATERIAL: Rubber Lined

DRIVE: 11 kW

51. Sylvite Dewatering Screen

SUPPLIER: Hornert Vibration Technic or equivalent

TYPE: U35W

SIZE: 1500 x 3000 mm

MATERIAL: Rubber Lined M. Steel

ALTERNATIVE: Belt Filter

MOTOR: 2 x 2.3 kW

52. Reversible Screw Feeder

SUPPLIER: Jacmor or equivalent

SIZE: 300 mm dia

LENGTH: 6 m

MATERIAL: Rubber Lined M. Steel

DRIVE: 5.5 kW Reversible

53. 1st Dissolution Tank

SIZE: 2m dia

CAPACITY: 7 m³

MATERIAL: Mild Steel

LINING: Rubber
54. **Agitator**

   **SUPPLIER:** Lightnin or equivalent  
   **TYPE:** Mountable  
   **MOTOR:** 0.37 kW

55. **Centrifuge Feed Pump**

   **SUPPLIER:** Warman or equivalent  
   **TYPE:** 6/4–AH  
   **DUTY:** 220 m³/hr at 24 m head  
   **MATERIAL:** Rubber Lined  
   **DRIVE:** 37 kW

56. **Centrifuge**

   **SUPPLIER:** Siebtechnic or equivalent  
   **TYPE:** Vibrating Screen  
   **SIZE:** HSG 1100  
   **MOTOR:** 30 kW Main Drive  
     4 kW Vibrator  
     0.75 kW Oil Pump

57. **2nd Dissolution Tank**

   **SIZE:** 2 m dia  
   **CAPACITY:** 7 m³  
   **MATERIAL:** Mild Steel  
   **LINING:** Rubber
58. Agitator
SUPPLIER: Lightnin or equivalent
TYPE: Mountable
MOTOR: 0.37 kW

59. 2nd Dissolution Tank Pump
SUPPLIER: Warman or equivalent
TYPE: 6/4 AH
DUTY: 220 m³/hr at 24 m head
MATERIAL: Rubber Lined
DRIVE: 37 kW

60. K₂SO₄ Guard Screen
SUPPLIER: CMI or equivalent
TYPE: Static Sieve Bend

61. Pond Return Hopper No. 2
SUPPLIER: Warman or equivalent
SIZE: 8/6
MATERIAL: Rubber Lined M. Steel

62. Pond Return Pump
SUPPLIER: Warman or equivalent
TYPE: 6/4–AH
DUTY: 220 m³/hr at 15 m Head
MATERIAL: Rubber Lined
DRIVE: 22 kW
63. **Dryer Feed Screw Feeder**

   **SUPPLIER:** Jacmor or equivalent
   **SIZE:** 400 mm dia
   **LENGTH:** 10 metres
   **MATERIAL:** Rubber Lined M. Steel
   **DRIVE:** 5.5 kW Reversible

64. **Dryer**

   **SUPPLIER:** Wests Process Eng. or equivalent
   **TYPE:** Fluid Bed 3 m dia
   **FEED RATE:** 32.5 tph
   **FUEL:** Fuel Oil, 8GJ/hr
   **INCLUSIONS:** Oil Firing System
   Fluidising Fan
   Exhaust Fan
   Multiclone Dust Collector
   Controls

65. **Product Conveyor**

   **CAPACITY:** 40 tph
   **BELT WIDTH:** 600 mm
   **BELT TYPE:** Cleated, lift type
   **BELT LENGTH:** 30 m
   **BELT RISE:** 17 m
   **MOTOR:** 4 kW
66. Transfer Conveyor No. 1
   CAPACITY: 40 tph
   WIDTH: 450 mm
   LENGTH: 10 m
   MOTOR: 1.5 kW

67. Transfer Conveyor No. 2
   CAPACITY: 40 tph
   WIDTH: 450 mm
   LENGTH: 8 m
   MOTOR: 1.5 kW

69. KCl Product Bin
   CAPACITY: 180 m³ (1 month)
   WIDTH: 8 metres
   MATERIAL: Mild Steel

70. K₂SO₄ Product Bin
   CAPACITY: 180 m³ (1 month)
   WIDTH: 8 metres
   MATERIAL: Mild Steel

71. Thenardite Product Bin
   CAPACITY: 260 m³ (3 days)
   WIDTH: 8 metres
   MATERIAL: Mild Steel
11 PROJECT IMPLEMENTATION SCHEDULE AND DISBURSEMENT SCHEDULE
Project Schedule

A project schedule has been prepared for the scope of this report. The overall project timing will vary depending on the final scope of the project and relevant manufacturers' workload and deliveries at the time of project commencement. The following schedule shows the estimated project duration to be 12 months. A maximum project duration for the "worst case" is estimated to be 15 months.

The brine chiller plant and the power generators are expected to be the longest delivery items.

Capital Disbursement

The anticipate on-going capital expenditure for the establishment of this project is indicated as a percentage of the total cost, by the "S" curve on the project schedule.
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REFERENCES

1 COMPREHENSIVE UTILISATION OF BRINES FROM KARINGA CREEK DRAINAGE SYSTEM, NORTHERN TERRITORY. (CONFIDENTIAL)

A technical feasibility assessment for commercial production of high value salt chemicals

by A. V. ARAKEL; Geo Processers, August 1991.

2 GEOLOGY, HYDRO-GEOCHEMISTRY AND INDUSTRIAL MINERAL RESOURCES IN THE KARINGA CREEK DRAINAGE SYSTEM, NORTHERN TERRITORY. (CONFIDENTIAL)


by A. V. ARAKEL; Geo Processes, October 1990.

3 STATE OF THE ART OF SOLUTION MINING FOR SALT, POTASH AND SODA ASH

by M. T. Nigbor, Mine Engineering Div., Denver, 1981 (?)

4 SME MINERAL PROCESSING HANDBOOK VOL 2

by N. L. Weiss, Ed

5 SOME ASPECTS OF THE PHYSICAL CHEMISTRY OF POTASH RECOVERY BY SOLAR EVAPORATION OF BRINES

by P Hadzeriga, June 1964
13. APPENDIX - GLOSSARY
**APPENDIX - GLOSSARY**

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>THENADITE</td>
<td>A colourless, greyish white, yellowish, yellow-brown, or reddish orthorhombic mineral consisting of sodium sulphate (Na₂SO₄)</td>
</tr>
<tr>
<td>HALITE</td>
<td>Native salt; and evaporite mineral occurring as isometric crystals or in massive, granular or compact form. Also known as common salt, rock salt (NaCl)</td>
</tr>
<tr>
<td>MIRABILITE</td>
<td>A yellow or white monoclinic mineral consisting of hydrous sodium sulphate, occurring as a deposit from saline lakes, playas, and springs and as an efflorescence. The pure crystals are known as Glauber's salt (Na₂SO₄·10H₂O)</td>
</tr>
<tr>
<td>PLAYA</td>
<td>1. A low, essentially flat part of a basin or other undrained area in an arid region</td>
</tr>
<tr>
<td></td>
<td>2. A small, generally sandy land area at the mouth of a stream or along the shore of a bay</td>
</tr>
<tr>
<td></td>
<td>3. A flat, alluvial coastland, as distinguished from a beach.</td>
</tr>
<tr>
<td>PLAYA LAKE</td>
<td>A shallow temporary sheet of water covering a playa in the wet season.</td>
</tr>
<tr>
<td>EVAPORITE</td>
<td>Deposits of mineral salts from sea water or salt water due to evaporation of the water.</td>
</tr>
<tr>
<td>EVAPORITE POND</td>
<td>Any containment for brines or solution-mined effluents constructed to permit solar evaporation and harvesting of dewatered evaporite concentrates.</td>
</tr>
<tr>
<td>BRINE</td>
<td>Sea water (or ground water) containing a higher concentration of dissolved salt than that of the ordinary ocean.</td>
</tr>
<tr>
<td>SYLVITE</td>
<td>A salty tasting, white or colourless isometric crystal occurring in cubes or crystalline masses or as a saline residue; the chief ore of potassium. Also known as sylvine (KCl)</td>
</tr>
</tbody>
</table>
EPSOMITE
A mineral that occurs in clear, needle-like, orthorhombic crystals; commonly, it is massive or fibrous; lustre varies from vitreous to milky; hardness is 2-2.5 on Moh's scale, and specific gravity is 1.68; it has a bitter taste and is soluble in water. Also known as epsom salt. (MgSO_4·7H_2O)

POTASH
White, water soluble, deliquescent powder, melting at 891°C, insoluble in alcohol; used in browning, ceramics, explosives, fertilisers and as a chemical intermediate. Also known as potassium carbonate; salt of tartar. (K_2CO_3)

CARNALLITE
A milky-white or reddish mineral that crystallises in the orthorhombic system and occurs in deliquescent masses; it is valuable as an ore of potassium.

DELIQUESCENCE
The absorption of atmospheric water vapour by a crystalline solid until the crystal eventually dissolves into a saturated solution.

BITTERN
Concentrated sea water or brine containing the bromides and magnesium and calcium salts left in solution after sodium chloride has been removed by crystallisation.

GLAUBERITE
A brittle, gray-yellow, monoclinic mineral having vitreous lustre and saline taste. (Na_2Ca(SO_4)_2)

GYPSUM
A mineral, the commonest sulphate mineral; crystals are monoclinic, clear, white to grey, yellowish, or brownish in colour, with well-developed cleavages; lustre is subvitreous to pearly; hardness is 2 on Moh's scale and specific gravity is 2.3; it is calcined at 190°-200°C to produce plaster of paris. (CaSO_4·2H_2O)
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONCENTRATION</td>
<td>The process of increasing the concentration of a solution by removal of solvent to point in saturation of solute/s. Further concentration produces crystallisation.</td>
</tr>
<tr>
<td>CRYSTALLISATION</td>
<td>The process by which molecular compounds in solid form originate and grow because of solubility changes of the compounds in a solution. The process produces a crystalline, rather than amorphous, colloidal or gelatinous material.</td>
</tr>
<tr>
<td>SCHOENITE</td>
<td>A mixture of magnesium and potassium hydrated sulphate.</td>
</tr>
</tbody>
</table>