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Department of Conservation and Land Management

Solar Saltfield at Toolbin Lake

Feasibility Study

AUGUST 2003

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Solar Saltfield at Toolibin Lake

Feasibility Study

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1. Summary
1 Summary

1.1 Background

Toolibin Lake is located 20 km southeast of the town of Wickepin in the wheat belt of Western Australia. The biodiversity of the lake is seriously threatened by increasing salinity due to rising hyper-saline ground water.

As part of a salinity management plan, the Department of Conservation and Land Management (DCLM) has constructed a channel to divert saline surface water flows around Toolibin Lake and has installed bores in the aquifers below the lake bed to lower the levels of saline groundwater. Pumping operations run 24 hours per day, 7 day per week, removing approximately 300,000 m³ of saline ground water per year. This water is currently discharged by pipeline into nearby Taarblin Lake.

Given the need to pump saline ground water as a key element of the Salinity Management Plan, the construction and operation of a solar saltfield at Toolibin Lake offers an opportunity to:

- Provide a commercial mechanism for removal of salt from the area and
- Defray costs of groundwater pumping

1.2 Saltfield Design

The conceptual design for a saltfield at Toolibin Lake is based upon an available groundwater flow of 300,000 m³/a, at a total salt concentration of 40 g/l.

Table 1 shows the required brine supply volume, evaporation pond and crystalliser areas for annual salt production increasing from the base model of 5,000 tonnes to 20,000 tonnes.

**Table 1 – Salt Production vs. Annual Brine Flow and Saltfield Area**

<table>
<thead>
<tr>
<th>Annual Salt Production Tonnes</th>
<th>Annual Brine Supply Volume m³</th>
<th>Evaporation Pond Area ha</th>
<th>Crystalliser Area ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>5,000</td>
<td>260,000</td>
<td>34</td>
<td>4</td>
</tr>
<tr>
<td>6,000</td>
<td>310,000</td>
<td>41</td>
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<td>7,500</td>
<td>390,000</td>
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<td>10,000</td>
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<td>650,000</td>
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<td>13</td>
</tr>
<tr>
<td>17,500</td>
<td>910,000</td>
<td>120</td>
<td>15</td>
</tr>
<tr>
<td>20,000</td>
<td>1,000,000</td>
<td>137</td>
<td>17</td>
</tr>
</tbody>
</table>
1 Summary

1.3 Geotechnical

A geotechnical investigation covering the likely extent of the saltfield was conducted.

This investigation confirmed the suitability of the soil on site for use in constructing evaporation and crystalliser ponds. Providing appropriate site preparation and soil placement methods are used, the high clay content of the soil will result in low to very low permeability impoundments, eliminating the need for liners in the evaporation or crystalliser ponds.

All fill required for pond embankment construction can be sourced from within the pond system. Because of the highly plastic nature of soils at the site, good compaction and moisture control will be necessary during construction to ensure the soils achieve the required water retention characteristics and strength.

1.4 Saltfield Operations

The conceptual layout for the solar saltfield proposed at Toolibin Lake is shown on the attached drawings.

The first pond in the saltfield has been designed to maximise potential salt production with sufficient capacity to store the groundwater pumped through the winter, allowing a greater brine flow to be pushed through the pond system during the summer. This additional storage also provides the saltfield operator with flexibility in the control of brine flow through the saltfield for the production of quality salt.

The permanent production facilities comprise the permanent earthworks that form the evaporation ponds and crystallisers plus pumps, pipework and flow control structures.

The permanent production equipment includes salt washing and stockpile plant. A 50 t/h capacity wash plant is envisaged. Also required is a small front-end loader to maintain the feed of salt to the wash plant and manage the product stockpiles.

Contractor production equipment will be utilised during the annual harvest period. For harvesting, it is proposed that a grader is used to rip the crystalliser salt surface, then form windrows, for loading by front end loader to trucks for haulage the short distance to the wash plant feed stockpile.

The management of the saltfield operation needs to be undertaken throughout the year by a permanent employee of the Saltfield Operations.

1.5 Market Analysis

In WA, the transportation distances, both inter and intra-state, (compared to the other States of Australia) mean that Toolibin should be primarily targeting the WA market.

The base production levels considered by this study could be accommodated within the existing market, but for production quantities greater than 5,000 t/a to be sold into the WA market it is expected that existing suppliers would have to be displaced.
1 Summary

Given the extended time until salt will be available for sale and the range of markets that will need to be targeted to generate sales, a single base price of $55/t for quality washed salt at site has been adopted for this study.

1.6 Cost Estimation and Financial Analysis

Based on the conceptual engineering design, the brine supply volume and the saltfield area, capital and operating costs have been determined and a range of data generated from the base 5,000 t/a concept design. Financial analysis using Net Present Value (NPV) methods has been run using these estimates to predict the model discount rate for a range of target production and sales tonnages.

The financial analysis assumes a 30 year repayment period for the DCLM costs, for the funding of the construction of the permanent production facilities, with interest set at the Government Bond Rate of 6.7%. The Project Return Period for the Operator’s costs has been set as 15 years. The results of the analysis are summarised in the following table:

Table 2 – Salt Production vs. Capital Cost Estimate, Operating Cost and Internal Rate of Return

<table>
<thead>
<tr>
<th>Annual Salt Production Tonnes</th>
<th>Capital Cost Estimate</th>
<th>Saltfield Operating Cost per tonne</th>
<th>Internal Rate of Return with DCLM Funding</th>
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</thead>
<tbody>
<tr>
<td>5,000</td>
<td>$1,620,000</td>
<td>$46.00/t</td>
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<td>6,000</td>
<td>$1,780,000</td>
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<td>$3,100,000</td>
<td>$25.00/t</td>
<td>16.25%</td>
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1.7 Results

The key findings of the feasibility study investigations and analyses were:

a) The climatic conditions at Toolibin Lake are suitable for the operation of a solar saltfield.

b) The Toolibin Lake site is suitable for the construction of a solar saltfield.

c) The capital cost for the establishment of a saltfield is substantial, with an outlay of $1.6M required for the commercial construction of a 5,000 t/a facility. The cost to establish the saltfield pond system is a significant proportion of this cost, in particular the cost for construction of Pond 1 with adequate capacity to hold brine supplied at a constant rate throughout the year.

d) The financial analysis shows that the saltfield project does not provide a return on investment at 5,000 t/a or 10,000 t/a with $55/t nett sale price. The saltfield needs to produce and sell at least 15,000 t/a of quality salt.
1 Summary

1.8 Conclusions

a) The Toolibin Lake site is suitable for the construction and operation of a solar saltfield and the available groundwater supply of 300,000 m$^3$/a can support a saltfield operation producing 6,000 t/a of washed salt.
b) Because of transport costs, the market for Toolibin salt is within Western Australia. All sales will be sensitive to competition from other suppliers and any attempt to sell significant quantities is likely to meet with strong resistance, with downward pressure on selling price.
c) Toolibin will need to sell value added product, in 25 kg bags, to attract local sales and broad market penetration.
d) As a stand alone enterprise, the saltfield project will not provide an adequate return on investment for sales volume of less than 12,500 t/a.

The key risks are:
- Lack of quality control due to operational inexperience
- Lack of marketing expertise in salt and vulnerability to a price war with existing suppliers

The volume of sales and the nett sale price that can be obtained are the most significant factors for the commercial viability of the saltfield. They are also potentially the largest variables.
2. Introduction
2 Introduction

2.1 Background

Toolibin Lake is located 20 km southeast of the town of Wickepin in the wheat belt of Western Australia. The lake and its catchments form part of the headwaters of the Blackwood River and have been listed as a Wetland of International Importance under the Ramsar Convention. The biodiversity of the lake is seriously threatened by increasing salinity due to rising hyper-saline ground water levels and the lake and its catchment is one of six natural diversity recovery catchments established by the Western Australian Government under the State Salinity Action Plan (1996).

As part of a Salinity Management Plan the Government, through the Department of Conservation and Land Management, is undertaking activities to lower the levels of saline groundwater. The salinity control measures have been successful in limiting the damage to the Toolibin Lake vegetation and it is intended to continue with the wetland recovery program, expanding it as necessary.

2.2 Previous Investigations

A broad range of investigations have been undertaken to determine the appropriate activities necessary to protect and recover the biodiversity at Toolibin Lake, arriving at the current Salinity Management Plan.

These investigations have included the collection of local background data about the region and Toolibin Lake catchments. As a result, there is significant relevant geophysical survey data available about physical attributes of the region including topography, geology, hydrology, soils and vegetation. The investigations also provide a sound understanding of the nature of local groundwater.

The previous investigations have also raised a number of potentially commercial opportunities that could be associated with saline groundwater management, that may enhance and improve the economics of the overall operation at Toolibin Lake. These include:

- Solar Saltfield to produce commercial salt.
- Sale of bitterns liquor.
- Recovery of chemical salts from bitterns liquor.
- Heat energy or power from solar ponds.
- Aquaculture in warm saline ponds.

2.3 Current Operations

As part of the current Salinity Management Plan, a channel has been constructed to divert saline water inflows around Toolibin Lake and bores have been installed in the aquifers below the lake bed to lower the levels of saline groundwater. Electrical power has been established on the site and pumping operations are continued on a 24 hour per day, 7 day per week basis, removing approximately 300,000 m$^3$ of saline ground water per annum. This water is currently discharged by means of pipelines into nearby Taarblin Lake.
2 Introduction

While the current pumping operations at the Toolibin Lake catchment area have been successful in controlling the levels of saline groundwater at Toolibin Lake, it would be preferable to remove salt from the area and achieve some commercial return, rather than transferring it to Taarblin Lake.

The availability of the current flow of saline ground water, of known and reliable quality and quantity, is seen as an opportunity for the construction and operation of a Solar Saltfield at Toolibin Lake.

2.4 Scope of Study

The key elements of this Engineering Feasibility Study into the construction and operation of a Solar Saltfield at Toolibin Lake include:

- Site survey necessary to define the topography;
- Soils investigation, soils analyses and interpretation;
- Engineering concept development for a practical scheme;
- Estimation of the construction and operating costs;
- Market analysis of potential product sales and revenue;
- Financial analysis and scenario modelling.

Based on the currently available brine supply of 300,000 m$^3$ per annum, a saltfield concept has been developed for a production rate of 5,000 t/a. This base concept has then been increased in scale over a range of scenarios covering annual production rates up to 20,000 t/a, to determine the potential income that may be derived. Financial analysis techniques have been applied to determine the return on investment offered by these scenarios and identify the economic value of the proposed Solar Saltfield Project.

The report includes the following deliverables:

- Results of site topographical survey;
- Results of site geotechnical and soils survey;
- Review of proposed site location for construction;
- Saltfield design criteria, conceptual volume balance and pond areas;
- Saltfield layout with earthworks profiles;
- Salt processing plant process flow sheet;
- Description of Project facilities and operating requirements;
- Estimate of capital and operating costs with an accuracy of +/-20%;
- Financial analysis using discounted cash flow techniques, incorporating the capital and operating costs and revenues over a range of scenarios;
- Analysis of the existing salt market and potential sales;
- Comparison of financial options and a conclusion based on an informed review of overall results.
3. Solar Salt Production
3 Solar Salt Production

3.1 Pond System

The production of salt by solar evaporation in ponds is a technology that has been used from ancient times. Modern techniques of solar salt production have been refined to provide a controlled operation that will produce a better quality product; however the basic principles of pond operation are effectively the same as those used for many centuries.

This overview provides a simple description of how a solar pond system produces sodium chloride (common salt). The detailed chemistry of salt production from seawater and natural brines is very complex and is not described in this report.

The solar saltfield comprises a series of shallow ponds, interconnected by flow control structures. The ponds progressively decrease in area, effectively in inverse ratio to the increasing concentration of the salt solution as it moves through the pond system. The saltfield layout, included in the Appendix, shows the general arrangement of the pond system proposed for Toolibin Lake.

At Toolibin Lake, so that the pond system may be operated independently from the continuous groundwater pumping regime required for the Salinity Management Plan, the first pond has been designed with sufficient volume to accommodate at least six month’s yield of groundwater pumping, plus a probable pond level increase from winter rain. This allows the saline groundwater that is pumped to be held over the winter months, when evaporation is low, and released on demand to maintain the brine depth set for each pond in the system.

3.2 Deposition of Salts

The groundwater contains a mixture of salts, which have differing solubilities, depending upon the temperature, density and chemical composition of the solution. Less soluble salts, such as calcium and magnesium carbonates and calcium sulphate (gypsum) tend to precipitate out of solution more quickly than salts such as sodium chloride or potassium chloride. Some salts, including magnesium sulphate, are even more soluble than sodium chloride and will tend to stay in solution longer. Therefore the composition of the brine varies as it evaporates and the less soluble salts crystallise and precipitate out of solution.

A chart illustrating this process is included in the Appendix and shows the deposition of salts during the evaporation of seawater at 25°C. This chart has been prepared for the production of 1,000,000 t/a of salt from seawater, however the saline groundwater used in the Toolibin Lake pond system will behave in a similar manner.

The main salt of interest is sodium chloride, therefore the solar saltfield pond system must be designed to minimise the loss of sodium chloride salt and allow it to be harvested as efficiently as possible. This objective is balanced by the need to produce a high quality product, with as little contamination by other salts (such as calcium or magnesium sulphate or magnesium chloride) as possible. In order to produce a high purity sodium chloride it is necessary to manage the flow of brine through the pond system so that the least soluble salts are allowed to precipitate early in the sequence of ponds.
3 Solar Salt Production

3.3 Crystalliser Ponds

The sodium chloride enriched solution moves progressively through the ponds until it approaches its solubility limit. At this point, the saturated brine (or “pickle”) reaches a density of about 1.2 kg/m³ and sodium chloride will begin to precipitate out of solution, along with any remaining calcium sulphate that has not precipitated in earlier ponds.

The proposed saltfield layout shows four evaporation ponds and two pickle ponds feeding a cluster of four “crystalliser” ponds, where the saturated brine is held and with continuing evaporation and increase in brine density sodium chloride is precipitated. The use of two pickle ponds is proposed so that the density of the saturated brine may be better controlled before its transfer as a batch to a crystalliser pond.

As the sodium chloride rich solution continues to evaporate, the density of the solution will increase until the salts which are more soluble than sodium chloride also begin to precipitate. To avoid contamination of the precipitated sodium chloride this residual liquor is drained off the crystallisers and pumped to waste. About 20% of the sodium chloride remains in this liquor and is lost to the system. These more soluble salts, which include magnesium, calcium and potassium chlorides, magnesium sulphate, and (to a lesser extent) sodium or magnesium bromides, are known collectively as “bitterns”.

Towards the end of the summer, the crystalliser ponds are completely drained exposing the deposited salt in readiness for harvesting.

The crystallisers are engineered with hard flat floors that allow the salt which deposits on the floor of the ponds to be harvested using mobile equipment, while minimising the risk of contamination by soil from the walls or base of the pond.
4. Project Description
4 Project Description

4.1 Equipment and Facilities

The Solar Saltfield proposed at Toolibin Lake requires a range of equipment and facilities, which can be grouped as:

- Permanent production facilities
- Permanent production equipment
- Contractor production equipment
- Utilities and support facilities
- Infrastructure

The following sections describe a saltfield facility capable of handling the current total annual volume of saline groundwater pumped from under Toolibin Lake and capable of producing 5,000 t/a of sodium chloride under the climatic conditions prevailing in the region.

4.2 Permanent Production Facilities

The permanent production facilities comprise the permanent earthworks that form the evaporation and crystalliser ponds, plus other structures required for the production of salt. Permanent production facilities include:

- Evaporation ponds
- Crystalliser ponds
- Pond interconnecting feed and drainage systems
- Pumping stations
- Product stockpile laydown and hard stand

The design criteria and operational requirements for these facilities are:

4.2.1 Evaporation Ponds

A series of six (6) earth formed ponds of reducing area, sized to match the required saltfield production capacity and the evaporation performance prevailing in the region. In operation, the density of the brine in each pond is managed within a set range, as it progresses from pond to pond. At Toolibin Lake, the first pond has extra depth and capacity to store groundwater pumped during the winter when there is little or no evaporation, plus to provide for the retention of rainfall caught within the pond system. The last two ponds operate in parallel to allow better control of the saturated brine or “pickle” density, prior to its release to the pump bay and transfer to the crystallisers.

4.2.2 Crystalliser Ponds

A set of four (4) earth formed crystalliser ponds, sized to match the saturated (maiden) brine output from the evaporation ponds. The pond area required has been divided so that liquor density can be better managed, providing for better control over the quality of the salt deposited.

Over the course of a year, each crystalliser pond receives batches of saturated brine from the evaporation ponds, depending on the availability of brine and the brine levels in the crystalliser. Bitterns liquor will be periodically released from the crystalliser, to
4 Project Description

minimise the deposition of magnesium salts. Immediately prior to harvest, the crystallisers will be drained and the salt floor exposed, ready for harvesting.

The saltfield as designed does not have the facility to produce saleable bitterns. A more highly concentrated product is required, which requires additional evaporation ponds.

4.2.3 Pond interconnecting feed and drainage systems
These channels, pipes and control structures allow control of the flow of brine from pond to pond, using hydraulic gradient from Pond 1 to Pond 5.

4.2.4 Pumping stations
The transfer from the evaporation ponds to the crystallisers cannot be achieved by gravity and the saturated brine must be pumped. Likewise, the supply of brine to the washing plant for product washing and the transfer of bitterns to Taarblin Lake require pumping.

4.2.5 Product stockpile laydown and hard stand
Earthworks are required to provide a stable, all weather laydown area to hold harvested salt, prior to the washing process, plus to stockpile the washed salt prior to further processing or transportation to customers.

4.3 Permanent Production Equipment

The permanent production equipment includes salt washing and stacking plant, power supply and controls, plus mobile equipment required to feed salt to the wash plant and manage stockpiles.

4.3.1 Salt washing and stacking plant
Salt washing and stacking plant, power supply and controls are initially required after the first harvest. As this is specialised plant, it will not be available from a harvesting contractor and must be included in the permanent facilities. A 50 t/h capacity plant is proposed for the 5000 t/a project. With increased plant utilisation, this capacity plant should be sufficient for an increase in production rate up to 20,000 t/h.

4.3.2 Mobile equipment.
A small front end loader with a nominal 2 m³ bucket will be required to manage the stockpiles at the washplant. The loader will reclaim harvested salt for feed to the washplant and handle washed salt for further processing or load salt into road trucks for despatch to customers, for bulk sales. The loader will also be used for general maintenance around the site. As the annual operating hours for this loader will be low, the cost of a refurbished Cat 928 (or similar) has been included in the capital cost estimates.

4.4 Contractor Production Equipment

During a brief period in late summer the salt will be harvested from the 4 crystallisers. As this is only undertaken over a very short period, it is proposed that a local civil works contractor’s equipment will be utilised on hire or under subcontract.
4 Project Description

The equipment required is commonly available and includes a grader, front-end loader and two road trucks, which need to be clean and well maintained to limit contamination of product. A special salt blade may be required on the grader. The grader will be required to rip the salt surface, and then windrow it, for loading by front-end loader from the crystalliser floor to trucks for haulage the short distance to the wash plant feed stockpile. The front-end loader must be capable of loading trucks with 12.5 t payload trailers in order to achieve an average harvesting rate not less than 150 t/h.

4.5 Utilities and Support Facilities

The following utilities and facilities are required to support the saltfield operations:

- Site access roads and vehicle hard stand areas
- Office and amenities
- Laboratory and chemical store
- Workshop/equipment store and fuel storage
- Power supply, area lighting and communications (telephone)
- Potable water supply for amenities only, sewerage and area drainage
- Gates and security fences

The capital and operating cost estimates for the project include costs associated with the construction, operation and maintenance of these facilities.

4.6 Infrastructure

The following external services and facilities will be provided by others at the saltfield boundary at no cost to the project:

- Brine supply - The groundwater bores, pumps and pipelines are existing facilities. Saline groundwater will be supplied to the saltfield at the agreed rate.
- Bitterns disposal - Bitterns liquor will be accepted into the existing brine disposal pipeline at the project boundary. The Project must provide pressure sufficient for liquor transfer to Taarblin Lake.
- Land tenure – Access will be provided to the land on which the project is constructed and the area will be sufficient to provide space for an agreed level of future expansion. All necessary land use approvals will be obtained to ensure the project can proceed.
- External services - Electrical power, potable water and telephone access will be provided at the project boundary.
- Access roads - A formed earthen road will be provided from the Wickepin-Harrismith Road to the project boundary. The saltfield project must allow for the grading and maintenance of the access road.
5. Construction and Operation
5 Construction and Operation

5.1 Saltfield Design

The design of the saltfield, including the area and arrangement of the evaporation ponds and crystallisers, depends upon a number of factors that include:

- Site location and levels
- Geotechnical properties of soils at the site
- Local climatic conditions
- Groundwater/brine chemistry and product composition/quality requirements
- Operational requirements

5.2 Site Investigation

A geotechnical investigation was carried out to provide a preliminary assessment of the soil conditions at the site. This assessment investigated:

- The suitability of soils at the site for use in constructing earth embankments
- The on-site availability of suitable borrow material for use in constructing earth embankments
- Soil strength and permeability characteristics
- Site preparation and construction requirements

The Site Geotechnical Investigation Report is included in the Appendix.

In general the investigation showed:

- The soil conditions are relatively uniform across the proposed saltfield site. Soils to a nominal depth of 0.5 m comprise medium to high plasticity silty or sandy clays of alluvial or aeolian origin that have a relatively low dispersivity.
- The permeability characteristics of shallow soils at the site are generally suitable for use in constructing water (or brine) impoundments. Using the correct earthmoving equipment and procedures, plus adequate engineering supervision, the soils on site are suitable for the construction of pond embankments. Careful site preparation will be required to minimise the potential loss of brine from the ponds and also ensure a suitable working surface upon which to develop salt floors. Low permeability linings are not required.
- All fill required for pond and crystalliser embankment construction can be excavated from within each pond. Topsoil stripping and embankment construction may be achieved with less than 200mm removed from the pond floors.
- A channel should be constructed to divert external stormwater runoff around the saltfield.
- The engineering properties of the soil are generally suitable for support of light structures. A maximum allowable bearing capacity of 100 kPa is recommended for structural foundations supported on shallow soils at the site.
5 Construction and Operation

- It is likely that sufficient quantities of lateritic gravel suitable for use as road base will be available in relatively close proximity to the site. A potential borrow area for gravel was identified on the Wickepin-Harrismith Road, approximately 14 km northwest of the project site.

5.3 Evaporation Pond and Crystalliser Area

The area required for evaporation ponds and crystallisers depends upon the concentration of the groundwater/brine feedstock and the net rate of evaporation. The minimum area requirements have been calculated by means of a volume balance spreadsheet that allows a range of production scenarios to be modelled. The model is based upon empirical performance data derived from established saltfield operations and established solar salt technologies.

At Toolibin Lake the groundwater is more concentrated than standard seawater (35 g/l TDS) and the area required for evaporation is therefore proportionately less than that for an equivalent seawater system. However the net evaporation is low when compared to locations in the north of the state and the area required for evaporation must therefore be proportionately greater.

The spreadsheet developed for this project and the adjusted evaporation and rainfall data for the Toolibin Lake region are included in the Appendix. The spreadsheet model is a reconciliation of the movement of brine and the associated chemical salts through the saltfield pond system and the following is a description of the way the model works.

The fixed model inputs are:
- brine feed salt content (TDS)
- target annual salt production
- mean monthly evaporation
- mean monthly rainfall

Other fixed inputs include factors for:
- evaporation efficiency at various brine densities
- pond seepage losses
- washing and handling losses
- sodium chloride loss in bitterns release

Starting from the target production level (5000 t/a, 10000 t/a, etc), the spreadsheet calculates the quantity of saturated brine needed and the minimum area of crystalliser ponds required. The number of crystallisers has been selected empirically, based on saltfield operating experience.

Next, the spreadsheet uses the calculated quantity of saturated brine to calculate the volume of feed brine required and the total area of evaporation ponds (condensers) required. The number of evaporation ponds and their relative areas from Pond 1 to Pond 4 has been selected empirically, based on saltfield operating experience.
5 Construction and Operation

A conservative value of 40 g/l has been used in the spreadsheet for the groundwater feed salt content. This value allows for a decrease in concentration over the life of the project. It falls at the lower end of the range of values expected for Toolibin Lake groundwater, which is currently yielding water with a salt concentration of slightly more than 50 g/l. The use of an assumed concentration of 40 g/l total salt in the groundwater feed may result in a slight over estimation of the area of evaporation ponds required.

The results of the spreadsheet calculations for each of the throughput scenarios modelled are presented in the Appendix. Table 3 summarises the results and shows the brine supply volume, evaporation pond and crystalliser area for eight annual salt production rates increasing from the base scenario of 5,000 tonnes to 20,000 tonnes.

Table 3 – Salt Production vs. Annual Brine Supply and Pond Area

<table>
<thead>
<tr>
<th>Annual Salt Production t</th>
<th>Annual Brine Supply Volume m³</th>
<th>Evaporation Pond Area ha</th>
<th>Crystalliser Area ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>5,000</td>
<td>260,000</td>
<td>34</td>
<td>4</td>
</tr>
<tr>
<td>6,000</td>
<td>310,000</td>
<td>41</td>
<td>5</td>
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<td>7,500</td>
<td>390,000</td>
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<td>86</td>
<td>11</td>
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<tr>
<td>20,000</td>
<td>1,000,000</td>
<td>137</td>
<td>17</td>
</tr>
</tbody>
</table>

5.4 Pond Design

The primary aim of the Salinity Management Plan is to draw down the groundwater by pumping and this is done at a steady rate throughout the year. However, the demand for brine for salt production will predominantly occur during the summer months when there is significant net evaporation. To accommodate this variance in brine demand and take full advantage of the available groundwater supply, the first pond has been designed with sufficient storage capacity to accommodate the continuing supply of groundwater during months of low or negative net evaporation, when evaporation is less than rainfall.

5.4.1 Pond Layout and Geometry

The layout of the ponds takes into account the site topography as well as the location of the existing access road. The crystallisers are located at the eastern end of the ponds. This locates the harvesting, washing, stockpiling and product despatch close to the existing access road and the Wickepin-Harrismith Road.

The ponds have been arranged to provide the required pond area, for 5,000 t/a salt production, while maximising the pond base area / wall volume ratio. Other design features include the recommendations from the Site Geotechnical Investigation Report, which are summarised in the following section.
5 Construction and Operation

5.4.2 Earthworks Construction

The site preparation works in the areas to be occupied by the evaporation pond embankments and by the crystalliser ponds include:

- Clearing and removal of any vegetation and of superficial soil layers, containing appreciable quantities of root matter or other organic debris
- Inspection of the cleared surface for visible root channels or soft spots
- Removal of any unsuitable soft material and replacement with suitable soil fill
- Scarification of the surface to a nominal depth of 200mm, followed by proof rolling

Pond embankments will require engineering compaction to minimise permeability and to provide adequate strength. It is recommended that embankment soils be placed in layers not exceeding 250 mm loose thickness and compacted to a density of not less than 95% of maximum dry density (Standard Compaction test). The moisture content of soils during compaction should be in the range of 0 to +2% of the field optimum moisture. Embankment walls should be constructed with a minimum crest width of 1.5m and batter slopes not exceeding 1 vertical in 3 horizontal.

The material for construction of the embankments may be sourced from within the pond areas, which has the following advantages:

- Minimises material haul distances.
- Minimises the area of disturbance necessary for construction.
- Reduces required embankment height and width as the pond floors may be set below the surrounding natural ground level.

Uncompacted, in-situ soils may soften on prolonged contact with water. Therefore, it is recommended that areas subject to traffic loading, such as hardstand areas and access roads, should be sheeted with suitable road base material having a soaked CBR value of 10 (or greater). A nominal thickness of 175mm of road base is recommended. In constructing access roads it will be necessary to provide adequate drainage to prevent inundation of the road formation.

Where the top of a pond embankment will have regular traffic, it shall also have a road base capping.

The floor of each crystalliser must be scarified, graded and compacted to minimise leakage of saturated brine, plus provide a sound trafficable surface for the development of a salt pavement. The compact, level floor will assist the uniform deposition of salt crystals and pool-free drainage.

The relatively large wall length and small area of the crystallisers increases the potential for erosion of crystalliser walls and the contamination of the final product by soil. Therefore, the use of protective geo-fabric liners on the crystalliser walls is recommended.
5 Construction and Operation

5.5 Construction Schedule

Pond 1 will be the first completed, to allow the containment of groundwater brine and the commencement of the solar evaporation process. To take full advantage of seasonal evaporation the brine should be introduced as soon as the springtime positive evaporation commences. There is therefore a need for the construction programme to balance the early supply of brine with a need for a practical, start to earthworks during dry weather. Construction of Ponds 2, 3 and 4 will follow and when available, brine will be allowed to flow into the later ponds. Thus, by the time earthworks construction is completed, there will already be a significant volume of brine across the pond system.

In the second year, saturated brine will be available for discharge to the crystallisers and by the end of the summer a full year’s production of salt will have formed on the base of the crystallisers. This salt will not be harvested and will remain to form a load bearing clean salt floor ready for the deposition of the following year’s harvest.

This construction schedule is shown on a chart in the Appendix.

5.6 Site Operations

5.6.1 Pond and Crystalliser Operation

Evaporation pond and crystalliser operations will be carried out throughout the year by a permanent employee of the Saltfield Operations. It is expected that this person will be suitably qualified to satisfy the requirements for a Registered Manager in accordance with the regulations administered by the Department of Minerals and Energy. The Manager’s duties include:

- Manage the commercial, subcontract and practical aspects of saltfield operations
- Receive ground water from the Lake Toolibin pumping operation
- Monitor the brine level and salt concentration in each of the ponds and adjust the outlet weirs to control release to the downstream ponds
- Undertake laboratory functions on site, necessary for the control of saltfield process chemistry and biology
- Monitor the Pond 5 salt concentration and plan the “batch” transfer of saturated brine to the crystallisers
- Monitor the progressive build up of crystallised salt product in the four crystallisers and release bitterns
- Plan and prepare for the annual harvest

5.6.2 Product Quality

The chemistry of Toolibin Lake ground water differs to seawater in that it has a higher total salt content than seawater. The groundwater has proportionately higher magnesium and sulphate content than seawater (and correspondingly lower sodium and chloride). Whilst these differences affect the pond areas, they will have no effect on product quality with correct saltfield operation.
5 Construction and Operation

It is expected that yield of sodium chloride will be approximately 10% less than seawater of the same total salinity, but this is offset by the higher salinity of the ground water. The quantity of bitterns will be almost double the volume released from an equivalent seawater saltfield. The impact of additional sulphate ions on the chemistry, taste and odour of the product can be controlled by the operator through bitterns release and product washing.

Conventional solar saltfields such as those operating in the North West of Australia produce a chemical grade sodium chloride with a purity of 99.7% NaCl (by weight, dry basis) and it would be possible with good management and precise operating controls, to produce salt of similar quality at Toolibin Lake. However the target domestic markets do not require salt of such purity and a lower quality product allows some operating flexibility and less stringent controls.

5.6.3 Crystalliser Salt Floor
Once the crystallizer area is flooded with brine some softening of the site materials will occur. It is expected that the site materials will remain relatively strong and support substantial wheel loads, especially using low pressure pneumatic tyres. However to provide a good working surface and to limit potential for rutting and salt contamination, a 60 to 70mm salt floor is recommended on top of a saturated, compacted clay base.

This salt floor should be deposited by the end of the first full year of production. It will not be harvested but left as a base for the deposition of the following year’s harvest.

5.6.4 Salt Harvesting
Due to the relatively small scale of the saltfield, harvesting and washing will be undertaken by contractors, under the control and supervision of the Registered Manager. The costs of mobilisation, plus the seasonal nature of the process, lead to the decision to harvest once per year, at the end of the summer period.

Near the end of March each year it is expected that salt crystallisation will have reached its peak and Pond 1 will have been drawn down to its lowest level. Harvesting needs to be completed before onset of autumn or winter rains to maximise the volume of salt harvested and also allow the salt floor to be protected from the rain with saturated brine.

Each of the crystallisers in turn will be drained using a mobile pump to increase the rate of draw down of the water level and empty the pond in the shortest possible time. Saline groundwater is added at the intake of the bitterns pump to prevent crystallisation of salts in the pump and pipeline. The bitterns liquor will be transferred to Lake Taarblin.

A laser level controlled grader will rip the salt to a predetermined depth, to preserve the salt floor and provide a common fracture plane at harvest. The grader will then grade the salt into windrows to allow a front-end loader to load the salt into trucks, leaving a clean level salt floor. The trucks will transport the salt to the process area, dumping it in a stockpile area adjacent to the wash plant feed hopper.
5 Construction and Operation

5.6.5 Salt Washing, Stockpiling and Drying
The washing process is shown on the Process Schematic Flow Sheet included in the Appendix. With the small area of the crystallisers, a higher level of contamination and foreign objects is expected.

Salt is reclaimed from the harvested salt stockpile by front-end loader and placed in the wash plant feed hopper above the screw washer. The screw washer is fitted with spray bars that spray the salt with saturated brine from Pond 4 or recycled brine from a dedicated wash pond, minimising the dissolution of salt crystals.

The action of the screw washer and the wash brine spray is designed to:
- Float off dust, trash and organic material and remove them in the overflow,
- Drop out sand and fine particles, particularly gypsum, and remove in the underflow,
- Dissolve magnesium salts and some gypsum,
- Separate and dewater the first stage washed salt.

The washed salt is lifted from the wash trough, drained by the action of the screw, and transferred to the woven stainless steel wire wash belt, where the remaining gypsum, magnesium salts and fine salt particles are removed by washing with brine solution.

The wash belt deposits the clean product onto a belt stacker and the washed salt is stockpiled and allowed to drain.

On despatch, the moisture content provided by stockpile draining and air-drying will be about 3%.

The “dirty” water from the washing process is returned to the wash pond or Pond 4, where it will contribute to the next year’s production.

5.6.6 Salt Handling and Transportation
For bulk sales, the washed salt will be loaded into road trucks by the Operation’s own front-end loader, for despatch to the customer. Road haulage will be undertaken by contractors, either on a campaign basis or on demand, to match the market or downstream processing requirements.

5.6.7 Downstream Processing and Packaging
To obtain broader market sales and further added value, the supply of a bagged product is required. While it may be feasible to operate a bagging plant on site and to supply a bagged product for direct sale to the market, this also requires an operation that includes marketing and direct sales. The proper assessment of this option depends on the market opportunities closer to the date when salt will be available for sale. As it is expected that the additional marketing, handling, packaging and equipment costs will be recovered by an increase in the selling price, this option is not further investigated in this study.
5 Construction and Operation

For some markets a refined product, dried and screened, is required. This option has not been further evaluated, as refining requires expensive plant that could not be justified at the production rates proposed for this project and without an assured market.

5.6.8 Capital Asset Maintenance
In all cases, the operations that occur over the entire year rely on assets that are held permanently on the site. The Registered Manager will be responsible for the maintenance of these assets, ensuring their continued performance in salt production and protecting the Owner’s investment in these assets. Major maintenance work will be undertaken as required, by local contractors.
6. Environmental Management
6 Environmental Management

The Toolibin saltfield will be an operation running in parallel to the Salinity Management Plan that is managed and administered by DCLM. The effects of any environmental impacts from the saltfield must be included in the overall management program for the region. DCLM recognise this fact and will obtain the environmental approvals for the saltfield. The saltfield manager will be responsible to DCLM to ensure the agreed operating parameters are satisfied and the lease agreement will regularise this relationship through an Environmental Management Plan.

The saltfield does not adversely change the basic environmental impacts of the Salinity Management Plan. The effect is to remove salt from the system and return the unchanged residual liquors back to Lake Taarblin, the base case of the Salinity Management Plan. Notwithstanding this basic premise, the saltfield does create new impacts that have to be quantified, managed and reported. These include:

- Construction activities, particularly earthworks;
- The risk of seepage of high density brine into the surface water aquifers;
- The risk of erosion damage from the catastrophic failure of the pond embankments;
- The presence of the saltfield operators and sub-contractors and the impact of their activities.

A solar saltfield is essentially an environmentally benign operation that will exist because of the need to restore a damaged environment. The scale of the project is significant but the area of land affected is relatively small. There are also environmental benefits from the increase in bird life that will be attracted to the water and brine shrimp as a new source of food.
7. Market Analysis
7 Market Analysis

7.1 Introduction

Saline groundwater can be made into usable product of some value. However salt is available from a lot of sources in Australia and marketing the product is a principal function of removing salt from the environment.

A detailed product and market analysis was completed as part of the report on Commercial Use of Saline Groundwater Extracted from the Toolibin Lake District, 1999.

This section provides an overview of current production and markets, and presents the assumptions made in the determination of the selling price used for this Feasibility Study.

7.2 Competitors

Australia is amongst the world’s largest producers of solar salt. The majority is produced in the northwest of Western Australia by Dampier’s Salt operations at Port Hedland, Dampier and Carnarvon, and Onslow Salt and Shark Bay Salt. These saltfields account for more than 9 Mt/a of Australia’s total production.

Australia’s domestic and industrial demand totals less than 2 Mt/a, and is principally supplied by a different scale of salt producer.

These include:
- Cheetham Salt 600,000 t/a
- Penrice Salt 700,000 t/a
- WA Salt Supply 140,000 t/a
- SunSalt (Hattah) 20,000 t/a
- Pyramid Salt 5,000 t/a

7.3 Transport Costs

Salt is a low-value commodity and the cost of transport from the saltfield to the market is a significant proportion of the purchase price and thus a very significant factor in the product’s position in the market.

Supplying the other states with salt would not be possible because of transport costs and more competitive producers in those states.

When compared with salt producers in the eastern states, the Western Australian salt producers have significantly greater transport distances to the major domestic markets and must therefore focus primarily on the local market. Similarly, the eastern states producers would have to pay between $40 and $60/t to transport salt to WA and cannot therefore compete competitively with local suppliers.
7 Market Analysis

This factor is recognised by Cheetham Salt, who are represented in Western Australia by WA Salt Supply.

The major producers, based on the northwest coastal fringe, also do not sell salt into the domestic salt market. The salt is exported with the majority of the salt produced shipped to Asian markets for use in chemical and manufacturing industries. The small market size and the extremely long distance from the northwest saltfields means there has not been a serious attempt to sell northwest salt in local markets.

7.4 Local Market

In the domestic market, there are many different salt products that are distinguished by chemical composition, grain size and packaging.

These products include:

- Chemical grade salt as feedstock to industry
- Hides and skins tanning salt
- Stock food additives and saltlicks
- Swimming pool salt
- Salt for resin regeneration in water softeners
- General food grade salt
- Domestic table salt (cooking, iodised, flake, coarse grind)
- Boutique salt (gourmet, specialised)

While there is considerable data available about salt, there are no reputable public records of a breakdown in the types of salt consumed in Australia or West Australia. Current total consumption in WA is assessed as approximately 145,000 t/a. Using USA and world consumption patterns, with allowance for WA's population and industry demographics, the following market breakdown is deduced:

- Chemical industry feed stock 80,000 t/a
- Hides and skins tanning salt 20,000 t/a
- Other processes (dyeing, etc) 10,000 t/a
- Stock feed and salt licks 10,000 t/a
- Swimming pool salt and water softener salt 18,000 t/a
- Food grade salt 5,000 t/a
- Table salt 2,000 t/a
- Gourmet salt 50 t/a

Total 145,000 t/a

While sectors of the salt market are growing, for instance pool salt, it is not a rapidly expanding market. The market for human consumption salt has remained at a constant level.
7 Market Analysis

As a result it is easy to conceive that the domestic market would become saturated with a small number of 5,000 tonne capacity producers acting in direct competition with existing suppliers.

7.5 Market Competition

The majority of the domestic WA market is supplied by WA Salt. A small amount of salt is brought in from the eastern states for table salt and the remaining local salt producers are small enterprises taking advantage of local salt lakes to produce a low grade salt for stock feed, hide and tanning salt.

WA Salt has operations based at Koolyanobbing and Esperance, with a refinery in Perth. It markets a broad range of products, ranging from the pure chemical grades, through commercial food grade salt and table salt, to pool salt and tannery salt.

WA Salt is the primary competitor for Toolbin and will not readily give up any portion of its share of this market. The saltfield at Toolbin cannot produce salt more cheaply than WA Salt, which has existing facilities without significant capital debt and with minimal saltfield operating costs.

It is possible that there would not be a viable niche for even one additional producer if there was stiff competition from WA Salt.

7.6 Target Market

The larger users of salt are from the Chlor-alkali industry. They require large quantities of extremely high quality salt, which is not an option for this project at this time. There might be potential for salt to be sold to the larger users in the chlor-alkali industry, if up to six quality salt producers of 5,000 tonne capacity.

Salt for human consumption has also not been considered, as to comply with Australia's food safety standards the level of quality assurance required is much higher and increased capital is required for laboratory and processing facilities. The production of salt for human consumption is best considered after expertise gained in the production of salt for other markets.

The initial marketing strategy should be to look at the lower end of the salt quality spectrum, as the greater market potential will be from lower quality grades of salt, such as stock salt and swimming pool salt.

Toolbin is well located to sell salt into the wheatbelt region of Western Australia. Local rural producers purchase stock salt for their use and stock salt should have a competitive edge in the local agricultural districts. This market is small and seasonal but should form an important part of sales.

Swimming pool salt is also in this category and penetration into the local pools salt market could have potential. This market is expanding but tends to attract small buyers only. This creates difficulty in distribution and sales. Markets are tightly held and require consistent high levels of quality, customer service and marketing skill to obtain and maintain market share.
7 Market Analysis

In summary the potential markets in the region that could be supplied are:

- High Quality Stock Salt
- Pool Salt.
- Hide Salt. Small Market

To directly supply these markets it is necessary that once harvested, the salt is washed in a saturated brine to remove impurities in a solid form and then stacked in a manner that allows the soluble impurities to drain to waste.

Stock feed, hide, pool and water softener salt are normally sold as drained in a wet form with 3 – 5% moisture. Pool and water softener salt is often partially dried to facilitate screening when producing a consistent product size.

The potential market for high quality skin salt has not been considered, as textile and skin salt has to be dried to less that 0.1% moisture. The salt is normally dried in a gas fired rotary kiln. For this project the additional capital and operating costs for the plant cannot be justified. A significant share of the market for refined salt needs to be targeted before this step is taken.

7.7 Packaging

Even washed salt has only a limited retail market while in bulk. It is possible to sell to the wholesaler or bulk user in this form but the price is reduced.

Salt is normally supplied in 25 kilogram bags or 1 tonne bulk bags. To retail the salt, it would normally have to be at least bagged in 25 kg bags. The smaller bags are closed with sewn thread. Entry into the retail / wholesale market will require a reasonably well presented bag, particularly for the swimming pool market.

Bagged salt is sold on pallets (1000 or 1200kg) and shrink wrapped for security and water and dust proofing. Packaging at cost is in excess of $ 30.00 / tonne.

7.8 Marketing

The selling function for Toolibin is essentially that of price and service by tailoring the product to the customer’s requirements and therefore reducing costs.

The customers for salt are few. All sales could be negotiated on a personnel level. Promotions are mainly done by providing ‘free’ samples to customers for trials.

To counter the economies of scale of other producers, Toolibin needs to focus on ability to supply small quantities at the quality required by the clients, capitalising on the avoidance of costs for refining to a greater than needed standard.

Because the principal competitors also provide salt for human consumption, most of their salt is treated as if it will be used in that market. The result is that the quality often exceeds that required for the stock and hide salt market.
7 Market Analysis

Toolibin also needs to target regional sales to give it a competitive advantage in transport costs. The Toolibin saltfield is closer to the significant majority of WA customers and has a potential freight cost advantage of at least $15/t on the alternative source of salt at Esperance or Lake Deborah, Koolyanobbing.

Salinity and salinity control in rural areas have a high profile in WA and projects that are active at addressing this issue will find strong community support. This factor may also help to provide Toolibin salt with a high level of acceptance in the market for stock salt, pool salt and hide salt.

7.9 Price

Salt presented for sale as a bulk commodity at the production site by the much more cost-effective multi-million tonne per annum producers, exporting from the northwest, has a mean selling price of around A$30/t. Smaller producers supplying to the domestic market cannot be expected to supply high quality salt at the same bulk rate.

It is assumed that the salt will be harvested, washed and then either sold bulk or further processed to bagged salt (25kg). Given the need to focus on ability to supply small quantities at the quality required by the customer over a broad market range, the sale price will also vary over a range. Also the potential return will be impacted by whether prime transport rates are applied or long term transport contracts negotiated. There may also be opportunity to use lower back haul rates for some sales.

Extensive market research and focused product development is required for a reasonable level of accuracy to be attained for the projected salt sales. For all sales, competition will have the effect of reducing the price.

Given the above variables and the extended time until salt will be available for sale, a range of product sale prices is not appropriate for this study. Thus, for this analysis the base price of $55/t bulk at site has been adopted. This price has been based on an average market price of $145/t, in 25kg bags. This is considered a sound base price for bulk salt, after removal of the additional costs for direct sales, packaging, handling and distribution, but incorporating profit margin.

The costs deducted in establishing this base price are:
- Procurement of packaging, pallet $30/t
- Additional labour $20/t
- Additional equipment costs $ 5/t
- Transport $25/t
- Additional direct marketing $10/t

The installation of a bagging plant will cost approximately $50,000.

7.10 Future Opportunities

It is expected that through efficiencies in design and construction of economically sized saltfields and the subsequent production of high quality low cost salt close to markets, that market demand will evolve.
7 Market Analysis

There is also potential for increased earnings with alternative products once the saltfield is established. The following are seen as options to increase profitability, but not core business.

7.10.1 Bitters
A by-product of the salt production is the bitters.

After further processing, the uses of this product include:

- Road dust suppression
- Earthworks stabilisation
- Fertiliser additive
- Chemical salts production

The bitters released from the crystallisers will have approximately 359 g/L TDS and needs to be further evaporated to provide a marketable product. In evaporating to a SG of 1.300 (over 480 g/L TDS), a major proportion of the remaining sodium chloride is precipitated out and the bitters can be sold as a road base stabiliser or dust suppressant.

Additional pond area is required for this further evaporation and because the rate of evaporation falls rapidly with such high salinity brine, further evaporation can only be completed during the high evaporation months.

Potential customers are rural shires and mining companies.

While the benefits of using bitters as an effective means of dust control and as a compacting agent at a relatively low cost compared to traditional road repair techniques have been well publicised and it is considered a cost effective method of reducing dust from gravel roads and ongoing maintenance costs, it is expected that trialling by customers will be necessary and it will take several years before the demand is at a high level.

The product is commonly applied at a rate of one litre per metre square and could retail for anything between four and forty cents per litre, depending on the level of product support.

While approximately four percent of the initial brine will be released as bitters, it is expected that the potential production of this product will be less than two percent of the initial brine volume.

As there is little current demand for this product, it’s production and sale has not been included in this study.

Alternatively, process technology has recently been developed by the CSIRO in conjunction with Sunsalt for the production of magnesium sulphate salts from bitters. Production equipment has been installed at Sunsalt. The production and sale of magnesium sulphate salts may be a future option for Toolibin.
7 Market Analysis

7.10.2 Food Salts
Toolbin salt may have a unique appeal in taste, as a ground water salt, and may sell well in the gourmet market, where prices for small parcels of salt are as much as $500/t, but total sales in current markets are unlikely to exceed 50 tonnes.

The market for gourmet salt is very limited with several salt producers having to work very hard to penetrate those markets. These producers have learned that gourmet salt is a luxury item that is price sensitive in that if money tightens, sales drop dramatically.

Aggressive marketing is required if any salt is to be sold as a gourmet salt in Australia or overseas. Both markets are near saturation and competitive. It would take considerable time and money to develop access to these markets.

Asian markets see salt as a commodity and perceive all salt as the same. As such they will not spend more for a gourmet salt.

Japan does recognise that a gourmet salt could taste different, but entering that market is very difficult due to the salt industry distribution network within the country. Japan has a structured multilayered network, convoluted and interwoven requiring time and money to penetrate. This has high risk, as the Japanese economy is price sensitive, especially to luxury items.

The European markets, and especially the United Kingdom, have some interest in gourmet salt, but there are several established niche producers. Most consumers, due to ongoing “Health Awareness” campaigns, perceive salt as an unhealthy item. As such the demand for additional specialised salt is limited and heavily sought after by other salt suppliers. A few large grocery chains control the distribution of gourmet salts in the UK and they require stringent compliance reporting systems and competitive pricing, making the UK a difficult market to enter.

Due to the higher costs for production and marketing, the production of food grade salt has not been included in this feasibility study.
8 Financial Analysis
8 Financial Analysis

8.1 Financial Support

As this project is enhancement to the existing Toolibin Lake Salinity Management Plan, not all costs of establishing the solar saltfield have been considered as project costs.

Further, the Department of Conservation and Land Management (DCLM) will provide capital funds to support the development of the saltfield. In return DCLM expects to gain through lease or other means a return over the life of the project equivalent to or greater than repayment of principal plus interest at the Government Bond Rate. DCLM funds are to be used to construct the fixed facilities that constitute the saltfield. These saltfield facilities will therefore be owned by DCLM and leased back to the saltfield operator. The financial model carries this capital expenditure as a Lease Cost, and “repays” it with interest as a fixed annual payment, commencing in the first year of full operation.

8.2 Capital Cost Estimate

The capital works stage of the project includes construction of the saltfield pond system, plus procurement, construction and commissioning of the permanent plant and equipment and the support facilities. Based on the saltfield design described in the previous sections, capital cost estimates have been developed for the saltfields required for salt production rates from 5,000 t/a up to 20,000 t/a. These capital cost estimates are based on development of a single site at Toolibin Lake, with the assumption that sufficient brine can be extracted locally.

The capital cost estimates are included in the Appendix and are summarised in the following Table 4:

<table>
<thead>
<tr>
<th>Annual Salt Production tonnes</th>
<th>DCLM Capital Funding Estimate</th>
<th>Total Capital Cost Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>5,000</td>
<td>$760,000</td>
<td>$1,620,000</td>
</tr>
<tr>
<td>6,000</td>
<td>$850,000</td>
<td>$1,780,000</td>
</tr>
<tr>
<td>7,500</td>
<td>$950,000</td>
<td>$1,920,000</td>
</tr>
<tr>
<td>10,000</td>
<td>$1,100,000</td>
<td>$2,160,000</td>
</tr>
<tr>
<td>12,500</td>
<td>$1,300,000</td>
<td>$2,450,000</td>
</tr>
<tr>
<td>15,000</td>
<td>$1,400,000</td>
<td>$2,640,000</td>
</tr>
<tr>
<td>17,500</td>
<td>$1,600,000</td>
<td>$2,940,000</td>
</tr>
<tr>
<td>20,000</td>
<td>$1,700,000</td>
<td>$3,100,000</td>
</tr>
</tbody>
</table>

The application of DCLM funds has been restricted to the construction of Evaporation Ponds 1 to 5, construction of all weather site access to the evaporation ponds, plus the construction of a boundary fence around the project site. A breakdown of the DCLM funded works is provided in the capital cost estimates.
8 Financial Analysis

The construction of the pump pond and crystallisers, the supply of the all production equipment including the washplant, plus the supply of all support facilities are to be funded directly by the Saltfield Operator.

The most significant component of the capital cost is the construction of the pond system. As there are no natural land formations at Toolibin that may be used for the retention of the brine, it is necessary to construct embankments for all ponds.

The requirement to construct Pond 1 with adequate capacity to hold brine supplied at a constant rate throughout the year also adds significantly to the cost of development of the saltfield. Although the area of Pond 1 is the same as the combined area of Ponds 2 to 5, the estimated construction cost is approximately 2.5 times greater, due to the height of the embankments required.

All weather access from the Wickepin-Harrismith Road and a power supply will be provided by others up to the saltfield boundary. They have not been considered a saltfield cost and have been excluded from the financial analysis. Also, the cost of the borefield and the running of the brine supply pumps have not been included in the economic analysis of the project. The reducing of the water is a public benefit and extends past the commercial regime of this project.

8.3 Operating Cost Estimate

The operating costs of the project include “Fixed” and “Variable” costs.

The Fixed Costs include the cost of the permanent staff, responsible for management of the operations, asset maintenance (by contract or permanent staff) and marketing. Also included are general compliance costs and cost of operations and administrative support (by contract or permanent staff). The cost of utilities plus, fuel, lubricants and maintenance for the saltfield’s plant and equipment has also been treated as a fixed cost. Some of the fixed costs relate directly to the size of the saltfield and increased costs have been allowed for with increased production capacity.

The Variable Costs have been restricted to the costs for the employment of contractors to harvest the salt and contractor assistance with the production of washed salt. While there may be a small reduction in total cost per tonne for increased tonnages, this reduction is not considered significant and a flat rate of $6.00/t has been applied.

The fixed and variable operating cost estimates are included in the Appendix and are summarised in the following Table 5:
8 Financial Analysis

Table 5 – Salt Production vs. Saltfield Operating Cost Estimate

<table>
<thead>
<tr>
<th>Annual Salt Production tonnes</th>
<th>Fixed Operating Cost Estimate</th>
<th>Variable Operating Cost Estimate</th>
<th>Total Operating Cost Estimate</th>
<th>Operating Cost per tonne</th>
</tr>
</thead>
<tbody>
<tr>
<td>5,000</td>
<td>$200,000/a</td>
<td>$6.00/t</td>
<td>$230,000/a</td>
<td>$46.00/t</td>
</tr>
<tr>
<td>6,000</td>
<td>$212,000/a</td>
<td>$6.00/t</td>
<td>$248,000/a</td>
<td>$41.30/t</td>
</tr>
<tr>
<td>7,500</td>
<td>$230,000/a</td>
<td>$6.00/t</td>
<td>$275,000/a</td>
<td>$36.70/t</td>
</tr>
<tr>
<td>10,000</td>
<td>$260,000/a</td>
<td>$6.00/t</td>
<td>$320,000/a</td>
<td>$32.00/t</td>
</tr>
<tr>
<td>12,500</td>
<td>$290,000/a</td>
<td>$6.00/t</td>
<td>$365,000/a</td>
<td>$29.20/t</td>
</tr>
<tr>
<td>15,000</td>
<td>$320,000/a</td>
<td>$6.00/t</td>
<td>$410,000/a</td>
<td>$27.30/t</td>
</tr>
<tr>
<td>17,500</td>
<td>$350,000/a</td>
<td>$6.00/t</td>
<td>$455,000/a</td>
<td>$26.00/t</td>
</tr>
<tr>
<td>20,000</td>
<td>$380,000/a</td>
<td>$6.00/t</td>
<td>$500,000/a</td>
<td>$25.00/t</td>
</tr>
</tbody>
</table>

8.4 Project Model

While the project life is expected to be 30 years plus, 15 years has been used in the financial model as income received beyond this period has little impact on the commercial viability of the project.

The range of annual production tonnages has been selected to allow the size of project at Toolibin Lake that is commercially viable to be established.

The financial analysis is based on the construction of the salt ponds and initial filling of the ponds and commencement of saturated brine production in the first year. In the second year the salt produced would be left in the crystallisers to form the salt floor. As a result, the first year of the analysis allows for capital works and filling the ponds, while the second year allows for operating costs, but no harvest costs and salt sales.

Also, the capital expenditure on the washplant plant and stockyard facilities has been delayed until the second year when there will be permanent staff available to assist in equipment selection and to supervise installation.

8.5 Financial Model

The capital and operating costs are used in a financial modelling spreadsheet to evaluate the benefit of future income in the repayment of initial capital expenditure. The spreadsheet uses discounted cash flow techniques to calculate the Net Present Value (NPV) of the project whereby future income or expenditure, expressed in current dollar terms, is factored back to the equivalent present day value.

The model includes the impact of taxation, maintains a capital depreciation account and carries losses forward, reflecting the predicted taxable income of each year. The income after tax is then factored back to the discounted present value, so the total net present value of the project may be assessed.
8 Financial Analysis

The model variables include:

- Annual production
- Discount rate
- Taxation rate
- Capital depreciation rate
- Capital cost (initial and future)
- Operating cost
- Product selling price

The taxation rate has been set at 30%, the Company Tax Rate, as defined by the Australian Tax Office (ATO), who have also set the depreciation rate for the capital assets at 1/(life of project) flat, applied to 150% of the value.

The sale price has been set at $55.00/t, as discussed in the Marketing Section of this report.

The only variable in the analysis is the discount rate, reflecting the rate of return expected from the capital investment. Where the cumulative income after tax exceeds the initial expenditure, the model discount rate has been adjusted to obtain a zero NPV. When the NPV is zero, the model discount rate is the project Internal Rate of Return (IRR).

Where the NPV is negative, the project cannot achieve the set rate of return and repay the capital invested. The IRR normally required for like projects is 12 to 15%.

8.6 Results

The Net Present Value Analysis is included in the Appendix and the results are summarised below.

A key requirement of the project is that the projected sales revenue exceeds operating expenditure. This is achieved at all salt production rates modelled.

However, the NPV is negative for the salt production rates of 5,000t/a, 6,000t/a and 7,500t/a, with the discount rate set at 1.0%. The large capital outlay cannot be repaid even at this low non viable rate of return. The Toolibin Lake Project is not viable with these levels of salt production. Given the very low rate of return, the provision of DCLM funding has no impact on the viability of the project, as the Government Bond Rate is higher than the internal rate of return of the project. This is demonstrated by comparison with the NPV Analysis with the Operator providing all the capital funding.

At salt production rates of 10,000t/a and above, a higher model discount rate is achieved. With higher internal rate of return, the provision of DCLM funding has a significant positive impact on the viability of the project.

The rates of return, with and without DCLM funding, are presented in the following Table 6:
Financial Analysis

Table 6 – Salt Production vs. Rate of Return

<table>
<thead>
<tr>
<th>Annual Salt Production (t)</th>
<th>Rate of Return with DCLM Funding</th>
<th>Rate of Return without DCLM Funding</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,000</td>
<td>2.1 %</td>
<td>1.1 %</td>
</tr>
<tr>
<td>12,500</td>
<td>7.25 %</td>
<td>3.5 %</td>
</tr>
<tr>
<td>15,000</td>
<td>10.75 %</td>
<td>5.75 %</td>
</tr>
<tr>
<td>17,500</td>
<td>13.75 %</td>
<td>7.0 %</td>
</tr>
<tr>
<td>20,000</td>
<td>16.25 %</td>
<td>8.75 %</td>
</tr>
</tbody>
</table>

Typically for satisfactory return on investment, including profit and risk margins, an IRR greater than 12% is sought for like projects. For 15,000 t/a salt production and sales, and DCLM funding of fixed infrastructure, the return on investment is at level that warrants further detailed project investigation. For 17,500 t/a salt production and sales, which would require a 300% increase in the available brine supply, a solar saltfield may be commercially viable.

8.7 Depreciation Benefits

The project carries a depreciation write-off to year 30, which would be of value to a profitable operation owning this project. The early years all carry a tax loss, which could be utilised by such an organisation to minimise tax on their existing operation.

There is also an opportunity to class the project “R&D”, allowing a further gearing of the taxation reductions, with 125% deductibility in the first three years, increasing to 175% in the fourth year. This could be applied to the overall operation’s taxable income to reduce the tax liability in those early years. Further research would need to be done to determine how this aspect could best be applied for this project.
9 Risk Analysis
9 Risk Analysis

9.1 General

An assessment of the activities associated with the development and operation of the proposed saltfield has identified the following areas of risk:

- Construction activities, particularly earthworks
- Variations in the quantity and quality of feed brine
- Variations in the nett evaporation at the saltfield location
- Saltfield management experience
- Markets, competition and selling price pressures

There are other establishment risks such as the obtaining of access to the required land area and the obtaining of necessary mining lease, which are outside the scope of this study. Also, issues that may impact on the life of project, such as success of groundwater interception in the reducing of salinity and the loss of adequate brine supply have not been assessed.

9.2 Construction

The viability of the project is to a large degree dictated by the saltfield construction cost and the delay until product will be available for sale.

While the clay soils in the region are suitable for construction of the pond system, the control of construction activity under wet conditions during the winter months would be difficult. The weather delays and potential increased costs are best avoided by programming construction activities to take place over the summer months. This construction requirement is countered by the need to commence the production of saturated brine as early as possible as at least one year’s evaporation effort is required to produce adequate maiden brine for transfer to the crystallisers for the deposition of the salt floor. The best start time is therefore early summer with, ideally, brine supplied to an incomplete pond system as early as possible.

During the life of the project it is expected that storm damage will occur, particularly to earthworks. Embankments with 1 in 3 batters have been recommended to limit any impact of local slumping and for long term stability. The pond embankments must be located so that they do not impede natural stormwater flow but allow stormwater to be directed around the pond system, thus limiting potential for a catastrophic event such as the breaching of an embankment and the lose of brine from the pond system. At Toolibin, provision has been included for the construction of a by-pass channel to direct storm water away from the pond embankments. The pond system also has freeboard capacity to retain stormwater that falls within the pond system.
9 Risk Analysis

9.3 Brine Supply

A primary operation risk is the quantity and quality of brine supply.

9.3.1 Quantity

DCLM have established a good level of reliability in their operation of the Toolibin Lake Salinity Management Plan and will supply an agreed annual volume of groundwater required to achieve the target production for the saltfield. To achieve the objectives of the Salinity Management Plan continuous pumping is required and an extended disruption in the supply of brine is not expected.

The increased storage capacity of Pond 1 will allow the supply of brine to the pond system to be maintained if temporary disruption to supply, but continuous brine supply is necessary during the summer period, when brine demand is at a peak, for the saltfield to operate at full capacity.

In years with high nett evaporation, additional brine supply may be required if the saltfield production is to be maximised and the drying out of evaporation ponds during the months of peak evaporation is to be prevented. The supply of this additional brine is more complicated for a borefield supplied saltfield and it may require the provision of additional bores to supplement the brine supply in these periods.

9.3.2 Quality

The groundwater pumped from aquifers below Toolibin Lake, currently has a TDS of 48g/L. Although no reduction in salinity has been noted since the commencement of the pumping, the pond system design for this feasibility study has been conservatively based on a total TDS of 40g/L to allow for the future possible reduction in the groundwater salinity. The resultant concept design for the evaporation pond system has a greater area than is currently necessary for the target level of salt production.

Saltfield operations can be adversely affected by blue-green algae growths, particularly where high nutrient levels in the brine. The groundwater analyses do not show significant levels of phosphorus or nitrogen nutrients and algae growth is not considered a high risk. Stable operation of the downstream (high salinity) ponds will further reduce the risk. The more stable the chemical environment in a saltfield the less chance that an adverse biology will develop.

9.3.3 Seepage Losses

While provision has been included to check the pond floors for weak/ permeable spots with scarifying and compaction if necessary and provision made for brine seepage loss in the pond system design, the seepage may be greater than allowed for.

Whilst the design and construction standards minimise this risk, in any new saltfield the seepage losses will be greater at start up and decline with operation of the field. The losses gradually reduce as a biofilm forms on the floor of the ponds and acts as a sealing layer. The precipitation of the less soluble salts, such as calcium and magnesium carbonates and calcium sulphate (gypsum), in Ponds 4 & 5 will also act to significantly reduce seepage losses.
9 Risk Analysis

9.4 Local Climate

The driving force in a solar saltfield is nett evaporation.

The concept design is based on mean values for evaporation and rainfall at the saltfield location and continual variance in operating conditions is to be expected. The risks resulting from this variance cannot be avoided and must be managed to minimise the impact on total salt production:

- In the pond system there is buffering capacity, by adjustment of pond depth and salinity gradient. The brine levels across the pond system may be drawn down during period of high nett evaporation and raised in period of low nett evaporation, when the precipitation of salt will be reduced.

  While significant rainfall may result in reduced production of saturated brine and consequently less salt production in a year, the salt remains in the system and will be available in subsequent seasons.

- The depth of brine cover in the crystallisers may also be varied, but for the production of high quality salt a shallow depth of brine should be avoided and the crystallisers must not run out of saturated brine as this will damage salt quality in the exposed crystalliser. Therefore, it is important not to have too many crystallisers or crystallisers that are too large for the field capacity.

- When increased maiden brine supply to the crystallisers, the bitterns discharge point may be lowered to increase throughput and/or dye modification used for increased evaporation and salt precipitation.

- A significant risk scenario may occur if there is rain when the crystallisers are drained for harvesting. The rain caught within the crystallisers will dissolve precipitated salt which will not only be lost to the current year's production but require considerable time and evaporation effort to recover. With saturated brine cover there is less risk of dissolving the precipitated salt.

9.5 Knowledge and Skill

The operation of a saltfield requires considerable knowledge and skill. The production quality and quantity is sensitive to the relative skill of the saltfield managers.

The person appointed to the position of manager must be capable and multi-skilled. For a new operation such as Toolibin there is limited local knowledge and no established skill base, however in Western Australia solar salt production is a mature industry with over 40 years experience and there is a wide body of corporate and individual experience available to support the manager.
9 Risk Analysis

9.6 Market

The WA market is a mature market dominated by a major supplier with flexible sources of supply. Toolibin will be sensitive to competition from WA Salt and other suppliers.

A significant risk for Toolibin is the inaccurate estimate of the market potential. The risks are:

a) Sales volume below expectation and
b) Selling price lower than expected.

The expected markets may not be secured because of increased competition. The critical factor is price and this competition would have the effect of reducing the price.

For small sales volume, in relation to the total market, the existing suppliers may accept a new supplier without significant reaction. However any attempt to sell significant quantities is likely to meet with a commercial response such as the lowering of price.

One option to avoid such a scenario is to become a sub-supplier to one of the existing salt suppliers. Toolibin could sell to WA Salt or others, a high quality product closer to the customer and at a lower freight cost than they can currently get from their existing natural sources. However, due to the high capital cost of establishing the saltfield, Toolibin can not afford to sell all product at a low supplier price and will need to sell added value product to achieve an adequate return on investment.

A further significant risk for the Project is that the time span for the sale of product is optimistic. This applies both to the availability of the target tonnage of washed salt and the sale of this target tonnage. The associated marketing problems with a new brand and the time taken to establish credibility as a new supplier in the marketplace will have an impact on the growth of sales. Toolibin will need to produce salt that compliments the resources of other WA suppliers while it develops its own markets, in order to obtain the required volume of sales.

Having established and secured a market, the harvest and marketing effort must be co-ordinated. There needs to be a close match between production and sales, as there is the potential for the annual harvest to vary by as much as fifty percent. This risk may be overcome by holding stock or by organising an alternative supply, by negotiating a salt supply contract with a competitor.
10 Results and Conclusions
10 Results and Conclusions

10.1 Results

The key findings of the feasibility study investigations and analyses have been:

a) The climatic conditions at Toolibin Lake are suitable for the operation of a solar saltfield.

b) The Toolibin Lake site is suitable for the construction and operation of a solar saltfield.
   - The site is substantially level
   - The local soil is suitable for construction, both for structural stability and low permeability
   - Pond lining will not be necessary

c) The Toolibin Lake salinity control operation provides a reliable supply of brine for the operation of a saltfield. The current bore field can provide sufficient brine feed to support a saltfield operation producing 6,000 t/a of washed salt.

d) Because of transport costs, the market for Toolibin salt is within Western Australia which is a relatively small market with well established suppliers. All sales will be sensitive to competition from other suppliers. Toolibin will need to sell value added product, in 25 kg bags, to attract local sales and broad market penetration.

The market strengths of Toolibin will be:
   - Closer to major metropolitan markets
   - Central location to the WA rural sector
   - Opportunity for personal contact with the customers
   - Ability to service customers at short notice
   - Smaller scale should allow flexible production allowing exploitation of "niche" markets

Quality washed salt is required for the range of products for which the market analysis has shown a base price of $55/t at site.

e) The capital cost for the commercial construction of a 5,000 t/a saltfield facility is $1.6M. The cost to establish the saltfield pond system is a significant proportion of this cost, in particular the cost for construction of Pond 1 with adequate capacity to hold brine supplied at a constant rate throughout the year.

This establishment cost does not include the provision of services and infrastructure to the site boundary or the bore field and brine supply network.

f) The financial analysis shows that with $55/t nett sale price, the saltfield will not generate adequate return on the Operator’s investment for salt production and sales less than 15,000 t/a.
10 Results and Conclusions

10.2 Alternative Funding

For this report, the financial analysis model has been run with a fixed selling price of $55 and the model discount rate determined. The model discount rate at which the Project Net Present Valve (NPV) is zero is the Project IRR.

To assess how the viability of the saltfield may be impacted by alternative funding, the financial analysis model has been rerun with the model discount rate fixed at 12% and the Sale Price at which the Project Net Present Valve (NPV) is zero determined.

The required sale prices to achieve a project IRR of 12%, for a range of salt production and sales, are presented in the following Table 7 for alternative capital arrangements:

Table 7 – Salt Production vs. Nett Sale Price

<table>
<thead>
<tr>
<th>Salt Production</th>
<th>Full Cost</th>
<th>Capital repayment but no Interest</th>
<th>+ No Washplant</th>
<th>+ No Capital repayment</th>
</tr>
</thead>
<tbody>
<tr>
<td>5,000</td>
<td>$100</td>
<td>$94</td>
<td>$78</td>
<td>$72</td>
</tr>
<tr>
<td>6,000</td>
<td>$90</td>
<td>$84</td>
<td>$71</td>
<td>$66</td>
</tr>
<tr>
<td>7,500</td>
<td>$78</td>
<td>$73</td>
<td>$62</td>
<td>$58</td>
</tr>
<tr>
<td>10,000</td>
<td>$67</td>
<td>$62</td>
<td>$54</td>
<td>$51</td>
</tr>
<tr>
<td>12,500</td>
<td>$60</td>
<td>$55</td>
<td>$49</td>
<td>$46</td>
</tr>
<tr>
<td>15,000</td>
<td>$56</td>
<td>$51</td>
<td>$46</td>
<td>$43</td>
</tr>
<tr>
<td>17,500</td>
<td>$51</td>
<td>$48</td>
<td>$44</td>
<td>$40</td>
</tr>
<tr>
<td>20,000</td>
<td>$49</td>
<td>$45</td>
<td>$42</td>
<td>$38</td>
</tr>
</tbody>
</table>

- Column 1: Full Project Costs, as per NPV with Capital Assistance
- Column 2: DCLM Funding repaid over 30 years, but no payment of interest
- Column 3: No Washplant. $400,000 removed from Operator’s expenditure
- Column 4: No repayment of DCLM Funding

The deductions have been applied cumulatively, but allow the interpretation of the relative impact on the project of the alternative funding options. In this analysis the operating costs, including harvesting costs, have been maintained as set for the financial analysis in the report.

Even with no repayment of capital or interest payment for the permanent production facilities funded by DCLM, a selling price greater than $55/t is required for a saltfield of 7,500 t/a capacity.
10 Results and Conclusions

While it is possible that a cooperative of local farmers and contractors in the Shire could construct a 5,000t/a saltfield for a significantly reduced capital cost, this may be equated to the non repayment of DCLM funding, which requires a sale price greater than $70/t for there to be an adequate return on the saltfield Operator’s investment. To achieve the set rate of return with a lower sale price, a reduction in overhead and operating costs is required.

While a 5,000t/a saltfield is a manageable saltfield size for local farming management, the operation of a saltfield requires considerable knowledge and skill, as identified in the risk analysis. Production quality and quantity is sensitive to the relative skill of the saltfield manager.

To achieve effective reduction in overhead and operating costs, the saltfield needs to share resources with another enterprise that can offer the necessary operating and marketing expertise at a reduced cost.

10.3 Higher Production Capacity

The concept design for a saltfield at Toolibin is based upon an available groundwater supply of 300,000 m³/a. For higher production tonnage, a significantly greater volume of brine is required as presented in the following Table 8:

Table 8 – Salt Production vs. Brine Volume

<table>
<thead>
<tr>
<th>Annual Salt Production t</th>
<th>Annual Brine Supply Volume m³</th>
<th>Annual Maiden Brine Supply Volume m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>5,000</td>
<td>260,000</td>
<td>30,000</td>
</tr>
<tr>
<td>6,000</td>
<td>310,000</td>
<td>35,000</td>
</tr>
<tr>
<td>7,500</td>
<td>390,000</td>
<td>44,000</td>
</tr>
<tr>
<td>10,000</td>
<td>520,000</td>
<td>59,000</td>
</tr>
<tr>
<td>12,500</td>
<td>650,000</td>
<td>74,000</td>
</tr>
<tr>
<td>15,000</td>
<td>780,000</td>
<td>89,000</td>
</tr>
<tr>
<td>17,500</td>
<td>910,000</td>
<td>105,000</td>
</tr>
<tr>
<td>20,000</td>
<td>1,000,000</td>
<td>120,000</td>
</tr>
</tbody>
</table>

For Toolibin this additional volume of brine would need to be extracted from the aquifers below Toolibin Lake. The sale prices in Table 7 do not allow for the cost of pumping this additional brine. If the saltfield operator were required to pay, the return on investment would be less and they will likely seek suitable sites in other locations.

However, to obtain the brine required for a larger saltfield, it is not necessary that the brine be supplied from one location. An expanded regional operation could be considered where brine would be concentrated at the source, before transfer to a central site with the saltfield facilities including crystallisers, washplant, product stockpiles, mobile pumps & equipment, workshop, stores, laboratory and bagging plant etc.
10 Results and Conclusions

A prime requirement for an expanded operation would be the guaranteed supply of brine. Table 8 shows the volume of brine required as feed to the evaporation ponds and the volume of saturated ‘maiden’ brine feed to the crystallisers required to produce the target annual tonnage. Transfer to the central site could be by use of satellite brine pumping stations or brine channels or as unwashed salt.

10.4 Conclusions

The following conclusions can be drawn from this feasibility study and report:

a) The Toolibin Lake site is suitable for the construction and operation of a solar saltfield and the available groundwater supply of 300,000 m³/a can support a saltfield operation producing 6,000 t/a of washed salt.

b) Because of transport costs, the market for Toolibin salt is within Western Australia. All sales will be sensitive to competition from other suppliers and any attempt to sell significant quantities is likely to meet with strong resistance, with downward pressure on selling price.

c) As a stand alone enterprise, the saltfield project will not provide an adequate return on investment for sales volume of less than 12,500 t/a, with $55/t nett bulk salt sale price.

The key risks are:
- Lack of quality control due to operational inexperience
- Lack of marketing expertise in salt and vulnerability to a price war with existing suppliers

The volume of sales and the nett sale price that can be obtained are the most significant factors for the commercial viability of the saltfield. They are also potentially the largest variables.
11 Bibliography
11 Bibliography

Actis Environmental Services, 1999; Commercial use of saline groundwater extracted from the Toolibin Lake District.


CSIRO Division of Soils, 1993; Soils: an Australian Viewpoint, CSIRO Melbourne.

Dogramaci S et al, 2002; Water balance and salinity trend, Toolibin Catchment, WA. Dept of Environment, Water and Catchment Protection.


Farm Map Consulting for Fugro Airborne Surveys, 2000; Toolibin Lake, Upgrading Catchment Interpretation.
Appendix A  Drawings
### Drawing List

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<th>Drawing No.</th>
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<tr>
<td>7053-01</td>
<td>Toolibin Solar Saltfield Project - Project Site Plan</td>
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<td>7053-02</td>
<td>Toolibin Solar Saltfield Project – Layout Plan</td>
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<tr>
<td>7053-03</td>
<td>Toolibin Solar Saltfield Project – Evaporation Ponds, Crystallisers and Site Road Typical Sections and Details</td>
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<td>7053-04</td>
<td>Toolibin Solar Saltfield Project – Survey Results and Test Pit Locations</td>
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<td>7053-05</td>
<td>Toolibin Solar Saltfield Project - Process Schematic Flow Sheet</td>
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<td>Construction Schedule</td>
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Appendix B  Site Geotechnical Investigation Report
B.1 Introduction

Design of the saltfield requires geotechnical knowledge of the proposed site to determine:

- the suitability of the local soils to form the base of the evaporation ponds and crystallisers, for use in the construction of pond embankments and to provide road building materials
- the relevant geotechnical design parameters such as strength, permeability and bearing capacity
- the availability of local materials for construction

A geotechnical investigation covering the likely extent of the solar saltfield and support facilities was conducted. Various methods were used to identify and characterise the soils underlying the site to a depth of approximately 1m. An experienced geotechnical engineer undertook the site investigation, recommended relevant soil testing and interpreted the results.

A topographic survey was performed immediately after the geotechnical investigation to provide additional elevation data and related site information (for example, drain invert levels) considered relevant to this study. The survey also identified the locations and elevations of the geotechnical test holes.

B.2 Geology

The 1:250,000 geology series map sheet for Corrigin indicates that the project site is located on a low lying river terrace underlain by materials deposited by the river (alluvium) and by wind (aeolian). An upper terrace underlain by weathered materials which may have been transported down slope by gravity (colluvium) is located immediately north of the site.

The aeolian materials are noted as comprising mainly silt and sands in sheet and dune deposits near playa lakes. The colluvial materials comprise silt, sand and gravel on the lower hill slopes. Both materials are underlain at depth by granite bedrock.

B.3 Soils

Toolibin Lake and its catchment are located at the headwaters of the Blackwood River on the Yilgarn Block. The Yilgarn block is an area of relatively flat crust uplifted during the Tertiary era. The geomorphology of the area surrounding Toolibin Lake is characterized by laterised plateaus underlain by Precambrian granites and gneissess and undulating plains dissected by saline drainage lines.

More detail on the surface soils in this locality is provided in “Soils, An Australian View Point”. This publication indicates that the laterised plateaus are generally underlain by yellow earths; the undulating valley sides and floors with solodized solonetz and solodic soils; and the dissecting remnant and existing drainage lines with solonchak soils.
Laterized profiles are comprised of three zones of material formed through the leaching and oxidation of minerals, normally aluminium and iron. The upper soil layer consists of a ferruginous zone comprised mainly of laterite. Below this zone is a mottled zone and then pallid a zone. These deeper zones are generally comprised of kaolinitic grey to white clay soils.

Solodized solonetz and solodic soils are generally comprise surficial deposits of grey to brown loose, coarse sands or clayey sands overlying red-orange and grey–brown sandy clays and clays.

Solonchak soils typically comprise brown to grey sandy clays. The solonchak clays commonly exhibit a very thin surface crust with polygonal cracking.

“Soils, An Australian View Point”, indicates that saline soils are generally associated with two types of landscapes. One of these landscapes is that formed along the dismembered remnants of relict drainage ways. Clearing and extensive development can also result in secondary salinisation of these soils. As a result, these areas are likely to be vegetated with salt tolerant species such as samphire and saltbush. Isolated saline depressions which form along these drainage ways are referred to as playas.

B.4 Site Description

The site is located to the west of Toolibin Lake. In this locality the topography is relatively flat, rising slightly along the northern boundary of the site to a low hill crest. A relatively narrow and shallow drain and adjacent berm runs along the northern boundary of the site, in front of the toe of the hill.

The ground slopes down to the east of the site, towards Toolibin Lake. A large drainage channel is located along the southern boundary of the site. This channel is arranged to divert saline surface waters around Toolibin Lake for discharge into Taarblin Lake.

The site is vegetated mainly with saltbush and grasses. The eastern part of the site has been used for trial plantings of indigenous trees.

B.5 Field Investigation Methodology

- The field investigation for the saltfield site included: a “walk over” reconnaissance of the site and adjacent areas
- Disturbed sampling of near surface soils in two potential borrow areas located to north of the site, a using pick and shovel. These sites were named TP 1 and TP2.
- Drilling of hand auger holes at three locations within the western part of the site and recovery of a disturbed sample from each location. These sites were named TP 3 to TP5. Test site TP 3 was located towards the north-western corner of the saltfield site and TP4 towards the south-western corner.
Test site TP 5 was located along the southern boundary of the site, towards the middle of the site. A bulk sample was also obtained adjacent to TP3.

- Identification of a potential off site source of fill named TP6
- Inspection of two samples of near surface soils collected by DCLM from two locations on the eastern part of the site (TP7 and TP8).

The hand auger holes were advanced to a depth of 1m or to the intersection of clay, whichever was the shallowest. A falling head (slug) permeability testing was commenced in hand auger hole TP5 to allow qualitative assessment of the rate at which water may seep through the floors of the proposed saltfield ponds. Testing was terminated prior to completion of the test due to poor weather conditions. The test hole was holding water well up until the time that the test was interrupted.

The locations of the test pits are shown on drawing 7053-04.

B.6 Field Investigation Results

The following observations were made during the reconnaissance of the site:

- The hill to the north of the site is covered with colluvial soil derived from a lateritic profile. This soil is comprised of a sandy clay with a trace of fine laterite gravel.
- There are outcrops of calcrete visible across the toe of the low lying hill north of the site.
- Zones of white to grey clay outcrop south of the hill but north of the swale. Removal of the near surface soils adjacent to these areas indicates that the clayey material extends under the near surface soils. Vegetation is sparse on or near this material.
- The silty clay soil excavated from the drain has been used to create the berm immediately down hill. There is no evidence of erosion on either the berm or drain.
- The diversion drain south of the project site is in a good condition. There is some evidence of erosion. This is limited to rills near star pickets located along the crest of the drain.
- The materials within both drains and the swale are battered at around 1(V):3(H). There is no evidence of instability in any of the cut or filled slopes.
- After heavy rainfall, the near surface soils become soft and slippery.

Visual classification of the soils intercepted by the three field hand auger holes drilled at the western part of the site, (TP3 to TP5), indicated a similar sub-surface profile consisting of:

- Silty CLAY: grey and dry, forming a hard cracked crust at the surface with fine sand locally. Changing in colour to orange-brown and/or grey-white below 100 mm to 300 mm depth.

The two samples of near surface soils excavated by DCLM from the eastern part of the site (TP7 and TP8) were also visually assessed. This assessment indicated that these samples consisted of:
- Silty CLAY: brown to orange brown, with sand.

Visual assessment of the materials intersected in borrow area and in the hand auger holes indicates that the soils underlying the western part of the site are very similar except for colour.

Visual assessment of soil samples from the eastern end of the site indicates that the soils underlying the eastern part of the site are similar to those underlying the western part of the site.

### B.7 Laboratory Investigation

A number of disturbed samples were obtained during the field investigation. These samples were inspected and the samples considered to be representative of the top 0.5 m of the soils covering the site and the borrow area were submitted for testing. The samples submitted were:

- Silty Clay, Grey-white (TP1 – 0.2 to 0.4 m depth)
- Silty Clay, Grey-white (TP2 – 0.2 to 0.4 m depth)
- Silty Clay, Orange-brown with grey-white mottling (TP3 – 0.2 m depth)

The following laboratory test were undertaken:

- Atterberg limits (plasticity)
- Particle size grading
- Permeability
- California Bearing Ratio (CBR)

Subsequent to the testing of samples recovered during the field investigation, two larger samples were provided by DCLM. These bulk samples were compared with the samples obtained during the field investigation. As the materials were visually similar, it was considered that further sample testing was not warranted.

### B.8 Laboratory Investigation Results

The results of laboratory results are as follows:

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<th>Test Location</th>
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<tr>
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<td>Not tested</td>
<td>4</td>
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<tr>
<td>Laboratory Maximum Dry Density</td>
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<td></td>
<td></td>
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<tr>
<td>Laboratory Optimum Moisture Content</td>
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<td>CBR (unsoaked, 98 % std MDD)</td>
<td>9</td>
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<tr>
<td>Percent of material less than 2 mm</td>
<td>95%</td>
<td>98%</td>
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</table>
Percent of material less than 75μm 72% 74%
Percent of material less than 2μm 58% 58%
Laboratory Permeability 4.72 x 10⁻⁹ m/s

The Atterberg limit tests show that the clay soils are similar and exhibit medium to high plasticity. The tests for TP2 and TP3 also indicate that both materials have a similar particle size distribution consisting of clays with fine sand and a trace of silt. These tests indicate that other than colour, the clay materials underlying the site are very similar in grading and plasticity.

Dispersion tests show that the clay soils are unlikely to disperse if immersed in water. Unsoaked, the clay soils provide a sub grade CBR of 9. This test was undertaken on material compacted to 98 % maximum dry density (Standard).

Laboratory permeability tests on the clay soils also show that if these near surface soils were to be scarified and recompacted to 95 % maximum dry density (Standard), a permeability of around 10⁻⁷ and to 10⁻⁹ m/s could be achieved.

The laboratory tests show little variation in the properties of the soils tested.

B.9 Engineering Assessment

The main geotechnical engineering considerations relevant to the design of the salt ponds relate to:

- Earthworks for the pond embankments
- Permeability of the pond floors
- Site infrastructure including foundations for administration buildings and access road

B.9.1 Pond Embankments

Approximately five kilometres of embankments will be required to form the ponds. The proposed embankments will be between 0.6 and 1.8 m high. Suitable quantities of fill material will need to be obtained to construct these embankments.

The most economic solution is to obtain this fill from within the project site. The materials available on the project site comprise mainly clays of medium to high plasticity. These materials are likely to soften significantly with prolonged contact with water due to their plastic nature.

However, inspection of the existing drain south of the project site and a smaller catch drain and swale located north of the project site shows that these local clay materials have been successfully used to build formations of similar height to those required for the proposed pond embankments.

Borrowing of material from within the project site is therefore considered the most suitable option for winning embankment fill material. This will involve stripping of material to a uniform depth from within the impoundment and placing the material in a controlled engineering manner.
For these materials to be used for construction of the pond embankments, the main issues which will need to be addressed during detailed design and construction are:

- Erosion along the shoreline due to wave run up or rainfall run off;
- Piping through the embankment or foundation.
- Slope stability

The development of failure mechanisms caused by erosion can be controlled by a number of engineering measures. These include:

- providing protection along the embankments in the form of grassing, riprap and/or geotextile lining,
- adopting flatter side slopes
- constructing the crest wider than otherwise required to provide sacrificial edges.
- treating the fill materials with additives such as lime to provide a more stable surface
- capping the clays with imported material which has a higher resistance to erosion.

Pond 1, being the largest pond and having the longest “fetch”, may develop waves and run-up at the downwind shore. Flatter batters and a wider crest are recommended. To protect the Pond 1 internal batter from undercut and erosion, the placement of rock armor may be required. Covering the full batter is a significant expense and given that the water depth is variable and there is potential for shielding by the high embankments, the requirement could be quite limited. It best be considered as a potential maintenance cost and is not recommended for inclusion in the feasibility study.

To prevent erosion along the external base of the pond embankments, catch drains should be located upstream of the ponds to divert water around the embankments. For most of the saltfield a diversion drain is formed by the access track around the north of the saltfield.

To prevent piping failure and to minimize the likelihood of slope instability, the following measures can generally be undertaken:

- Remove unsuitable softened foundation material to minimize differential settlement along the embankment.
- Minimize the differential head between either side of the pond embankment or lengthen the flow path through the embankment by widening the crest and/or flattening the embankment slopes.
- Adopt low permeability materials that are less likely to pipe.
- Provide proper moisture content and compaction control throughout the embankment and across the foundation
- Undertake regular maintenance of the embankment to remediate disturbance due to animals and erosion
For the purpose of the feasibility study, the following geotechnical design features or practices are recommended:

- the embankment foundations should be proof rolled to identify soft spots and any soft spots identified removed and replaced with suitable fill material.

- a design batter similar to that observed for the drains and berms on the project site is required. This batter slope should be 1(V): 3(H) or flatter. Embankment slope angles will need to be confirmed during the detailed design of the ponds.

The materials on the project site are of relatively low permeability, but of medium to high plasticity. Good construction control will be required to ensure these materials are properly placed and compacted.

The clay soils will need to be placed as close as possible to their optimum field moisture content. A range of +0% to +2% of field optimum moisture content is recommended. The materials should be compacted to achieve at a density not less than 95 % maximum dry density (modified).

Vehicle access may also be required along the pond embankments. It is recommended that trafficked surfaces are sheeted with a suitable road base material. Depending on traffic loading, it is estimated that this would consist of 200mm of crushed pisolith gravel or similar obtained from local sources.

**B.9.2 Evaporation Pond Floors**

It is important that loss of brine from the ponds is minimized.

The site investigation indicates the presence of a clayey foundation across most of the proposed ponds. This layer is considered sufficiently impermeable to limit the loss of water from within the ponds. Due to the presence of this clay layer, impermeable liners are not considered necessary.

However, it should be noted that the site was originally vegetated with Salmon Gum trees. As a result, old roots may have produced seepage paths through the clay layer. It is therefore recommended that where root holes are apparent, the exposed clay layer should be scarified and then proof rolled.

**B.9.3 Crystalliser Floors**

For good saltfield operation, a level trafficable floor is required within the crystallisers.

Once the crystallizer area is flooded with brine some softening of the site materials will occur. It is expected that the site materials will remain relatively strong and support substantial wheel loads, especially using low pressure pneumatic tyres. However to limit potential for rutting and salt contamination, a 60 to 70mm salt floor is recommended on top of a saturated, compacted clay base.

The crystallizer pond floors need to be prepared in a similar manner to the foundations for the pond embankments. The following practices are recommended:

- Proof roll, identify soft spots, remove and replace with suitable fill material
- Scarify the floor area a nominal depth of 200mm, trim and grade to level
- Compact to achieve at a density not less than 95% maximum dry density (modified)

### B.9.4 Site Infrastructure
It is assumed that a few small administration buildings will be required for the project site. These buildings are likely to be constructed on shallow footings founded in the near surface clay soils. Based on the results of laboratory testing, the foundations for these buildings should be designed in accordance with AS2870 based on a Class M (possible S) site. Foundation loads should be limited to an allowable bearing capacity of $Q_a = 100$ kpa.

### B.9.5 Access Roads
Sub grade assessment of the near surface soils indicates a design CBR of 9. This design CBR value is likely to reduce to less than 2 when the soils become wet. It is therefore recommended that all access roads be constructed on platforms consisting of at least 200 mm of general fill with a soaked CBR of 10.

Adequate drainage should also be provided along the road to prevent inundation of the road formation. Where access roads cannot be constructed on a raised platform, consideration should be given to installing sub soil drains and replacing the near surface soils with suitable fill material with a design soaked CBR of at least 10.

The design CBR of this topping material should be at least 10. A potential borrow area for this material was identified on the Wickepin-Harrismith Road approximately 14 km north west of the project site (TP6). Alternatively, visual inspection indicates that deposits of laterite gravel could be won from nearby hillcrest adjacent to the project site.

### B.10 Engineering Recommendations

In summary, the following design recommendations should be adopted
- Embankments can be constructed from the materials available on the project site.
- Embankments shall be constructed with side slopes battered at 1V:3H or flatter.
- The internal slope of Pond 1 should be protected with suitable rip rap material to minimise erosion
- The crystalliser pond floors should be scarified and compacted to provide a low permeability in situ clay liner.
- Fill materials used in the construction of pond embankments must be properly placed and compacted in accordance with the recommendations made previously in this report.
- Catch drains shall be provided to divert water around the project site
- Where vehicle access is required in the ponds, soft spots should be identified by proof rolling, removed and replaced with compacted fill.
- Where vehicle access is required on roads or on embankment crests, a running surface of 200 mm thick, soaked CBR 10 material should be provided.
B.11 **Materials Test Certificates**

The following Materials Test Certificates are appended to this report:

- **Atterberg Limits and Linear Shrinkage**
  - TP#1, TP#2, TP#3

- **Determination of the Emerson Class of a Soil**
  - TP#3

- **Particle Size Distribution**
  - TP#3

- **Permeability Test Results**
  - TP#3
Appendix C  Site Survey
# Survey Co-ordinates Listing

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**Note:** Australian grid zone 50.
TP6 is the gravel borrow pit located along the Wickepin-Harrismith Road.
Appendix D  Pond System Design
Pond System Design

Chart – Deposition of Salts during the Evaporation of Seawater, 25 C

Evaporation and Rainfall Data Schedule

D.1 Evaporation and Rainfall Data

D.2 Product Chemistry

D.3 Pond System Design
  D.3.1 Inputs
  D.3.2 Design Spreadsheet
  D.3.3 Production Scenarios

Pond System Design Spreadsheets (Brine Salinity 40 g/l TDS)
  • 5000 t/a
  • 6000 t/a
  • 7500 t/a
  • 10000 t/a
  • 15000 t/a
  • 20000 t/a

Pond System Design Spreadsheet (Brine Salinity 48 g/l TDS)
  • 7000 t/a
D.1 Evaporation and Rainfall Data

Spreadsheets that summarise the concept design of the pond system for the proposed solar saltfield are included in this Appendix.

The first schedule is Evaporation and Rainfall Data provided by the Bureau of Meteorology. Also included on this schedule is the determination of the mean values for monthly evaporation and rainfall that have been used as fixed inputs for the design of the pond system.

D.2 Product Chemistry

The following section provides background information on the chemistry of the ground water at Toolibin Lake.

The groundwater was analysed by DCLM and the results have been compared with the work by Bassegio on standard seawater, for confirmation of the assumptions and ratios used in the determination of pond areas and required brine volumes.

D.2.1 Results of Chemical Analyses

<table>
<thead>
<tr>
<th>Brine Source</th>
<th>TDS</th>
<th>Na</th>
<th>K</th>
<th>Mg</th>
<th>Ca</th>
<th>Cl</th>
<th>SO₄</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g/l</td>
<td>g/l</td>
<td>g/l</td>
<td>g/l</td>
<td>g/l</td>
<td>g/l</td>
<td>g/l</td>
</tr>
<tr>
<td>Seawater @ 35g/l TDS</td>
<td>34.80</td>
<td>10.74</td>
<td>0.39</td>
<td>1.30</td>
<td>0.42</td>
<td>19.24</td>
<td>2.71</td>
</tr>
<tr>
<td>Seawater @ 50g/l TDS</td>
<td>49.72</td>
<td>15.34</td>
<td>0.56</td>
<td>1.86</td>
<td>0.60</td>
<td>27.49</td>
<td>3.87</td>
</tr>
<tr>
<td>Recorded Toolibin ground water</td>
<td>53.31</td>
<td>15.60</td>
<td>0.12</td>
<td>2.86</td>
<td>0.71</td>
<td>28.50</td>
<td>5.52</td>
</tr>
<tr>
<td>Predicted Toolibin ground water</td>
<td>47.88</td>
<td>12.70</td>
<td>0.10</td>
<td>2.82</td>
<td>0.52</td>
<td>26.70</td>
<td>5.04</td>
</tr>
</tbody>
</table>

The above table shows the concentration of ions in seawater and Toolibin groundwater brine that has been provided as the base data for this study. The values in *italics* are extrapolated figures.

This information has been further developed to predict the yield of various mineral salts.

D.2.2 Ratios of Major Ions

<table>
<thead>
<tr>
<th>Brine Source</th>
<th>TDS</th>
<th>Mg/Na</th>
<th>Na/Cl</th>
<th>Ca/SO₄</th>
<th>Mg/SO₄</th>
<th>Mg/Cl</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g/l</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard Seawater</td>
<td>35</td>
<td>100%</td>
<td>101%</td>
<td>100%</td>
<td>100%</td>
<td>101%</td>
</tr>
<tr>
<td>Adjusted Standard Seawater</td>
<td>50</td>
<td>101%</td>
<td>101%</td>
<td>101%</td>
<td>101%</td>
<td>101%</td>
</tr>
<tr>
<td>Actual Toolibin ground water</td>
<td>53</td>
<td>152%</td>
<td>99%</td>
<td>84%</td>
<td>108%</td>
<td>151%</td>
</tr>
<tr>
<td>Predicted Toolibin ground water</td>
<td>48</td>
<td>184%</td>
<td>86%</td>
<td>67%</td>
<td>117%</td>
<td>158%</td>
</tr>
</tbody>
</table>
The calculation results in the above table are also based on the work by Bassengio and show the ratio of ions in the Total Dissolved Salts (TDS) contained in the brine matched with results for standard seawater evaporated to the same density.

These ion ratios may be converted into the proportions of the various salts, as presented in the following table.

### D.2.3 Proportions of Major Salts

<table>
<thead>
<tr>
<th>Brine Source</th>
<th>TDS g/l</th>
<th>CaSO₄</th>
<th>MgSO₄</th>
<th>MgCl₂</th>
<th>NaCl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Seawater</td>
<td>35</td>
<td>1.428</td>
<td>2.132</td>
<td>3.408</td>
<td>27.52</td>
</tr>
<tr>
<td>Adjusted Standard Seawater</td>
<td>50</td>
<td>2.04</td>
<td>3.045</td>
<td>4.882</td>
<td>39.30</td>
</tr>
<tr>
<td>Actual Toolibin ground water</td>
<td>53</td>
<td>2.414</td>
<td>4.78</td>
<td>7.428</td>
<td>37.84</td>
</tr>
<tr>
<td>Predicted Toolibin ground water</td>
<td>48</td>
<td>1.768</td>
<td>4.75</td>
<td>7.29</td>
<td>35.04</td>
</tr>
</tbody>
</table>

This table summarises the proportions of the major salts in the groundwater brine and compares those with the proportions for a standard seawater brine of the same density.

The table shows that the ground water has magnesium and sulphate levels that are higher than comparable standard seawater brine. At Toolibin, at the same discharge SG for bitterns, there will be a higher concentration of MgCl₂ and less NaCl than there would be for standard seawater brine. In the operation of the saltfield, as the density of the brine increases, the production of salt from the Toolibin brine will be marginally less for the same evaporation effort.

### D.3 Pond System Design

#### D.3.1 Inputs

The fixed inputs to the pond system design spreadsheet include:

- brine feed salt content (TDS)
- target annual salt production
- mean monthly evaporation in the Toolibin area
- mean monthly rainfall in the Toolibin area

Other fixed inputs include factors for:

- reduced evaporation when large water body and high salinity
- sodium chloride loss in bitterns release
- pond seepage losses
- washing and handling losses

The design factors used in the spreadsheet have been calculated from the results of work by Bassegio and experience on Australian saltfields. All factors are based on the evaporation of sea water brines.
D.3.2 Design Spreadsheet
The steps in the establishment of pond areas and potential salt production included on the spreadsheet are:

- The nett monthly evaporation is calculated by applying evaporation efficiency factors to the Evaporation and Rainfall Data. A large water body evaporation rate is roughly 70% of the evaporation rate in a Class ‘A’ evaporation pan, used in all official meteorological stations in Australia. This accounts for the increased local humidity effect of a large water body. The second factor accounts for the effect of salinity on evaporation. While this may be negligible in low salinity brines, the factor is considered a reasonable estimate for the reduction in evaporation rate for the range of salt saturation from initial brine to bitterns release.

- Using the nett monthly evaporation and applying factors for the tonnage of salt produced per tonne of water evaporated, the volume of crystallised salt that may be produced per hectare is established.

- The required volume of saturated (maiden) brine, per hectare, is established. This calculation includes factor adjustments for the ratio of bitterns to maiden brine and recovery of NaCl per total NaCl in solution. Maiden brine is brine that has reached saturation but has not dropped any salt. The term saturated brine has a broader use and also applies to brine at bitterns SG.

- The crystalliser area is determined for the input annual production tonnage plus an allowance for harvesting, wash plant and handling losses. Total crystallised salt available and assumed washing and handling losses are indicated on the individual spreadsheets.

- The evaporation pond area required to match the crystalliser area is then determined using a calculated ratio for the transfer of the 40 g/l TDS brine supply to maiden brine.

- Using the same ratios, the required annual brine supply is determined and a provision for pond seepage losses is incorporated. The provision for seepage loss is considered to be conservative and with the deposition of salts within the pond system seepage is expected to reduce over time.

The washing and handling losses indicated on the spreadsheets have been incorporated to cover the following expected losses in the operation of the saltfield and washplant:

- Washplant loss of at least 15%, dependent on the rejection size for fine salt. A small saltfield has a higher risk of producing small crystals because of a relative shortage of saturated brine and shallow crystalliser fills.

- Harvesting loss of 2 or 3%.

The spreadsheets also show the required brine supply matched to continuous brine feed, from bores, and the varying depth of storage required in Pond 1. Based on an assumed March harvest, the spreadsheet identifies the highest level in Pond 1 as being in September. As pond area is matched to production capacity, the maximum level indicated is constant for all production scenarios but it will vary year to year dependent on actual evaporation and rainfall. It is assessed that the months of May, June, July and August are months of negative evaporation. September is a month of breakeven evaporation. For simplicity, only the saturated brines are considered in the calculation and it is likely that the low salinity brines would still have a positive evaporation during September and some of the winter months.
A hydraulic gradient is required to push brine through the evaporation ponds. To reduce potential for fluctuations in pond densities and consequent impact on pond biology a minimum pond operating depth of 300mm has been assumed and a typical minimum freeboard of 300mm.

D.3.3 Production Scenarios
Eight production scenarios, with target tonnages from 5,000 t/a to 20,000 t/a with brine salinity of 40 g/l, have been modelled. A further production scenario has been modelled with brine salinity of 48 g/l to show the impact of a different salinity on the pond system design.

The target annual production scenario of 6,000 t/a, with a required brine supply of 310,000 m³/a, most closely matches the current available brine supply with a salinity of 40 g/l. This requires 5 ha of crystalliser ponds and 41 ha of evaporation ponds.

However, with brine salinity of 48 g/l and a brine supply of 300,000 m³/a, the target annual production is 7,000 t/a, with 6 ha of crystalliser ponds and 40 ha of evaporation ponds required. A 20 percent increase in crystalliser area is required with effectively the same area of evaporation ponds.

The concept design is based on mean values for evaporation and rainfall at this location. This implies that for 50% of the operating years, when there is lower nett evaporation, the saltfield may not achieve the target annual production and for 50% of the operating years the production target should be achieved or exceeded. To exceed the target, additional brine supply is necessary. This is more complicated for a bore supplied saltfield and may require the provision of additional bores to supplement the brine supply in these periods.

This does not necessarily imply that the pond system design based on mean evaporation values is at risk of being under-designed. Nett evaporation is one of a number of variables in saltfield performance and production levels and it is considered that the use of the mean values provides a sound base for the assessment of pond requirements and salt production.

In the pond system design there is buffering capacity, by adjustment of pond depth and salinity gradient. The brine levels across the pond system may be drawn down during period of high nett evaporation and raised in period of low nett evaporation.

While the depth of brine cover in the crystallisers may be varied, for the production of high quality salt the crystallisers must not run out of saturated brine as this will damage salt quality in the exposed crystalliser. Therefore it is important not to have too many crystallisers or crystallisers that are too large for the field capacity.

Also, when increased maiden brine supply, the bitterns discharge point may be lowered to increase throughput and/or dye modification used for increased evaporation.
Appendix E  Financial Analysis
Capital Cost Estimates
- 5000 t/a
- 6000 t/a
- 7500 t/a
- 10000 t/a
- 15000 t/a
- 20000 t/a

Operating Cost Estimates
- Fixed Costs
- Harvesting Costs

Net Present Value Analysis
- 5000 t/a
- 6000 t/a
- 7500 t/a
- 10000 t/a
- 15000 t/a
- 20000 t/a
Appendix F  Site Photographs
1. Looking Due North across Pond 1

2. Drain Channel. Looking East from Pond 1/2 Embankment
3. Test Pit 1 Sample. North Embankment of Pond 1