# 4. EXISTING WAGERUP REFINERY

## 4.1 ALUMINA REFINING PROCESS

As with the majority of other commercial alumina refineries throughout the world, the Wagerup refinery uses the Bayer process to refine alumina from bauxite ore. This involves a number of key steps, including:

- Bauxite grinding;
- Slurry storage;
- Digestion;
- Clarification;
- Precipitation; and
- Calcination.

A simplified process flow diagram of the Bayer process used at the Wagerup refinery is presented in Figure 6.

### 4.1.1 Bauxite Grinding and Slurry Storage

Bauxite is ground to less than 1.5 mm particle size at the refinery, using semi-autogenous grinding mills (SAG and/or Ball mills) to ensure sufficient solid-liquid contact during the digestion phase, which improves alumina extraction efficiency. A solution of hot concentrated sodium hydroxide (NaOH, i.e. caustic soda) liquor, taken from the recycled caustic liquor circuit, is added to the bauxite during grinding to produce a slurry. The slurry is pumped to a series of holding tanks prior to the next stage of the Bayer process. The holding tanks allow for minor interruptions to the ground bauxite supply and allow desilication (the removal of silica from the liquor) to commence.

### 4.1.2 Digestion

The bauxite slurry is pumped from the holding tanks to the digestion units where additional hot recycled caustic liquor is added to the ground bauxite slurry. The digestion process removes the hydrated alumina from other insoluble oxides by reacting it with sodium hydroxide according to the following reaction:

$$Al_2O_3.xH_2O + 2NaOH \rightarrow 2NaAlO_2 + (x+1)H_2O$$

The slurry leaves the digestion units containing the alumina in solution (often referred to as green liquor), and other undissolved ore solids.

### 4.1.3 Clarification

In the clarification stage of the process, undissolved ore solids are separated from the green liquor. This is achieved using large clarification vessels (mud thickeners), which allow the undissolved bauxite solids to settle out. These bauxite solids are then passed through a counter-current washing train (mud washers) using water to recover as much of the caustic as possible to enable it to be returned to the recycled caustic liquor circuit. The washed solids from the counter-current washing train are called process residue and are pumped to the RDA (refer to Section 4.2).

Approximately halfway through the mud washing process the overflow stream is heated and contacted with lime slurry. This is known as the causticisation process, where a portion of the sodium carbonate that is formed in the liquor is converted back to sodium hydroxide. Without causticisation, the refinery would require large quantities of fresh caustic to be added to the liquor for the refinery to remain productive.

### 4.1.4 Organic Removal

Organic material is naturally present in bauxite ore and in some of the specialised chemicals added throughout the Bayer process (such as flocculants). This organic matter reacts to form various organic sodium compounds and, over time, the level of organics builds up in the recycled caustic liquor circuit, reducing the efficiency of precipitation (see Section 4.1.5). These organic compounds can also adversely affect the formation of alumina tri-hydrate crystals, resulting in poor quality alumina product.

The build up of organics is controlled in two ways. Firstly, sodium oxalate (the most significant organic) is concentrated and removed by a sequence of seeding, precipitating, and washing to produce a wet oxalate cake. This oxalate cake is currently being stored in a secure part of the residue storage area. The Proposal will see the commissioning of oxalate kilns, which convert oxalate to carbonate by thermal decomposition.

Secondly, bulk organics destruction is achieved by taking a small liquor side stream to the liquor burning plant. Here, the liquor is concentrated by evaporation, slurried with fine alumina dust, and combusted in a rotary kiln. The organics are oxidised, and the resulting sodium aluminate is returned to the liquor circuit.

### 4.1.5 Precipitation

Green liquor is passed to precipitation after being cooled via a heat exchange process. The heat from the green liquor is transferred to the cold spent liquor (i.e. liquor from which the alumina has been removed) that is returned to the start of the digestion process. The cooled liquor is seeded with small crystals of alumina tri-hydrate, which act as nuclei for more alumina tri-hydrate to precipitate. The seeded liquor is passed through a series of large precipitator vessels, where the crystals agglomerate and grow. When the hydrate slurry leaves the last precipitator vessels, it is classified (sorted) by size. The coarser particles are transferred to calcination, and the finer particles are thickened, filtered, and recycled to the start of the precipitation process as seed crystals. The spent liquor which is produced during the classification, thickening, and filtration processes is then recycled to the digestion process and used once more to dissolve fresh alumina.

### 4.1.6 Calcination

Calcination involves washing and drying the alumina hydrate ($Al_2O_3.3H_2O$), then heating it to about 1,000 °C to drive off chemically combined water. The final product is alumina ($Al_2O_3$) a dry, pure white, sand-like material, which is the feedstock for aluminium smelters. Particulate emissions from the calciners are currently controlled using an electrostatic precipitator on each calciner.

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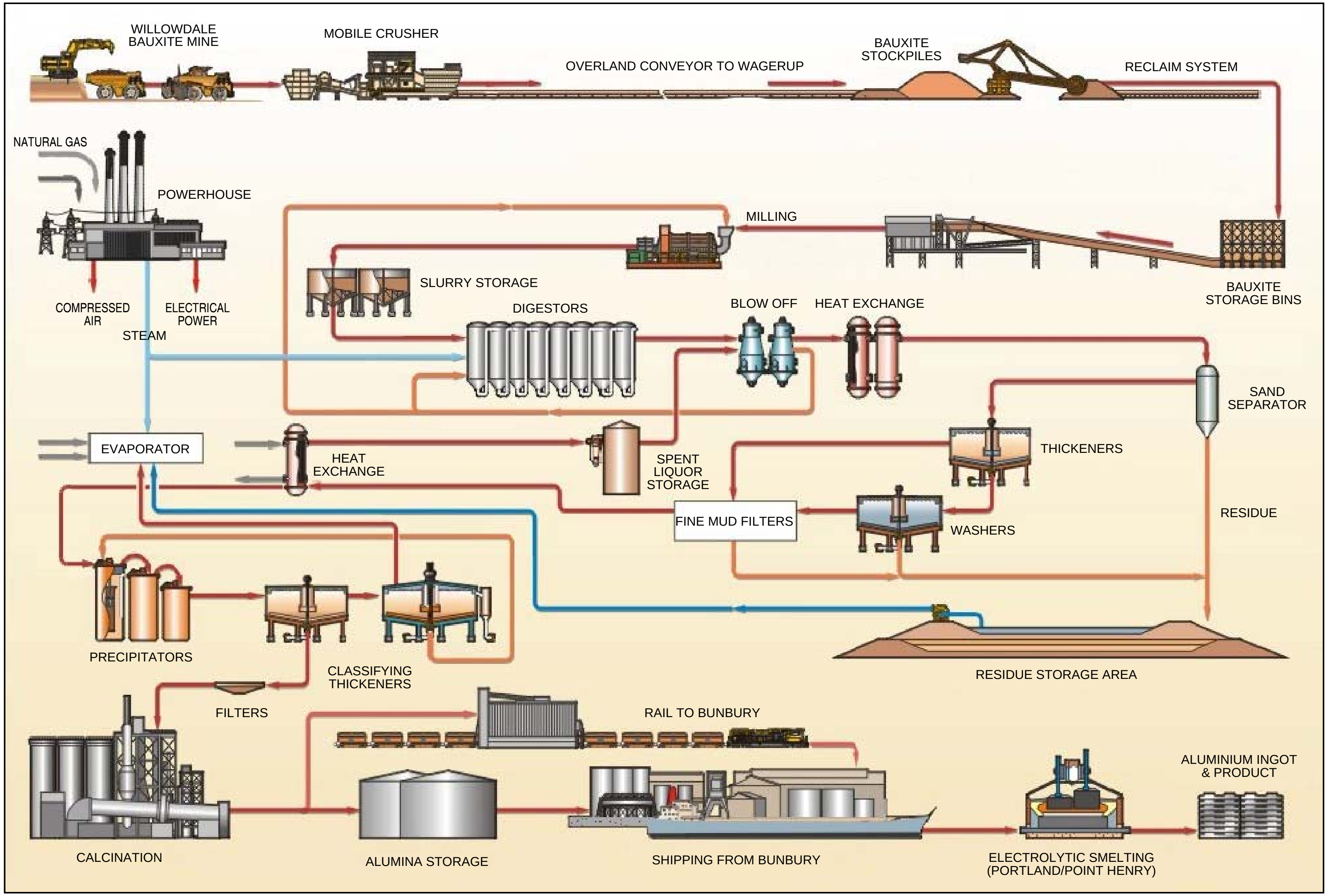
# BAYER PROCESS FLOW DIAGRAM




SOURCE: ALCOA, August 2003

**Figure 6**

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## 4.2 BAUXITE RESIDUE STORAGESTORAGE AREA

The refining process produces a residue consisting of caustic-insoluble components (predominantly oxides of iron and silicon) which have passed through the Bayer process unaltered, and residual quantities of caustic soda not recovered in the residue washing stage.

The residue is separated into different size fractions as part of the refining process. The coarse fraction is known as the “sand” fraction (approximately 40%) and the fine fraction is known as “mud” (approximately 60%). The sand and mud fractions are currently pumped to the residue area through separate pipelines and are handled separately within the storage operation. As part of this proposal, the mud and sand fractions will be combined prior to pumping to the residue area, and then separated in a sand separation unit within the residue area. Pipelines return cooled liquor and collected runoff water from the residue area back to the refinery for reuse in the process. Residue from Darling Range bauxite is produced at a rate of approximately two dry tonnes per tonne of alumina produced.

Prior to 1991 residue was stored within ‘wet lakes’: large lined impoundments where the wet residue dried out in the sun and consolidated under its own weight. In 1991, the Wagerup refinery adopted an alternative drying technology termed 'dry stacking'. The residue is pre-thickened then deposited in thin layers which are left to dry in the sun. The solar drying of the residue produces a high density, stable stack of residue, allowing a form of upstream embankment construction to be employed. RDA2 is the only drying area that has not been converted to dry stacking and it is proposed to convert RDA2 to dry stacking as part of the Proposal. Dry residue stacking is now the preferred method of storage and planning of future facilities is based on an extrapolation of Alcoa's current management practices.

The existing residue area covers approximately 546 hectares (ha) (to the outer drain) of which about 170 ha are currently used for active drying of the residue (RDA1-7), 12 ha for the thickener bypass, 69 ha for alkaline water storage and 32 ha for fresh water storage. The existing RDAs are shown in Figure 7.

To manage the long term development and ultimate closure of the residue area, Alcoa has developed a Long Term Residue Management Strategy (LTRMS) in consultation with government agencies and members of the neighbouring community. The LTRMS outlines the strategies to ensure that the residue area at Wagerup will be stable and self sustaining, and will no longer require further management when refinery operations cease. The LTRMS covers the proposed 30 year plan for residue management at Wagerup and is reviewed and updated on a five yearly basis. Further detail on the LTRMS is provided in Section 5.2.

The Residue Planning Liaison Group (RPLG) was formed to facilitate the planning, review and endorsement of the LTRMS developed by Alcoa for submission to the Minister for the Environment. The RPLG has membership from the Department of Industry and Resources, Department of Environment (and Water and Rivers Commission), Ministry of Planning, Agriculture Western Australia, the Peel Development Commission, Department of Conservation and Land Management and Alcoa. As a result of consultation on the LTRMS, the Waroona Shire Council made a request to become a member of the RPLG in July 2003.

Expansion of the residue area within the 30 year plan is an ongoing process with construction work on RDA7 completed during the 2004/5 summer period and construction of RDA8 and a new fresh water detention pond planned for the 2005/6 summer period (Figure 7).

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# FUTURE EXPANSION OF THE RDA WITHIN THE 30 YEAR LTRMS

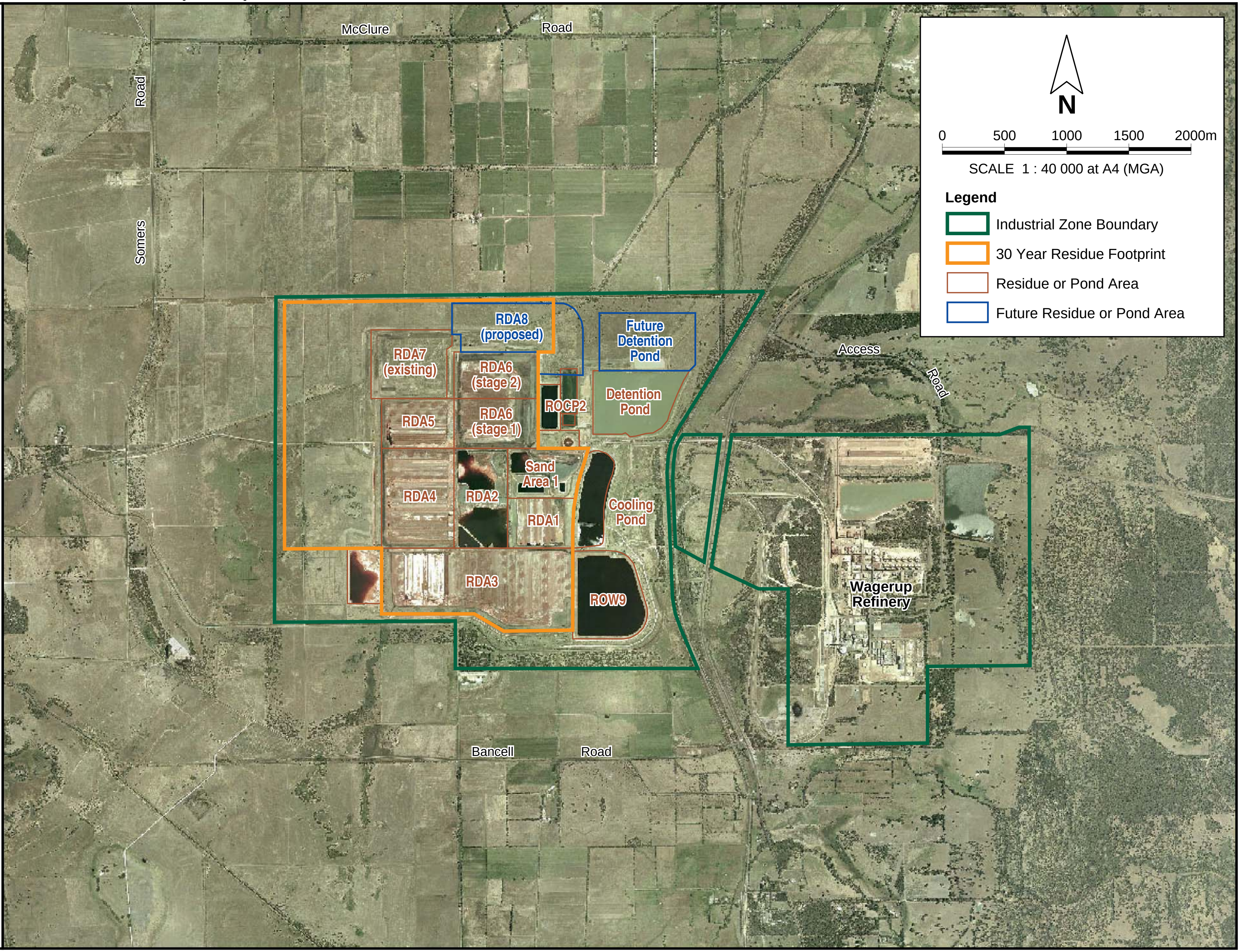


**Figure 7**

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### 4.2.1 Alternative Uses of Residue

Development of alternative uses for bauxite residue has been one of the major objectives of Alcoa's residue development program since 1978. The primary focus of this work is to demonstrate that bauxite residue is a potentially useful material rather than a waste product, and to investigate whether proposed uses are environmental acceptable and commercially viable. The company recognises that if significant re-use can be achieved, the rate of expansion of the residue area can be slowed.

A number of opportunities for residue re-use are being investigated as a part of Alcoa's research and development program. These include:

- Use of the fine residue fraction (red mud) as a soil amendment within the Peel-Harvey catchment and wider areas;
- Separation of lime residue from the process rather than disposal with the bauxite residue. A range of potential uses for this lime residue are being investigated including its use as agricultural lime and as a raw material in other industries.
- Washing and mineral separation of the coarse residue fraction (residue sand). A number of potential uses for each of the mineral fractions are being investigated including the use of a high silica fraction as a concrete aggregate and a high iron fraction as a low grade feed for iron production.

Much of the research work is being coordinated through the recently formed Centre for Sustainable Resource Processing (CSRP), and is being supported by a range of research groups, Universities and government agencies. Agriculture Western Australia continues to be very supportive of the use of the fine residue fraction as a soil amendment (Alkaloam) with ongoing monitoring of a number of sites within the Peel Harvey Catchment. Ongoing monitoring was a condition of the EPA approval for broad scale application and the results from this monitoring are reported both publicly and to the Department of Environment.

Waste minimisation using methods such as recycling and reuse is a growing trend in industry and also in the general community. In part, this initiative is in response to the increasing cost of land disposal of wastes and the potential adverse environmental impacts. Concepts such as Sustainable Development and Life Cycle Analysis also encourage this approach. By identifying and demonstrating a range of technically and economically feasible alternative uses, bauxite residue may become a resource rather than a waste.

## 4.3 BAUXITE MINING

Ore for Wagerup refinery is supplied from the Willowdale mine (Figure 4) located east of Wagerup within Mineral Lease 1SA (ML1sa). The current approved five-year mining plan for Willowdale (for 2005-2009) projects the production of approximately 9 Mtpa of bauxite, all of which is currently supplied to Wagerup from the Orion mining region via a system of overland conveyors. The rate of mining will need to increase incrementally from 9Mtpa to approximately 16 Mtpa to support the proposed expansion of Wagerup refinery. This additional ore will be sourced by bringing forward the planned development of mining within the Larego mining region, south of the current mining operations. This will require both an extension and an upgrade of the overland conveyor system. Mining in the Larego region was previously scheduled to commence in around 2017, but will now commence in late 2007 (if the Proposal is approved) and continue for approximately 10 years in tandem with operations at Orion. Subsequent mining operations will be scheduled in regions further to the south and east of Larego.

The EPA has advised that the mining operations within ML1sa, which are managed by the MMPLG process, are addressed by an existing approval process and, with the sole exception of management of noise from overland bauxite conveyors, are not to be included in the ERMP.

### 4.3.1 Mine Planning and Management

Mining is undertaken in accordance with Alcoa's five-year Mining and Management Program which is reviewed annually by the Mining and Management Program Liaison Group (MMPLG) and approved by the Minister for State Development, who also advises the Minister for Environment. The MMPLG is chaired by the Department of Industry and Resources (DoIR) on behalf of the Minister for State Development. The other state government agencies represented on the MMPLG are Conservation and Land Management (CALM), Water Corporation (WC) and Department of Environment (DoE) (Figure 8).

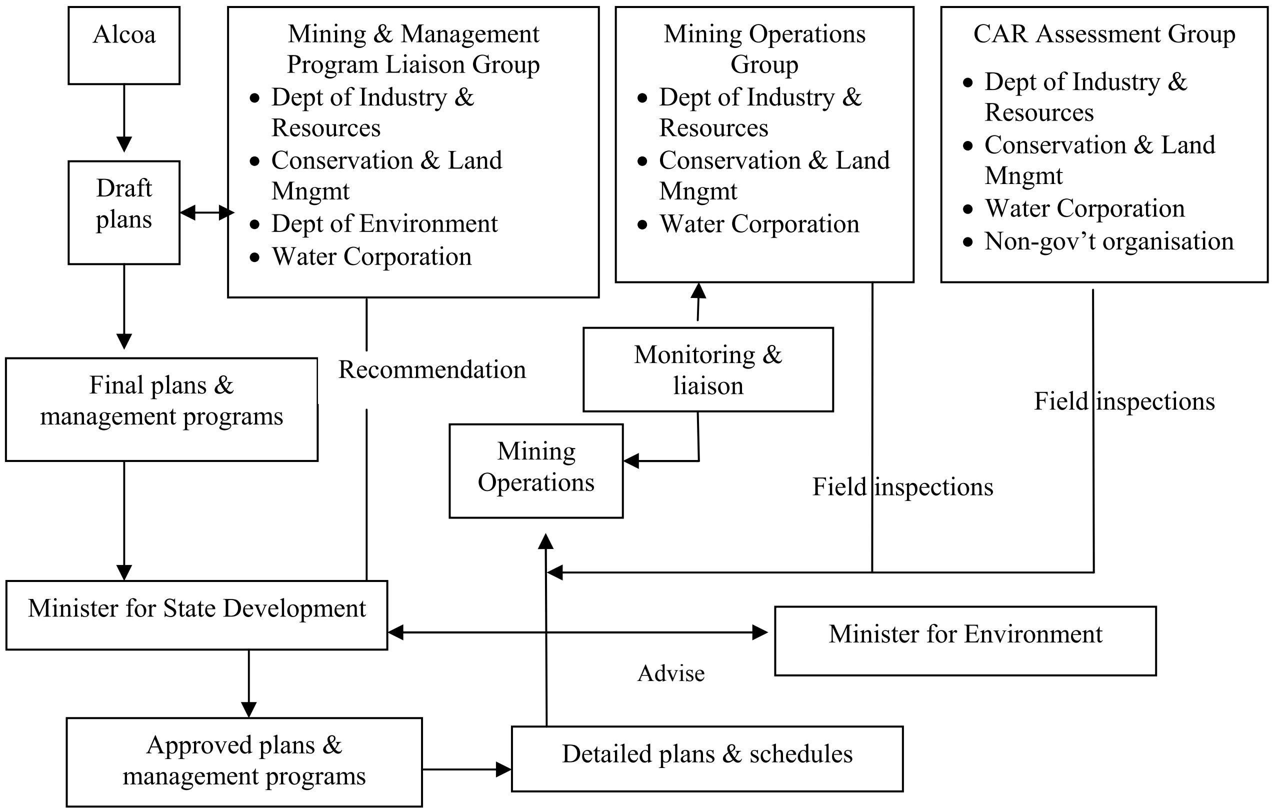


**Figure 8: Mine plan approval process through the MMPLG and sub-committees**

The Mine Operations Group (MOG) and CAR (Comprehensive, Adequate and Representative) Assessment Group (CARAG) are sub-committees of the MMPLG. The role of MOG is to oversee and report to the MMPLG on the environmental (including forest clearing) and community issues arising from the day to day operational activities conducted at Alcoa's mines. CARAG was set-up as a result of a process being agreed to by the MMPLG and the EPA to evaluate Alcoa's planned incursions into CAR Informal Reserves within Alcoa's mining lease as required under the Regional Forest Agreement. CARAG reports its findings and recommendations to the MMPLG, which in turn makes its recommendation direct to the EPA on the acceptability of Alcoa's proposals.

The annual process for review and approval of the five-year Mining and Management Program (MMP) is as follows and presented in Figure 9:

a. A review of the previous five-year Mining and Management Program is undertaken each July/August;
b. A site visit and presentation is made to Local Government representatives and neighbours in August and September each year;
c. Alcoa prepares a draft five-year Mining and Management Program incorporating feedback from the various stakeholders, and presents it to the MMPLG by 1st October each year;

d. The MMPLG reviews the draft five-year Mining and Management Program and provides feedback to Alcoa by the end of November. The MMPLG meets with Alcoa and visits the site during this process;
e. A final five-year Mining and Management Program, incorporating the MMPLG recommendations is prepared and submitted to the Minister for State Development by late December;
f. The Minister for State Development advises the Minister for Environment and Heritage of the MMPLG recommendations;
g. Approval of the Mining and Management Program by the Minister for State Development is usually issued by the end of January. Approval may be subject to a number of conditions.

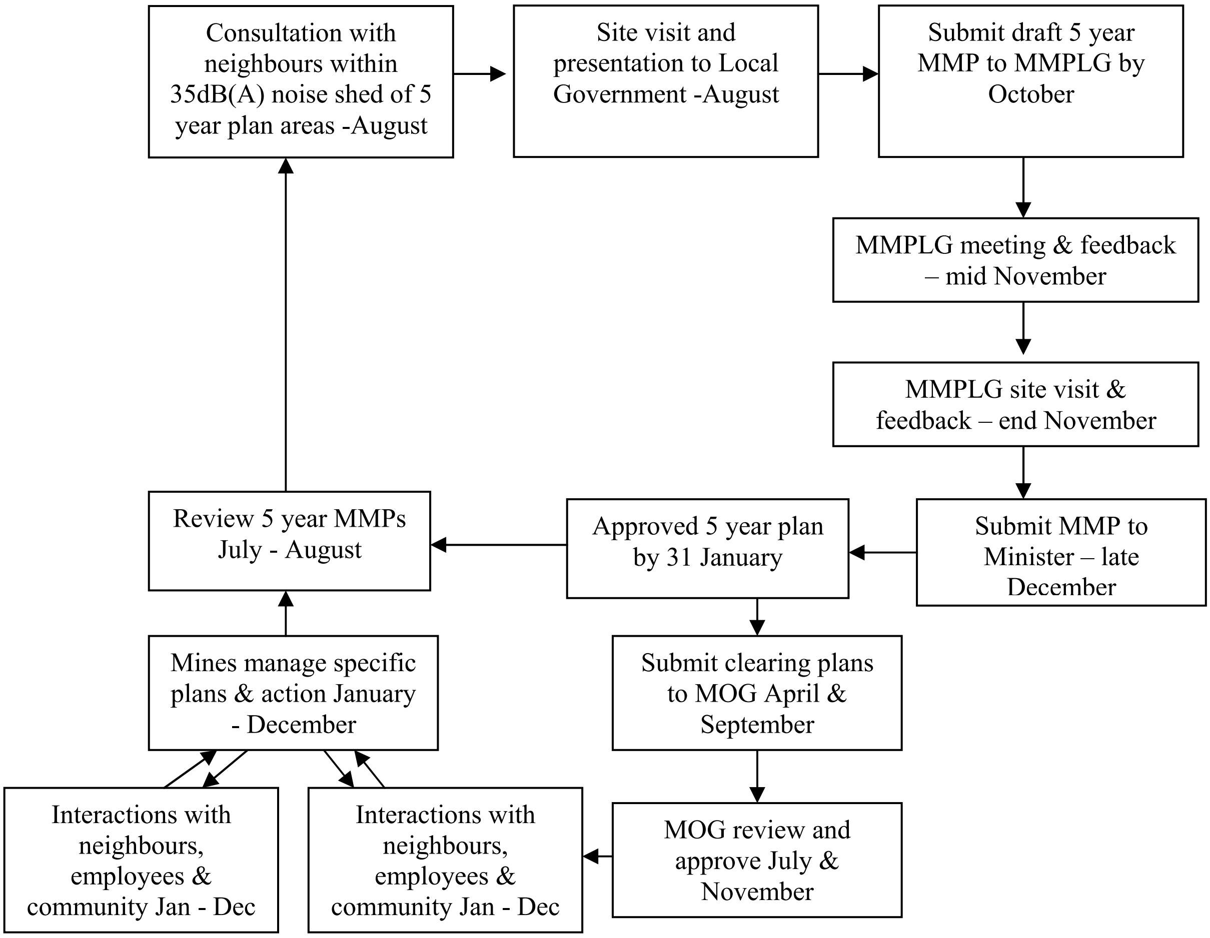


**Figure 9: Consultation and reporting process of the Mining and Management Program**

The consultation process is facilitated through the Mining Community Relations Officer, who ensures effective two-way communication with the community. This two-way communication includes mail-outs of information to the local community, single issue consultative processes, neighbour visits to discuss Alcoa's operations, mine open days, presentations to neighbour groups and local government, mine tours and information displays at local events.

### 4.3.2 Working Arrangements

Agreements between Alcoa and government regulators are outlined in the Alcoa/CALM Working Arrangements and the Alcoa/Department of Environment/Water Corporation Water Working Arrangements. The Water Working Arrangements set the framework for cooperative and efficient interaction between Alcoa mining operations at Huntly and Willowdale with the DoE and the WC for water resource management and protection. They complement existing Working Arrangements in place between CALM and Alcoa which define agreed standards and prescriptions for mine rehabilitation and forest management.

The Working Arrangements are written and reviewed jointly by Alcoa and the relevant agencies and are designed to cover a two to five year period, however they may be updated at any time if significant new environmental information becomes available.

The intent of the Working Arrangement is to maintain a coordinated approach to the management of mining operations and the protection of biodiversity and water resources. They provide a clear map of the relationships between Alcoa and the government agencies and the agreed procedures and guiding principles that are to be followed. These Working Arrangements do not cover the detailed management of each of the stages of Alcoa's operations, which are presented in annual Mining and Management Programs and Environmental Management Manuals submitted to Government.

The Working Arrangements do not limit the statutory functions, rights and obligations of CALM, the DoE or the Water Corporation. Where there is a conflict between any practice or activity undertaken pursuant to these Working Arrangements and to the observance of any right or obligation of CALM, the DoE or Water Corporation, the latter prevails.

The EPA has advised that the mining operations which are managed by the MMPLG process in ML1sa, are addressed by an existing approval process and therefore are not to be included in the ERMP.

## 4.4 SERVICES AND UTILITIES

### 4.4.1 Raw Materials and Product Transportation

#### 4.4.1.1 Overland Conveyors

Ore is currently transported from the Willowdale mine to the Wagerup refinery by a system of two overland conveyors. Bauxite ore crushed at the mine is discharged onto a conveyor 9.4km long equipped with a 915mm wide belt running at 6.5m/sec with a drive station at Arundel. At this point the ore is transferred to a second conveyor 8.8km long equipped with a

915mm wide belt running at 5.5m/sec with drive stations at Arundel and Bancell. This second conveyor delivers ore to the bauxite stockpiles at the refinery.

4.4.1.2 Rail Transport and Bunbury Port

Alumina is transported by rail from the Wagerup refinery to Alcoa's port facilities at Bunbury and caustic is transported by rail from Bunbury to the Wagerup refinery. Australian Rail Group (ARG) is contracted to provide rail freight of alumina and caustic. ARG operates three sets of alumina trains (one loco and between 34 and 38 wagons each) and one caustic train (one loco and 20 wagons) which provide the daily rail services to and from Alcoa's facilities at Pinjarra, Wagerup, Kwinana and Bunbury.

For Alcoa's Wagerup refinery there are currently three trains, and occasionally four trains transporting alumina each day to the Bunbury Port. Each train is between 34 to 38 wagons in length.

Typically one train, and occasionally two trains, per day is required to carry caustic from Bunbury to the Wagerup refinery. Each train is 20 wagons in length.

ARG is currently reviewing its rail operations and has flagged it intends to operate four sets of alumina trains (one loco and approximately 28 to 32 wagons each) and two sets of caustic trains (one loco and approximately 10 wagons each) from around mid 2005. This will result in an average increase of two alumina trains and one caustic train per day to and from Wagerup, however trains will be shorter.

Alcoa's Bunbury Port facility was opened in 1976 to meet expanding alumina output from the Pinjarra refinery. The port supported expanded production when Wagerup commenced operations in 1984. Worsley also uses Bunbury Port for the export of alumina. In 2003, 8.4 Mtpa of alumina was shipped from Bunbury by Alcoa and Worsley.

4.4.1.3 Road Transport

Currently most vehicle movements to and from the Wagerup refinery are associated with road freight and employee vehicles. The permanent workforce at the refinery results in approximately 450 passenger vehicles per day entering and exiting the site.

Road freight movements associated with deliveries to the Wagerup refinery are estimated at 121 movements (one-way) per week. The majority of these are from the north and travel along the South West highway through the Waroona townsite. There are approximately seven large trucks transporting lime and one general freight semi-trailer into Wagerup every day. Lime movements make up 47% of daily vehicle freight movements into the refinery. The refinery also receives approximately eight general freight vehicles per day, including five tray trucks and three 1-tonne courier vehicles. Nine other movements occur on a weekly or fortnightly basis and are associated with activities such as fuel delivery, laboratory supplies, domestic rubbish collection and recycling.

The road freight movement associated with mining is estimated at 46 freight movements (one-way) per week, made up of fuel and oil transport, general deliveries, explosives, logging and mulch. It should be noted that mining is not included in the assessment of this Proposal, but mining freight movements are described here at the request of the Noise and Transport working group (a local community-based consultation committee).

The road freight movements associated with the refinery and mining represents approximately 7% of all freight movements on South West highway. This is based on Main Roads daily class data giving an average of 36,000 vehicle movements and 4680 freight movements (class 3 to 12) per week.

### 4.4.2 Energy Requirements

The Wagerup refinery uses natural gas as its main energy source, as it is less expensive and is considered to have less environmental impact than other carbon-based energy sources. The on-site powerhouse boilers produce steam used for heating in the Bayer process, and to generate electricity using turbo-alternators to power the refinery and ancillary facilities. Natural gas is also used as fuel for the calciners, and will be combusted in the oxalate kilns.

Alcoa is constantly examining ways to reduce energy consumption and improve the overall energy efficiency of the refinery including measures such as waste heat recovery. These energy efficiency programs have resulted in Alcoa's Australian alumina refineries making significant energy efficiency improvements.

### 4.4.3 Refinery Water Supply

Wagerup refinery is almost totally dependent on surface water sources to provide process make-up water. The catchments that provide water for the Wagerup refinery include the refinery site and residue area, and surrounding land including Darling Range and agricultural catchments. Make-up water is taken from three licensed surface water sources: Black Tom Brook, Yalup Brook and the Harvey River Main Drain (refer section 7.5.2). In addition, rainfall runoff and water contained in the caustic soda and bauxite is added to the water circuit. Water is also purchased (700 kL in 2004 and 660 kL in 2003), when required, from Harvey Water.

The RDAs have base drainage systems that collect residue leachate and rainfall infiltration. All rainfall runoff from the refinery, residue area and process water ponds is transferred to the cooling pond or runoff water storage pond during winter and then used as make-up water for the refinery during summer. On average, total water storage in the residue area water circuit is approximately 3,000 ML (averaged over 2002/3).

Annual water consumption is primarily determined by the process conditions and is largely independent of prevailing weather conditions. Overall, the Wagerup refinery uses approximately two kilolitres (kL) of water per tonne of alumina product.

Alcoa has developed a water balance model for the Wagerup refinery to predict water consumption and supply requirements under varying process and weather conditions (refer to Figure 10).

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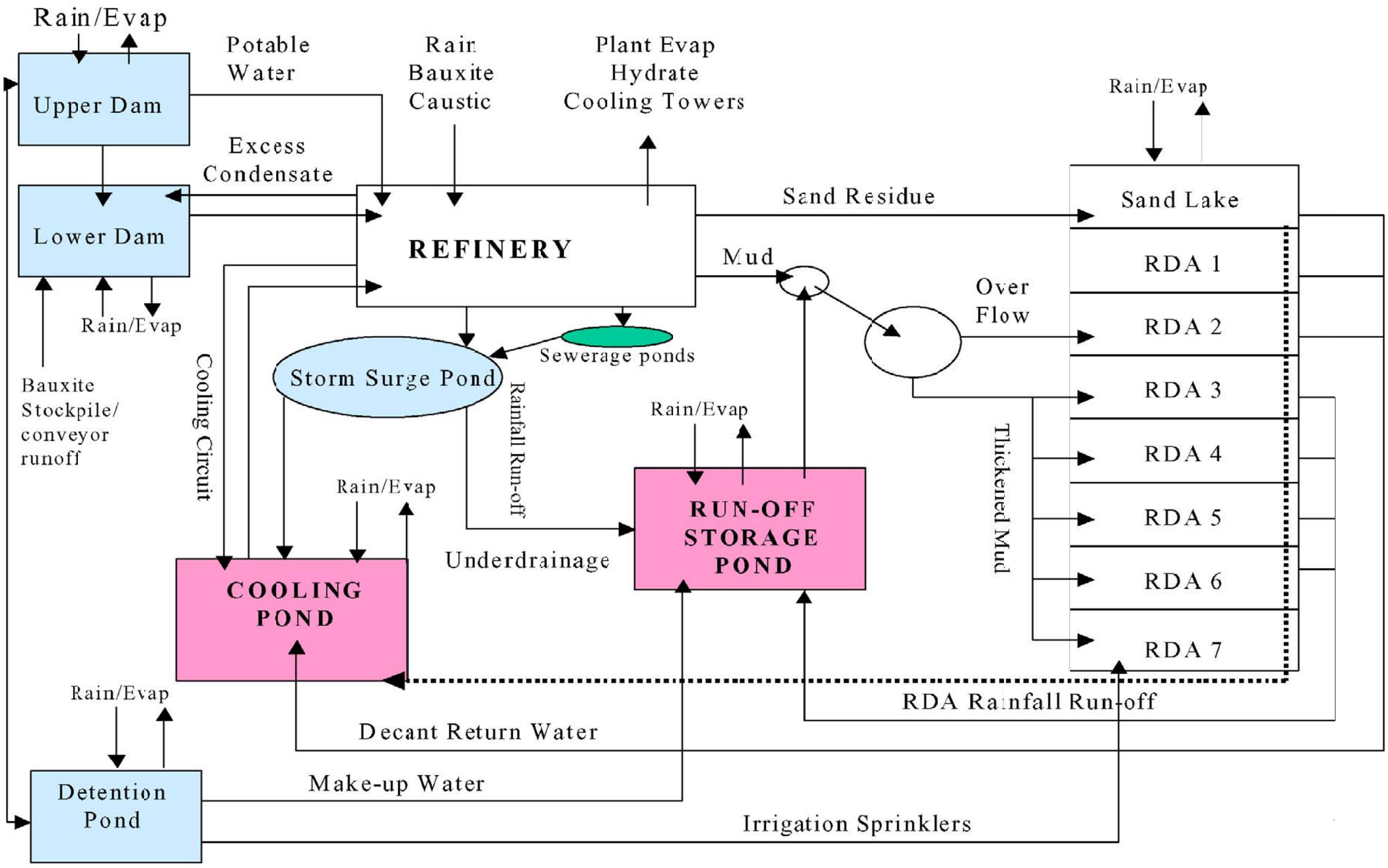
**WATER CIRCUIT DIAGRAM**




SOURCE: ALCOA Wagerup.

**Figure 10**

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Table 1 below summarises the existing refinery consumption and supply in average rainfall and runoff years.

**Table 1: Refinery Water Consumption & Supply - Average Rainfall/Runoff conditions**

*Refinery Water Consumption*

| | **Current Refinery (MLpa)** |
|---|---|
| Evaporation Losses from Fresh Water Surfaces | 1,400 |
| Evaporation Losses from Liquor Surfaces | 1,000 |
| Moisture lost with Stored Residue | 2,400 |
| Cooling Evaporation from Liquor Ponds | 730 |
| Vapour losses from in- plant processes & vessels (including cooling towers) | 1,730 |
| Residue Dust Control Sprinklers | 2,200 |
| **Total Consumed** | **9,460** |

*Refinery Water Supply*

| | **Current Refinery MLpa** |
|---|---|
| Moisture with Bauxite & Reagents | 1,000 |
| Rainfall collected in Fresh Water Reservoirs | 700 |
| Rainfall Runoff from Plant Area | 270 |
| Rainfall Runoff & Drainage from Residue & Liquor Pond Areas | 2,390 |
| Surface Water Sources (Licence)<br>- Nth & Sth Yalup Br (1600 MLpa)<br>- Black Tom Br (2500 MLpa)<br>- Harvey R Main Drain (4400 MLpa) | <br>1,200<br>1,500<br>2,100 |
| Groundwater (550 MLpa) | 300 |
| **Additional Sources (as identified in this study)** | |
| **Total Supplied** | **9,460** |

Refer to Appendix A for an indication of the Wagerup refinery water consumption and supply under drought conditions. Water requirements and supply alternatives for the Proposal are discussed in Section 5.3.3 and also presented in detail in Appendix A.