Dewatering of Bauxite Residue Storage Areas

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SUMMARY This paper discusses the methods used to remove caustic water from decommissioned residue storage areas associated with an alumina refinery.

Studies leading to the current dewatering methods have covered such areas as the water balance within the areas, geomechanical and hydrogeological properties of the residue, required properties for future alternative use of the area, and economic evaluations.

A number of methods for dewatering the residue deposits have been studied and trialled and two techniques have been installed on a large scale. The evaluation of these techniques are discussed and comparisons made.

1 INTRODUCTION

The Alcoa Kwinana Refinery produces alumina from bauxite mined in the Darling Range. Once the alumina has been extracted from the bauxite, the remaining residue consisting mainly of finely divided iron and silica minerals in a caustic solution is disposed of in specially constructed sealed impoundments.

The site was constructed in a natural valley but with some cut to fill earthworks to complete the dyke construction. Because of the permeable nature of the natural sandy-limestone foundation soils, the pond was lined with a 400mm thick clay sealing layer which was covered with a 300mm thick sand layer for protection against physical damage and drying. A cross section of the lake is shown schematically in Figure 2.

The first site used for this purpose during the period of 1963 to 1968 was Residue Storage Area 'A' (later followed by Areas 'B' and 'C' successively). See Figure 1.

Residue was then deposited into the pond as a low density slurry. Settling characteristics of the coarse (sand) and fine (mud) fractions resulted in discrete sand and mud zones as the residue was deposited. During the active life of the disposal area, liquor was removed by decanting from the surface of the settled residue, leaving a saturated sand and mud deposit behind.

The Company is under obligation to endeavour to rehabilitate the disposal sites such that they 'will support buildings for light industry'. Dewatering is an essential element of this rehabilitation process for a number of reasons. Firstly, to drain the surface of the area such that vegetation can be established, secondly, to drain the residue deposit to aid consolidation.

![Figure 1: Location Plan - Residue Storage Areas for Kwinana Refinery](image)

![Figure 2: Typical Cross Section through Residue Storage Area](image)
and strength development, and thirdly, to reduce the potential for the escape of caustic liquor to underlying groundwater.

2 DEWATERING

2.1 Initial Dewatering System

The earliest attempts to dewater the residue deposits consisted of sumps surrounded by aggregate filters, however blinding of the filter resulted in rapid decrease in yield. A more extensive system for the evaporation of caustic water was indicated and a wellpoint system utilizing venturi pumps was installed in 1975, and has operated since that time (called the 'eductor system'). The wellpoints were located in 250mm diameter sand columns. A temporary casing was jetted in, the pumps were installed and the casing filled with local sand prior to withdrawal. The principle of the eductor system is indicated on the cross section, Figure 3.

![Figure 3 Cross Section of 'Eductor System' Wellpoint](image)

The expected net yield of each wellpoint was 1-5 litres per minute and the first eductor system included 130 units. The overall design recovery rate was somewhat arbitrary.

Initially the eductor system operated effectively and lowered the water table within the pond to 5m below the surface level. However, the decrease in available head, along with the blockage or breakdown of individual bores or pumps resulted in the reduction of the system capacity to approximately 30% of its design flow. At this reduced capacity, the system was just keeping up with rainfall infiltration and would not have been capable of reducing the water table any further.

A comprehensive geotechnical and hydrological study was completed in 1981. This study confirmed the suitability of the area for future development, however recommended further work to dewater the residue deposit. (Refer to Parker, Walker and Gibson, 'Geotechnical Study for Dewatering of a Red Mud Storage Site', this proceedings).

Following the study, it was decided to upgrade the dewatering system such that it could reduce the free water table in the deposit to a minimum practical level within three years. This involves removal of the remaining 75,000 kilolitres (kl) of freely available liquor as well as keeping pace with rainfall infiltration.

2.2 Design of Upgraded System

The low permeability of the fine fraction of the residue makes direct pumping from this material impractical and it is likely that the location of the original eductor wellpoints in such material contributed to their low performance.

The 300mm sand layer overlaying the clay seal (Figure 2) was the key element in the design of the upgraded system. This sand layer acts as a continuous aquifer over the full base area of the pond and if effectively drained can collect water readily from the coarse sandy residue zones as well as the finer material.

A system of bores carefully constructed to draw water from the sand layer was conceived. A finite element model was utilized to locate the dewatering bores. This approach led to a grouping of the bores in the deepest area of the deposit. Location and pumping rate were also based on a dewatering target which was 'to draw down the free water table in the sand layer to the minimum practical level (or 10m below the ground surface) over a 3-5 year period and to maintain it at that level'. This final condition would expose only 30% of the clay seal to a positive hydrostatic head. The minimum practical level was a function of the drawdown of the water table resulting from a certain pumping rate. The final design was a compromise between having many small pumps with small drawdowns, and fewer larger pumps with higher drawdowns.

The total flow rate required from the system was determined by the time limit imposed for dewatering. The final design was for 15 bores pumping at a rate of 10-12 kl/day per bore. The location of the bores is shown in Figure 1.

An investigation was made of available pumping systems which could meet this design criteria, and a trial was conducted with a small electric submersible pump, and a standard windmill pump. It was feared that scale formed by the precipitation of salts in the liquor could result in high maintenance requirements. However, this was not confirmed during the trial period and it was concluded that either system could achieve and sustain the required pumping rate. Other considerations however, resulted in the choice of windmill pumps over electrically driven submersible pumps. These included: difficulties in the provision of additional power to the site; installed capital cost of each unit; operating power costs; and ease of field maintenance.

The open coastal location of Area 'A' results in high wind exposure and while detailed wind data was not available it was predicted that high pumping availability would achieve the required average design flow. The simplicity of the equipment was also expected to result in low maintenance downtime.
2.3 Installation Methods

Accurate levels of both sand layer and clay were essential to ensure that the bore casing did not penetrate the clay seal, so creating a leak path for the caustic water to reach the groundwater, and that the bottom of the bore screen was seated on the clay seal to take full advantage of the thin sand blanket. An investigation bore was installed at each proposed dewatering bore location using the air core drilling method which can safely and accurately define the level and depth of the strata thereby giving an indication of the suitability of the site. A piezometer was also installed in the investigation borehole. The piezometer was later used in assessing transmissivity at the site with the pumping bore and to measure drawdown due to pumping. (See Figure 4).

Figure 4 Typical Dewatering Windmill Installation

Once the site suitability was confirmed by the piezometer bore, dewatering bores were installed using the cable tool drilling technique. Firstly, a 200mm diameter steel casing was installed to the clay seal. The permanent 100mm diameter PVC casing with stainless steel screen was then inserted and the annulus gravel packed before withdrawal of the steel casing. (See Figure 4). Each bore was then pumped to measure the yield of water at the location.

The windmill pump selected was an Aerotor 2.4m (8ft) diameter mill with a 63mm (2.1/2in) pump. The trial indicated that this mill could deliver the required design flow.

Installation of the system was completed in September 1982. (See Figure 5).

2.4 Monitoring and Results

Monitoring of the installation included the total flow from each bore, the static water level in the sand cover and the settlement of the residue surface.

The average flow per bore over the first four months of operation was within the design range of 10-12 kl/day.

Over the same period the upgraded system effectively reduced the water table in the sand layer by 2m more than the eductors alone could achieve.

By the end of the 1982-83 summer, the water table had reached its historical low level. At this point the eductors became ineffective and their use had to be discontinued. The windmills however, have continued pumping and maintained the lower levels through the winter period.

Settlement monitoring to date has not shown any significant change in ground surface level. This is to be expected as the water table in the pond has not been reduced below the historical summer water level achieved through previous eductor pumping. Settlement will continue to be monitored and changes could be expected to take place as the water table is further lowered.

Monitoring of individual bores has revealed a decrease in performance in several cases. Low flow rates and intermittent dry bore conditions have caused some maintenance problems. The cause of the decreased flow is as yet unknown, although water level readings suggest constriction of flow at or near to the screen. The most likely reasons are blinding of the gravel pack by fine residue or chemical precipitation. Investigations into this problem are continuing.
The performance of the remaining bores continues to meet or better the design expectations. Low wind conditions have not been a significant problem and windmill and pump maintenance has been of a minor field oriented type.

3 CONCLUSION

The installation of an upgraded dewatering system utilizing windmills in Residue Storage Area 'A' has been a successful and cost effective way of speeding up the dewatering process. Based on this success, the system has been adopted for Areas 'B' and 'C'.

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