CLOSURE AND REHABILITATION OF ALCOA'S KWINANA REFINERY RESIDUE STORAGE AREAS ABC

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Abstract

Residue Storage Areas A, B & C (Areas ABC) were operated between 1963 and 1976, with approximately 13.4 million tonnes of residue material deposited. The deposits have been progressively de-watered between 1974 to 2000 allowing for a reduction in alkalinity of the entrained water within the deposit and assisting with consolidation of the deposit. Since 1992, washed residue sand has been used to cap and re-contour the surface of the storage areas and improve the suitability of the areas for future land use.

Areas ABC are Alcoa's first residue areas to be closed in WA. The land on which these storage areas are located is leased from the State Government, and part of the closure process requires return of the land to Landcorp, the State Government agency responsible for the site. Prior to this hand-back, management plans for the area were developed and these are discussed in this paper. Parts of Areas ABC were handed back to Landcorp in March 2000 and have since been incorporated into the Motorplex site, which was opened in December 2000.

1. Introduction

When the Kwinana Alumina Refinery was commissioned in 1963, alumina production was 110,000 tonnes per annum. This rate increased steadily to 1.2 million tonnes per annum by 1971 and further small incremental improvements have seen the rate increase to its present level of 1.9 million tonnes per annum.

The Kwinana refinery is situated on the shores of Cockburn Sound, twenty kilometres south of Fremantle. The bauxite, from which the alumina is extracted, is railed from the Huntly mine located in the Darling Range. The refined alumina is shipped by sea to smelters and chemical plants in Victoria and overseas. The residues from the refining process consist mainly of a coarse sand, rich in silica, and a fine mud which contains a higher content of iron. The process liquor associated with the stored residues is alkaline.

The original bauxite residue storage areas, known as Areas ABC, are situated two kilometres from the refinery on land owned by the government. Under the Alumina Refinery Agreement Act this land is to be returned to the government when Alcoa has finished using it for residue storage. The land is to be made suitable for future uses, such as light industry, by capping the storage areas with a sand layer.

Preparation of the land for hand-back, and discussions surrounding conditions of hand-back, have been underway for a number of years. In August 1998, the Ministry for Planning approached Alcoa with a view to establishing a motor sports complex (Motorplex) that would extend onto part of Areas ABC. The Government engaged an engineering consultant to briefly examine the site and recommend on its suitability. In September 1998 the Minister for Planning announced that this area was the preferred site for the Kwinana Motorplex, and further planning, engineering and environmental consultants were appointed, with a target of having the speedway part of the complex in operation by December 2000.

This paper describes the work done to prepare the site for hand-back, and the management plans developed for a range of issues and future responsibilities associated with the deposit.

2. Background

2.1 *Lease Agreement*

The land referred to as residue storage Areas ABC was made available to Alcoa by the State under the Alumina Refinery Agreement Act 1961, and was to be returned to the State when Alcoa had completed residue storage activities.

The Act calls on Alcoa to:

> "fill the land, mainly with iron oxide but partially with sands, to within 2 feet of the agreed level, and complete the filling of portions of 10 acres or more with sands, within 2 years. Reasonable efforts shall be made to ensure that portions so filled will support buildings for light industry. The Company's rights and interests in those portions would then cease and determine".

2.2 *Land Ownership*

Areas ABC are bound by Anketell Road to the north, Rockingham Road to the west and Thomas Road to the south. Part of the land is vested in the State Planning Commission and part is vested in the Western Australian Land Authority (LANDCORP).

2.3 *History of Filling*

Storage of residue in Areas ABC commenced when the Kwinana Alumina Refinery was commissioned in 1963. The amount of residue stored in Areas ABC is outlined in Table 1.

Table 1 — Filling history of Areas ABC

RESIDUE STORAGE AREA	AREA (Ha)	YEARS OF OPERATION	ESTIMATE OF RESIDUE IN THE DEPOSIT
A	17.8	1963–68	Total ABC 13.4 Mt
B	23.8	1967–71	
C	50.6	1970–76	

2.4 *Method of Construction*

Areas ABC were formed by damming small valleys or depressions within the sandy coastal environment. The maximum height of the embankments was around 20 metres. Subsurface conditions in the general vicinity of the storage areas consist mainly of permeable sands, and weakly cemented limestone, which has highly variable permeability. In some areas the limestone is cavernous near the water table.

The presence of these highly permeable natural materials necessitated the installation of low permeability clay seals to restrict seepage of alkaline leachate from the deposits. The clay liner was formed by initially mixing 75mm of imported clay with the in-situ sand and compacting it to form a 150mm layer. On this sand/clay mix a 380mm thick layer of compacted imported clay was placed in two approximately equal lifts. A layer of 300mm of local sand was then placed over the clay liner as protection against climatic extremes and traffic damage.

2.5 *Deposit Capping*

Areas ABC were originally filled via 'wet' deposition with a mixture of residue mud and residue sand. The coarse sand fraction tended to settle around the perimeter of the deposit with fine mud concentrated toward the centre of the deposit. After completion of residue deposition in the areas, the surface was drained and allowed to settle and consolidate. Over a period of several years, the sand that had settled around the perimeter was pushed over the predominantly mud areas, to provide a sand-capping layer that allowed machinery access for dust control activities and establishment of vegetation. The resulting sand cover layer varied in thickness from several metres near the perimeter to less than 1 metre near the centre. Over the period 1972–1992 the surface covering of sand was progressively drained through the installation of surface ditches, and the deposit de-watered through the installation of eductor pumping systems, supplemented with windmill pumping. Surface vegetation was established which included grasses, shrubs and trees. In addition some agricultural land use trials were carried out.

In 1990, Alcoa investigated the opportunity to improve the surface condition of the deposit through the placement of additional residue sand. This would allow re-contouring of the areas, making them more suited to a wider range of future land uses, including light industrial development, which was the use preferred by Landcorp, the State Government agency responsible for the land. A proposal to undertake this re-contouring over a 10 to 12 year period was developed in conjunction with Landcorp, and was progressively implemented, commencing in 1992.

The sand capping was completed over Areas ABC from 1992 to 2000. During the installation of this sand capping, a sub-surface drainage system was installed. The drainage system consisted of a network of perforated pipes designed to collect rainfall infiltration and prevent any perched water table from rising to the point where it could effect surface vegetation.

2.6 *Deposit De-watering*

Area A

Pumping systems, which utilised pumps called eductors, were installed in Area A in 1974. In 1982 windmills were

Figure 1 — Location of Alcoa's Residue Storage Areas

installed to increase the rate of liquor recovery. Both the eductor system and the windmills continued to operate until 1992 when they were removed to allow the additional sand capping to be installed. The windmill bores were retained for possible future use. However, the pumps have not been reinstalled, which means that the internal water table has gradually risen to the point where the new subsurface drainage system has come into effect. Water collected by the subsurface drainage system, which contains some alkali is collected and returned to the refinery.

During the period of operation of the Area A pumping systems, the average yield was around 8 kl/hr. The total alkalinity (TA) of the recovered water had declined from around 20 gpl initially to around 7.5 gpl.

Area B

A similar eductor pumping system was installed in Area B in 1975. In 1983 windmills were installed to increase the rate of liquor recovery. The eductors and windmills continued to be operated until the capping of Area B commenced in 1993. A number of the windmills were re-commissioned in 1996 after completion of the sand capping work and operated until 2000.

During the period of operation of the Area B pumping systems, the average yield was around 10 kl/hr. The TA of the recovered liquor had declined from around 22 gpl initially to around 10 gpl.

Area C

An eductor system for Area C was installed in 1975 and windmills were installed in 1984 to increase the rate of liquor recovery. In 1995, the eductors and windmills on Area C were shut down for investigations and remedial work associated with the clay seal. There has not been any liquor recovery from Area C since this time.

During the period of operation of the Area C pumping systems, the average yield was around 16 kl/hr. The TA of the recovered liquor had declined from around 22 gpl initially to around 12 gpl.

2.7 *Surface Rehabilitation*

The original surface of Areas ABC was successfully revegetated using a variety of techniques. However settlement resulted in depressed central areas that were difficult to drain and had high seasonal water tables, resulting in some salt and alkalinity damage to vegetation. The subsequent re-contouring of the surface, which incorporates a sub-surface drainage system to control the water table, provides a more suitable capping on which to establish a sustainable vegetative cover. The current state of the surface vegetation on each of the areas is described below.

Area A

A number of large trees (*Eucalyptus camaldulensis*) remain on the western boundary as a remnant of the original rehabilitation of the site undertaken in the late 1970's. Revegetation work undertaken during the early 1990's resulted in a series of discrete stands of native vegetation randomly distributed across the surface. A perimeter of similar age native vegetation on the northern and eastern boundaries provided an intermittent visual screen of the area from the private road system within the residue area. These areas were established using an irrigation system. The remainder of the open surface of Area A was covered with a mixture of pasture grasses and weeds. The area had adequate vegetated cover to prevent significant airborne dust generation. The majority of this vegetation has since been removed by the Motorplex construction.

Area B

This area also retains a number of large trees (*Eucalyptus camaldulensis)*, planted in the mid-1970's, on the eastern boundary. Remnants of the perimeter vegetation, also established in the 1970's and dominated by *Acacia spp.*, remain on the northern boundary. The intermittent, native screening vegetation described on Area A, above, was also established on the western boundary of Area B. The remainder of the open surface area has been revegetated using a mixture of cereal rye grass and medic. The vegetation cover provides effective control of airborne dust generation.

Trials using flyash from Western Power, Kwinana Power Station, and BP Catalyst from the BP Oil Refinery as soil amendments were conducted in 1996. They proved to be quite effective in improving a number of the qualities of the residue sand for vegetation, and the BP catalyst continues to be used as an amendment in current vegetation programs. Clone planting trials for a number of native vegetation species has been established on the area since 1998.

A fenced, excavated sump was established in the north west corner of Area B and provides a receiving area for water from the surface drainage systems The drainage water collected in the sump is returned to the refinery process circuit.

Area C

Remnants of initial 1970's revegetation, including a few larger trees, and alkaline-tolerant tree clone trials established in 1980's are still evident but much has been eliminated by the sand placement operations in 2000. The open surface area has been revegetated using the same cereal rye-grass/medic combination described for Area B.

2.8 *Groundwater Contamination*

Contamination of the groundwater beneath and extending from Areas ABC was first detected in 1973. A plume of alkaline contamination, confined within the bottom third of the 20 metre deep aquifer and extending several hundred metres beyond the northern boundary of Area A in a north-west direction, was identified. A groundwater recovery system was installed along the northern boundary of Area A across the plume width and has been successful in capturing the contaminated groundwater flow.

Investigations were also conducted to establish the source of the contamination and a number of defects in the clay seal beneath Area C were identified. A chemical grouting technique was developed and applied in 1981. It was subsequently estimated that this grouting program achieved a 70%–80% reduction in leakage.

Groundwater recovery and monitoring continues, and Alcoa submits annual reports to the State Government on groundwater quality for the area.

3. Closure Management Plan

During late 1995, Alcoa conducted an assessment to identify the potential hazards associated with the future use of Residue Storage Areas ABC for light industry.

It should be noted that the approach adopted was not designed to ascertain the acceptability of risks, but rather to identify the nature and relative magnitude of hazards which may be present and recommend approaches to risk management. Acceptability of the risks would be determined following consideration of the risk analysis and risk management plans.

3.1 *Assessment and Management of Potential Hazards*

3.1.1 *Alkalinity of Bauxite Residue*

During the alumina refining process, the bauxite is mixed with a caustic soda solution to dissolve the alumina. The residual solids and entrained water retain some of this caustic soda. Typically, the water with the residue solids has a total alkalinity of around 20 g/l, expressed as sodium carbonate, and a pH of around 13.

The residue sand used to cap the deposit is deficient in nutrient, still retains some of the residual alkalinity, and compacts to a relatively high strength material. Hence, the sand requires significant input to achieve a stable, self-sustaining vegetated surface. This work involves addition of gypsum to lower the pH, spreading of organic and inorganic fertilisers, and ripping of the surface to reduce the level of compaction.

Proposed Risk Management Plan

A number of drainage systems have been installed within the deposit to aid the leaching of the residue sand cover layer. These include:

(i) Perimeter drains to collect rainfall runoff and transfer this runoff to a main collection sump.

(ii) A sub-surface drainage system located near the base of the sand-covering layer. This drainage system is designed to collect rainfall that leaches through the covering sand layer. This system will also help maintain a low water table within the sand covering, enabling the establishment of a range of vegetation types on the surface.

(iii) A pumping system designed to lower the water table and recover alkaline water from within the body of the deposit. While this system is no longer in use, it was very effective in recovering a significant amount of the alkaline water contained within the residue deposit.

Alkaline water, recovered via these systems, is collected in a sump from where it is pumped back into the refinery for use as make-up water.

3.1.2 *Groundwater Contamination*

The clay seals below Areas ABC have generally performed better than design, exhibiting average permeability around two orders of magnitude less than the original design values. Groundwater contamination has nevertheless occurred due to localised defects in the clay seal. The resulting contaminated groundwater plumes have been controlled by operation of recovery bores located to intercept the flow. In 1981 the largest single defect beneath Area C was grouted, resulting in a 70% reduction of leakage from this source. Control of the contaminant plume requires ongoing groundwater recovery. This recovered water is all utilised by the refinery for process make-up.

It is anticipated that groundwater contamination control will be required in the long term to protect the water quality down gradient of Areas ABC.

Proposed Risk Management Plan

A detailed review of Kwinana's groundwater management strategy was completed in 1998. The review made the following key recommendations:

- Long term management of groundwater contamination should focus on improved systems of capture and recovery of contaminants from the aquifer. Any increase in contaminant flux due to eventual seepage through the clay seals is likely to require improvements in the groundwater recovery systems over time to maintain down-flow groundwater quality. Little additional benefit was likely from continuing the leak grouting program.
- Further de-watering of Areas ABC can help reduce the head on the base seal of the deposits, thereby reducing the rate of seepage and hence contaminant load. However, this will have little effect on the amount of groundwater that will need to be recovered to control the plume. The contaminant plume will be diffuse, and a similar through-flow will be intercepted to maintain down-gradient water quality. Decisions on future de-watering should be based on the value of the recovered caustic and the practicality of operating extensive de-watering systems once the land is redeveloped for other uses.

3.1.3 *Potential for People to Come into Contact with Alkaline Material*

The alkaline drainage water presents the greatest potential for harm to people. The drainage waters can still be alkaline enough to be corrosive to sensitive skin, particularly the eyes. There are a number of ways people may conceivably come into contact with alkaline drainage water.

(i) During routine operation or maintenance of the drainage systems.

(ii) Through ponded water collected in open excavations or as a result of a failure of the surface drainage systems.

(iii) Through uncontrolled or unauthorised access to the main collection/recovery sump.

Proposed Risk Management Plan

Maintenance of the drainage systems will ensure that ponding of alkaline water does not occur. Maintenance workers will need to be made aware of the alkaline nature of the residue and drainage water and provided with suitable personal protective equipment if working on these systems. Unauthorised access to drainage sumps and manholes needs to be prevented by appropriate means such as security fencing and signage.

3.1.4 *Naturally Occurring Radionuclides Contained within the Residue*

Bauxite mined in the Darling Range contains small amounts of naturally occurring radioactive elements such as uranium and thorium. The extraction of around 30% of the bauxite as alumina results in a proportional increase in the concentration of these elements in the residue when compared to the bauxite that is processed. Measurements of radiation above Areas ABC have been found to be similar to levels measured along the Darling Scarp.

The WA Health Department's Radiological Council was consulted in 1995 and it advised that an average level of 0.35 µGy/hr would be considered suitable for light industrial land uses. This was based on the Council's assessment of the likely exposure of people working on the area compared with the internationally accepted incremental dose limit of 1mSv/annum for members of the general public. The Radiological Council considered that the completed site should not increase exposures by more than 0.5 mSv/annum when compared to background levels. The Radiological Council also recommended further monitoring of thoron and radon emissions from the residue, and that prior to future land use mechanisms be applied to prevent excavation into the residue material.

Subsequent radon and thoron monitoring has been undertaken and results indicate that levels on the residue are similar to background levels.

Proposed Risk Management Plan

A detailed radiological survey of the site was completed in 1999. Levels were found to be similar to or marginally above the levels set by the Radiological Council. As a result of further consultation with the Radiological Council, it was agreed that a natural sand layer would be added to the residue sand capping to ensure the levels remained well below the levels considered as acceptable by the Radiological Council.

3.1.5 *Surface Settlement*

Foundation conditions on some parts of Areas ABC will be highly variable due to the presence of layers of mud and sand in the residue profile. The sands are reasonably well consolidated but the mud deposits will compress under additional applied load, which could result in significant settlement of foundations or structures. Differential settlement could also occur across a structure and result in cracking of concrete or other damage. However, the capping of the area with residue sand and the presence of predominantly sandy areas particularly around the perimeter, means that there are areas within the deposits that are quite suitable for lighter foundations. Heavier structures would require special foundations such as concrete rafts.

Proposed Risk Management Plan

Most of Areas ABC could be used successfully for light industrial or other purposes. However, it is essential that any development that results in additional surface loading,

takes account of the foundation conditions at the specific site. While significant geotechnical data is available for the storage areas, more specific investigations aimed at specific development proposals are considered essential.

4. Development of the Mototplex on the Site

In August 1998 the Ministry for Planning approached Alcoa with a view to establishing a motor sports complex (Motorplex) that would extend onto part of Areas ABC. The Government engaged an engineering consultant to briefly examine the site and recommend on its suitability.

In September 1998 the Minister for Planning announced that an area including part of Areas ABC was the preferred site for the Kwinana Motorplex, and further planning, engineering and environmental consultants were appointed, with a target of having the complex in operation by December 2000.

Conceptual plans were developed and a Public Environmental Review of the proposal was released on the 28th of June, 1999. Following the public review and comment stage, the EPA released its recommendations regarding the project in September, 1999. In its report the EPA gave conditional support to the proposal, while noting that noise and individual risk (due to the proximity of major chemical and other industries) require special management.

While the environmental approval process was underway, the project proponent, the WA government sponsored Western Australian Sports Centre Trust, proceeded with land acquisition and detailed design of the facilities. Since the land area in question is part of Alcoa's 'minesite' under the Department of Minerals and Energy's jurisdiction, Alcoa was required to submit a 'notice of abandonment of mining operations' to initiate land transfer. This was accomplished through a staged approach to allow completion of sand capping and revegetation operations while still meeting the Motorplex's timing constraints.

Construction of the Motorplex was completed during the second half of 2000 and the facility was officially opened in December 2000. Special design considerations were given to a number of aspects of the Motorplex to specifically accommodate the issues discussed above. For example;

- No heavy structures were placed on the residue deposits. The layout of the facility was based around use of the residue areas for car parking and marshalling areas for the speedway cars.
- Storm water drainage systems were installed to protect and compliment the existing sub-surface drainage systems. Security fencing and signage was erected around sump areas designed to collect peak rainfall run-off.
- An easement was retained for access by Alcoa to continue with ground water monitoring and recovery of contaminated groundwater.

Since the opening of the Motorplex over two years ago, there have not been any issues related to managing the site in the context of it being a former residue storage area. Development of the Motorplex stands as a very good example of the potential for redevelopment and re-use of areas previously used to store the residue from an alumina refinery.

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