Appendix G

Soils, Geology and Hydrogeology

RPS Group

TABLE OF CONTENTS

LIST OF TABLES

1 SOILS, GEOLOGY AND HYDROGEOLOGY

1.1 INTRODUCTION

RPS Group was commissioned by Golder Associates UK Ltd, on behalf of Aughinish Alumina Ltd (AAL), to undertake an Environmental Impact Assessment of their current proposals to develop the Alumina Plant at Aughinish, Co. Limerick. The proposals include the raising, extension and associated modifications to the Bauxite Residue Disposal Area (BRDA). It also includes the retention of the current (2004) alumina production capacity of 1.6 mtpa and a future increase in alumina production capacity to 1.95 mtpa.

This chapter of the EIS addresses the impact on the soils, geology and hydrogeology. This assessment forms part of the main Environmental Impact Statement for the proposed development. This report should be read in conjunction with the site layout plans for the proposed development and the project description section of the EIS. In the assessment, particular attention is focused on the likely presence of contaminated soils and groundwater and on sensitive receptors such as groundwater dependent ecosystems, vulnerable aquifers or water supplies.

The AAL Plant is located on Aughinish Island, on the south side of the Shannon Estuary between Askeaton and Foynes, some 30km from Limerick City. The island is approximately 400 hectares (ha) in aerial extent and is separated from the mainland by the north-northeast (NNE) – south-southwest (SSW) trending Poulaweala Creek and by the west-northwest (WNW)– east-southeast (ESE) trending Robertstown River. The mainland to the east and south of the island is mostly in agricultural use. Foynes is the nearest settlement and lies approximately 2 kilometres (km) west of the plant. Foynes, a deep water port, has much industrial activity. Other settlements of note in the area are Barrigone, 2 km to the south and Askeaton, 6 km to the east.

The plant is located in Aughinish East while Aughinish West is occupied by the existing BRDA (Phase 1), and what is know as the stormwater pond (SWP) and the liquid waste pond (LWP). The existing BRDA occupies an area of approximately 103 ha.

The site is licensed by the Environmental Protection Agency (EPA) under an Integrated Pollution Control (IPC) Licence (Reg. No. 562).

The natural topography reaches a maximum elevation of 21 metres above Ordnance Datum (m AOD) along a ridge of higher ground on Aughinish East. The natural topography on Aughinish West is low lying and has been modified by the presence of the existing BRDA which currently extends to a maximum elevation of 19.5 metres (m). The area of the proposed Phase 2 BRDA is also low-lying, varying from sea level to about 10 m AOD, apart from an area of stockpiled material in the northeast footprint which reaches 16 m AOD.

Parts of the island and neighbouring hinterland as well as surrounding waterways have been designated as protected areas under the Wildlife Act 1976, the Wildlife Amendment Act 2000 and the Natural Habitats Regulations, 1997. These areas are described as a large tidal system with intertidal mudflats, fringing reedbeds, swamps, polders, salt marsh and wet marsh habitats. The mudflats abound with invertebrates, which are a food source for wading birds and ducks. The estuarine habitats are potential receptors of groundwater discharges from the site. Invertebrates and birds supported by them are potentially at risk.

1.2 BACKGROUND

The alumina plant at Aughinish has been in operation since 1983. The plant produces alumina from imported bauxite ore. The alumina is subsequently exported to smelting plants overseas. The raw product is imported and the finished product is exported at the jetty to the north of the plant on the Shannon estuary. Current alumina production capacity at the plant is 1.6 million tonnes per annum.

The production process involves caustic digestion which utilises dilute caustic soda to dissolve alumina. A by-product of this process is a solids residue containing residual caustic soda. The finer sized proportion of the residue (90% to 95% of the waste stream) is material known as 'red mud'. The distinctive red colour is due to iron oxide in the parent bauxite deposits. The remaining coarser sized proportion is known as 'process sand'. After repeated washing to remove the entrained caustic liquor, the red mud is pumped via a 1km pipeline as a paste to the bunded storage area on the south west of the island, the BRDA (Phase 1). The mud is discharged to the BRDA as a 60% solids suspension and undergoes air-drying by evaporation, which dewaters the mud. The mud is laid in thin layers (up to 300mm) and is exposed for as long as possible (3-6 months) to allow drying and maturing. The surface of the BRDA is naturally sloped by the paste deposition process and this prevents ponding of water on the red mud surface and also promotes maturing of the red mud. Rainwater tends to fill up desiccation cracks, which develop in the mud and typically extend to 200-250mm. However, the water is displaced once successive mud layers are deposited.

The red mud has an elevated pH, typically between 12.3 to 12.5, a soluble soda level of 4000-8000 mg/kg and a soluble alumina level of 2000-4000 mg/kg. As such, red mud is classified as non-hazardous.

Surface water runoff from the BRDA drains to a perimeter interceptor channel (PIC). The PIC is bounded by an inner permeable rockfill dike, which contains the residue, and an outer impermeable dike, which retains stormwater. Water is pumped from there to the Storm Water Pond (SWP) for intermediate storage. From the SWP, the water is pumped to the South pond on Aughinish East and on for treatment. Excess process water from the plant is also collected and stored in the South pond. There are other ponds on site (the North, East and West ponds receive plant rainwater runoff and/or wastewater). Some of this water is recovered to the plant for re-use and the balance is treated for disposal. The treated wastewater is pumped to the LWP for cooling prior to discharge to the Shannon Estuary.

The SWP is unlined at its base where it directly overlies estuarine deposits. Where underlain by thin soils and limestone outcrop in the east, it has been lined with high-density polyethylene (HDPE) liner. There is evidence that the base of the SWP is leaking. Following recent investigations (Golder Associates, January 2005) in this area, a proposal was made to intercept and recover the leak pending full lining of the SWP.

The process sand is trucked from the process plant and is used to construct ramps and access roads within the BRDA. Minor amounts of other residue are also produced for disposal within the BRDA. One of these materials – salt-cake – is considered hazardous due to its high alkalinity and this is stored within a cell in the BRDA.

The original (Phase 1) BRDA was unlined. This was because the red mud itself is quite impermeable due to its fine size. The BRDA was extended to the east in 1995 with planning permission to reach a maximum height of 26mAOD. The extended BRDA has been fully lined using a geomembrane (1mm or 2mm HDPE), placed on a layer of processed glacial till.

1.3 METHODOLOGY

This report is based on a desk study, site visits and a summary of the available and relevant data on the area:

- Aughinish Alumina Ltd. Annual Environmental Reports. IPC Licence Reg. No. 562.
- Dames & Moore, April 2000. Report on the Installation of the Mud Stack Extension Monitoring Wells, Aughinish Alumina Ltd, Aughinish Island, Co. Limerick.
- Dames & Moore, 1999. Report on Groundwater Quality Study at the Aughinish Alumina Facility, Aughinish Island, Co. Limerick.
- Engineering and Resource Consultants (Ercon) on behalf of Alcan Contractors Ltd. Bauxite Beneficiation Plant, Aughinish Island. Report on Hydrogeological Investigation. Report No. TR123. 1974.
- Geological Survey of Ireland (GSI), 1999. "Geology of the Shannon Estuary". Sheet 17. Scale 1:100,000.
- GSI, 1999. "Geology of the Shannon Estuary. A Geological Description of the Shannon Estuary Region including parts of Clare, Limerick and Kerry, to accompany the Bedrock Geology 1:100,000 Scale Map Series, Sheet 17, Shannon Estuary.
- GSI & Limerick County Council, 1998. County Limerick Groundwater Protection Scheme.
- GSI Groundwater Maps online at www.gsi.ie.
- GSI, well records database.
- Golders Associates, April 2005. The Preliminary Design for the Phase 2 Bauxite Residue Storage Area at Aughinish Alumina.
- Golder Associates, October 2004. Report on Geotechnical Investigation and Borrow Assessment for the Phase 2 Bauxite Residue Disposal Area at Aughinish Alumina.
- URS, 2002. Groundwater flow modelling within the mud stack area of Aughinish Alumina in support of the closure plan.
- URS, Sept 2003. BRDA Drilling and Monitoring.
- URS, 2002. Groundwater flow modelling within the mud stack area of Aughinish Alumina Limerick.
- Fehily Timoney & Co., April 1998. Assessment of Underground Storage Tanks.

Site visits were undertaken on 13 January 2005 and on 23 February 2005.

This environmental impact assessment was prepared in accordance with Guidelines on the information to be contained in Environmental Impact Statements (EPA 2002) and Geology in Environmental Impact Statements, A Guide by the Institute of Geologists in Ireland (IGI, 2002). Reference has also been made to the EPA Interim Report, 2004 *Towards Setting Guidelines Values for the Protection of Groundwater in Ireland.*

1.4 RECEIVING ENVIRONMENT

1.4.1 Soils and Subsoils

1.4.1.1 Aughinish East – Plant Area

Soils are thin or absent on Aughinish East where the plant is located. Loose grey limestone gravel fill (typically from 0 to 8 m) overlies the natural subsoils or bedrock.

Subsoils where present, generally as infill along certain fracture zones, are described as limestone till (gravely clay) overlying channel fill clays. Some of these subsoil channels have been found to be up to 42m thick.

1.4.1.2 Aughinish West – Phase I BRDA

On Aughinish West, beneath the existing (Phase 1) BRDA, subsoils are described as estuarine clays, silts and peats, overlying gravely clay till with silty sand lenses. Subsoil thickness varies on Aughinish West but tends to thin eastwards towards areas where bedrock outcrops or is close to surface. To the east of the BRDA, close to the stormwater pond, subsoils are 7m thick. To the west of the BRDA subsoil thickness increases to 26m.

The BRDA itself is comprised of red mud organised in a series of terraces built up in 2m steps. The terraces are constructed of limestone rocks, separated from the mud beneath by a layer of process sand or a geotextile. The layers of mud in the existing BRDA alternate with occasional thin layers of straw (deposition of straw for dusting prevention has ceased since 2001) and more commonly process sand.

In 2004, the maximum elevation in the existing BRDA was recorded at approximately 19.5mAOD with the maximum elevation in the Phase I extension area at 12 mAOD. Glacial Till material has been removed from parts of the site and deposited elsewhere during its development.

Drilling (URS, 2003) has identified that the red mud is over 20m deep at the centre of the stack.

1.4.1.3 Aughinish West & Glenbane West – Phase 2 BRDA

Across the extent of the Phase 2 BRDA footprint, soils are described as dark brown and loamy and are generally 0.15 to 0.2 metres (m) thick.

Site investigations (Golder Associates, Oct 2004) in the proposed Phase 2 BRDA have identified up to 7.2 metres of estuarine clays and silts with rare bands of compressed peat along the western flank of the existing facility. In the east of the Phase 2 BRDA footprint, the estuarine deposits were found to vary from 0.5 to 5.0 metres thick. Thin (up to 1m approx) deposits of highly compressed peat underlie the estuarine deposits in places. The estuarine soils tend to occupy the lower topographic areas.

Glacial till, described as clayey, sandy, gravels is found both underlying the estuarine soils and also at surface where it occupies the higher ground in the east of the Phase 2 BRDA footprint. The clay content varies between 8% to 10% and is classified as low plasticity.

A glacial ridge, approximately 200m long by 220m wide, occupies the southern flank of the Phase 2 BRDA footprint between the reclaimed Poulaweala Creek to the north and a disused railway line to the south. Further seams of glacial till are found within the footprint and along the western flank. The creek has been reclaimed to the south-west of the access road to the island and is tidal to the north east.

A stockpile of glacial till, estuarine material and boulders lies in the northeast section of the Phase 2 BRDA footprint. The stockpile reaches a max elevation of 16masl and was placed there during the construction of the Phase I extension as it was unsuitable for use.

1.4.2 Bedrock Geology

According to GSI bedrock maps for the area, geologically, Aughinish Island is subdivided in two. The eastern half of the island is mapped as being underlain by Carboniferous aged Waulsortian limestones, described as pure unbedded lime mudstones. The western half is mapped as being underlain by the Rathkeale Formation: dark muddy limestone and shaly mudstone (impure limestones).

The limestone rocks have undergone broad folding and faulting. The main fault zones trend NNE-SSW and WNW-ESE and are visible in outcrop along the shoreline as well as being reflected in the rectangular pattern of waterways that surround the island: Poularone Creek, Poulaweala Creek and the Robertstown River.

Bedrock outcrops extensively in eastern Aughinish and forms the eastern boundary to the existing BRDA.

Within the Phase 2 extension area, limestone outcrops to the northeast and south east of Poulaweala Creek. A series of boreholes (reported in Golder Associates, October 2004) were drilled along the footprint of the Phase 2 extension wall. Depth to bedrock was found to be shallow in the east and in the south east close to the railway embankment where it was encountered between 0.7 and 5.7m bGL. Bedrock was not encountered in the western boreholes which were drilled to a maximum depth of 9 mbGL.

1.4.3 Hydrogeology

1.4.3.1 Aquifer Classification

The Waulsortian Limestones are reported (GSI, 1998) to be extensively karstified and dolomitised. Karstification is a process by which some of the pre-existing fissure and fractures in the limestone bedrock are slowly enlarged as the groundwater passing through them dissolves away the limestone. As a consequence, an uneven distribution of permeability develops. The substantial fall in sea level during the Pleistocene allowed drainage of the limestones and karstification to occur considerably below present day drainage levels. The subsequent rise in sea level would have flooded these voids creating the present day aquifer. In the Aughinish area karstification is reported to occur to depths of 60 metres. Dolomitisation is a process by which circulating groundwater replaces calcium with magnesium and results in an increased porosity and permeability of the host rock.

The Waulsortian Limestone Formation in the Aughinish-Askeaton area is classified by the GSI as a regionally important karstified aquifer (Rk) where the development potential is limited by the concentration of flow in conduits. This type of aquifer is characterised by large spring flows, a high 'flashy' groundwater throughput, variable well yields and low storage. Locating areas of high permeability is difficult and therefore groundwater development can be problematic. Detailed investigations have identified a limited resource potential (Ercon, 1974) on the island due to large variations in permeability over short distances, limited local recharge and saline intrusion.

The presence of a turlough (seasonal lake) in the central plant area reflects the karstic nature of the aquifer.

The Rathkeale formation is considered to be of low permeability due to the high proportion of shale. This rock unit has been classified by the GSI as a locally important aquifer, which is moderately productive only in local zones (LI). Groundwater in the bedrock tends to be confined by overlying low permeability deposits where present.

Based on the GSI classifications, the Phase 2 BRDA extension is largely underlain by the locally important aquifer, however the eastern site is underlain by the regionally important karstic aquifer. The non-saline groundwater on Aughinish Island and Island Mac Teige are believed not to be connected hydrologically to freshwater aquifers on the mainland and discharge as springs around the margins of the islands.

1.4.3.2 Groundwater Monitoring

A groundwater monitoring regime is in place at AAL as an IPC licensing requirement. The monitoring programme is undertaken at the following locations:

i. Springs which discharge from the limestone bedrock at the foreshore (ES1-16), at the transfer tower (TT4) and the Turlough. These are taken as the principal indicators of groundwater quality discharging from the plant area.

ii. Observation wells beneath the plant (POW1 to 33); south pond area (SPW1-6) and north pond area (NPW1to 3), installed to monitor within the limestone bedrock.

iii. Observation wells BH1 to 4 in the underground fuel storage tank area, which serve as a leak detection system.

iv. Observation wells on the perimeter of the BRDA (OW1-OW23) installed within estuarine alluvium, glacial till and limestone bedrock. In April 1997, observation wells 3, 4, 5 & 6 were capped as part of the Phase 1 BRDA extension.

The wells/springs are monitored on a monthly basis for water level and selected chemical parameters (groundwater quality). The springs are monitored for water quality and flow.

More recently, monitoring wells have been installed within estuarine deposits in the proposed Phase 2 Extension Area for which groundwater monitoring data is being collected.

1.4.3.3 Groundwater Level

Plant Area

Groundwater levels beneath the plant in January 2004 varied from 2.2 to 16.4mAOD metres across the site and fell by a maximum of 3.8m during summer (by July 2004).

In the north pond area winter (Jan 2004) groundwater levels were 6.6mAOD and fell by up to 0.8m by July 2004. Groundwater levels in the south pond area ranged from 7.7mAOD to 11.5mAOD in January and fell by up to 2.6m in summer (i.e. by July 2004).

BRDA

The study undertaken by URS in 2002 (URS, 2003), identified that groundwater levels within the BRDA were high, generally amount 1m below the surface of the BRDA. At one location (BH-D) groundwater was found to be artesian. One monitoring well was installed into the estuarine silts beneath the BRDA. It was found that the groundwater head at this location was below that of groundwater within the BRDA, implying a downward hydraulic gradient from the BRDA into the estuarine deposits.

Based on 2004 data, bedrock groundwater levels at the perimeter of the existing Phase I BRDA generally varied from 1.0 to 1.8 m AOD during winter falling by up to 0.8m during summer. Water levels with the Glacial Till varied from 1.2 to 1.9mOD in January and fell by up to 0.9m by end of summer (August 2004). Water levels within the estuarine deposits ranged from 2.7 to 3.9mAOD around the perimeter of the BRDA and generally fell by between 0.5 and 1 metres by end of summer, apart from in the area adjacent to the stormwater pond where a drop of over two metres was recorded. South of the existing BRDA, monitoring well OW17 within the estuarine silts and sands tends to overflow following periods of heavy rainfall.

Phase 2 BRDA

Within the Phase 2 BRDA footprint, groundwater strikes were encountered between 2.1 and 7.5mbGL within more permeable gravel lenses of the estuarine deposits, within gravels and peat beneath the estuarine deposits and at the bedrock/overburden interface. Groundwater rose to within 0.5 to 3.1m of the surface, confined by the overlying low permeability silty estuarine deposits. The estuarine deposits were found to be moist to very moist with moisture content increasing with depth. Groundwater within the estuarine soils in this area fluctuates between 0.5 and 1.5 metres below ground level (mbGL).

1.4.3.4 Groundwater Flow

Plant Area

Studies by Dames & Moore (D&M), 1999, incorporating geophysical surveys, borehole drilling, geochemical sampling and groundwater modelling indicates that freshwater on the island is derived from rainfall, which has infiltrated and become perched above brackish seawater and is separated from fresh groundwater on the mainland by a saline wedge, a result of the density contrast between fresh and saline water. On site groundwater monitoring indicates that groundwater is recharged locally.

A combination of geophysical studies (Dames & Moore,1999) and borehole drilling has ascertained that much of the bedrock beneath the Plant is massive, unfractured and dry. This data, combined with groundwater modelling demonstrated that groundwater flows were concentrated in four major fracture zones of higher hydraulic conductivity:

Fracture Zone 1: NE-SW trending in the SW plant area travelling beneath the West pond and intersecting ES1 a groundwater spring discharge.

Fracture Zone 2: Variable trending fracture network in the eastern plant area, between Area 07 (precipitation) and Poulaweala Creek and intersecting springs ES7/12 and ES16.

Fracture Zone 3: A roughly trending N-S trending fracture zone in the southern plant area, between Area 04 (Digestion) and the Turlough.

Fracture Zone 4: NE-SW trending fracture zone in western plant area, originating near the Bauxite Store, and intersecting ES-9.

These fracture zones are typically 2-10m below ground level. In between the unfractured and fractured rock are zones of more diffuse, thinner fractures, which migrate downwards and laterally towards the larger fracture zones. The majority of groundwater flow within the bedrock beneath the Plant is expected to converge on these larger fractures zones and discharge at springs, with only a small proportion of groundwater discharging as baseflow to the estuary. A total of 18 springs (ES1-ES16, TT4 and the Turlough) have been identified. The main spring flow was measured at ES1 (14.7m^3/hr –Jan to April 1999). Elsewhere in the same period ES16 had a flow rate of 7m^3/hr; ES7/12 4.7m^3/hr; the Turlough 3m^3/hr and TT4 1.9m^3/hr. The remainder of the foreshore springs had estimated flows of less than 1m^3/hr. The total estimated spring discharge was 34m^3/hr. All major spring discharges are intercepted if showing elevated alkalinity and pumped back to site for treatment. Currently ES1, ES7/12 and ES16 are being intercepted. The smaller alkaline spring discharges mix with and are neutralised by the CO2 enriched saline water. Discharges from ES 4 since ceased.

BRDA

The D & M, 1999 investigations, involved geophysical surveys in the north and west of the BRDA and groundwater modelling. This data, combined with ongoing site water quality monitoring, indicates that gravel deposits in the subsoils allow active groundwater flow and groundwater is largely brackish or saline.

Groundwater within the alluvium and till deposits flows in a radial pattern from the BRDA area towards the estuary, Robertstown River and Poulaweala Creek. Beneath the stack, downward flow into the deeper gravely tills occurs where the red mud has been stacked to significant thickness (up to 20m). Under these conditions the hydraulic head within the unlined BRDA results in downward flow across the estuarine deposits. Within the stack, groundwater flow within the mud layers will be predominantly vertical, whereas flow will be diverted horizontally within the higher permeability layers of sand. Therefore a significant proportion of groundwater within the stack discharges to the perimeter drain.

Shallow groundwater outside the BRDA to the west and south, discharges at low tide to the estuary via the OPW channel via a flap valve to maintain a low groundwater level in the proposed Phase 2 BRDA area.

Phase 2 Extension Area

Within the proposed Phase 2 extension area groundwater flow is expected to discharge to Poulaweala Creek. There are a number of small spring discharges from the limestone outcrop to the northeast and southeast of the creek.

Groundwater within the limestone bedrock flows radially from the limestone ridge in East Aughinish towards the sea. A proportion of flow originating as recharge on the limestone ridge passes beneath the BRDA.

Flow gradients are generally upwards on the downgradient side of the BRDA as groundwater flowing at depth in the bedrock and till deposits discharges to the estuary.

The non-saline groundwater on Aughinish Island and Island Mac Teige are believed not to be connected hydrologically to freshwater aquifers on the mainland but to discharge as springs around the margins of the islands. This is not the case for groundwater on Glenbane West on the mainland, where the eastern and south eastern sectors of the Phase 2 BRDA are proposed. Virtually all the ground water flow is to the west and north west from the elevated limestone outcrops, beneath the Phase 2 BRDA and towards the saline ground waters of the Poulaweala Creek.

1.4.3.5 Permeability

The permeability (K) of the Waulsortian Limestone bedrock is found to vary significantly. Without any structural discontinuities, the limestone has a very low K. A detailed hydrogeological study (Ercon, 1974) carried out in east Aughinish, where the plant is sited, found seven out of eighteen boreholes were dry, one of which was within 3m of the maximum yielding well (216m^3/day). Recovery tests carried out in groundwater observation wells indicate the K of the limestone to range from 8.0E-06 m/s to 1.1E-09 m/s (9.5E-05 to 0.7 metres per day (m/d).

The D & M 1999 studies identified a range of K values on Aughinish East (Plant Area) as follows:

- 3.5m/d (4.1E-05m/s)within large fracture zones
- 2.6 m/d (3.0E-05m/s) within more permeable bedrock in the eastern plant area
- 0.007m/d (8.1E-08m/s) within very low permeability bedrock beneath the central plant area
- 0.26m/d (3.0E-06m/s) within the low permeability bedrock elsewhere in the plant area
- 0.086m/d (1.0E-06m/s). within glacial channel infill

The D&M 1999 studies indicated permeability values of 1.9E-05m/s to 4.6E-06 m/s in bedrock the Phase I BRDA Extension area.

For the purpose of the design of the Phase 2 BRDA, the permeability of the fractured limestone is considered to be 1E-05 to 1E-07 m/s (8.64E-01 to 8.64E-03m/d). The same permeability has been applied to the Rathkeale Formation limestones representing a conservative approach.

Laboratory permeability values in the estuarine soils are in the range 1E-10 m/s to 1E-07 m/s but higher values, in the range 5E-09 m/s and 5E-06m/s were obtained from in situ tests. For analysis in the design of the Phase 2 BRDA, the in situ values are taken as 1E-07m/s to 1E-08 m/s.

Laboratory permeability obtained in the glacial tills are in the range 4.0E-10 m/s to 2.2E-09 m/s. In situ tests gave values between 2.5E-06 m/s and 3.9E-09 m/s. Based on available data, the in-situ permeability is likely to range from 1E-06 m/s to 1E-09 m/s.

The permeability of the deeper older red dud has been estimated to be 1E-08 m/s to 1E-09 m/s. The shallower mud has a lower permeability, estimated to be 4 E-06m/s. The mud is reported to have a high porosity (70% of total volume). Therefore the red mud within the stack will store a lot of water but only allow very slow groundwater flow within the deposited mound. The process sand is estimated to have a permeability of 1E-04 to 1E-05 m/s and to have a porosity of 0.25 to 0.5.

1.4.3.6 Groundwater Usage

A GSI well record data base search within an approximate 1 km radius of the site indicated three groundwater well records for the island: one at Aughinish East, one at Aughinish West and a third in the south close to the intersection of the access road to the island and Poulaweala Creek. The first two encountered 3.7m of overburden and were drilled to 39m and 45.7m respectively into limestone bedrock. Both had poor wells yields. The third is a shallow dug well to 1.2 m into the upper weathered bedrock with an unknown yield. These wells are no longer in use and there are no groundwater abstraction wells on Aughinish Island. The plant obtains its water supply from mains water which is pumped from the River Deel via the Limerick County Council municipal water treatment plant nearby.

On the mainland, GSI records indicate abstraction wells both within the locally important and the regionally important aquifers. There are five wells on the mainland within one kilometre of the Phase 2 extension: two at Oorla, and one each at Robertstown, Glenbane East and Morgans North. The wells at Oorla and Robertstown are recharged from the south and are separated from the proposed extension area by the Robertstown River and would be isolated from it by the saline wedge. The other two wells would be recharged from the higher ground to their southeast. The zone of contribution for the well in Glenbane East is upgradient to the extension area and within a different catchment. Whereas The well in Morgans North is side gradient to it, therefore neither are likely to be impacted by the proposed extension asthe proposed BRDA is to be located where the aquifer discharges to the coast.

1.4.3.7 Groundwater Quality

Introduction

The hydrochemistry of groundwater beneath the site is dominated by the presence of limestone in both the bedrock and subsoils and by the effects of saline intrusion. Groundwater is hard, calcium bicarbonate type water and has a high levels of sodium and chloride where seawater mixing occurs at the island margins. The pH of seawater would be expected to be around 8, soda levels 10.7g/L and chloride 19g/L. The normal pH range in groundwater is 6.5 to 9.5.

The principle contaminant of concern arising from the alumina production process is dilute sodium aluminate which is characterised by elevated pH, elevated alkalinity and elevated aluminium relative to native groundwater. Fluoride, a common element in bauxite ore, is also present in the sodium aluminate solution and so is a potential contaminant of concern.

The red mud, process sand but particularly the salt cake, has a high pH, alkalinity, soda and aluminium content. A study undertaken by URS (URS 2003) measured groundwater pH in monitoring wells within the BRDA and within the estuarine silts beneath it. The pH of groundwater within the BRDA mud was in the range 12.9 -13.4. The pH of groundwater within the estuarine silts was 12.8. It was believed that drilling operations had contaminated this sample and was therefore not representative. However, given the downward gradient established from the BRDA to the underlying deposits, there is likely to be some seepage of contaminants through the base of the unlined original BRDA.

Recent chemical tests carried out on the red mud, process sand and salt cake are shown on Table 1.

Table 1: Chemical test results on Red Mud, Process Sand and Salt Cake.

Determinant	Red Mud	Sand	Salt Cake	Leachate from Red Mud	Leachate from Process Sand
PH	12.1	12.2	13.4	11.8	11.7
Soda (mg/kg)	4,956	4,288	241,120	3,870	1,156
Total Alkalinity (mg/kg) CaCO3	9,145	7,431	341,905	6,980	3,327
Aluminium (mg/kg)	27,250	18,557	221,870	1,084	745

Note mg/kg for solid samples, mg/l for leached samples.

Further testing of contaminant water within the pores of the red mud and measured from piezometers installed into the Phase 1 BRDA indicated the values shown on Table 2.

Table 2: Chemical test results for PIC, and Piezometers within the BRDA.

Determinant	Laboratory	Perimeter Interceptor Channel	Piezometer North Side	Piezometer South Side
PH	AAL	12.54	12.57	12.97
Soda (g/l)	AAL	3.24	3.88	14.22
Conductivity (uS/cm)	AAL	12,040	13,060	43,100
Aluminium (mg/l)	AAL	252	307	484
	TELLAB	365	406	558

The high values in the piezometer installed on the south side is believed to be due to the presence of process sand which is being recharged with high soda liquor from the salt cake waste area. This will be confirmed with the on going sampling regime.

The principle potential contaminants from the on-site oil storage and distribution facilities are petroleum hydrocarbons and from the sewage treatment system: ammonia, nitrate and faecal coliforms.

As mentioned above, groundwater quality monitoring is undertaken at an existing network of groundwater monitoring wells and identified springs as part of the IPC licence (Register No. 562) requirements. The analysis includes pH, total alkalinity, electrical conductivity (EC), chloride, fluoride and soda. Magnesium, metals (Al, As, Cd, Cr, Cu, Fe, Hg, Ni, Pb, Zn) and sulphate are also analysed within the BRDA perimeter (OW) wells. The monitoring frequency varies depending on the parameter being monitored but is generally undertaken on a monthly or quarterly basis.

Plant Area

Estuarine Springs

The main indicators of groundwater quality beneath the plant are taken to be the estuarine spring discharges (ES1 to 16). Table 3 contains a summary of analyses undertaken on those streams (ES) for the 2003 reporting period (i.e. average of data) and as set out in the most recent Annual Environmental Report (AER).

ES 2, ES 3, ES 9 and ES 10 are subject to saline intrusion and therefore the soda values subject to NaCl interference.

Table 3: Summary of Estuarine Spring water quality results 2003

Sample Location	pH	Conductivity µS/cm	Soda (g/L)
ES 1	**12.7**	17,448	4.7
ES 2	7.9	24,851	7.1
ES 3	7.9	17,128	5.2
ES 5	8.7	475	0.1
ES 6	7.5	754	0.1
ES 8	**10.1**	14,264	3.5
ES 9	8.7	19,183	5.2
ES 10	7.8	4,481	1.1
ES 11	7.5	1,105	0.2
ES 7/12	**12.0**	7,247	2.0
ES 13	**12.6**	13,767	2.8
ES 14	**12.6**	14,300	3.1
ES 15	8.4	843	0.2
ES 16	8.4	734	0.2
EPA Interim Guideline for Groundwater	6.5-9.5	1,000	0.15

Emboldened results indicate pH above 9.5, i.e. above the normal range.

Six of the springs have a pH greater than 9.5 indicating contamination from plant processes. ES1 (major spring discharge west side), ES7/12 (south east plant), ES13 and ES14 (west side) have a pH greater 12. ES8 has a pH above 10. Where there is a perceptible flow, these streams are intercepted and pumped to the Effluent Treatment plant for neutralisation and disposal. This currently occurs at ES1, ES7/12 and ES 16.

Studies by Dames & Moore (1999) identified elevated pH and aluminium in both ES1 and ES7. The source of contamination is considered to be the leakage of caustic liquors stored in the south western plant area including the West Pond. The main source areas and pathway for discharge to these springs are detailed in Table 4. Results for 2004 indicate that groundwater in this area still has high pH.

Table 4: Sources and Pathways of Estuarine Spring Contamination

DISCHARGE POINT	MAIN PATHWAY	POTENTIAL SOURCE OF CONTAMINATION
ES 1	Fracture Zone 1	Area 04 – Digestion; Area 65 – Liquor Purification; Area 27 – Sand Separation Area 28 – Decanting, Mud Washing and the West Pond.
ES7/12	Fracture Zone 2 and generally higher K fractured rock	Area 06 - Hydrate Thickening; Area 07 - Precipitation & Calcination; East Pond.
ES13 ES14	Fracture Zone 4	Area 1 - Bauxite Storage Area 12 - Alumina Storage
ES8	Glacial Channel connecting to Fracture Zone 1 and 3 and low to medium K bedrock.	Area 38 - Fuel Oil & Liquid Caustic Storage; Bayer Plant in General.

Plant Observation Wells

Table 5 contains a summary of analyses undertaken on all groundwater-monitoring locations at the AAL facility during 2003 as set out in the most recent AER (2004). The table also includes data on those wells located around the north pond (NP) and the south pond (SP). Information on the status of these wells is provided on a monthly basis. The values reported are the average of analytical results returned during the 2003 monitoring period. The emboldened results indicate the result is above relevant maximum admissible concentrations or abnormally high.

The results indicate that there is still groundwater contamination (particularly elevated pH, alkalinity, fluoride) in several Plant observation wells and in the south pond (SP2) and north pond areas (NPW2). Fluoride is particularly high in POW1 near the Area 18 Test, in POW7 Area 41 – Vacuum Flash Heat Exchange POW17 Area 7 – Precipitation & Calcination and North Pond Observation Well 1. Data available for 2004 indicate that groundwater in these areas remains contaminated.

Table 5 Summary of POW monitoring groundwater quality results 2003

Well Ref	Location	Soda (g/l)	pH	Conductivity (µs/cm)	Alkalinity (mg/l $CaCO_3$)	Chloride (mg/l)	Fluoride (mg/l)
POW 1	Area 72, 73 74	11.6	12.5	42,322	17,504	315.0	18.1
POW 2	Area 28 - Decanting and Mud Washing	1.3	11.7	4,101	1,230	151.2	1.4
POW 3	Area 65 - Liquor Purifaction	1.6	11.8	4,941	1,849	143.7	2.6
POW 5	Area 28 - Decanting and Mud Washing	3.9	11.9	10,151	6,073	84.1	8.0
POW 6	Area 18 – Test Tanks	4.9	11.1	14,575	7,590	55.7	2.8
POW 7	Area 41 – Vacuum Flash Heat Exchange	18.7	12.3	52,112	28,627	300.6	33.8
POW 8	Area 7 – Precipitation & Classification	0.1	8.3	442	134	28.1	0.5
POW 9		0.0	7.8	424	202	16.8	0.5
POW 10		2.0	10.8	6,056	3,178	48.7	4.3
POW 11	Area 6 – Hydrate Thicknening	2.4	12.2	9,135	4,138	56.8	4.9
POW 12	Area 6 - Hydrate Thickening	0.6	10.5	1,891	993	31.8	1.2
POW 13	Drainage Pond East	0.2	7.8	837	520	30.2	0.6
POW 14	Area 7 – Preciptation & Calcination	0.1	7.4	820	346	27.8	0.6
POW 15		0.1	7.4	719	295	58.6	0.5
POW 16	Area 6 – Hydrate Thickenning	0.8	9.1	2,421	1,422	38.1	2.0
POW 17	Area 7 – Preciptation & Calcination	6.8	12.4	23,871	13,545	101.3	12.2
POW 18	Area 6 – Hydrate Thickening	2.3	12.1	12,012	5,134	52.9	4.1
POW 19		2.0	12.1	6,782	3,323	47.5	3.7
POW 20		1.0	11.5	3,134	1,691	36.6	1.9
POW 21	Area 56	0.1	8.3	476	170	29.0	0.5
POW 22	Area 7 Precipitation & Classification	0.0	8.1	426	159	25.6	0.5
POW 23	Area 9 & 10 Calcination	0.2	9.0	655	223	30.2	0.8
POW 24		3.4	12.5	15,809	6,549	115.7	5.8
POW 25		0.1	9.3	414	158	15.2	0.5
POW 28	Drainage Pond East	1.4	11.9	5,395	2,221	34.7	2.9
POW 29		0.7	10.3	2,266	1,252	37.7	2.2
POW 30		0.3	8.9	1,045	505	35.2	1.1
POW 31		0.0	7.3	537	251	22.8	0.5
POW 32		0.1	7.5	584	259	34.0	0.5
POW 33		0.2	8.1	785	350	36.4	0.5
SPW 1	South Pond	1.1	8.3	3,102	411	107.8	1.0
SPW 2		1.2	10.6	3,394	1,310	80.7	7.7
SPW 3		0.1	7.9	501	202	27.3	0.6
SPW 4		0.1	8.3	300	114	19.4	0.5
SPW 5		0.4	9.5	1,421	271	43.1	1.1
SPW 6		0.3	9.1	490	347	16.7	1.3
NPW 1	North Pond	0.8	10.2	2,238	1,222	44.2	1.9
NPW 2		1.4	9.9	3,064	1,679	65.8	2.6
NPW 3	North Pond	0.2	8.0	486	174	30.7	0.5
EPA Interim Guideline Value for Groundwater		0.15	6.5 - 9.5	1,000	No abnormal change*	250	1.0
Typical Seawater Composition		10.7	8	30,000	>150	19,000	1.0

* Normal levels for this aquifer type would be expected to be 250-400 mg/L.

Underground Fuel Storage

Under Condition 9 of the IPCL, AAL undertakes biannual sampling from four monitoring boreholes located around an underground bund in the central plant area.

There are three underground storage tanks contained within the concrete bund, one for petrol (25,000 l) and two for diesel storage – derv (45,000 l) and marked diesel (45,000 l). The invert depth of the base of the concrete bund is approximately 5 metres below ground level. The sampling points are located within gravels beneath the concrete bund and indicate if the tank is leaking. The white diesel tank was confirmed as leaking and has been removed from service and a new above ground white diesel tank installed. The two diesel tanks will be decommissioned by end of 2005 and the petrol is scheduled for 2006.

The results of biannual testing during 2003 are tabulated below.

Table 6 BH1 to 4 Monitoring Results (July 2003)

Borehole Ref.	DRO (μg/l)	PRO (μg/l)
BH 1	459	<10
BH 2	52,372	8,164
BH 3	<10	<10
BH 4	<10	<10

DRO – Diesel range Organics; PRO – Petrol(eum) range organics

Table 7 BH1 to 4 Monitoring Results (Dec 2003)

Borehole Ref.	DRO (μg/l)	BTEX (μg/l)
BH 1	587	<1
BH 2	29,477	<1
BH 3	<1	<1
BH 4	<1	<1

Based on the analytical results, the contaminant most evident in BH 2 is taken to be diesel in origin. Review of the results available to date indicates a significant variation in determinant concentration between biannual sampling and between successive years. This may be due to a range of factors including seasonal variation in water table levels.

. The most recent monitoring data is as follows:

Table 8 Monitoring Results (Dec 2004)

Borehole Ref.	DRO (μg/l)	PRO (ug/l)
BH1	<10	<10
BH2	400	<10
BH3	<10	<10
BH4	<10	<10

The results show that there has been significant reduction in contamination to below the detection limit in most boreholes. Traces of DRO are still detectable in BH4. Thus it appears that the problem has been correctly diagnosed and the corrective action has been successful. Monitoring of all 4 boreholes will continue at the normal 6 monthly frequency to confirm its ongoing success.

Phase 1 BRDA

Observation wells - General

Table 9 contains a summary of analyses undertaken on all BRDA Observation Wells for 2003 as reported in the most recent AER.

In total, nineteen Observation Wells (OW) are sampled and analysed monthly to monitor groundwater quality around the BRDA and the associated Storm Water Pond (SWP). These wells are generally coupled with the first drilled into the glacial till layer and the 2nd drilled deeper into the limestone bedrock. Additional Wells are installed within the estuarine silts and clays.

Fifteen of the nineteen wells are located around the perimeter of the BRDA. The other four of the wells, OW 1,2, 20 and 21 are located down-gradient from the SWP.

Observation wells - BRDA

Of the fifteen monitoring wells around the BRDA, only seven of them are not impacted by saline intrusion (OW13,14,,15,16,17,18,19). A summary of the principal groundwater data for these seven freshwater wells is as follows:

Table 9 Summary of 2003 Groundwater monitoring for (OW13, 14, 15,16,17,18,19)..

Parameter	Average	Range	EPA Interim Guideline Value for Groundwater	Typical Seawater Composition
PH (pH units)	7.4	7.2-7.8	6.5 - 9.5	8.1 – 8.3
Alkalinity	260	180-360	No abnormal change from normal range (250-400)	
Soda	<100	0-100	200	10,700
Aluminium	0.5	0.4-0.6	0.2	0.002
Fluoride	0.5	0..4-0.6	1.0	1.0
Conductivity (µs/cm)	700	500-1160	1,000	30,000

* units in mg/L unless otherwise stated.

Groundwater in these wells is fresh and relatively contamination free, apart from traces of heavy metals (Al, Cd, Hg, Ni, Pb) and magnesium (OW 13 only).

A study undertaken in November 1999 (Dames & Moore, 2000) identified that there was no significant seepage from the Phase 1 BRDA extension area to the east to groundwater, signifying that the lining system placed was providing adequate protection of groundwater. The above monitoring results concurs with this as no significant contamination was identified in downgradient wells (OW16, 17, 18 19).

Monitoring data from the other eight wells around the BRDA (OW7,8, 9, 10, 11,12 , 22 and 23) indicates the influence of brackish to saline water that render the water unsuitable for abstraction.

These wells are located along the northern boundary of the BRDA adjacent to the estuary and along the western boundary close to the OPW channel and the Robertstown River. For example, EC reaches over 25,000 us/cm in OW10, OW11 and OW12, chloride reaches over 11,000 mg/L and soda is up to 8.6g/L. Although pH is normal, alkalinity, sulphate and magnesium are high (up to approx 1,500; 820 and 780 mg/L respectively). The salt content of seawater would be expected to be about 35,000 mg/L, largely comprised of sodium and chloride. Sulphate, magnesium, calcium and potassium are all major constituents in seawater.

These eight wells also exhibit other trace mineral characteristics including slightly elevated aluminium and fluoride suggesting that there is some gradual seepage from the BRDA into this brackish water.

Observation wells – Downstream of SWP

Monitoring data from the 4 wells downstream of the SWP (OW1, 2, 20 and 21) indicate that there is groundwater contamination in the glacial till and limestone bedrock to the northeast of the SWP. PH (>11), fluoride (55mg/L), aluminium (90-145mg/L) and alkalinity (over 8,000 mg/L) are significantly elevated within OW1 (glacial till) and OW2 (bedrock). However, the monitoring well installed in the estuarine deposits (OW20, 21) in this area remains relatively contamination free (pH normal, aluminium less than 1mg/L, fluoride 0.5-1.2mg/L0. From examination of the drilling records for OW1 and OW2, it is believed that the well monitoring within the glacial till (OW1) is affected by groundwater from the bedrock (OW2). The high pH, alkalinity and fluoride combined with low magnesium and low chloride indicate that Sodium aluminate from the SWP is the source of contamination. Recent detailed investigations (Golder Associates, 2004) involving geophysics in this area concluded that the contamination was originating from leakage of the SWP. The cause of the contamination is believed to be a result of damage to the geomembrane lining covering the near surface limestone out crop at the base of the SWP upstream of OW 1 and OW 2. Remedial works are being implemented to contain this leakage (see Section 1.7: Remedial and Reductive Measures below.

Table 10: Summary of BRDA observation wells groundwater quality monitoring results 2003

Ref	Lithology	pH	EC µS/cm	Cl Mg/l	Fl mg/l	Na G/l	Alk mg/l $CaCO_3$	Al mg/l	S04 mg/L	As mg/l	Cd mg/l	Cr mg/l	Cu mg/l	Fe mg/l	Hg mg/l	Ni mg/l	Pb mg/l	Mg mg/l	Zn mg/l
OW 1	Till	11.1	**12,933**	**253**	**55.0**	**5.9**	**8,199**	**92**	**444**	0.005	**0.02**	**0.04**	0.02	0.2	0.001	**0.2**	**0.08**	0.02	0.02
OW 2	Bedrock	11.5	**13,456**	**252**	**54.8**	**6.1**	**8,558**	**145**	**502**	0.005	**0.02**	**0.04**	0.02	0.1	0.001	**0.2**	**0.08**	0.02	0.03
OW 7	Till	7.5	**6,385**	**1,774**	**1.1**	**1.5**	**748**	**0.7**	**442**	0.005	**0.02**	**0.04**	0.02	0.1	0.001	**0.05**	**0.07**	**146**	0.02
OW 8	Bedrock	7.8	**12,872**	**4,231**	0.8	**3.5**	**842**	**1.0**	**723**	0.005	**0.02**	**0.04**	0.02	0.2	**0.278**	**0.08**	**0.07**	**287**	**0.85**
OW 9	Till	7.0	**17,045**	**6,095**	1.0	**4.7**	**827**	**1.4**	**816**	0.005	**0.02**	**0.04**	0.02	0.1	**0.002**	**0.1**	**0.07**	**388**	0.03
OW 10	Bedrock	7.1	**26,189**	**11,192**	1.0	**6.4**	**242**	**1.6**	**712**	0.005	**0.04**	**0.04**	0.02	0.1	0.001	**0.2**	**0.1**	**780**	**2.5**
OW 11	Till	7.2	**28,766**	**11,501**	0.7	**8.6**	**1,578**	**1.1**	**796**	0.005	**0.04**	**0.04**	0.02	0.2	**0.002**	**0.2**	**0.09**	**724**	0.05
OW 12	Bedrock	7.3	**27,358**	**10,732**	0.6	**8.3**	**1,225**	**1.1**	**700**	0.005	**0.03**	**0.04**	0.02	0.1	**0.002**	**0.16**	**0.09**	**689**	**0.1**
OW 13	Bedrock	7.8	515	29	0.5	0.02	179	**0.7**	10.7	0.005	**0.01**	0.03	0.01	0.1	**0.002**	**0.03**	**0.05**	**108**	0.02
OW 14	Bedrock	7.4	602	33	0.5	0.03	226	**0.6**	25.7	0.005	**0.01**	0.03	0.01	0.1	**0.003**	**0.03**	**0.05**	11.6	0.02
OW 15	Bedrock	7.3	567	22	0.5	0.02	267	**0.6**	3.0	0.005	**0.01**	0.03	0.01	0.1	**0.003**	**0.03**	**0.05**	8.9	0.02
OW 16	Bedrock	7.2	756	55	0.5	0.05	336	**0.5**	8.7	0.005	**0.01**	0.03	0.01	0.1	**0.002**	**0.03**	**0.05**	16.3	0.02
OW 17	Tills/ Estuarine	7.2	1,158	147	0.5	0.1	353	**0.5**	40.0	0.005	**0.01**	0.03	0.02	0.1	**0.003**	**0.03**	**0.05**	22.3	0.02
OW 18	Till	7.3	654	23	0.5	0.03	264	**0.4**	39.7	0.005	**0.01**	0.03	0.01	0.2	**0.003**	**0.03**	**0.05**	9.6	0.02
EPA Interim Ground-water	-	6.5-9.5	1,000	250	1.0	0.2	No abnormal change	0.2	200	0.01	0.005	0.03	0.03	0.2	0.001	0.02	0.01	50	0.1
Typical Seawater	-	8.1-8.3	30,000	19,000	1.0	0.7		0.001	2,500	0.003	0.0001	0.0002	0.0009	0.0034	0.00015	0.007	0.00003	1,300	0.005

Ref	Lithology	pH	EC µS/cm	Cl mg/l	Fl mg/l	Na G/l	Alk mg/l $CaCO_3$	Al mg/l	S04 mg/L	As mg/l	Cd mg/l	Cr mg/l	Cu mg/l	Fe mg/l	Hg mg/l	Ni mg/l	Pb mg/l	Mg mg/l	Zn mg/l
OW 19	Bedrock	7.2	694	43	0.5	0.04	265	**0.5**	15.7	0.005	**0.01**	0.03	0.01	**0.03**	**0.003**	**0.03**	**0.05**	11.2	0.02
OW 20	Estuarine	7.6	**2,870**	**958**	**1.2**	**0.7**	**533**	**0.4**	177	0.005	**0.01**	0.03	0.01	**0.03**	**0.002**	**0.03**	**0.06**	**56.4**	0.02
OW 21	Estuarine	7.1	**24,848**	**10,248**	0.5	**6.7**	**2,303**	**0.4**	4.3	0.005	**0.03**	**0.04**	0.03	0.1	**0.006**	**0.1**	**0.07**	**842**	0.02
OW 22	Estuarine	7.0	**3,214**	**805**	0.6	**0.5**	**494**	**0.6**	161	**0.02**	**0.02**	**0.04**	0.01	0.05	**0.003**	**0.04**	**0.05**	71	0.03
OW 23	Estuarine	7.1	1,885	**292**	0.7	**0.3**	**565**	**0.4**	135	0.01	**0.01**	0.03	0.01	0.03	**0.003**	**0.03**	**0.05**	**59.1**	0.02
EPA Interim Ground-water	-	6.5-9.5	1,000	250	1.0	0.15	No abnormal change	0.2	200	0.01	0.005	0.03	0.03	0.2	0.001	0.02	0.01	50	0.1
Typical Seawater	-	8.1-8.3	30,000	19,000	1.0	0.7		0.001	2,500	0.003	0.0001	0.0002	0.0009	0.0034	0.00015	0.007	0.00003	1,300	0.005

Emboldened indicates results higher than would be expected for groundwater.

PHASE 2 EXTENSION AREA

The results of groundwater quality monitoring undertaken within the Phase 2 extension area is shown on Table 11.

Table 11. Phase 2 Extension Area Groundwater Quality Monitoring Results April 2005

Well Ref	Horizon	Soda (mg/l)	pH	Conductivity (μs/cm)	Alkalinity (mg/l $CaCO_3$)	Chloride (mg/l)	Fluoride (mg/l)
BH1	Estuarine SAND AND GRAVEL	749	8.2	3,010	**660**	634	<0.1
BH2	GRAVEL (Till)	2,340	8.2	10,730	450	4,069	**1.1**
BH3	Estuarine SILT	1,412	8.0	7,020	**813**	1,426	<0.5
BH4	Estuarine SILT	324	8.3	2,220	257	539	0.2
BH5A	PEAT	6,342	8.3	27,700	**723**	11,621	<1.0
BH8?	*No installation/backfill?*	*40?*	*7.9*	*802*	*395*	*47*	*0.3*
EPA Interim		*150*	*≥6.5 ≤9.5*	*1,500*	*No abnormal change*	*250*	*1.0*
Seawater		*10,500*	*8-8.3*	*30,000*		*19,000*	*1.0*

The results indicate that the baseline shallow groundwater quality within the estuarine silts, peats and gravels in the Phase 2 footprint is alkaline and tends to be brackish, i.e. affected by saline influence.

1.4.3.8 Groundwater Vulnerability

Groundwater vulnerability is a measure of the ease which pollutants can infiltrate to the aquifer. This classification is derived from DoEHLG/EPA/GSI vulnerability mapping guidelines presented in Table 12:

Table 12: Vulnerability Mapping Guidelines (DoEHLG/EPA/GSI, 1999)

Vulnerability Rating	Hydrogeological Conditions				
	Subsoil Permeability (Type) and Thickness)			Unsaturated Zone	Karst Features
	High permeability (sand/gravel)	Moderate permeability (e.g. sandy subsoil)	Low permeability (e.g. clayey subsoil, clay, peat)	(Sand/gravel aquifers only)	(<30m radius)
Extreme (E)	0 – 3.0m	0 – 3.0m	0 – 3.0m	0 - 3.0m	-
High (H)	>3.0m	3.0 – 10.0m	3.0 – 5.0m	>3.0m	N/A
Moderate (M)	N/A	>10.0m	5.0 – 10.0m	N/A	N/A
Low (L)	N/A	N/A	>10.0m	N/A	N/A

The karstic nature of the Waulsortian limestone aquifer and the absence of protective subsoil renders the aquifer extremely vulnerable to pollution over much of Aughinish East. The exception is where deep channel infill occurs, rendering the vulnerability low.

Aquifer vulnerability in the Phase 2 extension area tends to be extreme in the east where subsoils are thin or absent and reducing to generally moderate elsewhere.

1.4.3.9 Groundwater Protection

The GSI, EPA and DOEHLG have developed guidelines for the protection of groundwater quality and quantity. The guidelines present a risk based approach to groundwater protection and sustainable development.

As discussed above, and based on geological mapping, the proposed Phase 2 BRDA, is to be located on a locally important aquifer in its west and over a regionally important aquifer in its east. The presence of estuarine clays and silts in the west renders groundwater moderately vulnerable whereas this increases to extreme vulnerability in the east where bedrock outcrops. The resource protection responses for landfills from the Groundwater Protection Scheme Guidelines are relevant for the BRDA. These responses are shown on Table 13.

Table13: Response Matrix for Landfills (DoEHLG/EPA/GSI, 1999)

Vulnerability Rating	RESOURCE PROTECTION (Aquifer Category)					
	Regionally Important (R)		Locally Important (L)		Poor (P)	
	Rk	Rf/Rg	Lm/Lg	Ll	Pl	Pu
Extreme (E)	R4	R4	R3^{2}	R2^{2}	R2^{2}	R2^{1}
High (H)	R4	R4	R3^{1}	R2^{1}	R2^{1}	R1
Moderate (M)	R4	R3^{1}	R2^{2}	R2^{1}	R2^{1}	R1
Low (L)	R3^{1}	R3^{1}	R1	R1	R1	R1

Note: Shading denotes response for proposed Phase 2 BRDA.

The majority of the Phase 2 BRDA lies within the R2^{1} resource protection response category for landfills whereas in the eastern sector lies with the R4 response. These responses are described as

R2^{1} Acceptable, subject to guidance in the EPA Landfill Design Manual or conditions of a waste licence.

- Special attention should be given to checking for the presence of high permeability zones. If such zones are present then the landfill should only be allowed if it can be proven that the risk of leachate movement to these zones is insignificant. Special attention must be given to existing wells downgradient of the site and to the projected future development of the aquifer.

R4 Not acceptable.

The siting of landfills on or near regionally important aquifers should only be considered:

- Where the hydraulic gradient (relative to the leachate level at the base of the landfill) is upwards for a substantial proportion of each year (confined aquifer situation).
- Where the proposed landfill is located in the discharge area of an aquifer. In this case surface water may be more at risk.
- Where a map showing a regionally important aquifer includes low permeability zones or units which cannot be delineated using existing geological and hydrogeological information but which can be found by site investigations. Location of a landfill site on such a unit may be acceptable provided leakage to the permeable zones or units is insignificant.

- Where the wastes types are restricted and the waste acceptance procedures employed are in accordance with the criteria specified by the EPA.

The Phase 2 BRDA, largely lies in a R2[1] response category which would be acceptable subject to paying special attention to the existence of high permeability zones and existing down-gradient wells. The locally important aquifer in this area is characterised by low permeability and there are no existing down gradient wells. However, in the eastern and south-eastern sector, where the proposed Phase 2 BRDA overlies the extremely vulnerable regionally important aquifer, the response category would be not acceptable. However, since the Phase 2 BRDA in this area will be located in the discharge area of the aquifer, as evidenced by local springs, then the siting of the BRDA in this area should be considered. Groundwater monitoring in this area will be undertaken to establish hydraulic gradient.

1.5 CHARACTERISTICS OF THE PROPOSAL

1.5.1 Introduction

The proposed development covers the following areas of the Aughinish Alumina facility:

- Increase in the height of the existing Phase 1 BRDA from Stage 7 perimeter (central elevation of 27.5m AMSL) to Stage 10 perimeter (central elevation of 32m AMSL)

- Provision of a Phase 2 BRDA as an extension to the existing Phase 1 BRDA

- Relocation of the Salt Cake Disposal Area from Phase 1 to the composite lined section of the Phase 1 Extension BRDA

- Upgrade of the Water Management System, the Storm Water Pond and the Liquid Waste Pond

- Retention of the existing alumina production capacity of 1.60 million metric tonnes per annum with associated emissions within permitted Integrated Pollution Control Licence limits,

- Increase in existing alumina production capacity to 1.95 million tonnes per annum with associated emissions to remain within permitted Integrated Pollution Control Licence limits.

1.5.2 Increased Plant Production

The development consists of utilising all existing permitted plant and machinery to achieve a production capability consistent with having removed internal processing bottlenecks in the plant and optimising the chemical and recovery process of alumina from bauxite. A technology termed digestion 'sweetening' will be employed, selected for its energy efficiency and utilising digestion waste steam to conduct part of the additional digestion load. As a result digestion energy consumption per tonne of alumina hydrate will fall from about 148 kg/tonne to 140 kg/tonne (HFO equivalent).

The plant will implement higher rates of bauxite storage, conveying, crushing, grinding and slurry transfer. The concentration of the circulating caustic soda will be increased by some 10% and the removal of impurities from the circulating caustic will be increased by improved cooling and seed evaporation of the stream of caustic being filtered of impurities.

1.5.3 Phase 2 BRDA

It is proposed to develop a Phase 2 BRDA to the immediate south of the existing Phase I BRDA. Part of the footprint extends across Poulaweala Creek and onto the townlands of Island Mac Teige and Glenbane West as far south as a disused railway line. The Creek has been backfilled during the construction of the access road to the island. Phase 2 is 70 hectares and will have a maximum central elevation of 32m AOD.

The Phase 2 BRDA will be composite lined at its base and beneath its surrounding PIC, the latter formed by constructing an outer low permeability embankment wall and an inner permeable perimeter embankment wall. The PIC will connect with the Phase 1 PIC on the western side.

The bulk of the inner perimeter embankment wall will consist of random rockfill. A filter of Terram 2000 over a 500 mm thick processed rockfill will be provided to prevent migration of fines from the glacial till into the rockfill.

Where the Phase 2 BRDA crosses the backfilled Poulaweala Creek it may be necessary to remove unsuitable soft foundation material which formed the base of the Creek.

Unsuitable stockpiled material will be removed and, depending on quality, used for restoration, landscaping or backfilling drainage ditches.

The Phase 2 BRDA will cut into the existing ground in the central section of the southern flank.

1.5.4 Phase I BRDA

It is proposed to raise the existing Phase 1 BRDA from a maximum central elevation of 26mAOD to 32 mAOD. The raises will be constructed of rockfill placed on a layer of approximately 600mm of process sand or Terram 2000 (minimum required to support the dump trucks). The sand and Terram also prevent rockfill punching through the red mud. A filter of processed rockfill and Terram will be placed upstream of the rockfill to prevent the migration of fines.

A disused sludge pond in the south west of the Phase I BRDA is located along the dam alignment of the proposed extension. The sludge is not suitable for foundation material and will be removed. The total volume is likely to be in excess of 120,000m^3. The exact volume will be determined by probing during construction. One option for its removal would require a 10m wide rock causeway to be constructed to enable access to remove the sludge. The void created by sludge removal will be replaced by process sand, with rockfill at the perimeter if necessary. The sludge contains gelatinous alumina hydrate from the Waste Water Treatment plant and gypsum from the Boilerhouse Demineralisation plant. The removed sludge will be either dewatered in geotextile bags and placed on the Phase I or Phase 2 BRDA or returned to the plant for thickening. Trials will be undertaken to determine the most beneficial method. Other removal techniques are currently being researched..

In the future, build up of sludges will diminish by using filters on the BRDA which prevents the migration of fines entering the SWP or PIC. Sludges will not be stored in ponds in future.

The existing salt cake disposal area will be capped and a new salt cake area created in the Phase I BRDA lined extension area. The salt cake consists principally of crystallised sodium salts of carbonate, sulphate, and oxalate together with adsorbed sodium humates and entrained sodium aluminate liquor.

1.5.5 Stormwater Pond

The existing SWP will be raised from an existing crest elevation of 4.7mAOD to 6.0mAOD. This is necessary to accommodate run-off from both the Phase 1 and Phase 2 BRDA. The sides will be raised with the use of gabions. The SWP shares an internal wall with the liquid waste pond (LWP) and the perimeter interceptor channel (PIC). Raising will be carried out with the LWP in operation. The walls of the LWP will also be raised by the corresponding height increase of the SWP.

The effluent water will be removed from the SWP by pumping and discharging as much as possible back to the plant for treatment and the remainder being pumped into the completed Phase 2 BRDA. Subsequently all runoff flows will be diverted to the Phase 2 BRDA while the SWP is out of service for full lining and raising. The discharged effluent water will migrate to the low area of the Phase 2 BRDA which is the south western sector of Poulaweala Creek. The SWP basin will be cleaned of sediment. The sediment will be placed in geotextile bags to dewater and placed on the Phase 1 or 2 BRDA. It is proposed to remove the existing partial lining system within the SWP and bury it within Phase I as construction debris It is understood that this lining system is currently limited to the sides of the SWP and that the majority of the base is unlined. The SWP will be composite lined at its base including the side walls.

1.5.6 Liquid Waste Pond (LWP)

The Liquid waste pond will be raised from its current crest elevation of 4.7mAOD to 6.0mAoD on its external wall with the Bird Sanctuary, the internal dividing wall between the LWP and the SWP and between the LWP and the access ramp.

This will be achieved by steepening the existing embankment side slopes and with gabions. The raising will occur while the LWP is in operation and before raising of the SWP. After completion of raising of the SWP, the treated effluent normally directed to the LWP will be directly pumped to the Shannon post treatment and any surplus effluent remaining in the LWP will be temporarily stored in the SWP if needed to allow inspection and repair of the existing LWP basin lining.

The side slopes on the downstream side of the LWP, where it adjoins the bird sanctuary, could be steepened from 4H:1V to 2.5H:1V, provided the rate of construction is controlled by monitoring pore water pressure development in the foundation estuarine soils.

1.6 POTENTIAL IMPACTS OF THE PROPOSAL

1.6.1 Increased Plant Production

The higher rates of bauxite storage, conveying, crushing, grinding and slurry transfer and the increased concentration of the circulating caustic soda could, theoretically, increase the level of groundwater contamination beneath the site as a result of ongoing operational spillages and leaks.

In addition there is an ongoing threat of leakage or spillages from areas where fuel oils are stored or conveyed and from the sewerage network. In this regard, as 65% of the steam production will be derived from natural gas rather than from HFO as at present, the threat of oil spillage is somewhat reduced.

1.6.2 Phase 2 BRDA, Stormwater Pond and Liquid Waste Pond Raising

1.6.2.1 Construction Phase

Soils

The proposed development will require the stripping of topsoils resulting in a loss of estuarine soils over the entire footprint of the Phase 2 BRDA. This is an essential part of the development and is an impact that cannot be mitigated. Site investigations to date have estimated the volume of topsoils to be stripped is approximately 200,000m^3.

In addition, it is estimated that 50,000 m^3 of unsuitable stockpiled subsoils will be removed from beneath the embankment footprint in the north east sector.

Earth materials will be required for the initial construction phase of the Phase 2 BRDA, raising of the SWP and the LWP. The estimated volumes required are as follows:

Table 14: Estimated Earth Materials Volumes (m^3) Required for Construction.

Subsoil Type	Phase 2 BRDA	SWP	LWP
Processed Glacial Till	125,000	36,000	3,000
Glacial Till	125,000	14,000	-
Rockfill	250,000	-	-
Processed Rockfill	60,000	1,000	-
Drainage Backfill	3,000	-	-

This includes earth materials required for backfilling of existing drains prior to the placement of composite lining. Some 3,000m of existing drainage ditches will be need to be cleared of vegetation and organic debris from the sides and base.

During the construction phase, a limited amount of fuels and hazardous materials will be used to fuel vehicles and plant machinery, which will also have the potential to impact the soil environment if not stored and handled in an environmentally sound manner.

Geology

Bedrock forming the higher ground will be removed by ripping or blasting to facilitate construction of the Phase 2 BRDA. The removal of this material is considered to be an essential part of the development and cannot be mitigated.

It will be necessary to import rockfill as foundation material for the proposed development.

Hydrogeology

During the construction phase, a limited amount of fuels and hazardous materials will be used to fuel vehicles and plant machinery, which will also have the potential to impact on groundwater quality if not stored and handled in an environmentally sound manner.

The removal of unsuitable soft soils/subsoils will potentially result in an increase aquifer vulnerability making groundwater more vulnerable to pollution.

Observation wells OW16, OW17, OW18 and OW19 will be lost as a result of the construction of the Phase 2 BRDA. These wells monitor groundwater just beyond the southern boundary of the existing Phase I BRDA.

There is a potential for leakage of liquid waste and stormwater from the LWP and PIC respectively to the SWP during its raising. This could leach into the groundwater system and cause contamination if not adequately controlled.

1.6.2.2 Operational Phase

There is no significant impact on the geology of the area during the operational phase as a result of the proposed development.

Due to the impermeable nature of the BRDA and the increased generation of surface water runoff, there will be a localised reduction in recharge to the aquifers underlying the Phase 2 BRDA, most notably in the eastern part of the site. However, the Phase 2 BRDA is located in an area where the aquifer is discharging to the estuary, the freshwater resource in this area is limited due to the proximity of saline water and the resource is not currently used.
The removal of unsuitable soft subsoils will potentially increase aquifer vulnerability resulting in groundwater being more vulnerable to pollution.

There is potential to impact soil and groundwater quality during the operational period as a result of leakage of leachate through the base of the BRDA and from the perimeter channel. This potential will increase as the Phase 2 BRDA enlarges due to the increased hydraulic head associated with successive rises in stack height. Similarly there is a potential for additional leakage of contaminated groundwater due to the raising of the existing BRDA as well as due to the raising of the SWP. Approximately a third of the Phase 2 BRDA footprint encroaches on Glenbane West. Of this area, there is approximately 7Ha where the seepage could potentially migrate away from the BRDA and further inland on Glenbane West. Further hydrogeological investigations are planned to assess and address this risk.

It is proposed to composite line the Phase 2 BRDA the PIC and the SWP. The linings will be installed in accordance with strict quality assurance procedures. However, some defects are likely to occur and this will result in seepages through the base which could potentially contaminate estuarine subsoils and groundwater. Seepage volumes through the composite lined system have been estimated (Golder Associates, Oct 2004) based on modeling using Monte Carlo simulations. The permeabilities used in the model simulations were those obtained as a result of on site tests. The results of total seepage estimates from the Phase 2 BRDA at Stage 10 including the perimeter interceptor channel (PIC) and SWP are summarized on Table 15. These are the 90%, 50% and 10% probability results. The 90% probability means that there is a 90% chance that the seepage value will be exceeded. The 10% probability means that there is only a 10% chance that the seepage value be exceeded and is therefore the worst case scenario represented. The 50% probability is the likely seepage value.

Table 15: Estimated Seepage Volumes (Golder Associates, April 2005).

STRUCTURE	SEEPAGE (m^3/day)		
	90%	50%	10%
Phase 2 BRDA	30	90	225
PIC	1	1	3
SWP	1	3	8
TOTAL	**32**	**94**	**236**

However, as the SWP was previously lined at its sides only there will be a reduction in the leachate volume infiltrating to groundwater from this area, which should result in an improvement in groundwater quality in this area. Potential receptors are habitats and wildlife in the estuary as well as groundwater users south of Poulaweala Creek.

Contaminant Transport Modelling

Contaminant Modelling was carried out by Golders as part of the preliminary design of the Phase 2 BRDA. For details of the modelling, refer to Golder Associates, Design report, April 2005. The primary objective of the contaminant modelling is to determine the likely concentration of key contaminants emanating from the Phase 2 BRDA. This is carried out probabilistically using Landsim software. Three key determinants have been used in the contaminant model; soda, aluminium and pH. The seepages used in the analyses are those given in Table 15 above. The values used in the contaminant analyses are based on the relevant values within the BRDA (i.e. north side piezometer) and the leached values from the red mud test work (refer section 1.4.3.7).

The Phase 2 BRDA has been modelled with a lifetime of 20 years after which the facility will be closed. After closure the renewal of the source of contamination is cut off although the peak contaminant plume may not have arrived at the receptor.

The receptor for estimating the contaminant concentrations in the groundwater is assumed to be immediately above the limestone aquifer at the downstream of the embankment wall toe of the BRDA. The peak contaminant levels are tabulated below for the 90%, 50% (mean) and 10% probability of exceedance. Two models were run, the first model assumes a thickness of 5 to 10m of estuarine soils and glacial till overlying the limestone, which prevails over much of the footprint of the Phase 2 BRDA. The second model assumes only 0 to 1m of glacial till over the limestone which is expected to be the stratigraphy beneath the footprint of the Phase 2 BRDA located on the mainland of West Glenbane and parts of the Island Mac Teige. Because of the limited thickness of the low permeability glacial till over the limestone, the travel time of the contaminant plume to the top of the aquifer and to the downstream toe of the perimeter interceptor channel will be considerably faster.

The determinant concentrations used are tabulated below for a triangular distribution of probability of occurrence.

Table 16: Determinant Concentrations Used in Modelling Seepage (Golder Associates, April 2005).

Species	Minimum (mg/l)	Average (mg/l)	Maximum (mg/l)
Aluminium	200	400	600
Soda	3500	4000	4500
pH	12	12.5	13.0

The results of the analysis are presented below for time intervals of 10 years, 30 years and 100 years for the 5 to 10m of estuarine soils and glacial till over the limestone.

Table 17: Modelling Results for 5 to 10m of Estuarine Soils/Glacial Till over Limestone (Golder Associates, April 2005).

10 years			
	90% Peak Conc. (mg/l)	**50% (Av.) Peak Conc. (mg/l)**	**10% peak Conc. (mg/l)**
Species	D/S toe BRDA	D/S toe BRDA	D/S toe BRDA
Aluminium	0	0	0
Soda	0	0	20
pH	7.5	7.5	12.2
30 years			
	90% Peak Conc. (mg/l)	**50% (Av.) Peak Conc. (mg/l)**	**10% peak Conc. (mg/l)**
Aluminium	0	10	190
Soda	20	100	2350
pH	10.2	12.1	12.7
100 years			
	90% Peak Conc. (mg/l)	**50% (Av.) Peak Conc. (mg/l)**	**10% peak Conc. (mg/l)**
Aluminium	20	190	350
Soda	300	2570	3500
pH	12.0	12.2	12.8

Virtually all the seepage emanating from Phase 2 BRDA will be directed towards the saline groundwater between the Robertstown River and the Poulaweala Creek. The contaminant plume will be neutralised by buffering of soda ions from the saline groundwater. The saline groundwater has very high soda content and very high conductivity. The pH values at the receptor are conservative and do not take into account any dilution by rainfall infiltration. It is likely that the contaminant plume will take between 10 and 30 years to reach a receptor some 50m away.

The thinner soils overlying the limestone in West Glenbane and areas of the Island Mac Teige will allow for the rapid migration of contaminants and this is indicated by the results of the analysis. These are presented below for time intervals of 3 years, 10 years, 30 years and 100 years for 0 to 1m thickness of glacial till over the limestone.

Table 18: Modelling Results for 0 to 1m of Estuarine Soils/Glacial Till over Limestone (Golder Associates, April 2005).

	3 years		
	90% Peak Conc. (mg/)l	**50% Av. Peak Conc. (mg/l)**	**10% peak Conc. (mg/l)**
Species	D/S toe BRDA	D/S toe BRDA	D/S toe BRDA
Aluminium	0	0	40
Soda	0	10	300
pH	7.5	7.5	11.8
	10 years		
	90% Peak Conc. (mg/)l	**50% Av. Peak Conc. (mg/l)**	**10% peak Conc. (mg/l)**
Aluminium	0	30	150
Soda	0	250	1500
pH	7.5	11.3	12.5
	30 years		
	90% Peak Conc. (mg/)l	**50% Av. Peak Conc. (mg/l)**	**10% peak Conc. (mg/l)**
Aluminium	20	90	250
Soda	200	1000	2500
pH	10.8	11.9	12.7
	100 years		
	90% Peak Conc. (mg/)l	**50% Av. Peak Conc. (mg/l)**	**10% peak Conc. (mg/l)**
Aluminium	30	130	290
Soda	350	1500	3000
pH	11	12.4	12.8

It is likely that the contaminant plume will take between 3 to 10 years to reach a receptor some 50m downstream of the BRDA. Virtually all of the contaminant plume will mix with saline groundwater adjacent to the Poulaweala Creek and Robertstown River.

The average seepage that could migrate to the mainland on Glenbane West based on a composite lined facility is estimated to be 9m^3/day. The resulting contaminant concentrations at the downstream toe of the perimeter interceptor channel are tabulated below.

Table 19: Modelling Results for 0 to 1m of Estuarine Soils/Glacial Till over Limestone with Composite Liner (Migrating Towards Glenbane West) (Golder Associates, April 2005).

10 years			
	90% Peak Conc.(mg/)l	**50% Av. Peak Conc.(mg/l)**	**10% peak Conc.(mg/l)**
Species	D/S toe BRDA	D/S toe BRDA	D/S toe BRDA
Aluminium	0	15	100
Soda	0	120	1100
pH	7.5	11.0	11.4
30 years			
Aluminium	5	50	190
Soda	95	550	2045
pH	10.4	11.6	12.7
100 years			
Aluminium	15	90	245
Soda	180	970	2150
pH	10.7	11.9	12.8

With a double composite lined facility, the seepage through the bottom lining is reduced significantly to approximately a mean value of 20 litres/day and at this volume there would be a slight impact to the quality of ground water.

1.7 REMEDIAL OR REDUCTIVE MEASURES

1.7.1 Plant Area

1.7.1.1 Construction Phase

A site management plan will be prepared for the control of pollution to soils and water during extension of the bauxite storage area. Construction staff will be trained and an on site representative will be responsible for its implementation.

In order to prevent the accidental release of hazardous materials (fuels, paints, cleaning agents, etc.) during construction site activity, all hazardous materials will be stored within secondary containment designed to retain at least 110% of the storage contents. Temporary bunds for oil/diesel storage tanks will be used on the site during the construction phase of the project. Safe materials handling of all potentially hazardous materials will be emphasized to all construction personnel employed during this phase of the project.

A sediment erosion control plan will be employed during the construction phase. The plan will include the following measures:

- Interceptor drains, siltation ponds and silt traps will be employed to channel surface runoff from construction areas and trap silt prior to discharge to surface waters.
- Construction activities will be scheduled such as to minimise the area and period of time that soil will be exposed.
- Disturbed ground adjoining new roadways will be regraded and revegetated on completion of roadways.
- Vehicular movement will be restricted to prevent unnecessary erosion.

1.7.1.2 Operational Phase

A groundwater management strategy is in place incorporating prevention, containment and recovery:

- Tank overflow events are minimised by a high level alarm system which generates alarms to a number of key individuals.
- Bunding structures and underground process effluent and sewer pipelines are inspected and tested on a three-year cycle. Visible cracks and other defects are repaired and drop tests employing dye are carried out to determine leak-tightness. A major programme of steel plating of sumps, wet bunds and process drains is underway. All non-process effluent drains (sanitary) have been tested and significant effort has been invested in repairing and resealing lines were necessary.
- The groundwater recovery and recycling program captures all flowing streams above pH 9 (currently capturing ES1, ES7/12 and ES 16, TT4, POW1, POW17 and A38 boreholes) and routes them to the effluent treatment area. Furthermore, a deep abstraction well will be installed at POW1, the West Pond, East Pond, Area 9: Calcination and TT4.
- Groundwater quality monitoring will continue at the estuarine springs, plant observation wells and turlough. This will act as an ongoing indication of groundwater quality to which appropriate response measures will be implemented as necessary.

1.7.2 Phase 2 BRDA, SWP and LWP

1.7.2.1 Construction Phase

Soils

Topsoil stripped will be temporarily stockpiled for use in the restoration of the side slopes of the Phase 1 and the construction of the Phase 2 BRDA. Topsoils designated for the rehabilitation of the lower slopes of Phase 1 will be placed immediately. The remaining topsoil will be stockpiled on site in designated areas. They will have a side slope of less than 2H:1V and a max height of 5m.

The organic and estuarine material from the unsuitable stockpiles will be mixed in with the stockpiled topsoils. Cobbles and boulders from the processing of glacial till within the unsuitable stockpile will be used for backfilling the existing drainage ditches.

Vegetation and organic debris cleared from existing drainage ditches will be reused in landscaping where feasible. Otherwise it will be stockpiled on site in designated areas.

Depending on the condition of the existing gabions in the SWP, they will be reused in construction. The proposed raising of the SWP will require the removal of sediment which will be placed in the BRDA as per the existing IPC Licence

Glacial till will be reused on site as borrow material. Additional rotary drilling and excavations will be carried out prior to the detailed design to confirm the glacial till quantities. Trial pitting will be undertaken to determine the amount of unsuitable material to be removed in the stockpile areas which encroach on the embankment footprint on the north east flank. Current estimates based on trial pit excavations indicate an upper limit of 250,000 m^3 of processed glacial till would be available for re-use.

A site management plan will be prepared for the control of pollution to soils during construction. Construction staff will be trained and an on site representative will be responsible for its implementation.

In order to prevent the accidental release of hazardous materials (fuels, paints, cleaning agents, etc.) during construction site activity, all hazardous materials should be stored within secondary containment designed to retain at least 110% of the storage contents. Temporary bunds for oil/diesel storage tanks should be used on the site during the construction phase of the project. Safe materials handling of all potentially hazardous materials will be emphasized to all construction personnel employed during this phase of the project.

A sediment erosion control plan will be employed during the construction phase. The plan will include the following measures:

- Interceptor drains, siltation ponds and silt traps will be employed to channel surface runoff from construction areas and trap silt prior to discharge to surface waters.
- Construction activities will be scheduled such as to minimise the area and period of time that soil will be exposed.
- Disturbed ground adjoining new roadways will be regraded and revegetated on completion of roadways.
- Vehicular movement will be restricted to prevent unnecessary erosion.

Geology

Additional rotary drilling and excavations will be carried out prior to the detailed design to confirm the rippability of the near surface bedrock. Excavated rock will be used in the construction of the Phase 2 BRDA. The balance of rockfill material will be sourced from the quarry at Barrigone which lies approximately 1km to the south.

Hydrogeology

A site management plan will be prepared for the control of pollution to water, including groundwater, during construction. Construction staff will be trained and an on site representative will be responsible for its implementation.

In order to prevent the accidental release of hazardous materials (fuels, paints, cleaning agents, etc.) during construction site activity, all hazardous materials will be stored within secondary containment designed to retain at least 110% of the storage contents. Temporary bunds for oil/diesel storage tanks will be used on the site during the construction phase of the project. Safe materials handling of all potentially hazardous materials will be emphasised to all construction personnel employed during this phase of the project.

The loss of observation wells for the existing BRDA will be mitigated by installing a network of groundwater monitoring wells beyond the perimeter of the proposed extension within appropriate water bearing horizons in the estuarine and glacial deposits and bedrock. The locations of the bedrock monitoring wells will be determined with the aid of geophysics to target water bearing fracture zones. A spacing interval around the perimeter of approximately 200m within the bedrock and 100m within the subsoils is proposed. In addition three new monitoring wells are proposed within the estuarine deposits, glacial till and bedrock to the north of the SWP. Baseline water quality monitoring and water level monitoring will be undertaken in all wells prior to operation of the Phase 2 BRDA.

The water level in the PIC will be reduced to as low as possible by allowing water to be pumped into the Phase 2 BRDA once completed. The water level in the LWP will be dropped as far as practically possible to reduce seepage into the excavation of the SWP. Construction work on the SWP raising will be undertaken during the summer.

Contaminant seepages which could arise from the structures adjacent to the SWP (Phase 1 DRDA, PIC and LWP), will be assessed and remediation instigated during construction of the SWP raising. This may take the form of sealing with clay/bentonite or by collecting and pumping from beneath the lining.

A comprehensive quality assurance programme will be carried out during the construction of the facility to ensure that it will function according to its design intent during the operational stage. This will include

- Testing the permeability of the clay lining for every 10,000m^3 of glacial clay lift placed.
- Monitoring of pore pressure development in the estuarine soils and glacial till foundation materials will be undertaken during construction using piezometers.
- The installation of the geomembrane and the geotextiles will be in accordance with manufacturer's guidelines, contractors method statements and the construction drawings.

A geophysical leak detection survey will be undertaken after the geomembrane has been installed.

1.7.2.2 *Operational Phase*

Hydrogeology

In order to prevent leakage of contaminants to soil and groundwater, the proposed Phase 2 BRDA, PIC, and SWP will be composite lined with a series of low permeability materials to be approved by the EPA. This lining will form a barrier within which potential contaminants will be contained within the BRDA. The composite liner currently proposed comprises:

Table 20: Details of composite liner

Perimeter Interceptor channel	Thickness	Permeability (m/s)
Concrete Working Surface (allows machine access for maintenance)	100mm	-
Terram 2000/500grms geotextile	-	-
2mm thick Smooth HDPE	2mm	-
Processed Glacial Till	Minimum 1000mm thick on side slopes and 300mm thick at the base	$\leq 10^{-9}$
Geosynthetic clay liner	10mm	10^{-11}

Phase 2 BRDA Basin Area	Thickness	
Smooth HDPE	1.5mm	
Geosynthetic clay liner or Bentonite enriched soil	10mm 300mm thick	10^{-11}

Phase I Downstream Slope and Phase 1 Embankment Walls Extension	Thickness	
Smooth HDPE	2 mm	
Geosynthetic clay liner	10mm	10^{-11}
Processed Glacial Till	300mm thick	$\leq 10^{-9}$

SWP	Thickness	
Side Slopes		
Smooth HDPE 2mm	2mm	
Geosynthetic clay liner 10mm	10mm	10^{-11}
Processed Glacial Till		$\leq 10^{-9}$
Base If Dry	**Base If seepages**	
GCL	Geosynthetic clay liner	10^{-11}
Geotextile	Processed Glacial Till 1m	$\leq 10^{-9}$

LWP	Thickness	
HDPE	2mm	
Geosynthetic clay liner		10^{-11}

A double composite lining is being considered in a 7ha area where the Phase 2 BRDA footprint encroaches on West Glenbane and where seepage could migrate further inland. The double composite lining system will consist of two composite linings of 2mm HDPE underlain by GCL with a drainage blanket in between. Any leakage through the upper composite lining system would be collected in a 500mm thick drainage blanket above the lower composite lining system and pumped to the perimeter interceptor channel. This is a very conservative approach and during the detailed design phase additional site work, topographical survey work and detailed contaminant modelling will be undertaken to determine where the double composite lining system is required and its lateral extent. The majority of seepage from the Phase 2 BRDA located on West Glenbane will migrate towards the Poulaweala Creek underneath the facility and will be buffered by the saline ground water.

Further, site investigation work will be undertaken along this section to determine the regional groundwater flow, together with the mass in situ permeability of the limestone and presence and thickness of any glacial till capping the limestone. Also, the topographical survey will be completed in this area along with surveying in monitoring well elevations. Modifications may be made to the proposed lining system at the detailed design stage.

During operations of the Phase 2 BRDA, any contaminant plume emanating from the BRDA and onto the mainland of Glenbane West will be identified by the monitoring well system. Further work using resistivity geophysical techniques will be undertaken to pin point the plume. Pumping from the monitoring wells will be undertaken to contain the contaminated plume and the water discharged into the perimeter interceptor channel.

A geophysical resistivity survey has defined the extent of the contaminant plume from the SWP leakage. This is estimated to be approximately 110m across and extends laterally at least 240m into but below the surface of the bird sanctuary to the north of the SWP. The geophysicas determined that the contaminant plume is confined to the limestone by the glacial till and low permeability of the estuarine soils beneath the bird sanctuary. This agrees with the current understanding there is a connection between the glacial till and the bedrock in OW1. Although it difficult to predict precisely it is possible that the contamination has extended to a depth of between 40m and 80m below ground level. It has been concluded that no impact to the bird sanctuary is envisaged from the high alkalinity contaminant plume travelling in the limestone through brackish water to the estuary. Aughinish island is hydrogeologically isolated from the mainland and the contaminant plume will be eventually neutralised via pH buffering by the surrounding saline intrusion zone within the groundwater. The groundwater on the island is not abstracted.

Following investigation of cause and extent, a containment and repair programme is proposed. Interim remedial measures are underway until the stormwater pond can be desludged and relined as per the proposed development: groundwater from OW 1 and 2 are pumped back to the storm water pond, and subsequently on for treatment, on a continuous basis. In the short term, it is proposed to reduce recharge of contaminants into the limestone outcrop beneath the SWP by recovery pumping from specifically designed abstraction wells. The first will be located in the dividing wall between the SWP and the LWP and will extend to 30m within the limestone bedrock. In addition, it is proposed to recover the accumulated leakage by an abstraction well immediately downstream of the SWP designed to intercept the existing contaminant plume as it exits the SWP and pumping the contaminated water back to the SWP. Three new observation wells will be installed downgradient of the SWP to monitor groundwater quality at multi levels within the estuarine deposits, glacial till and bedrock. This will clarify whether the contamination is restricted to the bedrock as it believed.

The long term solution to prevent the leakage will be to reline the SWP, as described above. This will require an alternative storm water storage facility while the existing SWP is emptied and out of service for at least 6 months to facilitate the relining of the pond. This will only be feasible when the new lined area of the Phase 2 Bauxite Residue Disposal Area (BRDA) is available in circa 2008.

The existing groundwater monitoring network along with the newly installed wells north of the SWP and around the Phase 2 extension will be monitored on a regular basis as per IPCL requirements. Water quality and water level monitoring will be undertaken at an appropriate frequency to act as an early warning system for the migration of contaminants from the proposed extension such that appropriate remedial measures can be implemented if necessary.

1.7.3 Predicted Impact of the Proposal

The excavation and removal of soils, subsoil and weathered/outcropping bedrock will result in a permanent negative impact to the soils and geology where excavation occurs on the site. The impact will be limited to areas where excavation will occur, namely where unsuitable soils occur or in areas where bedrock is at or near surface. The subsoils and bedrock encountered below the site are commonly occurring in the area and are not considered being of economic value as a mineral resource.

Given the groundwater management strategy being put in place at the AAL Plant, the increased production should not result in increased groundwater contamination or increased migration of contaminants to the estuary. It is anticipated that the bund and drain steel plating programme will render all estuarine springs (ES) below pH 9. Ongoing monitoring will confirm this.

The capping of the existing salt cake area in the unlined BRDA and construction of a new salt cake area in the lined Phase I extension represents a *positive impact* on soil and groundwater quality as the source of potential contaminants will be reduced. Current monitoring indicates no leakage of contaminants to groundwater down-gradient of the lined extension.

The lining of the Storm Water Pond at its side and base represents a positive impact of the proposed development as it is anticipated to result in an improvement in groundwater quality beneath the pond and consequently beneath the bird sanctuary in the estuary. The raising of the SWP will allow effluent in the LWP to be temporarily stored in the SWP such that its lining can be inspected and repaired if necessary, further improving groundwater quality.

The Phase 2 BRDA will be composite lined and groundwater quality will be monitored in wells immediately downgradient of the facility. Given the mitigation measures proposed to control and manage potential pollutions sources, the impact to groundwater quality from these materials is predicted to be slight provided the mitigation measures recommended are adhered to.

1.8 MONITORING

1.8.1 Construction Phase

Monitoring of pore pressure development in the estuarine soils and glacial till foundation materials will be undertaken during construction using piezometers.

Prior to construction, groundwater levels in the existing monitoring wells installed at the perimeter of the Phase 2 BRDA and in the extension area will be monitored on a regular basis. Baseline water quality monitoring will also be undertaken for a suite of parameters, subject to EPA approval, comprising pH, conductivity, alkalinity, soda, fluoride, metals (aluminium, arsenic, cadmium, chromium, copper, iron, mercury, nickel, lead, zinc), magnesium and sulphate.

In addition to the existing monitoring wells to be retained, baseline water quality monitoring will be undertaken in the monitoring wells to be installed downstream of the new PIC.

1.8.2 Operational phase

The following monitoring will be undertaken during the lifetime of the facility:

- The piezometric levels at the base of BRDA to monitor the head and any seepages across the geomembrane;
- The phreatic surface in the red mud during its life;
- pH, conductivity, and other water quality measurements as above to be agreed with the EPA in the monitoring wells immediately downstream of the perimeter interceptor channel.

1.7.3 Reinstatement

Where possible, any remaining topsoil will be separated from the underlying till subsoil during soil stripping so that the topsoil can be used to cover any landscape planting created with the subsoil material. Any available mineral rich topsoil will provide a base for landscape planting.

Vegetation and organic debris cleared from existing drainage ditches will be reused in landscaping where feasible.

Subsoils which have been removed will be re-used where suitable on site as general fill material within landscaping mounds.

Where possible the excavated rock material will be re-used on site as rockfill material.

Otherwise normal post construction re-instatement will take place.