REPORT

EIA For Ash Co-Disposal For Bluewaters III and IV

Prepared for

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Section 1 Introduction

ES 1 Executive Summary

The disposal of Ash generated by Bluewater III & IV power plants with run-of-mine overburden sediments from the Ewington II mine, is the focus of this report. This report builds on the earlier work to provide an overall view of the disposal of Ash from the approved Bluewaters I & II power plants and Ash from the proposed Bluewaters III & IV power plants with run-of-mine overburden sediments at both the Ewington I & II mines.

The results of bulk leaching test following Australian Standard Leaching procedures using 1:20 mix with rainfall equivalent deionized water indicates the following regards the potentials for leaching of metals from the run-of-mine overburden from Ewington II and Muja power station ash:

- Ash releases aluminium, arsenic, beryllium, boron, cadmium, chloride, cobalt, copper, iron, nickel, manganese, sulphate and zinc in trace amounts.
- Ash releases aluminium, cadmium, manganese, and nickel at levels above the Australian Drinking Water Guidelines (ADWG).
- Composite overburden predominantly releases aluminium, boron, cadmium, chloride, cobalt, copper, fluoride, iron, nickel, manganese, and zinc in trace amounts
- Overburden releases aluminium, iron, and nickel at levels above ADWG

Results of the field investigation of the infiltration capacities of the overburden on run-of-mine dumps indicates the measured capacities were highly variable and ranged from 0.22 m day^{-1} to 18.1 m day^{-1} . These results are from what is believed to be the most representative method, that involving a maintaining a 5 cm constant head in 0.2m diameter bucket. The results of the site investigation at Ewington two are indicative of a more permeable overburden as opposed to a less permeable one.

Sampling results of runoff and surface water from coal measures, overburden and in-pit sumps indicates this water :

- is acidic with pH measured between 3.22 to 4.90;
- is fresh to brackish, with conductivity in uS/cm between 43 to 2,640, and with major cations and anions within previous ranges measured in the mines;
- contains some relatively high sulphate and sulphur concentrations, up to 1,390 mg/L and 464 mg/L, respectively;
- contains some relatively high aluminium and Zinc concentrations; up to 127 mg/L and 21.4 mg/L, respectively;
- exceeds compliance criteria for iron (less than 3.0mg/L) in 3 of the 14 samples, and for manganese (less than 0.5 mg/L) in 2 of the 14 samples (Water Authority, Water Resources Directorate July 1988);
- Exceeds the Australian Drinking Water guideline value of the drinking water standard for the following constituents: Cadmium (0.002 mg/L); Lead (0.01 mg/L); Selenium (0.01mg/L); and Sulphate (250 mg/L).

The results of the analyses of ground water samples from the five production bores and one piezometer indicate that, pH, Conductance, major cations and anions are within the range of previous groundwater samples in the area. In addition the following results are of note:

- exceeds compliance criteria for iron (less than 3.0mg/L, Water Authority, Water Resources Directorate July 1988); and,

- does not exceed the health guideline value of the Australian Drinking Water guideline for any other constituent..

Water balances for Ewington I and Ewington II during mining and for closure were developed. These water balances are intended to provide context for water and solutes generated from the areas of Ash Co-disposal relative to those generated from the surface water catchment (8.1 km^2 for Ewington 1 and 13 .9 km^2 for Ewington II) and groundwater catchment(46 km^2). The catchment areas of the ash co-disposal areas are 6.35 km^2 and 5.9 km^2 for Ewington 1 and Ewington II, respectively.

Regarding the contribution of infiltration of rainfall through Ash to the salinity, aluminium, iron, and zinc solute loads in the overall catchment area, they are minor for both pre-closure and post closure conditions. While infiltration of rainfall in the area of Ewington I and II Ash Co-disposal contributes between 17 % to 2 % of the total water budget during pre-closure and post closure, respectively, the contribution to the solutes is generally less than 1% of the total solute load in the total Catchment . In general the infiltration of rainfall through the overburden portion of the Ash Co-Disposal area, and from runoff from overburden in the Ash Co-Disposal area contribute more to the overall solute loading in the catchment as a whole, than does the Ash for both Pre- and Post Closure.

Simulations of groundwater flow and solute transport at Ewington II were performed to investigate ash co-disposal impacts on the ground water table. The distribution of solutes based on FEFLOW model, adapted to reflect ash co-disposal as integrated with current mine plans and design pit dewatering borefields are presented. Results of the predictive modelling (mining and final void) show the dilution of solute concentrations in the water table zone, understanding that the simulated original solute concentrations were Aluminium, 14.8 mg/L; Cobalt, 0.1 mg/L; Nickel, 0.04 mg/L; Sulphate, 56.6 mg/L; and, Zinc, 0.3 mg/L. The solute concentrations are typically diluted by two to ten times in the water table within the Premier Coal Measures. Transport of the solutes is towards the eastern Ewington I where the stratigraphy to be mined and production bores are deepest and last developed.

Water resources management and monitoring recommendations to verify the predictive findings include:

- Further definition of baseline surface water and groundwater environments.
- Characterisation of runoff from areas disturbed by mining to determine impacts of mining on the surface water quality.
- Better characterisation of the effects of the overburden dumps on groundwater quality.
- Establishment of monitoring bore network at the Ewington I and Ewington II Mines to measure the potential impacts of ash co-disposal on the groundwater environments.

INTRODUCTION

Griffin Energy is seeking regulatory approvals for the construction of Bluewaters III & IV power plants. A direct result of the increased power generation from Bluewater III & IV would be the doubling of the ash generated by Bluewaters I & II power plants. In total about 700,000 tons per annum (tpa) of Ash would be generated by the approved (Bluewaters I & II) and proposed (Bluewaters III & IV) power plants.

Ash co-disposal, that is the disposal of Ash generated by Bluewater I & II power plants with run-of-mine overburden sediments from the Ewington I mine, was addressed in URS (2008). The disposal of Ash generated by Bluewater III & IV with run-of-mine overburden sediments from the Ewington II mine, is the focus of this report. This report builds on the earlier work to provide an overall view of the disposal of Ash from the approved Bluewaters I & II power plants and Ash from the proposed Bluewaters III & IV power plants with run-of-mine overburden sediments at both the Ewington I & II mines.

Solutes from the disposed ash are expected to be transported by rainfall infiltration to both the active mining environment and the water table. Subsequent to mining, the final mined void would be expected to form a long-term groundwater sink and be the local focus of groundwater flow. The solutes from the co-disposed ash may be of comparatively low pH and characterised by metals concentrations that may exceed ANZECC Guidelines for fresh water aquatic ecosystems.

The run-of-mine overburden sediments also typically generate acidic runoff and solutes that may have metals concentrations that exceed guidelines for fresh water aquatic ecosystems and drinking water. Coal measures successions and Collie Basin groundwater resources are typically characterised by limited acid buffering capacity.

The objectives of this study is to demonstrate and understand the potential issues and environmental impacts associated with solutes, outline management strategies that mitigate environmental risks and provide a sustainable approach to the ash co-disposal.

Section 2 Scope of Report

The scope of this report is to build on previous and current studies evaluating the impact on the local groundwater resources from solutes generated by Ash from the Bluewater power plants (I to IV) being co-disposed with overburden from the Ewington I & II mines. Specific objectives addressed by this report include the following:

1. Determination of the potentials for leaching of metals and organics from the run-of-mine overburden and power station ash.
2. Characterise infiltration capacities of the overburden on run-of-mine dumps. A site investigation to determine the rates of infiltration on current, recent and aged overburden dump surfaces.
3. Sampling results of runoff and surface water from coal measures, overburden and in-pit sumps. This sampling is useful in providing indications of the varied contributions of surface water and groundwater to the pit water and salt balances and surface water quality.
4. Sampling results of groundwater from existing multipiezometers to expand the baseline quality database, particularly metal concentrations.
5. Water balances for Ewington I and Ewington II during mining and for closure. These water balances are intended to provide context for the catchments hosting co-disposed ash compared to the entire pit and final void catchments.
6. Salt and soluble metals balances for Ewington I and Ewington II during mining and for closure (final voids). These salt and soluble metals balances are intended to provide context for the catchments hosting co-disposed ash compared to the entire pit and final void catchments.
7. Simulations of groundwater flow and solute transport at Ewington II to investigate ash co-disposal impacts on the water table and surface water. The simulations will use a FEFLOW model, adapted to reflect ash co-disposal as integrated with current mine plans and design pit dewatering borefields.
8. Evaluation of the Ewington I and Ewington II ash co-disposal and closure voids in context with long-term water supply strategies outlined in “Water Source Options in the Collie-Wellington Basin”.

Section 3 Background

The Collie Basin predominantly hosts fresh groundwater resources and fresh water ecosystems. In a broader context, the Wellington Catchments has previously been used for domestic water supplies and historically also hosts fresh water ecosystems. In the future, there is potential that the groundwater resources of Ewington I and Ewington II may be diverted to domestic beneficial uses. This opportunity is framed in “Collie-Wellington Basin Water Source Options Steering Committee; Water Source Options in the Collie-Wellington Basin 2007”.

Ewington I and Ewington II occur in the Premier Sub-basin of the Collie Basin (Figure A-1). Mining development of Ewington I is yet to commence. Development of Ewington II by a truck and shovel mining method commenced in December 1995. Initial mining is framed on starter pit excavations where coal seams sub-crop at shallow depths, with overburden disposed in pit-perimeter areas. Subsequently as the pit is expanded and deepened, overburden is disposed in dumps that backfill the mined void.

Both Ewington I and Ewington II are characterised by shallow water table settings. Both mines will excavate beneath the water table, with dewatering ahead of mining being an integral part of pit development. Local groundwater resources are fresh and acidic, with Total Dissolved Solids (TDS) concentrations typically less than 300 mg/L and pH in the range 4.9 to 5.5.

In a local context it is understood that both during mining and for a long period after mining (and perhaps indefinitely), the mined void would form a surface water and groundwater sink. During mining, it is intended that all surface water and groundwater catchments associated with the areas of co-disposed ash would be diverted to the pits. Leachates linked to the co-disposed ash would be intercepted by pit dewatering infrastructure, including in-pit sumps. After mining, both surface water and groundwater flows would occur to the final mined voids. For tens of decades the final voids would host pit lakes characterised by water levels substantially lower than the natural water table setting. Ultimately, the pit lake levels are expected to stabilise at elevations marginally below the natural water table setting, thus forming a long-term sink.

Elevation of the steady-state pit lake levels would be influenced by the lake surface areas (associated with evaporation losses) and the extents of the surface water catchments.

In a regional context, the Ewington I and Ewington II Mines are located within the drainage basin of the Collie River East and South branches, which ultimately lead to the Wellington Dam. Any outflows from Ewington I and Ewington II, either as surface water or groundwater throughflow would probably be within the catchment of the Collie River South Branch.

It is also possible in the longer-term after mining that the final voids would be used to harvest water resources for industrial and/or domestic water supplies.

3.1 Characteristics of Collie Group Sediments

Numerous studies of the Collie Group, that forms the Permian coal measures of the Collie Basin, have been undertaken. Many of these studies have a research basis (such as for the Australian Coal Association Research programme), linked to understanding the acidity associated with mined voids in the Collie Basin. Results from these studies assist in the characterisation of the Collie Group mineralogy and water quality in post-mining settings. The studies have been focussed on three coal mining areas: WO5B (Lake Kepwari, in the Muja Coal Measures), Chicken Creek Area 4C (Premier Coal Measures) and Ewington 2 (Ewington Coal Measures).

Kaolinite and quartz are the typical major minerals of the Collie Group. Dissolution of kaolinite provides sources of aluminium, calcium and magnesium. Both kaolinite and quartz provide sources of silica. The Collie Group also hosts pyrite (FeS_2). In comparative terms, however, the sulphur contents are low in both the overburden and coal of the Collie Group. Pyrite may be a contributing cause of acidity. A primary reaction to generate acid is sulphide mineral oxidation, due to the presence of atmospheric oxygen. Oxidation may also be promoted microbially, increasing the rates of reaction for acid generation.

In acidic environments, pyrite weathers to jarosite ($KFe_3[SO_4]_2[OH]_6$). The presence of jarosite is observed in the near surface zones of overburden dumps at WO5B (Susanto, 2001), indicative of pyrite oxidation. Gibbsite ($Al[OH]_3$) is also present at WO5B, indicating the precipitation of aluminium, occurrence of comparatively low aluminium concentrations in Lake Kepwari and potential aluminium – hydroxide buffering.

The formation of iron-sulphate minerals is interpreted to reduce the acidity of mine waters:

- Oxidation of iron results in an irreversible loss of acidity, which limits further decreases of pH.
- Precipitation of iron-sulphate minerals (such as jarosite) is a mechanism to reduce concentrations of iron and sulphate in solutes and pit lakes. The precipitated minerals may be meta-stable and subject to dissolution, thus not necessarily limiting future generation of acid (Susanto, 2001).
- Precipitation of aluminium-sulphate minerals (such as jurbanite) is a mechanism to reduce concentrations of aluminium and sulphate in solutes and pit lakes.

Correlations of surface water pH with the mineralogy of catchment sediments (Dinelli and Tateo, 2002) indicate:

- Sites dominated by iron-based minerals have significantly lower pH compared with aluminium-based minerals and detrital material.
- Solutes with pH 2 to correspond with iron (III) buffering.
- Solutes with pH 4 to 5.5 are buffered by aluminium (III).
- Solutes with pH 6 to 9 are normal carbonate buffering (Susanto, 2001; Nixdorf et al., 2000).
- The ratio of iron to aluminium in sediments may be a guide to acidity.

Overburden samples have been collected from shallow 2.4 to 2.7 m depth holes in the WO5B dumps (Craven, 2003). The samples, of different colour and composition (Table 3-1 and Table 3-2), were subject to static batch acid generation tests over a duration of six days.

Table 3-1 Summary of Samples and Acid Generation Tests at WO5B

Sample	Description	Solute pH		Electrical Conductivity (µS/cm)	Redox Potential (Mv)
		Day 2	Days 4 to 6		
B2	Dark grey	-	-	-	-
B3	Mid-grey	4.15	4.15	621	-
BF	Black, some orange	4.14	4.14	616	-
WF	White/grey	4.33	4.36	162	-
S1	Orange	4.85	5.68	228	147
S2	Dark grey	3.76	3.74	731	194
S3	Brown	4.51	7.40	408	159
S4	Dark grey	3.37	3.38	1,247	269
S5	Black/orange	3.56	3.55	911	258
S6	Beige	4.68	4.70	443	203
S7	Brown	4.90	5.77	210	133
S8	Black	3.07	3.07	2,110	300
S9	Beige	5.76	5.91	98	168
S10	Orange	5.48	6.25	146	162

Table 3-2 Summary Results of Batch Tests at WO5B

Colour	Samples	Final pH Range	Electrical Conductivity (µS/cm)	Redox Range (Mv)
Grey/black	S2, S4, S5, S8	3.07 – 3.73	730 – 2,110	194 – 300
Dark, mixed	BF, B3	4.14 – 4.15	616 – 621	-
Pale	WF, S6	4.36 – 4.70	162 – 443	203
Brown/orange	S1, S3, S7, S10	4.70 – 6.25	146 - 408	133 - 162

The batch test results reflect varied acid generation within individual samples. Measured pH varies in the range 3.1 to 5.8. Samples with an initial pH > 4.5 showed a significant increase over six days. Samples below pH 4 showed a steady trend, with little variation over the six days. Further, the batch test results demonstrate rapid reaction times once wetting occurs, with the most dramatic changes in pH, Electrical Conductivity and redox potentials evident during the first day.

The results indicate:

- Poor correlations between iron to aluminium ratios versus pH.
- A stronger correlation between total carbon (percent by weight) versus pH.
- Dark grey to black samples have considerable acid generation capacity, typically linked to comparatively high iron contents (ppm), with the iron in forms that are soluble.
- Conductivity and redox potentials for the dark grey to black samples are comparatively higher than for other samples.
- Pale samples and those brown to orange in colour showed little to very little acid generation and comparatively low redox potentials.

Redox values from the batch experiments are between the manganese and iron reduction zones defined by Hemond and Fechner – Levy (2000). As such, the generated acid is due to either:

- Mineral dissolution in the presence of water and oxygen.
- Oxidation of pyrite and other minerals through reaction with iron (III), not oxygen.

As all redox values are above that for iron reduction (0 mV), mineral dissolution is probably the predominant cause of acid generation (Craven, 2003).

Column leaching tests on the same samples (B2, BF and BW) showed (Craven, 2003):

- Initial pH in the range 3.95 to 4.80 increased over the first day of irrigation and again, to a lesser extent on the second day. Thereafter, the pH stabilised in the range 4.5 to 5.9.
- Electrical Conductivity values, initially about 1,000 µS/cm or more, declined to below 200 µS/cm during the first day of irrigation and subsequently showed further slow declining trends.
- Individual columns take about two days to reach a quasi-steady state.

Conclusions determined by Craven (2003) include that most sediments demonstrate acid generation. The predominant method of acid generation is secondary mineral dissolution, rather than sulphide oxidation.

At Ewington 2, the overburden sediments, as elsewhere, predominantly comprise quartz and kaolinite, with substantially subordinate goethite and gibbsite. Lake bed sediments are predominantly kaolinite, though in comparative terms they contain higher contents of sulphate, iron and aluminium than the overburden sediments. The occurrence of low sulphate, iron and aluminium concentrations in the Ewington 2 pit lake is interpreted (Sappal et al., 2000) to be due to the precipitation of associated secondary hydroxide and oxide minerals. This interpretation is supported by the occurrence of precipitated minerals ferrihydrite ($Fe[OH]_3$), goethite ($FeO.OH$), gibbsite ($Al[OH]_3$), jarosite ($KFe_3[SO_4]_2[OH]_6$) and jurbanite ($Al[SO_4][OH]5H_2O$)in the lake bed sediments, forming a sink for sulphate, iron and aluminium. This interpretation is similar to that by Craven (2003).

3.2 Infiltration within Overburden Dumps

Sediments in the overburden dumps do not have the same properties of undisturbed successions. The unsaturated zone is widely varied, incorporating fine-grained sediments, granular and boulder rocks, unconsolidated to compacted profiles and, dry to slurry-form deposits.

Flow in the unsaturated profile within the overburden dumps may occur in preferred paths, such as macro-pores, fractures and channels (Craven, 2003). The influence of macro-pores decreases with depth. The occurrence of preferred flow paths may limit potential for acid generation - reducing the extent (surface area) of overburden exposure to infiltrating water and oxygen. The wetting front may propagate quickly to significant depths, but bypass a large part of the overburden matrix (Craven, 2003).

Oxidising conditions prevail beneath the surface of the overburden dumps, promoted by the percolation of water and the availability of oxygen and organic matter. Infiltrating water may contribute to soil moisture, unsaturated flow or groundwater flow beneath the water table. Both sulphur and iron redox fronts propagate, with the weathering front, substantially beneath the surface of overburden dumps. Acid production varies both spatially and temporally. Based on the batch test results, acidity reactions are limited by water (infiltration) diffusion within pore spaces and oxygen concentrations in the overburden successions. Both aspects change with depth; the compaction and consolidation effects of increasing depth of burial impose limitations on the diffusion processes. Acidity generated in the unsaturated profile is transported by diffusive and advection processes.

Gerke et al., (1998 and 2001) simulated the solute leaching in overburden dumps from mining, exploring the effects of physical and chemical heterogeneity. The findings (Figure 3-1) provided by these investigations in heterogeneous settings over a 20-year period include:

- Penetration by infiltration to about 13 m depth.
- High pH of infiltrating waters.
- Increased buffering of acidic pH in a heterogeneous setting.

The results are dependent in part on the mineralogy of the overburden dumps. Notwithstanding, there are clear indications of limitations in acid generation, depth of burial and solubility. The precipitation and dissolution of secondary minerals affects the acid mine drainage, by locally retarding and releasing the solutes.

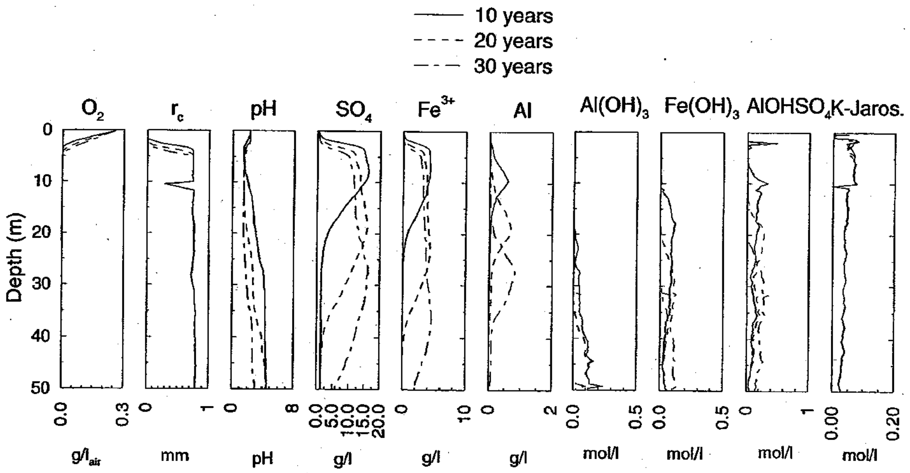

Figure 3-1 Vertical Profiles of Solute Concentrations in Overburden Dumps (*Gerke et al., 2000*)

3.3 Pit Lake Water Quality

The Collie Basin is characterised by numerous voids that are relics of prior coal mining activities. Many of the voids date back to the 1940s (Wallsend), 1950s (Black Diamond, Ewington No.1 (referred to as Bluewaters), Stockton and WO3), 1960s (Centaur and Ewington 2) and 1990s (WO5B (referred to as Lake Kepwari), WO5C, WO5D, WO5F, WO5H and Chicken Creek) and consequently have had extended periods for inundation. Each of the voids now hosts a pit lake. All of the pit lakes in the Collie Basin are characterised with acidity, with pH typically in the range from 3.5 to 4.5. The pit lakes are receptors for multiple water inputs, including rainfall, runoff, seepage from unsaturated overburden dumps, groundwater flow (both from overburden dumps and *insitu* Collie Group successions) and in several cases (Lake Kepwari, Chicken Creek Area 4C and Stockton) diverted stream flow. Comparative contributions from the various sources of water are expected to be widely varied, both spatially and temporally. Many of the pit lakes are much deeper than natural lakes or wetlands and this aspect influences their limnology and water balance. Early in their development the pit lakes form sinks that host both salts and dissolved metals. Over time, the pit lakes or parts thereof may develop a through-flow component to the water balance.

Sedimentary successions around the pit lakes vary from the Muja, Premier and Ewington Coal Measures, invariably exposed in the pit walls above the pit lake or in overburden dumps on adjacent areas.

Acidification of the pit lakes occurs through the interaction of water and sediments in a variety of different processes. The range of processes includes sulphide oxidation, dissolution of primary minerals, microbiological action that accelerate chemical reactions, precipitation of secondary minerals and weathering. Rainfall, runoff, infiltration within the unsaturated profile and groundwater flow provide sources of water that interact with the sediments. Acid input to lakes from overburden (unsaturated and saturated) may be minor compared with other processes, such as runoff and erosion. Topography influences both the magnitude of erosion and the rates of infiltration. Climate also plays a significant role, with variations of rainfall intensity and frequency of significant rainfall events providing influences on infiltration. These aspects may influence acid generation.

Acidity of pit lakes may also be limited by a lack of transport mediums for solutes generated within the adjoining unsaturated overburden dumps. Thus the acidity of the pit lakes may be dependent on the solubility of jarosite under prevailing pH conditions and a transport medium. In Lake Kepwari (Susanto, 2001), comparatively low sulphate concentrations reflect that the dissolution of jarosite and transport of solutes is limited. Levels of pH in the lake are typically steady, suggesting future change is unlikely.

Similar to other pit lakes in the Collie Basin, there are low concentrations of iron, aluminium and sulphate in Lake Kepwari (Susanto, 2001). This characteristic is interpreted to result from the formation of secondary minerals including jarosite, ferrihydrite, gibbsite, goethite and jurbanite as precipitates in the lake environment.

Measured water quality in Lake Kepwari is shown in Table 3. Sampling initially occurred in June 2001, at two locations and from depths about 1 m below the lake surface (Susanto, 2001). The pit lake at this time was understood to be fully mixed, thus without lateral or vertical stratification. Further sampling occurred in May 2006 (McCullough and Lund). At this time, the concentrations of aluminium, cobalt and zinc in Lake Kepwari exceeded drinking water quality guidelines. Aluminium is considered responsible (McCullough and Lund, 2006) for pH buffering. Aluminium toxicity is derived from its replacement of divalent metal complexes, specifically calcium and magnesium. Note that Lake Kepwari seasonally receives diverted stream flow from the Collie River South Branch.

Samples have also been collected from the WO5F, Chicken Creek Area 4C and Ewington 2 pit lakes. Analyses of water quality are also shown in Table 3-3.

The WO5F pit lake is a shallow excavation within the upper Muja Coal Measures to the west of WO5B. The local catchment includes laterite and this may influence the pit lake quality in terms of aluminium and iron contents.

At Chicken Creek, the sampling occurred before the diverting of stream flow from Collie River East Branch (August 2005) and thus reflects inputs for the local catchment and Premier Coal Measures only.

The Ewington 2 pit lake is of also of pH ~4, with low concentrations of sulphate and metals (McCullough, 2007). Overburden is in the low-acid range and where acid generating potential exists, it is in part due to a lack of acid-neutralising capacity rather than high pyrite contents.

The measured pit lake water quality provides reasonable guidelines for the future mined voids, such as at Ewington I and Ewington II. The existing pit lakes at Chicken Creek and Ewington 2 may be the most representative of final voids at Ewington II and Ewington I. These pit lakes are characterised by waters wherein the concentrations of aluminium (13 to 19 mg/L), iron (3 to 13 mg/L), manganese (0.6 to 1.5 mg/L), nickel (0.1 to 0.2 mg/L) and lead (0.02 to 0.05 mg/L) exceed drinking water guidelines. Zinc is also manifest in concentrations (0.4 to 1 mg/L) marginally below the drinking water guidelines.

Table 3-3 Pit Lakes Water Quality (1999 to 2007)

Parameter	Measured Quality (mg/L, unless otherwise specified)			
	Lake Kepwari[1]	WO5F[2]	Chicken Creek[3]	Ewington 2[4]
pH (units)	4.3 – 4.8	3.4	3.0 – 3.3	4.2 – 4.4
Aluminium	1.1 - 3.9	15	13 - 19	15
Iron	0.2 – 0.3	3.5	7 - 13	3.5
Calcium	21 – 31	19	17 - 22	19
Magnesium	52 – 81	32	56 - 81	32
Sodium	260 – 391	95	250 - 310	95
Potassium	5.5 - 5.7	67	7.0 – 8.4	67
Copper (µg/L)	<5 - <10	<10	14 - 16	10
Manganese	0.21 – 0.26	1.5	0.58 – 0.80	1.5
Sulphate	110	110	110 – 140	-
Chloride	560	-	-	-
Bromide	3.1 – 3.3	-	-	-
Silica	9.0 – 9.2	-	-	-
Arsenic (µg/L)	<1	-	<10	-
Boron	15	-	0.025	-
Cadmium	<0.002	0.001	0.001	0.001
Cobalt	0.05 – 0.07	-	0.13 – 0.15	-
Chromium (µg/L)	<10	-	4	-
Nickel (µg/L)	60 – 70	-	150 - 180	-
Lead (µg/L)	6.2	20	30 - 50	20
Selenium (µg/L)	<5	-	<20	-
Zinc	0.45 – 0.51	-	0.7 – 1.0	-

Notes:
1. Lake Kepwari samples occur from 2001, 2006 and 2007. Depths of sample collection range from 1, 5, 20 and 40 m.
2. For WO5F the date of sampling is uncertain.
3. Sampling from Chicken Creek Area 4C occurred during May and July 2005 and subsequently February, May and July 2005.
4. Sampling from Ewington 2 occurred in 1999.

Section 4 Mining Plans

Mining plans for Ewington I and Ewington II reflect the present-day needs to service existing supply demands and forecasts of future demands linked to new power station facilities and markets. The mine plans are subject to change. Actual mining plans and developments will be linked to updates of the coal reserves, optimised approaches to pit development and coal supply contracts.

Development of Ewington I is planned to commence in 2008. Initial developments may begin with a trial pit, the focus of which would be to obtain bulk samples of coal for appraisal of mining methodology, impacts of faults on coal seam distributions and coal quality and initial power station use. Subsequently, the mining activities would expand from the trial pit. The mine plan for Ewington I is shown on Figure A-2. This plan is based on extraction of 3 Mtpa of coal, with the E32 Seam floor forming the base of the pit. The major coal resources occur in the form of the Moira (E10), Stockton (E20) and Wallsend (E30) seams of the Ewington Coal Measures. The 3 Mtpa mine plan provides for a mine life of about 30 years.

Mining at Ewington II has been focussed on extraction of the P10, P20 and P30 Seams of the lower Premier Coal Measures since late-1995. Early during 2007, mining developments below the P30 Seam were initiated. Ultimately the pit will be excavated to extract the P40, P50 and P60 Seams, deepening the historical operations by about 55 m. Indicative plans for mining developments of the P30 and P60 Seams are shown on Figure A-3 (a and b).

Overburden from the mining operations would initially be disposed on dumps in perimeter areas of the pit. Subsequently, as the pit develops, the mined overburden would backfill the mined void. Ash would be disposed as a run-of-mine operation within the perimeter and backfill overburden dumps in settings above the natural water table. The ash would be delivered in a comparatively dry (15% moisture content) form suitable for transport in trucks and tipping over the edges of the overburden dumps. Disposed ash would have limited exposure to the environment, typically being covered by run-of-mine overburden within days of tipping. Mix ratios of overburden to ash are expected to be variable depending on the size (height, width and breadth) of the waste dumps and extent of concurrent co-disposal areas. Overburden to ash run-of mine mix ratios are expected to range from about 10:1 to 100:1, with ratios between 50:1 and 100:1 being typical.

Section 5 Known Hydrogeology

The Ewington mines occur within the Collie Basin, one of numerous small sedimentary basins within the Yilgarn Block of the Darling Plateau (Churchward and McArthur 1980). The Collie Basin occurs within crystalline basement rock (including gneiss and granite) of Archaean age and is fault-bound to the north/north east and south/south west with local deposition of Permian coal-bearing sediments. The Collie Basin occupies approximately 230 km^2 and is elongated northwest to southeast over a 26 km length and 15 km width. It consists of two sub-basins, with the Ewington deposits occurring on the western flank of the northern Premier Sub-basin.

In a regional context, the Ewington I and Ewington II Mines are located within the drainage basin of the Collie River East and South branches, which ultimately lead to the Wellington Dam. Historically, the Wellington Dam has supplied water for domestic use to the Collie district and the Great Southern Towns and irrigation water to the Swan Coastal Plain. The quality of the water in the Wellington Catchment has over time been increasingly influenced by salinisation effects due to clearing and land degradation, such that at present the water stored in Wellington Dam is only used for irrigation.

The stratigraphic successions and coal seams that form Ewington I and Ewington II occur within the Ewington Coal Measures and lower Premier Coal Measures, on the western limits of the Premier Syncline in the Premier Sub-basin of the Collie Basin (Figure A-5 and A-6). A plan view of the stratigraphic and structural setting of Ewington I and Ewington II is shown on Figure A-7. Locally both the Ewington and Premier Coal Measures successions dip gently to the east.

Groundwater exploration programmes have been completed within both Ewington I and Ewington II. These programmes have occurred in several campaigns since 1984 and typically have been focused on investigation of groundwater levels, characterisation of aquifer system hydraulics and groundwater quality. Supporting data are available from other parts of the Premier Sub-basin where other water supply and mine dewatering investigations have been completed. Mining at Ewington II has historically been supported by dewatering. The dewatering programme has enhanced the knowledge of the local hydrogeology.

5.1 Aquifer Systems and Nomenclature

Numerous aquifer systems occur in the coal measures successions within Ewington I and Ewington II. Generally, the aquifer systems take their name from the underlying coal seam. The aquifer systems relevant to Ewington I and Ewington II are different.

5.1.1 Ewington I

The aquifer systems and hydrostratigraphy linked to the Ewington I Deposit include:

- Lower Allanson Sandstone, which subcrops over significant areas of the domain.
- Ewington Coal Measures and associated Moira, Stockton and Wallsend aquifers.
- Westralia Sandstone, which will not be exposed by mining (except on fault zones) but occurs beneath the lower-bound P32 Seam that is planned to be excavated.

The aquifer nomenclature and hydrostratigraphy of Ewington I are shown on Figure A-5. All aquifer systems have a regional extent throughout the domain of the Premier Syncline.

5.1.2 Ewington II

Numerous aquifer systems occur in the profile planned to be developed at Ewington II. The aquifers take their name from the underlying coal seams (Figure A-6). The aquifer systems include:

- P10 Aquifer
- P20 Aquifer - dewatered in previous mining operations
- P30 Aquifer
- P40 Aquifer
- P50 Aquifer - dewatered in current mining operations
- P60 Aquifer
- P80 Aquifer - depressurised in the current mining operations
- Allanson Sandstone

5.2 Groundwater Flow

The coal measures succession is understood to form a leaky multiple aquifer system. Sandstone beds form the predominant aquifers and predominantly control groundwater occurrence and flow. Typically, the individual aquifers are inter-bedded sandstone, clay, mudstone/shale successions wherein lateral flow is intrinsically promoted by the bedding characteristics. Individual coal seams and adjoining mudstone/shale beds form aquitards, but do vertically transmit groundwater flows under the stress of differential drawdowns resulting from groundwater abstraction.

Groundwater flow within the stratigraphic successions is predominantly influenced and controlled by:

- Distribution and transmissivity of sandstone beds.
- Hydraulic characteristics of faults that occur in the immediate project area.
- Juxtapositioning of sandstone beds across fault zones.
- Joints and bedding structures in the sandstone, shale and mudstone beds.
- Vertical transmissivity of the coal and mudstone/shale aquitard beds.

5.3 Fault Structures

Faults are common within the Collie Basin and influence groundwater flow and the layout and development plans for most mines, including Ewington I and Ewington II. The distributions of the faults are predominantly based on interpretations of drill-hole data and correlations of coal seam intersections and stratigraphic markers. Unless defined by close-spaced drilling, the positions, strike, dip and throw of most faults are strongly inferred. Where close-spaced drilling data are available, these data usually are constrained to comparatively small portions of the strike length and stratigraphic succession. Typically, the faults are normal strike-slip and dip-slip structures, characterised by:

- Strikes parallel and sub-parallel to the north-westerly structural axis of the Premier Sub-basin.
- Dip directions towards the southwest and deepest areas of the preserved sedimentary successions.
- Variations in vertical throws (dip slips) along the strike lengths.

- Sinistral and dextral strike slip-displacement on opposite limbs of the sub-basin synclinal structures.
- Drag flexures in the sediments adjoining the fault zone.

The interpreted and known (exposed in-part by mining) faults vary significantly in their lengths and throws. Each of these aspects leads to potential variations in the influences and controls that the faults impose on both local and regional groundwater flow. It is significant that many of the faults traverse along their strike length different stratigraphic units (Premier Coal Measures, Allanson Sandstone, Ewington Coal Measures, Westralia Sandstone and the Stockton Group) that might influence their local characteristics and controls on groundwater flow.

Also, faults that intersect several stratigraphic units have increased potentials for lateral and/or vertically linking of aquifer systems than those transecting only single stratigraphic units. For instance, the faults that occur within Ewington II have potentials to laterally and vertically link the major aquifers formed by the lower Premier Coal Measures Allanson Sandstone Ewington Coal Measures and Westralia Sandstone. At Ewington I, the faults have reduced potentials to influence the dewatering, providing potential lateral and vertical links only to the aquifers formed by the Ewington Coal Measures and Westralia Sandstone.

Most faults are interpreted to be transmissive, at least in part, be it with lateral or vertical flow components or both. In this context it is understood that the faults predominantly increase the potentials for transmission of groundwater from aquifer systems not actively being dewatered for mining.

5.4 Groundwater Levels

5.4.1 Ewington I

Historical groundwater levels indicative of water table elevations at Ewington I are shown in Table 5-1.

Table 5-1 Selected Historical Ewington I Groundwater Levels

Aquifer Systems	Multipiezometers	Measured Groundwater Levels (mAHD)		
		1984	1993	2004
Allanson Sandstone	MEW18		216.06	210.98
Moira	MEW15, MEW13, MEW20	- , 210.26, -	201.94, - , 216.53	194.36, - , 212.85
Wallsend	MEW15, MEW13, MEW20	- , 209.87, -	202.14, - , 215.98	197.29, 207.07, 212.08
Westralia Sandstone	MEW15, MEW13, MEW20	- , 214.47, -	>202.53, - , 213.13	197.82, 207.45, 210.20

The available groundwater level data provide broad coverage of Ewington I and indicate:

- The ground topography controls on the water table elevations and groundwater flow directions.
- Groundwater flow is predominantly to the southeast, into a tributary of the Collie River South Branch.
- In the northern Ewington I, groundwater flow occurs into small-scale catchments and tributaries of the Collie River East Branch. Groundwater flow directions vary through northwesterly, northerly and northeasterly.
- In the north, there is a vertical downward hydraulic gradient, indicating that the water table aquifer recharges the underlying aquifer systems. Further to the south, there is evidence of a reversal in

hydraulic gradient – particularly beneath valley floor areas – indicating discharge from the deeper aquifer systems to the water table. In 1993 (and prior), the deeper aquifer systems were locally artesian beneath valley-floor locations.

- Water table elevations have declined during the monitoring period. The measured drawdowns are typically in the range from 2 to 7 m. Most commonly they are 2 to 3 m, but greater within the eastern and southern portions of Ewington I. The drawdowns are likely to be linked to long-term trends of below-average annual rainfall and cumulative regional drawdown impacts due to groundwater abstraction, within the Premier Sub-basin, for mine dewatering and power station water supply.

5.4.2 Ewington II

Pre-mining water table elevations at Ewington II occurred in the range from 195 to 208 mAHD, with flow typically to the southwest and tributaries of the Collie River South Branch. Historical groundwater levels indicative of water table elevations at Ewington II are shown in Table 5-2.

A vertical groundwater gradient commonly occurred from the water table zone to the underlying multiple-layered coal measures succession.

There was evidence at Ewington II of long-term passive dewatering of the water table zone and deeper aquifer systems linked to reductions in annual rainfall and groundwater abstraction.

Table 5-2 Selected Historical Ewington II Groundwater Levels

Aquifer Systems	Multipiezometers	Measured Groundwater Levels (mAHD)		
		April 2003	July 2003	September 2004
P10	ME29	NR	178.0	NR
P20	ME29	NR	169.7	167.4
P30	ME27 and ME29	163.1	158.1-158.8	153.8
P40	ME27 and ME29	164.5	156.7-158.4	149.9
P50	ME28, ME30	162.7	161.8	154.0, 158.5
P60	ME28, ME30	165.0	162.5	154..3, 161.1
P80	ME28, ME30	169.7	167.5	161.2, 167.0

5.5 Interpreted Hydraulic Parameters

Results of the groundwater exploration programmes and aquifer tests have been applied to interpret the hydraulic characteristics of the aquifer systems formed by the coal measures successions at Ewington I and Ewington II. The interpretations have been derived after proportioning of production bore yields based on likely contributions from individual aquifer systems as determined from:

- Measured aquifer responses to abstraction.
- Geophysical log profiles and aggregate sandstone bed thicknesses.
- Comparative assessments.

The interpreted hydraulic parameters for the Ewington Coal Measures and Westralia Sandstone aquifer systems within Ewington I are summarised in Table 5-3. Those for the lower Premier Coal Measures within Ewington II are shown in Table 5-4.

Table 5-3 Interpreted Ewington I Aquifer Parameters

Aquifer	Aquifer Tests				Hydraulic Conductivity (m/day)	Storativity (Dimensionless)
	Transmissivity (m^2/day)					
	EW540	PEW1	PEW2	PEW3		
Upper Moira		84	80	229	1.2 - 3.9	(3.8 - 7.0) $x10^{-4}$
Lower Moira	28	20	21	15	0.7 - 2.3	(1.0 - 6.3) $x10^{-5}$
Wallsend		7		12	0.7 - 1.2	(0.1 - 9.2) $x10^{-4}$
Upper Westralia Sandstone	3	37		37	0.2 - 2.5	(0.9 - 1.1) $x10^{-4}$
Lower Westralia Sandstone	12	14		14	0.4 - 1.4	(0.02 - 3.3) $x10^{-3}$

Table 5-4 Interpreted Ewington II Aquifer Parameters

Aquifer	Aquifer Tests				Hydraulic Conductivity (m/day)	Storativity (Dimensionless)
	Transmissivity (m^2/day)					
	PB4	PE32	PE42	PE46		
P10						
P20	20				2.3	
P30	10				1.3	
P40	270				11.4	
P50	115 - 150	141	251	283	8.0 - 29.0	(4.5 - 5.8) $x10^{-5}$
P60	45	18	13	46	1.0 - 3.0	(2.9 - 8.6) $x10^{-6}$
P80	60 - 100	290 - 350	155	112	3.9 - 11.0	(3.1 - 7.2) $x10^{-5}$
Allanson Sandstone			250	189	7.8 - 8.5	NR

In a regional context, data are also available from other project areas. A comparative broad summary of interpreted aquifer parameters within the lower Premier Coal Measures, Allanson Sandstone, Ewington Coal Measures and Westralia Sandstone is provided in Table 5-5.

Table 5-5 Interpreted Hydraulic Parameters – Regional Premier Sub-Basin

Aquifer System	Transmissivity (m^2/day)					Effective Hydraulic Conductivity (m/day)				
	Premier Mine	Shotts Borefield	Chicken Creek Mine	Ewington II Mine	Ewington I Mine	Premier Mine	Shotts Borefield	Chicken Creek Mine	Ewington II Mine	Ewington I Mine
P5	80 - 170	300	4			2 - 4	1.1-7.7	0.3		
P10	15 - 115		-			0.5 - 6		-	1	
P20	10 - 115		50 - 200	20		1 - 10		1 - 10	2	
P30	20 - 50			10		2 - 4			1 - 1.5	
P40	20 - 30		50 - 100	170 - 210		1		7 - 12	16 - 20	
P50	20 - 30			115 - 150		1			8 - 12	
P60	20			45		0.5			1 - 3	
P80				60 - 100					4 -11	
Allanson Sandstone				190 - 250	80- 200				8 - 9	2.5
Ewington Coal Measures					10 - 20					1.0 - 1.5
Westralia Sandstone					10 - 40					0.5 - 2.5

5.6 Groundwater Quality

The Collie Basin predominantly hosts fresh groundwater resources. In the future there is potential that the groundwater resources of Ewington I and Ewington II may be diverted for domestic beneficial uses.

Groundwater quality data for Ewington I and Ewington II are available from samples sourced from test production bores. The test production bore samples are considered to be representative, typically having been collected after removal from storage of significant groundwater volumes. The test production bores are typically up to 150 m in depth and consequently sample the water table zone and shallow aquifer successions above this depth. Operating production bores at Ewington I and Ewington II range in depths up to 120 and 190 m.

The available baseline groundwater quality data for Ewington I and Ewington II are summarised in Table 5-6 and Table 5-7. These baseline data do not incorporate a comprehensive suite of metals.

The available data indicate that:

- Local groundwater resources are fresh, with Total Dissolved Solids (TDS) concentrations typically less than 300 mg/L.
- pH in the range 4.9 to 5.5.
- Total Suspended Solids (TSS) concentrations of <3 mg/L, typical of production bore abstractions.
- Soluble iron concentrations <2 mg/L.
- Silica (SiO_2) concentrations of 5 to 15 mg/L.

The available data provides general compliance with quality criteria for disposal into the local fresh water environment, with the exception of pH values that may be too low.

Compliance criteria (Water Authority, Water Resources Directorate July 1988) used at present by the regulators to manage disposal of groundwater and mine water into the local environment within the Wellington Catchment are as follows:

a) Total Dissolved Solids less than 550 mg/L.

b) pH in the range 5.0 to 8.5.

c) Suspended solids less than 80 mg/L.

d) Oil and grease less than 5 mg/L.

e) Iron less than 3 mg/L.

f) Manganese less than 0.5 mg/L.

g) Dissolved oxygen not less than 5 mg/L.

Other constituents (including metals) less than the recommended criteria for potable use, given in the NH&MRC/Australian Water Resources Council publication “Guidelines for Drinking Water Quality in Australia 1987”.

There are in place at present active plans to mitigate both the causes and effects of salinisation within the Wellington Catchment to add value to the available water resources. A ministerial condition of approval for Harris Dam requires the ultimate return of the Wellington Dam to potable quality, with the intention that it be used for domestic water in the future. The existing final voids in the Collie Basin that do not contain ash are characterised by waters that exceed drinking water and fresh water ecosystem quality guidelines. The void waters are typically characterised by comparatively high concentrations of aluminium, iron, manganese, nickel, lead, silica and zinc. Accordingly, water that inundates the Ewington I and Ewington II final voids is unlikely to meet drinking water and fresh water ecosystem quality guidelines under any circumstances unless ameliorated by treatment. As such, neither of these guidelines is ideal for assessment of the mining and final void environment as water quality conditions in existing mined voids in the Collie Basin do not meet these guidelines.

Table 5-6 Measured Ewington I Baseline Groundwater Quality

Parameter[1]	Aquifer Test and Abstraction				
	EW540	PEW1	PEW2	PEW3	Operating Production
	Aquifers Sampled				
pH[2]	4.6 - 6.5	5.4	5.15	4.65	4.6 - 5.7
Conductivity[3]		480	180	310	247 - 378
TDS (grav.)	125 - 240	290	120	190	126 - 198
TSS		<2	<2	3	1 – 31
Sodium	32 - 66	67.5	31	48	29 – 56
Potassium		5.2	1.0	3.6	1.13 – 9.35
Calcium		2.3	<0.1	2.5	0.74 – 1.40
Magnesium		8	2.1	6.1	3.5 – 6.8
Soluble Iron	0.05 - 1.6	2.05	1.10	0.95	0.16 – 4.21
Chloride	53 - 78	120	45	95	57 – 103
Sulphate	<2 - 5	15	5	5	6 – 14
Silica[4]	<5 - 15	10	10	8	
Sulphide		1.2	2.0	<0.1	
Barium		0.2	0.2	<0.2	
Aluminium		0.2	<0.1	<0.1	0.01 - 0.24
Alkalinity		10	10	<5	5 – 25
Arsenic					<0.001
Cadmium					<0.001
Chromium					<0.001
Copper					<0.01 – 0.02
Manganese					<0.03 – 0.13
Nickel					<0.03
Lead					<0.001

Notes:

Notes:	1	Parameter: mg/L unless otherwise indicated
	2	pH: dimensionless
	3	Electrical Conductivity: µmhos/cm at 25ºC
	4	Silica, as SiO_2
	5	Production Bores PEW4 to PEW11, sampled in January and May 2007

Table 5-7 Measured Ewington II Baseline Groundwater Quality

Parameter[1]	PB4 Aquifer Test (1993)				Production Bores[2]	Production Bores[3]
	Aquifers Sampled					
	P20-P70	P20-P55	P20-40		P40 to P80	P10 to Allanson
pH[4]	4.95	5.10	4.90	5.10	5.1 - 5.5	4.0 – 6.1
Conductivity [5]	470	490	480	490	269 - 281	342 – 1,985
TDS (grav.)	260	280	300	280	132 - 140	173 – 958
TSS	1	<1	<1	<1	2 – 3	<1 – 7
Sodium	70	75	70	70	43	45 – 91
Potassium	1.65	0.55	0.60	0.50	1.61	1.55 – 8.37
Calcium	1.55	1.35	1.65	1.65	1.21	1.09 – 3.70
Magnesium	8	9.5	9.0	10.0	4.9	5.4 – 12.2
Soluble Iron	0.85	1.50	1.30	1.65	0.29	0.62 – 1.87
Chloride	120	125	120	120	109	89 - 191
Sulphate	10	25	25	25	4 – 9	19 - 63
Silica[5]	14	10	10	10	5.0	
Sulphide	<0.05	<0.1	<0.1	<0.1	NA	
Barium	<0.1	<0.1	<0.1	<0.1	NA	
Aluminium	5	0.1	0.1	0.2	<0.2	0.1 – 6.6
Alkalinity	0.3	5	5	5	7	2 – 9
Hydrogen Sulphide	0.3	<0.1	<0.1	<0.1	NA	
Arsenic						<0.001
Cadmium						<0.001 –
Chromium						<0.001 –
Copper						<0.01 – 0.02
Manganese						<0.03 – 0.09
Nickel						<0.03
Lead						<0.001

Notes:
1 Parameter: mg/L unless otherwise indicated
2 Sampled in September 2003 from operating production bores PE32 and PE37
3 Sampled in May 2007 from production bores PE31, PE32, PE38, PE45, PE46, PE47, PE54 and PE56.
4 pH: dimensionless
5 Electrical Conductivity: μmhos/cm at 25^{0}C
5 Silica, as SiO_2

Section 6 Ash Co-disposal

The ash generated from Bluewaters I to IV power plants is intended to be co-disposed at the Ewington I and Ewington II Mines. The ash would be placed above the pre-mining water table, co-disposed with run-of-mine overburden, and progressively covered to limit contact with rainfall and exposure to the environment. The ash would be end-dumped from overburden dumps, with trucks reversing to the edge of the dumps and tipping the ash on the outside of 6 to 20 m height slopes. The co-disposed ash may generate solutes linked to wetting by rainfall infiltration or runoff. Solutes from the co-disposed ash will originate in the unsaturated profile. Depending on the co-disposal setting, the solutes might migrate to pit-floor sumps in active mining areas or to the water table in the aquifer systems beneath the overburden dumps.

Evidence from the leaching tests suggest that the co-disposed ash is likely to generate solutes in the short term after wetting events. Co-disposed ash is most likely to be exposed to the elements in the first year after deposition, when depths of burial, compaction and consolidation are limited in the overburden dump settings above the water table. Thereafter, the potentials for wetting by infiltrating rainfall are expected to decrease.

Water balances in the unsaturated overburden dump profiles that host co-disposed ash would be widely varied. Spatial and temporal variation would be expected, reflecting different infiltration potentials, the occurrence of changes in slope, presence of preferred flow paths for infiltration, differences in the overburden dump materials, thickness of the overburden dump profile, moisture contents of the overburden materials and a raft of other factors. Notwithstanding the likelihood of varied and complex water balances, in fundamental terms, the ash co-disposal settings are expected to form comparatively small portions (less than 28%, approximately 13 km2) of the total catchment of the Ewington I and Ewington II mines (46 km2). Further, contributions from the unsaturated co-disposal profiles to the water balances for each site are expected to be comparatively minor and probably significantly less than 10% of the total water balance. This aspect would be manifest in the substantial dilution of the effects of the co-disposed ash on the water table and local groundwater resources.

For the previous study of Ewington I (URS 2008), the solute concentrations applied to modelling were derived from the 'Composite Overburden Bulk Leach', 'Column 1 – Composite Overburden' and 'Calculated Column Leaching 50:1 Overburden to Ash' data in Table 6-10. In each instance, the applied solute concentrations were intended to represent a worst-case. The solute concentrations applicable to the model as rainfall infiltration through overburden alone included: Aluminium 0.40 mg/L; Cadmium 0.02 mg/L; Cobalt 0.05 mg/L; Barium 0.021 mg/L; Nickel 0.30 mg/L; Sulphate 11 mg/L; and, Zinc 0.21 mg/L.

The solute concentrations applied to the model as rainfall infiltration through co-disposed overburden and ash at 50:1 mix ratios included: Aluminium 0.76 mg/L; Cadmium <0.025 mg/L; Cobalt 0.17 mg/L; Barium 0.026 mg/L; Nickel 0.42 mg/L; Sulphate 129 mg/L; and, Zinc 0.91 mg/L. Results regards the distribution with time of these constituents were presented in URS, 2008.

At present, the transport and fate of solutes from the Ewington I and II co-disposed ash are understood to include:

- Infiltration of rainfall. Typically in the Collie Basin, rainfall infiltration (recharge) is about 10% of the annual average rainfall (Varma, 2002).
- Adsorption of infiltrating rainfall by the co-disposed overburden and ash, both of which would initially be deposited in a comparatively dry state. The co-disposed ash would be predominately saturated prior to release of solutes.
- Generation of solutes in the unsaturated overburden dump profiles wherein a wetted, oxidation and redox front prevail. These profiles are expected to be varied, but typically hosted in the upper 10 to 15 m zones of the overburden dumps. Below about 15 m, any reactivity would be substantially diminished by the absence of water and oxygen.
- Predominant occurrence of flow on preferred paths within the unsaturated profile. Most preferred flow paths would be in overburden material that has boulder to blocky and coursed-grained fabrics. The co-disposed ash being fine grained is not expected to form preferred flow paths. Again, the preferred

flow paths would be expected to occur in the upper overburden dump profiles, promoted by limited depths of burial, compaction and consolidation.

- During mining at Ewington I, the solutes in vertical flow paths would infiltrate to the water table within the Westralia Sandstone. The Westralia Sandstone occurs beneath the Ewington I pit floor and would be intersected by numerous production bores intended to provide dewatering and depressurisation to elevations compatible with mining. As such, the solutes that infiltrate the Westralia Sandstone would be initially diluted and subsequently transported in predominantly lateral flow paths towards the production bores.

- During mining at Ewington II, the solutes in vertical flow paths would infiltrate to the water table within the Premier Coal Measures. The current water table at the mine site is significantly lower than the pre mining water table. The Premier Coal measure occur beneath the Ewington II pit floor and would be intersected by numerous production bores intended to provide dewatering and depressurisation to elevations compatible with mining. As such, the solutes that infiltrate the Premier Coal Measures would be initially diluted and subsequently transported in predominantly lateral flow paths towards the production bores.

- During mining at both Ewington I and II, the solutes in predominantly lateral flow paths would remain in the unsaturated profile and enter the pit either as seeps directly from the overburden dumps or on the pit floor. These solutes may be lost to evaporation or transported to in-pit sumps. Such solutes may also be mixed and diluted with rainfall runoff. Abstractions from the in-pit sumps would dispose of the solutes during the mining operations.

- Post-mining, solutes in both groundwater and runoff would be diverted into the Ewington I and II final voids due to the depressed water table caused by the mine dewatering activities. For many years, the lakes that would form in the final void at each mine are expected to form a sink, controlling the fate of and concentrating all solutes.

Rainfall that is directly incident with the co-disposed ash would shed from the overburden dumps. Watersheds from the co-disposed ash would preferably be diverted towards the pit and collected within pit-perimeter or in-pit sumps. Runoff from mine areas and water abstracted from in-pit sumps are typically acidic and of comparatively poor quality.

6.1 Ash Leaching Studies-Ewington I

The characterisation of the ash, transient potentials for generation of solutes and understanding of concentrations and flow paths of potential contaminants are integral to identifying and managing potential environmental impacts from ash co-disposal. When the disposed ash comes into contact with rainfall infiltration or rainfall runoff, water may be absorbed. Subsequently, soluble constituents including metals may dissolve and enter groundwater flow paths in the unsaturated profile.

A guideline for the preliminary assessment of the potential for liquid or solid waste, sediments, sludges or soils (such as co-disposed ash) to contaminate groundwater is provided by Standards Australia (Wastes, sediments and contaminated soils, AS 4439 Parts 1, 2 and 3 – 1997 and 1999). The guidelines refer to bulk leaching tests.

Studies by Burns and Roe Worley (June 2005) involved:

- Bulk leaching tests, conforming to AS4439.3-1997.

- Column leaching tests.

Each set of tests comprised irrigating overburden and ash material to evaluate rates of de-sorption and concentrations of soluble constituents. Composite overburden lithologies include sandstones, claystones, mudstones and carbonaceous shales and is characterised by high silica (sand) contents. Ash used was sourced from Muja Power Station, derived from the combustion of coal from the Muja and Premier Coal Measures. The ash is characterised by comparatively high concentrations of metals, including barium, beryllium, cadmium, cobalt, copper, iron, molybdenum, nickel, lead, sulphur, strontium, vanadium and zinc.

6.1.1 Bulk Leaching Tests- Ewington I

The bulk leaching tests were based on overburden and ash samples prepared to conform to AS4439.3 (1997), with solute analyses by ICP-MS. Irrigation was with water, simulating infiltration by rainfall. Such tests are used to provide a preliminary assessment of the potential for liquid or solid waste, sediments, sludges or soils (such as co-disposed ash) to contaminate groundwater. The tests enable the evaluation of the rates of de-sorption and concentration of soluble elements.

Results of the bulk leaching tests for Ewington I mine are shown in Table 6-1. In summary, the tests indicate:

- Composite overburden predominantly releases sodium and chloride, with subordinate calcium, magnesium, potassium, zinc, sulphur and aluminium.
- Ash releases sulphur, calcium, sodium, magnesium, strontium, fluoride, chloride, silica, potassium and aluminium together with metals zinc, boron, barium, nickel, manganese, cobalt and copper.
- Metals in the ash occur in more water soluble forms compared to in overburden lithologies.

Table 6-1 Bulk Leaching Test Results

Element	Solute Concentrations (mg/L, unless otherwise specified)	
	Muja Ash	Ewington 1 Overburden
pH (units)	4.76	5.5
Silver	0.01	0.01
Aluminium	2.5	0.06
Arsenic (µg/L)	<50	<50
Boron	0.37	<0.02
Barium	0.32	<0.05
Beryllium	<0.005	<0.005
Calcium	34	0.5
Cadmium	<0.05	<0.05
Chloride	3	6
Cobalt	0.07	<0.01
Chromium (µg/L)	10	<10
Copper (µg/L)	45	<10
Fluorine	4	<2
Iron	0.01	<0.01
Mercury	<5	<5
Potassium	2.55	0.2
Magnesium	4.6	0.29
Manganese	0.26	<0.01
Molybdenum	<0.05	<0.05
Sodium	8.45	5.5
Nickel (µg/L)	280	<20
Lead (µg/L)	<500	<500
Sulphate	129	0.2
Selenium (µg/L)	<500	<500
Silica	2.9	<0.4
Strontium	4.17	0.01
Titanium	<0.01	<0.01
Vanadium	0.01	<0.01
Zinc	0.91	0.21

Source: Burns and Roe Worley (June 2005)

6.2 Bulk Leaching-Ewington II

The bulk leaching tests were based on overburden and ash samples prepared to conform to the Australian standard leaching procedure (ASLP, 1:20 extraction using de-ionised H_2O). Irrigation was with de-ionized water, simulating infiltration by rainfall. Such tests are used to provide a preliminary assessment of the potential for liquid or solid waste, sediments, sludges or soils (such as co-disposed ash) to contaminate groundwater. The tests enable the evaluation of the rates of de-sorption and concentration of soluble elements. In addition leachable metals were determined for the worst case scenario for both the overburden and Ash using ASLP with 1:20 extraction using H_2SO_4 at pH 3.5. Results of the bulk leaching tests for Ewington II mine are shown in Table 6-1 and Appendix C. In summary, the tests indicate:

- Ash releases aluminium, arsenic, beryllium, boron, cadmium, chloride, cobalt, copper, iron, nickel, manganese, sulphate and zinc in trace amounts.
- Ash releases aluminium, cadmium, manganese, and nickel at levels above the Australian Drinking Water Guidelines (ADWG).

- Composite overburden predominantly releases aluminium, boron, cadmium, chloride, cobalt, copper, fluoride, iron, nickel, manganese, and zinc in trace amounts
- Overburden releases aluminium, iron, and nickel at levels above ADWG

Ash was received from Muja Power Station, Collie for determination of total metals and leachable metals by ASLP. Mine waste samples (over burden) were received from Griffin Coal's Ewington II coal mine for determination of net acid generating (NAG) potential, acid neutralising capacity (ANC) and both total and leachable metals. The overburden samples comprised laterite, sandstone, siltstone, mudstone, shale and coal. Results of the laboratory test work are presented in Table 6-2 and Table 6-3.

The overburden samples exceed the Australian Drinking Water Guidelines for Aluminum, 0.2 mg/L(6 of 6 samples), Iron, 0.2 mg/L (3 of 6 samples), and Nickel 0.02 mg/L (1 of 6 samples). The composite sample (extreme value Table 6-4) represents the highest concentration observed for all the overburden samples, the exception being pH which is the lowest value and represents the worst case scenario for the bulk leaching test with a rainfall equivalent deionized water. Further results of the bulk leaching indicates:

- Both the overburden and ash contain metals and trace elements that may be mobilised due to infiltration of rainfall and rainfall runoff.
- Solutes linked to predominantly laterite contain aluminium, boron, chloride, fluoride, iron, manganese, and zinc
- Solutes linked to predominantly sandstone overburden may typically include aluminium, boron, cobalt, fluoride, iron, manganese, and zinc.
- Solutes linked to predominantly siltstone overburden may typically include aluminium, cobalt, copper, iron, manganese, nickel, and zinc.
- Solutes linked to predominantly mudstone overburden may typically include aluminium, cobalt, iron, manganese, and zinc.
- Solutes linked to predominantly shale overburden may typically include aluminium, cobalt, copper, iron, manganese, and zinc.
- Solutes linked to Premier Coal Measures may typically include aluminium, boron, cobalt, copper, iron, manganese, nickel, and zinc.
- The predominant (in terms of mass) solutes linked to co-disposed overburden and ash typically include sulphate, aluminium, chloride, cobalt, iron, manganese, nickel, and zinc.

The inter-bedding of composite overburden and ash commonly limits the concentrations of the eluted elements compared to those from ash alone

Table 6-2 Ash and Overburden Metals Concentrations

Constituent	**Muja Ash Total Concentration**	**Muja Ash Leachable Fraction, H_2SO_4 pH3.5**	**Muja Ash Leachable Fraction, DI H_2O**	**Overburden Leachable Fraction. H_2SO_4 pH3.5**	**Overburden Leachable Fraction, DI H_2O**	**ADWG [2]**
	mg/kg	**mg/L**	**mg/L**	**mg/L [1]**	**mg/L [1]**	**Mg/L**
Aluminum	115,000	5	2.6	6.1	15	0.2
Arsenic	49	0.07	<0.05	<0.05	<0.05	0.007
Boron	83	0.17	0.14	0.02	0.04	4
Beryllium	21	0.014	0.01	<0.001	<0.001	
Cadmium	<1	0.006	0.005	<0.002	<0.002	0.002
Choride	1	0.6	0.6	2.6	5	250
Cobalt	19	0.094	0.087	0.17	0.14	
Copper	85	0.12	0.083	0.069	0.003	2
Flouride	1.4	1.4		0.23	0.1	1.5
Iron	38,000	0.034	0.009	1.4	1.7	0.3
Mercury	<0.02	<0.0001		<0.0001	<0.0001	0.001
Manganese	220	0.25	0.24	0.11	0.074	0.1
Nickel	270	0.2	0.18	0.06	0.04	0.02
Lead	30	<0.02	<0.02	<0.02	<0.02	0.01
Antimony	<1	<0.05	<0.05	0.5	<0.05	0.003
Selenium	<1	<0.05	<0.05	6.1	<0.05	0.01
Sulphate	-	-	180	<0.02	54	250
Zinc	100	0.7	0.79	0.5	0.25	3

1-highest concentration observed from six samples.

2-Australian Drinking Water Guideline (ADWG).

Table 6-3 Overburden Composition – Net Acid Generating (NAG), Acid Neutralizing Capacity (ANC), and Total Metals

Constituent	Laterite	Sandstone	Siltstone	Mudstone	Shale	Coal
pH	7.4	7.2	4.4	2.9	4.8	2.1
	Kg H_2SO_4/tonne sample					
NAG	<1	<1	7	83	5	200
ANC	2	<0.5	<0.5	<0.5	<0.5	<0.5
	grams/tonne sample					
Aluminum	66,900	963	3,360	41	13,900	5,730
Arsenic	2	<1	<1	<1	4	<1
Boron	<5	<5	<5	<5	<5	<5
Beryllium	0.29	<0.05	0.32	0.13	1.8	1.5
Cadmium	<0.05	<0.05	<0.05	<0.05	0.13	<0.05
Cobalt	2.8	1.6	4.8	1.2	4.3	8.4
Copper	0.4	0.6	4.3	0.2	20	6.1
Iron	18,000	660	620	5	3,000	3,300
Mercury	0.06	0.02	<0.02	<0.02	0.09	<0.02
Manganese	19	1.9	4.9	0.4	4.7	2.5
Nickel	9	2	5	1	12	15
Lead	6.2	6.9	14	<0.5	37	7.8
Antimony	<1	<1	<1	<1	<1	<1
Selenium	<1	<1	<1	<1	<1	<1
Zinc	<5	<5	10	8	40	17

1-highest concentration for all samples, the exception being pH where the lowest value was selected

Ewington II lithology indicates that significant aluminium (Al), iron (Fe) and minor manganese (Mn), lead (Pb), nickel (Ni) and cobalt (Co) occur predominantly in the laterite, siltstone, coal and shale. Of the species likely to generate pyritic acid rock drainage (NAG pH<4.5, NAG>5kg H_2SO_4/t)[i], mudstone is largely demineralised, while siltstone is likely to contribute only aluminium with trace iron, cobalt, copper (Cu), manganese, nickel and zinc (Zn) [lead is essentially insoluble due to the sulphate common ion effect]. Coal has the highest potential for both pyritic acid generation and consequential metal leaching, however, residual coal in waste will be less than 2% of the mined composition.

Sulphate concentrations in Table 6-4 indicate that coal is the most reactive source of acidity while siltstone sulphate concentrations indicate a reasonably weathered or at worst transitional chemistry, as indicated by the low, relative increase in solubility of metals in de-ionised water compared to sulphuric acid (Table 6-5). This implies that the soluble metals are already available as sulphate salts (cobalt, manganese, nickel and aluminium) and solubilities are only marginally increased by acid leaching. The final pH after addition of lixivant has a significant impact on aluminium and iron solubility (Table 6-4 and Table 6-5) that is not indicative of leachability.

Table 6-4 Overburden Composition – Leachable Metals (de-ionised water)

Constituent	Laterite	Sandstone	Siltstone	Mudstone	Shale	Coal	Composite all samples 1

pH	7	7	4.5	5.9	5.4	3.9	3.9
	mg/L rainwater equivalent infiltration						
Aluminum	15	2.6	2.4	0.29	0.43	3.6	15
Arsenic	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Boron	0.04	0.03	<0.02	<0.02	<0.02	0.02	0.04
Beryllium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Choride	5	<5	<5	<5	<5	<5	5
Cobalt	<0.005	0.006	0.14	0.016	0.027	0.049	0.14
Copper	<0.002	<0.002	0.002	<0.002	0.002	0.003	0.003
Fluoride	0.1	0.06	<0.05	<0.05	<0.05	<0.05	0.1
Iron	1.7	0.1	0.47	0.011	0.02	0.93	1.7
Mercury	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Manganese	0.004	0.003	0.074	0.007	0.02	0.062	0.074
Nickel	<0.01	<0.01	0.04	<0.01	<0.01	0.02	0.04
Lead	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Sulphate	2.0	2.0	48	12	15	54	54
Zinc	0.014	0.014	0.25	0.078	0.13	0.24	0.25

1-highest concentration for all samples, the exception being pH where the lowest value was selected

Table 6-5 Mine Overburden Composition – Leachable Metals (H_2SO_4, pH 3.5)

	Laterite	Sandstone	Siltstone	Mudstone	Shale	Coal	Composite all samples[1]
pH	4.8	3.9	3.3	3.8	3.8	3.4	3.3
	mg/L rainwater equivalent infiltration						
Aluminum	0.15	3.1	4.7	1.7	1.6	6.1	6.1
Arsenic	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Boron	<0.02	<0.02	<0.02	<0.02	<0.02	0.02	0.02
Beryllium	<0.001	<0.001	0.004	0.005	0.004	0.01	<0.001
Cadmium	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Choride	1.8	<0.5	2.6	1.2	1.5	1.1	2.6
Cobalt	0.027	0.069	0.17	0.1	0.089	0.062	0.17
Copper	<0.002	0.069	0.006	<0.003	0.005	0.015	0.069
Fluoride	0.12	0.13	0.13	0.15	0.23	0.16	0.23
Iron	0.031	0.26	0.88	0.1	0.15	1.4	1.4
Mercury	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Manganese	0.062	0.044	0.11	0.031	0.084	0.083	0.11
Nickel	<0.01	<0.01	0.05	0.06	0.02	0.03	0.06
Lead	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Zinc	0.024	0.087	0.26	0.3	0.5	0.28	0.5

1-highest concentration for all samples, the exception being pH where the lowest value was selected

An analysis of Ewington II stratigraphy indicates that the identified constituents – sandstone, siltstone, mudstone, shale and coal - occur with different proportions throughout the stratigraphic section. The inferred characterisation is presented in Table 6-6.

Table 6-6 Ewington II Inferred stratigraphy

	Sandstone	**Siltstone**	**Mudstone**	**Shale**	**Coal**
Ewington II	**% Composition**				
P08	50.24	5.09	9.1	35.49	0.08
P10	36.16	32.15	22.77	8.04	0.88
P20	51.96	19.88	14.11	13.47	0.58
P24	58.8	3.09	24.07	13.76	0.28
P30	73.54	6.19		19.93	0.34
P35	66.68	8.16		25.08	0.08
P40	62.82	10.83	7.22	18.41	0.72
P50	73.21	2.84	4.05	19.62	0.28
P51	88.24			9.8	1.96
P60	69	9.95	1.9	18.67	0.47
P61	79.08	18.48		2.22	0.22
Average:	**64.52**	**10.6**	**7.57**	**16.77**	**0.54**

Calculating results from sulphate concentrations in Table 6-4, NAG results in Table 6-3 and inferred stratigraphy from Table 6-5, it is possible to arrive at a quantitative stratigraphic distribution of potentially acid forming substrates, as presented in Table 6-6.

Mine waste, overburden, is commonly inferred to be non-acid forming (NAF) if Sulphide-S is less than 0.3% [Graeme Campbell & Associates, 2004]. Interpretation of the data in Table 6-7 and Table 6-11 implies that, on average:

- 65% of waste material is non-acid forming
- 17% of waste material is potentially acid forming (PAF) to 5kg H_2SO_4 per tonne (Sulphide-S ~ 0.16%, probably NAF)
- 10% of waste material is potentially acid forming to 7kg H_2SO_4 per tonne (Sulphide-S ~ 0.23%, probably NAF)
- 7.5% of waste material is acid forming to 83kg H_2SO_4 per tonne
- 0.5% of waste material is acid forming to 200kg H_2SO_4 per tonne

The NAG pH result indicated in Table 6-2 versus that shown in Table 6-1 for both mudstone (pH 2.9→5.9) and coal (pH 2.1→3.9) indicates that the contained sulphides are readily oxidised and would exhibit short lag times (weeks to months) given appropriate wetting and drying cycles.

The above data can be used to infer potential outcomes that would be likely to occur from using the waste generated from mining at Ewington II as overburden in the Ash Co-disposal area. The inferred outcomes are presented in Table 6-7.

Table 6-7 Overburden Inferred Results

	Weighting	Potential Acid Forming	Sulphide-S	Sulphate
Ewington II	**%**	**kg H2SO4/t**	**%**	**mg/kg**
P08	**3.7**	**9.5**	**0.31**	**9.6**
P10	**4.2**	**21.7**	**0.71**	**19.6**
P20	**13**	**13.7**	**0.45**	**13.9**
P24	**16.1**	**20.5**	**0.67**	**7.5**
P30	**7.5**	**1.4**	**0.04**	**7.3**
P35	**2**	**1.8**	**0.06**	**8.7**
P40	**19.2**	**7.6**	**0.25**	**9.9**
P50	**14.3**	**4.4**	**0.14**	**6.2**
P51	**1.1**	**0.5**	**0.02**	**3.9**
P60	**18.8**	**3.1**	**0.1**	**8.9**
P61	**0.2**	**1.3**	**0.04**	**10.2**
Average		**9.2**	**0.30**	**9.45**

Ewington II Waste material used as overburden in Ash co-disposal generated from level P30 and lower can be inferred to be non-acid forming. Equally, level P08 is most likely non-acid forming. The potential acid forming capacity for the materials that will be used as overburden for Ash Co-disposal would vary between 0.5 kg H^2SO^4 per tonne to 21.7 kg H^2SO^4 and the weighted average would be 9.2 kg H^2SO^4 for a completely mixed sample representing all the stratigraphic horizons. This totally mixed sample would likewise be Non Acid Forming as the % sulphide of the mixed sample would be less than 0.3%. While management of metals leachability is beyond the scope of the current study it should be noted that that confining acid generating mine waste (P10 to P24) to levels below the ash placement level and below the final water table level could potentially reduce or eliminate the possibility for leaching aluminium, arsenic, boron, cadmium, manganese and nickel from the Ash at levels above ADWG guideline values.

6.2.1 Column Leaching Tests-Ewington I

Columns were constructed of 0.1 x 1.0 m polycarbonate tubes and filled with overburden and ash without compaction. Water irrigated the columns at a constant 5 L/m^2hr (equivalent to infiltration of 5 mm/hr or 120 mm/day or 840 mm/week) rate for a period of ten weeks, maintaining saturated conditions in each column. Solutes were collected on a routine weekly schedule and analysed by ICP-MS. Column configurations using deionised water are summarised in Table 6-8.

In Column 3, the ash was inter-bedded with the composite overburden, broadly simulating co-disposal in a run-of-mine overburden dumps setting, with subsequent burial by overburden. The 9:1 ratio of overburden to ash is conservatively low, providing a worst-case representation of this aspect.

Rates of irrigation are extreme. Based on actual recharge being about 10% of the annual average rainfall, then the weekly column irrigation represents about 10 years of recharge. Further, the columns remain fully saturated, limiting natural oxidation and wetting/drying climatic influences. The extreme rates of irrigation and absence of oxidation and associated processes that might generate acid solutes skew the column leach tests. The results of the column leaching tests for selected elements are shown in Table 6-9.

Table 6-8 Column Leaching Test Configurations[1]

Column Number	Overburden		Ash (Kg)	Irrigation Water	
	Weight (Kg)	Type		Salinity	pH
1 Composite Overburden	9	composite	0	deionised	6.5
2 Ash	0		1	deionised	6.5
3 Overburden : Ash	9	composite	1	deionised	6.5

Notes: [1] After Burns and Row Worley (June 2005).

Table 6-9 Selected Column Leaching Test Results

Column	Week	Solute Concentrations (mg/L)							
		Al	Cd	Co	Ba	Ni	S	SO_4	Zn
1	1	0.40	0.02	0.05	0.021	0.30	35	104	27
	2	0.01	-	-	0.008	-	5	16	0.7
	5	-	-	-	0.008	0.01	2	7	0.9
	10	-	0.001	-	0.006	-	1	4	0.3
2	1	10.6	0.055	0.45	0.46	1.30	231	693	4.95
	2	0.53	0.001	0.01	0.97	0.01	11	34	0.06
	5	0.02	-	-	1.01	0.01	2	6	-
	10	0.03	0.001	-	2.01	-	1	3	-
3	1	2.20	0.045	0.65	0.047	0.90	293	879	85
	2	0.14	0.002	0.03	0.044	0.03	16	48	3.3
	5	0.06	-	-	0.026	-	4	12	0.3
	10	0.06	0.001	-	0.016	0.03	2	5	0.1

The results of the column leaching tests indicate that solute concentrations are greatest in the first week and typically decay by 60 to 95% during the subsequent week. The available data do not, however, further discriminate solute concentrations during the first week of irrigation. Initial solute concentrations are not defined.

Ewington II Waste material used as overburden in Ash co-disposal generated from level P30 and lower can be inferred to be non-acid forming. Equally, level P08 is most likely non-acid forming. The potential acid forming capacity for the materials that will be used as overburden for Ash Co-disposal would vary between 0.5 kg H_2SO_4 per tonne to 21.7 kg H_2SO_4 and the weighted average would be 9.2 kg H_2SO_4 for a completely mixed sample representing all the stratigraphic horizons. A management strategy that would potentially mitigate the environmental risks of Ash co-disposal in the Ewington II mine would involve disposing of the acid generating overburden from the P10 to P24 layers to levels below the ash placement level and below the final water table level. Placement of the overburden below the Ash and below the water table would potentially reduce or eliminate the possibility for leaching aluminium, arsenic, boron, cadmium, manganese and nickel from the Ash at levels above ADWG guideline values. A similar result might be possible at the Ewington I mine though a similar analyses of the source overburden at Ewington I would be required in order to make this determination.

6.3 Composite of Leaching Results-Ewington I & Ewington II

The results of the bulk leaching and column leaching tests substantially vary. Notwithstanding, the results are supported by the understanding that existing final voids in the Collie Basin are inundated with and characterised by waters with qualities that exceed drinking water and fresh water ecosystem quality guidelines. None of these voids contain ash. The void waters are typically characterised by comparatively high concentrations of aluminium, iron, manganese, nickel, lead, silica and zinc. Runoff from the disturbed areas at Ewington I and Ewington II may typically exceed quality guidelines for both drinking water and fresh water ecosystems. Also, water that inundates the final void is unlikely to meet these quality guidelines under any circumstances unless ameliorated by treatment. Aluminium and nickel are considered to pose the most significant long-term risk by exceeding the quality criteria. Both overburden and ash materials would contribute to potential loadings. The co-disposed ash would predominantly provide comparatively short-term loadings of boron, cadmium (with overburden), manganese, silica, strontium, sulphate and zinc (with overburden). Further, the highest loadings would occur during the first winter after co-disposal.

To develop a composite understanding of the findings it is important to recognise that:

- The quality of water in existing pit lakes provides a guide to the likely quality at Ewington I and Ewington II, albeit that ash-co-disposal may slightly alter both the water balance and solutes.
- The bulk leaching tests conform to Standards Australia and are intended to provide indicative solutes released by rainfall infiltration. As such, the results of these tests are preferably applied.
- Once co-disposed, the ash would be buried in an unsaturated matrix of overburden that is expected to host preferred seepage paths for infiltrating rainfall. The occurrence of preferred flow paths may limit the interaction of infiltration with the co-disposed ash.

A comparative outline of the bulk leaching and initial column leaching test data for Ewington I are provided in Table 6-10 while equivalent bulk leaching test data for Ewington II are provided in Table 6-11.

Table 6-10 Comparative Assessment of Leaching Test Data At Ewington I and Pit Lake Water Quality

		Solute Concentrations (mg/L)							
		Leaching Test Data							
Test	**Week**	**Al**	**Cd**	**Co**	**Ba**	**Ni**	**S**	**SO_4**	**Zn**
Composite Overburden Bulk Leach	-	0.06	<0.05	<0.01	<0.05	<0.02	4	11	0.21
Column 1 - Composite Overburden	1	0.40	0.02	0.05	0.021	0.30	35	104	27
Ash Bulk Leach	-	2.5	<0.05	0.07	0.32	0.28	-	129	0.91
Column 2 – Ash	1	10.6	0.055	0.45	0.46	1.30	231	693	4.95
Column 3 – 9: 1 Overburden to Ash	1	2.2	0.045	0.65	0.047	0.90	293	879	85
Calculated Bulk Leach 9:1 Ratio Overburden to Ash[1]	-	0.304	<0.05	<0.02	<0.07	<0.05	-	22.8	0.28
Calculated Bulk Leach 50:1 Ratio Overburden to Ash[1]	-	0.108	<0.05	<0.01	<0.06	<0.03	-	13.3	0.22
Calculated Column Leaching 50:1 Overburden to Ash[1]	1	0.76	0.025	<0.17	0.026	0.42	-	259	38.6
Calculated Bulk Leach 100:1 Ratio Overburden to Ash[1]	-	0.08	<0.05	<0.01	<0.05	<0.02	-	12.2	0.22
Typical Pit Lakes (Chicken Creek and Ewington 2)		15	0.001	0.14	-	0.16	-	130	0.9
Drinking Water Guidelines		*0.2*	*0.002*	*<0.05*	*0.7*	*0.02*	-	*500*	*3.0*

Notes: [1] Calculated concentrations are based on an equal weighting of the bulk leaching test results from the composite overburden and ash.

Table 6-11 Comparative Assessment of Leaching Test Data At Ewington II and Pit Lake Water Quality

	Solute Concentrations (mg/L)						
	Leaching Test Data (Ash & Overburden 1 is Bulk Leaching with DI, Ash & Overburden 2 is Bulk Leaching with pH 3.5 H2 SO4)						
Test	**Al**	**Cd**	**Co**	**Fe**	**Ni**	**SO_4**	**Zn**
Composite Overburden 1 Bulk Leach	**15**	**<0.002**	**0.14**	**1.7**	**0.04**	**54**	**0.25**
Ash 1 Bulk Leach	**2.6**	**0.005**	**0.087**	**0.009**	**0.18**	**180**	**0.79**
Composite Overburden 2 Bulk Leach	**3.2**	**<0.002**	**0.11**	**1.4**	**0.031**	**-**	**0.5**
Ash 2 Bulk Leach	**5**	**0.006**	**0.094**	**0.034**	**0.2**	**-**	**0.7**
Calculated Bulk Leach 50:1 Ratio Overburden 1 to Ash 1	**14.8**	**<0.002**	**0.1**	**1.7**	**0.04**	**56.5**	**0.3**

Calculated Bulk Leach 50:1 Ratio Overburden 2 to Ash 2	**3.2**	**<0.002**	**0.1**	**1.4**	**0.03**	**-**	**0.5**
Calculated Bulk Leach 100:1 Ratio Overburden to Ash 1	**14.9**	**<0.002**	**0.1**	**1.7**	**0.04**	**55.2**	**0.3**
Calculated Bulk Leach 100:1 Ratio Overburden 2 to Ash 2	**3.2**	**<0.002**	**0.1**	**1.4**	**0.03**	**-**	**0.5**
Typical Pit Lakes (Chicken Creek and Ewington 2)	**15**	**0.001**	**0.14**	**0.9**	**0.16**	**130**	**0.9**
Drinking Water Guidelines	**0.2**	**0.002**		**0.3**	**0.02**	**250**	**3**

6.4 Known Effects of Overburden Dumps

Based on the composite assessments, the concentrations of aluminium, cadmium, nickel and zinc solutes from the co-disposed overburden and ash might exceed drinking water guidelines at both Ewington I and Ewington II. The concentrations implied from the bulk leaching tests are interpreted to be most representative of the initial solute concentrations due to rainfall infiltration and rainfall runoff. Results of concentrations of rainfall runoff from overburden based on water quality analyses are presented in the next section (7.2).

6.4.1 Ewington I

For the previous study of Ewington I (URS 2008), the solute concentrations applied to modelling were derived from the 'Composite Overburden Bulk Leach', 'Column 1 – Composite Overburden' and 'Calculated Column Leaching 50:1 Overburden to Ash' data in Table 6-10. In each instance, the applied solute concentrations were intended to represent a worst-case. The solute concentrations applicable to the model as rainfall infiltration through overburden alone included: Aluminium 0.40 mg/L; Cadmium 0.02 mg/L; Cobalt 0.05 mg/L; Barium 0.021 mg/L; Nickel 0.30 mg/L; Sulphate 11 mg/L; and, Zinc 0.21 mg/L.

The solute concentrations applied to the model as rainfall infiltration through co-disposed overburden and ash at 50:1 mix ratios included: Aluminium 0.76 mg/L; Cadmium <0.025 mg/L; Cobalt 0.17 mg/L; Barium 0.026 mg/L; Nickel 0.42 mg/L; Sulphate 129 mg/L; and, Zinc 0.91 mg/L. Results regards the distribution with time of these constituents were presented in URS, 2008.

6.4.2 Ewington II

For Ewington II, the solute concentrations applied to modelling were derived from the 'Composite Overburden 1 Bulk Leach', 'Ash 1 Bulk Leach' and 'Calculated Leaching 50:1 Overburden to Ash 1' data in Table 6-11 In each instance, the applied solute concentrations were intended to represent a worst-case. The solute concentrations applicable as rainfall infiltration through overburden alone includes: Aluminium 15 mg/L; Cadmium <0.002 mg/L; Cobalt 0.14 mg/L; Iron 1.7 mg/L; Nickel 0.04 mg/L; Sulphate 54 mg/L and, Zinc 0.25 mg/L.

The solute concentrations applied to the model as rainfall infiltration through co-disposed overburden and ash at 50:1 mix ratios included: Aluminium 14.8 mg/L; Cobalt 0.1 mg/L; Nickel 0.04 mg/L; Sulphate 56.5 mg/L and, Zinc 0.3 mg/L.

In terms of initial recharge concentrations from areas of co-disposed ash, those for aluminium, iron, and nickel potentially will exceed drinking water guidelines. It is evident from the range of concentrations presented that there may be only subtle consequences of ash co-disposal compared to the potential impacts of the overburden backfill alone at both Ewington I and Ewington II.

Section 7 Site Investigation

In the following section the results of the following activities are presented:

- Field testing of the Infiltration capacities of the overburden on run-of-mine dumps at Ewington I and Ewington II;
- water quality analyses of runoff and surface water from coal measures, overburden and in-pit sumps; and,
- water quality analyses of groundwater from existing multipiezometers.

7.1 Infiltration Capacity

A site investigation was carried out in April 2008 to characterise the infiltration capacities of the overburden on run-of-mine dumps using low level of intrusion (hand auger and shallow drilling) methods. Two types of tests were conducted, both constant head tests. In the first test a 0.2 m diameter bucket was buried to a depth of 5 cm and a constant head of 3 cm was maintained during the test. In the second test a 0.054 diameter PVC pipe was augered to a depth of 60cm, the space around the pipe was backfilled with the cuttings and a constant head of 1.1m was maintained during the test. The volume of water was recorded with time and the Infiltration Rate (Table 7-1) was determined. Results from the 0.054m diameter pipe are shown in gray in Table 7-1. In general the infiltration rates were highly variable and ranged from ranged from 0.22 m day^{-1} to 18.1 m day^{-1} using the 0.2m bucket to 0.38 m day^{-1} to 798 m day^{-1} using the 0.054 m diameter pipe. The infiltration rate measured in the 0.054m diameter pipe were generally higher than the infiltration rate measured with the 0.2m diameter bucket, based on the higher head used during the field test. The 0.2 m diameter bucket is believed to be a closer approximation of the actual values. Given the short term nature of the field tests and considering the processes involved in infiltration, the results indicate the occurrence of more transmissive soil types rather than less transmissive types. Figure A-9 shows the location where the tests were conducted.

Table 7-1 Infiltration Test Results

Site Nr	Q = (m3/d)	Infiltration Rate m/d
1	0.02	0.75
	0.04	1.36
2	0.53	16.79
3	0.57	18.10
4	0.05	1.69
	1.25	546.10
5	0.10	3.03
	0.10	42.16
6	0.39	12.44
	0.07	32.75
7	0.01	0.22
	0.00	0.38
8	0.04	1.29
	0.04	15.37
9	0.12	3.75
	1.83	798.55
10	0.19	6.17

	0.37	159.75
11	0.03	0.96
	0.67	291.54

7.2 Water Quality

During the first week of April 2008 twenty sites were sampled to determine the water quality of surface water, runoff, and ground-water at the Ewington mines. Surface water and runoff was collected at fourteen different sites (sumps Table 7-2), and ground water was sampled at 6 bores (5 production bores and one piezometer) (Figure A-10). Sampled water was analysed for pH, conductivity, discrete chloride, major dissolved anions and cations, total metals, total mercury, and fluoride.

The surface water and runoff samples collected in sumps around the Ewington mines can be characterized as follows:

- is acidic with pH measured between 3.22 to 4.90;
- is fresh to brackish, with conductivity in uS/cm between 43 to 2,640, and with major cations and anions within previous ranges measured in the mines;
- contains some relatively high sulphate and sulphur concentrations, up to 1,390 mg/L and 464 mg/L, respectively;
- contains some relatively high aluminium and Zinc concentrations; up to 127 mg/L and 21.4 mg/L, respectively;
- exceeds compliance criteria for iron (less than 3.0mg/L) in 3 of the 14 samples, and for manganese (less than 0.5 mg/L) in 2 of the 14 samples (Water Authority, Water Resources Directorate July 1988);
- Exceeds the Australian Drinking Water guideline value for the following constituents:
  - Cadmium (0.002 mg/L) in 7 of the 14 samples;
  - Lead (0.01 mg/L) in 6 of 14 samples;
  - Selenium (0.01mg/L) in 1 of 14 samples; and
  - Sulphate (250 mg/L) in 5 of 14 samples.

The results of the analyses of ground water samples from the five production bores and one piezometer indicate the following regards to pH, Conductance, and major cations and anions.

- is acidic with pH measured between 5.87 to 6.29; and
- is fresh with conductance, uS/cm, measured between 322 to 505, and with major cations and anions within previous ranges measured in the groundwater.

In the analyses of metals from groundwater samples collected during this study, the following results are of note:

- exceeds compliance criteria for iron (less than 3.0mg/L) in 2 of the 6 samples (Water Authority, Water Resources Directorate July 1988); and,
- does not exceed the Australian Drinking Water guideline value for any other constituent.

Table 7-2 Results of Water Quality analyses of surface water sumps Ewington mines

Parameter	Sump 1	Sump 2	Sump 3	Sump 4	Sump 5	Sump 6	Sump 7	Sump 8	Sump 9
pH Value	3.78	3.99	3.22	3.59	3.68	4.90	4.08	4.50	3.95
Conductivity	380.00	2640.00	1980.00	991.00	761.00	198.00	336.00	43.00	473.00
Sulphate as SO4 2-	146.00	452.00	1390.00	448.00	129.00	13.00	60.00	6.00	152.00
Sulphur as S	49.00	151.00	464.00	149.00	43.00	4.00	20.00	2.00	51.00
Silica	0.80	2.40	2.40	5.30	8.80	2.60	3.90	0.50	3.70
Silicon	0.35	1.14	1.12	2.48	4.09	1.20	1.83	0.23	1.74
Chloride	11.80	596.00	27.50	59.80	119.00	48.50	46.60	24.40	100.00
Calcium	8.00	14.00	47.00	17.00	4.00	1.00	3.00	<1	6.00
Magnesium	10.00	92.00	80.00	32.00	35.00	3.00	9.00	<1	13.00
Sodium	15.00	426.00	44.00	42.00	48.00	26.00	32.00	2.00	30.00
Potassium	<1	5.00	<1	4.00	5.00	3.00	3.00	<1	4.00
Aluminium	12.00	7.67	127.00	46.40	3.69	1.34	3.29	0.23	11.40
Antimony	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	<0.001	<0.001	0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Beryllium	0.01	0.02	0.12	0.03	0.01	<0.001	0.00	<0.001	0.01
Barium	0.01	0.02	0.01	0.05	0.07	0.01	0.03	0.01	0.04
Cadmium	0.00	0.01	0.02	0.01	0.00	<0.0001	0.00	<0.0001	0.00
Chromium	0.00	0.00	0.03	0.01	<0.001	<0.001	0.00	<0.001	0.00
Cobalt	0.24	1.13	3.86	0.80	0.10	0.01	0.13	0.01	0.28
Copper	0.00	0.01	0.04	0.02	0.01	<0.001	0.00	<0.001	0.00
Lead	0.01	0.02	0.09	0.05	0.01	<0.001	0.01	0.00	0.02
Manganese	0.07	1.43	0.69	0.31	0.05	0.04	0.08	0.01	0.10
Molybdenum	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	<0.010	<0.010	0.03	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Silver	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Strontium	0.03	0.27+C87	0.51	0.24	0.07	0.02	0.07	0.01	0.11
Titanium	0.02	0.01	0.01	0.03	0.02	0.05	0.02	<0.01	<0.01
Vanadium	<0.01	<0.01	0.04	0.02	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	0.84	5.39	21.40	4.34	0.40	0.06	0.75	0.04	1.23
Boron	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Iron	0.85	0.38	7.48	4.23	6.92	0.41	0.41	<0.05	0.53
Mercury	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Fluoride	<0.1	0.30	0.20	0.20	<0.1	<0.1	<0.1	<0.1	0.10

Table 7-2 (continued) Results of Water Quality analyses of surface water sumps Ewington mines

Parameter	Sump 10	Sump 11	Sump 12	Sump 13	Sump 14	Max	Avg
pH Value	4.13	3.66	4.29	3.82	4.29	4.90	3.99
Conductivity	355.00	664.00	73.00	1000.00	154.00	2640.00	717.71
Sulphate as SO4 2-	78.00	320.00	12.00	361.00	31.00	1390.00	257.00
Sulphur as S	26.00	107.00	4.00	120.00	10.00	464.00	85.71
Silica	2.00	0.70	0.50	4.40	1.30	8.80	2.81
Silicon	0.95	0.32	0.24	2.04	0.62	4.09	1.31
Chloride	48.40	25.10	5.20	102.00	16.00	596.00	87.88
Calcium	5.00	11.00	<1	17.00	3.00	47.00	11.33
Magnesium	9.00	14.00	<1	29.00	3.00	92.00	27.42
Sodium	29.00	16.00	3.00	59.00	9.00	426.00	55.79
Potassium	2.00	<1	<1	4.00	<1	5.00	3.75
Aluminium	4.81	38.10	0.59	35.60	1.88	127.00	21.00
Antimony	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	<0.001	<0.001	<0.001	<0.001	<0.001	0.01	0.01
Beryllium	0.00	0.02	<0.001	0.02	0.00	0.12	0.02
Barium	0.03	0.00	0.01	0.02	0.02	0.07	0.02
Cadmium	0.00	0.00	0.00	0.00	0.00	0.02	0.00
Chromium	0.00	0.01	<0.001	0.00	<0.001	0.03	0.01
Cobalt	0.17	0.47	0.02	0.44	0.04	3.86	0.55
Copper	0.00	0.00	<0.001	0.00	<0.001	0.04	0.01
Lead	0.01	0.00	0.00	0.00	0.00	0.09	0.02
Manganese	0.10	0.11	0.01	0.37	0.14	1.43	0.25
Molybdenum	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	<0.010	<0.010	<0.010	<0.010	<0.010	0.03	<0.010
Silver	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Strontium	0.08	0.06	0.02	0.19	0.03	0.51	0.11
Titanium	0.02	0.01	<0.01	0.02	0.02	0.05	0.02
Vanadium	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	0.03
Zinc	0.96	2.42	0.11	2.34	0.20	21.40	2.89
Boron	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Iron	0.62	2.06	0.31	1.43	0.38	7.48	2.00
Mercury	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Fluoride	<0.1	0.10	<0.1	0.10	<0.1	0.30	0.17

Table 7-3 Results of Water Quality analyses of groundwater bores and a piezometer near the Ewington mines

Parameter	PE56	PE55	Piezo P60	PEW4	PEW5	PEW7	Min	Max	Avg
pH Value	6.19	6.20	6.02	6.29	5.87	5.95	5.87	6.29	6.09
Conductivity	322.00	373.00	505.00	392.00	367.00	327.00	322.00	505.00	381.00
Sulphate as SO4 2-	8.00	14.00	7.00	9.00	7.00	8.00	7.00	14.00	8.83
Sulphur as S	3.00	5.00	2.00	3.00	2.00	2.00	2.00	5.00	2.83
Silica	11.80	12.40	32.40	13.20	8.40	9.90	8.40	32.40	14.68
Silicon	5.49	5.77	15.10	6.14	3.94	4.61	3.94	15.10	6.84
Chloride	82.10	90.90	123.00	93.50	91.90	80.40	80.40	123.00	93.63
Calcium	<1	<1	3.00	2.00	1.00	1.00	<1	3.00	1.75
Magnesium	5.00	6.00	8.00	5.00	6.00	5.00	5.00	8.00	5.83
Sodium	43.00	51.00	60.00	53.00	49.00	45.00	43.00	60.00	50.17
Potassium	5.00	7.00	11.00	6.00	2.00	3.00	2.00	11.00	5.67
Aluminium	0.03	0.02	0.29	0.03	0.28	0.07	0.02	0.29	0.12
Antimony	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Beryllium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Barium	0.09	0.13	0.41	0.09	0.04	0.04	0.04	0.41	0.13
Cadmium	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	0.002	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.002
Copper	0.004	0.01	0.001	0.001	0.001	0.003	0.001	0.007	0.003
Lead	0.001	0.00	0.01	0.00	0.01	0.00	0.001	0.01	0.00
Manganese	0.02	0.04	0.14	0.07	0.03	0.03	0.02	0.14	0.05
Molybdenum	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Silver	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Strontium	0.03	0.03	0.06	0.04	0.02	0.02	0.02	0.06	0.03
Titanium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	0.03	0.11	0.01	0.02	0.03	0.03	0.01	0.11	0.04
Boron	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Iron	0.49	1.11	17.80	3.20	1.46	1.18	0.49	17.80	4.21
Mercury	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Fluoride	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Section 8 Water, Salt and Solute Balances

To understand the physical process responsible for salinity and leachate mobilisation, an understanding of water movement in the surface and subsurface is required. To develop simple conceptual solute and water balance models all information gained during this study was collated for each mine area and identified as either catchment inputs or catchment outputs. Figure 8-1 presents a schematic diagram of the conceptual water balance for the Ewington I and Ewington II mine areas. The water balance was used to develop salt and soluble metals balances which were then used to provide the context for evaluating the catchments hosting co-disposed ash compared to the entire surface water and sub crop catchments.

Water balances in the unsaturated overburden dump profiles that host co-disposed ash would be widely varied. Spatial and temporal variation would be expected, reflecting different infiltration potentials, the occurrence of changes in slope, presence of preferred flow paths for infiltration, differences in the overburden dump materials, thickness of the overburden dump profile, moisture contents of the overburden materials and a raft of other factors. Notwithstanding the likelihood of varied and complex water balances, in fundamental terms, the ash co-disposal settings form comparatively small portions (less than 28%, approx 13km ^{2}) of the total catchment of the Ewington I and Ewington II mines (46 km ^{2}). The catchment not only includes the surface water catchment areas for the two mines but also includes the subsurface catchment areas; that is those subcrop areas surrounding the mines that due to mine dewatering are now contributing to the water budget of the mines (Figure 8-1). Further, contributions from the unsaturated co-disposal profiles to the water balances for each site are expected to be comparatively minor and probably significantly less than 10% of the total water balance because of the collective poor permeability of the ash (http://www.rmajko.com/soilstab.htm) and the preferred pathways being through the overburden rather than the ash, in addition to the relatively minor differences in solutes from ash versus solutes from overburden. These aspects would be manifest in the substantial dilution of the effects of the co-disposed ash on the water table and local groundwater resources.

Groundwater recharge is mainly from infiltration of rainfall. Previous studies suggest that the net average recharge to groundwater is about 12 % of the annual rainfall. Annual average rainfall is 939 mm/yr at Collie (1899-2007) and 675 mm/yr at the Muja mine site. The net recharge to the water table aquifer is about 80 mm/yr, based on a 12% recharge rate and 675 mm/yr rainfall. Recharge is thus reduced during a drought, as has occurred during the last 5 years as annual rainfall in the last 5 years was well below the 20-year average.

Groundwater discharge typically would occur to the Collie River and its tributaries; by evaporation from areas with a shallow water table; and, into the Ewington I and II mine voids. Local mine dewatering has reversed groundwater flow gradients in the superficial aquifer so that groundwater now flows towards the mines and thus accounts for the increased catchment area of the mines.

The catchment areas of the ash co-disposal areas is 6.35 km^{2} and 5.9 km^{2} for Ewington 1 and Ewington II, respectively while the surface water catchment for both mines is 8.1 km^{2} and 13.9 km^{2}, respectively.

In general terms, groundwater recharge in the present study was defined as that part of the rainfall which reaches the groundwater via soil and the unsaturated zone. As groundwater recharge is controlled by a wide range of variables and with limited detailed soil data covering the study area, the soil water balance method (AgET) was identified as the most appropriate. Results from the water balence model simulations provided estimates for evapotranspiration, deep percolation, and runoff. The resulting water flow rates were used to calculate annual contributions of water and solutes to Ewington I and II minesystem. Solute volumes were calculated using measured and estimated solute concentrations of rainfall, runoff and groundwater measured during the investigation. Provisions were made to accommodate leaching by the recharge water.

AgET is a simple Water Balance Calculating program developed by the Natural Resource Management Unit, Agriculture WA and the University of Melbourne (Argent and George, 1997). This model uses average climatic data and representative soil and plant information obtained within the agricultural areas of Western Australia. Estimations of ET are based on the Pan Evaporation Method (FAO, 1977). A pan coefficient of 0.8 is used to calculate potential evaporation from pan evaporation. AgET is not designed to cope with excessive waterlogging and lateral flow. Equivalent crop coefficients for bare soil are presented on Figure 8-2. Bare soil was used as it represent the worst case scenario for the water balance by maximizing infiltration/recharge. The rooting depths for bare soil are summarised in Table 8-1.

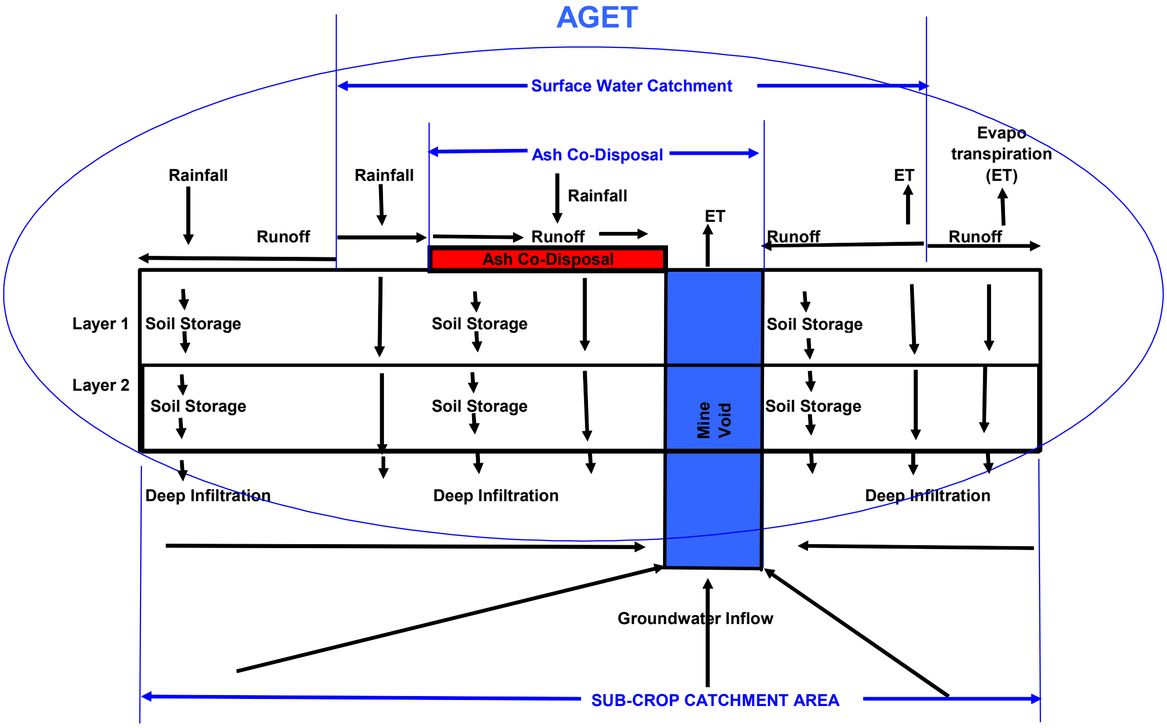

Figure 8-1 Conceptual Water Balance Model

In AgET, water simply moves straight through the soil profile ignoring influences other than plant water use, evaporation and runoff. AgET also does not consider recharge associated with water-logging and preferred pathway flow or the impact of low permeability (clay stringers) or horizontal flow. As a result, deep percolation on some soil types may be higher or lower than the model suggests.

The AgET model was used to calculate daily water balance of the Ewington I and II area using 1954-93 daily rainfall data. This is a simple water balance model that uses average climatic data and representative soil information obtained within the agricultural areas of Western Australia.

Table 8-1 Rooting Depths for Different Soil Scenarios

Crops/Soil	Rooting Depth (m)		
	Minimum	Effective	Maximum

Bare Soil Scenario 1	0.2	1	3
Bare Soil Scenario 2	0.2	2	3

Water use is by plants or by evaporation. Plant water use is based on leaf area index of the different crops and this closely ties to rooting depth. The daily water balance for any soil is based upon the soil moisture available over the lesser of the soil layer thickness and the effective rooting depth of the water use by plants or by evaporation. Thus, if the evaporation occurs from the A-horizon, the balance is performed on the A-horizon: any drainage from the A-horizon goes to the deep flow component. AgET takes no account of the water table and all calculations are carried out as if the water table is too deep to impact on the plants.

The basic steps in the operation of AgET each day are:

1. Determine the rainfall for the day, with allowance made for runoff from intense storms.
2. Determine ET for the day. This is dependent upon the climate (evaporation), equivalent monthly crop factor for bare soil and the moisture available in the soil.
3. Perform the water balance for the day by adding rainfall and subtracting ET. This also determines if there is any surface runoff, how much moisture drains into different soil levels and how much water goes to deep flow.
4. Alter the current soil moisture levels to reflect the results of the daily balance.

The water balance components of rainfall, runoff, evapotranspiration, soil storage and deep flow are summed to provide monthly and annual data. Each simulation reported results for probability of exceedence representing a predicted drying climate (75%), mean or current climate (50%) and a wet climate (25%). Outputs from these AgET simulations are semi-quantitative.

Predicted surface run-off and deep percolation generated under deep sandy soils with 1.5 m deep horizon A, and 1.5 m deep horizon B for bare soils are summarised in Table 8-2 and 8-3 for two effective depths (Table 8-1) . This simulation is believed to be representative of current conditions. An available water of 135 mm 1.5 m^{-1} with Ksat of 8 mm day^{-1} was used for horizon A and 195 mm 1.5 m^{-1} with Ksat of 20 mm day^{-1} used for horizon B. It is interesting to note that soil infiltration capacity results at the Ewington II mine using the 0.2 m bucket ranged from 220 mm day^{-1} to 18,100 mm day^{-1}. The magnitude of K sat and soil infiltration capacity values are not that far out of line with one another considering the soil infiltration only occurs for a portion of the time (less than 1 % of the time) when rainfall occurs.

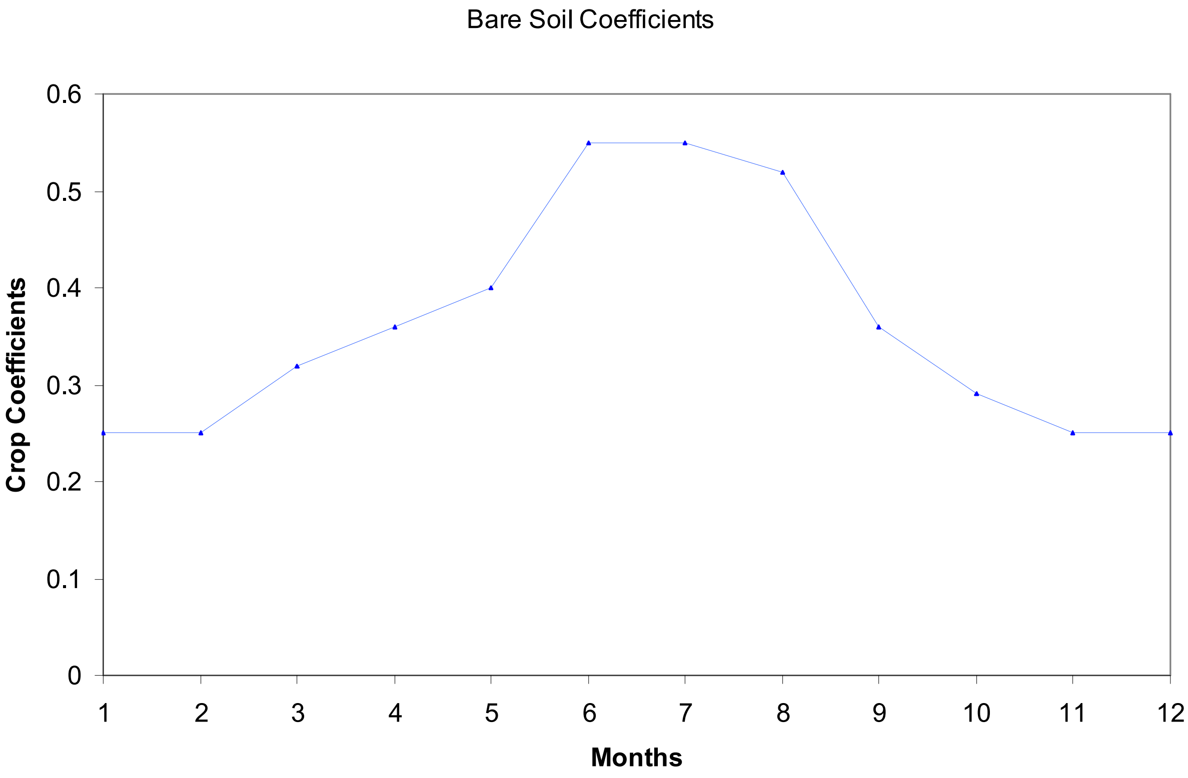

Figure 8-2 Equivalent crop coefficients for bare soil.

Table 8-2 Predicted Runoff and Deep Flows of Bare Sandy Soil (effective depth 1 m)

Probability Of Exceedence		Annual Rainfall (mm	Current ET mm (% of Rainfall)	Current Runoff mm (% of Rainfall)	Current Deep Percolation mm (% of Rainfall)
Ewington I & II	Dry (75%)	764	211 28%	11 1%	392 51%
	Mean (50%)	871	227 26%	35 4%	480 55%
	Wet (25%)	996	250 25%	65 7%	630 63%

Table 8-3 Predicted Runoff and Deep Flows of Bare Sandy Soil, effective depth 2m.

Probability Of Exceedence	Annual Rainfall (mm	Current ET mm (% of Rainfall)	Current Runoff mm (% of Rainfall)	Current Deep Percolation mm (% of Rainfall)

Ewington I & II	Dry (75%)	764	209 27%	7 1%	352 46%
	Mean (50%)	871	227 26%	24 3%	418 48%
	Wet (25%)	996	249 25%	46 5%	557 56%

AgET simulations indicate deep percolation is the most significant proportion of the water balance (annual rainfall) for current conditions assuming sandy soils and different effective depths for evapotranspiration (ET). In an average year, 46% to 63% of annual rainfall is estimated to go to deep percolation. Given that this is a soils water budget model, it can reasonably be expected that not all deep percolation is expected to go to groundwater recharge given depths to the water table approaching 20 m.. Estimates of the amount of rainfall that goes to groundwater recharge from other studies indicate recharge is 12% of rainfall. Second in importance in the water budget, with a range between 25% to 28 %, is loss due to evapotranspiration, and only 1% to 7% of the budget is surface water runoff.

Soil depths included 1.5 m deep horizon A and 1.5 m deep horizon B for bare soils. An available water of 180 mm 1.5 m^{-1} with Ksat of 0.5 mm day^{-1} was used for horizon A and 165 mm 1.5 m^{-1} with Ksat of 15 mm day^{-1} used for horizon B. Predicted surface run-off and groundwater recharge generated for clay soils which might represent post closure conditions under bare soil scenarios for two effective depths (1 & 2 m) are presented in Table 8-4 and Table 8-5.

In the post closure scenario with the equivalent of clay soils assumed, runoff is the most significant component of the water balance and ranges 42% to 56 % of the budget (rainfall). ET is the 2nd most important component of the water balance, ranging 30 % to 37% of the rainfall; and deep percolation is the least important, ranging between between 2% to 7 % of rainfall. Deep percolation is significantly lower than estimated values of recharge.

Table 8-4 Predicted Runoff and Deep Flows of Clay Soil (effective depth 1 m)

Probability Of Exceedence		Annual Rainfall (mm	Current ET mm (% of Rainfall)	Current Runoff mm (% of Rainfall)	Current Deep Percolation mm (% of Rainfall)
Ewington I & II	Dry (75%)	764	250 33%	368 48%	49 6%
	Mean (50%)	871	274 31%	450 52%	58 7%
	Wet (25%)	996	295 30%	561 56%	61 6%

Table 8-5 Predicted Runoff and Deep Flows of Clay Soil, effective depth 2m.

Probability Of Exceedence		Annual Rainfall (mm	Current ET mm (% of Rainfall)	Current Runoff mm (% of Rainfall)	Current Deep Percolation mm (% of Rainfall)
Ewington I & II	Dry (75%)	764	281	318	18

			37%	42%	2%
	Mean (50%)	871	299 34%	381 44%	30 3%
	Wet (25%)	996	295 30%	561 56%	61 6%

Table 8-6 Water Quality of the various water balance components of the Ewington I & II catchment

in mg/l	Mine Runoff	Groundwater	Rainfall [2]	Surface Water Runoff [4]	50:1 Overburden to Ash [3]	Overburden	Ash
Salinity 1	574	305	0	100	305	305	305
Aluminium	21.0	0.12	0	0.1	14.9	15	2.6
Iron	2.00	4.21	0	1	1.7	1.7	0.009
Zinc	2.89	0.04	0	0.1	0.3	0.26	0.7

The significance of the AgET results are that they are conservative estimates and indicate the relative water balance from existing conditions to post closure. The simulations indicate that there would be a reduction in the amount of water available for leaching salinity and metals from the soil profile between existing conditions and closure. That is there would be less rainfall infiltrating the land surface under closure conditions.

To test the contribution of solutes leached from Ash relative to the solute contributions from other components of the water budget the salt and solute metals balance were computed using salinity, aluminium, iron and zinc concentrations observed in the sumps, groundwater, 50:1 Ash overburden co-disposal and results presented earlier in this report. The assumed values of the water quality contribution from various sources are shown in Table 8-6.

Water/solute balances based on the water quality parameters presented in Table 8-6 and the results of AGET for sandy and clayey soils (Table 8-2 and Table 8-4) for mean conditions and 1 m effective depth were developed for closure and post closure conditons (Table 8-6). Sandy soils were assumed for the Ash Co-Disposal area, while clayey soils were assumed for the Surface Water and the Sub Crop Catchment areas outside the area of Ash Co-Disposal. Clayey soils are believed to better represent the Latterite which occurs near land surface over most of the basin. It was also assumed that the equivalent of Latterite type soils would be used during the closure process for the Ash Co-Disposal Area. Time was not considered in the development of the water balance. The effect of time would be to dilute the contribution of Ash to the water/solute balance because it will take 9 years for Ash Co-Disposal to reach its total disposed area (5.9 km^2) at Ewington II and a similar time frame at Ewington.

Table 8-7 Water Solute Balance, Ewington I & II Catchment

	PRE CLOSURE			POST CLOSURE		
	Total Catchment	**Ash Contribution[1]**	**% Ash Contribution to Total**	**Total Catchment**	**Ash Contribution**	**% Ash Contribution to Total**
Volume in m3	**33,490,000**	**5,880,000**	**17.56%**	**33,490,000**	**710,500**	**2.12%**
TDS Kilograms	**4,455,826**	**35,165**	**0.79%**	**3,255,645**	**4,249**	**0.13%**

Al Kilograms	145,668	300	0.21%	81,473	36	0.04%
Fe Kilograms	26,271	1	0.004%	27,423	1.04	0.00%
Zn Kilograms	9,912	91	0.92%	11,576	91	0.79%

1-volume is inclusive of the area of overburden

Regarding the contribution of Ash to the salinity, aluminium, iron, and zinc solute loads to the total catchment, they are minor (see Table 8-6) for both pre-closure and post closure conditions. While the area of Ewington I and II Ash Co-disposal contributes between 17 % to 2 % of the total water in the overall catchment during pre-closure and post closure, respectively, the contribution to the solutes is generally insignificant during both pre- and post closure. The percent contribution of the leachate attributable to Ash is generally less than 1 % of the total solute load in the total Catchment in kilograms of Total Dissolved Solids (TDS), Aluminium (Al), Iron (Fe), and Zinc (Zn).

Table 8-8 Contribution as a Percent of the Total Catchment (Pre Closure)

PRE CLOSURE									
	Ash Co-Disposal					Rest of the Catchment			
	Infiltration thru Ash [2]	Infiltration thru Overburden [2]	Runoff from Overburden	Remainder	Total	Surface Water Catchment [1]	Sub Crop Catchment [1]	Total (m^3 or Kilograms per year)	Total
Volume of Water	17.6%		8.3%	6.0%	31.9%	25.4%	42.8%	33,490,000	100%
TDS	0.8%	39.5%	35.8%	0.1%	76.5%	11.0%	12.4%	4,455,826	100%
Al	0.2%	59.4%	40.1%	0.0%	99.7%	0.2%	0.1%	145,668	100%
Fe	0.0%	37.3%	21.2%	0.0%	58.5%	19.2%	22.3%	26,271	100%
Zn	0.9%	14.5%	81.1%	0.0%	96.6%	2.9%	0.5%	9,912	100%

1-less area of Ash Co-Disposal for Surface Water Catchment, less area of Ash Co-Disposal and Surface Water Catchment for the Sub-Crop Catchment.

2-volume includes contribution from both overburden and Ash in m^3

The water and salt and soluble metal balances during pre closure indicates the following (see Table 8-6):

- The most significant contribution to the total water budget is from water originating from the water originating from the Sub- Crop Catchment area outside the Surface Water Catchment area. The contribution is 43% of the overall catchment water balance. Second in importance is the contribution from the Surface Water Catchment area outside the Ash Co-Disposal area (25% of the total).
- The most significant contribution to the salt budget, total dissolve solids (TDS), is from infiltration through the overburden in the area of Ash Co-Disposal (40% of total budget) followed by the runoff from the area of Ash Co-Disposal (36% of total salt budget).

- The most significant contribution to soluble Aluminium budget is from infiltration through the overburden in the area of Ash Co-Disposal (59% of total budget) followed by the runoff from the area of Ash Co-Disposal (40% of total salt budget).
- The most significant contribution to soluble Iron budget is from infiltration of water through the overburden in the area of Ash Co-Disposal (36% of total budget) followed by water originating in the Sub-Crop Catchment area outside the Surface Water Catchment area (22%) followed closely by runoff from the area of Ash Co-Disposal (21% of total budget).
- The most significant contribution to soluble Zinc budget is from runoff from the area of Ash Co-Disposal (81% of total budget) followed by infiltration of water through the overburden in the area of Ash Co-Disposal (14% of total budget).

Table 8-9 Contribution as a Percent of the Total Catchment (Post Closure)

	POST CLOSURE								
	Area of Ash Co-Disposal					Rest of the Catchment			
	Infiltration thru Ash [2]	Infiltration thru Overburden [2]	Runoff from Overburden	Remainder	Total	Surface Water Catchment [1]	Sub Crop Catchment [1]	Total (m^3 or Kilograms per year)	Total
Volume of Water	2.12%		10.02%	19.7%	31.86%	25.36%	42.78%	33,490,000	100%
TDS	0.13%	6.53%	59.20%	0.2%	67.88%	15.11%	17.01%	3,255,645	100%
Al	0.04%	12.82%	86.51%	0.0%	99.38%	0.41%	0.21%	81,473	100%
Fe	0.004%	35.737%	24.489%	0.0%	60.230%	18.417%	21.353%	27,423	100%
Zn	0.79%	12.45%	83.83%	0.0%	97.07%	2.49%	0.44%	11,576	100%

1-less area of Ash Co-Disposal for Surface Water Catchment, less area of Ash Co-Disposal and Surface Water Catchment for the Sub-Crop Catchment.

2-volume includes contribution from both overburden and Ash in m^3

The water and salt and soluble metal balances during post closure indicates the following (see Table 8-6):

- The most significant contribution to the total water budget is from water originating from the water originating from the Sub- Crop Catchment area outside the Surface Water Catchment area. The contribution is 43% of the overall catchment water balance.
- The most significant contribution to the salt budget, total dissolve solids (TDS), is from runoff from the area of Ash Co-Disposal (59% of total budget) followed by the Sub- Crop Catchment area outside the Surface Water Catchment area (17% of total salt budget) and then from the Surface Water Catchment area outside the area of Ash Co-Disposal (15% of total salt budget).
- The most significant contribution to soluble Aluminium budget is from runoff from the area of Ash Co-Disposal (87% of total budget) followed by infiltration through the overburden in the area of Ash Co-Disposal (13% of total salt budget).
- The most significant contribution to soluble Iron budget is from infiltration of water through the overburden in the area of Ash Co-Disposal (36% of total budget) followed by runoff from the area

of Ash Co-Disposal (24%) followed closely by water originating in the Sub-Crop Catchment area outside the Surface Water Catchment area (21% of total budget).

- The most significant contribution to soluble Zinc budget is from runoff from the area of Ash Co-Disposal (83% of total budget) followed by infiltration of water through the overburden in the area of Ash Co-Disposal (12% of total budget).

This simple water, salt, and soluble metal balances calculations are one of a range of methods available to estimate the concentration of salt and soluble metals entering the groundwater system from Ash Co-Disposal. In the following section another method – predictive groundwater flow and transport modelling is discussed.. These methods are conservative in that geochemical processes that might remove solutes from the flow system as discussed in the Background section of the report, are not considered.

Section 9 Groundwater Flow Model

Conceptual ash co-disposal strategies have been formulated for Ewington I and II to develop an understanding of the potential solute impacts. The formulated strategies for Ewington I & II are based on:

- Available mine plans for pit advancement.
- Assessments of pre-mining water table elevations.
- Structure mapping of the E32 Seam that forms the pit floor in Ewington I.
- Structure mapping of the P8 Seam that forms the pit floor in Ewington II
- Annual volumes of ash to be co-disposed.
- Co-disposal of all ash above the pre-mining water table.

The approach involved has been to adapt and apply the groundwater flow model used for dewatering design studies. Adaptations to the model have included:

- Assigning of domains for the co-disposed of ash based on the annual pit developments and interpreted backfill schedules.
- Assignment of rainfall recharge to the areas of ash co-disposal.
- Incorporating the findings of the bulk leaching and column leach tests.

The model incorporates the mine development schedules. In the model, annual mine blocks are discretised. This aspect enables the simulation of in-pit backfill dumps (wherein the ash is co-disposed) in transient annual sequences. The model enables the annual transient prediction of the solutes generated from the co-disposed ash.

The predictive models are anticipated to be framed based on worst-case water balances. Parameterisation of the model is conservative in limiting recharge (and consequently solute dilution) and regarding the mobility of metals (with no adsorption within the unsaturated or saturated groundwater flow paths in overburden and the Westralia Sandstone, Ewington I, and overburden and the Premier Coal measures, Ewington II).

A predictive groundwater flow model has been applied to evaluate the potential changes in groundwater quality due to ash co-disposal at Ewington II. The model is developed in FEFLOW and was originally applied for design of the Ewington I.

9.1 Model Form

The model domain comprises all of the Premier Sub-basin.

Data used in model construction include:

- Topography.
- Geological model floor elevations for the coal seams of the Premier Coal Measures and Ewington Coal Measures as provided by the mining companies.
- Structure contours of other stratigraphic units compatible with those developed by the Water and Rivers Commission (2002) for the development of a Collie Basin model.
- Geophysical log interpretations of the typical thickness of coal seams, shale, mudstone and siltstone beds that form confining layers.
- Groundwater levels observed throughout the Premier Sub-basin.
- Existing production bores and groundwater abstraction histories for mining and water supply projects.

9.2 Model Parameters and Material Types

Individual aquifers and aquitards are represented in the model as different material types, each with discrete hydraulic parameters. The interpreted hydraulic conductivity values within the Premier Sub-basin have been applied to characterise the hydraulic behaviours of the individual aquifer systems. The applied values are not lower-bound or upper-bound but broadly represent the middle of the interpreted range. In all cases, the assigned values represent the entire domain of each individual aquifer.

The applied parameters (Table 9-1) are based on calibration of the model, involving the comparison of long-term simulated and actual aquifer system responses to pit dewatering and water supply abstractions.

Recharge is not applied to the model, except in association with the co-disposed ash.

Table 9-1 Model Layers and Aquifer Properties

Layer No.	Slice No.	Description	Hydraulic Conductivity (m/day)			Specific Yield (dimension-less)	Specific Storage (1/m)
			K_x	K_y	K_z	S_y	S_s
1	1	Nakina Formation	1	1	0.1	0.050	1.00E-09
2	2	Muja Coal Measures	1	1	0.1	0.050	1.00E-09
3	3	Muja 2 Coal Measures	1	1	0.1	0.050	1.00E-09
4	4	Muja 3 Coal Measures/Shallow Premier Coal Measures	1	1	0.1	0.050	1.00E-09
5	5	P2 and P3 Seam Premier Coal Measures	0.001	0.001	0.000005	0.010	1.00E-09
6	6	P5 Aquifer	1	1	0.1	0.050	1.00E-09
7	7	Premier 5 and Premier 6 Seams	0.001	0.001	0.00005	0.010	1.00E-09
8	8	P10 Aquifer	1	1	0.1	0.050	1.00E-09
9	9	P10 Seam	0.001	0.001	0.00005	0.010	1.00E-09
10	10	P20 Aquifer	3	3	3	0.050	1.00E-09
11	11	P20 Seam	0.001	0.001	0.00005	0.010	1.00E-09
12	12	P30 Aquifer	3	3	3	0.050	1.00E-09
13	13	P30 Seam	0.001	0.001	0.00005	0.010	1.00E-09
14	14	P40 Aquifer	3	3	3	0.050	1.00E-09
15	15	P40 Seam	0.001	0.001	0.00005	0.010	1.00E-09
16	16	P50 Aquifer	10	10	10	0.050	3.80E11
17	17	P50 Seam	0.001	0.001	0.00005	0.010	1.00E-11
18	18	P60 Aquifer	2	2	2	0.050	4.70E-11
19	19	P60 Seam	0.001	0.001	0.00005	0.010	1.00E-11
20	20	P80 Aquifer	7	7	7	0.050	1.00E-10
21	21	P80 Seam	0.001	0.001	0.00005	0.010	1.00E-11
22	22	Allanson Sandstone	8.5	8.5	8.5	0.050	5.33E-11
23	23	Allanson Sandstone	4	4	4	0.050	5.33E-11

24	24	Confining Layer – Mudstone/Shale/Silt	0.001	0.001	0.005	0.010	1.00E-11
25	25	Allanson Sandstone	4	4	4	0.050	5.33E-11
26	26	Confining Layer – Mudstone/Shale/Silt	0.001	0.001	0.005	0.010	1.00E-11
27	27	Allanson Sandstone	3	3	3	0.050	5.33E-11
28	28	Confining Layer Mudstone/Shale/Silt	0.001	0.001	0.005	0.010	1.00E-11
29	29	Allanson Sandstone	2	2	2	0.050	5.33E-11
30	30	E01 and E03 Seam Interval, Ewington Coal Measures	0.01	0.01	0.00005	0.050	5.00E-09
31	31	Moira Aquifer	3.4	3.4	0.34	0.050	1.00E-11
32	32	Moira, Stockton and Wallsend Seams	0.4	0.4	0.004	0.050	1.00E-11
33	33	Westralia Sandstone	0.7	0.7	0.07	0.008	7.50E13
34	34	Stockton Group	0.001	0.001	0.00005	0.010	1.00E-11
35	35	Achaean Bedrock	8.64E-14	8.64E-14	8.64E-14	0.000	1.00E11

The model was simplified for the solute transport simulations. The solute transport model comprises seven layers and only broadly represents the structure and stratigraphy in the model area.

Table 9-2 Model Layers and Hydraulic Parameters

Model Layer	Description	Hydraulic Conductivity (m/day)	Specific Yield (dimensionless)
1	Nakina Formation	3.4	0.05
	Muja Coal Measures		
	Muja 2 Coal Measures		
	Muja 3 Coal Measures/Shallow Premier Coal Measures		
	P2 and P3 Seam Premier Coal Measures		
	P5 Aquifer		
	Premier 5 and Premier 6 Seams		
	P10 Aquifer		
	P10 Seam		
	P20 Aquifer		
	P20 Seam		
	P30 Aquifer		
	P30 Seam		
	P40 Aquifer		
	P40 Seam		
	P50 Aquifer		
	P50 Seam		
	P60 Aquifer		
	P60 Seam		
	P80 Aquifer		
	P80 Seam		

2	Allanson Sandstone	3.4	0.05
	Allanson Sandstone		
	Confining Layer – Mudstone/Shale/Silt		
	Allanson Sandstone		
	Confining Layer – Mudstone/Shale/Silt		
	Allanson Sandstone		
	Confining Layer Mudstone/Shale/Silt		
	Allanson Sandstone		
	E01 and E03 Seam Interval, Ewington Coal Measures		
3	Moira Aquifer	3.4	0.05
4	Moira, Stockton and Wallsend Seams	0.4	0.05
5	Westralia Sandstone	0.7	0.008
6	Stockton Group	0.001	0.01
7	Achaean Bedrock	8.64E-14	0.00001

9.3 Simulation of Faults

The developed groundwater flow model does not discretise any fault zones. In the vicinity of fault zones, each model layer thins and changes elevation to accommodate the throw on the fault zones. As such the simulated fault zones:

- Juxtapose aquifers and aquitards based on the mapped stratigraphy.
- Typically reduce the local aquifer transmissivity as layers thin, forming partial barriers to lateral and vertical groundwater flow.
- Form multiple-layer successions of interbedded aquifers and aquitards that form partial barriers to lateral and vertical groundwater flow.
- Retain the layer-cake structure of the aquitards, maintaining their integrity and limiting the vertical linking of aquifer systems by faulting.

This approach enables the simplification of the model structure. It also intentionally promotes vertical flow through aquitards due to leakage effects rather than the *ad hoc* and arbitrary vertical linking of aquifers by faults.

9.4 Ewington II Predictive Dewatering Simulations

The developed groundwater flow model was applied to simulate the dewatering of Ewington I together with the impacts of the ash co-disposal in overburden dumps. The results were documented in URS , 2008. The developed groundwater flow model has been applied here to simulate the dewatering of Ewington II together with the impacts of the ash co-disposal in overburden dump profiles. Fundamental aspects of the modelling approach include:

- Available mine plans for pit advancement.
- Assessments of pre-mining water table elevations.
- Structure mapping of the E32 Seam that forms the pit floor in Ewington I.
- Structure mapping of the P8 Seam that forms the pit floor in Ewington II

- Annual volumes of ash to be co-disposed.
- Co-disposal of all ash above the pre-mining water table.

The model starting groundwater level is 215 mAHD. This water table elevation is broadly compatible with the observed groundwater levels within the Ewington Coal Measures in the northern portion of Ewington I and north western part of Ewington II. This water table setting has been modified by recent abstractions. This approach has been applied understanding that:

- Abstractions from the lowermost Premier Coal Measures and Allanson Sandstone only commenced at Ewington II during the later half of 2003.
- The drawdown impacts of historical abstractions on Ewington I are constrained to eastern and southern areas where Allanson Sandstone subcrops.
- The simulated groundwater levels at Ewington I and II are likely to be conservatively high in the east and south, but typically within 2 or 3 m of those observed.

Long-term groundwater abstractions throughout the Premier Sub-basin have stressed the aquifer systems formed by the Muja Coal Measures, Premier Coal Measures and Allanson Sandstone. The abstractions have resulted in regional depressurisation and local dewatering of these aquifer systems. Aquifer systems formed by the Ewington Coal Measures and Westralia Sandstone have been less influenced by these abstractions – less significant groundwater abstraction has occurred from these stratigraphic successions.

The developed groundwater flow model shows that drawdown impacts from historical pit dewatering and water supply abstractions propagate at least locally into the aquifer systems lower in the stratigraphic succession. Confining layers formed by coal seams and mudstone/shale beds limit the vertical flow of groundwater, but have leaky behaviour and as such are not considered to be aquicludes. This leaky behaviour is manifest in abstractions from Ewington II, as evident from local depressurisation of the lower Premier Coal Measures and Allanson Sandstone.

9.5 Simulated Pit Dewatering Strategy

The developed groundwater flow model has been applied to Simulate the dewatering of Ewington II together with the impacts of Ash Co-disposal in overburden dumps. The model was then used to develop an understanding of the potential solute impacts. The formulated strategies for Ewington II are based on:

- Close adherence to the mine plans and future development schedules, except the start date has been shifted from June 2007 to June 2008.
- The incorporation of design production bores and abstractions for pit dewatering.
- Commencement of dewatering of the deeper Premier Coal Measures aquifer systems during November 2004.
- The incorporation of concurrent abstractions from existing pit dewatering and water supply operations.
- The incorporation of concurrent abstractions from existing and other proposed pit dewatering operations at the Premier Mine.
- Configuring of the backfill parallel to the consecutive mining blocks.

- Co-disposal of ash in backfill overburden dumps beginning a year after mining of the equivalent areas.

The Ewington II model starting head condition (215 m AHD in 1981) is broadly compatible with the observed groundwater levels in the lower Premier Coal Measures and Allanson Sandstone at locations distant from the sub-crop zones in western areas of the Premier Syncline. In the sub-crop zones, there is a tendency for the piezometers either to become dry or to reflect a shallow perched water table that does not represent the deeper confined aquifer systems.

Subsequently, annual aggregate abstractions from the different mines and water supply sources have been applied. Hydraulic conductivity and storage (confined and unconfined) aspects of the model have been varied during the calibration process to test the model sensitivity to these aspects and to deliver the required outcomes.

In order to understand, in broad terms, the drawdown impacts of long-term historical and future abstractions, the model incorporates the Muja Mine, Shotts Borefield, Premier Mine (Pit 1 and Pit 4) and Ewington II Mine as sources of abstraction. Abstraction histories incorporated into the model from these sources date back to 1981. The cumulative impacts of these historical and current abstractions predominantly control the observed groundwater levels and groundwater level trends in the relevant aquifer systems. Rainfall during the past two decades has been below the long-term average, and may also contribute to observed declines in water table elevations.

The Ewington II model calibration is focussed on the lower Premier Coal Measures (below the P5 Seam) and Allanson Sandstone aquifer systems, compatible with the dewatering focus in the Ewington II Mine. During the 1980s, there are few data on groundwater levels. The drawdown impacts of groundwater abstraction from the Shotts Borefield, which is screened over the lower Premier Coal Measures and Allanson Sandstone, are difficult to gauge. Over time, the monitoring network for the deeper aquifer systems has dramatically improved, enabling the cumulative impacts of the abstractions from the Shotts Borefield and mine dewatering activities to be better measured.

The Ewington II model provides a robust correlation to the lower-bound groundwater levels and trends interpreted and measured in the Premier Coal Measures and upper Allanson Sandstone, particularly in the period from mid-2000. The Ewington II model accuracy diminishes within the lower Allanson Sandstone, Ewington Coal Measures and Westralia Sandstone, predominantly because the starting head conditions are too low and consequently less representative. Also in the model, the simulated drawdowns tend to propagate beyond the confining layers formed by the coal seams and mudstone/shale beds to the Allanson Sandstone and Ewington Coal Measures successions. In reality, the observed groundwater levels in the lower Allanson Sandstone and Ewington Coal Measures are not strongly influenced by groundwater abstractions to date.

The predictive modelling has demonstrated the need for 15 production bores (four in-pit and eleven pit-perimeter) to adequately dewater and depressurise the aquifer profiles linked to the proposed mining developments to the P60 Seam. Large-scale groundwater abstraction is required to facilitate dewatering within the initial drop-pit limits. The predictive modelling is based on most production bores being commissioned during the period November 2005 through January 2006. Key aspects of the modelling include:

- Two existing water supply bores continue to operate;
- two additional in-pit production bores are commissioned by end – October 2004;
- all eleven pit-perimeter production bores are commissioned by end-January 2005;
- the in-pit production bores operate to July 2006; and
- the design dewatering system operates until July 2030, accommodating long-term mining plans at Ewington II.

Simulated and transient rates of abstraction from the design production bores for both Ewington I & II are outlined in Table 9-3. Locations of the design production bores and their operating schedules are shown on Figure A-12.

The results of the pit dewatering simulations for Ewington II are shown on Figure 9(a to j). The figures are focussed on the P20 layer that immediately underlies the pit floor. This succession will host the water table beneath the backfill overburden dumps. Both the pit dewatering and mining processes will act to dewater and depressurise the P10 through P 60 and the P80 layer, respectively.

Backfill within the pit would rest on the P60 Seam floor. As such, infiltration and seepage from the backfill profile, including solutes from the co-disposed ash, would enter the water table within the P8 to P10 layers of the Premier Coal measures.

Table 9-4 Simulated Annual Aggregate Pit Dewatering Abstractions for Ewington I & II

Projections	Ewington I Abstraction (ML/annum)	Ewington II Abstraction (ML/annum)
Year 1	2,503	20,500
Year 2	12,643	20,500
Year 3	10,504	20,500
Year 4	9,584	20,500
Year 5	8,771	14,200
Year 6	8,078	14,200
Year 7	7,529	14,200
Year 8	7,029	14,200
Year 9	6,373	14,200
Year 10	5,938	14,200
Year 11	6,585	14,200
Year 12	6,692	14,200
Year 13	6,453	14,200
Year 14	6,488	14,200
Year 15	6,309	13,700
Year 16	6,082	13,700
Year 17	6,076	13,700
Year 18	5,909	13,700
Year 19	5,471	13,700
Year 20	5,498	20,500
Year 21	5,197	20,500
Year 22	5,353	20,500
Year 23	4,938	20,500
Year 24	5,205	14,200
Year 25	4,812	14,200
Year 26	4,669	14,200

9.6 Ewington II Predictive Ash Co-disposal Simulations

The solute transport and water balance aspects of the ash co-disposal areas are complex. Our approach to the predictive modelling has been to adapt the groundwater flow model used for Ewington II dewatering design studies based on interpretations of the bulk leaching tests findings. Adaptations to the model have included:

- The framing of annual pit developments based on the 9-year mining schedule (Figure A-3 and A-4).
- The simplification of model to facilitate transient solute transport simulations.
- Assigning of areas for the co-disposed of ash based on interpreted annual backfill schedules. The simulated backfill schedules are shown on Figure A-14.
- The application of recharge is only to areas where ash is co-disposed.
- Assigning to the recharge of a nominal solute concentration of 100 mg/L. This concentration can subsequently be factored to estimate selected solute concentrations in the water table.
- Simulation of the groundwater over a period of 30 years after the end of mining.

Key aspects of the developed model are summarised below.

Importantly, the model represents groundwater flow in the saturated profile beneath permanent water table. The model does not simulate groundwater flow in the unsaturated profile. A recharge rate is applied to the backfill areas wherein ash has been co-disposed. The recharge rate is 0.00048 m/day per unit area (equivalent to 175 mm/annum rainfall recharge, about 12.5% of the annual average rainfall, 1400 mm/year) and is assigned an initial solute concentration of 100 mg/L. The recharge rate is maintained on the overburden dumps from their beginning until the end of the simulations. In the model, the recharge and associated solute is applied directly to the water table. Each year, a new recharge area is added to the model, representing the backfill progress onto the next block that has been mined. As such, as the transient model progresses the areas subject to recharge progressively increase. It is anticipated that this approach represents a worst case scenario as it presumes all co-disposed ash may be infiltrated by rainfall recharge indefinitely. This is unlikely as infiltration through the backfill profiles would decrease as depth of burial and compaction increase.

The applied 100 mg/L solute concentration is arbitrary, with initial intentions to demonstrate potential dilution of solutes as they enter the water table. Subsequently, the recharge may be assigned the concentrations derived from the bulk leaching tests as below:

- Aluminium 14.8 mg/L;
- Cobalt 0.1 mg/L;
- Nickel 0.04 mg/L;
- Sulphate 56.5 mg/L; and,
- Zinc 0.3 mg/L.

The simulated solute concentrations applied to the recharge substantially decay in yearly increments after the initial year of application (Figure 9-1) to individual co-disposal overburden dumps. These reductions are based on the bulk leaching tests and assuming that in the years after the first winter, solute concentrations would be limited by:

- Unsaturated flow on preferred paths in overburden materials.

- Decreased potentials for direct exposure of the co-disposed ash to rainfall, as depths of burial increase.
- Increased overburden to ash ratios.

This approach is semi-qualitative.

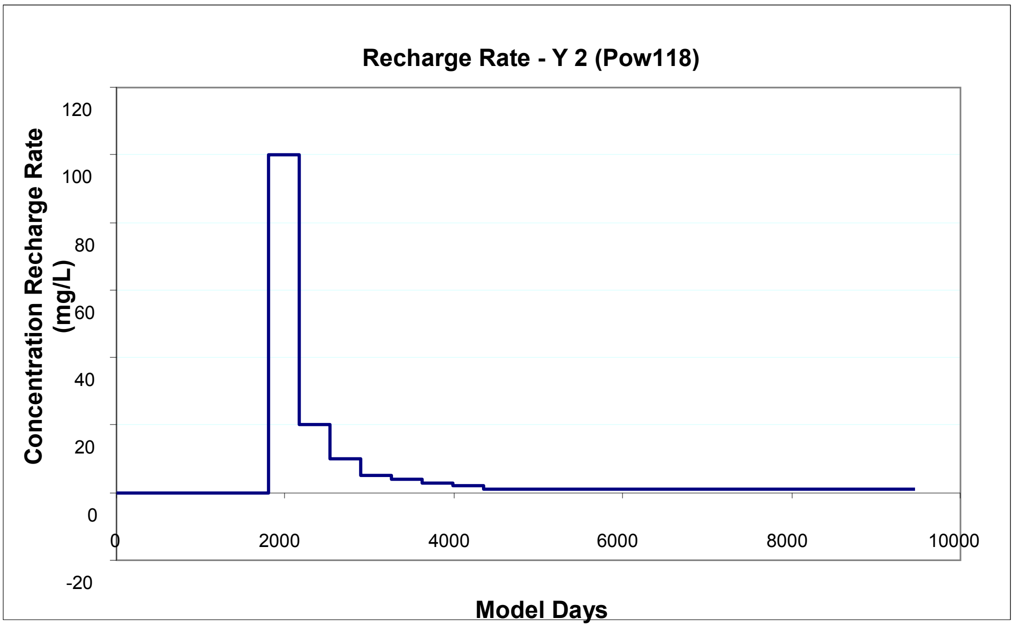

Figure 9-1 Decay of Simulated Solute Concentration with Time

The predictive model ran for 30 years to cover the mining and backfilling sequence and to evaluate the solute transport after mine closure. The recharge settings were kept constant for the period from 15 to 30 years, as there is an absence of new co-disposal sources. During this period since most co-disposal occurred on top of older backfill dumps, the flow paths for solutes being transported to the water table would effectively be lengthened. The recharge from the last mining sequence was replicated in the final model which ran for 20 years.

Results of the predictive modelling (mining and final void) for Aluminium, Cobalt, Nickel, Sulphate, and Zinc are provided on Figure A-15 (15.1 to 15.30). The results show the dilution of solute concentrations in the water table zone, understanding that the simulated original solute concentrations were Aluminium, 14.8 mg/L; Cobalt, 0.1 mg/L; Nickel, 0.04 mg/L; Sulphate, 56.6 mg/L; and, Zinc, 0.3 mg/L. The results show that solute concentrations are typically diluted by two to ten times in the water table within the Premier Coal Measures. Transport of the solutes is towards the eastern Ewington I where the stratigraphy to be mined and production bores are deepest and last developed.

Section 10 Water Resources Management

The predictive findings of the ash co-disposal for Ewington I & II outline potential local expression of solutes within the groundwater environment. As a result of the simulated pit dewatering abstractions and depressed water table in the vicinity of Ewington I &II, however, the solutes occur in a groundwater sink. That is, groundwater transporting the solutes is flowing towards the lowest elevation on the pit floors of each mine and thereafter towards the final voids that would be manifest after mining. A lake would form in the final void for each mine. These pit lakes would also form a groundwater and surface water sink and control the fate of solutes after mining. Irrespective of the potential solutes linked to ash co-disposal, the lakes in the final voids are not expected to meet quality guidelines for drinking water or fresh water ecosystems.

To ensure the fate of all solutes, ash should only be co-disposed beneath the surfaces of overburden dumps from which runoff would be diverted towards the pit. Ash should not be co-disposed beneath the outer perimeter of the overburden dumps. The preferential hosting of co-disposed ash in overburden dumps that backfill the mined void would assist in achievement of this outcome. By this approach, the fate of solutes is controlled by the management of in-pit water.

Notwithstanding, solutes from the co-disposed ash would need to be put in context with other impacts of mine development. It is understood that the quality of both surface water and groundwater in the vicinity of Ewington I and II may be diminished due to mining activity. Both the shedding of runoff over exposed coal measures successions and infiltration of solutes through overburden dumps are known to influence water quality. Typically, changes in quality are manifest by increased acidity and elevated concentrations of sulphate, aluminium, iron, manganese, nickel, lead, silica and zinc. These impacts need to be characterised in order to differentiate and understand the potential impacts linked to ash disposal.

Water resources management initiatives are consequently expected to include:

- Further definition of baseline surface water environments to enable benchmarking of management plans. Of particular interest are the natural watercourses that occur in proximity to the planned initial overburden dumps. Analyses of the runoff outside the area of mining would allow for an improved water solute balance in the Surface Water Catchment area of Ewington I and II.
- Characterisation of runoff from areas already disturbed by mining activities. Data should be sought from Ewington II and subsequently from Ewington I after mining has commenced. In the analyses of measured qualities, it may be important to understand the source of the water sample, be it from recent runoff, retention in an in-pit sump or groundwater seepage from the pit walls or floor. The targeted analyses should focus on the constituents potentially originating from Ash Co-Disposal.
- Improved definition of the groundwater environments to include metals and other potential solutes leached from Ash Co-Disposal during the sampling of the new and existing monitoring bores.
- Characterisation of the effects of the overburden dumps on groundwater quality by discrete sampling programmes beneath aged and recent overburden dumps at Ewington II and later at Ewington I. The installation of monitoring bores at Ewington II would also support this characterisation.
- Characterise infiltration capacities of the overburden on run-of-mine dumps. The existing site investigations described herein should be expanded to include longer term tests to better discriminate the rates of infiltration.
- Establishment of monitoring bore networks for monitoring solute transport, at the Ewington I and Ewington II Mines, to detect any potential impacts on groundwater resulting from ash co-disposal activities. The monitoring bores that are to be installed to monitor for potential impacts, referred to as "design" monitoring bores, would be established in two campaigns.

  The first campaign would occur in the short-term at both Ewington I (prior to mining) and Ewington II, with a focus on better definition of the baseline quality of shallow groundwater beneath the planned toe of initial pit-perimeter overburden dumps.

The second campaign would occur once ash co-disposal has commenced. Monitoring bores would be installed at selected locations on the exposed pit floor in areas where backfill overburden dumps will host co-disposed ash. Each monitoring bore at Ewington I would investigate the shallow water table zones within the Westralia Sandstone, extending perhaps 12 m below the water table. As the water table will be lowered over time (mining and dewatering activities), each monitoring bore would be constructed with a minimum of two or three standpipes: the shallowest standpipe intercepting the initial water table zone/aquifer, the second standpipe intercepting the next aquifer in the sequence, and so on. At Ewington II, the monitoring bores would investigate the Premier Coal Measures successions that occur at shallow depths beneath the pit floor.

For the first campaign, a minimum of three monitoring bores would be required at selected pit-perimeter and pit-floor locations where ash co-disposal is planned. One monitoring bore would be in a control location, intended to provide ongoing baseline data that captures the influences of mining and overburden dumps on the water table and shallow groundwater. The other two monitoring bores would be to characterise the water table environments most likely to be influenced by solutes from ash co-disposal (on solute flow paths from the co-disposed ash). These two monitoring bores may eventually be lost during the dumping of overburden, thus potentially needing to be replaced.

The second campaign of monitoring bores would investigate the water table zone and shallow groundwater beneath the initial overburden dumps that host co-disposed ash. These monitoring bores would potentially replace those lost due to mining activities. It is intended that the second campaign monitoring bores be drilled through the overburden dumps at locations known to host co-disposed ash and where solutes from the co-disposed ash would be transmitted to the water table. It is these monitoring bores that will define the impacts of the co-disposed ash in comparative terms to the control sites. Rates of transport of solutes in the groundwater environment would be comparatively slow (perhaps a few tens of metres per year) and consequently the second campaign monitoring bores must be located close to source areas of the co-disposed ash.

The timing of the design monitoring bore installation campaigns is important. For the initial campaign, the longer lead-time of installation ahead of ash co-disposal would provide improved seasonal aspects of baseline data and understanding of the influences of both dewatering and mining on groundwater quality. Further, the occurrence of solutes from the co-disposed ash may be strongly seasonal; the infiltration of rainfall is expected to be the primary mechanism for transport of solutes. The proposed monitoring locations are shown on Figures A-16 and A-17.

Section 11

Water Resources Monitoring Programme

The objectives of a monitoring programme appropriate for the assessments of the impacts of mining on the shallow groundwater and surface water resources is outlined in Table 11-2; while the details of the actual monitoring are outlined in Table 11-2. This programme should be reviewed on an annual basis as part of the annual reporting requirements. The programme does not address the post-mining period.

Table 11-1 Objectives of Monitoring Programme

Objective	Key Items	Outcomes
1. Definition of current and seasonal baseline groundwater and surface water environments – before the commencement of mining at Ewington I & of Ash Co-Disposal at Ewington II.	• Sampling of local watercourses to characteristics stream flows and surface water to groundwater interactions. • Groundwater level monitoring in existing monitoring bores to define seasonal and other transient changes in the aquifer systems predominantly formed by the Westralia Sandstone (Ewington I) and Premier Coal Measures (Ewington II). • Sampling of existing monitoring bores to define hydrochemistry parameters, in particular pH and metals concentrations and seasonal changes.	• Baseline interpretations for quantitative and qualitative assessments of impacts.
2. Assessment of the impacts of mining and overburden dumps on surface water and groundwater environments.	• Characterisation of surface runoff within existing Ewington II areas disturbed by mining and subsequently at Ewington I. • Characterisation of the effects of overburden dumps on groundwater quality. This would require the installation of monitoring bores at Ewington II to investigate the shallow water table beneath the overburden dumps. • Drilling and construction of the design pit-perimeter and in-pit control monitoring bores. • Measurement of groundwater levels and groundwater quality in the control monitoring bores.	• Differentiation of potential impacts other than co-disposed ash.
3. Assessment of the impacts of ash co-disposal on local water resources.	• Drilling and construction of the design pit-perimeter and in-pit ash co-disposal monitoring bores. • Measurement of groundwater levels and groundwater quality in the ash co-disposal monitoring bores. • Comparative assessments of the impacts of mining disturbances, overburden dumps and ash co-disposal on the shallow groundwater quality. • Verification and improved confidence in the predictive models.	• To develop an understanding of the impacts of mining on the groundwater and surface water resources. • To provide data to appropriately define and manage any adverse impacts from the ash co-disposal.
4. Provision of data for refinement of the groundwater flow model.	• Refinement of model parameters based on findings of monitoring programmes and water balance. • Refinement of model parameters and predictive outcomes if appropriate to enhance management objectives.	• Increase confidence in the model and predictive outcomes.
5. Meeting reporting requirements of the regulators.	• Annual reporting of the measured impacts of ash co-disposal. • Review of water resources management protocols to ensure they remain effective. • Forecasts of future impacts.	• Compliance with the terms, limitations and conditions of Licence.

Table 11-2 Monitoring Programme

Monitoring	Parameters	Monitoring Frequency
	BASELINE SAMPLING	
Local Monitoring Bores[1]	Groundwater Levels	Monthly
	Groundwater Quality: pH, EC and temperature, TDS, Al, As, Be, B, Ca, Cd, Cl, Co, Cr, Cu, Fe, K, Na, Mg, Mn, Mo, Ni, Pb, SO_4, Si, Sr, V and Zn.	Quarterly (April, July, October, January)
Stream Flow Stations Boronia Gully and tributaries to Collie River South Branch.	Stream Flow Quality: pH, EC and temperature, TDS, Al, As, Be, B, Ca, Cd, Cl, Co, Cr, Cu, Fe, K, Na, Mg, Mn, Mo, Ni, Pb, SO_4, Si, Sr, V and Zn.	Quarterly (April, July, October, January) at times of flow.
Surface Water in Areas Disturbed By Mining	Surface Water Quality: pH, EC and temperature, TDS, Al, As, Be, B, Cd, Co, Cr, Cu, Fe, Pb, Mn, Mo, Ni, Sr, V and Zn.	Campaign sampling base on occurrences of run-off and in-pit pumping from sumps.
	DURING MINING	
Local Monitoring Bores[1]	Groundwater Levels Groundwater Quality: pH, EC and temperature, TDS, Al, As, Be, B, Ca, Cd, Cl, Co, Cr, Cu, Fe, K, Na, Mg, Mn, Mo, Ni, Pb, SO_4, Si, Sr, V and Zn.	Monthly Quarterly (April, July, October, January)
Surface Water and Sump Abstractions	Abstraction Volumes	Monthly
	Abstraction Quality: pH, EC and temperature, TDS, Al, As, Be, B, Ca, Cd, Cl, Co, Cr, Cu, Fe, K, Na, Mg, Mn, Mo, Ni, Pb, SO_4, Si, Sr, V and Zn.	Quarterly (April, July, October, January)
Review Reporting	Preparation of Reviews that detail the operational and technical aspects of the project. It is important that the Reviews provide definitive assessments and review of: • All monitoring data. • Water resources management protocols to ensure they remain effective. • Divergence of ash co-disposal compared to the design. • Forecasts of future impacts. • Interpretations of interpreted compared with predicted solute impacts and divergence from baseline conditions. • Trigger points linked to quality criteria for drinking water and freshwater ecosystems. • Impacts on stream flows. • Revisions to the known hydrogeology.	Annual.

Note: 1 The local monitoring bores at Ewington I and Ewington II would be a specific network designed to monitor the groundwater quality in the vicinity of overburden dumps within which ash is and is not co-disposed. This network would also include one or two control sites wherein baseline is observed.

Section 12 Conclusion

The Collie Basin predominantly hosts fresh groundwater resources and fresh water ecosystems. In a broader context, the Wellington Catchment has previously been used for domestic water supplies and historically also hosts fresh water ecosystems. Ewington I and Ewington II Mines occur in the Premier Sub-basin of the Collie Basin. Both mines are characterised by shallow water table settings and will be excavated beneath the water table, with dewatering preceeding mining. Local groundwater resources measured during this study are fresh and slightly acidic, with the conductance, uS/cm, measured between 322 to 505, and pH in the range 5.87 to 6.09. In addition analyses of the major cations and anions indicates they are within previous ranges measured in the groundwater.

During mining and for a long period after mining (and perhaps indefinitely), the mined void will form a surface water and groundwater sink. During mining, surface water and groundwater catchments associated with the areas of co-disposed ash would be diverted to the pits. Solutes linked to the co-disposed ash would be intercepted by pit dewatering infrastructure, including in-pit sumps. After mining, both surface water and groundwater flows would occur to the final mined voids. For tens of decades the final voids would host pit lakes characterised by water levels substantially lower than the natural water table setting. Ultimately, the pit lake levels are expected to stabilise at elevations below the natural water table setting, thus forming a long-term sink.

Sampling results of runoff and surface water from coal measures, overburden and in-pit sumps indicates the runoff water originating in Ewington II :

- is acidic with pH measured between 3.22 to 4.90;
- is fresh to brackish, with conductivity in uS/cm between 43 to 2,640, and with major cations and anions within previous ranges measured in the mines;
- contains some relatively high sulphate and sulphur concentrations, up to 1,390 mg/L and 464 mg/L, respectively;
- contains some relatively high aluminium and Zinc concentrations; up to 127 mg/L and 21.4 mg/L, respectively;
- exceeds compliance criteria for iron (less than 3.0mg/L) and for manganese (less than 0.5 mg/L, Water Authority, Water Resources Directorate July 1988);
- Exceeds the Australian Drinking Water guideline value for Cadmium (0.002 mg/L), Lead (0.01 mg/L), Selenium (0.01mg/L), and Sulphate (500 mg/L) .

Most Collie Group sediments demonstrate acid generation. The Net Acid generating capacity of the sediments that will comprise the overburden in Ewington II measured during this investigation ranges between less than one grams per tonne to 200 grams per tonne. Acidification of pit lakes in the Collie Basin occurs through the interaction of water and sediments. The pit lake waters are typically characterised by elevated concentrations of aluminium, iron, manganese, nickel, lead, silica and zinc compared to local groundwater. Aluminium and nickel are considered to pose the most significant long-term risk by exceeding quality criteria.

Ash from the approved Bluewaters I and II power plants plus that from the proposed Bluewater III and IV would be disposed as a run-of-mine operation within perimeter and backfill overburden dumps in settings above the natural water table at both Ewington I and II. The ash would be delivered in a comparatively dry (15% moisture content) form and tipped over the edges of the overburden dumps. Disposed ash would have limited exposure to the environment, typically being covered by run-of-mine overburden within days of tipping. Mix ratios of overburden to ash are expected to be variable with overburden to ash run-of mine mix ratios expected to range from about 10:1 to 100:1, with ratios between 50:1 and 100:1 being typical. The co-disposed ash may generate solutes linked to wetting by rainfall infiltration or runoff. Solutes from the co-disposed ash will originate in the unsaturated profile. The results of bulk leaching test following Australian Standard Leaching procedures using 1:20 mix with rainfall equivalent deionized water indicates the following regards the potentials for leaching of metals from the run-of-mine overburden from Ewington II and Muja power station ash:

- Ash releases aluminium, arsenic, beryllium, boron, cadmium, chloride, cobalt, copper, iron, nickel, manganese, sulphate and zinc in trace amounts.
- Ash releases aluminium, cadmium, manganese, and nickel at levels above the Australian Drinking Water Guidelines (ADWG).
- Composite overburden predominantly releases aluminium, boron, cadmium, chloride, cobalt, copper, fluoride, iron, nickel, manganese, and zinc in trace amounts
- Overburden releases aluminium, iron, and nickel at levels above ADWG

Co-disposed ash from the Bluewaters I to IV power stations is most likely to be exposed to the elements in the first year after deposition at the Ewington I and II mines, when depths of burial, compaction and consolidation are limited. Thereafter, the potentials for wetting by infiltrating rainfall are expected to decrease. Flow in the unsaturated profile within the overburden dumps at both Ewington I and II may occur in preferred paths, such as macro-pores, fractures and channels. The influence of macro-pores decreases with depth and the solute leaching in overburden dumps in heterogeneous settings is understood to penetrate to depths in the order of 10 to 15 m. The occurrence of preferred flow paths may also limit potentials for acid generation - reducing the extent (surface area) of overburden exposure to infiltrating water and oxygen.

Results of the field investigation of the infiltration capacities of the overburden on run-of-mine dumps indicates the measured capacities were highly variable and ranged from 0.22 m day^{-1} to 18.1 m day^{-1}. These results are from what is believed to be the most representative method, that involving a maintaining a 5 cm constant head in 0.2m diameter bucket. The results indicate the presence of more permeable overburden at the Ewington II mine as opposed to a less permeable one.

At present, the transport and fate of solutes from the Ewington I & II co-disposed ash are understood to include:

- During mining, the solutes in vertical flow paths would infiltrate to the water table within the Westralia Sandstone at Ewington I and within the Premier Coal Measures at Ewington II. Transport of the solutes is towards the pit and dewatering bores, influenced by the groundwater sink developed from dewatering and mining activities.
- During mining, the solutes in predominantly lateral flow paths would remain in the unsaturated profile and enter the pit either as seeps directly from the overburden dumps or on the pit floor. The pit forms a sink for solutes in both the surface water and groundwater from the unsaturated profile.
- Post-mining, solutes in both groundwater and runoff would be diverted into the final void, which remains a sink for many years.

The ash co-disposal settings (6.35 km^2 and 5.9 km^2 for Ewington 1 and Ewington II, respectively) represent a comparatively small portion (less than 30%) of the Sub-Crop catchment area for both Mines (46 Km^2). Water balances for Ewington I and Ewington II during mining and for closure were developed. These water balances are intended to provide context for water and solutes generated from the areas of Ash Co-disposal relative to those generated from the surface water catchments (8.1 km^2 for Ewington 1 and 13 .9 km^2 for Ewington II) and the Sub-Crop groundwater catchment area.

In general terms, groundwater recharge was defined as that part of the rainfall which reaches the groundwater via soil and the unsaturated zone. As groundwater recharge is controlled by a wide range of variables and with limited detailed soil data covering the study area, the soil water balance method (AgET) was identified as most appropriate for developing water and solute balences. Results from the water balance model simulations provided estimates for evapotranspiration, deep percolation, and runoff. The resulting water flow rates were used to calculate annual contributions of water and solutes from the area of ash co-disposal at Ewington I and II mines, the surface water catchment outside the area of Ash Co-Disposal, and the Sub Crop catchment outside the area of the Surface Water Catchment. Overburden to Ash of 50:1 was assumed. Solute volumes were calculated using solute concentrations of rainfall, runoff,, and groundwater; either measured during the investigation or as estimated during this study.

Section 12 Conclusion

Provisions were made to accommodate leaching by the recharge water based on the bulk leaching results. Sandy soils were assumed for the area of Ash Co-Disposal for Pre-Closure, while clayey soils were assumed for Post-Closure and for the Surface Water and Sub-Crop Catchment areas for both Pre- and Post-Closure. Clayey soils are believed to best represent the Latterite found near land surface throughout most of the area.

Time was not considered in the development of the water balances. The effect of time would be to dilute the contribution of Ash to the water/solute balances of the area. Under current plans it will take at least 9 years for Ash Co-Disposal to reach its total disposal area (5.9 km^2) at Ewington II and a similar time frame at Ewington. As such the water and solute balances represent a worst-case scenario.

Regarding the contribution of infiltration of rainfall through Ash to the salinity, aluminium, iron, and zinc solute loads in the overall catchment area, they are minor for both pre-closure and post closure conditions. While infiltration of rainfall in area of Ewington I and II Ash Co-disposal area contributes between 17 % to 2 % of the total water budget in the overall catchment during pre-closure and post closure, respectively, the contribution to the solutes is generally insignificant during both pre- and post closure. The percent contribution of the leachate attributable to Ash is generally less than 1% of the total solute load in the total Catchment in kilograms of Total Dissolved Solids (TDS), Aluminium (Al), Iron (Fe), and Zinc (Zn). In general the infiltration of rainfall through the overburden portion of the Ash Co-Disposal area, and runoff from overburden in the Ash Co-Disposal contribute more to the overall solute loading in the catchment as a whole, than does the Ash for both Pre- and Post Closure. The contribution of rainfall through the overburden to solutes in the overall catchment ranges from 15 to 59 % of the indicative solutes during Pre-Closure to 7 to 36 % during Post-Closure. Similarly runoff from the overburden dumps contributes between 36 to 81% of the indicative solutes during Pre-Closure to 10 to 83 % during Post-Closure.

The groundwater flow model used for Ewington II dewatering design was adapted for the predictive model, which represents groundwater flow in the saturated profile beneath the permanent water table. A recharge rate of 0.00026 m/day per unit area (equivalent to 95 mm/annum rainfall recharge, about 10% of the annual average rainfall) is assigned to the co-disposal overburden dumps together with an initial solute concentration of 100 mg/L. The recharge rate is maintained on the overburden dumps from their beginning until the end of the simulations. In the model, the recharge and associated solute is applied directly to the water table. Each year, a new recharge area is added to the model, representing the backfill progress onto the next block that has been mined. As such, as the transient model progresses the areas subject to recharge progressively increase. The simulated solute concentrations applied to the recharge substantially decay in yearly increments after the initial year of application to individual co-disposal overburden dumps.

It is anticipated that this modelling approach represents a worst case scenario as it presumes all co-disposed ash may be infiltrated indefinitely by rainfall recharge. Further, recharge is not applied to other areas of the model domain. As such, the dilution effects of recharge to the Premier Coal Measures are understated in the simulations. The predictive modelling outcomes show:

- Substantial solute dilution upon entry to the water table.
- Transport of solutes along flow paths within the Premier Coal Measures to dewatering bores and the final void (acting as a groundwater sink). The solutes do not leave the pit area.
- Substantial dilution of the solutes along the flow paths.
- Dilution of the solutes over time, as the concentrations of the solutes entering the water table decrease.
- Limited differences between the solute concentrations derived for overburden dumps with and without ash co-disposal.
- Comparatively low solute concentrations compared to those measured in existing pit lakes.

Section 12 Conclusion

The model water balance is constrained to recharge (on the co-disposal overburden dumps) and groundwater in storage. Even under these constraints, it is apparent that the contributions of solutes from the overburden dumps to the Premier Coal Measures groundwater flow are comparatively small. Contributions to the final void after the completion of mining would be many times smaller again after consideration of rainfall, runoff, groundwater contributions from the rest of the flow system in areas not overlain by overburden dumps.

Based on the predictive modelling, the solutes generated by ash co-disposal within the overburden dumps would not form a large part of the water or salt balance. The impacts of the ash co-disposal on groundwater are likely to be minor, decrease with time and difficult to differentiate from the impacts of overburden. The major contributors to acidity of the pit lakes and associated solute concentrations are groundwater recharge upon completion of mining and rainfall runoff. The quality of both of these water sources would be adversely influenced by contact with exposed *insitu* and excavated Collie Group sediments in the pit area and overburden dumps.

Water resources management and monitoring recommendations to verify the predictive findings include:

- Further definition of baseline surface water and groundwater environments.
- Characterisation of runoff from areas disturbed by mining to determine impacts of mining on the surface water quality.
- Better characterisation of the effects of the overburden dumps on groundwater quality.
- Establishment of monitoring bore network at the Ewington I and Ewington II Mines to measure the potential impacts of ash co-disposal on the groundwater environments.

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Section 14 Limitations

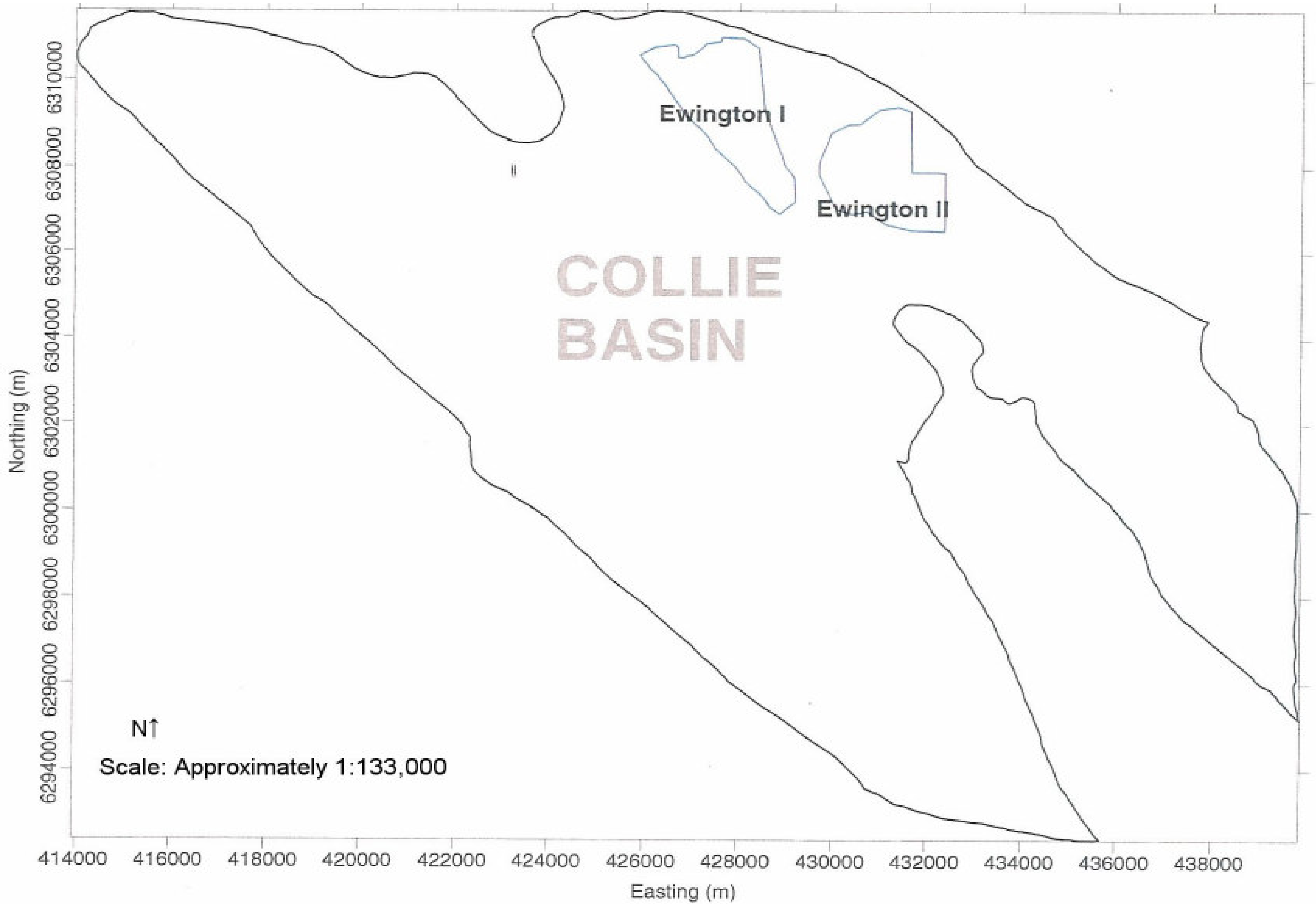
This report contains information obtained by inspection, sampling, testing or other means of investigation. This information is directly relevant only to the points in the ground where they were obtained at the time of the assessment. The interpretations indicate the inferred ground conditions only at the specific locations tested. The precision with which conditions are indicated depends largely on the frequency and method of sampling, and the uniformity of conditions as constrained by the project budget limitations. The behaviour of groundwater and some aspects of contaminants in soil and groundwater are complex. Our conclusions are based upon the analytical data presented in this report and our experience. Future advances in regard to the understanding of chemicals and their behaviour, and changes in regulations affecting their management, could impact on our conclusions and recommendations regarding their potential presence on this site.

Where conditions encountered at the site are subsequently found to differ significantly from those anticipated in this report, URS must be notified of any such findings and be provided with an opportunity to review the recommendations of this report.

Whilst to the best of our knowledge information contained in this report is accurate at the date of issue, subsurface conditions, including groundwater levels can change in a limited time. Therefore this document and the information contained herein should only be regarded as valid at the time of the investigation unless otherwise explicitly stated in this report.

Appendix A Figures

FIGURES



Client: Griffin Energy Pty Ltd URS	Project: Bluewaters EIA for Ash Co-Disposal	Title: Ewington I & II Location
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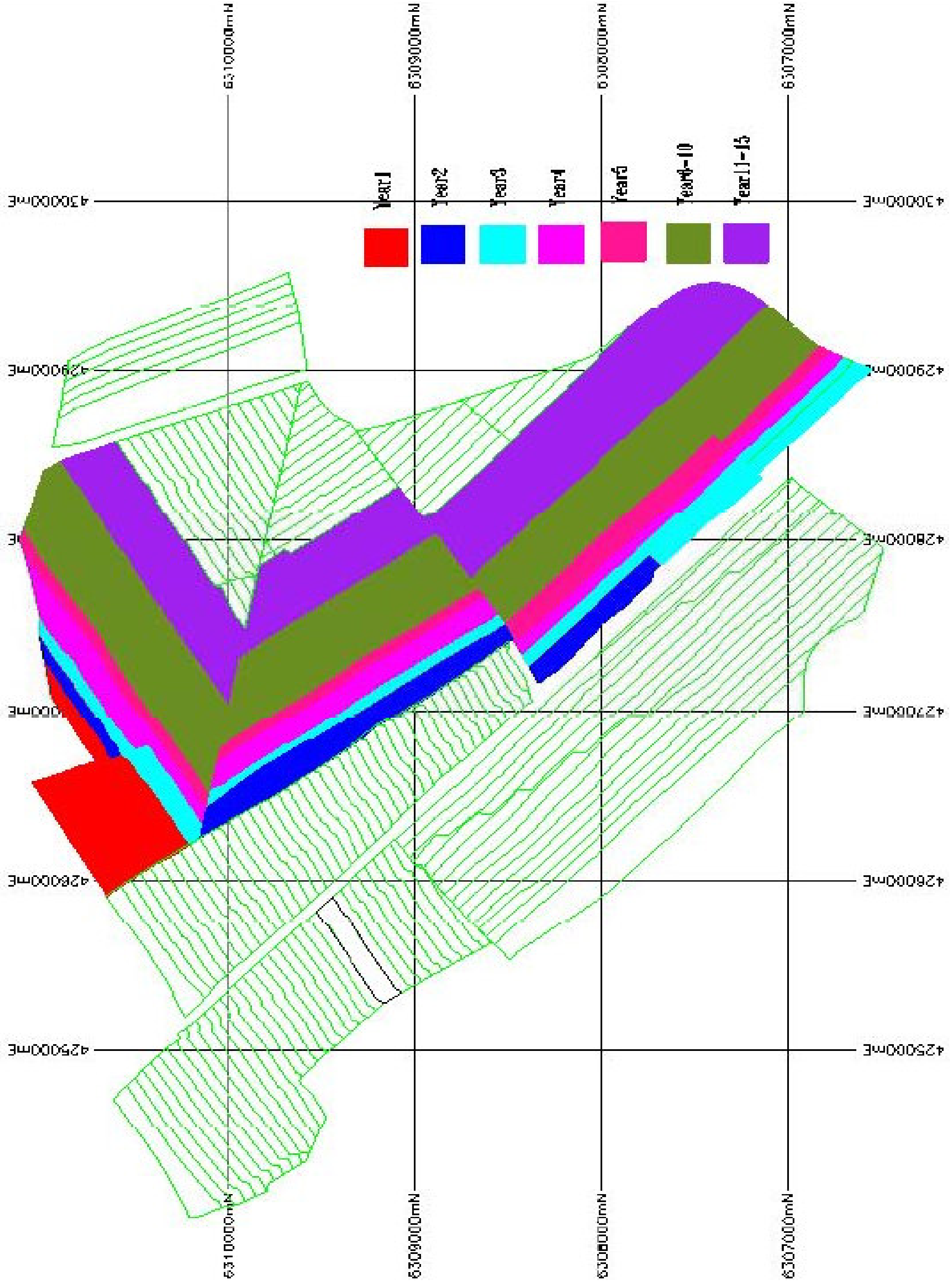
	Job No: 4296750 / File No:	Figure A-1



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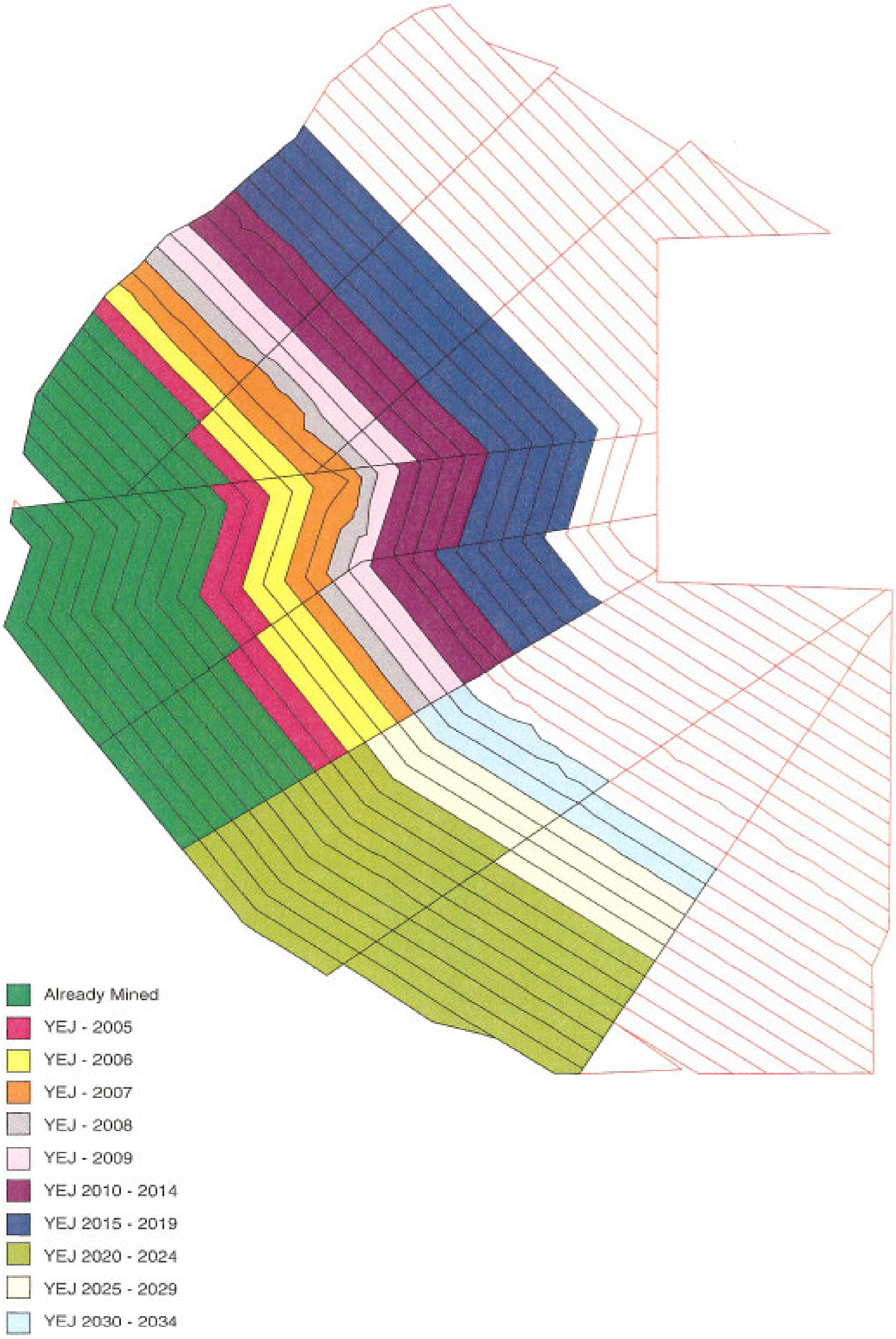
	Drawn:	Approved: IB	Date:June 2008
	Job No: 4296750	File No:	Figure A-2



Client:

Griffin Energy Pty Ltd

URS

Project:

Bluewaters EIA for Ash Co-Disposal

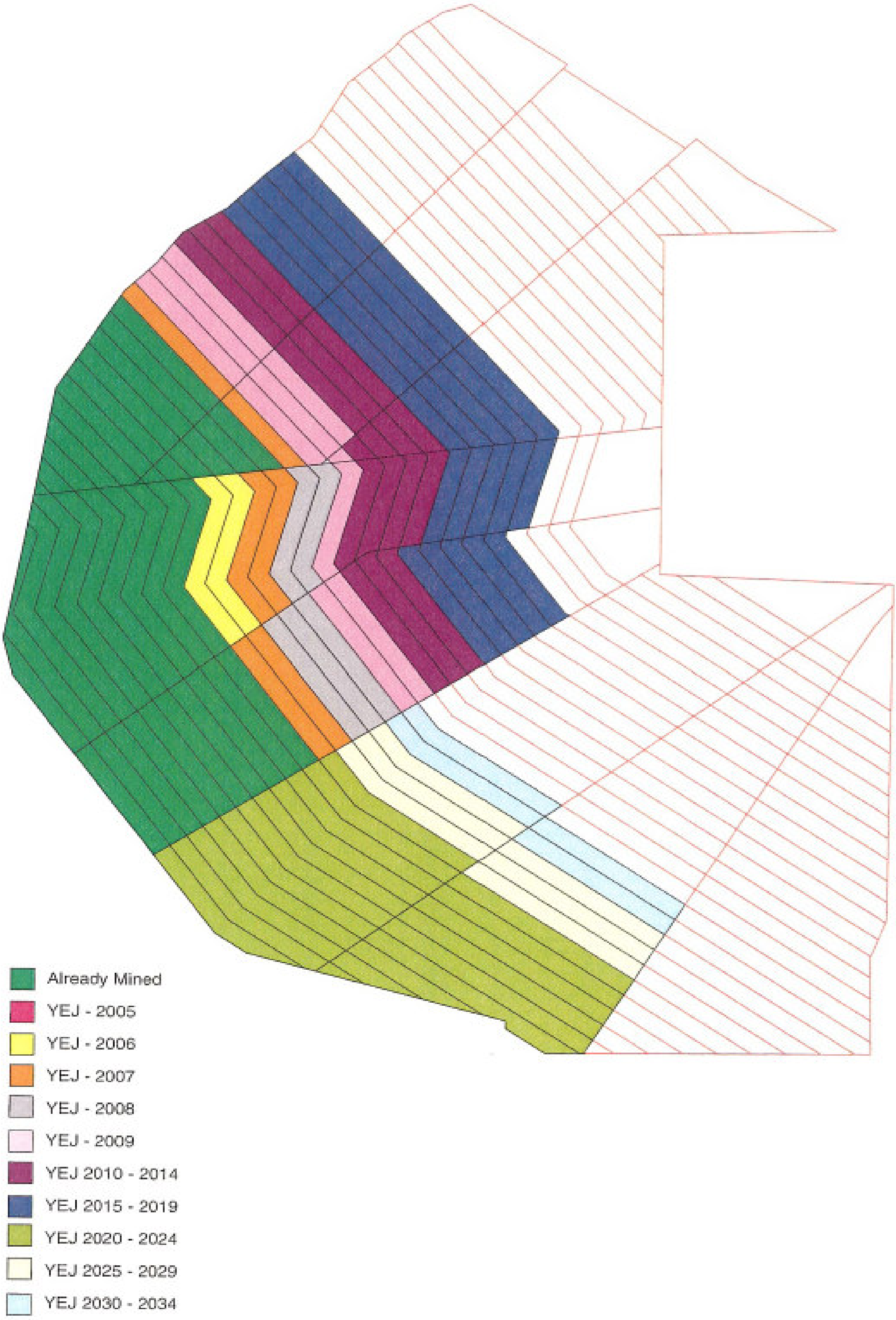
Drawn:
Approved: IB
Date:June 2008

Job No: 4296750
File No:

Title:

Indicative Ewington II Mine Plan - P32 Seam

Figure A-3



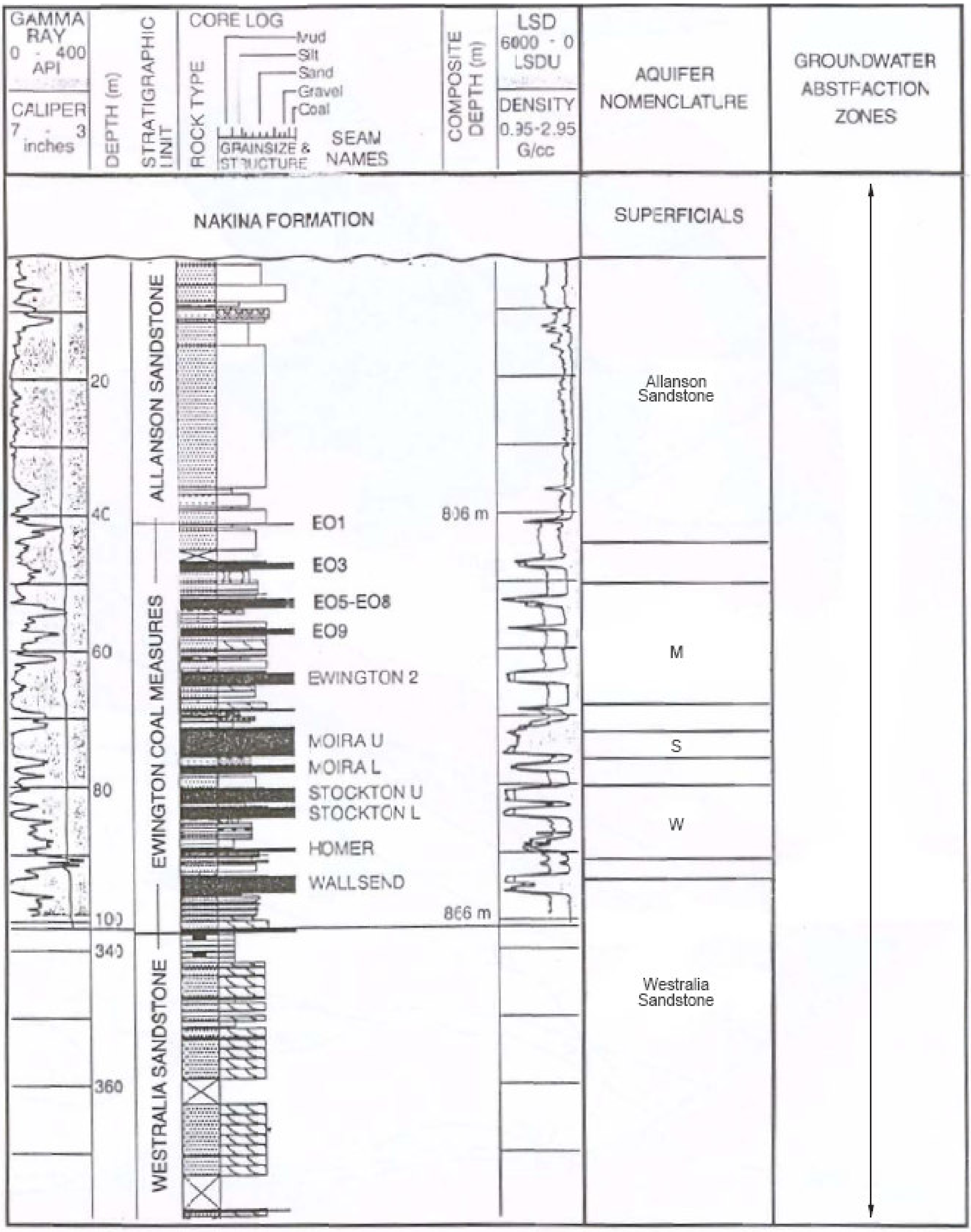
Client:
Griffin Energy Pty Ltd

Project:
Bluewaters EIA for Ash Co-Disposal

Title:
Indicative Ewington II Mine Plan - P60 Seam

Drawn:
Approved: IB
Date:June 2008
Figure A-4

Job No: 4296750
File No:



Client:

Griffin Energy Pty Ltd

Project:

Bluewaters EIA for Ash Co-Disposal

Title:

HYDROSRATIGRAPHY - EWINGTON I DEPOSIT

Drawn:

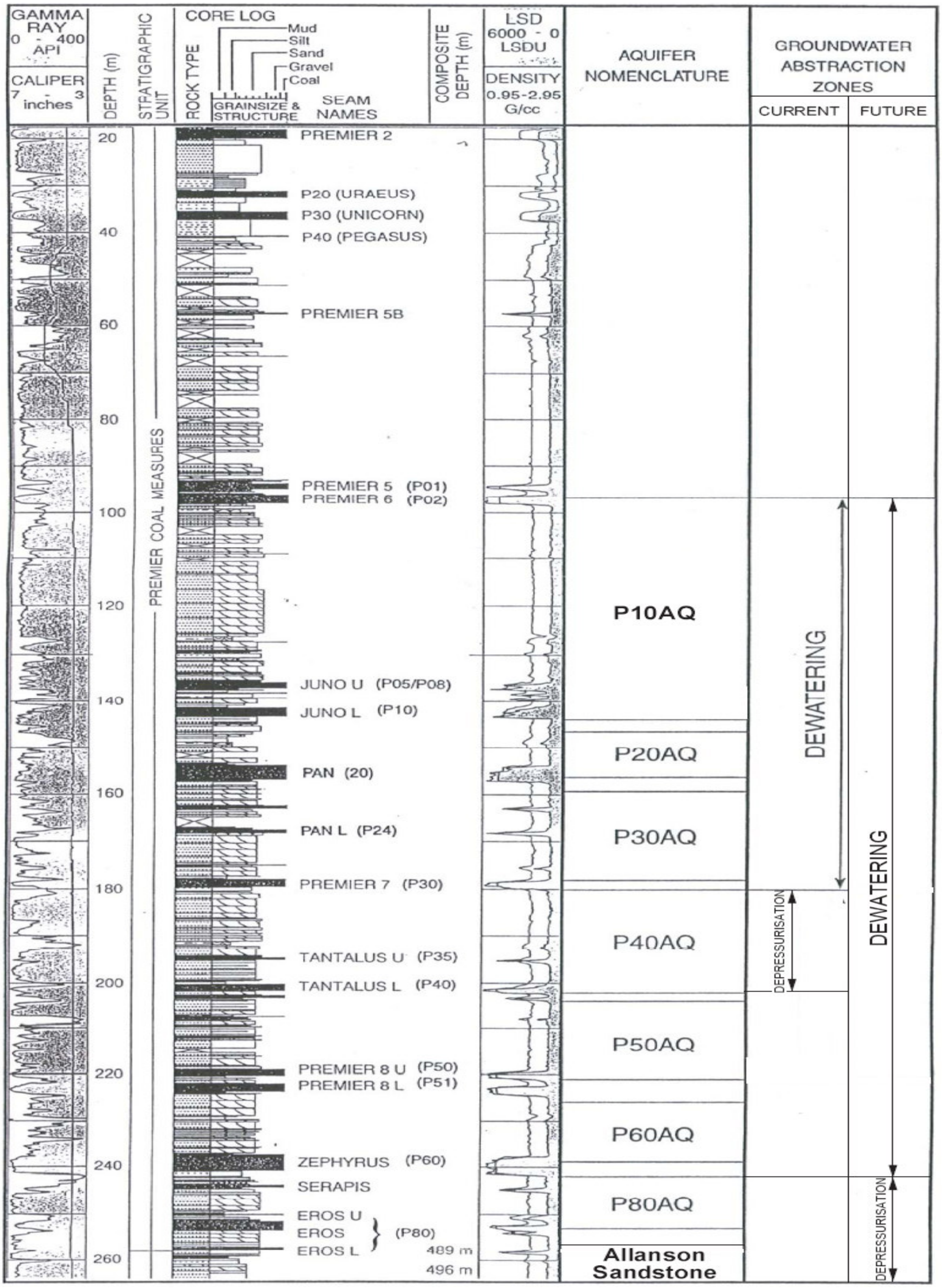
Approved: IB

Date:June 2008

Figure A-5

Job No: 4296750

File No:



Client:

Griffin Energy Pty Ltd

URS

Project:

Bluewaters EIA for Ash Co-Disposal

Title:

HYDROSRATIGRAPHY - EWINGTON II DEPOSIT

Drawn:

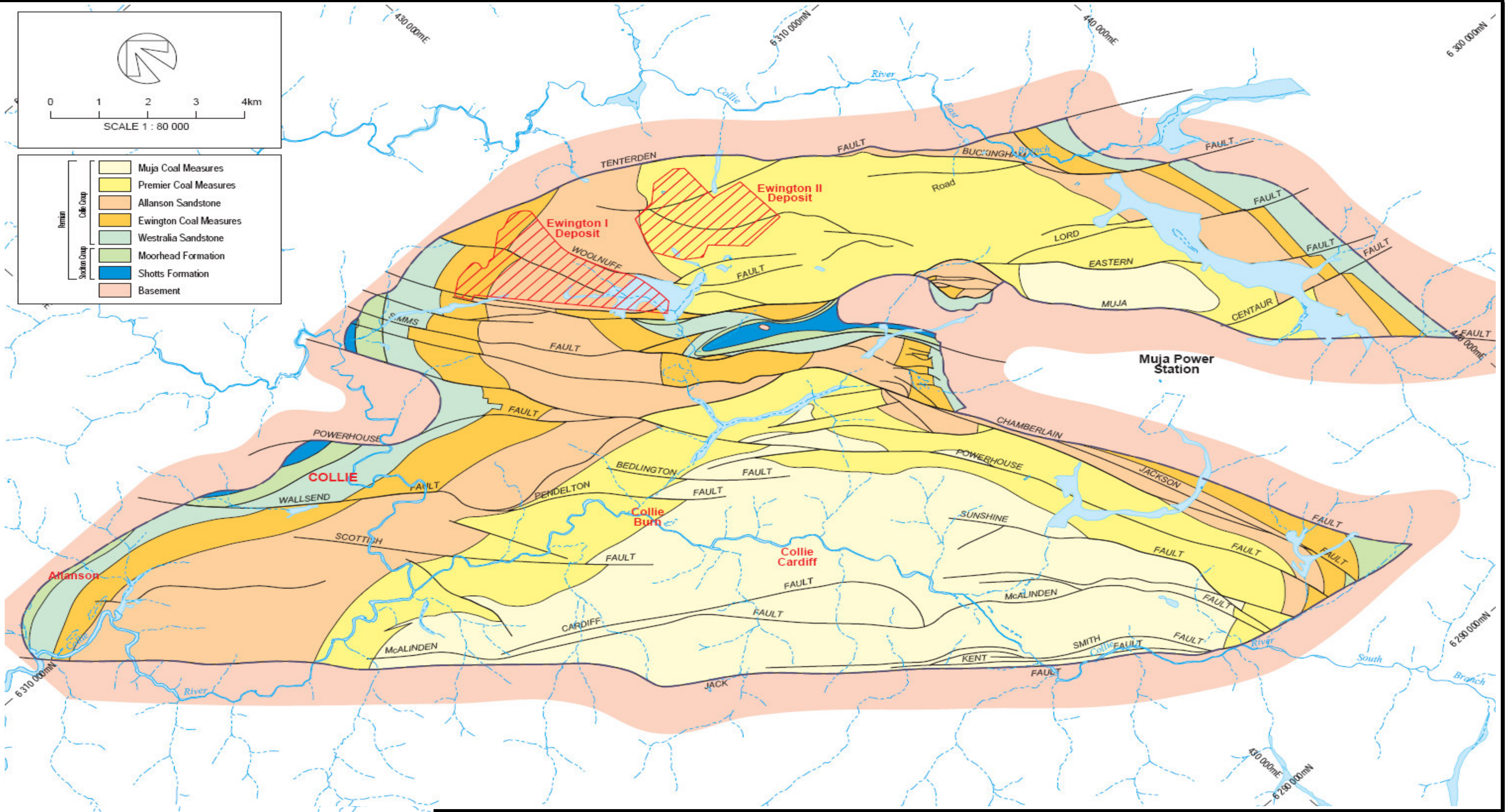
Approved: IB

Date:June 2008

Figure A-6

Job No: 4296750

File No:



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Griffin Energy Pty Ltd

Project:
Bluewaters EIA for Ash Co-Disposal

Title:
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Drawn:

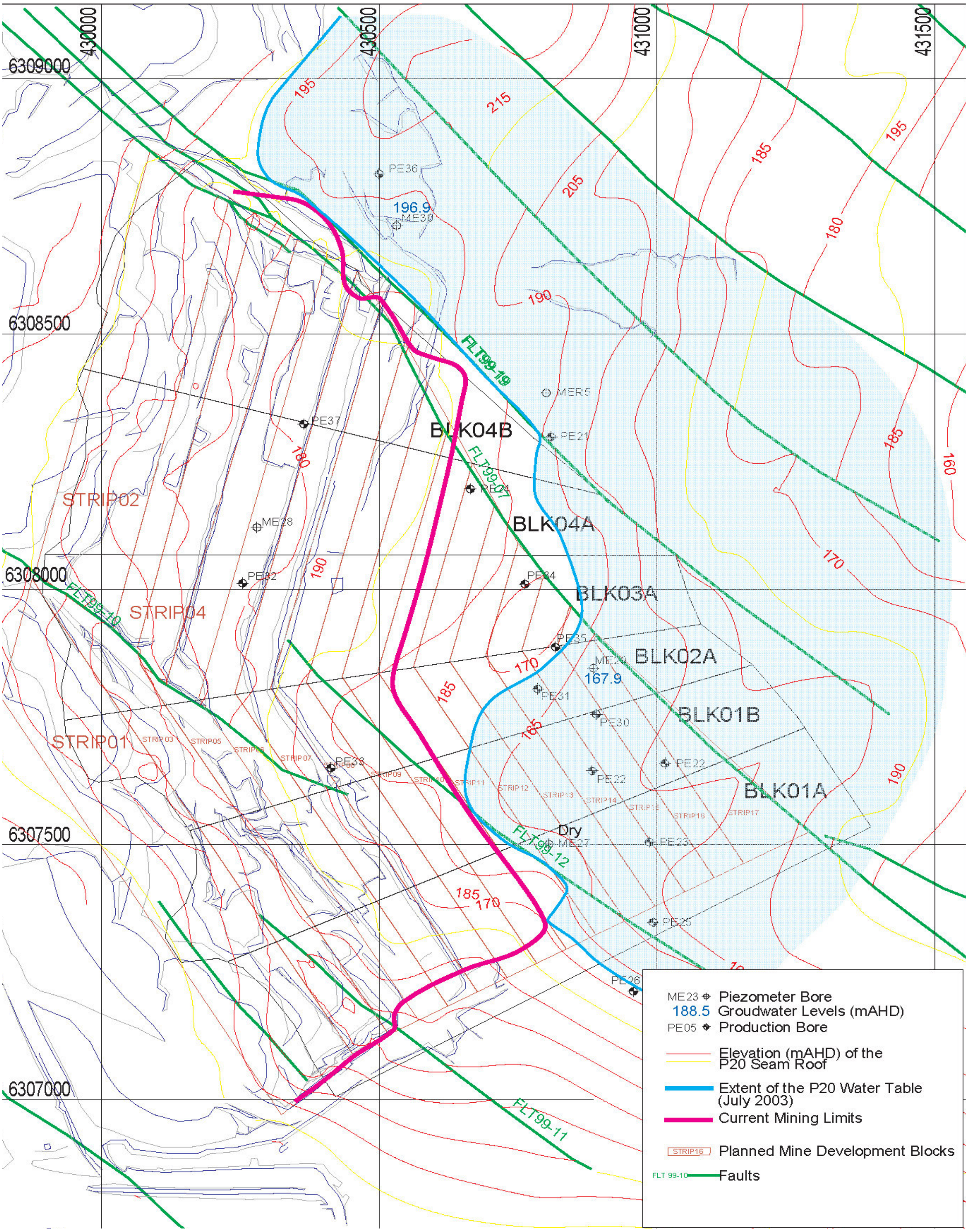
Approved:

Date:June 2008

Job No: 4296750

File No:

Figure A-7



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	Job No: 4296749 File No:	

Client:

Griffin Energy Pty Ltd

URS

Project:

Bluewaters EIA for Ash Co-Disposal

Drawn:

Approved: IB

Date:June 2008

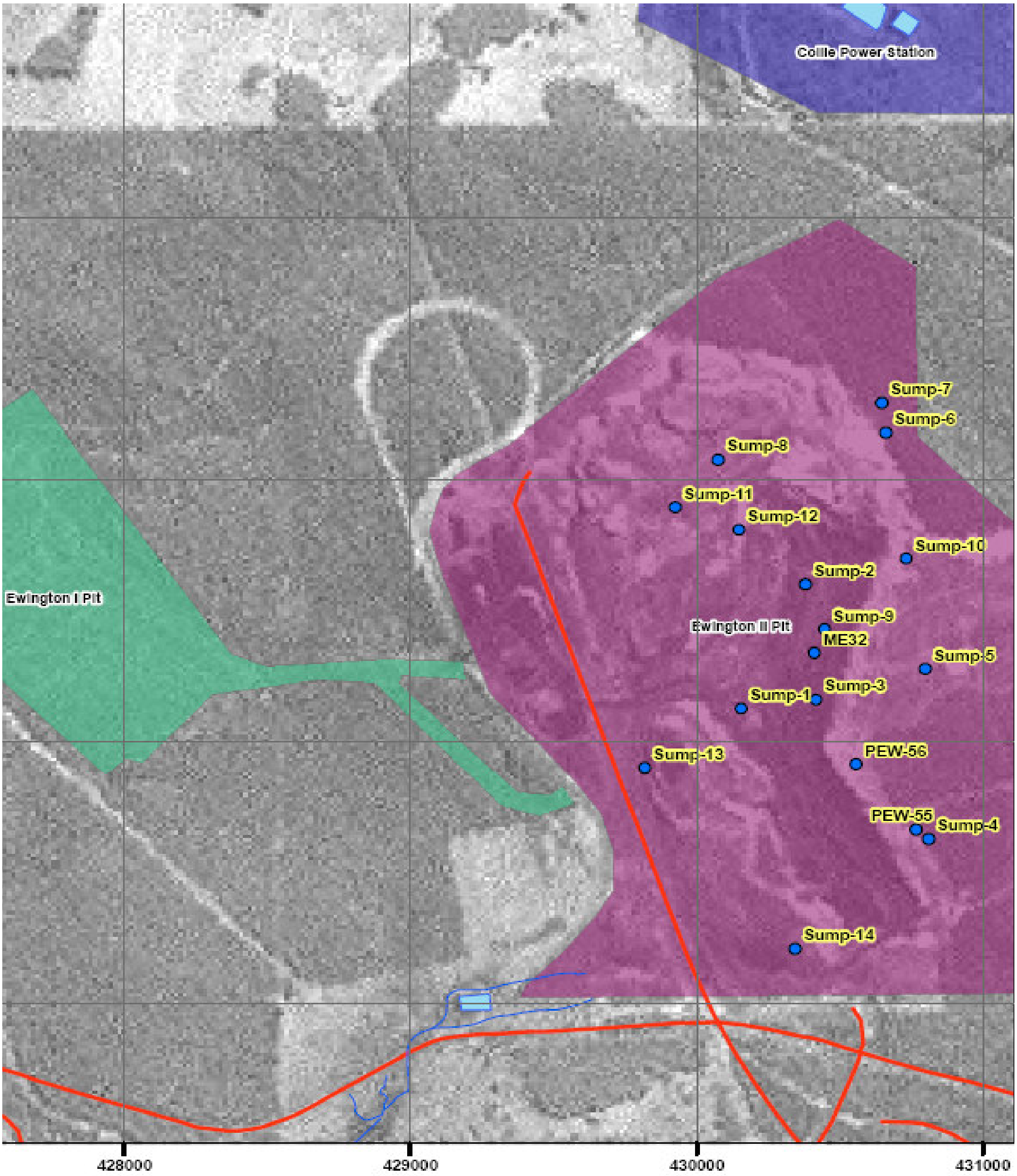
Job No: 4296750

File No:

Title:

Ewington II Mine
Infiltration Test Points

Figure A-9



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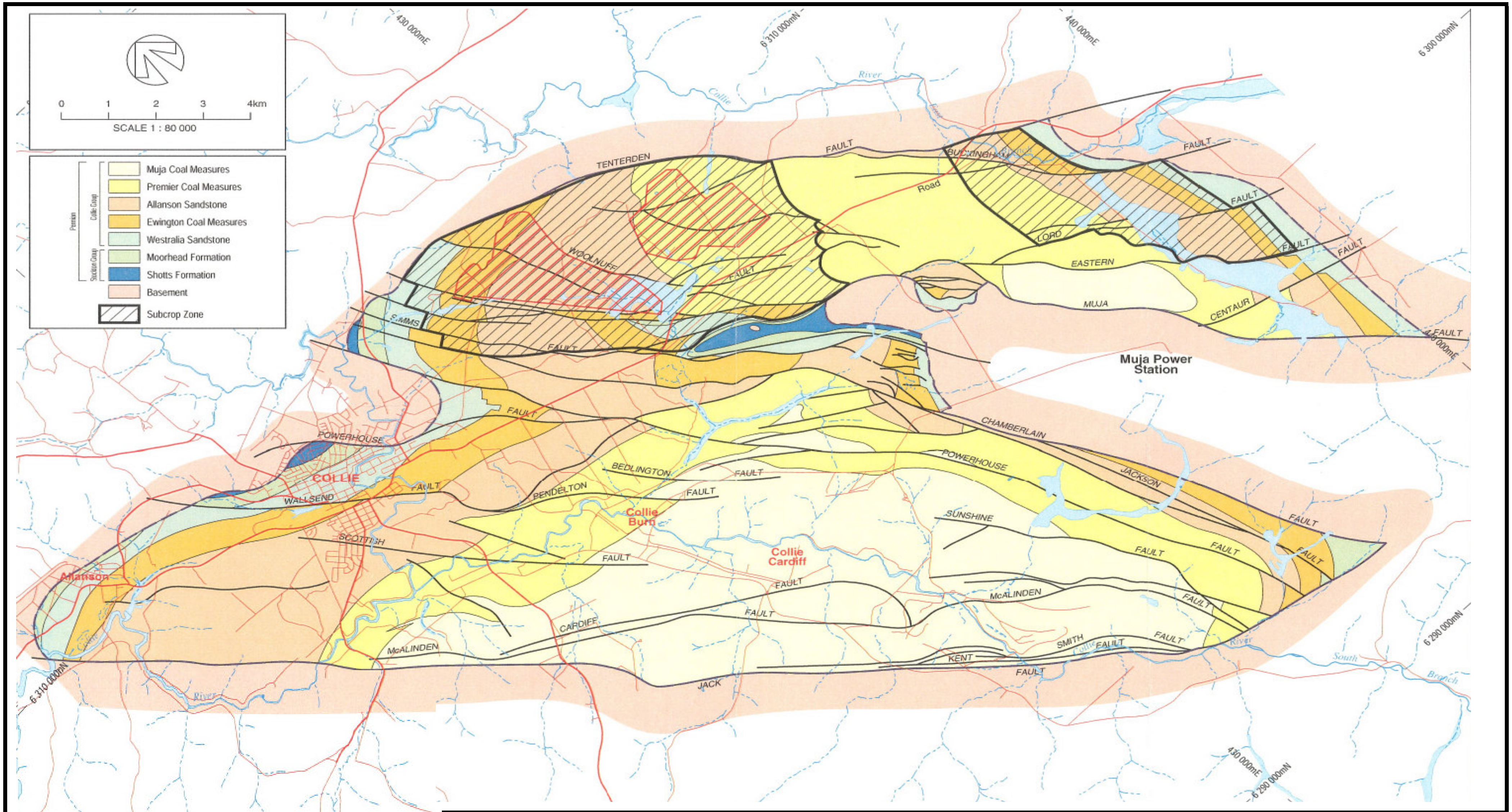
	Job No: 4296750	File No:		



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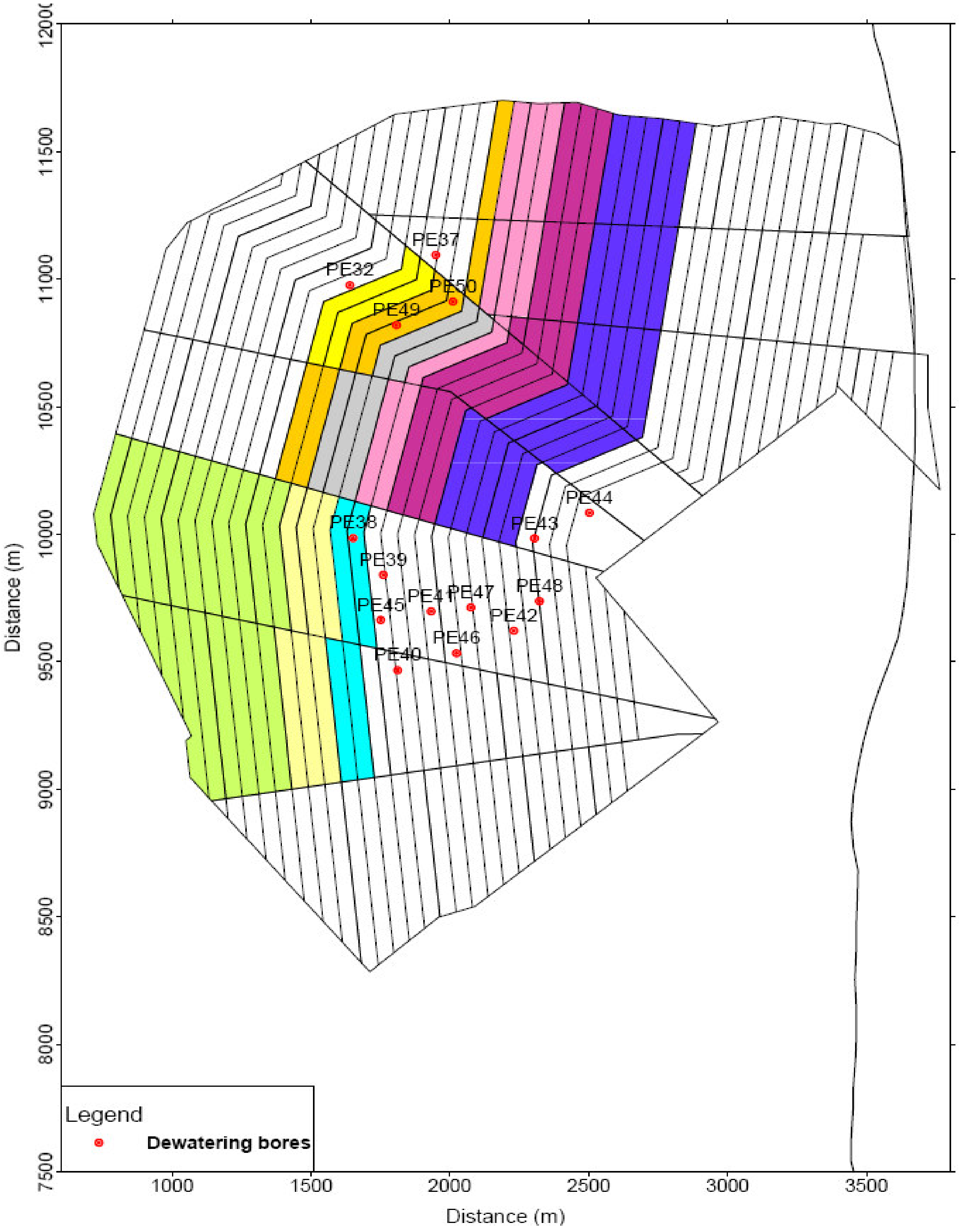
Project:
Bluewaters EIA for Ash Co-Disposal

Title:
Subcrop Zones Potentially Dewatered and Depressurised By Mine Dewatering Abstractions

Drawn:	Approved:	Date:June 2008
Job No: 4296750	File No:	

Figure A-11



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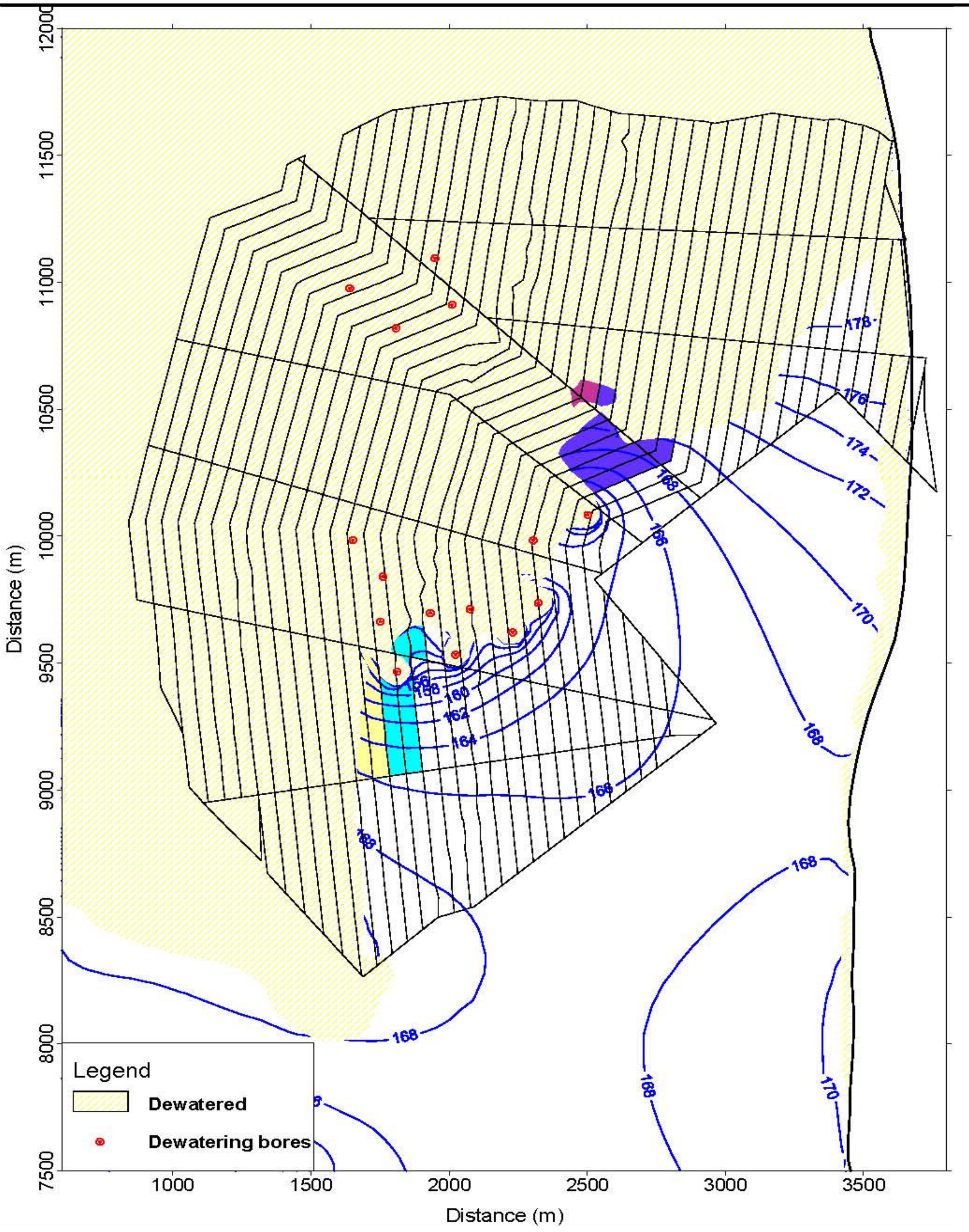


Client:

Griffin Energy Pty Ltd

URS

Project:

Bluewaters EIA for Ash Co-Disposal

Title:

Predicted Dewatering of P20 - Year 1

Drawn:

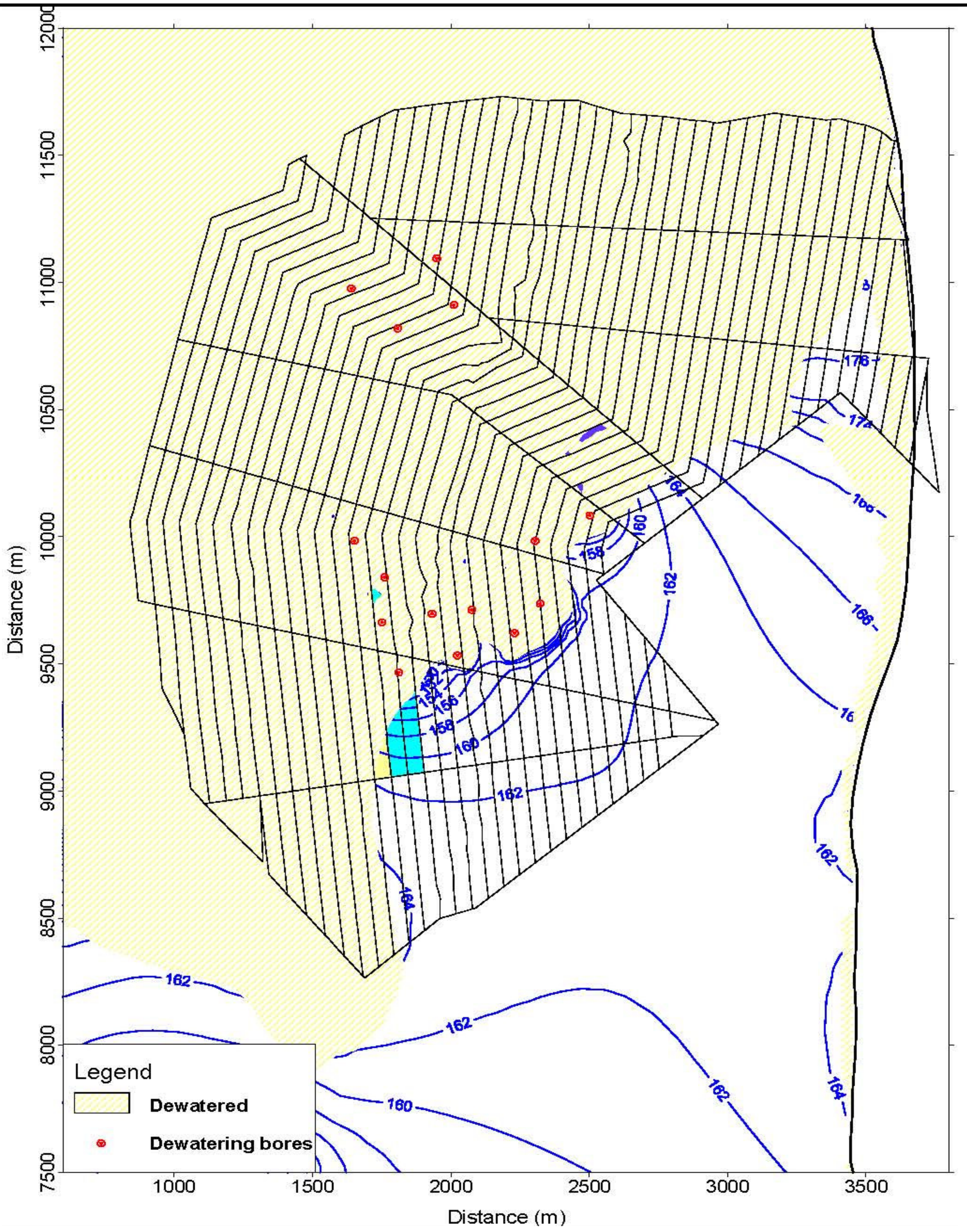
Approved: IB

Date: June 2008

Figure A-13a

Job No: 4296749

File No:



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Griffin Energy Pty Ltd

URS

Project:

Bluewaters EIA for Ash Co-Disposal

Title:

Predicted Dewatering of P20 - Year 2

Drawn:

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Date: June 2008

Figure A-13b

Job No: 4296749

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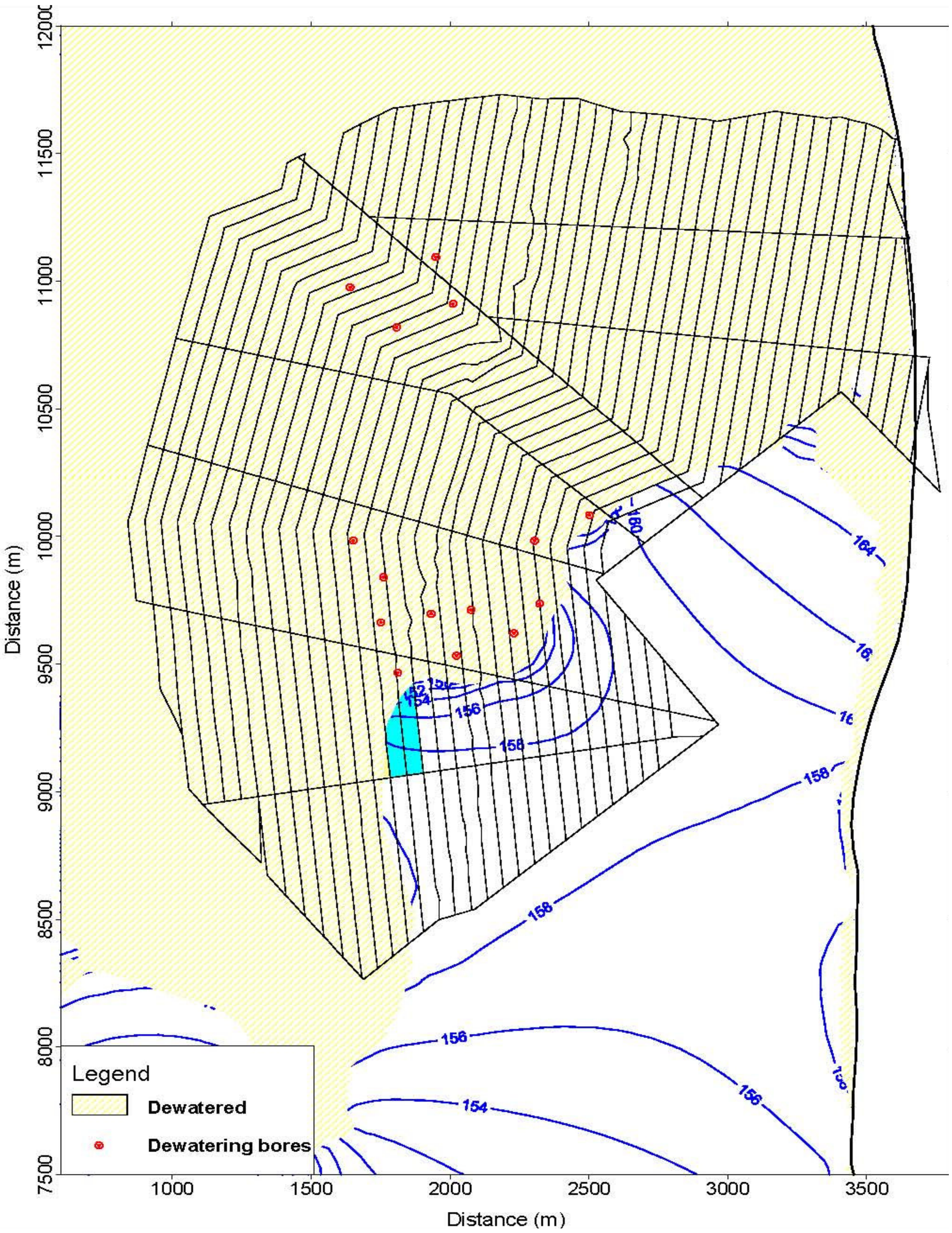

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URS	Drawn: / Approved: IB / Date: June 2008	Figure A-13c
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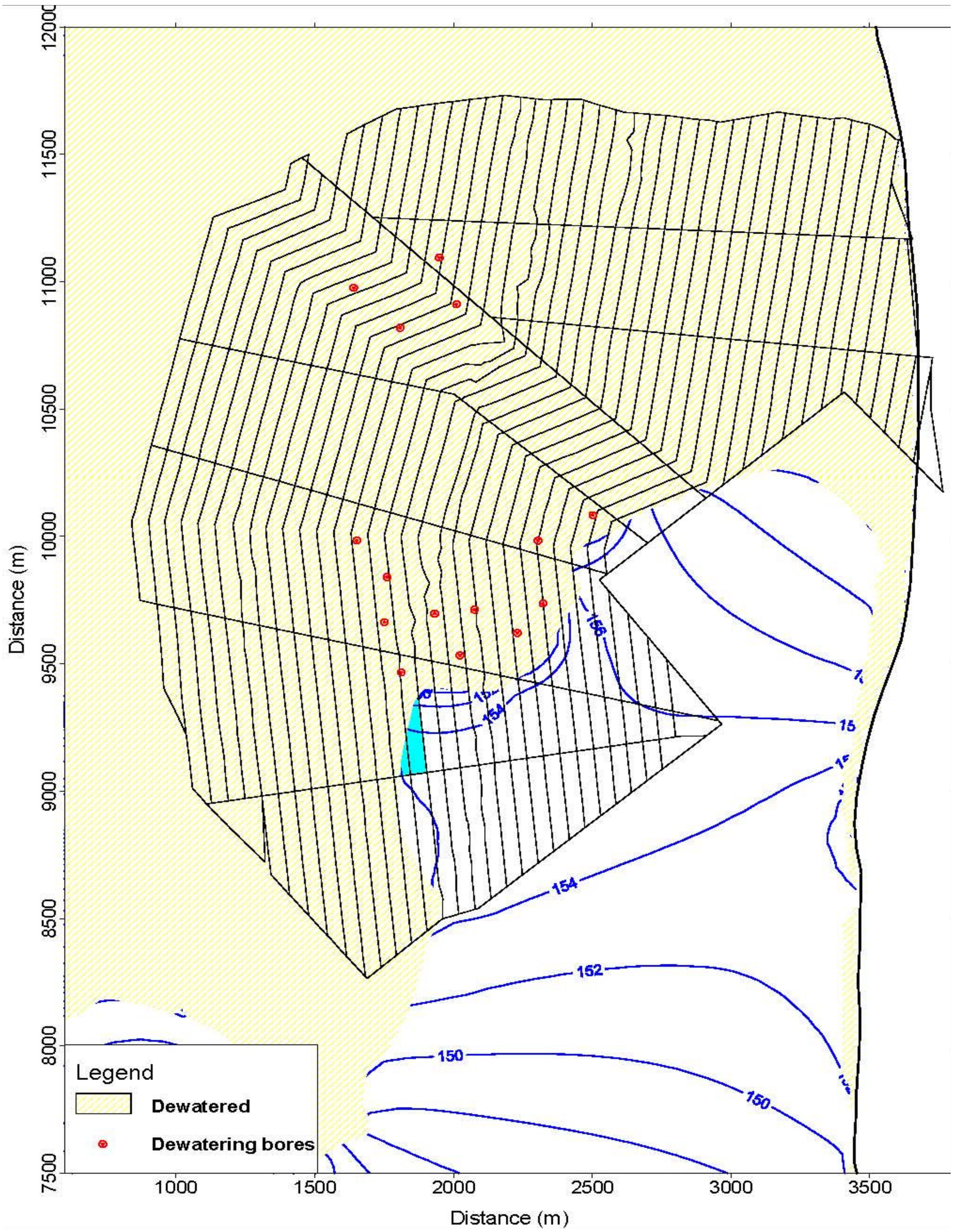

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Griffin Energy Pty Ltd

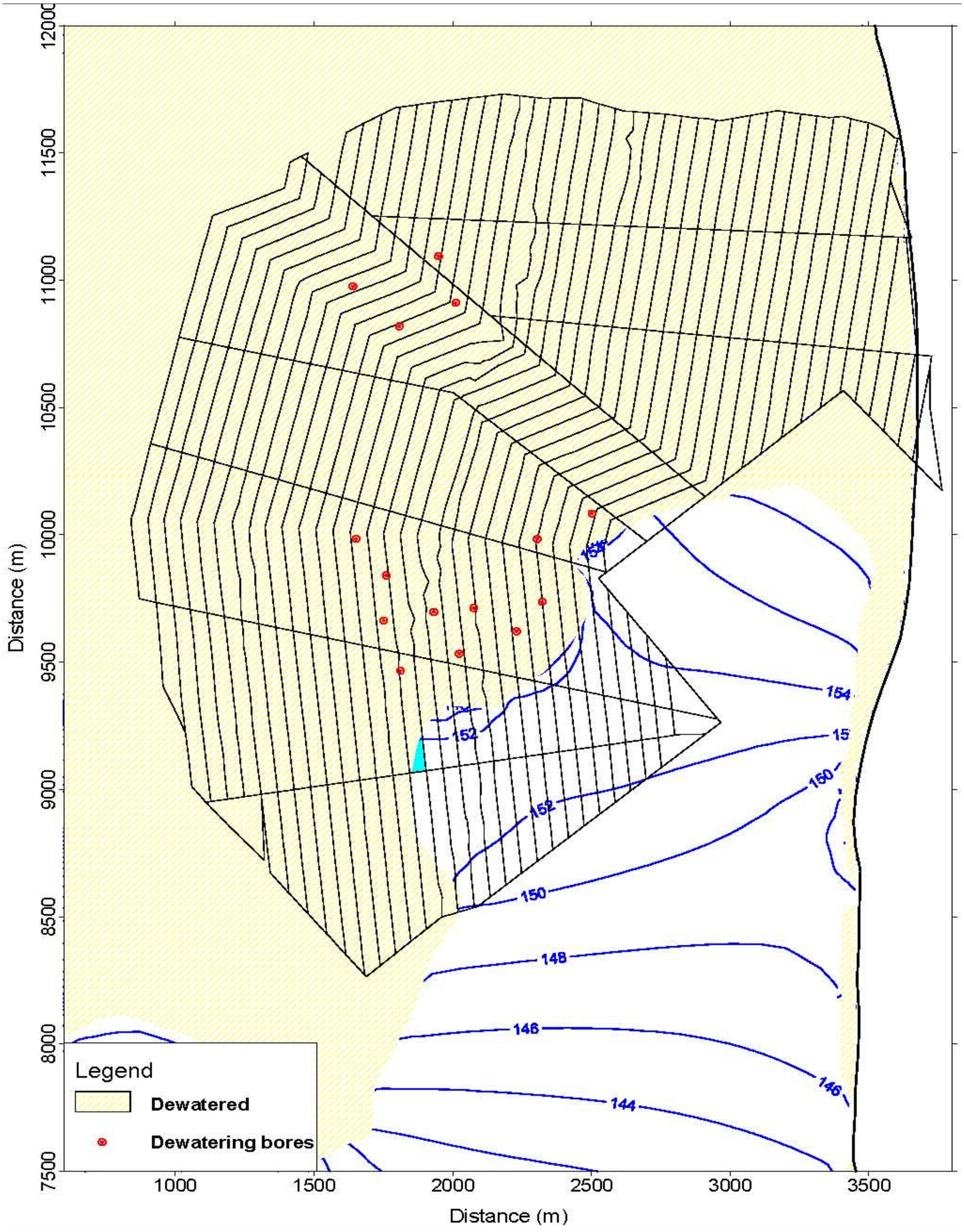
URS

Project:
Bluewaters EIA for Ash Co-Disposal

Title:
Predicted Dewatering of P20 - Year 4

Drawn:
Approved: IB
Date: June 2008
Job No: 4296749
File No:

Figure A-13d



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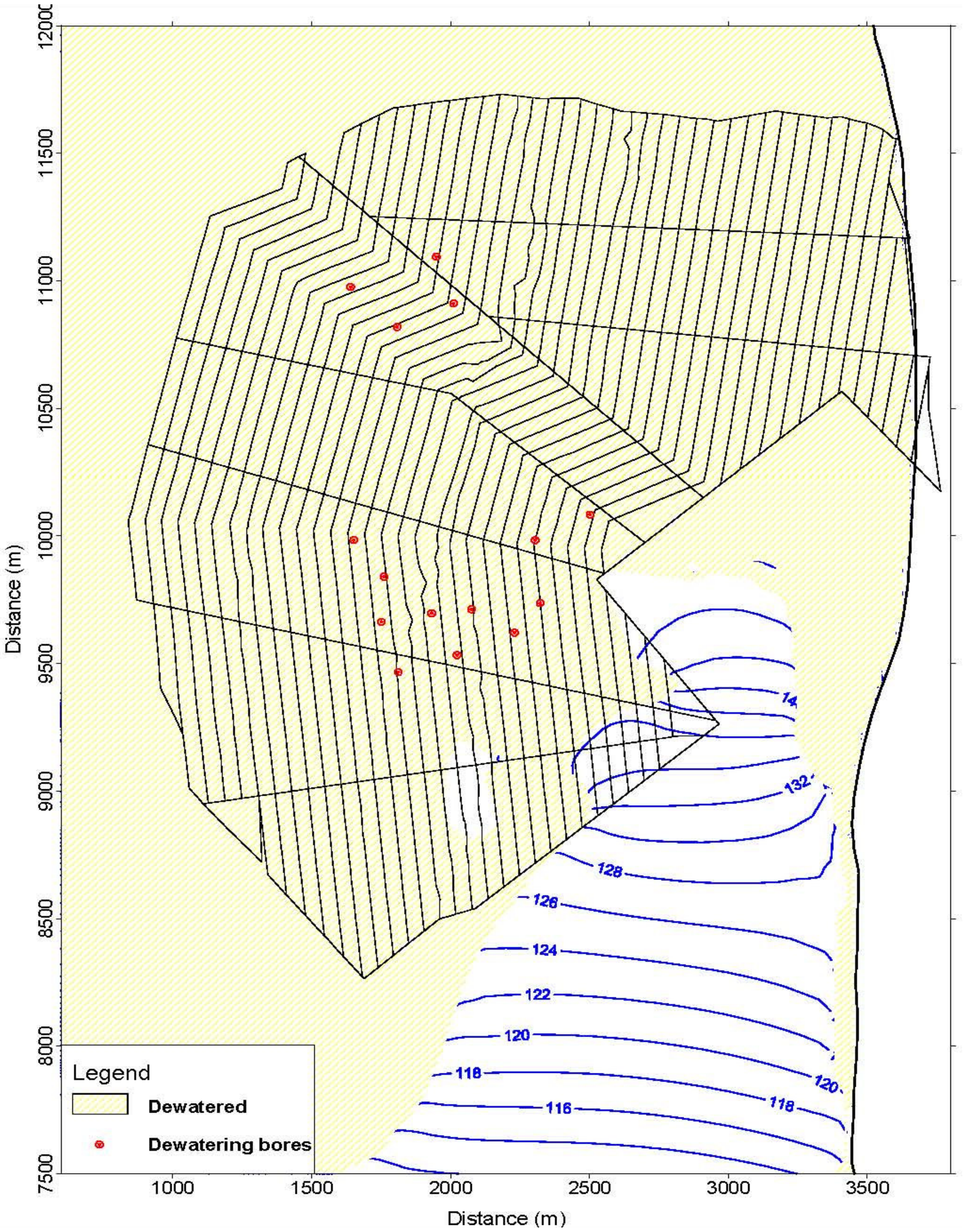
	Job No: 4296749	File No:	Figure A-13e



Client:

Griffin Energy Pty Ltd

URS

Project:

Bluewaters EIA for Ash Co-Disposal

Drawn:

Approved: IB

Date: June 2008

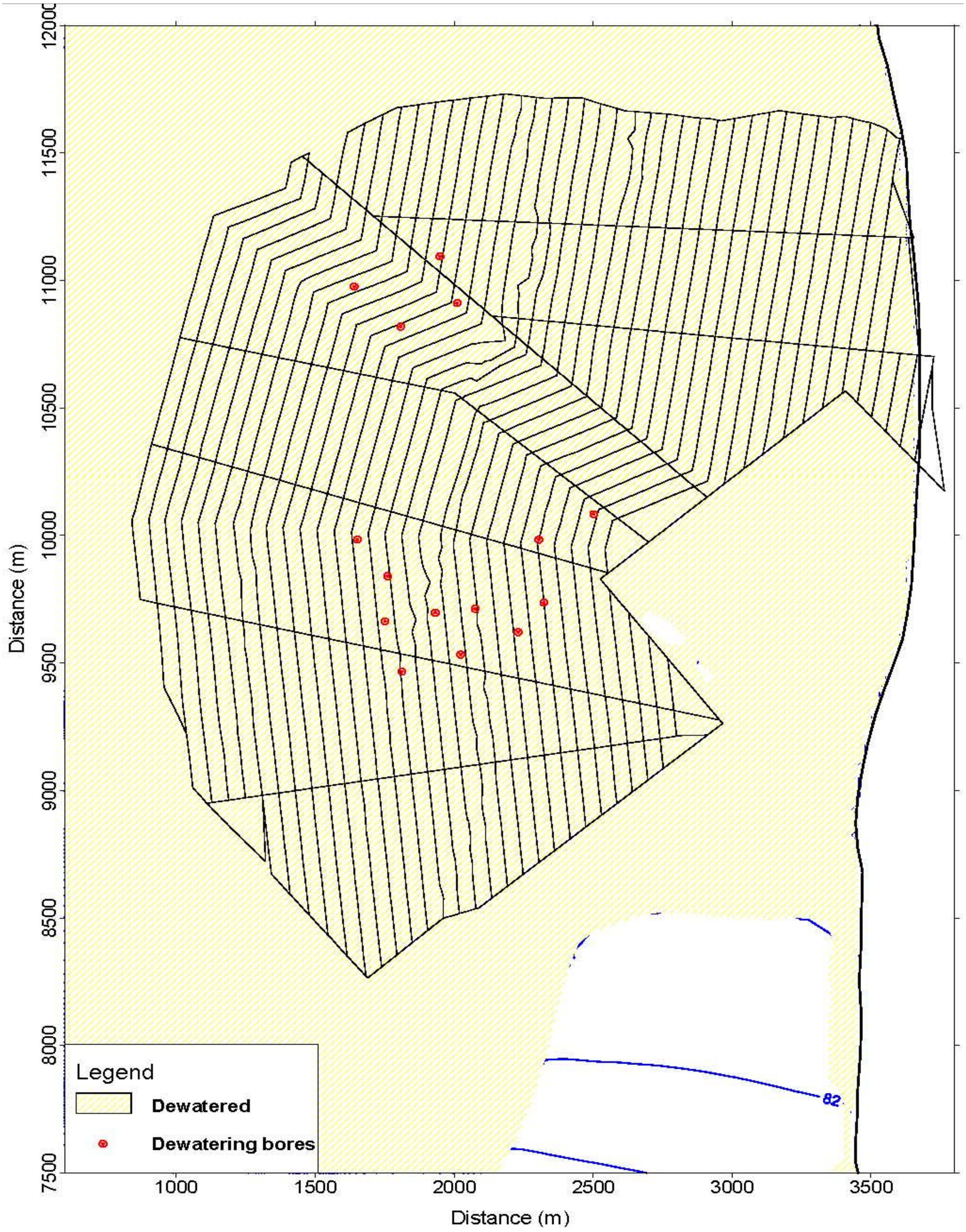
Job No: 4296749

File No:

Title:

Predicted Dewatering of P20 - Year 10

Figure A-13f



Client: Griffin Energy Pty Ltd URS	Project: Bluewaters EIA for Ash Co-Disposal	Title: Predicted Dewatering of P20 - Year 20
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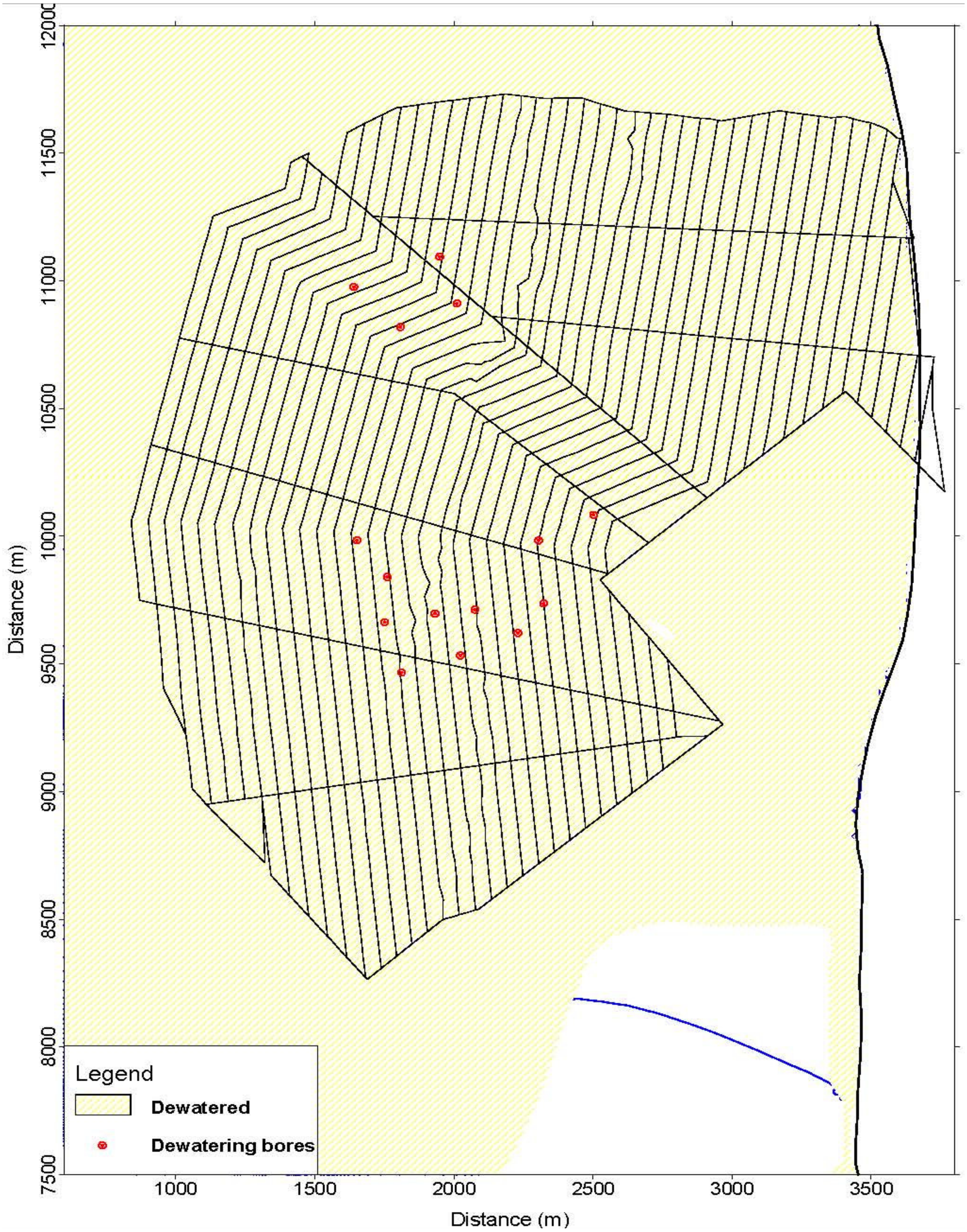
	Job No: 4296749 | File No:	



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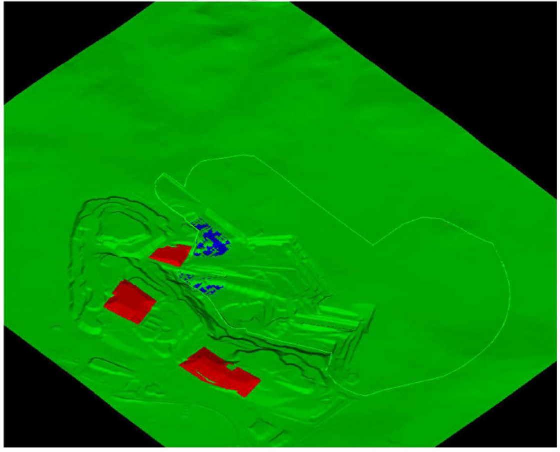
Griffin Energy Pty Ltd	Bluewaters EIA for Ash Co-Disposal	Predicted Dewatering of P20 - Year 26
URS	Drawn: Approved: IB Date: June 2008 Job No: 4296749 File No:	Figure A-13h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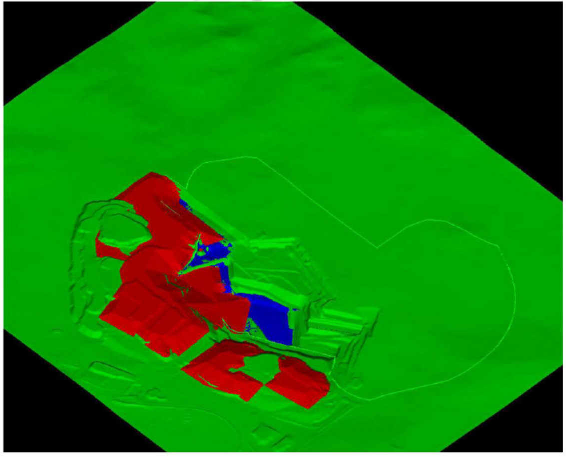
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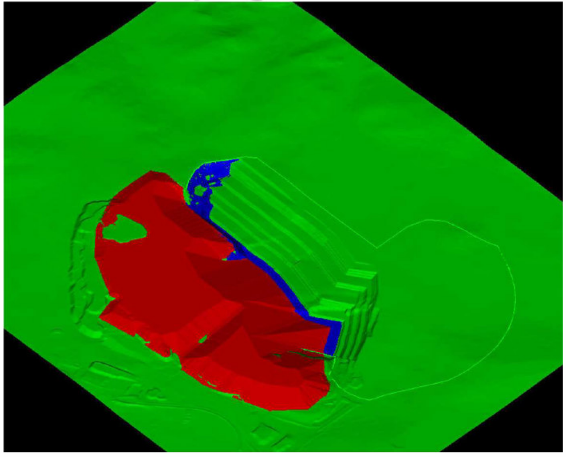
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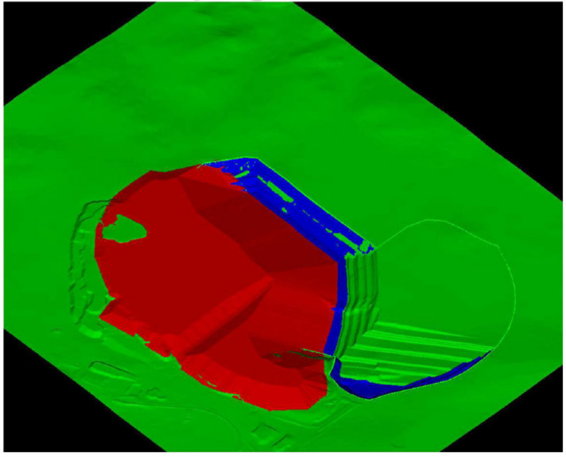
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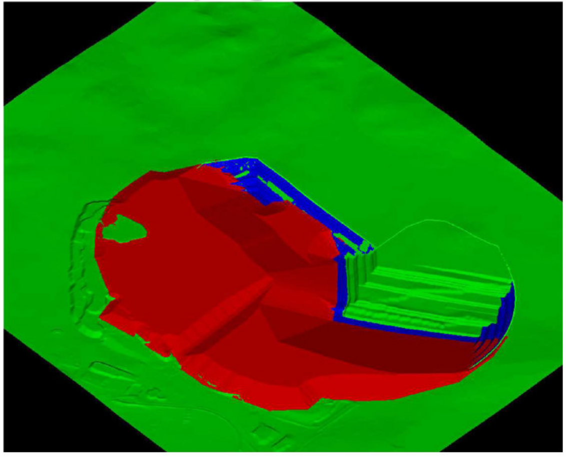
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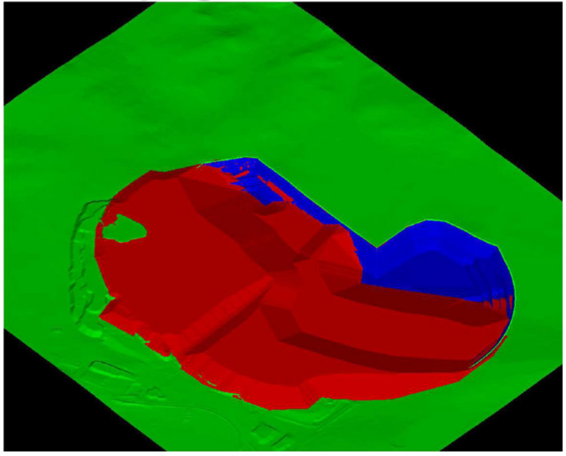
Dumping – End of Mine Life

Client: Griffin Energy Pty Ltd	Project: Bluewaters EIA for Ash Co-Disposal			Title: Simulated Backfill Schedules
	Drawn:	Approved: IB	Date: June 2008	Figure A-14
	Job No: 4296750	File No:		

Client:
Griffin Energy Pty Ltd

Project:
Bluewaters EIA for Ash Co-Disposal

Title:
Ewington II Proposed New Piezo Locations

Drawn:
Approved: IB
Date:June 2008
Job No: 4296750
File No:

Figure A-16

Appendix B Lab Tests

Water Quality Results

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **EP0801822**	Page	: 1 of 10
Client	: **URS AUSTRALIA PTY LTD**	Laboratory	: Environmental Division Perth
Contact	: MR EMAD SAHOURYEH	Contact	: Michael Sharp
Address	: LEVEL 3, HYATT CENTRE 20 TERRACE RD EAST PERTH WA, AUSTRALIA 6004	Address	: 10 Hod Way Malaga WA Australia 6090
E-mail	: emad_sahouryeh@urscorp.com	E-mail	: michael.sharp@alsenviro.com
Telephone	: +61 08 9221 1630	Telephone	: +61-8-9209 7655
Facsimile	: +61 08 9221 1639	Facsimile	: +61-8-9209 7600
Project	: 42906750	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 07-APR-2008
Sampler	: C.O	Issue Date	: 17-APR-2008
Site	: ----		
		No. of samples received	: 20
Quote number	: EN-001-07 BQ	No. of samples analysed	: 20

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED ACCREDITATION

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Alan Foley	Senior Chemist - Inorganics	Perth Inorganics
Dilani Fernando	Senior Inorganic Instrument Chemist	Inorganics
Terrance Hettipathirana	Senior ICP/MS Chemist	Inorganics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been preformed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insuffient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = Chemistry Abstract Services number
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **EGO20: Silver ICP-MS results when required have been confirmed by ICP-OES and LOR has been raised accordingly.**

Analytical Results

Sub-Matrix: **WATER**			*Client sample ID*	**Sump 1**	**Sump 2**	**Sump 3**	**Sump 4**	**Sump 5**
			Client sampling date / time	07-APR-2008 10:02	07-APR-2008 10:02	07-APR-2008 10:02	07-APR-2008 10:02	07-APR-2008 10:02
Compound	*CAS Number*	*LOR*	*Unit*	**EP0801822-001**	**EP0801822-002**	**EP0801822-003**	**EP0801822-004**	**EP0801822-005**
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**3.78**	**3.99**	**3.22**	**3.59**	**3.68**
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**380**	**2640**	**1980**	**991**	**761**
ED040F: Dissolved Major Anions								
Sulphate as SO4 2-	14808-79-8	1	mg/L	**146**	**452**	**1390**	**448**	**129**
^ Sulphur as S	63705-05-5	1	mg/L	**49**	**151**	**464**	**149**	**43**
^ Silica	7631-86-9	0.1	mg/L	**0.8**	**2.4**	**2.4**	**5.3**	**8.8**
Silicon	7440-21-3	0.10	mg/L	**0.35**	**1.14**	**1.12**	**2.48**	**4.09**
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1.0	mg/L	**11.8**	**596**	**27.5**	**59.8**	**119**
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**8**	**14**	**47**	**17**	**4**
Magnesium	7439-95-4	1	mg/L	**10**	**92**	**80**	**32**	**35**
Sodium	7440-23-5	1	mg/L	**15**	**426**	**44**	**42**	**48**
Potassium	7440-09-7	1	mg/L	<1	**5**	<1	**4**	**5**
EG020T: Total Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**12.0**	**7.67**	**127**	**46.4**	**3.69**
Antimony	7440-36-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	**0.005**	<0.001	<0.001
Beryllium	7440-41-7	0.001	mg/L	**0.005**	**0.020**	**0.117**	**0.032**	**0.007**
Barium	7440-39-3	0.001	mg/L	**0.005**	**0.021**	**0.006**	**0.050**	**0.065**
Cadmium	7440-43-9	0.0001	mg/L	**0.0021**	**0.0091**	**0.0208**	**0.0099**	**0.0008**
Chromium	7440-47-3	0.001	mg/L	**0.002**	**0.004**	**0.027**	**0.013**	<0.001
Cobalt	7440-48-4	0.001	mg/L	**0.243**	**1.13**	**3.86**	**0.799**	**0.103**
Copper	7440-50-8	0.001	mg/L	**0.003**	**0.009**	**0.036**	**0.019**	**0.008**
Lead	7439-92-1	0.001	mg/L	**0.008**	**0.015**	**0.087**	**0.053**	**0.010**
Manganese	7439-96-5	0.001	mg/L	**0.068**	**1.43**	**0.687**	**0.311**	**0.048**
Molybdenum	7439-98-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	7782-49-2	0.010	mg/L	<0.010	<0.010	**0.032**	<0.010	<0.010
Silver	7440-22-4	0.001	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010
Strontium	7440-24-6	0.001	mg/L	**0.029**	**0.277**	**0.510**	**0.239**	**0.070**
Titanium	7440-32-6	0.01	mg/L	**0.02**	**0.01**	**0.01**	**0.03**	**0.02**
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	**0.04**	**0.02**	<0.01
Zinc	7440-66-6	0.005	mg/L	**0.837**	**5.39**	**21.4**	**4.34**	**0.404**
Boron	7440-42-8	0.05	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Iron	7439-89-6	0.05	mg/L	**0.85**	**0.38**	**7.48**	**4.23**	**6.92**
EG035T: Total Mercury by FIMS								

Analytical Results

Sub-Matrix: **WATER**			Client sample ID	**Sump 1**	**Sump 2**	**Sump 3**	**Sump 4**	**Sump 5**
			Client sampling date / time	07-APR-2008 10:02	07-APR-2008 10:02	07-APR-2008 10:02	07-APR-2008 10:02	07-APR-2008 10:02
Compound	*CAS Number*	*LOR*	*Unit*	**EP0801822-001**	**EP0801822-002**	**EP0801822-003**	**EP0801822-004**	**EP0801822-005**
EG035T: Total Mercury by FIMS - Continued								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	<0.1	**0.3**	**0.2**	**0.2**	<0.1

Analytical Results

Sub-Matrix: **WATER**			*Client sample ID*	**Sump 6**	**Sump 7**	**Sump 8**	**Sump 9**	**Sump 10**
			Client sampling date / time	07-APR-2008 10:02	07-APR-2008 10:02	07-APR-2008 10:02	07-APR-2008 10:02	07-APR-2008 10:02
Compound	*CAS Number*	*LOR*	*Unit*	**EP0801822-006**	**EP0801822-007**	**EP0801822-008**	**EP0801822-009**	**EP0801822-010**
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**4.90**	**4.08**	**4.50**	**3.95**	**4.13**
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**198**	**336**	**43**	**473**	**355**
ED040F: Dissolved Major Anions								
Sulphate as SO4 2-	14808-79-8	1	mg/L	**13**	**60**	**6**	**152**	**78**
^ Sulphur as S	63705-05-5	1	mg/L	**4**	**20**	**2**	**51**	**26**
^ Silica	7631-86-9	0.1	mg/L	**2.6**	**3.9**	**0.5**	**3.7**	**2.0**
Silicon	7440-21-3	0.10	mg/L	**1.20**	**1.83**	**0.23**	**1.74**	**0.95**
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1.0	mg/L	**48.5**	**46.6**	**24.4**	**100**	**48.4**
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**1**	**3**	<1	**6**	**5**
Magnesium	7439-95-4	1	mg/L	**3**	**9**	<1	**13**	**9**
Sodium	7440-23-5	1	mg/L	**26**	**32**	**2**	**30**	**29**
Potassium	7440-09-7	1	mg/L	**3**	**3**	<1	**4**	**2**
EG020T: Total Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**1.34**	**3.29**	**0.23**	**11.4**	**4.81**
Antimony	7440-36-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Beryllium	7440-41-7	0.001	mg/L	<0.001	**0.001**	<0.001	**0.005**	**0.002**
Barium	7440-39-3	0.001	mg/L	**0.014**	**0.025**	**0.005**	**0.036**	**0.028**
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	**0.0007**	<0.0001	**0.0031**	**0.0010**
Chromium	7440-47-3	0.001	mg/L	<0.001	**0.002**	<0.001	**0.001**	**0.002**
Cobalt	7440-48-4	0.001	mg/L	**0.013**	**0.133**	**0.008**	**0.278**	**0.173**
Copper	7440-50-8	0.001	mg/L	<0.001	**0.002**	<0.001	**0.004**	**0.002**
Lead	7439-92-1	0.001	mg/L	<0.001	**0.010**	**0.001**	**0.020**	**0.005**
Manganese	7439-96-5	0.001	mg/L	**0.040**	**0.079**	**0.009**	**0.101**	**0.097**
Molybdenum	7439-98-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	7782-49-2	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010
Silver	7440-22-4	0.001	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010
Strontium	7440-24-6	0.001	mg/L	**0.024**	**0.067**	**0.009**	**0.106**	**0.080**
Titanium	7440-32-6	0.01	mg/L	**0.05**	**0.02**	<0.01	<0.01	**0.02**
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	7440-66-6	0.005	mg/L	**0.057**	**0.750**	**0.039**	**1.23**	**0.961**
Boron	7440-42-8	0.05	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Iron	7439-89-6	0.05	mg/L	**0.41**	**0.41**	<0.05	**0.53**	**0.62**
EG035T: Total Mercury by FIMS								

Analytical Results

Sub-Matrix: **WATER**			Client sample ID	**Sump 6**	**Sump 7**	**Sump 8**	**Sump 9**	**Sump 10**
			Client sampling date / time	07-APR-2008 10:02	07-APR-2008 10:02	07-APR-2008 10:02	07-APR-2008 10:02	07-APR-2008 10:02
Compound	*CAS Number*	*LOR*	*Unit*	**EP0801822-006**	**EP0801822-007**	**EP0801822-008**	**EP0801822-009**	**EP0801822-010**
EG035T: Total Mercury by FIMS - Continued								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	<0.1	<0.1	<0.1	**0.1**	<0.1

Analytical Results

Sub-Matrix: **WATER**			Client sample ID	Sump 11	Sump 12	Sump 13	Sump 14	PE56
			Client sampling date / time	07-APR-2008 10:02	07-APR-2008 10:02	07-APR-2008 10:02	07-APR-2008 10:02	07-APR-2008 10:02
Compound	*CAS Number*	*LOR*	*Unit*	EP0801822-011	EP0801822-012	EP0801822-013	EP0801822-014	EP0801822-015
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	3.66	4.29	3.82	4.29	6.19
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	664	73	1000	154	322
ED040F: Dissolved Major Anions								
Sulphate as SO4 2-	14808-79-8	1	mg/L	320	12	361	31	8
^ Sulphur as S	63705-05-5	1	mg/L	107	4	120	10	3
^ Silica	7631-86-9	0.1	mg/L	0.7	0.5	4.4	1.3	11.8
Silicon	7440-21-3	0.10	mg/L	0.32	0.24	2.04	0.62	5.49
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1.0	mg/L	25.1	5.2	102	16.0	82.1
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	11	<1	17	3	<1
Magnesium	7439-95-4	1	mg/L	14	<1	29	3	5
Sodium	7440-23-5	1	mg/L	16	3	59	9	43
Potassium	7440-09-7	1	mg/L	<1	<1	4	<1	5
EG020T: Total Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	38.1	0.59	35.6	1.88	0.03
Antimony	7440-36-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Beryllium	7440-41-7	0.001	mg/L	0.015	<0.001	0.017	0.001	<0.001
Barium	7440-39-3	0.001	mg/L	0.002	0.010	0.022	0.015	0.091
Cadmium	7440-43-9	0.0001	mg/L	0.0040	0.0002	0.0027	0.0004	<0.0001
Chromium	7440-47-3	0.001	mg/L	0.006	<0.001	0.004	<0.001	<0.001
Cobalt	7440-48-4	0.001	mg/L	0.471	0.015	0.435	0.042	0.002
Copper	7440-50-8	0.001	mg/L	0.004	<0.001	0.003	<0.001	0.004
Lead	7439-92-1	0.001	mg/L	0.003	0.002	0.004	0.002	0.001
Manganese	7439-96-5	0.001	mg/L	0.110	0.014	0.374	0.138	0.022
Molybdenum	7439-98-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	7782-49-2	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010
Silver	7440-22-4	0.001	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010
Strontium	7440-24-6	0.001	mg/L	0.059	0.016	0.186	0.032	0.028
Titanium	7440-32-6	0.01	mg/L	0.01	<0.01	0.02	0.02	<0.01
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	7440-66-6	0.005	mg/L	2.42	0.110	2.34	0.200	0.034
Boron	7440-42-8	0.05	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Iron	7439-89-6	0.05	mg/L	2.06	0.31	1.43	0.38	0.49
EG035T: Total Mercury by FIMS								

Analytical Results

Sub-Matrix: **WATER**			Client sample ID	**Sump 11**	**Sump 12**	**Sump 13**	**Sump 14**	**PE56**
			Client sampling date / time	07-APR-2008 10:02	07-APR-2008 10:02	07-APR-2008 10:02	07-APR-2008 10:02	07-APR-2008 10:02
Compound	*CAS Number*	*LOR*	*Unit*	**EP0801822-011**	**EP0801822-012**	**EP0801822-013**	**EP0801822-014**	**EP0801822-015**
EG035T: Total Mercury by FIMS - Continued								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	**0.1**	<0.1	**0.1**	<0.1	<0.1

Analytical Results

Sub-Matrix: **WATER**			Client sample ID	**PE55**	**Piezo P60**	**PEW4**	**PEW5**	**PEW7**
			Client sampling date / time	07-APR-2008 10:02	07-APR-2008 10:02	07-APR-2008 10:02	07-APR-2008 10:02	07-APR-2008 10:02
Compound	*CAS Number*	*LOR*	*Unit*	**EP0801822-016**	**EP0801822-017**	**EP0801822-018**	**EP0801822-019**	**EP0801822-020**
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**6.20**	**6.02**	**6.29**	**5.87**	**5.95**
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**373**	**505**	**392**	**367**	**327**
ED040F: Dissolved Major Anions								
Sulphate as SO4 2-	14808-79-8	1	mg/L	**14**	**7**	**9**	**7**	**8**
^ Sulphur as S	63705-05-5	1	mg/L	**5**	**2**	**3**	**2**	**2**
^ Silica	7631-86-9	0.1	mg/L	**12.4**	**32.4**	**13.2**	**8.4**	**9.9**
Silicon	7440-21-3	0.10	mg/L	**5.77**	**15.1**	**6.14**	**3.94**	**4.61**
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1.0	mg/L	**90.9**	**123**	**93.5**	**91.9**	**80.4**
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	<1	**3**	**2**	**1**	**1**
Magnesium	7439-95-4	1	mg/L	**6**	**8**	**5**	**6**	**5**
Sodium	7440-23-5	1	mg/L	**51**	**60**	**53**	**49**	**45**
Potassium	7440-09-7	1	mg/L	**7**	**11**	**6**	**2**	**3**
EG020T: Total Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**0.02**	**0.29**	**0.03**	**0.28**	**0.07**
Antimony	7440-36-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Barium	7440-39-3	0.001	mg/L	**0.130**	**0.411**	**0.092**	**0.036**	**0.043**
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	7440-48-4	0.001	mg/L	**0.001**	<0.001	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L	**0.007**	**0.001**	**0.001**	**0.001**	**0.003**
Lead	7439-92-1	0.001	mg/L	**0.001**	**0.006**	**0.002**	**0.005**	**0.004**
Manganese	7439-96-5	0.001	mg/L	**0.041**	**0.135**	**0.068**	**0.028**	**0.031**
Molybdenum	7439-98-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	7782-49-2	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010
Silver	7440-22-4	0.001	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010
Strontium	7440-24-6	0.001	mg/L	**0.032**	**0.059**	**0.035**	**0.022**	**0.023**
Titanium	7440-32-6	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	7440-66-6	0.005	mg/L	**0.110**	**0.008**	**0.016**	**0.029**	**0.025**
Boron	7440-42-8	0.05	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Iron	7439-89-6	0.05	mg/L	**1.11**	**17.8**	**3.20**	**1.46**	**1.18**
EG035T: Total Mercury by FIMS								

Analytical Results

Sub-Matrix: **WATER**			Client sample ID	**PE55**	**Piezo P60**	**PEW4**	**PEW5**	**PEW7**
			Client sampling date / time	07-APR-2008 10:02	07-APR-2008 10:02	07-APR-2008 10:02	07-APR-2008 10:02	07-APR-2008 10:02
Compound	*CAS Number*	*LOR*	*Unit*	**EP0801822-016**	**EP0801822-017**	**EP0801822-018**	**EP0801822-019**	**EP0801822-020**
EG035T: Total Mercury by FIMS - Continued								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1

Report of Examination

4290 6750
07E1891; 3.1.1
Jenny McGuire

URS Australia
Level 3, 20 Terrace Rd
East Perth
WA 6004

Attention : Ian Brunnes

Report On:
6 samples received on 16/04/2008

CCWA ID	**Material**	**Client Description**
07E1891 / 001	soil	Laterite out of pit (SE Cnr)
07E1891 / 002	soil	Sandstone P32 overburden (P30 floor)
07E1891 / 003	soil	Coal (P30)
07E1891 / 004	soil	Shale (Shale stockpile)
07E1891 / 005	soil	Pyrite Shale P30 floor
07E1891 / 006	soil	Mixed Sandstone, Shale Coal Dump Example (P32

CCWA ID **Client ID** **Sampled**		07E1891/001 Laterite	07E1891/002 Sandstone	07E1891/003 Coal	07E1891/004 Shale
Analyte	**Unit**				
Al	mg/kg	66900	963	5730	13900
As	mg/kg	2	<1	<1	4
B	mg/kg	<5	<5	<5	<5
Be	mg/kg	0.29	<0.05	1.5	1.8
Cd	mg/kg	<0.05	<0.05	<0.05	0.13
Co	mg/kg	2.8	1.6	8.4	4.3
Cu	mg/kg	0.4	0.6	6.1	20
Fe	mg/kg	18000	660	3300	3000
Hg_total	mg/kg	0.060	0.020	<0.020	0.090
Mn	mg/kg	19	1.9	2.5	4.7
Ni	mg/kg	9	2	15	12
Pb	mg/kg	6.2	6.9	7.8	37
pH_ASLP		7.0	7.0	3.9	5.4
Sb	mg/kg	<1	<1	<1	<1
Se	mg/kg	<1	<1	<1	<1
Zn	mg/kg	<5	<5	17	40
Al	mg/L	15	2.6	3.6	0.43
As	mg/L	<0.05	<0.05	<0.05	<0.05

Chemistry Centre of Western Australia
Environmental Chemistry Section

Report of Examination

CCWA ID **Client ID** **Sampled**		07E1891/001 Laterite	07E1891/002 Sandstone	07E1891/003 Coal	07E1891/004 Shale
Analyte	**Unit**				
B	mg/L	0.04	0.03	0.02	<0.02
Be	mg/L	<0.001	<0.001	0.005	<0.001
Cd	mg/L	<0.002	<0.002	<0.002	<0.002
Cl	mg/L	5	<5	<5	<5
Co	mg/L	<0.005	0.006	0.049	0.027
Cu	mg/L	<0.002	<0.002	0.003	0.002
F	mg/L	0.10	0.06	<0.05	<0.05
Fe	mg/L	1.7	0.10	0.93	0.020
Hg	mg/L	0.0001	<0.0001	<0.0001	<0.0001
Mn	mg/L	0.004	0.003	0.062	0.020
Ni	mg/L	<0.01	<0.01	0.02	<0.01
Pb	mg/L	<0.02	<0.02	<0.02	<0.02
Sb	mg/L	<0.05	<0.05	<0.05	<0.05
Se	mg/L	<0.05	<0.05	<0.05	<0.05
Zn	mg/L	0.014	0.014	0.24	0.13

CCWA ID **Client ID** **Sampled**		07E1891/005 Pyrite Shale	07E1891/006 Mixed Sandstone,
Analyte	**Unit**		
Al	mg/kg	41	3360
As	mg/kg	<1	<1
B	mg/kg	<5	<5
Be	mg/kg	0.13	0.32
Cd	mg/kg	<0.05	<0.05
Co	mg/kg	1.2	4.8
Cu	mg/kg	0.2	4.3
Fe	mg/kg	5	620
Hg_total	mg/kg	<0.020	<0.020
Mn	mg/kg	0.4	4.9
Ni	mg/kg	1	5
Pb	mg/kg	<0.5	14
pH_ASLP		5.9	4.5
Sb	mg/kg	<1	<1
Se	mg/L		<0.05
Se	mg/kg	<1	<1
Zn	mg/kg	8	10
Al	mg/L	0.29	2.4
As	mg/L	<0.05	<0.05
B	mg/L	<0.02	<0.02
Be	mg/L	<0.001	0.001

Report of Examination

CCWA ID		07E1891/005	07E1891/006
Client ID		Pyrite Shale	Mixed Sandstone,
Sampled			

Analyte	**Unit**		
Cd	mg/L	<0.002	<0.002
Cl	mg/L	<5	<5
Co	mg/L	0.016	0.14
Cu	mg/L	<0.002	0.002
F	mg/L	<0.05	<0.05
Fe	mg/L	0.011	0.47
Hg	mg/L	<0.0001	<0.0001
Mn	mg/L	0.007	0.074
Ni	mg/L	<0.01	0.04
Pb	mg/L	<0.02	<0.02
Sb	mg/L	<0.05	<0.05
Se	mg/L	<0.05	
Zn	mg/L	0.078	0.25

Analyte	**Method**	**Description**
Al	iMET1WCICP	Aluminium
Al	iMET2SAICP	Aluminium, dry basis
As	iMET1WCICP	Arsenic
As	iMET2SAICP	Arsenic, dry basis
B	iMET1WCICP	Boron
B	iMET2SAICP	Boron, dry basis
Be	iMET1WCICP	Beryllium
Be	iMET2SAICP	Beryllium, dry basis
Cd	iMET1WCICP	Cadmium
Cd	iMET2SAICP	Cadmium, dry basis
Cl	iCL1WAAA	Chloride
Co	iMET1WCICP	Cobalt
Co	iMET2SAICP	Cobalt, dry basis
Cu	iMET1WCICP	Copper
Cu	iMET2SAICP	Copper, dry basis
F	iF1WASE	Fluoride
Fe	iMET1WCICP	Iron
Fe	iMET2SAICP	Iron, dry basis
Hg	iHG1WCVG	Mercury
Hg_total	iHG2STVG	Mercury, total, dry basis.
Mn	iMET1WCICP	Manganese
Mn	iMET2SAICP	Manganese, dry basis
Ni	iMET1WCICP	Nickel
Ni	iMET2SAICP	Nickel, dry basis

Report of Examination

Analyte	Method	Description
Pb	iMET1WCICP	Lead
Pb	iMET2SAICP	Lead, dry basis
pH_ASLP	iASLP	pH ASLP extract
Sb	iMET1WCICP	Antimony
Sb	iMET2SAICP	Antimony, dry basis
Se	iMET1WCICP	Selenium
Se	iMET2SAICP	Selenium, dry basis
Zn	iMET1WCICP	Zinc
Zn	iMET2SAICP	Zinc, dry basis

These results apply only to the sample(s) as received. Unless arrangements are made to the contrary, these samples will be disposed of after 30 days of the issue of this report. This report may only be reproduced in full.

The sample(s) were extracted in accordance with AS 4439.3-1997 using DI water as the extractant - Final pH of extract reported above. Results reported are concentrations found in the 1:20 extract.

Particles less than 2 mm analysed for soil samples. Metals analysis performed using mixed acid (Nitric/Hydrochloric) microwave assisted acid digestion (USEPA 3051A modification). Analysis of metals by ICPAES.

Jenny McGuire
Science Business Manager
Environmental Chemistry Section

09/05/2008

Appendix C Bulk Leaching Results

Bulk Leaching Tables

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[i] Campbell, R.N, Lindsay, P, Clemens, A.H *Acid generating potential of waste rock and coal ash in New Zealand coal mines*, International Journal of Coal Geology, Volume 45, Issues 2-3, January 2001.
Australian Mineral Industries Research Association (AMIRA) *Acid Rock Drainage Handbook*

	ANC	NAG	Al	As	B	Be	Cd	Cl	Co	Cu	F	Fe	Hg	Mn	Ni	Pb	Sb	Se	Zn
ADWG Health	g/m^3		0.2	0.007	4		0.002	250		2	1.5	0.3	0.001	0.5	0.02	0.01	0.003	0.01	3
	kg H_2SO_4/tonne		**Metals – kg/tonne**																
Nakina laterite	2.000		66,900	2	<5	0.29	<0.05	2000	2.8	0.4	40	18,000	0.06	19	9	6.2	<1	<1	<5
JUNO U (P05/P08)		9.536	5,527	1.40	<5	0.66	<0.05	**ND**	2.66	7.54	**ND**	1,420	0.042	2.89	5.56	17.16	<1	<1	15.21
JUNO L (P10)		21.693	2,559	<1	<5	0.28	<0.05	**ND**	2.74	3.24	**ND**	703	<0.02	2.70	3.57	9.92	<1	<1	8.24
PAN (P20)		13.671	3,034	<1	<5	0.33	<0.05	**ND**	2.52	3.86	**ND**	885	0.023	2.62	3.81	11.29	<1	<1	8.42
PAN L (P24)		20.534	2,572	<1	<5	0.29	<0.05	**ND**	1.97	3.24	**ND**	825	0.024	2.01	3.22	9.54	<1	<1	7.62
PREMIER 7 (P30)		1.383	3,639	<1	<5	0.37	<0.05	**ND**	2.32	4.62	**ND**	1,121	0.033	2.62	4.15	13.19	<1	<1	8.43
TANTALUS U (P35)		1.760	4,337	<1	<5	0.47	<0.05	**ND**	2.51	5.67	**ND**	1,236	0.036	2.82	4.70	14.86	<1	<1	10.63
TANTALUS L (P40)		7.554	3,514	<1	<5	0.38	<0.05	**ND**	2.41	4.50	**ND**	1,048	0.029	2.61	4.11	12.60	<1	<1	8.93
PREMIER 8U (P50)		4.442	3,481	<1	<5	0.36	<0.05	**ND**	2.20	4.42	**ND**	1,087	0.032	2.46	3.98	12.59	<1	<1	8.29
PREMIER 8L (P51)		0.530	2,263	<1	<5	0.19	<0.05	**ND**	1.94	2.53	**ND**	918	0.026	2.18	3.12	9.80	<1	<1	<5
ZEPHYRUS (P60)		3.123	3,560	<1	<5	0.37	<0.05	**ND**	2.40	4.52	**ND**	1,083	0.031	2.66	4.14	12.96	<1	<1	8.48
SERAPIS		1.306	1,661	<1	<5	0.10	<0.05	**ND**	2.21	1.66	**ND**	708	<0.02	2.47	2.75	8.77	<1	<1	<5

Metals - ASLP using DI Water - g/m^3

	Al	As	B	Be	Cd	Cl	Co	Cu	F	Fe	Hg	Mn	Ni	Pb	Sb	Se	Zn
Nakina laterite	15	<0.05	0.04	<0.001	<0.002	2.4	<0.005	<0.002	0.1	1.7	0.0001	0.004	<0.01	<0.02	<0.05	<0.05	0.014
JUNO U (P05/P08)	1.6	<0.05	<0.02	<0.001	<0.002	1.9	0.021	<0.002	<0.05	0.08	<0.0001	0.013	<0.01	<0.02	<0.05	<0.05	0.072
JUNO L (P10)	1.8	<0.05	<0.02	<0.001	<0.002	1.6	0.051	<0.002	<0.05	0.19	<0.0001	0.027	0.012	<0.02	<0.05	<0.05	0.111
PAN (P20)	1.9	<0.05	<0.02	<0.001	<0.002	1.3	0.035	<0.002	<0.05	0.15	<0.0001	0.019	<0.01	<0.02	<0.05	<0.05	0.083
PAN L (P24)	1.8	<0.05	<0.02	<0.001	<0.002	1.1	0.015	<0.002	<0.05	0.08	<0.0001	0.008	<0.01	<0.02	<0.05	<0.05	0.052
PREMIER 7 (P30)	2.2	<0.05	0.022	<0.001	<0.002	1.1	0.018	<0.002	<0.05	0.11	<0.0001	0.010	<0.01	<0.02	<0.05	<0.05	0.051
TANTALUS U (P35)	2.1	<0.05	0.020	<0.001	<0.002	1.2	0.021	<0.002	<0.05	0.11	<0.0001	0.013	<0.01	<0.02	<0.05	<0.05	0.060
TANTALUS L (P40)	2.0	<0.05	<0.02	<0.001	<0.002	1.2	0.024	<0.002	<0.05	0.12	<0.0001	0.014	<0.01	<0.02	<0.05	<0.05	0.064
PREMIER 8U (P50)	2.1	<0.05	0.022	<0.001	<0.002	1.1	0.014	<0.002	<0.05	0.09	<0.0001	0.008	<0.01	<0.02	<0.05	<0.05	0.045
PREMIER 8L (P51)	2.4	<0.05	0.027	<0.001	<0.002	1.0	0.009	<0.002	0.053	0.10	<0.0001	0.005	<0.01	<0.02	<0.05	<0.05	0.028
ZEPHYRUS (P60)	2.1	<0.05	0.021	<0.001	<0.002	1.2	0.022	<0.002	<0.05	0.12	<0.0001	0.013	<0.01	<0.02	<0.05	<0.05	0.059
SERAPIS	2.5	<0.05	0.024	<0.001	<0.002	1.2	0.029	<0.002	<0.05	0.16	<0.0001	0.016	<0.01	<0.02	<0.05	<0.05	0.057

ADWG Health	g/m^3		0.2	0.007	4		0.002	250		2	1.5	0.3	0.001	0.5	0.02	0.01	0.003	0.01	3
	kg H_2SO_4/tonne		**Metals – kg/tonne**																
	ANC	NAG	Al	As	B	Be	Cd	Cl	Co	Cu	F	Fe	Hg	Mn	Ni	Pb	Sb	Se	Zn
Nakina laterite	2.000		66,900	2	<5	0.29	<0.05	2000	2.8	0.4	40	18,000	0.06	19	9	6.2	<1	<1	<5
JUNO U (P05/P08)		9.536	5,527	1.40	<5	0.66	<0.05	**ND**	2.66	7.54	**ND**	1,420	0.042	2.89	5.56	17.16	<1	<1	15.21
JUNO L (P10)		21.693	2,559	<1	<5	0.28	<0.05	**ND**	2.74	3.24	**ND**	703	<0.02	2.70	3.57	9.92	<1	<1	8.24
PAN (P20)		13.671	3,034	<1	<5	0.33	<0.05	**ND**	2.52	3.86	**ND**	885	0.023	2.62	3.81	11.29	<1	<1	8.42
PAN L (P24)		20.534	2,572	<1	<5	0.29	<0.05	**ND**	1.97	3.24	**ND**	825	0.024	2.01	3.22	9.54	<1	<1	7.62
PREMIER 7 (P30)		1.383	3,639	<1	<5	0.37	<0.05	**ND**	2.32	4.62	**ND**	1,121	0.033	2.62	4.15	13.19	<1	<1	8.43
TANTALUS U (P35)		1.760	4,337	<1	<5	0.47	<0.05	**ND**	2.51	5.67	**ND**	1,236	0.036	2.82	4.70	14.86	<1	<1	10.63
TANTALUS L (P40)		7.554	3,514	<1	<5	0.38	<0.05	**ND**	2.41	4.50	**ND**	1,048	0.029	2.61	4.11	12.60	<1	<1	8.93
PREMIER 8U (P50)		4.442	3,481	<1	<5	0.36	<0.05	**ND**	2.20	4.42	**ND**	1,087	0.032	2.46	3.98	12.59	<1	<1	8.29
PREMIER 8L (P51)		0.530	2,263	<1	<5	0.19	<0.05	**ND**	1.94	2.53	**ND**	918	0.026	2.18	3.12	9.80	<1	<1	<5
ZEPHYRUS (P60)		3.123	3,560	<1	<5	0.37	<0.05	**ND**	2.40	4.52	**ND**	1,083	0.031	2.66	4.14	12.96	<1	<1	8.48
SERAPIS		1.306	1,661	<1	<5	0.10	<0.05	**ND**	2.21	1.66	**ND**	708	<0.02	2.47	2.75	8.77	<1	<1	<5

Metals - ASLP pH 3.5 - g/m^3

	Al	As	B	Be	Cd	Cl	Co	Cu	F	Fe	Hg	Mn	Ni	Pb	Sb	Se	Zn
Nakina laterite	0.15	<0.05	<0.02	<0.001	<0.002	1.8	0.03	<0.002	0.10	0.03	<0.0001	0.06	<0.01	<0.02	<0.05	<0.05	0.02
JUNO U (P05/P08)	2.5	<0.05	<0.02	<0.001	<0.002	0.76	0.08	0.04	0.17	0.24	<0.0001	0.06	0.015	<0.02	<0.05	<0.05	0.26
JUNO L (P10)	3.2	<0.05	<0.02	<0.001	<0.002	0.08	0.11	0.03	0.14	0.41	<0.0001	0.07	0.031	<0.02	<0.05	<0.05	0.22
PAN (P20)	3.0	<0.05	<0.02	<0.001	<0.002	**ND**	0.09	0.04	0.15	0.34	<0.0001	0.06	0.021	<0.02	<0.05	<0.05	0.21
PAN L (P24)	2.6	<0.05	<0.02	<0.001	<0.002	0.07	0.08	0.04	0.15	0.23	<0.0001	0.05	0.018	<0.02	<0.05	<0.05	0.20
PREMIER 7 (P30)	2.9	<0.05	<0.02	<0.001	<0.002	0.08	0.08	0.05	0.15	0.28	<0.0001	0.06	<0.01	<0.02	<0.05	<0.05	0.18
TANTALUS U (P35)	2.9	<0.05	<0.02	<0.001	<0.002	**ND**	0.08	0.05	0.16	0.28	<0.0001	0.06	<0.01	<0.02	<0.05	<0.05	0.20
TANTALUS L (P40)	2.9	<0.05	<0.02	<0.001	<0.002	0.03	0.09	0.05	0.15	0.29	<0.0001	0.06	0.013	<0.02	<0.05	<0.05	0.20
PREMIER 8U (P50)	2.8	<0.05	<0.02	<0.001	<0.002	0.01	0.08	0.05	0.15	0.25	<0.0001	0.05	<0.01	<0.02	<0.05	<0.05	0.18
PREMIER 8L (P51)	3.0	<0.05	<0.02	<0.001	<0.002	**ND**	0.07	0.06	0.14	0.26	<0.0001	0.05	<0.01	<0.02	<0.05	<0.05	0.13
ZEPHYRUS (P60)	2.9	<0.05	<0.02	<0.001	<0.002	**ND**	0.08	0.05	0.15	0.29	<0.0001	0.06	<0.01	<0.02	<0.05	<0.05	0.18
SERAPIS	3.3	<0.05	<0.02	<0.001	<0.002	**ND**	0.09	0.06	0.13	0.36	<0.0001	0.06	<0.01	<0.02	<0.05	<0.05	0.13