

**GROUNDWATER MODELLING
ASSESSMENT
FACTUAL REPORT - ASH PONDS
TALLAWARRA LANDS, YALLAH, NSW**

Prepared for:

TRUenergy
Level 33, 385 Bourke Street
MELBOURNE VIC 3000

Report Date: 10 May 2011
Project Ref: ENAUWOLL04009AE

Written by:

Reviewed/Approved by:



CORINNA DE CASTRO
Senior Hydrogeologist



PAUL TAMMETTA
Associate Hydrogeologist

10 May 2011

TRUenergy
Level 33, 385 Bourke Street
MELBOURNE VIC 3000

Attention: Anthony Savenkov

Dear Anthony,

**RE: GROUNDWATER MODELLING ASSESSMENT FACTUAL REPORT – ASH PONDS,
TALLAWARRA LANDS, YALLAH, NSW**

We are pleased to present our report for the above site.

We draw your attention to the attached sheets entitled "Important information about your Coffey Environmental Report". These sheets should be read in conjunction with this report.

Thank you for your commission for this work and we look forward to continuing our work on the groundwater modelling assessment. Should you have any questions in relation to the report, please do not hesitate to contact the undersigned.

For and on behalf of Coffey Environments Pty Ltd



CORINNA DE CASTRO
Senior Hydrogeologist

RECORD OF DISTRIBUTION

No. of copies	Report File Name	Report Status	Date	Prepared for:	Initials
1	ENAUWOLL04009AE-R02.pdf	FINAL	10 May 2011	TRUenergy	CDC
1	ENAUWOLL04009AE-R02.doc	FINAL	10 May 2011	Coffey Environments	CDC

CONTENTS

LIST OF ATTACHMENTS	I
ABBREVIATIONS	III
1 INTRODUCTION	1
1.1 General	1
1.2 Scope of Work	1
2 SITE CHARACTERISATION	3
2.1 Site Location and Landuse	3
2.2 Topography and Surface Water Drainage	3
2.3 Rainfall and Evaporation	4
2.4 Geology	5
2.5 Hydrogeology	5
2.5.1 Groundwater Dependent Ecosystems	6
2.5.2 Registered Groundwater Bores	6
2.6 Ash Pond Details	7
2.6.1 History	7
2.6.2 Subsurface Conditions	7
2.6.3 Geotechnical Laboratory Results	7
3 PROPOSED SITE DEVELOPMENT	9
4 INVESTIGATION LEVELS	10
4.1 Groundwater, Surface Water and Leachate Samples	10
4.2 Coalwash, Ash and Soil Samples	10
5 FIELD AND LABORATORY INVESTIGATIONS	12
5.1 Previous Field Investigations	12
5.2 Current Field Investigations	12
5.3 Groundwater Monitoring Well Installation	12

CONTENTS

5.4	Aquifer Testing	16
5.5	Groundwater Sampling	16
5.6	Surface Water Sampling	17
5.7	Coalwash, Ash and Soil Sampling	17
5.8	Field Quality Control Procedures	18
5.9	Laboratory Analysis	19
6	RESULTS	20
6.1	Groundwater Levels and Flow	20
6.2	Aquifer Properties	21
6.2.1	Hydraulic Conductivity	22
6.2.2	Effective Porosity	24
6.2.3	Hydraulic Gradients	24
6.2.4	Rate of Groundwater Movement	24
6.3	Water Sampling	25
6.3.1	Observations	25
6.3.2	Field Quality Parameters – Groundwater	25
6.3.3	Field Quality Parameters – Surface Water	26
6.4	Coalwash, Ash and Soil Sampling	26
6.4.1	Observations	26
6.5	Laboratory Results	26
6.5.1	Data Validation	26
6.5.2	Major Ions	26
6.5.3	Comparison of Laboratory Results to Groundwater, Surface Water and Leachate Water Investigation Levels	27
6.5.4	Comparison of Laboratory Results to Soil Investigation Levels	27
7	HYDROGEOLOGICAL CONCEPTUAL MODEL	28
7.1	Flow Mechanisms	28
7.1.1	Groundwater Recharge	28
7.1.2	Groundwater Discharge	28
7.1.3	Groundwater Flow Volumes	29

CONTENTS

7.2	Groundwater Quality and Contaminant Sources	29
7.3	Proposed Groundwater Modelling	31
8	CONCLUSIONS	33
9	RECOMMENDATIONS	34
10	LIMITATIONS	35
11	REFERENCES	36

LIST OF ATTACHMENTS

Important information about your Coffey Environmental Report

Tables (Text)

- Table 1: Mean Rainfall and Evaporation Data
- Table 2: Summary of Local Geological Units
- Table 3: Summary of Soil Investigation Levels Adopted for the Site
- Table 4: Existing Groundwater Monitoring Well Details (MW01 to MW10 and TAGM/D3)
- Table 5: New Groundwater Monitoring Well Details (MW11 to MW18)
- Table 6: Summary of Coalwash, Ash and Soil Sampling Locations
- Table 7: Monitoring Well Groundwater Levels from 12 April 2011
- Table 8: Summary of Aquifer Test Results
- Table 9: Reference Values for Ash Hydraulic Conductivity
- Table 10: Summary of Leachate Results

Tables (Attached)

- Table LR1: Summary of Laboratory Results for Groundwater and Surface Water Samples
- Table LR2: Summary of Laboratory Results for Groundwater and Surface Water Samples for Previous and Current Coffey Investigations
- Table LR3: Summary of Laboratory Results for Coalwash, Ash and Soil Samples

Figures

- Figure 1: Site Locality Plan
- Figure 2: Site Layout Plan Showing Geology Map
- Figure 3: Proposed Development – Concept Masterplan 17 August 2010
- Figure 4: Groundwater Monitoring Well Locations, Surface Water and Soil Sample Locations
- Figure 5: Groundwater Hydrographs
- Figure 6: Pump Test WTAQ Analysis
- Figure 7: Slug Test Analysis Hvorslev Method
- Figure 8: Constant Discharge Test Recovery Analysis Jacob Method
- Figure 9: Piper Plot
- Figure 10: Pathways in Redox Reactions of Nitrogen

LIST OF ATTACHMENTS

Appendices

Appendix A: Existing Monitoring Well Borelogs

Appendix B: New Monitoring Well Borelogs

Appendix C: Test Pit Logs

Appendix D: Chain of Custody Documentation

Appendix E: Laboratory Reports

Appendix F: Interpreted Groundwater Contour Map

Appendix G: Data Validation

ABBREVIATIONS

AHD	Australian Height Datum
bgl	below ground level
DO	Dissolved Oxygen
EC	Electrical Conductivity
GDE	Groundwater Dependent Ecosystem
µg/L	micrograms per litre
mg/L	milligrams per litre
MW	Monitoring Well
NOW	NSW Office of Water
RL	Reduced Level
SWL	Standing Water Level
TDS	Total Dissolved Solids
TOC	Top of Casing

1 INTRODUCTION

1.1 General

Coffey Environments Australia Pty Ltd (Coffey) was commissioned by TRUenergy Tallawarra Pty Ltd (TRUenergy) to carry out a groundwater modelling assessment at the former ash pond areas of the Tallawarra lands surrounding the Tallawarra Power Station, Yallah Bay Road, Yallah, NSW, hereafter referred to as the 'site' (Figure 1). This factual report provides a summary of the additional data collected since December 2010 to be used in the next phase of the assessment, numerical groundwater flow and transport modelling. The work was completed generally in accordance with our proposal, ENAUWOLL04009AE-P01, dated 8 December 2010.

Coffey has previously assessed the groundwater quality at Tallawarra Lands (Coffey Environments, 2010a and 2010b). The assessments identified elevated concentrations of heavy metals (including arsenic, copper, nickel and zinc) and ammonium above the adopted investigation levels for protection of aquatic ecosystems. The report recommended that any future disturbance to the ash ponds should take into account groundwater issues and ensure that the disturbances avoid creating preferential pathways for groundwater to discharge directly into the surrounding receiving environment (Coffey Environments, 2010b).

A preliminary hydrogeological assessment was conducted in the areas of the ash ponds (Coffey Environments, 2010c), including assessing groundwater flow directions and likely preferential pathways in the vicinity of the ash ponds; assessing potential groundwater volumes flowing from the ash ponds and a qualitative assessment of potential impacts to groundwater levels as a result of the proposed development at Tallawarra Lands.

The objective of this assessment by Coffey is to conduct a more detailed and quantitative hydrogeological assessment at the site including numerical groundwater modelling. The assessment will provide more information for the groundwater dependent ecosystem (GDE) study and risk assessment by Eco Logical Australia, including assessing groundwater levels and quality in areas away from the ash ponds such as the wetland area to the east of Ash Pond 3.

This factual report presents additional hydrogeological data collected since December 2010 (groundwater levels, quality and permeability data) as well as laboratory leachate results for coal wash, ash and natural clay material at the site to assess the potential sources of the ammonium and heavy metal concentrations recorded in the groundwater prior to commencement of groundwater flow and transport modelling.

1.2 Scope of Work

The following scope of work was carried out to obtain, analyse, and report the additional data:

- Additional groundwater data collection including:
 - Installation of eight additional groundwater monitoring wells (MW11-MW18). Two monitoring wells were installed in the wetland area to the east of Ash Pond 3, one west of Ash Pond 2, one on the bank of Duck River (discharge location south of Ash Pond 2) and one background well to the west of Ash Pond 3. Three wells were installed for the pumping test in Ash Pond 2 to assess the vertical hydraulic conductivity of the ash (the main factor controlling the capacity of the ash mounds to emit groundwater).
 - Survey of the eight new groundwater monitoring wells.

- Logging of groundwater levels since December 2010 at five selected wells using electronic down-hole data loggers to assess the response of groundwater levels to rainfall recharge and seasonal variations. Following installation of the new monitoring wells, two additional data loggers were installed at two locations.
- Collection of groundwater samples from nine existing wells, six new wells (sampling of one of the three wells installed for the pumping test as distances between these wells is approximately 3m) and an existing well TAGM/D3 (installed by others).
- Collection of two surface water samples, one in the Ash Pond 3 lake and one in the pond west of Ash Pond 2 in the vicinity of the well (MW14) installed in this area.
- Laboratory analysis of groundwater and surface water samples for dissolved heavy metals (arsenic, cadmium, chromium, copper, lead, molybdenum, nickel and zinc), ammonium, nitrate, nitrite, total kjeldahl nitrogen (TKN) and total nitrogen. The following parameters were also measured in the field – pH, temperature, redox potential, dissolved oxygen and electrical conductivity.
- Field assessment of aquifer parameters (transmissivity and hydraulic conductivity). The aquifer tests included a constant rate pump test with multiple observation piezometers in Ash Pond 2, two slug tests and two constant rate single well pumping tests in natural material and the ash.
- Collection of 15 samples for leachate analysis to further assess the possible source of ammonium on site. Representative samples from the coal wash, ash and natural clay material in the wetland environment were analysed for the nitrogen suite (ammonium, nitrate, nitrite, TKN and total nitrogen) as well as heavy metals (arsenic, cadmium, chromium, copper, lead, molybdenum, nickel and zinc).
- Data analysis. Data collected as part of the pump test was analysed to provide an assessment of aquifer transmissivity and vertical hydraulic conductivity of the ash material. The slug test data was analysed to provide values of hydraulic conductivity within close vicinity of the wells. Data collation included preparation of hydrographs from the water level logger data and tabulation of laboratory results.
- Preparation of this report summarising the results of fieldwork, presenting and interpreting analytical results and findings, comparing contaminant concentrations to applicable guidelines and assessing the potential sources of the ammonium and heavy metal concentrations recorded in the groundwater prior to commencement of groundwater flow and transport modelling.

2 SITE CHARACTERISATION

2.1 Site Location and Landuse

The site is located on the eastern side of the Princes Highway, Yallah, NSW and occupies an area of about 535.9 ha. The site is irregular in shape with an approximate length (north-south) of 3.4 km and an approximate width (east-west) of 2 km. The site excludes the area occupied by Tallawarra gas fired power station and public access areas around the Lake Illawarra foreshore, owned by the Lake Illawarra Authority. The northern portion of the site is generally vacant and used as grazing land. The northern portions of the site have the occasional structure and several farm dams. The area south of Yallah Bay Road has been significantly disturbed to allow development of three ash ponds which were filled with ash during the operation of the coal fired power station. This area has also been significantly filled.

The surrounding landuses include:

- Princes Highway to the west;
- Residential dwellings to the north and south;
- Lake Illawarra to the east; and
- The power station located near the central southeastern boundary, north of Yallah Bay Road.

The site locality, site layout and general surrounding landuses are shown in Figure 1.

2.2 Topography and Surface Water Drainage

The study area has varying topography from near level ground to steep slopes. The topography near the northern site boundary forms part of a steep hill side (Mount Brown) sloping down towards the east, south and southeast. South of these steep areas, the slope flattens slightly and becomes rolling hills. The ground surface south of Yallah Bay Road is generally near level (<1° grade) and forms part of an alluvial floodplain and wetlands with exception of areas near the western boundary. The area near the western site boundary (south of Yallah Bay Road) appears to be locally elevated, rising towards the Princes Highway to the west and sloping down towards the east.

Reference to the Albion Park 1:25,000 Topographic Map indicates that the study area ground surface ranges in elevation between 0 m and 100 m above Australian Height Datum (AHD). This is consistent with survey data provided by Landteam which indicated an elevation between 0 m and 110 m AHD.

In areas north of Yallah Bay Road, surface water is expected to follow the land topography initially discharging into several unnamed watercourses and farm dams that occupy this area of the site. Some of these watercourses appear to flow into Duck Creek or directly into Lake Illawarra. The area south of Yallah Bay Road is bisected by Duck Creek which flows from the northwest to the east before discharging into Lake Illawarra. Wollingurry Creek and several drains/unnamed watercourses occupy this area of the site and flow into Duck Creek. This area of the site is also occupied by three ash settling ponds which have been mostly filled with ash derived from the former coal fired power station. One of the ponds (Ash Pond 3) in the south western area of the site was only partially filled with ash allowing the remaining areas to be filled with water.

The topography and watercourses are shown in Figure 1 and Figure 2.

2.3 Rainfall and Evaporation

The Albion Park (Wollongong Airport) automatic weather station (AWS) 68241 is approximately 2 km inland to the south west of the site at an elevation of 8 m AHD. Climate data has been recorded at this location since 1999. The Port Kembla AWS 68131 is located on the coast approximately 12 km to the north east of the site at an elevation of 9 m AHD. Climate data has been recorded at this location since 1963.

Recorded data at Albion Park and Port Kembla has been sourced from the Bureau of Meteorology website www.bom.gov.au. No pan evaporation data is available from the Albion Park or Port Kembla station and limited pan evaporation data is available in the study area. Pan evaporation data was sourced from the University of Wollongong (website), which is located approximately 14 km to the north east of the site.

Table 1 lists the mean rainfall recorded at Albion Park and Port Kembla and the pan evaporation recorded at the University of Wollongong. Mean annual rainfall is approximately 866 mm at Albion Park and 1104 mm at Port Kembla. Mean monthly rainfall is highest in summer and autumn and lowest in winter and spring. Evaporation also varies with the seasons and is highest in the spring and summer months (from October to February). Mean annual evaporation is 1278 mm, which exceeds mean annual rainfall.

Table 1: Mean Rainfall and Evaporation Data

	Albion Park Rainfall (mm)	Port Kembla Rainfall (mm)	Pan Evaporation (mm)
Monthly			
January	64	94	152
February	157	129	120
March	72	141	105
April	71	104	84
May	70	88	71
June	78	112	63
July	69	54	74
August	29	73	90
September	41	59	108
October	73	89	127
November	82	88	129
December	68	74	158
Annual			
Mean	866	1104	1278

2.4 Geology

Reference to the 1:50,000 Kiama Geological Series Sheet (9028-1, First Edition) prepared by the NSW Department of Mines (1974) indicates the study area is underlain by the following four geological units:

- Alluvium;
- Dapto Latite Member;
- Budgong Sandstone; and
- Berry Siltstone.

The Dapto Latite Member, Budgong Sandstone and Berry Siltstone form part of the Shoalhaven Group of rocks. The geological map has been overlaid onto the site aerial photograph and is shown in Figure 2.

The geological map shows the area south east of Ash Pond 2 as alluvium, while subsurface investigations (Coffey Environments, 2010a) have indicated this area is underlain by shallow bedrock of the Berry Siltstone formation. Wollingurry Point (Figure 1) is known to exhibit rock outcrop.

The geological map provides a description of each of these units along with their depositional sequence. This has been summarised in Table 2.

Table 2: Summary of Local Geological Units

Geological Unit	Geological Description	Age and Depositional Sequence
Alluvium (Qa)	Alluvium, gravel, beach and dune sand	Quaternary. At the site typically overlies the Berry Siltstone.
Dapto Latite Member (Psgd)	Melanocratic coarse grained to porphyritic latite	Early Permian. At the site overlies the Budgong Sandstone.
Budgong Sandstone (Psg)	Red-brown and grey volcanic sandstone	Early Permian. At the site overlies the Berry Siltstone.
Berry Siltstone (Psb)	Mid-grey to dark-grey siltstone to fine sandstone	Early Permian. The oldest identified geological formation at the site.

In addition to these natural sequences, the study area also has the three bodies of ash (which each host groundwater) and also coalwash used for the ash dam bund walls and for construction purposes.

2.5 Hydrogeology

Based on local topography and geology, two main aquifer systems have been identified previously in the study area (Camp Scott Furphy, 1993). A shallow aquifer consists of unconsolidated sediments such as gravels, clays and sands within approximately 5m of the ground surface. Deeper aquifers are associated with rock fractures within the Budgong Sandstone or the underlying Berry Siltstone sandstones and siltstones. For the purposes of the current assessment, the shallow aquifer is of

greater importance, as the proposed development includes excavations that will generally be shallower than 6 m.

In addition to the groundwater system in natural materials, all three ash bodies maintain saturation, and form additional (artificial) groundwater systems.

The estuarine/alluvial sediments form a continuous groundwater system over the site. Groundwater in the ash will interact with the estuarine/alluvial system by downward vertical flow (given the prevailing groundwater levels). Groundwater flow in the estuarine / alluvial sediments is generally easterly, towards the various watercourses and Lake Illawarra. Further information on groundwater levels and flow on site is provided in Section 6.1 and Section 7.

Away from the ash ponds in the more elevated areas north of Yallah Bay Road, it is likely that the groundwater will be hosted by the Budgong Sandstone. This is consistent with the results of our previous investigation (Coffey Geosciences, 2002) where two groundwater monitoring wells were installed to depths of 1.7 m and 4 m north of the power station within the residual or weathered sandstone rock. These wells were observed to be dry at the time of monitoring. Groundwater within the residual clay above the bedrock may be considered as an ephemeral perched groundwater system depending on rainfall recharge, although most rainfall would run off due to the steep slopes and nature of the clay soils (low infiltration rates).

Groundwater monitoring wells located in the lower areas of the power station near the foreshore of the lake recorded depths to groundwater ranging between 1.76 m and 2.23 m below ground level (Coffey Geosciences, 2002). This is similar to groundwater levels reported for the power station area during 2010 (Earth2Water, 2010).

2.5.1 Groundwater Dependent Ecosystems

Groundwater Dependent Ecosystems (GDEs) are defined as ecosystems whose current composition, structure and function are reliant on a supply of groundwater (Eamus, 2009). Potential GDEs present at the site are detailed in the GDE risk assessment study (Eco Logical Australia, 2010). It was assessed that potential dependency on groundwater was likely for all terrestrial vegetation types at the site, including the SEPP 14 wetlands south of Duck Creek and in the vicinity of Lake Illawarra. The estuarine alluvial wetlands were assessed as being more dependent on tidal inundation of saline waters rather than groundwater dependency.

For all ecosystems on site it was assessed that alterations to hydrological regimes (both surface and groundwater) could potentially threaten the vegetation communities.

The Draft Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources identifies a potential GDE in the vicinity of Macquarie Rivulet (NSW Office of Water, 2010). The exact location of the GDE has not been confirmed by the NSW Office of Water.

2.5.2 Registered Groundwater Bores

A survey of groundwater bores within a 4.5 km radius of the study area registered with the NSW Office of Water (NOW) was carried out as part of the previous Coffey investigation (Coffey Environments, 2010a). The search results indicated that there were 40 registered bores but only nine of which had work summary sheets. The groundwater bores were located in an inferred upgradient direction and generally to the north and west of the site. The closest bore, GW033541, was located approximately

1.5 km to the north west of the site. The work summary sheets and groundwater bore locations were previously presented in earlier reports (Coffey Environments, 2010a and 2010c).

2.6 Ash Pond Details

2.6.1 History

Three ash ponds were constructed at the site between around 1955 and 1983 for the placement of ash, a by-product of the coal combustion process at the former coal fired power station located to the north. The ash ponds occupy approximately two-thirds of the lower lying area south of Yallah Bay Road. The ash pond walls were constructed of fill comprising a combination of coalwash and soil that appears to have been placed directly on the former ground surface, as there has been no evidence of excavation revealed in the site history (Coffey Environments, 2010a). Typically the ash pond bund walls are in the order of 5 m high and approximately 30 m wide but this is variable. The ash ponds were progressively filled with ash that was hydraulically pumped into the ponds via overland pipelines until the power station ceased operations in 1989. As the ponds reached capacity, they were capped with coalwash and/or general fill and revegetated. Ash Pond 3 did not reach its full capacity with several areas filled with water.

It is known that over an indeterminate trial period between 1955 and 1989, a limited amount of ammonia (in an unknown form) was applied to the coal prior to combustion to reduce the amount of nitrogen gasses in the waste.

2.6.2 Subsurface Conditions

The origin and quality of the fill used to construct the bund walls of the ash ponds were not confirmed through the history study conducted previously (Coffey Environments, 2010a). The fill used to construct the bund walls was assessed as an engineered type fill, and as such it was considered unlikely to contain significant quantities of materials such as concrete, timber, bricks, etc, that would result in areas where preferential groundwater flow could occur.

14 locations were either excavated or drilled through the fill bund walls of the ash ponds (Coffey Environments, 2010a). The materials encountered in the bund walls included a general fill material (comprising clay, clayey silt or sand) and coalwash. 19 locations were either excavated or drilled through the ash ponds. Ash was exposed at the surface, in particular in Ash Pond 3. Typically a coalwash or clay cap was encountered ranging in thickness between 0.05 m and 0.6 m.

Ash was identified below the cap to depths of between 0.15 m and 11 m. Typically natural clayey soils were noted at the base of the ponds. At some locations silty sand, sand or weathered rock was encountered at the base of the ponds. In general, the average ash thickness at each pond is:

- Ash Pond 1: 11 m;
- Ash Pond 2: 11 m; and
- Ash Pond 3: 3 m.

2.6.3 Geotechnical Laboratory Results

The laboratory testing results previously reported (Coffey Environments, 2010a) indicated the following:

- Most of the samples from the ash material indicated about 90% of the material passed the 75 µm sieve, indicating the tested samples contained silt or clay sized particles.
- For the ash samples, a significant proportion of the soil was graded in the 'silt' particle size range in three out of the four samples tested in hydrometer test samples.
- Out of the 16 samples tested within the ash, 6 contained predominantly (>50%) sand sized particles. The remaining 10 samples tested within the ash contained predominantly silt or clay sized particles.
- Some variability occurs within the ash materials, with some silty and some sandy ash materials.

3 PROPOSED SITE DEVELOPMENT

The development proposal involves the establishment of a number of land uses throughout the study area. Details regarding the proposed development were obtained from the Urban Design Masterplan (Warren Lee Urban Design, 2010).

The proposed development areas are illustrated in Figure 3 and include:

- Northern Precinct - Residential development in the north east of the site along the Lake Illawarra foreshore.
- Central Precinct - Residential development, a local centre and an employment zone in the central western parts of the site, north of Duck Creek and Yallah Bay Road.
- Central Precinct - An employment area and tourism facility in the central and eastern parts of the site.
- Lakeside (Southern) Precinct - An employment precinct, primary school, retirement village and residential development in the south west of the site.
- Significant dedication of various parts of the site for environmental and open space purposes, as listed by Eco Logical Australia (2010):
 - Provision of a significant environmental corridor for Duck Creek.
 - A large environmental reserve in the south east incorporating two SEPP 14 wetlands.
 - Conservation of two artificial wetlands in the south west for incorporation into open space areas.
 - An environmental reserve on the upper slopes of Mount Brown.
 - An environmental reserve on the central western boundary.
 - Provision of riparian zones for affected waterways.
 - Large areas of open space reserves.

4 INVESTIGATION LEVELS

4.1 Groundwater, Surface Water and Leachate Samples

The investigation levels for groundwater, surface water and leachate samples used in this assessment are the same as those used in previous reports (Coffey Environments, 2010a and 2010b), and are based on the Australia and New Zealand Environment and Conservation Council (ANZECC) *Guidelines for Fresh and Marine Water Quality 2000* (ANZECC, 2000). The guidelines for protection of marine water ecosystems of the receiving waters have been adopted, since the receiving waters are in an estuarine environment.

The adopted criteria are summarised in the attached results Tables LR1, LR2 and LR3.

4.2 Coalwash, Ash and Soil Samples

The soil sample results for coalwash, ash and natural clay samples were primarily used for comparison to leachate water quality results to compare leachability of the different materials and sources of potential contamination to the groundwater system. Soil investigation levels are included in this assessment and are the same as those used in the previous report (Coffey Environments, 2010a), and are based on the National Environment Protection (Assessment of Site Contamination) Measure 1999 (NEPM) from the National Environment Protection Council (NEPC, 1999).

For assessing contamination levels in soil in urban settings, the NEPC (1999) present health based investigation levels (HILs) for different land uses (e.g. industrial/commercial, residential, recreational etc.) as well as provisional phytotoxicity based investigation levels or ecology based investigation levels (EILs).

There are several proposed land uses for the site including residential, primary school, retirement villages, sporting grounds, tourism, commercial and industrial. The soil investigation levels adopted for the site will depend on the proposed land use. It is considered the following HILs are applicable to the site:

- NEHF A – Residential with gardens and accessible soil (home grown produce contributing less than 10% fruit and vegetable intake, no poultry). Includes childcare centres, preschools, primary schools, townhouses and villas;
- NEHF D – Residential with minimal access to soil including high-rise apartments and flats;
- NEHF E – Parks, recreational open space, playing fields, including secondary schools; and
- NEHF F – Commercial or industrial.

The EILs (for sandy loams with a pH of 6 to 8) are considered suitable to assess potential phytotoxicity of site soils and will be assessed in areas where land use HILs NEHF A, NEHF D, NEHF E and NEHF F apply. Phytotoxicity criteria for the protection of plants are generally not applicable for commercial/industrial sites (NEHF F). Table 3 summarises which soil investigation level will be adopted based on the proposed land use at the various test pit locations.

The adopted criteria are summarised in the attached results Table LR3.

Table 3: Summary of Soil Investigation Levels Adopted for the Site

Area of Site	Coffey Test Pit	Proposed Landuse	Adopted Investigation Levels
Zone 2(A)	CTP87 and CTP88	Environmental reserve, sports ground, tourism, industrial	NEHF E, EILs NEHF F
Zone 3(A)	CTP90, CTP91 and CTP92	Lakeside residential precinct, primary schools, retirement village, commercial	NEHF A, EILs NEHF F
Zone 4(A)	CTP89	Open space, environmental management (no development)	NEHF E, EILs
Zone 4(C)	CTP93 and CTP94	Open space, environmental management (no development)	NEHF E, EILs

5 FIELD AND LABORATORY INVESTIGATIONS

5.1 Previous Field Investigations

Ten groundwater monitoring wells have been previously installed by Coffey: MW01 to MW09 as part of the initial site investigation (Coffey Environments, 2010a) and MW10 as part of a further assessment of groundwater quality (Coffey Environments, 2010b). Existing monitoring well borelogs are attached in Appendix A and well details are summarised in Table 4. Monitoring wells MW06 and MW08 are screened in the ash within Ash Pond 2. Monitoring wells MW03 and MW04 are located within Ash Pond 3 and are screened in the underlying alluvial/estuarine or residual material. The remaining monitoring wells are screened in alluvial/estuarine sediments with one monitoring well MW07 screened in weathered sandstone bedrock of the Berry Siltstone formation. Monitoring well locations are shown in Figure 4.

An additional monitoring well installed by others, TAGM/D3, is also included in Table 4 and Figure 4. Construction details are not known.

5.2 Current Field Investigations

Field investigations were carried out between 22 December 2010 and 18 April 2011 in the full time presence of a Coffey engineering geologist or environmental scientist. Data loggers were installed in five existing monitoring wells on 22 December 2010 and two new monitoring wells on 3 February and 18 February 2011. Monitoring wells MW11 to MW18 were installed between 31 January and 4 February 2011. The location and elevation (ground level and top of casing) of the monitoring wells were surveyed by Landteam on 8 March 2011. Survey details are summarised in Table 5. Aquifer testing was conducted on 17 February, 24 February and 15 March 2011. Groundwater and surface water samples were collected between 15 February and 8 March 2011. Coalwash, ash and soil samples were collected on 18 April 2011 for leachate analyses.

The following sections describe the field investigations in more detail.

5.3 Groundwater Monitoring Well Installation

Eight new groundwater monitoring wells, MW11 to MW18, were installed as part of the current groundwater assessment to obtain more data prior to commencement of groundwater modelling. Monitoring well borelogs are attached in Appendix B and well details are summarised in Table 5.

Monitoring wells MW11 to MW13 were installed within Ash Pond 2 in order to obtain ash aquifer properties from pump test analyses. MW14 was installed to the west of Ash Pond 2 to assess groundwater quality down gradient of Ash Pond 2. MW15 was installed adjacent to Duck Creek to assess groundwater quality at the discharge location down gradient of Ash Pond 2. MW16 and MW17 were installed in the wetland area to the east of Ash Pond 3 to assess groundwater quality in this area. MW18 was installed as a background well to the west of Ash Pond 3.

A trailer mounted Gemco drilling rig was used to install all monitoring wells except for MW15, which was installed using a hand auger due to access restrictions. During drilling and hand augering the subsurface conditions were logged and groundwater conditions noted. The drill rig used a 125 mm diameter solid stem auger fitted with a hardened steel V-bit or a diatube in the ash for MW11 to MW13. The lower 3.0 m section of each well was screened (except shallow well MW15 where the lower 1.0 m section was screened) with 50 mm machine slotted, Class 18, threaded PVC. Blank (unslotted)

Class 18 PVC was used to case each well to the ground surface. Coarse sand was placed within each well annulus to a level of approximately 0.5 m above the top of the slotted screen, followed by an annular seal of bentonite. Concrete was then placed to the surface. The top of each well was completed with a steel monument.

The eight monitoring wells were then developed using an electric submersible monsoon pump following installation.

The approximate locations of MW11 to MW18 are shown in Figure 4.

Table 4: Existing Groundwater Monitoring Well Details (MW01 to MW10 and TAGM/D3)

Well ID	Eastings (m MGA)	Northing (m MGA)	Location	Date Completed	Total Well Depth (m bgl)	Screen Interval (m bgl)	Screened Lithology	Diameter and Type of PVC Casing	Elevation Top of PVC Casing (m AHD)	Elevation Ground Surface (m AHD)
MW01	297731.9	6176080.1	Eastern edge of Ash Pond 3	4/3/2010	6.0	3.0 to 6.0	Alluvial/Estuarine (Clay) - connected with bund wall coalwash fill	50mm Class 18	2.82	2.68
MW02	297791.3	6176388.2	Eastern edge of Ash Pond 3	4/3/2010	5.8	2.8 to 5.8	Alluvial/Estuarine (Sand) - connected with bund wall coalwash fill	50mm Class 18	3.05	2.34
MW03	297545.0	6176690.5	Within Ash Pond 3	3/3/2010	5.8	2.8 to 5.8	Alluvial/Residual/ XW Sandstone - connected with ash fill	50mm Class 18	3.98	3.42
MW04	297590.9	6176299.8	Within Ash Pond 3	3/3/2010	6.2	3.2 to 6.2	Alluvial/Estuarine (Clay) - connected with ash fill	50mm Class 18	3.33	3.14
MW05	298381.4	6176516.4	South of Ash Pond 2	5/3/2010	7.5	4.5 to 7.5	Alluvial/Estuarine (Clay)	50mm Class 18	4.7	4.21
MW06	298481.4	6176739.3	Within Ash Pond 2	11/6/2010	7.5	3.0 to 7.5	Fill - Ash	42mm Class 18	10.92	10.28
MW07	298872.6	6176432.4	South of Ash Pond 2	5/3/2010	5.6	2.6 to 5.6	Weathered Sandstone (Berry Siltstone)	50mm Class 18	8.51	8.19
MW08	298837.0	6176677.1	Within Ash Pond 2	10/3/2010	3.6	0.6 to 3.6	Fill - Ash	42mm Class 18	6.51	5.96
MW09	298827.3	6177103.4	East of Ash Pond 1 adjacent to Lake Illawarra	5/3/2010	5.8	2.8 to 5.8	Alluvial/Estuarine (Clay)	50mm Class 18	3.07	2.38
MW10	297882.1	6176850.0	Outside ash ponds	17/8/2010	4.5	1.5 to 4.5	Alluvial/Estuarine (Sandy clay)	50mm Class 18	2.59	1.95
TAGM/D3	297629.8	6175761.6	South east of Ash Pond 3	Unknown	11.2	Unknown	Unknown	50mm	2.2	2.07

Table 5: New Groundwater Monitoring Well Details (MW11 to MW18)

Well ID	Easting (m MGA)	Northing (m MGA)	Location	Date Completed	Total Well Depth (m bgl)	Screen Interval (m bgl)	Screened Lithology	Diameter and Type of PVC Casing	Elevation Top of PVC Casing (m AHD)	Elevation Ground Surface (m AHD)
MW11	298321.8	6177203.7	Within Ash Pond 2	1/2/2011	10.0	7.0 to 10.0	Fill - Ash	50mm Class 18	11.79	11.10
MW12	298322.0	6177206.7	Within Ash Pond 2	1/2/2011	10.0	7.0 to 10.0	Fill - Ash	50mm Class 18	11.87	11.15
MW13	298319.2	6177205.4	Within Ash Pond 2	1/2/2011	7.0	4.0 to 7.0	Fill - Ash	50mm Class 18	11.88	11.11
MW14	298093.4	6176938.4	Outside ash ponds	1/2/2011	4.0	1.0 to 4.0	Alluvial/Estuarine (Sandy clay)	50mm Class 18	2.79	2.07
MW15	298379.1	6176480.3	Adjacent to Duck Creek	4/2/2011	1.5	0.5 to 1.5	Alluvial/Estuarine (Sandy clay)	50mm Class 18	1.36	0.62
MW16	297878.7	6176242.9	Wetland east of Ash Pond 3	31/1/2011	5.5	2.5 to 5.5	Alluvial/Estuarine (Clay)	50mm Class 18	1.92	1.30
MW17	297773.6	6176163.1	Wetland east of Ash Pond 3	31/1/2011	5.0	2.0 to 5.0	Alluvial/Estuarine (Sandy clay)	50mm Class 18	2.16	1.38
MW18	297113.4	6176542.0	Western site boundary	31/1/2011	5.8	2.8 to 5.8	Residual Clay/XW Sandstone	50mm Class 18	5.73	4.89

5.4 Aquifer Testing

Aquifer testing involved using data loggers and manual measurements of groundwater levels during the various tests to allow assessment of aquifer properties such as transmissivity and hydraulic conductivity. The aquifer tests conducted included the following:

- Constant discharge test with multiple observation piezometers within the ash at Ash Pond 2 (pumping of MW11);
- Constant discharge tests at two locations, MW09 adjacent to Lake Illawarra in clay material and MW04 at Ash Pond 3 in natural clay connected with the ash; and
- Slug tests at two locations, MW05 south of Ash Pond 2 in clay material and MW17 in the wetland area east of Ash Pond 3 in natural clay.

The pump test at MW11 was initially conducted on 24 February 2011 using an electric submersible Grundfos MP1 pump, with a maximum discharge rate of approximately 0.5 L/s. Due to higher than anticipated permeability of the ash material, this discharge rate was not sufficient to obtain the required drawdown response in the two observation wells, MW12 and MW13, located approximately 3 m from the pump well MW11.

A second pump test was conducted on 15 March 2011 using a centrifugal Grundfos JPB9 pump, with a maximum discharge rate of approximately 2 L/s. A discharge rate of 1 L/s was achieved at a groundwater depth of approximately 4 m below ground level. The higher discharge rate provided sufficient drawdown response to allow analysis of the data for assessing aquifer properties.

The slug tests and constant discharge tests were conducted on 17 February 2011 using an electric submersible monsoon pump, with a maximum discharge rate of approximately 0.1 L/s. The slug tests involved pumping the well dry and measuring water level recovery (rising head tests) and the constant discharge tests involved pumping the well at a constant rate for approximately 30 minutes (as these wells were not pumped dry) and measuring water level recovery.

5.5 Groundwater Sampling

Groundwater sampling was conducted between 15 February and 8 March 2011. Newly installed monitoring wells MW11 to MW18 were allowed to stabilise for at least 7 days prior to sampling being carried out. Six of the eight new monitoring wells were sampled as MW12 and MW13 were within 3 m of MW11 and were therefore not sampled. Sampling of groundwater from existing monitoring wells included MW01 to MW06, MW08 to MW10 and TAGM/D3. Standing water levels were checked using an electronic probe prior to sampling. Existing monitoring well MW07 was dry and therefore not sampled.

Typically two well volumes were removed from all wells during purging, where practicable. The volume was less at five locations (MW06, MW08, MW16, MW17 and MW18) where only one well volume was removed before the wells went dry and did not recover quickly.

Field parameters recorded during the well purging included temperature, pH, electrical conductivity (EC), dissolved oxygen (DO) and reduction oxidation potential (E_r) using a calibrated water quality meter.

The monitoring wells were purged and sampled using similar procedures as described in our previous reports (Coffey Environments, 2010a and 2010b) using dedicated disposable plastic bailers. The

groundwater samples were placed into appropriately preserved containers supplied by the contract laboratory. The groundwater samples for heavy metals analysis were filtered in the field with a 0.45µm filter. The groundwater samples were immediately stored in an esky cooled with ice.

5.6 Surface Water Sampling

Surface water locations were included in the sampling program to assess potential contaminant concentrations within close proximity to the discharge area west of Ash Pond 2 and at the surface of Ash Pond 3. Surface water sampling was carried out at two locations, designated SW7 and SW8 as follows:

- SW7 was collected in the pond to the west of Ash Pond 2 and in the vicinity of the newly installed monitoring well MW14.
- SW8 was collected in the lake within Ash Pond 3.

Field parameters were measured at each location using a calibrated water quality meter (temperature, pH, EC, DO and E_h). The water sample was collected with a telescopic sampler which was washed with a phosphate free detergent, rinsed with potable water followed by rinsing with distilled water between sampling locations.

The surface water samples were placed into appropriately preserved containers supplied by the contract laboratory. The surface water samples for heavy metals analysis were filtered in the field with a 0.45µm filter. The surface water samples were immediately stored in an esky cooled with ice.

5.7 Coalwash, Ash and Soil Sampling

An additional field program was conducted on 18 April 2011 to further assess the potential sources of contaminants in the groundwater system, particularly for ammonium. Test pits were excavated to a maximum depth of 3.7 m using a backhoe under the supervision of a Coffey environmental scientist. Test pit logs are included in Appendix C and test pit locations are illustrated in Figure 4.

Samples were collected of the ash, coal wash and natural clay material at the locations and depths listed in Table 6.

Table 6: Summary of Coalwash, Ash and Soil Sampling Locations

Area of Site	Coffey Test Pit	Sample Type and Location	Sample Depths (m)
Zone 2(A)	CTP87	Coalwash within the bund wall and access road of Ash Pond 2.	0.5-0.6 m, 1.4-1.6 m
Zone 2(A)	CTP88	Ash within Ash Pond 2, approximately 200 m east of MW06.	0.6-0.8 m, 3.5-3.7 m
Zone 4(A)	CTP89	Coalwash within the bund wall and access road of Ash Pond 3, approximately 10 m north of MW01.	0.5-0.6 m, 1.8-2.0 m
Zone 3(A)	CTP90	Coalwash within the bund wall and access road of Ash Pond 3, approximately 10 m west of MW02.	0.5-0.6 m, 1.8-2.0 m
Zone 3(A)	CTP91	Ash within Ash Pond 3, approximately 10 m north of MW04.	0.6-0.8 m, 1.6-1.8 m
Zone 3(A)	CTP92	Ash within Ash Pond 3, approximately 10 m north west of MW03.	0.6-0.8 m, 1.0-1.1 m
Zone 4(C)	CTP93	Natural clay material, approximately 2 m west of MW15 adjacent to Duck Creek.	0.6-0.7 m
Zone 4(C)	CTP94	Natural clay material, approximately 10 m north of MW17 in the wetland area.	0.4-0.5 m, 0.8-1.0 m

5.8 Field Quality Control Procedures

The field quality control consisted of the following:

- Sampling was performed generally in accordance with the procedures outlined in Coffey Environments relevant standard operating procedures, which are based on industry accepted protocols for environmental sampling. This was carried out by a trained and experienced environmental scientist or engineering geologist. Sampling staff had undergone Coffey Environments internal training procedures in accordance with the Coffey Environments standard operating procedures and supervised field training;
- Calibration of field instruments in accordance with manufacturer's instructions;
- Collection and analysis of two blind coded duplicate groundwater samples, QC01 (duplicate of primary sample MW05) and QC03 (duplicate of primary sample MW01) for dissolved heavy metals (arsenic, cadmium, chromium, copper, lead, molybdenum, nickel and zinc), ammonium, nitrate, nitrite, total kjeldahl nitrogen (TKN) and total nitrogen;

- Collection and analysis of three blind coded duplicate soil samples, QC1 (duplicate of clay primary sample CTP93/0.6-0.7), QC2 (duplicate of coalwash primary sample CTP89/1.8-2.0) and QC3 (duplicate of ash primary sample CTP91/0.6-0.8) for dissolved heavy metals (arsenic, cadmium, chromium, copper, lead, molybdenum, nickel and zinc), ammonium, nitrate, nitrite, TKN and total nitrogen; and
- Samples were transported in ice-cooled eskies to the contract laboratory, SGS Environmental Services Pty Ltd (SGS) in Sydney, which is NATA accredited for the analysis performed, under chain of custody conditions. Copies of the chain of custodies are included in Appendix D.

5.9 Laboratory Analysis

The groundwater, surface water and leachate water samples were tested for dissolved heavy metals (arsenic, cadmium, chromium, copper, lead, molybdenum, nickel and zinc), ammonium, nitrate, nitrite, TKN and total nitrogen.

Leachate analyses were conducted on samples of coalwash, ash and alluvial/estuarine sediments. The Australian Standard Leaching Procedure (ASLP) was conducted using neutral deionised laboratory water.

The solid samples of coalwash, ash and clay soils were also analysed for the same suite of heavy metals and nitrogen compounds.

The laboratory results are discussed in Section 6.5 and the laboratory reports are presented in Appendix E.

6 RESULTS

6.1 Groundwater Levels and Flow

Groundwater levels from the most recent gauging round conducted on 12 April 2011 are detailed in Table 7. In the alluvial/estuarine sediments, groundwater levels range from 0.36 m AHD at MW15 adjacent to Lake Illawarra, to 1.53 m AHD at TAGM/D3. Groundwater levels within Ash Pond 3 ranged from 2.15 m AHD at MW03 to 2.17 m AHD at MW04 for the natural alluvial/estuarine sediments below.

MW07 screened in weathered sandstone bedrock was dry. Groundwater levels within the ash in Ash Pond 2 ranged from 8.0 m AHD at MW11 to 4.34 m AHD at MW06. In the south eastern saltmarsh inundated area water levels were 0.86 m above ground level, at an elevation of 6.82 m AHD at MW08. This inundated area is bunded and considered as separate to the rest of the Ash Pond 1 and 2 system. Surface water drainage from Ash Pond 1 and 2 is directed towards the inundated area.

Table 7: Monitoring Well Groundwater Levels from 12 April 2011

Well ID	Location	Elevation Top of PVC Casing (mAHD)	Elevation Ground Surface (mAHD)	Groundwater Depth (mbgl)	Groundwater Level (mAHD)
MW01	Eastern edge of Ash Pond 3	2.82	2.68	1.57	1.11
MW02	Eastern edge of Ash Pond 3	3.05	2.34	1.20	1.14
MW03	Within Ash Pond 3	3.98	3.42	1.28	2.15
MW04	Within Ash Pond 3	3.33	3.14	0.98	2.17
MW05	South of Ash Pond 2	4.70	4.21	2.96	1.25
MW06	Within Ash Pond 2	10.92	10.28	5.95	4.34
MW07	South of Ash Pond 2	8.51	8.19	Dry to 5.6m bgl	Dry to 2.6m AHD
MW08	Within Ash Pond 2	6.51	5.96	-0.86 ¹	6.82 ¹
MW09	East of Ash Pond 1	3.07	2.38	1.44	0.94
MW10	Outside ash ponds	2.59	1.95	0.87	1.08
MW11	Within Ash Pond 2	11.79	11.10	3.10	8.00
MW12	Within Ash Pond 2	11.87	11.15	3.16	7.99
MW13	Within Ash Pond 2	11.88	11.11	3.12	7.99
MW14	Outside ash ponds	2.79	2.07	0.80	1.27
MW15	Adjacent to Duck Creek	1.36	0.62	0.26	0.36
MW16	Wetland east of Ash Pond 3	1.92	1.30	0.64	0.66
MW17	Wetland east of Ash Pond 3	2.16	1.38	0.41	0.98
MW18	Western site boundary	5.73	4.89	1.72	3.17
TAGM/D3	South east of Ash Pond 3	2.20	2.07	0.54	1.53

¹Above ground water level corresponds to surface water level in the inundated area of Ash Pond 2.

Groundwater level data loggers were installed on 22 December 2010 at five existing monitoring wells across the site (MW01, MW04, MW05, MW08 and MW09). In addition to these locations, two data loggers were installed at new monitoring well locations, one in Ash Pond 2 (MW11) and one in the wetland east of Ash Pond 3 (MW17). Hydrographs are illustrated in Figure 5. All monitoring wells show an increase in groundwater level for the rainfall events between 20 and 22 March 2011, where a total of 397 mm was recorded at the Wollongong Airport weather station in Albion Park, approximately 2 km south west of the site. The increase in groundwater levels ranged from approximately 0.8 m at MW11 in Ash Pond 2 to approximately 2.0 m at MW04 in Ash Pond 3. The increase of around 3.5 m at MW08 corresponds to an above ground surface water level in the inundated area of Ash Pond 2.

Based on analysis of groundwater level rises for the main rainfall event in March 2011, groundwater recharge from rainfall is assessed to be between approximately 8% and 10%. These estimates will be confirmed during further data analysis as part of numerical groundwater modelling.

Groundwater elevations from the existing ten Coffey monitoring wells and one additional monitoring well (TAGM/D3) previously installed by others were included in the interpreted groundwater contour map presented in the preliminary hydrogeological report (Coffey Environments, 2010c). The contour map is attached as Appendix F and shows that south of Duck Creek groundwater flow is to the north east towards Duck Creek, to the east towards Lake Illawarra and to the south east towards Macquarie Rivulet. Groundwater flow north of Duck Creek is radial from the elevated Ash Pond 1 and 2 area, towards Duck Creek and Lake Illawarra.

The elevated groundwater levels within the ash ponds are above the natural sediment. Groundwater flow from the ash ponds to the surrounding environment is assessed as being predominantly vertical flow through the base of the ponds rather than horizontal flow through the bund walls. No groundwater was observed as seepage from the bund walls during site visits for the current assessment and from discussions with Coffey staff who previously conducted the subsurface investigations in 2010. Most of the bund walls for Ash Pond 1 and 2 are vegetated with a range of species including swamp oaks (*Casuarina* and other tree species) and weeds. It is therefore assessed that if groundwater were to flow horizontally through the bund walls in this area, the groundwater would be consumed by evapotranspiration.

The ash level within Ash Pond 3 is lower than the bund walls and groundwater levels on the eastern edge of Ash Pond 3 are at an elevation of approximately 1 m AHD (MW01 and MW02), which is at a similar elevation to the surface water in the drainage channel flowing north to Duck Creek. The drainage channel is located approximately 10 m from monitoring wells MW01 and MW02. The lake in the southern part of Ash Pond 3 is connected to the groundwater system in this area. Surface water overflows from the lake are directed to the lake outside the bund wall to the west, which then flows in a series of drainage channels flowing east along the southern Ash Pond 3 boundary, and then north towards Duck Creek along the eastern Ash Pond 3 boundary.

6.2 Aquifer Properties

Movement of groundwater within the ash ponds and the natural alluvial/estuarine sediments is governed by aquifer properties including hydraulic conductivity, effective porosity and by the hydraulic gradient in the aquifer. These properties are reported in the following sections.

6.2.1 Hydraulic Conductivity

6.2.1.1 Constant Discharge Test with Multiple Observation Piezometers

In order to assess the hydraulic conductivity of the ash bodies, a pump test survey was conducted. The pump test comprised groundwater well installation followed by test pumping. One pumping well (MW11) screened between 7 and 10 m depth, and two monitoring wells (MW12 and MW13) were installed within Ash Pond 2. The monitoring wells were used for measuring drawdown in groundwater levels in the ash while pumping from the pumping bore located 3 m away. The monitoring well screens covered the depth intervals 7 to 10 m, and 4 to 7 m. This arrangement was used to obtain drawdown data that, when analysed using specialist pump-testing interpretation software (WTAQ), would provide an estimate for the important quantity of vertical hydraulic conductivity for the ash, in addition to the lateral hydraulic conductivity.

The computer code WTAQ (Barlow and Moench, 1999) was used for the analysis, in combination with software that can estimate parameter values in an iterative fashion by matching the model calculated values to actual field observations. WTAQ takes into account vertical heterogeneity (the fact that vertical and horizontal hydraulic conductivities are usually very different) and variable well screen lengths within an aquifer, and so is a powerful program for interpretation of pump test drawdown data.

Figure 6 shows the observed and calculated drawdowns for the pump test. The pumping well has also been used for analysis (in combination with a well loss drawdown component) as an additional check on calculated parameters. The match is considered good, and the conceptual model used by the software is valid. Calculated parameters are well resolved and have small error margins. Calculated aquifer parameters are a hydraulic conductivity of the ash of about 50 m/day, a vertical hydraulic conductivity of about 1 m/day, and a specific storativity of about 5×10^{-4} , indicating a more compressive aquifer than is typically seen for sediments.

6.2.1.2 Slug Test and Constant Discharge Single Well Tests

Slug tests were conducted at two locations, MW05 south of Ash Pond 2 in clay material and MW17 in the wetland area east of Ash Pond 3 in natural clay. Constant discharge tests were conducted at two locations, MW09 adjacent to Lake Illawarra in clay material and MW04 at Ash Pond 3 in natural clay connected with the ash. Interpretation graphs are shown in Figure 7.

The slug tests involved pumping the well dry and measuring water level recovery (rising head tests). Slug tests were analysed using the Hvorslev method (Hvorslev, 1951). The constant discharge tests involved pumping the well at a constant rate for approximately 30 minutes (as these wells were not pumped dry) and measuring water level recovery. Recovery data were analysed using the Jacob method (Cooper and Jacob, 1946). Interpretation graphs are shown in Figure 8.

Results for the above tests are detailed in Table 8. The ash material shows the highest permeability, with a horizontal hydraulic conductivity of approximately 50 m/day. The lowest permeability is for the alluvial/estuarine clay in the wetland area to the east of Ash Pond 3, with a hydraulic conductivity value of approximately 0.04 m/day. Intermediate values around 0.5 m/day were obtained for the sandy clays south and east of Ash Pond 2.

Table 8: Summary of Aquifer Test Results

Monitoring Well	Aquifer Test Type	Hydrogeological Unit	Horizontal Hydraulic Conductivity (m/day)	Comments
MW11-MW13	Pump test	Ash within Ash Pond 2	50	High permeability ash material
MW05	Slug test	Alluvial/estuarine clay	0.5	Higher permeability influenced by sandy clay material
MW17	Slug test	Alluvial/estuarine clay	0.04	Lower permeability wetland clay
MW04	Constant discharge test	Alluvial/estuarine clay connected with ash within Ash Pond 3	2.9	Higher permeability influenced by ash material
MW09	Constant discharge test	Alluvial/estuarine clayey sand and clay	0.4	Higher permeability influenced by sand layer at base of well

6.2.1.3 Previous Piezocone Data

Since groundwater flow from the ash dams was assessed as being predominantly vertical through the base of the ash ponds rather than horizontal, vertical hydraulic conductivity values were previously calculated from horizontal conductivity data (Coffey Environments, 2010c) assessed as part of the initial piezocone investigation works (Coffey Environments, 2010a). The time for 50% pore pressure dissipation was assessed and horizontal conductivity values were calculated using the method by Robertson et al (1997). Piezocone tests tended to fail in higher permeability strata such as coarse ash material. Approximately 50 % of the piezocone dissipation tests were recorded as failures, introducing a bias to the results.

Horizontal hydraulic conductivities measured from the piezocone dissipation tests ranged from 0.0002 m/day in the fine ash material to 0.02 m/day in the coarser ash material. This was similar to the underlying natural sediments, where horizontal hydraulic conductivities ranged from 0.0001 m/day to 0.01 m/day (Coffey Environments, 2010c). These values are up to five orders of magnitude lower compared to the Tallawarra aquifer test data summarised in Table 8. Results from aquifer tests conducted in piezometers or wells more accurately reflect aquifer properties because a greater volume of the aquifer is engaged during such tests. The small scale of the piezocone test method as well as a tendency toward successful tests in lower permeability layers, and test failures in higher permeability materials, as described below, may account for the differences between the data sets.

Pore water pressure dissipation times are variable, which is typical for this type of test. Several tests appear to have been conducted in drainage layers (in sand or other higher permeability material) encountered in the ash or underlying alluvial/estuarine sediments, resulting in shorter dissipation test times. These tests were generally not successful for assessing horizontal hydraulic conductivity, therefore the data previously tabulated may have included a greater proportion of the lower permeability material.

Such variations consisting of vertically and laterally discontinuous and irregular lenses are consistent with the visual and laboratory data from test pits and boreholes previously collected at the site (Coffey Environments, 2010a).

6.2.1.4 Reference Values for Ash

Reference values for hydraulic conductivity values of ash material from other published studies are listed in Table 9. The values listed for fly ash (0.0002 and 0.0004 m/day) and the geometric mean for the field testing from South Africa (0.02 m/day) are up to five orders of magnitude lower compared to the Tallowarra aquifer test data. The value for the coarse bottom ash material (15 m/day) is closer to the Tallowarra value of around 50 m/day and illustrates the wide range of hydraulic conductivity possible for the ash material.

Table 9: Reference Values for Ash Hydraulic Conductivity

Report Reference	Study Location	Horizontal Hydraulic Conductivity Values (m/day)				
		Fly Ash (Fine)	Bottom Ash (Coarse)	Average Saturated	Geometric Mean - Lab Testing	Geometric Mean - Field Testing
Muhardi et al, 2010	Tanjung Bin Ash, Malaysia	0.0004	15			
Mudd, 2000	Latrobe Valley, Victoria, Australia			0.3		
Yeheyis, 2008	Ontario, Canada	0.0002				
October et al, 2009	Various locations, South Africa				0.18	0.02

6.2.2 Effective Porosity

The effective porosity of a medium is that porosity which must be used to reproduce observed travel times in tracer experiments. It is also known as the kinematic porosity. Reasonable estimates of effective porosity for the ash and alluvial/estuarine sediments, based on bore logs, are 15% and 25% respectively.

6.2.3 Hydraulic Gradients

Based on the interpreted groundwater contour map presented in the preliminary hydrogeological report (Coffey Environments, 2010c) and attached in Appendix F, hydraulic gradients vary from 0.001 in the low lying wetland area east of Ash Pond 3 to steeper gradients of around 0.05 in the elevated Ash Pond 1 area towards Lake Illawarra.

6.2.4 Rate of Groundwater Movement

Since groundwater flow from the ash ponds is assessed as being predominantly vertical through the base of the ash ponds rather than horizontal, vertical hydraulic conductivity values are used to assess the rate of groundwater movement from the ash ponds. Based on an average vertical hydraulic conductivity of 1 m/day, an average effective porosity of 15% and a hydraulic gradient of 0.05 (see Section 6.2.3), the rate of vertical groundwater movement within the ash is around 0.3 m/day or 110 m/year.

Once groundwater reaches the base of the ash ponds, entry of the groundwater into the underlying alluvial/estuarine clay sediments is controlled by the lower permeability of the clay compared to the ash material. Based on an average horizontal hydraulic conductivity of 0.1 m/day, an average effective porosity of 25% and a hydraulic gradient of 0.001 (see Section 6.2.3), the rate of horizontal groundwater movement within the clay is around 0.0004 m/day or 0.2 m/year.

Groundwater discharge from the ash ponds is therefore limited by the aquifer properties of the alluvial/estuarine sediments.

Calculated rates of groundwater movement are highly variable depending on the adopted aquifer properties, gradients and local conditions considered.

6.3 Water Sampling

6.3.1 Observations

The following observations were made during sample collection:

- The surface water samples were slightly cloudy;
- Typically, the groundwater samples were slightly cloudy to turbid;
- The colour of the groundwater at MW01, MW02, MW04, MW05, MW09, MW10, MW17, MW18 and TAGM/D3 was generally brown to orange brown;
- The colour of the groundwater at MW03, MW06, MW08, MW11, MW14, MW15 and MW16 was generally grey to grey brown;
- No visual evidence of oily sheens or hydrocarbon odours were apparent during sampling;
- Slight organic odours were noted at the groundwater monitoring well locations MW01, MW02, MW09 and MW16; and
- Moderate decaying organic matter odour was noted at the well locations MW14 and MW15. Frogs were also noted within and outside the well MW15 adjacent to Duck Creek.

6.3.2 Field Quality Parameters – Groundwater

Groundwater quality parameters measured in the field are presented in Table LR1 and summarised below.

- DO measurements ranged between 0.9 mg/L (MW08) and 5.6 mg/L (MW17);
- E_r measurements ranged between reducing conditions, -150 mV (TAGM/D3) and oxidising conditions, +245 mV (MW09);
- EC measurements ranged between brackish conditions, 4.08 mS/cm (MW18) and saline conditions, 46.80 mS/cm (MW06);
- pH measurements ranged between acidic conditions with a pH of 4.2 (MW03 and MW09) and slightly alkaline conditions with a pH of 8.2 (MW11); and
- Temperature measurements ranged between 18.1°C (MW05) and 22.6°C (MW01 and MW04).

6.3.3 Field Quality Parameters – Surface Water

Surface water quality parameters measured in the field are presented in Table LR1 and summarised below.

- DO measurements ranged between 8.0 mg/L (SW7) and 6.9 mg/L (SW8);
- E_r measurements ranged between -56 mV (SW7) and +20 mV (SW8);
- EC measurements indicated brackish water and ranged between 5.85 mS/cm (SW8) and 6.04 mS/cm (SW7);
- pH measurements indicated slightly alkaline conditions and ranged between 8.1 (SW7) and 8.8 (SW8); and
- Temperature measurements ranged between 26.6°C (SW7) and 32.3°C (SW8).

6.4 Coalwash, Ash and Soil Sampling

6.4.1 Observations

The following observations were made during sample collection:

- The coalwash samples were generally fine to coarse grained gravels, black, with no odours noted;
- The ash samples were generally sandy silts, grey, with no odours noted; and
- The alluvial/estuarine sediment samples were generally sandy clays, dark brown or grey, with moderate organic odours noted.

6.5 Laboratory Results

The laboratory results are summarised in attached Tables LR1 to LR3. The laboratory certificates are included in Appendix E.

6.5.1 Data Validation

The data were assessed against predetermined Data Quality Objectives (DQOs) and Data Quality Indicators (DQIs) (completeness, comparability, representativeness, precision, and accuracy) for both field and laboratory procedures and results. Two data validation reports have been prepared and are included in Appendix G.

Based on the assessment, it is considered that the data collected for this assessment is adequate and meets the DQOs and DQIs.

6.5.2 Major Ions

The results for the major cations and anions are summarised in Table LR1 and are illustrated in a trilinear piper plot presented in Figure 9. The piper plot shows that the dominant water type for all groundwater samples is sodium chloride, irrespective of whether the groundwater is from the alluvial/estuarine sediments, residual sediments or connected with ash or coalwash material. Typical values for seawater were also plotted and included in Figure 9 to illustrate the similarities in composition between the groundwater and seawater. Considering the coastal site location, the seawater signature for the estuarine alluvial sediments is considered reasonable. The seawater signature of the ash and

coalwash may be due to mixing with alluvial/estuarine groundwater (at low elevations), and evaporative concentration of rainfall salts (at higher elevations in the ash). The signature of rainwater is typically very similar to the seawater signature.

6.5.3 Comparison of Laboratory Results to Groundwater, Surface Water and Leachate Water Investigation Levels

The laboratory results are summarised and compared to the adopted investigation levels in Table LR1. Concentrations of various heavy metals (arsenic, chromium, copper, lead, molybdenum, nickel and zinc), ammonium and total nitrogen exceed the adopted investigation levels at background locations, within the ash ponds and downslope of the ash ponds.

Table LR2 includes results from our previous assessments for comparison purposes. Results show generally similar concentrations, with the exception of a decrease in ammonium at MW01 from 12 mg/L in August 2010, to 2.2 mg/L in February 2011. Since the sampling procedures are the same between these sampling events, the likely reason for the change in concentration is not clear. The August 2010 sampling round did not include total kjeldahl nitrogen (TKN), and the differences may include an increase in organic nitrogen and a subsequent decrease in ammonium concentrations.

Table LR3 includes results for the leachate analyses conducted on solid samples of coalwash, ash and alluvial/estuarine sediments. The Australian Standard Leaching Procedure (ASLP) was conducted using neutral deionised laboratory water. The results indicate that concentrations of arsenic consistently exceed the adopted investigation level for leachate from the ash material and concentrations of molybdenum exceed the investigation level for the clay sediment south of Ash Pond 2. Leachate results are discussed further in Section 7.2.

6.5.4 Comparison of Laboratory Results to Soil Investigation Levels

Table LR3 includes results for the soil samples of coalwash, ash and clay soils analysed for the same suite of heavy metals and nitrogen compounds as the leachate tests. The results show that the heavy metals concentrations are below the investigation levels.

There are no nutrient guidelines as part of the NEPM guidelines (NEPC, 1999), and other agricultural guidelines depend on crop types, soil and fertiliser application, which are not considered applicable for this assessment. Soil results for the nitrogen suite are discussed further in Section 7.2.

7 HYDROGEOLOGICAL CONCEPTUAL MODEL

In order to understand the spatial and temporal variability of groundwater quality, it is important to have a conceptual model of the groundwater flowpath and the travel time from the contaminant source to the sampling point. Along the flowline, chemicals may become sorbed which retards their transport compared to the velocity of water. Furthermore, physical processes such as diffusion and dispersion cause mixing and smoothen concentration changes.

The following sections outline the hydrogeological conceptual model for the site to be used as a basis for the numerical groundwater modelling assessment.

7.1 Flow Mechanisms

7.1.1 Groundwater Recharge

Groundwater recharge to the aquifer can occur via the following processes:

- Direct rainfall infiltration;
- Runoff from the hills to the north and west reporting to the estuarine/alluvial aquifer; and
- Recharge from bedrock.

The upper layers of the underlying bedrock may provide minor groundwater recharge in dryer times. Depending on overall sediment thickness (and the closure of rock apertures and their weathering), the upper bedrock layers are expected to have lower overall permeability compared with the estuarine/alluvial aquifer.

Based on analysis of groundwater level rises for the main rainfall event in March 2011 (Figure 5), aquifer recharge estimates range between approximately 8% and 10%. These figures will be confirmed during further data analysis as part of numerical groundwater modelling.

7.1.2 Groundwater Discharge

Discharge of groundwater from the aquifer will occur via the following processes:

- Lateral flow to Lake Illawarra and other surface water bodies including Duck Creek, Wollingurrie Creek and drainage channels;
- Evapotranspiration by vegetation with sufficient root depth;
- Evaporation from ponded water; and
- Leakage to bedrock.

The upper layers of the underlying bedrock may accept groundwater leakage from the estuarine/alluvial aquifer in wetter times. Depending on overall sediment thickness (and the closure of rock apertures and their weathering), the upper bedrock layers are expected to have lower overall permeability compared with the estuarine/alluvial aquifer.

7.1.3 Groundwater Flow Volumes

Based on adopted aquifer parameters outlined in Section 6.2.4, the vertical groundwater velocity for the ash material is around 0.3 m/day or around 110 m/year and the horizontal velocity for the alluvial/estuarine clay is around 0.0004 m/day or around 0.2 m/year. Therefore the controlling influence on movement of groundwater from the ash mounds into the wider environment is controlled by the lower permeability of the alluvial/estuarine sediments.

Potential groundwater flux from the ash ponds was previously assessed based on a lower vertical hydraulic conductivity of the ash (0.0007 m/day) estimated from piezocone results (Coffey Environments, 2010c). Due to the limiting factors of the dissipation test from piezocone testing (as discussed earlier), a pump test with multiple observation piezometers in the ash was undertaken to obtain more reliable results. These results showed that the vertical hydraulic conductivity of the ash was likely to be significantly higher than the clay. Since the vertical hydraulic conductivity of the clay is likely to be significantly less than for the ash (1 m/day), the maximum seepage rate through the base of the ash will, in the long term, be controlled by the clay.

Movement of groundwater from the base of the ash ponds to receptors such as Duck Creek will be limited by the aquifer properties of the alluvial/estuarine sediments. These water budgets will be explored further as part of numerical groundwater modelling.

To compare the magnitudes of groundwater flow from the ash ponds and surface water flows within Duck Creek, the following information was previously reviewed (Coffey Environments, 2010c). The six hour duration 100 year ARI peak flow for Duck Creek at the Lake Illawarra outlet was reported to be 289 m³/s or around 24,970 ML/day (Bewsher, 2010). For the Duck Creek surface water catchment, average flows of approximately 1 m³/s or around 86 ML/day are considered reasonable (pers. comm. Bewsher, 2010). The average flow rate for Duck Creek is likely to be higher than the groundwater flux from the ash.

7.2 Groundwater Quality and Contaminant Sources

Assessment of groundwater within the ash ponds indicates isolated impact from arsenic (up to 330 µg/L at MW06), chromium (up to 330 µg/L at MW08), molybdenum (up to 110 µg/L at MW06) and nickel (up to 2,400 µg/L at MW08), above background or downslope concentrations. As previously reported, it is likely that the ash ponds are a source of dissolved heavy metals, however concentrations in the receiving surface water environment are generally within background ranges (Coffey Environments, 2010b).

The more complicated groundwater quality issue with respect to assessing a potential source is the elevated concentrations of ammonium found at the site. The pH-pe diagram illustrated in Figure 10 shows that for the pH values recorded at the site (less than pH 8), the ammonium ion (NH₄⁺) dominates, rather than ammonia (NH₃). Ammonia only dominates in alkaline conditions where pH values are greater than 9. This is the reason ANZECC (2000) trigger values for ammonia/ammonium are pH dependent (trigger values decrease as pH increases).

The highest ammonium levels recorded on site are south of Ash Pond 2 adjacent to Duck Creek (20 mg/L at MW15), west of Ash Pond 2 (15 mg/L at MW14) and south of Ash Pond 3 (17 mg/L at TAGM/D3). High organic nitrogen content is also a characteristic of the groundwater, with concentrations up to 22 mg/L adjacent to Duck Creek at MW15. Organic nitrogen concentrations are part of the total kjeldahl nitrogen (TKN) results, where:

(1) TKN = organic nitrogen + ammonium + ammonia

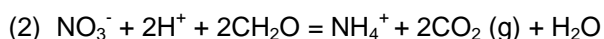
Since the highest ammonium concentrations are found outside the ash ponds, this shows either that:

- The dominant source of the ammonium used to be relatively mobile dissolved ammonia (in an unknown form) within coalwash and ash during deposition (which, for the ash, ceased in 1989). The ammonia could have leached from these sources quickly, leaving behind elevated concentrations at some distance from the ash ponds, representing the current position of the plume. This would require a significant source concentration to start with as movement of ammonium is slower than groundwater flow and there is adsorption to soil particles which reduces the concentration in groundwater; or
- The dominant source of the ammonium is related to natural degradation of nitrogen in the clay in a reducing environment with high natural organic matter content (microbial processes, commonly described as the nitrogen cycle).

Available data suggest that both sources listed above are active in producing ammonium, however the dominant process cannot be definitively identified at present.

In a wetland environment such as that found on site, decomposition of fresh and therefore more reactive organic matter is an important part of the aquatic chemistry. Organic matter in aquifers is mostly of sedimentary origin and consists of the remains of plants in terrestrial sediments, supplemented by plankton and animal residues in the case of marine and lacustrine sediments. The organic carbon content is generally lowest in sand deposits and highest in clays (Appelo and Postma, 2005).

The pathways in the reduction-oxidation (redox) reactions of nitrogen are illustrated in Figure 10. Dissimilation describes a chemical process involving the production of an inorganic compound or element from an organic one, while assimilation involves incorporation of the inorganic compound as part of an organic compound. Since reducing conditions are found at the site and no nitrate is found in the groundwater, the likely redox process occurring is the reduction of nitrate with organic matter and the production of ammonium. These reactions are mediated by microbial processes (Morel and Hering, 1993), and the overall redox reaction is written below:



The nitrogen cycle is clearly a complex system where natural processes can lead to variable concentrations of various forms of nitrogen depending on conditions such as the availability and amount of electron acceptors and donors (redox couples).

To assess a possible inorganic source of ammonium on site, additional sampling and chemical analysis of coalwash, ash and alluvial/estuarine clay was conducted. Analysis of the solid samples (prior to conducting neutral leachate tests) shows that both the natural clay soil and the coalwash have similar concentrations of TKN (mainly organic nitrogen), with the highest concentration found in the clay (5,300 mg/kg in the wetland east of Ash Pond 3). The highest TKN concentration found in the coalwash was 4,200 mg/kg while the highest concentration found in the ash was 1,100 mg/kg. The highest ammonium concentrations were found in the clay material with results ranging between 4.4 mg/kg and 11 mg/kg. Two samples from the ash within the saturated zone at the base of Ash Pond 3 showed similar concentrations to the clay (6.5 mg/kg and 11 mg/kg). It is considered that these ash samples were influenced by being in contact with the saturated zone and are within 0.1 m of the natural clay sediment.

Neutral leachate analyses were conducted on the solid samples using the Australian Standard Leaching Procedure (ASLP). ASLP is a laboratory procedure that has similarities to a process of accelerated weathering, but is certainly not equivalent to natural weathering.

An interpretation of the leachate results is provided in Table 10.

Table 10: Summary of Leachate Results

Aspect	Coalwash	Ash	Clay Soil	Comment
pH of final leachate	6.7 to 8.2	6.8 to 8.0	5.0 to 7.3	Weathering processes in clay soils may generate slightly acidic conditions, which could increase mobility of metals from fill material within the groundwater saturated zone.
Metals	As, Cu , Pb, Zn: higher total, lower leachability	As: higher leachability	Cu, Mo, Zn: higher leachability	Potential mobility of arsenic from ash, but low concentrations in leachate.
Ammonium	Low	Low	Higher	Trigger value for ammonia (measured as ammonium) is 0.91 mg/L for marine species and varies with pH. Adopting the marine trigger value (representing pH 8) would be conservative. Thus, ammonium does not appear to be an issue of concern with any of the materials assessed.
Total Nitrogen	Consistent TKN about 10 times trigger value, but generally lower than from clay soil (considering averages)	Consistent low TKN	Variable TKN	The highest leachate result for TKN (mainly organic nitrogen) is from the clay sample to the east of Ash Pond 3 in the wetland (17 mg/L), compared to the highest concentration in the coalwash (4.6 mg/L) or ash (0.42 mg/L).

Based on leachate results, coalwash appears to have elevated TKN concentrations, similar to the clay.

Ash has the potential to release arsenic as a result of weathering and/or saturation. Further detailed study will be conducted as part of numerical flow and transport modelling to assess the impact of such release because the chemical load of arsenic in ash is low.

It is likely that natural processes within the clay sediment are an important factor influencing ammonium and TKN concentrations on site.

7.3 Proposed Groundwater Modelling

Based on the results and discussion above we propose to simulate the transport of two chemicals, arsenic and ammonium, in the numerical flow and transport modelling.

Based on laboratory results, the source for arsenic will be the ash only. Given the low permeabilities of the clay, the source arsenic body may be described as a constant concentration source but this will be finalised following simple volumetric calculations of total arsenic present in the ash mounds.

It has not been possible to identify the dominant supplier of ammonium to the system (either as ammonium or from degradation of supplied material). Ammonium concentrations on site are likely to be

at least partly due to natural microbiological processes, however these will not be simulated because they are most probably a natural part of the system (rather than anthropogenic) and by definition are not related to the ash ponds or their bund walls. These processes will occur irrespective of the ash ponds. The focus of this study is only simulation of contaminants of concern emanating from the ash ponds and bund walls, therefore, based on laboratory results, the ammonium will be simulated as being sourced from the coalwash bund walls of the ash ponds.

8 CONCLUSIONS

The objective of this assessment by Coffey is to conduct a more detailed and quantitative hydrogeological assessment at the site including numerical groundwater modelling. The assessment will provide more information for the groundwater dependent ecosystem (GDE) study and risk assessment by Eco Logical Australia, including assessing groundwater levels and quality in areas away from the ash ponds such as the wetland area to the east of Ash Pond 3.

This factual report presents additional hydrogeological data collected since December 2010 (groundwater levels, quality and permeability data) as well as laboratory leachate results for coal wash, ash and natural clay material at the site to assess the potential sources of the ammonium and heavy metal concentrations recorded in the groundwater prior to commencement of groundwater flow and transport modelling.

Based on the results of the current assessment, the following conclusions are made:

- Based on hydrograph analysis of groundwater level rises for the main rainfall event in March 2011, groundwater recharge is estimated to range between approximately 8% and 10%.
- Groundwater flow from the ash ponds to the surrounding environment is assessed as being predominantly vertical through the base of the ponds rather than horizontal through the bund walls.
- Vertical hydraulic conductivity values were assessed for the ash material and are around 1 m/day.
- In the long term the maximum seepage rate from the ash ponds would be limited by the vertical hydraulic conductivity of the clay. Movement of groundwater from the base of the ash ponds to receptors such as Duck Creek will be limited by the aquifer properties of the alluvial/estuarine sediments.
- Based on leachate results, coalwash appears to have elevated TKN concentrations, similar to the clay.
- Ash has the potential to release arsenic as a result of weathering and/or saturation. Further detailed study will be conducted as part of numerical flow and transport modelling to assess the impact of such release because the chemical load of arsenic in ash is low.
- It is likely that natural processes within the clay sediment are an important factor influencing ammonium and TKN concentrations on site.

9 RECOMMENDATIONS

Based on the outcomes of the current assessment, the following recommendations are made:

- To better understand the addition of ammonium in the trial period at Tallawarra Power Station (and to help assess whether it is a possible source with current concentration levels) the following information would be useful:
 - The type of ammonium added;
 - The application schedule – the concentration, amount added and time period that it was added; and
 - Approximate placement of the ammoniated ash.
- To assist with modelling of ammonium transport, information on the groundwater sampling methodology conducted by ALS in October 2010 and January 2011 may provide an insight to the reason for significantly lower ammonium concentrations in those results compared to results from the three Coffey sampling rounds conducted.

10 LIMITATIONS

The findings contained in this report are the result of discrete/specific methodologies used in accordance with normal practices and standards. To the best of our knowledge, they represent a reasonable interpretation of the general condition at the areas of the site assessed at the time the investigations were carried out.

Under no circumstances, however, can it be considered that these findings represent the actual state of the site at all points.

This report should be read in conjunction with the attached sheet entitled 'Important Information about Your Coffey Environmental Report'

11 REFERENCES

- Appelo and Postma (2005) *Geochemistry, groundwater and pollution*. 2nd ed. CRC Press, Amsterdam.
- Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (2000) *National Water Quality Management Strategy - Australian and New Zealand Guidelines for Fresh and Marine Water Quality*.
- Barlow and Moench (1999) *WTAQ – A Computer Program for Calculating Drawdowns and Estimating Hydraulic Properties for Confined and Water-Table Aquifers*. Water-Resources Investigations Report 99-4225, US Geological Survey.
- Bewsher Consulting Pty Ltd (2010) *Tallawarra Lands Flood Risk Assessment* (Ref: J1898R_1, dated 27 October 2010).
- Camp Scott Furphy Pty Ltd (1993) *Council of the City of Wollongong and Council of Shellharbour Rural Development Area - On-site Effluent Treatment and Disposal Study*. Wollongong Council, Wollongong.
- Coffey Environments Pty Ltd (2010a) *Geotechnical, Contamination and Groundwater Investigation - Tallawarra Lands, Yallah, NSW* (Ref: ENVIWOLL00250AB-R04, dated 19 August 2010).
- Coffey Environments Pty Ltd (2010b) *Further Assessment of Groundwater Quality – Ash Ponds Tallawarra Lands, Yallah, NSW* (Ref: ENAUWOLL04009AB, dated 13 September 2010).
- Coffey Environments Pty Ltd (2010c) *Preliminary Hydrogeological Assessment – Ash Ponds Tallawarra Lands, Yallah, NSW* (Ref: ENAUWOLL04009AC, dated 23 November 2010).
- Coffey Geosciences Pty Ltd (2002) *Site Contamination Assessment, Tallawarra Power Station, Yallah, NSW* (Ref: E12538/1-AR, dated 2 July 2002).
- Cooper and Jacob (1946) A generalized graphical method for evaluating formation constants and summarizing well field history. *Am. Geophys. Union Trans.*, 27:526-534.
- Eamus (2009) *Identifying Groundwater Dependent Ecosystems – A Guide for Land and Water Managers*. Land & Water Australia, Canberra.
- Earth2Water Pty Ltd (2010) *Groundwater Site Assessment TRUenergy Tallawarra, Yallah, NSW* (Ref: E2W-0124 R001c, dated 20 July 2010).
- Eco Logical Australia Pty Ltd (2010) *Groundwater Dependent Ecosystems at Tallawarra Risk Assessment* (Ref: 10SYDECO-0071, dated 15 November 2010).
- Hvorslev (1951) Time lag and soil permeability in groundwater observations. Bulletin 36, U.S. Army Corps Engineers. Waterways Experimental Station, Vicksburg, Mississippi, 1951.
- Morel and Hering (1993) *Principles and Applications of Aquatic Chemistry*. John Wiley & Sons, Inc., Canada.
- Mudd (2000) *Solute Transport Modelling of Latrobe Valley Ash Disposal Sites*. School of the Built Environment, Faculty of Engineering & Science, Victoria University.
- Muhardi et al (2010) *Engineering Characteristics of Tanjung Bin Coal Ash*, *Electronic Journal of Geotechnical Engineering*.

National Environment Protection Council (NEPC) (1999) Schedule B (1) Guideline on the Investigation Levels for Soil and Groundwater. Guideline forms part of the National Environment Protection (Assessment of Site Contamination) Measure 1999.

NSW Office of Water (NOW) (2010) Draft Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources: Order. May, 2010. NSW Office of Water.

October et al (2009) Hydraulic and Transport Properties of Ash Dumps, 2009 World of Coal Ash (WOCA) Conference. May 2009 Lexington, USA.

Robertson et al (1997) Cone Penetration Testing in Geotechnical Practice. Blackie Academic & Professional.

Warren Lee Urban Design Pty Ltd (2010) Tallawarra Lands TRUenergy: Urban Design Masterplan 26 September 2010.

Yeheyis (2008) Evaluation of Coal Fly Ash for Use in Mine Waste Management. University of Western Ontario.

Important information about your **Coffey** Environmental Report

Uncertainties as to what lies below the ground on potentially contaminated sites can lead to remediation costs blow outs, reduction in the value of the land and to delays in the redevelopment of land. These uncertainties are an inherent part of dealing with land contamination. The following notes have been prepared by Coffey to help you interpret and understand the limitations of your report.

Your report has been written for a specific purpose

Your report has been developed on the basis of a specific purpose as understood by Coffey and applies only to the site or area investigated. For example, the purpose of your report may be:

- To assess the environmental effects of an on-going operation.
- To provide due diligence on behalf of a property vendor.
- To provide due diligence on behalf of a property purchaser.
- To provide information related to redevelopment of the site due to a proposed change in use, for example, industrial use to a residential use.
- To assess the existing baseline environmental, and sometimes geological and hydrological conditions or constraints of a site prior to an activity which may alter the sites environmental, geological or hydrological condition.

For each purpose, a specific approach to the assessment of potential soil and groundwater contamination is required. In most cases, a key objective is to identify, and if possible, quantify risks that both recognised and unrecognised contamination pose to the proposed activity. Such risks may be both financial (for example, clean up costs or limitations to the site use) and physical (for example, potential health risks to users of the site or the general public).

Scope of Investigations

The work was conducted, and the report has been prepared, in response to specific instructions from the client to whom this report is addressed, within practical time and budgetary constraints, and in reliance on certain data and information made available to Coffey. The analyses, evaluations, opinions and conclusions presented in this report are based on those instructions, requirements, data or information, and they could change if such instructions etc. are in fact inaccurate or incomplete.

Subsurface conditions can change

Subsurface conditions are created by natural processes and the activity of man and may change with time. For example, groundwater levels can vary with time, fill may be placed on a site and pollutants may migrate with time. Because a report is based on conditions which existed at the time of the subsurface exploration, decisions should not be based on a report whose adequacy may have been affected by time. Consult Coffey to be advised how time may have impacted on the project and/or on the property.

Interpretation of factual data

Environmental site assessments identify actual subsurface conditions only at those points where samples are taken and when they are taken. Data derived from indirect field measurements and sometimes other reports on the site are interpreted by geologists, engineers or scientists to provide an opinion about overall site conditions, their likely impact with respect to the report purpose and recommended actions. Actual conditions may differ from those inferred to exist, because no professional, no matter how well qualified, can reveal what is hidden by earth, rock and time. The actual interface between materials may be far more gradual or abrupt than assumed based on the facts obtained. Nothing can be done to change the actual site conditions which exist, but steps can be taken to reduce the impact of unexpected conditions. For this reason, parties involved with land acquisition, management and/or redevelopment should retain the services of Coffey through the development and use of the site to identify variances, conduct additional tests if required, and recommend solutions to unexpected conditions or other problems encountered on site.

Important information about your **Coffey** Environmental Report

Your report will only give preliminary recommendations

Your report is based on the assumption that the site conditions as revealed through selective point sampling are indicative of actual conditions throughout an area. This assumption cannot be substantiated until project implementation has commenced and therefore your report recommendations can only be regarded as preliminary. Only Coffey, who prepared the report, is fully familiar with the background information needed to assess whether or not the report's recommendations are valid and whether or not changes should be considered with redevelopment or on-going use of the site. If another party undertakes the implementation of the recommendations of this report there is a risk that the report will be misinterpreted and Coffey cannot be held responsible for such misinterpretation.

Your report is prepared for specific purposes and persons

To avoid misuse of the information contained in your report it is recommended that you confer with Coffey before passing your report on to another party who may not be familiar with the background and the purpose of the report. In particular, a due diligence report for a property vendor may not be suitable for satisfying the needs of a purchaser. Your report should not be applied for any purpose other than that originally specified at the time the report was issued.

Interpretation by other professionals

Costly problems can occur when other professionals develop their plans based on misinterpretations of a report. To help avoid misinterpretations, retain Coffey to work with other professionals who are affected by the report. Have Coffey explain the report implications to professionals affected by them and then review plans and specifications produced to see how they have incorporated the report findings.

Data should not be separated from the report

The report as a whole presents the findings of the site assessment and the report should not be copied in part or altered in any way. Logs, figures, laboratory data, drawings, etc. are customarily included in our reports and are developed by scientists, engineers or geologists based on their interpretation of field logs (assembled by field personnel), field testing and laboratory evaluation of field samples. This information should not under any circumstances be redrawn for inclusion in other documents or separated from the report in any way.

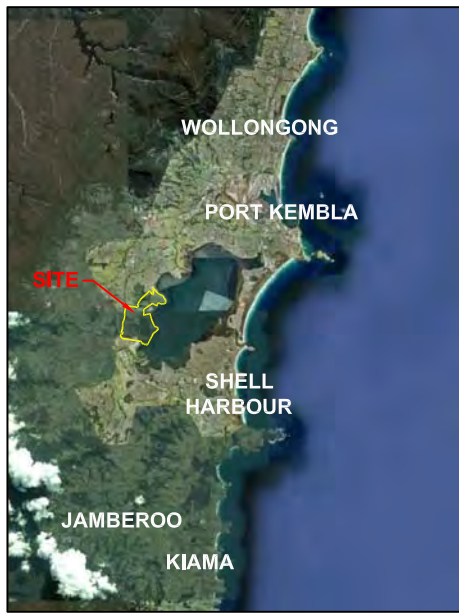
Contact Coffey for additional assistance

Coffey is familiar with a variety of techniques and approaches that can be used to help reduce risks for all parties to land development and land use. It is common that not all approaches will be necessarily dealt with in your environmental site assessment report due to concepts proposed at that time. As a project progresses through planning and design toward construction and/or maintenance, speak with Coffey to develop alternative approaches to problems that may be of genuine benefit both in time and cost.

Responsibility

Environmental reporting relies on interpretation of factual information based on judgement and opinion and has a level of uncertainty attached to it, which is far less exact than other design disciplines. This has often resulted in claims being lodged against consultants, which are unfounded. To help prevent this problem, a number of clauses have been developed for use in contracts, reports and other documents. Responsibility clauses do not transfer appropriate liabilities from Coffey to other parties but are included to identify where Coffey's responsibilities begin and end. Their use is intended to help all parties involved to recognise their individual responsibilities. Read all documents from Coffey closely and do not hesitate to ask any questions you may have.

Figures

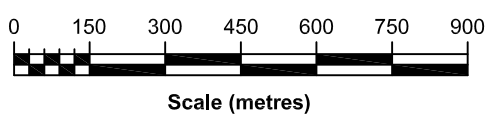


REGIONAL MAP (1:500,000)



LEGEND	
---	APPROXIMATE SITE BOUNDARY
---	AREA OF SITE FOR PROPOSED URBAN OR COMMERCIAL DEVELOPMENT

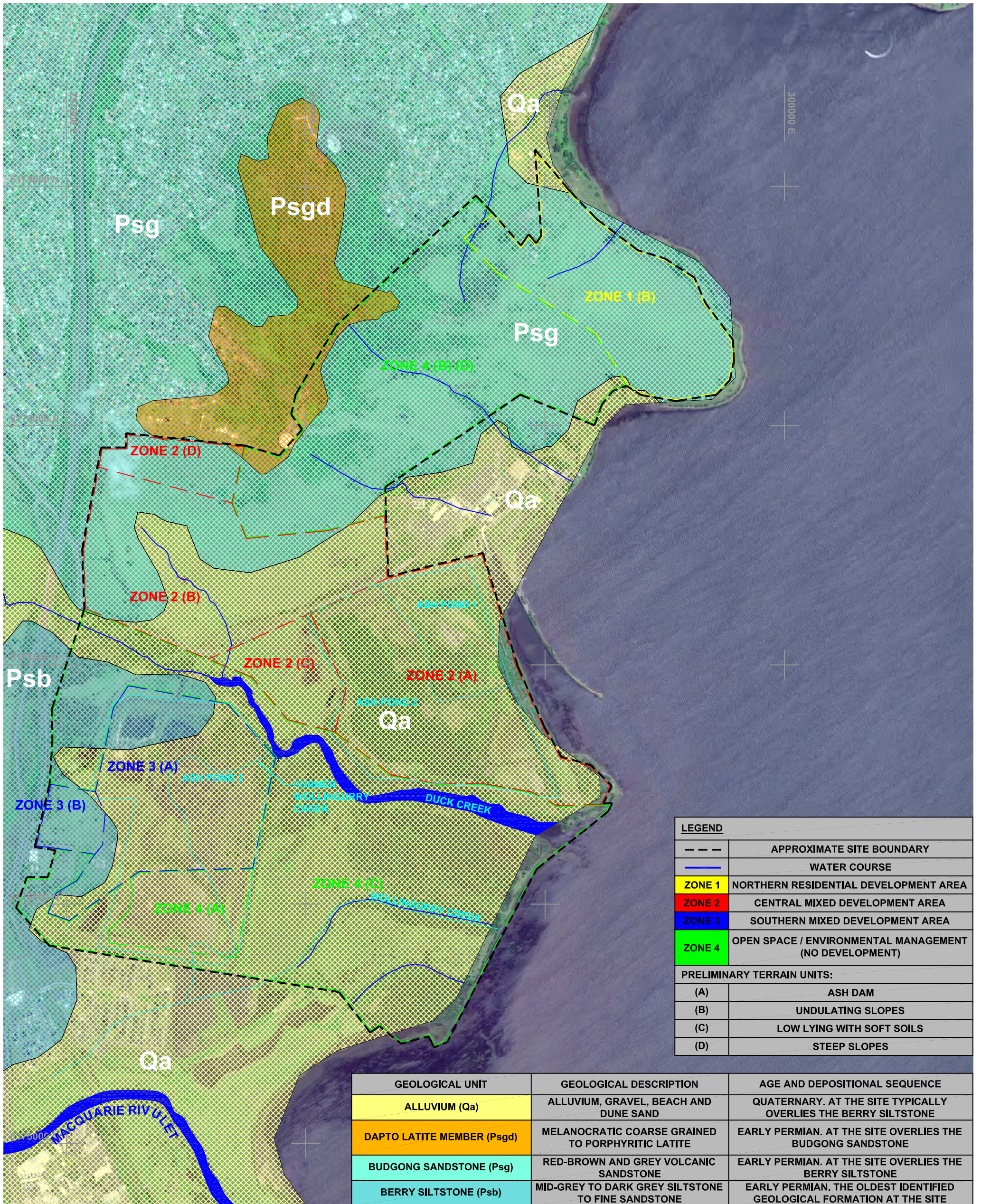
TOPOGRAPHIC IMAGE SOURCE: ALBION PARK 9028-1-N TOPOGRAPHIC MAP 1:25,000 2nd Ed, CENTRAL MAPPING AUTHORITY OF NSW, 1986
 AERIAL IMAGE SOURCE: GOOGLE EARTH PRO 2010
 AERIAL IMAGE ©: DIGITAL GLOBE 2010



drawn	CDC/AW
approved	PT
date	3/05/11
scale	1:15 000
original size	A3

coffey
 environments
 SPECIALISTS IN ENVIRONMENTAL,
 SOCIAL AND SAFETY PERFORMANCE

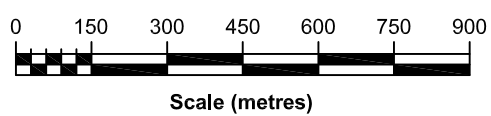
client:	TRUENERGY	
project:	GROUNDWATER MODELLING ASSESSMENT FACTUAL REPORT - ASH PONDS TALLAWARRA LANDS, YALLAH, NSW	
title:	SITE LOCALITY PLAN	
project no:	ENAUWOLL04009AE-R01	figure no: FIGURE 1



LEGEND	
---	APPROXIMATE SITE BOUNDARY
—	WATER COURSE
ZONE 1	NORTHERN RESIDENTIAL DEVELOPMENT AREA
ZONE 2	CENTRAL MIXED DEVELOPMENT AREA
ZONE 3	SOUTHERN MIXED DEVELOPMENT AREA
ZONE 4	OPEN SPACE / ENVIRONMENTAL MANAGEMENT (NO DEVELOPMENT)
PRELIMINARY TERRAIN UNITS:	
(A)	ASH DAM
(B)	UNDULATING SLOPES
(C)	LOW LYING WITH SOFT SOILS
(D)	STEEP SLOPES

GEOLOGICAL UNIT	GEOLOGICAL DESCRIPTION	AGE AND DEPOSITIONAL SEQUENCE
ALLUVIUM (Qa)	ALLUVIUM, GRAVEL, BEACH AND DUNE SAND	QUATERNARY. AT THE SITE TYPICALLY OVERLIES THE BERRY SILTSTONE
DAPTO LATITE MEMBER (Psgd)	MELANOCRATIC COARSE GRAINED TO PORPHYRITIC LATITE	EARLY PERMIAN. AT THE SITE OVERLIES THE BUDGONG SANDSTONE
BUDGONG SANDSTONE (Psg)	RED-BROWN AND GREY VOLCANIC SANDSTONE	EARLY PERMIAN. AT THE SITE OVERLIES THE BERRY SILTSTONE
BERRY SILTSTONE (Psb)	MID-GREY TO DARK GREY SILTSTONE TO FINE SANDSTONE	EARLY PERMIAN. THE OLDEST IDENTIFIED GEOLOGICAL FORMATION AT THE SITE

AERIAL IMAGE SOURCE: WOLLONGONG CITY COUNCIL 2010
 GEOLOGICAL MAP: 1:50,000 KIAMA GEOLOGICAL SERIES SHEET (9028-1, 1st EDITION) PREPARED BY THE NSW DEPARTMENT OF MINES (1974) FOR GEOLOGICAL SURVEY OF NSW



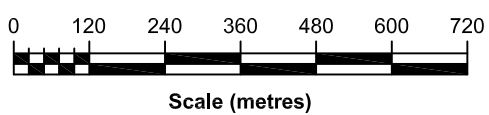
drawn	CDC / MH
approved	PT
date	3/05/11
scale	1:15 000
original size	A3

coffey
 environments
 SPECIALISTS IN ENVIRONMENTAL,
 SOCIAL AND SAFETY PERFORMANCE

client:	TRUENERGY	
project:	GROUNDWATER MODELLING ASSESSMENT FACTUAL REPORT - ASH PONDS TALLAWARRA LANDS, YALLAH, NSW	
title:	SITE LAYOUT PLAN SHOWING GEOLOGY MAP	
project no:	ENAUWOLL04009AE-R01	figure no: FIGURE 2



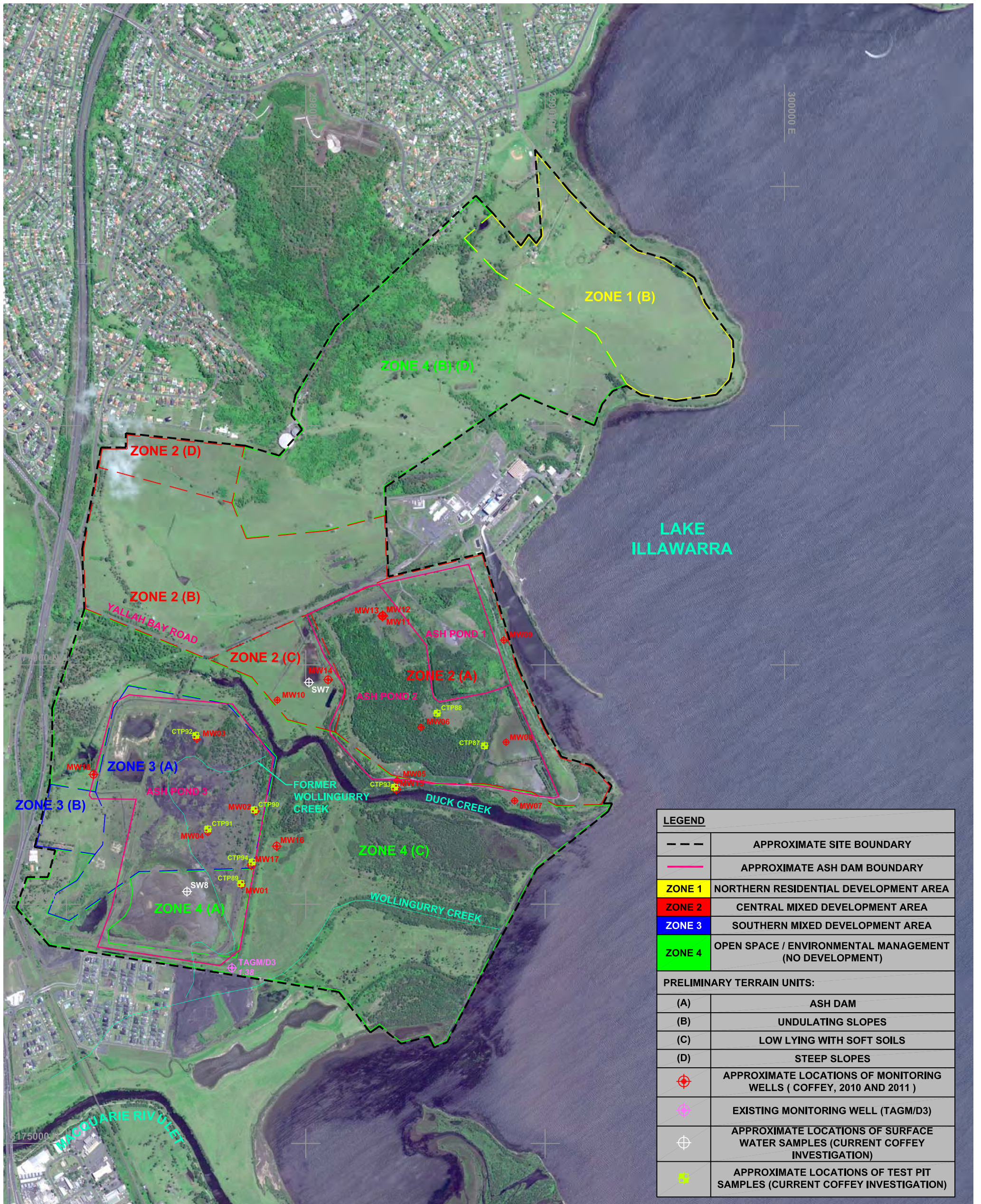
PLAN SOURCE: WARREN LEE URBAN DESIGN PTY LTD, TRUENERGY TALLAWARRA LANDS MASTERPLAN, 17 AUG 2010



drawn	CDC / MH
approved	PT
date	3/05/11
scale	1:12 000
original size	A3

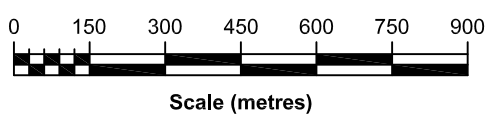


client:	TRUENERGY
project:	GROUNDWATER MODELLING ASSESSMENT FACTUAL REPORT - ASH PONDS TALLAWARRA LANDS, YALLAH, NSW
title:	PROPOSED DEVELOPMENT - CONCEPT MASTERPLAN 17 AUGUST 2010
project no:	ENAUWOLL04009AE-R01
figure no:	FIGURE 3



LEGEND	
---	APPROXIMATE SITE BOUNDARY
---	APPROXIMATE ASH DAM BOUNDARY
ZONE 1	NORTHERN RESIDENTIAL DEVELOPMENT AREA
ZONE 2	CENTRAL MIXED DEVELOPMENT AREA
ZONE 3	SOUTHERN MIXED DEVELOPMENT AREA
ZONE 4	OPEN SPACE / ENVIRONMENTAL MANAGEMENT (NO DEVELOPMENT)
PRELIMINARY TERRAIN UNITS:	
(A)	ASH DAM
(B)	UNDULATING SLOPES
(C)	LOW LYING WITH SOFT SOILS
(D)	STEEP SLOPES
⊕	APPROXIMATE LOCATIONS OF MONITORING WELLS (COFFEY, 2010 AND 2011)
⊕	EXISTING MONITORING WELL (TAGM/D3)
⊕	APPROXIMATE LOCATIONS OF SURFACE WATER SAMPLES (CURRENT COFFEY INVESTIGATION)
⊕	APPROXIMATE LOCATIONS OF TEST PIT SAMPLES (CURRENT COFFEY INVESTIGATION)

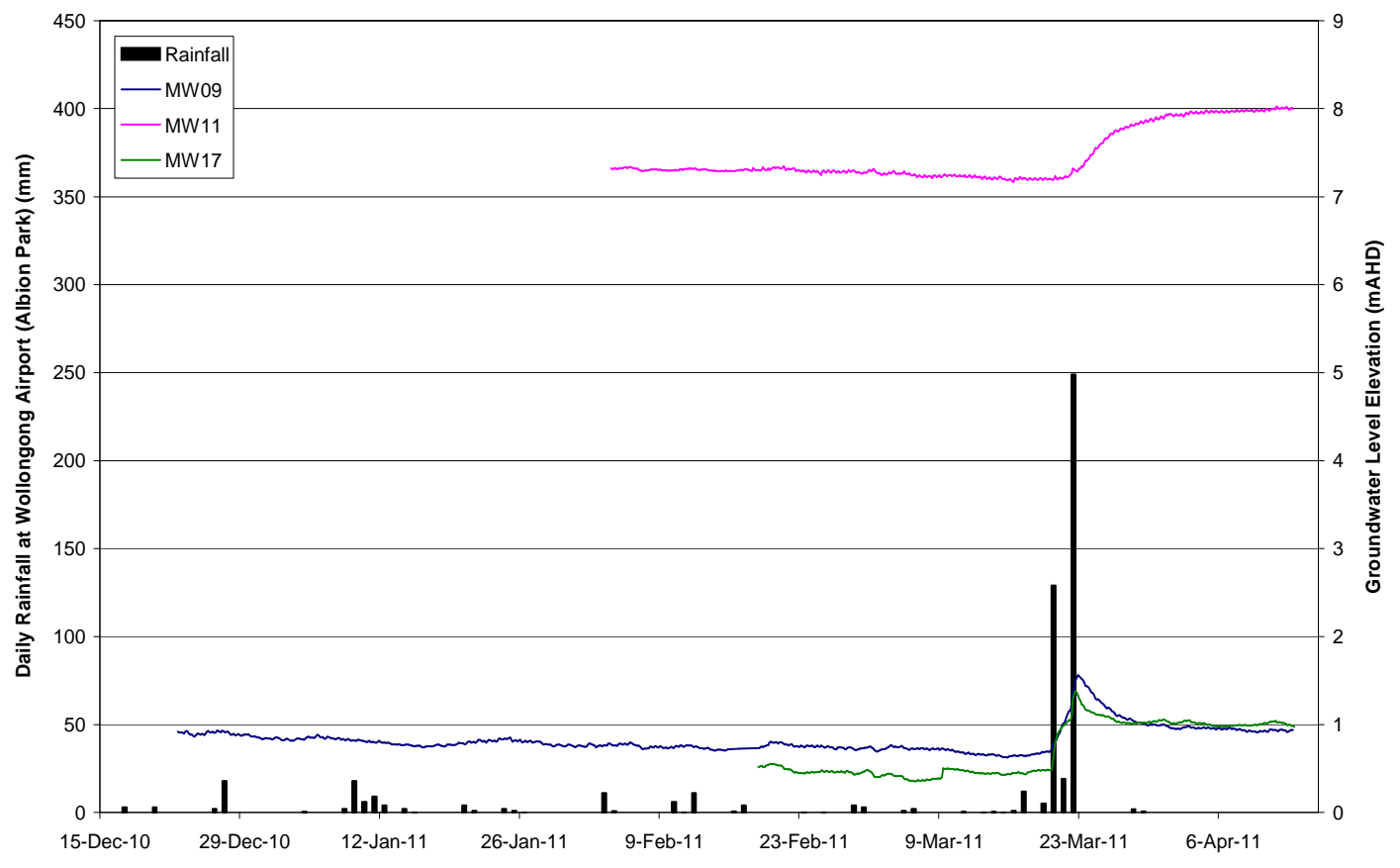
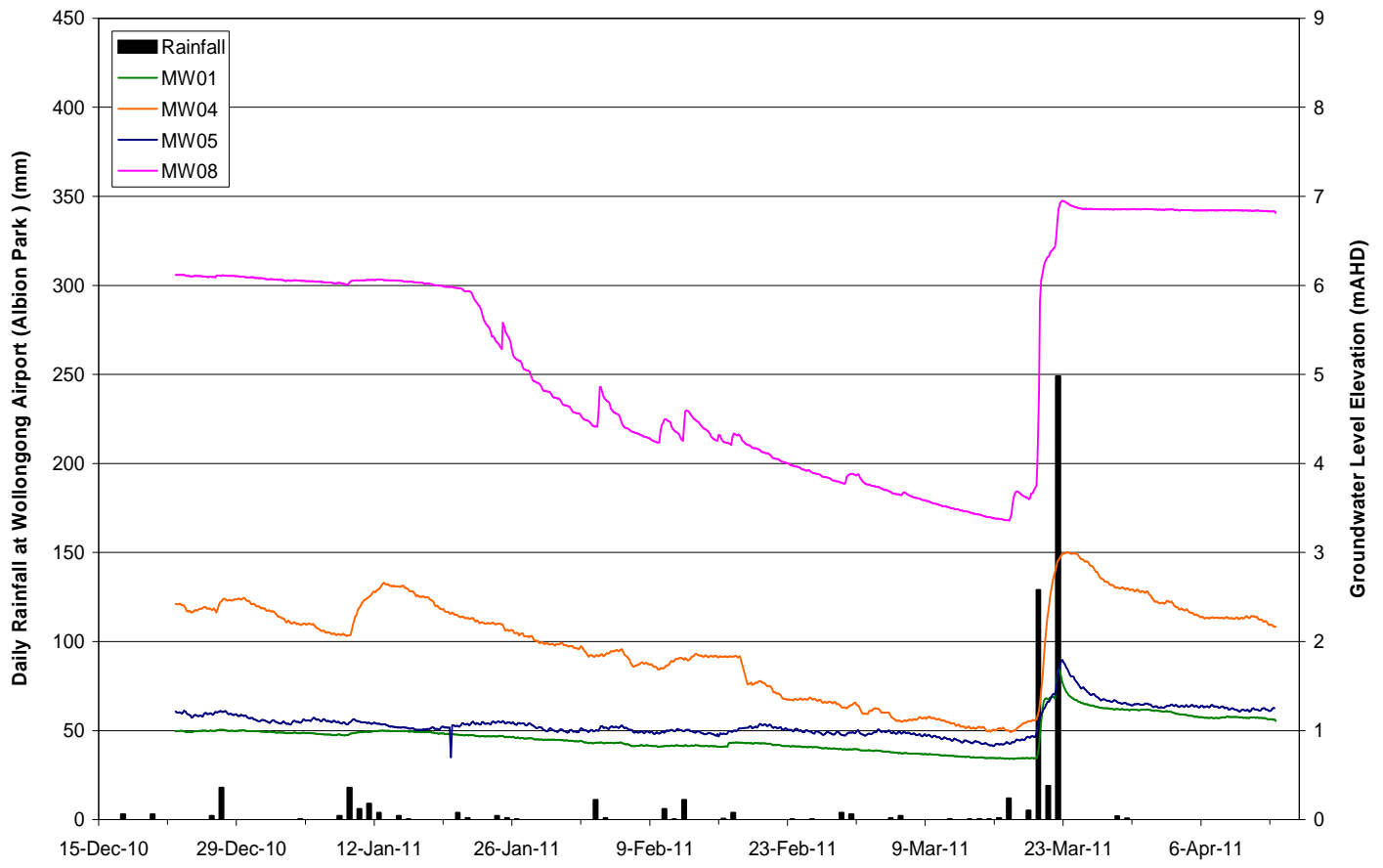
AERIAL IMAGE SOURCE: WOLLONGONG CITY COUNCIL 2010




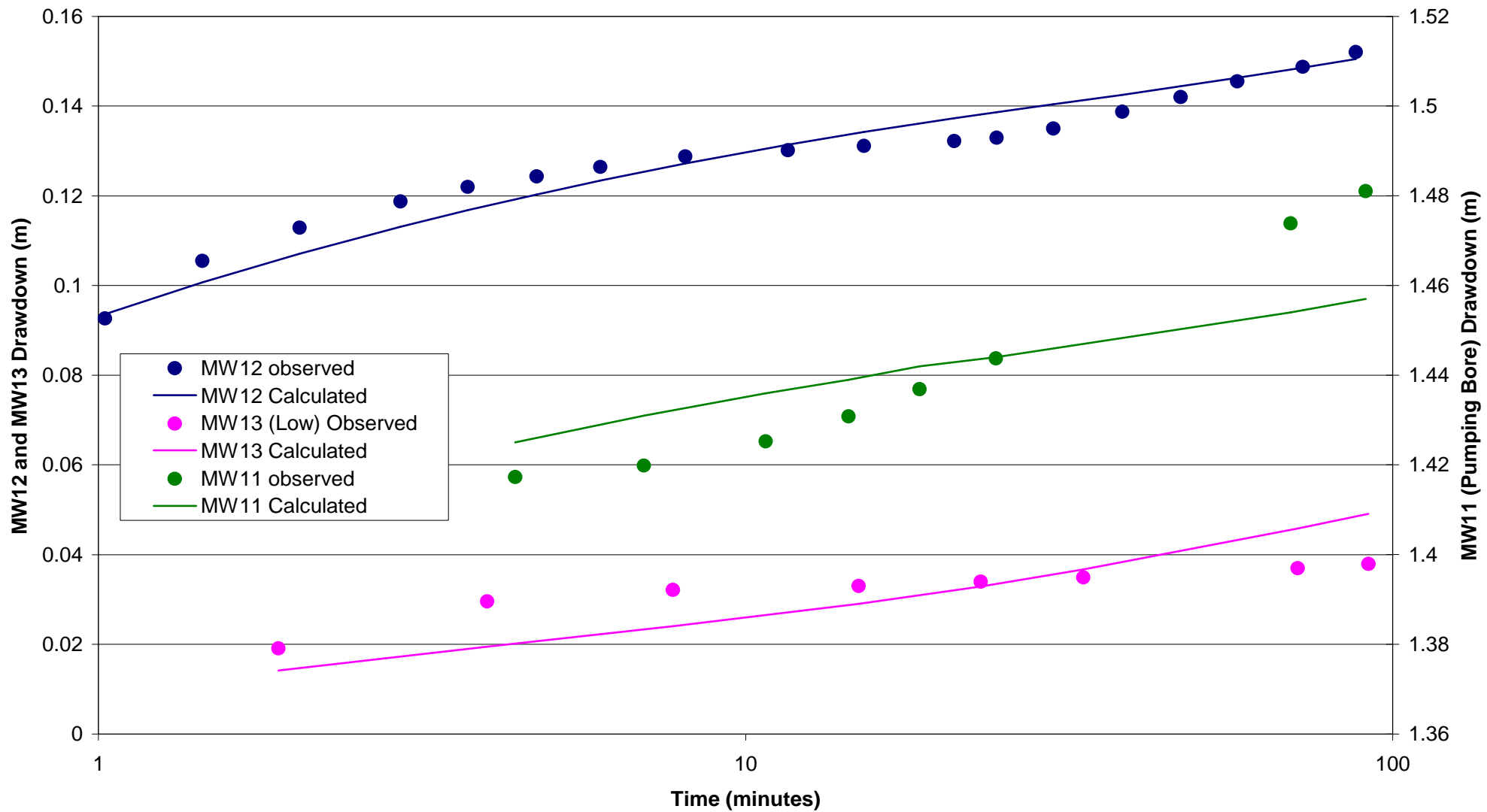
drawn	CDC/AW
approved	PT
date	3/05/11
scale	1:15 000
original size	A3


coffey
environments
SPECIALISTS IN ENVIRONMENTAL,
SOCIAL AND SAFETY PERFORMANCE

client:	TRUENERGY	
project:	GROUNDWATER MODELLING ASSESSMENT FACTUAL REPORT - ASH PONDS TALLAWARRA LANDS, YALLAH, NSW	
title:	GROUNDWATER MONITORING WELL LOCATIONS, SURFACE WATER & SOIL SAMPLE LOCATIONS	
project no:	ENAUWOLL04009AE-R01	figure no: FIGURE 4

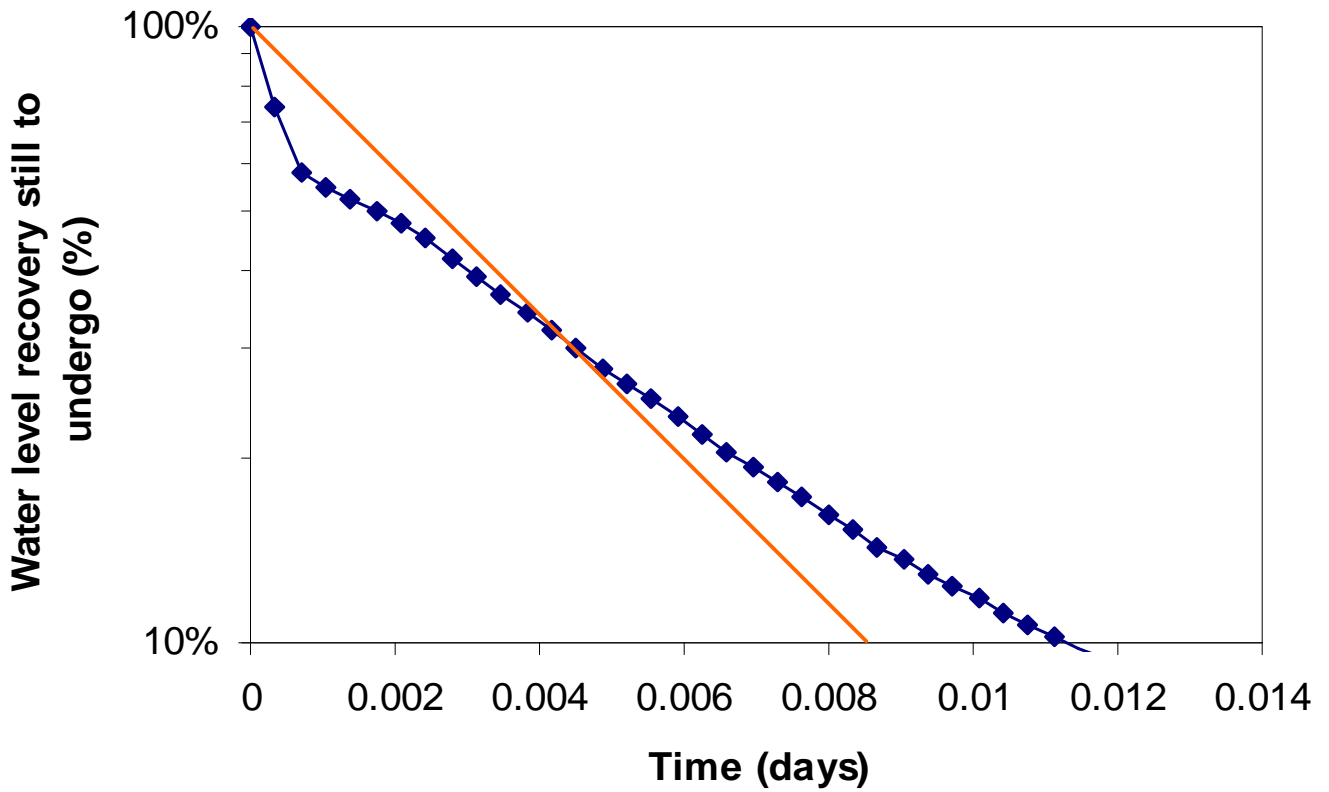


drawn	CDC	 SPECIALISTS IN ENVIRONMENTAL, SOCIAL AND SAFETY PERFORMANCE	client:	TRUenergy
approved	PT		project:	Groundwater Modelling Assessment Factual Report - Ash Ponds Tallawarra Lands, Yallah, NSW
date	2 May 2011		title:	GROUNDWATER HYDROGRAPHS
scale	NA		project no:	ENAUWOLL04009AE-R01
original size	A4		figure no:	FIGURE 5

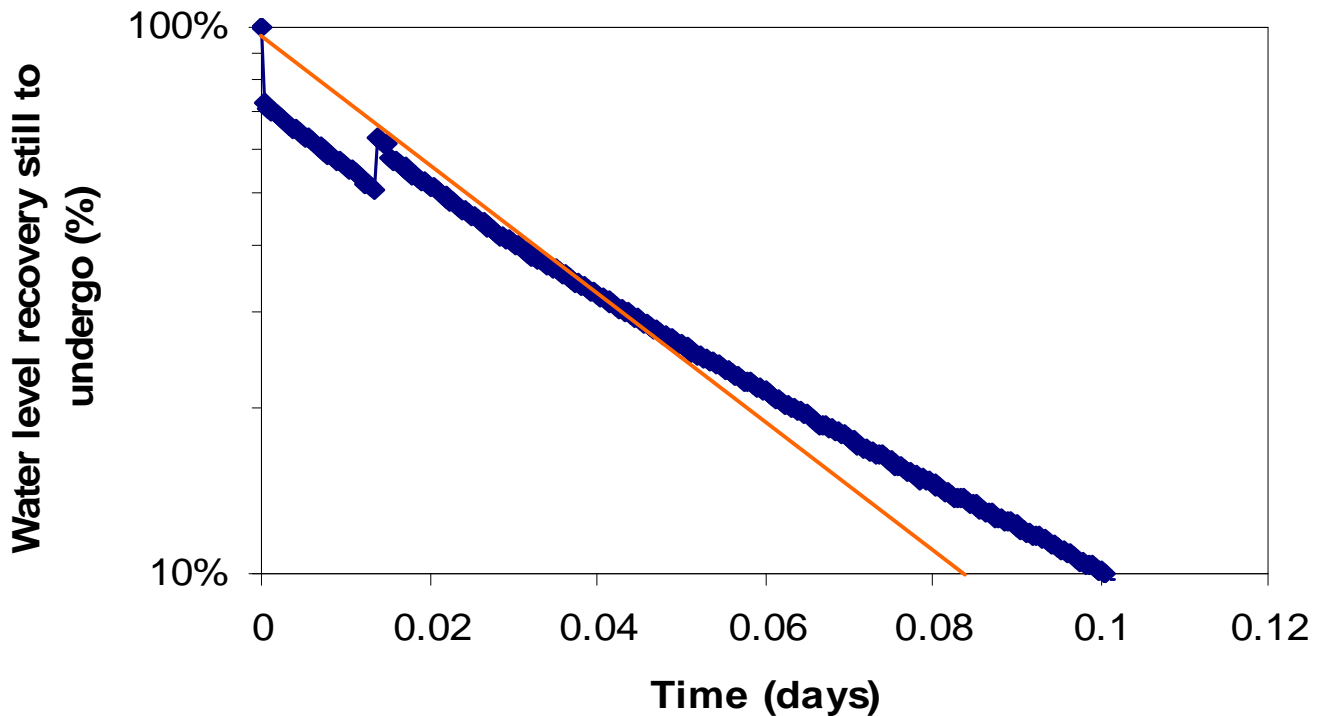


drawn	CDC	 SPECIALISTS IN ENVIRONMENTAL, SOCIAL AND SAFETY PERFORMANCE	client:	TRUenergy
approved	PT		project:	Groundwater Modelling Assessment Factual Report - Ash Ponds Tallawarra Lands, Yallah, NSW
date	2 May 2011		title:	PUMP TEST WTAQ ANALYSIS
scale	N/A		project no:	ENAUWOLL04009AE-R01
original size	A4		figure no:	FIGURE 6

MW05 Slug Test



MW17 Slug Test

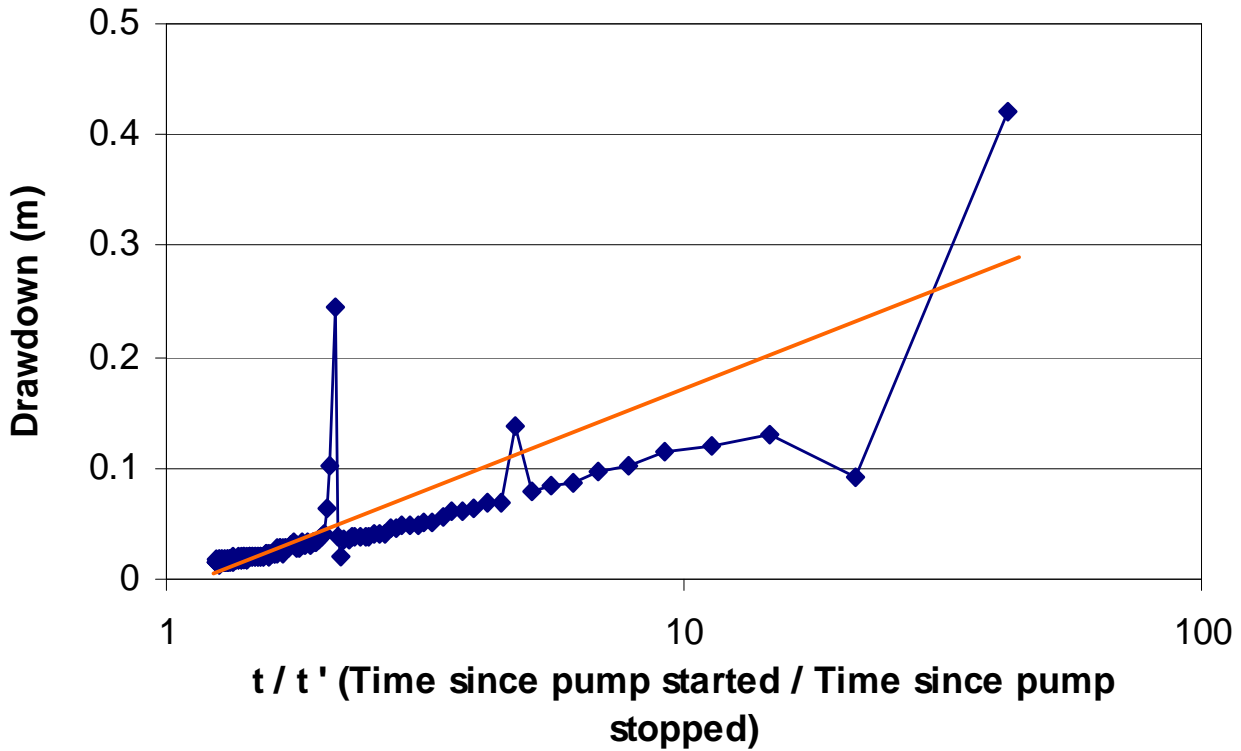


drawn	CDC
approved	PT
date	2 May 2011
scale	NA
original size	A4

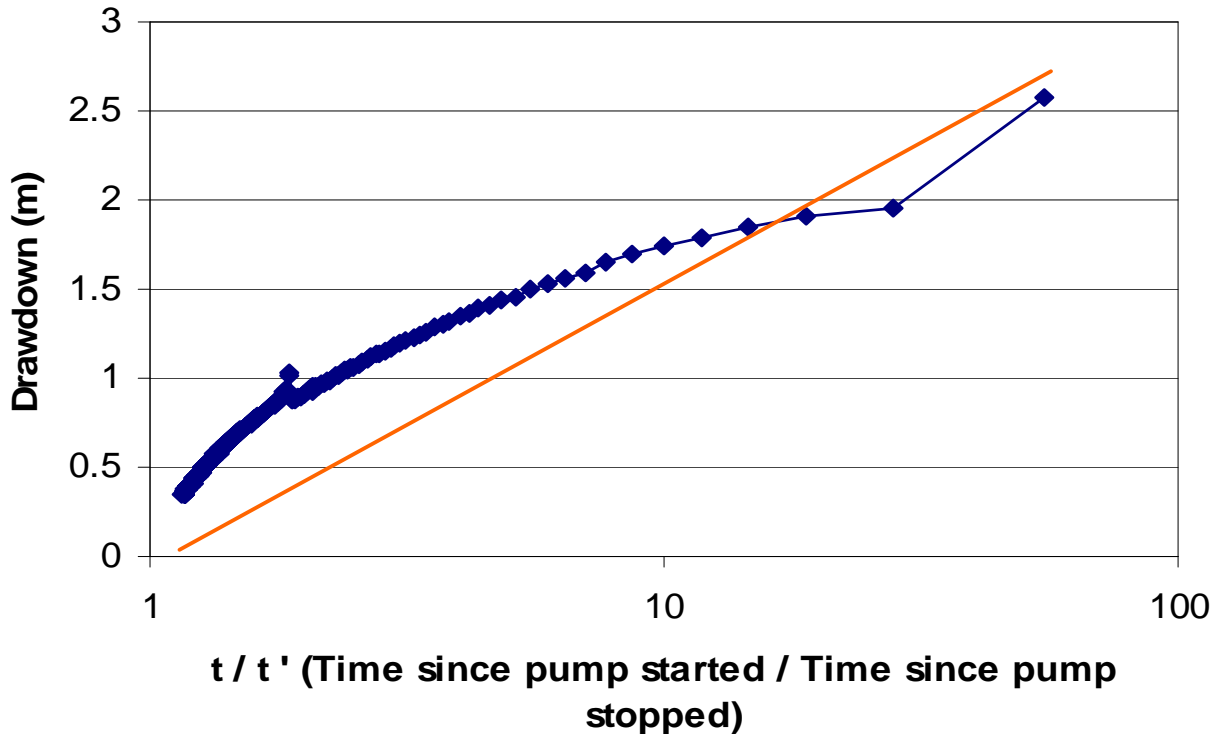



client:	TRUenergy	
project:	Groundwater Modelling Assessment Factual Report - Ash Ponds Tallawarra Lands, Yallah, NSW	
title:	SLUG TEST ANALYSIS HVORSLEV METHOD	
project no:	ENAUWOLL04009AE-R01	figure no: FIGURE 7

MW04 Constant Discharge Test - Recovery Phase



MW09 Constant Discharge Test - Recovery Phase

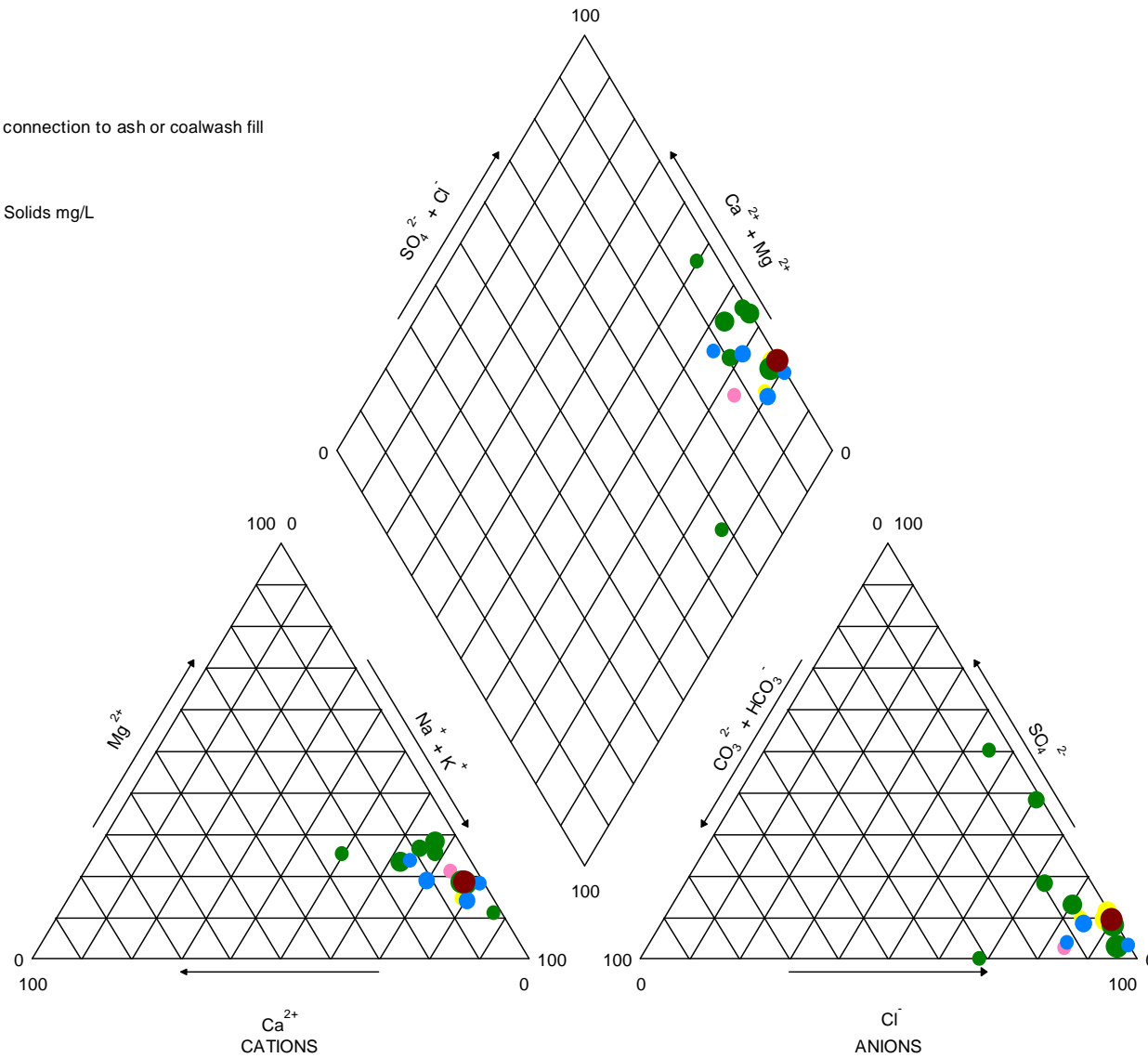


drawn	CDC	 <p>coffey environments</p> <p>SPECIALISTS IN ENVIRONMENTAL, SOCIAL AND SAFETY PERFORMANCE</p>	client:	TRUenergy
approved	PT		project:	Groundwater Modelling Assessment Factual Report - Ash Ponds Tallawarra Lands, Yallah, NSW
date	2 May 2011		title:	CONSTANT DISCHARGE TEST RECOVERY ANALYSIS JACOB METHOD
scale	NA		project no:	ENAUWOLL04009AE-R01
original size	A4		figure no:	FIGURE 8

EXPLANATION

- Residual
- Ash
- Alluvial / Estuarine
- Alluvial / Estuarine with connection to ash or coalwash fill
- Seawater

- 2660 Total Dissolved Solids mg/L
- 35195 Total Dissolved Solids mg/L

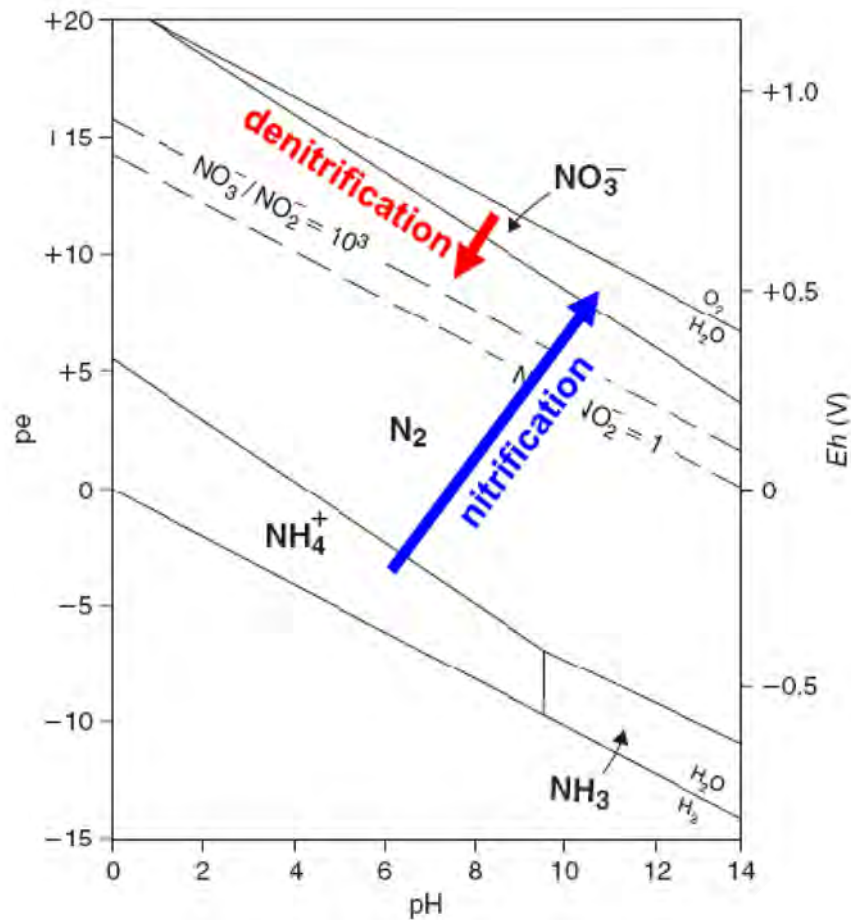
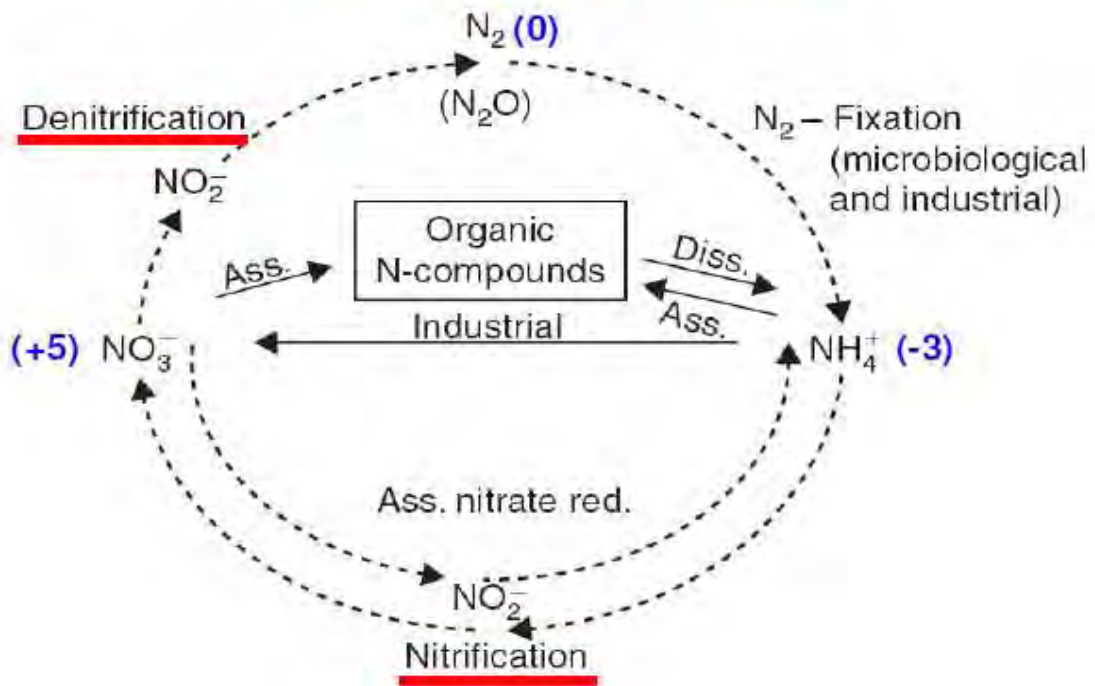


drawn	CDC
approved	PT
date	2 May 2011
scale	N/A
original size	A4



client:	TRUenergy
project:	Groundwater Modelling Assessment Factual Report - Ash Ponds Tallawarra Lands, Yallah, NSW
title:	PIPER PLOT
project no:	ENAUWOLL04009AE-R01
figure no:	FIGURE 9

The nitrogen cycle



drawn	CDC
approved	PT
date	2 May 2011
scale	NA
original size	A4



client:	TRUenergy
project:	Groundwater Modelling Assessment Factual Report - Ash Ponds Tallawarra Lands, Yallah, NSW
title:	PATHWAYS IN REDOX REACTIONS OF NITROGEN
project no:	ENAUWOLL04009AE-R01
figure no:	FIGURE 10

Tables

TABLE LR1:
SUMMARY OF LABORATORY RESULTS FOR GROUNDWATER AND SURFACE WATER SAMPLES
Major Ions, Heavy Metals, Ammonium, Nitrite, Nitrate, Total Kjeldahl Nitrogen and Field Measurements

(All results in µg/L, unless otherwise stated)

Sample ID		MW01	QC03	MW02	MW03	MW04	MW05	QC01	MW06	MW08	MW09	MW10	MW11	MW14	MW15	MW16	MW17	MW18	TAGM/D3	SW7	SW8
Material		Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Surface Water	Surface Water
Unit Screened or Surface Water Location	THRESHOLD CONCENTRATIONS	Alluvial/ Estuarine (Clay) - connected with bund wall coalwash fill	Duplicate of MW01	Alluvial/ Estuarine (Sand) - connected with bund wall coalwash fill	Alluvial/ Residual/ XW Sandstone - connected with ash fill	Alluvial/ Estuarine (Clay) - connected with ash fill	Alluvial/ Estuarine (Clay)	Duplicate of MW05	Fill (Ash)	Fill (Ash)	Alluvial/ Estuarine (Clay)	Alluvial/ Estuarine (Sandy clay)	Fill (Ash)	Alluvial/ Estuarine (Sandy clay)	Alluvial/ Estuarine (Sandy clay)	Alluvial/ Estuarine (Clay)	Alluvial/ Estuarine (Sandy clay)	Residual Clay/XW Sandstone	Alluvial/ Estuarine?	Pond near MW14 west of Ash Pond 2	Lake within Ash Pond 3
Date Sampled		16/02/11	16/02/11	16/02/11	16/02/11	16/02/11	15/02/11	15/02/11	24/02/11	24/02/11	15/02/11	08/03/11	16/02/11	16/02/11	16/02/11	16/02/11	16/02/11	16/02/11	16/02/11	15/02/11	16/02/11
MAJOR CATIONS																					
Calcium (mg/L)		110	-	210	20	280	380	-	480	330	420	440	84	1100	460	330	390	61	27	-	-
Magnesium (mg/L)		130	-	320	270	290	1100	-	1300	910	1500	270	120	1100	1300	840	740	150	110	-	-
Potassium (mg/L)		49	-	170	1.9	82	380	-	590	330	64	25	67	250	520	230	190	1.1	90	-	-
Sodium (mg/L)		640	-	3400	2300	2000	8800	-	10000	7200	6700	1000	1200	5500	10000	4100	3300	1000	1600	-	-
Iron (mg/L)		31	-	6.2	140	93	210	-	16	220	94	84	0.03	6.3	60	0.04	170	<0.02	1.3	-	-
MAJOR ANIONS																					
Bicarbonate Alkalinity as CaCO ₃ (mg/L)		320	-	810	<2	600	240	-	550	54	<2	250	290	1616	1005	1714	160	480	1614	-	-
Carbonate Alkalinity as CaCO ₃ (mg/L)		<2	-	<2	<2	<2	<2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	-	-
Chloride (mg/L)		1300	-	6100	4900	4500	18000	-	19000	14000	16000	1400	2200	12000	21000	7700	5400	1800	2000	-	-
Sulfate (mg/L)		80	-	830	220	610	2200	-	2700	2400	2200	2100	340	2600	850	2600	4600	79	0.6	-	-
TOTAL CATIONS AND ANIONS		2660	-	11846	7852	8455	31310	-	34636	25444	26978	5569	4301	24172	35195	17514	14950	3571	5443	-	-
HEAVY METALS (DISSOLVED)																					
Arsenic	2.3 ^{1b}	7	7	9	4	9	55	49	330	150	52	3	4	1	3	<4	<2	<1	<1	1	7
Cadmium	0.7 ^{1c}	<0.5	<0.5	<1	<1	<1	<0.5	<0.5	<2	<2	<0.5	<0.1	<0.5	<0.5	<0.5	<2	<1	<0.5	<0.5	<0.5	<0.5
Chromium	27.4 ^{1d}	<5	<5	<10	<10	<10	<5	<5	<20	330	<5	<1	<5	<5	<5	<20	<10	<5	<5	<5	<5
Copper	1.3 ¹	<0.5	<0.5	<1	6	<1	50	38	<2	7	33	<1	<0.5	<0.5	<0.5	<2	6	1	<0.5	<0.5	<0.5
Lead	4.4 ¹	<0.5	<0.5	<1	11	<1	7	6	<2	<2	9	<1	5	<0.5	<0.5	<2	8	1	<0.5	<0.5	<0.5
Molybdenum	23 ^{1a}	1	2	<2	<2	5	1	<1	110	12	<1	<1	27	4	2	9	2	2	<1	<1	9
Nickel	7 ^{1c}	5	5	<10	52	37	5	6	66	2400	<5	4	<5	<5	<5	<20	31	<5	<5	<5	<5
Zinc	15 ¹	67	52	54	230	88	73	69	49	90	160	57	19	30	40	40	150	67	32	30	43
NUTRIENTS																					
Ammonium (NH ₄ ⁺) as N	140-5960 ³	2200	2300	910	570	5200	9200	10000	5600	2000	1300	1500	330	15000	20000	1600	8500	50	17000	80	330
Nitrate as N	700 ^{1e}	<50	<10	<50	<50	<50	<250	<250	<250	<250	<250	<25	<25	<250	<250	<50	<50	39	<25	<25	<25
Nitrite as N		<5	6	<5	<5	<5	<5	<5	50	<5	<5	<5	<5	<5	<5	<5	5	<5	<5	<5	<5
Total Kjeldahl Nitrogen		3400	3600	4600	1200	9000	12000	10500	7200	7600	2600	3800	810	17000	42000	17000	9200	690	17000	4800	6700
Total Nitrogen (by calc.)	300 ²	3400	3600	4600	1200	9000	12000	10500	7250	7600	2600	3800	810	17000	42000	17000	9200	730	17000	4800	6700
FIELD MEASUREMENTS																					
Dissolved Oxygen (mg/L)		4.5	4.5	5.0	2.6	2.9	4.0	4.0	2.3	0.9	3.5	1.5	1.9	3.2	4.0	5.5	5.6	4.1	2.9	8.0	6.9
Electrical conductivity (mS/cm)		4.60	4.60	13.10	10.54	11.00	34.60	34.60	46.80	29.70	30.70	7.15	5.00	26.70	40.00	16.84	14.01	4.08	7.23	6.04	5.85
pH (Units)	7.0-8.5 ²	6.5	6.5	7.0	4.2	6.6	6.1	6.1	7.2	6.1	4.2	5.2	8.2	6.6	6.5	7.5	6.6	7.2	7.3	8.1	8.8
Er Redox (mV) ⁴		-100	-100	-140	238	-98	-17	-17	-73	-4	245	73	-52	-89	-90	76	-54	82	-150	-56	20
Eh Redox (mV) ⁵		99	99	59	437	101	182	182	126	195	444	272	147	110	109	275	145	281	49	143	219
Temp (°C)		22.6	22.6	20.1	20.4	22.6	18.1	18.1	19.5	21.8	18.8	19	20.1	19.9	20.0	21.6	19.7	20.6	22.1	26.6	32.3

NOTES:

- Bold** Concentration exceeds the Threshold Criteria
- ¹ Based on ANZECC/ARMCANZ (2000), Australian and New Zealand Guidelines For Fresh and Marine Water Quality (Marine water, South Eastern Australia, slightly to moderately disturbed system, 95% of species protected)
- ^{1a} Low reliability trigger values
- ^{1b} Low reliability trigger value for As(III) used
- ^{1c} Recommended 99% protection level used
- ^{1d} Based on the Chromium (III) trigger value
- ^{1e} Based on the freshwater trigger value
- ² ANZECC (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Table 3.3.2 (Estuarine trigger value)
- ³ ANZECC (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Table 8.3.7 (Marine trigger values, range is pH dependent as ammonia dominates at pH values > 9)
- ⁴ Er is oxidation reduction potential as measured with a platinum electrode and silver/silver chloride reference electrode (saturated KCl)
- ⁵ Eh is converted oxidation reduction potential relative to the standard hydrogen electrode (Eh = Er + 199 mV).
- Not Analysed
- See original laboratory reports for detection limits

TABLE LR2:
SUMMARY OF LABORATORY RESULTS FOR GROUNDWATER AND SURFACE WATER SAMPLES FOR PREVIOUS AND CURRENT COFFEY INVESTIGATIONS
Heavy Metals, Ammonium, Nitrite, Nitrate, Total Kjeldahl Nitrogen and Field Measurements

(All results in µg/L, unless otherwise stated)

Sample ID Material	THRESHOLD CONCENTRATIONS	MW01 Groundwater			MW02 Groundwater			MW03 Groundwater			MW04 Groundwater			MW05 Groundwater			MW06 Groundwater			MW08 Groundwater		
		Alluvial/Estuarine (Clay) - connected with bund wall coalwash fill			Alluvial/Estuarine (Sand) - connected with bund wall coalwash fill			Alluvial/Residual/ XW Sandstone - connected with ash fill			Alluvial/Estuarine (Clay) - connected with ash fill			Alluvial/Estuarine (Clay)			Fill (Ash)			Fill (Ash)		
		25-Jun-10	25-Aug-10	16-Feb-11	25-Jun-10	25-Aug-10	16-Feb-11	25-Jun-10	24-Aug-10	16-Feb-11	25-Jun-10	24-Aug-10	16-Feb-11	24-Jun-10	24/08/2010	16-Feb-11	24-Jun-10	25-Aug-10	24-Feb-11	24-Jun-10	25-Aug-10	24-Feb-11
HEAVY METALS (DISSOLVED)																						
Arsenic	2.3 ^{1b}	<10	4	7	<10	10	9	<10	4	4	<10	5	9	23	13	55	190	110	330	73	30	150
Cadmium	0.7 ^{1c}	<1	-	<0.5	<1	-	<1	<1	-	<1	<1	-	<1	<1	-	<0.5	<1	<2	<1	-	<2	
Chromium	27.4 ^{1d}	<10	-	<5	<10	-	<10	<10	-	<10	<10	-	<10	<10	-	<5	<10	<20	<10	-	330	
Copper	1.3 ¹	<10	<1	<0.5	<10	<1	<1	<10	<1	6	<10	3	<1	32	12	50	29	<1	<2	29	7	
Lead	4.4 ¹	<10	-	<0.5	<10	-	<1	<10	-	11	<10	-	<1	<10	-	7	<10	<2	<2	<10	<2	
Molybdenum	23 ^{1a}	-	-	1	-	-	<2	-	-	<2	-	-	5	-	-	1	-	-	110	-	12	
Nickel	7 ^{1c}	<10	5	5	<10	4	<10	44	45	52	<10	11	37	13	12	5	26	76	66	200	87	2400
Zinc	15 ¹	94	57*	67	63	53	54	130	170	230	110	69	88	100	87	73	140	61	49	130	81	90
NUTRIENTS																						
Ammonium (NH ₄ ⁺) as N	140-5960 ³	11000	12000	2200	870	950	910	330	390	570	6500	7300	5200	10000	12000	9200	6300	6700	5600	1600	1300	2000
Nitrate as N	700 ^{1e}	-	70*	<50	-	<100	<50	-	<50	<50	-	<50	<50	-	<250	<250	-	<250	<250	-	450	<250
Nitrite as N	-	-	30*	<5	-	<5	<5	-	<5	<5	-	<5	<5	-	<5	<5	-	120	50	-	42	<5
Total Kjeldahl Nitrogen	-	-	3400	-	-	4600	-	-	1200	-	-	9000	-	-	12000	-	-	7200	-	-	7600	-
Total Nitrogen (by calc.)	300 ²	-	-	3400	-	-	4600	-	-	1200	-	-	9000	-	-	12000	-	-	7250	-	-	7600
FIELD MEASUREMENTS																						
Dissolved Oxygen (mg/L)	-	2.6	5.4	4.5	3.0	4.9	5.0	2.1	4.9	2.6	2.0	4.7	2.9	3.9	4.4	4.0	3.7	6.4	2.3	4.6	8.1	0.9
Electrical conductivity (mS/cm)	-	8.07	23.80	4.60	17.65	18.76	13.10	9.92	11.12	10.54	12.07	12.11	11.00	46.20	48.60	34.60	31.80	53.80	46.80	26.40	26.00	29.70
pH (Units)	7.0-8.5 ²	7.3	7.1	6.5	7.2	7.1	7.0	5.2	4.8	4.2	6.4	6.4	6.6	6.5	6.6	6.1	6.8	7.0	7.2	6.8	6.4	6.1
Er Redox (mV) ⁴	-	-116	-63	-100	-96	-104	-140	108	126	238	-59	-89	-98	-73	-68	-17	3	-40	-73	-17	-42	-4
Eh Redox (mV) ⁵	-	83	136	99	103	95	59	307	325	437	140	110	101	126	131	182	202	159	126	182	157	195
Temp (°C)	-	20.8	19.0	22.6	20.0	17.0	20.1	20.5	19.0	20.4	20.7	18.2	22.6	18.3	17.4	18.1	15.3	13.5	19.5	18.5	14.1	21.8

Sample ID Material	THRESHOLD CONCENTRATIONS	MW09 Groundwater			MW10 Groundwater		MW11 Groundwater	MW14 Groundwater	MW15 Groundwater	MW16 Groundwater	MW17 Groundwater	MW18 Groundwater	TAGM/1 Groundwater	TAGM/3 Groundwater	SW1 Surface Water	SW2 Surface Water	SW3 Surface Water	SW4 Surface Water	SW5 Surface Water	SW6 Surface Water	SW7 Surface Water	SW8 Surface Water
		Alluvial/Estuarine (Clay)			Alluvial/Estuarine (Sandy clay)		Fill (Ash)	Alluvial/Estuarine (Sandy clay)	Alluvial/Estuarine (Sandy clay)	Alluvial/Estuarine (Clay)	Alluvial/Estuarine (Sandy clay)	Residual Clay/XW Sandstone	Alluvial?	Alluvial/Estuarine?	-	-	-	-	-	-	-	-
		24-Jun-10	25-Aug-10	15-Feb-11	24-Aug-10	08-Mar-11	16-Feb-11	16-Feb-11	16-Feb-11	16-Feb-11	16-Feb-11	16-Feb-11	24-Aug-10	16-Feb-11	24-Aug-10	24-Aug-10	24-Aug-10	24-Aug-10	25-Aug-10	25-Aug-10	15-Feb-11	16-Feb-11
HEAVY METALS (DISSOLVED)																						
Arsenic	2.3 ^{1b}	17	21	52	3	3	4	1	3	<4	<2	<1	2	<1	2	7	7	7	8	8	1	7
Cadmium	0.7 ^{1c}	<1	-	<0.5	-	<0.1	<0.5	<0.5	<0.5	<2	<1	<0.5	-	<0.5	-	-	-	-	-	-	<0.5	<0.5
Chromium	27.4 ^{1d}	<10	-	<5	<1	<1	<5	<5	<5	<20	<10	<5	<5	<5	-	-	-	-	-	<5	<5	
Copper	1.3 ¹	35	6	33	<1	<1	<0.5	<0.5	<0.5	<2	6	1	67	<0.5	2	<1	<1	<1	<1	<1	<0.5	<0.5
Lead	4.4 ¹	21	-	9	-	<1	5	<0.5	<2	8	1	-	<0.5	-	-	-	-	-	-	<0.5	<0.5	
Molybdenum	23 ^{1a}	-	-	<1	-	<1	27	4	2	9	2	-	<1	-	-	-	-	-	-	<1	9	
Nickel	7 ^{1c}	59*	49	<5	14	4	<5	<5	<5	<20	31	<5	14	<5	5	11	10	11	11	11	<5	<5
Zinc	15 ¹	170	270	160	47	57	19	30	40	40	150	67	490	32	76	25	41	37	29	20	30	43
NUTRIENTS																						
Ammonium (NH ₄ ⁺) as N	140-5960 ³	1200	1300	1300	430	1500	330	15000	20000	1600	8500	50	11	17000	100	340	250	250	230	200	80	330
Nitrate as N	700 ^{1e}	-	<250	<250	<25	<25	<25	<250	<250	<50	<50	39	12000	<25	8	<250	<250	<250	<250	<250	<25	<25
Nitrite as N	-	-	<5	<5	<5	<5	<5	<5	<5	<5	<5	5	670	<5	<5	<5	<5	<5	<5	<5	<5	<5
Total Kjeldahl Nitrogen	-	-	-	2600	-	3800	810	17000	42000	17000	9200	690	-	17000	-	-	-	-	-	-	4800	6700
Total Nitrogen (by calc.)	300 ²	-	-	2600	-	3800	810	17000	42000	17000	9200	730	-	17000	-	-	-	-	-	-	4800	6700
FIELD MEASUREMENTS																						
Dissolved Oxygen (mg/L)	-	6.2	5.5	3.5	5.6	1.5	1.9	3.2	4.0	5.5	5.6	4.1	0.9	2.9	8.9	7.9	7.5	8.3	9.6	10.7	8.0	6.9
Electrical conductivity (mS/cm)	-	37.50	40.30	30.70	7.49	7.15	5.00	26.70	40.00	16.84	14.01	4.08	0.55	7.23	11.00	44.80	45.20	46.70	50.10	51.80	6.04	5.85
pH (Units)	7.0-8.5 ²	4.2	4.1	4.2	6.4	5.2	8.2	6.6	6.5	7.5	6.6	7.2	5.4	7.3	7.6	8.2	8.2	8.3	8.3	6.5	8.1	8.8
Er Redox (mV) ⁴	-	199	228	245	-29	73	-52	-89	-90	76	-54	82	29	-150	52	77	60	20	152	161	-56	20
Eh Redox (mV) ⁵	-	398	427	444	170	272	147	110	109	275	281	228	49	251	276	259	219	351	360	143	219	219
Temp (°C)	-	18.7	12.2	18.8	15.0	19	20.1	19.9	20.0	21.6	19.7	20.6	15.3	22.1	14.7	16.7	15.1	14.4	19.8	19.0	26.6	32.3

NOTES:

- Bold** Concentration exceeds the Threshold Criteria
- ¹ Based on ANZECC/ARMCANZ (2000), Australian and New Zealand Guidelines For Fresh and Marine Water Quality (Marine water, South Eastern Australia, slightly to moderately disturbed system, 95% of species protected)
- ^{1a} Low reliability trigger values
- ^{1b} Low reliability trigger value for As(III) used
- ^{1c} Recommended 99% protection level used
- ^{1d} Based on the Chromium (III) trigger value
- ^{1e} Based on the freshwater trigger value
- ² ANZECC (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Table 3.3.2 (Estuarine trigger value)
- ³ ANZECC (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Table 8.3.7 (Marine trigger values, range is pH dependent as ammonia dominates at pH values > 9)
- ⁴ Er is oxidation reduction potential as measured with a platinum electrode and silver/silver chloride reference electrode (saturated KCl)
- ⁵ Eh is converted oxidation reduction potential relative to the standard hydrogen electrode (Eh = Er + 199 mV).
- Not Analysed
- See original laboratory reports for detection limits
- * Field or laboratory duplicate sample which was higher than the primary sample concentration

**TABLE LR3:
SUMMARY OF LABORATORY RESULTS FOR COALWASH, ASH AND SOIL SAMPLES
Heavy Metals, Ammonium, Nitrite, Nitrate and Total Kjeldahl Nitrogen
Soil and Leachate Water Results**

Sample ID	Units	LOR	THRESHOLD CONCENTRATIONS				CTP87/ 0.5-0.6	CTP87/ 1.4-1.6	CTP89/ 0.5-0.6	CTP89/ 1.8-2.0	QC2 (Duplicate of CTP89/ 1.8-2.0)	CTP90/ 0.5-0.6	CTP90/ 1.8-2.0	CTP88/ 0.6-0.8	CTP88/ 3.5-3.7	CTP91/ 0.6-0.8	QC3 (Duplicate of CTP91/ 0.6-0.8)	CTP91/ 1.6-1.8	CTP92/ 0.6-0.8	CTP92/ 1.0-1.1	CTP93/ 0.6-0.7	QC1 (Duplicate of CTP93/ 0.6-0.7)	CTP94/ 0.4-0.5	CTP94/ 0.8-1.0	
			ANZECC (2000)	HIL (NEHF A)	HIL (NEHF E)	HIL (NEHF F)	EIL	Coalwash	Coalwash	Coalwash	Coalwash	Coalwash	Coalwash	Ash	Ash	Ash	Ash	Ash	Ash	Ash	Soil (Clay)	Soil (Clay)	Soil (Clay)	Soil (Clay)	
Soil Results																									
HEAVY METALS																									
Arsenic	mg/kg	<3		100 ¹	200 ¹	500 ¹	20 ¹	9	12	5	<3	<3	15	<3	6	9	<3	<3	4	5	<3	<3	<3	5	<3
Cadmium	mg/kg	<0.3		20 ¹	40 ¹	100 ¹	3 ¹	0.7	0.5	0.4	0.5	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	
Chromium	mg/kg	<0.3		120,000 ^{1a}	240,000 ^{1a}	600,000 ^{1a}	400 ^{1a}	1.8	1.8	50	1.7	1.4	1.8	1.4	5.4	4.1	4.5	4.4	5.3	5.3	5.3	5	5.5	22	14
Copper	mg/kg	<0.5		1,000 ¹	2,000 ¹	5,000 ¹	100 ¹	17	21	22	21	22	23	19	9.1	5.2	5.7	5.7	6.8	6.5	5.8	9.2	7.8	46	12
Lead	mg/kg	<1		300 ¹	600 ¹	1,500 ¹	600 ¹	22	23	15	15	15	14	17	4	3	3	3	4	4	3	4	3	47	5
Molybdenum	mg/kg	<1						1.4	1.2	1.7	1.6	<1	1.1	<1	<1	<1	<1	1.2	<1	<1	2.2	1.8	2.3	1.2	
Nickel	mg/kg	<0.5		600 ¹	600 ¹	3,000 ¹	60 ¹	5.9	6.1	32	8.2	8.3	8.4	8.1	6.3	6.2	3.8	3.9	4	4.4	3.8	0.8	0.94	15	2.2
Zinc	mg/kg	<0.5		7,000 ¹	14,000 ¹	35,000 ¹	200 ¹	66	65	39	45	60	60	29	13	15	11	12	12	12	11	3.4	4	39	10
NUTRIENTS																									
Ammonium (NH ₄ ⁺) as N	mg/kg	<0.15						0.84	0.37	0.73	0.54	0.55	0.55	0.48	0.4	1.6	<0.15	0.15	11	0.54	6.5	11	6.7	4.4	11
Nitrate as N	mg/kg	<0.025						0.16	0.24	0.081	0.11	0.11	0.069	0.13	0.33	<0.025	0.06	0.062	0.037	<0.125	<0.125	<0.050	<0.050	0.17	<0.025
Nitrite as N	mg/kg	<0.025						0.03	0.03	0.03	0.03	0.03	0.04	0.03	<0.025	0.08	<0.025	0.04	0.07	0.06	0.05	0.04	0.05	0.04	0.04
Total Kjeldahl Nitrogen	mg/kg	<40						2800	1900	4200	2300	3100	3300	2400	1100	790	550	300	490	280	300	420	600	5300	450
Total Nitrogen (by calc.)	mg/kg	<20						2800	1900	4200	2300	3100	3300	2400	1100	790	550	300	490	280	300	420	600	5300	450
Leachate Results (ASLP⁵)																									
pH of Final Leachate	pH units	<0						7.7	6.8	7.0	6.8	8.2	6.7	6.7	6.9	6.8	7.9	7.7	8.0	7.8	7.2	7.3	7.3	5.0	5.0
HEAVY METALS (ASLP)																									
Arsenic	µg/L	<1	2.3 ^{2b}					<1	<1	<1	<1	<1	<1	<1	2	17	4	3	13	4	2	<1	<1	<1	<1
Cadmium	µg/L	<0.1	0.7 ^{2c}					<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	µg/L	<1	27.4 ^{2d}					<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Copper	µg/L	<1	1.3 ²					<1	<1	1	<1	<1	1	<1	<1	<1	<1	<1	<1	<1	1	<1	3	1	
Lead	µg/L	<1	4.4 ²					<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	2	<1
Molybdenum	µg/L	<1	23 ^{2a}					<1	<1	<1	<1	3	1	<1	<1	3	<1	1	5	15	7	29	24	<1	<1
Nickel	µg/L	<1	7 ^{2c}					<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1	<1	<1	2	<1
Zinc	µg/L	<1	15 ²					<1	<1	<1	<1	<1	1	<1	<1	<1	<1	<1	<1	<1	1	<1	<1	8	4
NUTRIENTS (ASLP)																									
Ammonium (NH ₄ ⁺) as N	mg/L	<0.01	0.14-5.96 ⁴					0.14	0.12	0.12	0.15	0.13	0.12	0.11	0.12	0.06	0.08	0.09	0.16	0.1	0.25	0.51	0.5	0.21	0.37
Nitrate as N	mg/L	<0.005	0.7 ^{2e}					0.039	0.033	0.036	0.029	0.017	0.022	0.034	0.031	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.006	0.01	0.025	<0.005
Nitrite as N	mg/L	<0.005						0.006	0.006	0.006	0.006	0.007	0.006	0.006	<0.005	0.007	0.005	0.007	0.007	0.006	0.008	0.02	0.02	0.008	0.007
Total Kjeldahl Nitrogen	mg/L	<0.2						4.6	1.7	2.6	3.7	3.3	3.6	2.6	0.34	<0.2	0.24	0.27	0.42	<0.2	0.3	8.7	5.3	17	0.57
Total Nitrogen (by calc.)	mg/L	<0.2	0.3 ³					4.6	1.7	2.6	3.7	3.3	3.6	2.6	0.34	<0.2	0.24	0.27	0.42	<0.2	0.3	8.7	5.3	17	0.57

NOTES:

Bold Concentration exceeds the Threshold Criteria

¹ Based on National Environment Protection (Assessment of Site Contamination) Measure 1999 (NEPM) from the National Environment Protection Council (NEPC, 1999)

^{1a} Based on Chromium III

² Based on ANZECC/ARMCANZ (2000), Australian and New Zealand Guidelines For Fresh and Marine Water Quality (Marine water, South Eastern Australia, slightly to moderately disturbed system, 95% of species protected)

^{2a} Low reliability trigger values

^{2b} Low reliability trigger value for As(III) used

^{2c} Recommended 99% protection level used

^{2d} Based on the Chromium (III) trigger value

^{2e} Based on the freshwater trigger value

³ ANZECC (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Table 3.3.2 (Estuarine trigger value)

⁴ ANZECC (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Table 8.3.7 (Marine trigger values, range is pH dependent as ammonia dominates at pH values > 9)

⁵ Australian Standard Leaching Procedure (ASLP) using deionised laboratory water (neutral leachate)

LOR Limits of Reporting