WONNERUP SOUTH

ACID SULFATE SOIL INVESTIGATION AND MANAGEMENT PLAN

Prepared For:	Cristal Mining Australia Limited
	Koombana Drive BUNBURY WA 6230
Report Number:	AD2013/004
Report Version:	Version 3
Report Date:	11 October 2013

DISCLAIMER

This document has been produced in accordance with and subject to an agreement between Aurora Environmental ("Aurora") and the client for whom it has been prepared Cristal Mining Australia ("Client"). It is restricted to those issues that have been raised by the Client in its engagement of Aurora and prepared using the standard of skill and care ordinarily exercised by Environmental/ Occupational Health and Safety consultants in the preparation of such documents.

Any person or organisation that relies on or uses the document for purposes or reasons other than those agreed by Aurora and the Client without first obtaining the prior written consent of Aurora, does so entirely at their own risk and should not alter their position or refrain from doing so in reliance of this document. Aurora denies all liability in tort, contract or otherwise for any loss, damage or injury of any kind whatsoever (whether in negligence or otherwise) that may be suffered as a consequence of relying on this document for any purpose other than that agreed by Aurora.

QUALITY ASSURANCE

Aurora Environmental has implemented a comprehensive range of quality control measures on all aspects of the company's operation.

An internal quality review process has been applied to each project task undertaken by us. Each document is carefully reviewed and signed off by senior members of the consultancy team prior to issue to the client.

Document No: CRI2013_002_Preparation of ASSMP_004_ga_V3

Report No: AD2013/004

Author:	Glen Alexander Senior Environmental Scientist	Signature	11 October 2013 Date
Reviewed by:	Damon Bourke Senior Environmental Scientist	Signature	11 October 2013 Date

DISTRIBUTION

No. of copies	Report File Name	Report Status	Date	Prepared for:	Initials
1	CRI2013_002_Preparation of an ASSMP_004_gma_V2	Version 3	11 October 2013	Cristal Mining Australia	GMA
1	CRI2013_002_Preparation of an ASSMP_004_gma_V2	Version 3	11 October 2013	Aurora Environmental	GMA

TABLE OF CONTENTS

TABLES IN TEXT

ATTACHMENTS

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

AHD	Australian Height Datum
ANC	Acid Neutralising Capacity
ASS	Acid Sulfate Soils
ASSMP	Acid Sulfate Soil Management Plan
BGL	Below Ground Level
COC	Chain of Custody
CRS	Chromium Reducible Sulfur
CSM	Conceptual Site Model
DEC	Department of Environment and Conservation
DER	Department of Environment Regulation (formerly DEC)
DSEWPaC	Department of Sustainability, Environment, Water, Population and Communities
HMC	Heavy Mineral Concentrate
LOR	Limit of Reporting
m	Metres
pH_F	Field pH
pH_{FOX}	Field Peroxide pH
pH_{KCl}	Potassium Chloride pH
NA	Net Acidity
NATA	National Association of Testing Authorities
QA	Quality Assurance
QC	Quality Control
SCR	Chromium Reducible Sulfur
SPOCAS	Suspension Peroxide Oxidation Combined Acidity and Sulfur method
SWL	Static Water Level
%S	Percentage Sulfur

1 INTRODUCTION

Aurora Environmental was engaged by Cristal Mining Australia Limited to conduct an acid sulfate soils (ASS) investigation for the Wonnerup South mineral sands tenement area (Wonnerup South). Wonnerup South is located approximately 8km east of Busselton (Figure 1) on Mining Tenement M70/785 within Lot 3819 Bussell Highway, Yalyalup (Figure 2). Wonnerup South is on the Swan Coastal Plain and is part of the Southern Perth Basin. The eastern boundary of Wonnerup South abuts the Wonnerup Mineral Sands Deposit (Wonnerup Deposit), which is also owned by Cristal Mining Australia Limited (Figure 3). Mining of the Wonnerup Deposit commenced in 2013.

Based on information provided to Aurora Environmental, Cristal Mining Australia Limited proposes to mine discrete heavy mineral remnants and strand-type deposits within Wonnerup South to a maximum depth of 7m below ground level (mBGL) which will extend below the water table in some areas. Mining operations will comprise the extraction and backfill of wet slurry material predominantly within the Bassendean Sand (Unit S_8) horizon. Proposed mine pits are identified on Figure 2, together with the outline of the modelled groundwater drawdown area.

Previous investigation and management of ASS at the adjoining Wonnerup Deposit was reported in Aurora Environmental (2012a). This ASS management plan (ASSMP) was approved by the Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) on 28 March 2013 and the Department of Environment and Conservation (DEC) (now the Department of Environment Regulation (DER)) on 16 August 2012. The ASS investigation for the Wonnerup Deposit (Aurora Environmental 2012a) was undertaken in consultation with *Identification and Investigation of Acid Sulphate Soils and Acidic Landscapes* (DEC, 2009) and the management plan component was developed in consultation with *Treatment and Management of Soils and Water in Acidic Landscapes* (DEC, 2011).

Prior to the investigation of ASS at Wonnerup South, Aurora Environmental conducted a desktop assessment in order to assess the similarities of Wonnerup South and the Wonnerup Deposit and to develop an appropriate sampling and analysis plan (SAP). Results of the desktop assessment, (Aurora Environmental, 2012b), show that the environmental settings at both sites are comparable, particularly with reference to the mapped geology, hydrogeological and hydrological regimes and potential ecological and human receptors. Consequently it was considered that a targeted ASS investigation should be undertaken with the dual purposes of investigating the ASS hazard and risk at the site and assessing whether the ASS characteristics between the sites are comparable.

The DEC (now the DER), recently released a new guideline (*Draft) Investigation and Management of Acid Sulfate Soil Hazards Associated with Silica and Heavy Mineral Sand Mining Operations* (DEC, 2012). This guideline prescribes a risk-based approach to assess and manage the disturbance of ASS associated with mineral sands mining. The framework provided in DEC (2012) has been used as the primary assessment document for the Wonnerup South ASS investigation reported herein.

1.1 BACKGROUND

Acid sulfate soils are wetland soils and unconsolidated sediments containing iron sulfides. When ASS or sulfidic sediments are exposed to atmospheric oxygen in the presence of water they form sulfuric acid and are prone to mobilise iron, aluminium, arsenic and other heavy metals from the soil profile. The release of these reaction products can be detrimental to biota, human health and built infrastructure.

In Western Australia it is accepted that ASS is commonly found associated with current or geologically recent estuaries and wetlands within 3m of surface levels. Sulfide-bearing sediments are also found in sediments on coastal plains in Western Australia at depths greater than 3m below the surface, associated with older geological features which are also associated with mineral sand deposits, including sands with negligible neutralising capacity and sulfide-rich siltstones of Cretaceous age (DEC, 2012).

1.2 PURPOSE AND APPROACH

The purpose of this ASS investigation is to assess the ASS hazard and risks associated with mining at Wonnerup South using DEC (2012) guidance for mineral sands mining.

The approach for the the ASS investigation was to undertake targeted drilling (six locations) within the Wonnerup South mine pits to demonstrate that the ASS characteristics for Wonnerup South are similar to the Wonnerup Deposit and that sufficient investigation has occurred to identify the presence of sulfidic material and prepare appropriate management strategies.

1.3 SCOPE OF WORK

The scope of works to conduct the ASS investigation for Wonnerup South includes the following:

- The completion of six continuous core drill holes targeted within the known mine pits to at least 1m below the maximum level of disturbance as per the agreed SAP;
- The collection and logging of soil samples at 0.5m intervals to the end of the hole;
- Field testing of all soil samples for pH_F and pH_{FOX};
- Laboratory analysis of soil samples that record a $pH_{FOX}<3$ using the Chromium Reducible Sulfur method (CRS);
- Collection and analysis of groundwater samples for a typical suite of ASS parameters from existing groundwater wells on site;
- Compilation and assessment of the ASS investigation results, incorporating data from the Wonnerup Deposit, if suitable; and
- Preparation of an ASS investigation and management plan utilising the DEC (2012) assessment framework.

2 FRAMEWORK FOR ACID SULFATE SOILS HAZARDS ASSOCIATED WITH MINERAL SANDS MINING

DEC (2012) provides a framework for assessing the ASS risks associated with mineral sands mining activities. The guidance and framework provided in that document will be used to assess the ASS hazard that is presented by the soils encountered at Wonnerup South.

The framework (schematically presented in Figure 3 of DEC, 2012) comprises six steps to assess the environmental risks associated with sulfide mineral oxidation. All six steps however may not be required, as the results of one step determine whether or not additional investigation, risk assessment, and/or mitigation steps are required. If a review of the site setting, including site specific data, identifies no significant hazard associated with sulfide oxidation, development of a monitoring regime and contingency measures is the sole additional step required.

The six steps of the framework are detailed as follows:

1. Step 1 is to develop an overall assessment of the sulfide oxidation hazard. This comprises the following: developing a conceptual site model, undertaking a field screening assessment of sulfide minerals in sediments, determining the extent of sediment disturbance by mining, and conducting an assessment of pathways and receptors for contamination. If there is a significant risk of hazard from sulfide oxidation, then further risk assessments and development of mitigation plans are required, as outlined in Step 2 to Step 5. Alternatively, if there is insignificant risk from sulfide oxidation the proponent can move to Step 6, the development of groundwater monitoring and contingency planning.
2. Step 2 is required if there is a significant risk of hazard from sulfide oxidation. This step requires estimating the source strength of contamination. This is done by firstly determining the pyritic sulfur content of sediments, and then relating the sediment sulfur levels to the potential water quality impacts that may occur (i.e. conduct a Tier 1 or Tier 2 prediction of water quality impacts).
3. Step 3 requires that an initial risk assessment of mine dewatering is undertaken. This step is likely to consider the cone of dewatering depression, groundwater rebound processes and natural attenuation of contaminants.
4. Step 4 comprises refining the conceptual site model using information from Step 2 and Step 3. The purpose of this is to identify and then to complete, any additional investigations that are necessary to finalise the risk assessment.
5. Step 5 is to commence planning for risk mitigation, once the conceptual site model is considered robust. It is likely this will include risk avoidance management by strategies such as minimizing the exposure of pyritic materials to oxygen and reducing the potential migration of contaminants to sensitive receptors.
6. Step 6 comprises the development of groundwater monitoring and contingency plans. The monitoring plans define the appropriate monitoring networks, parameters and trigger values

for on-going assessment of sulfide oxidation hazard, and the contingency plans identify actions to be undertaken should the triggers be exceeded. Step 6 is required for all assessments.

3 PREVIOUS ACID SULFATE SOILS INVESTIGATIONS

3.1 INTRODUCTION

An ASS investigation was conducted for the Wonnerup Deposit in 2010 (Figure 3). Based on the findings of this investigation an ASSMP was prepared in accordance with DEC (2011), titled *Acid Sulfate Soil Management Plan-Lot 100 Wonnerup South Road, Yalyalup* (Aurora Environmental, 2012a). The ASSMP was approved by DSEWPaC in accordance with Condition 15 of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) approval on 28 March 2013. Furthermore, completion of the ASSMP was required to meet Condition 30 of DEC Works Approval granted 16 August 2012 (Works Approval number: W5174/2012/1).

3.2 SUMMARY OF THE WONNERUP DEPOSIT ACID SULFATE SOILS INVESTIGATION

The southwest and northeast portions of the Wonnerup Deposit are mapped as 'high to moderate risk of ASS occurring within 3m of natural soil surface', associated with riverlines, with the remainder of the site mapped as 'moderate to low risk of ASS occurring within 3m of natural soil surface' (Landgate, 2009). Published information by Belford (1987) indicates the predominant surface geology at the Wonnerup Deposit comprises Unit S_8, Bassendean Sand, with areas of Unit Ms_2, Sandy Silt of the Guildford Formation, as well as Unit Msc_1, Clayey Sandy Silt, along the Sabina and Abba Rivers. In addition, there is an area mapped as Unit Cps_1, Peaty Clay, on the northern boundary of the site. Visual observations during the site inspection identified soil consistent with the mapped units, and wetland features in the area identified as Unit Cps_1.

A summary of the field test results (i.e. pH_F and pH_{FOX} testing), indicates the following:

- A total of 544 field tests were completed from 52 soil bores;
- One primary sample (0.18%) with a pH_F <4 was identified;
- Five primary samples (0.92%) with pH_{FOX} <3 were identified; and
- Four primary samples (0.74%) where the difference between pH_F and pH_{FOX} is greater than three were identified.

Based on the field test results only a very small fraction of samples would be considered to represent ASS material.

A summary of the laboratory analysis indicates the following:

- Acid-base accounting via the Suspension Peroxide Oxidation Combined Acidity and Sulfur (SPOCAS) method was used to calculate Net Acidity (NA) values (excluding ANC) for 244 soil samples (approximately 50% of all samples);
- The NA of 55 of the samples (22%) was equal to or less than the limit of detection (0.005%S);
- A total of 46 samples (18.47%) exceeded the DEC (2009) NA Action Criterion of 0.03%S;
- The maximum NA was 0.175%S; and

- The average NA was 0.021%S and the standard deviation was 0.028%S (using the limits of detection for samples reported as less than the detection limits).

The findings of the soil investigation identified that almost 20% of the tested samples could be considered to be ASS (i.e. exceeded NA Action Criterion of 0.03%S) and consequently their proposed disturbance would require management and monitoring in accordance with DEC (2011).

An assessment of groundwater analytes from 12 monitoring bores identified that groundwater at the Wonnerup Deposit is slightly acidic (pH 5.6-6.7) and contains varying levels of total acidity (range of 21mg$CaCO_3$/L to 190mg$CaCO_3$/L). When the groundwater results are compared to typical ASS indicator criteria (presented in DEC, 2011) the following parameters exceed the recommended range:

- Sulfate/chloride ratio above 0.5 in three groundwater monitoring bores;
- Sulfate/alkalinity ratio above 0.2 in three groundwater monitoring bores; and
- Dissolved aluminium above 1mg/L in one groundwater monitoring bore.

Further to identification that some of the Site soils had ASS characteristics that triggered the NA Action Criterion (0.03%S) and that groundwater beneath the Site had been slightly degraded by regional ASS processes, a management plan including a groundwater monitoring regime was prepared for implementation during and after disturbance of the soils/groundwater.

3.3 SUMMARY OF THE ACID SULFATE SOILS MANAGEMENT PLAN

The ASS investigation reported in Aurora Environmental (2012a) identified that the proposed disturbance of soils within the Wonnerup Deposit would require management in accordance with DEC (2011). Consequently an ASSMP was prepared which proposed neutralisation of disturbed soils using a suitable neutralising agent such as aglime. A calculated uncorrected liming rate of 5.74kg$CaCO_3$/m^3 soil was developed for all soils within the proposed mining area.

The groundwater at the Wonnerup Deposit had pH values between 5.6 and 6.7 with total acidity ranging from 21mg$CaCO_3$/L to 190mg$CaCO_3$/L. DEC (2011) guidelines require that dewatering effluent with a pH of less than six or total acidity of greater than 40mg$CaCO_3$/L, be treated via the addition of a neutralising agent prior to reinfiltration. Given that the groundwater is naturally acidic, a pH trigger of 5.5 was considered more appropriate for the site and is consistent with the site dewatering operating strategy (Cable Sands, 2011).

A comprehensive groundwater monitoring and contingency program is currently being implemented at the Wonnerup Deposit. More detailed information on management of soils, dewatering and groundwater at the Wonnerup Deposit is provided in Aurora Environmental (2012a).

4 WONNERUP SOUTH PROJECT AND SITE SETTING

4.1 LOCATION AND LAND USE

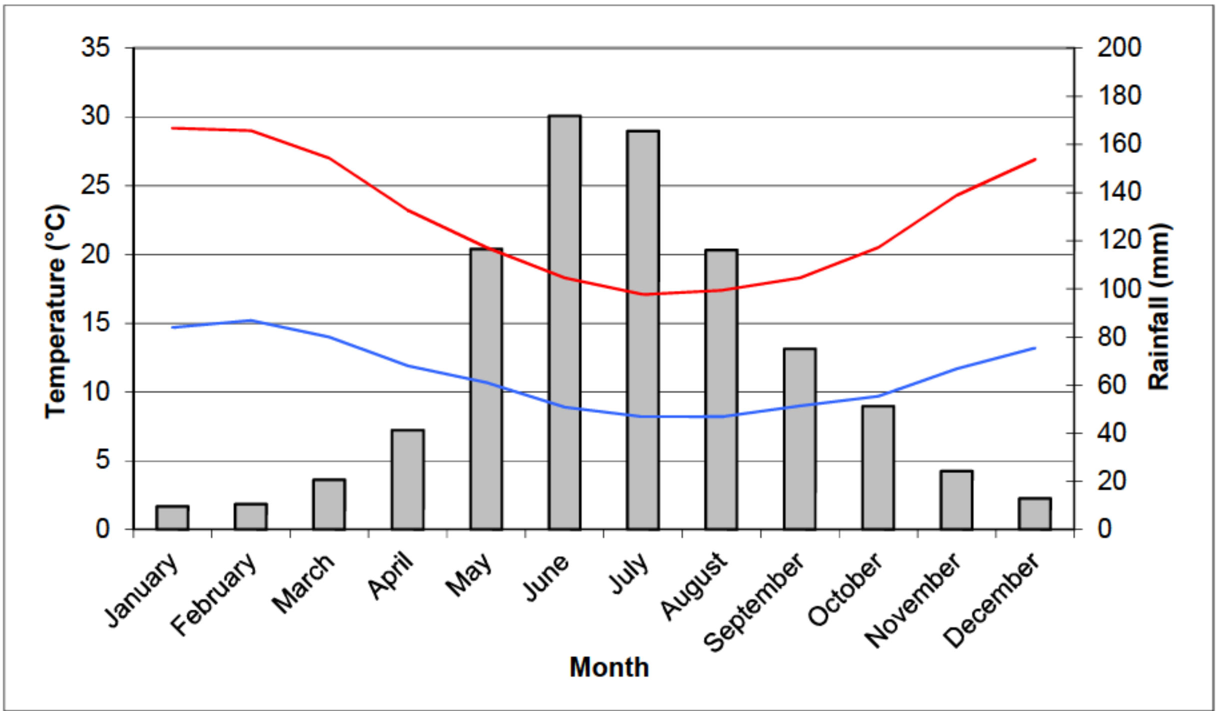
Wonnerup South is located within the locality of Yalyalup in the Shire of Busselton, approximately 8.5km east of Busselton in the Southwest region of Western Australia (Figure 1). It lies approximately 5km south of Geographe Bay, and 20km southeast of Cape Naturaliste. The Site is administered by the City of Busselton and is currently an operational cattle farm.

4.2 CLIMATE

The Geographe-Naturaliste coastline experiences a Mediterranean climate with warm to hot dry summers, and mild wet winters. High pressure cells dominate climatic patterns during summer, and the passage of cold fronts and associated low pressure cells dominate during winter. Strong sea breezes occur from late November to early March.

The annual rainfall averages between 800mm and 1000mm, peaking in June and July, as shown in Table A. In summer the average maximum temperature is 28°C with an average minimum temperature of 12°C. In winter the average maximum temperature is 16°C with an average minimum temperature of 5°C (Bureau of Meteorology, 2013).

TABLE A: ANNUAL AVERAGE CLIMATE DATA



Source: Bureau of Meteorology Busselton Station (Weather Station 009515).

4.3 GEOLOGY AND TOPOGRAPHY

Wonnerup South is located on the Swan Coastal Plain and is part of the Southern Perth Basin. The Southern Perth Basin boundaries are defined as Mandurah in the north, Augusta in the south, the Leeuwin-Naturaliste Ridge and the coast in the west, and the Darling Plateau in the east. The

Southern Perth Basin is characterised topographically by the elevated Blackwood Plateau and coastal plains sloping gradually towards the coast. Former marine erosion scarps separate the coastal plains from the plateau. The site is located on the coastal plain less than 5km from the current shoreline. Elevation across the site generally ranges between 5mAHD and 10mAHD.

The *Busselton Environmental Geology Sheet* (Belford, 1987) indicates the predominant surface geology within Wonnerup South comprises Unit S_8, Bassendean Sand (Figure 4). The Bassendean Sand unit is described as “very light grey at surface, yellow at depth, fine to medium-grained, sub-rounded quartz, moderately well-sorted, of eolian origin” (Belford, 1987). Regionally, the Bassendean Sand unit is generally flat to gently sloping (up to 10°), with an elevation of between 10mAHD and 32mAHD. This unit is known to host local accumulations of heavy minerals, such as ilmenite and rutile, as well as sulfides (Belford, 1987).

Unit Ms_2, sandy silt of the Guildford Formation, is mapped across the northern half of the site (Belford, 1987). The Guildford Formation unit is described as “strong brown to mid-grey, mottled, blocky, containing disseminated fine sand, hard when dry”, and being of alluvial origin (Belford, 1987). Regionally, Unit Ms_2 is flat-lying (less than 3° slope) with elevation of between 5mAHD and 12mAHD (Belford, 1987).

The Sabina River, located in the northeast corner of the site, is mapped by Belford (1987) as being hosted by Unit Msc_1, clayey sandy silt, which is described as comprising “pale brown, angular to rounded sand, with low cohesion and of alluvial origin” (Belford, 1987). This alluvial unit follows the alignment of the Sabina River with a gentle slope of approximately 3° within the site.

4.4 GEOMORPHOLOGY

The geomorphological units mapped at the site by Belford (1987) are consistent with the landform. An area of river floodplain is associated with the present location of the Sabina River; the southern portions of the site are identified as comprising degraded surface of eolian (Bassendean) dunes; and alluvial plain landforms are identified in the northern lower lying portion of the site (Belford, 1987).

4.5 DEC ASS MAPPING

The majority of Wonnerup South is mapped as being at “moderate to low risk of ASS occurring within 3m of natural soil surface” (Landgate, 2013), as presented on Figure 3. The Sabina River alignment in the northeast corner of the site is mapped as “high to moderate risk of ASS occurring within 3m of natural soil surface” (Landgate, 2013). This area of the Sabina River is directly downstream of the portion of the river assessed as part of investigations of the Wonnerup Deposit (Figures 2 and 3).

4.6 HYDROGEOLOGY

Regional groundwater quality was evaluated and reported by Hirschberg (1989) following an investigation of the groundwater resources between Capel and Dunsborough. The investigation considered mainly the hydrogeology of the shallow superficial aquifer and included assessment of interaction with the underlying Leederville Formation. Hirschberg (1989) found that the shallow unconfined groundwater in the area discharges into the rivers and drains and also over a salt water wedge near the coast and into the ocean. In addition, substantial groundwater is lost to evapotranspiration due to the very shallow depth to groundwater. Of note, based on a figure indicating the hydraulic head difference between the superficial formations and the Leederville Formation in Hirschberg (1989), it is apparent that the area containing Wonnerup South and the Wonnerup Deposit has a negative head difference: that is, the Leederville aquifer discharges upwards into the superficial aquifer in this area. Hirschberg (1989) concludes the report by noting that "*The unconfined groundwater is only of minor importance in this region because of the limited thickness and predominantly clayey nature of the superficial formations. It is commonly too saline for domestic use.*"

Bemax Resources Limited (now Cristal Mining Australia Limited) engaged URS to undertake a baseline assessment of the local groundwater environment and outline the potential environmental impacts associated with dewatering activities. This is reported in *Groundwater Environmental Impact Assessment-Wonnerup Deposit* (URS, 2008) and considers the Wonnerup Deposit to consist of what are now known as the separate Wonnerup Deposit and Wonnerup South sites.

URS (2008) reports, that the area comprising the Wonnerup Deposit and Wonnerup South is underlain by a vertical succession of aquifer systems. These include the superficial aquifers hosted by Bassendean Sand and Guilford Formation units (fluvial and alluvial deposits), and the Leederville Formation at depth.

The Bassendean Sand and Guildford Formation have an estimated thickness of 10-25m. Groundwater recharge in the superficial aquifer is predominantly from rainfall infiltration, both directly into the water table and via through-flow from upgradient recharge areas. The clays of the superficial formations form a basal layer partially confining the Leederville Aquifer.

The Leederville Formation, located beneath the superficial formations, hosts a major regional aquifer approximately 100m thick. The Leederville Aquifer is multi-layered and confined, and locally occurs between -7.5m AHD in the north of the site and -10m AHD towards the south of the site.

In 2006 nine groundwater monitoring bores were installed in the area comprising the Wonnerup Deposit and Wonnerup South to characterise the local superficial aquifer systems. Only two of these groundwater bores (WPMB08 and WPMB10) are located within Wonnerup South. These wells were installed to a depth of between 3mBGL and 7mBGL to characterise the water quality of the superficial formation.

URS (2008) reports that groundwater flows in a northwest direction towards the coast. Baseline groundwater elevations measured in February 2007 (i.e. during annual minimum water table elevation) ranged from approximately 12mAHD in the southeast of the Wonnerup South site to 4mAHD in the northwest (Figure 5).

Predictive modelling of groundwater drawdown for each of the mine pits located within Wonnerup South was completed by URS (2008 & 2013). The maximum groundwater drawdowns are up to 2m below annual average minimum groundwater levels (i.e. February 2007 values) and the maximum extent of the 0.1m dewatering drawdown zone of impact is shown on Figure 2.

4.7 WETLANDS

Wonnerup South is located approximately 2km south of the Vasse-Wonnerup Wetland system (Figure 1) which is recognised as a wetland of international importance under the Ramsar Convention. Given the identified northwest groundwater flow direction, the Wonnerup South site is up hydraulic-gradient from the wetland area. Consequently any groundwater impacts that may occur as a result of operations at Wonnerup South have potential to reach the wetland.

4.8 PROPOSED MINING OF WONNERUP SOUTH

4.8.1 Ore Body Method of Extraction

To access the Wonnerup South orebody, topsoil will be stripped to a depth of approximately 0.2m. The orebody comprises heavy mineral concentrate (HMC), sand (referred to as tails) and clay (referred to as fines). Approximately 3.8 million tonnes of ore will be extracted from Wonnerup South to recover 230,000 tonnes of HMC. Ore will be mined using front end loaders and assisted by bulldozers/scrapers working progressively across the Wonnerup South site. No active dewatering is proposed as part of mining activities at the site; instead, the dewatering will be undertaken passively as groundwater enters the mine pits. Dewatering management is discussed in Section 6.

4.1.2 Ore Body Processing

Following the initial removal of oversize material, the undersize fraction will then be pumped as slurry to the primary separation plant where HMC material is separated by conventional wet gravity methods.

After removal of the HMC through the primary separation plant, the sand tails by-product will be returned to the mine void as wet slurry to form backfill. The primary separation process also washes the clay fines from the ore and sand tails. To enable the process wash water to be reused, it is pumped to a thickener tank to which settling agents (flocculants and/or coagulants) are added. The thickener tank removes and concentrates the fines, which are then allowed to dry in solar drying ponds. Once the fines have dried to a manageable state, they are broken up for burial or blending within the backfill. The treated water is then recycled throughout the ore processing facility. All processing activities for Wonnerup South will be conducted using existing infrastructure at the Wonnerup Deposit.

5 WONNERUP SOUTH ACID SULFATE SOIL INVESTIGATION

5.1 DESKTOP ASSESSMENT AND SAMPLING AND ANALYSIS PLAN

Aurora Environmental undertook a desktop assessment in October 2012 (Aurora Environmental, 2012b) of the potential for ASS at Wonnerup South, in order to develop an appropriate Sampling and Analysis Plan (SAP) to be implemented as part of a staged investigation of ASS at the site.

As reported in the Aurora Environmental (2012b) SAP, ASS risk requiring investigation exists at Wonnerup South. Proposed development works at the site will directly disturb Bassendean Sands which have the potential to oxidise and release acidity into the surrounding soil and groundwater. Bassendean Sand is known to have an association with ASS and contains minimal buffering capacity. The Guildford Formation is also associated with ASS. Groundwater at the site is present at approximately 2mBGL and therefore dewatering will be required to facilitate mining to a maximum depth of 7mBGL. It is anticipated that dewatering may result in exposure of ASS material within the cone of depression.

Aurora Environment (2012b) reported that Wonnerup South and the Wonnerup Deposit have similar ASS risk mapping (Landgate, 2013), similar geological mapping (Belford, 1987) and similar proposed mining disturbances (i.e. both operations entail mining to 7mBGL and dewatering). On this basis it is considered that the Wonnerup South mineral sand resource is a spatial extension of the Wonnerup Deposit separated only by land tenure details (i.e. land ownership, public roads and mining tenements) and not differing substantially from each other in terms of environmental setting.

Due to the proximity and similarity of the sites, the findings of the ASS investigation at the Wonnerup Deposit (Aurora Environmental, 2012a) were considered during development of the SAP for Wonnerup South. Subsequently, the SAP (Aurora Environmental, 2012b) proposed a targeted ASS investigation involving limited drilling (six locations) be conducted within the proposed Wonnerup South mine pits (Figure 2) to confirm that the sites share similar ASS characteristics.

The SAP (Aurora Environmental, 2012b) was prepared on the basis that if both sites could be shown to have comparable environmental settings and ASS characteristics, this would demonstrate that sufficient investigation has occurred at Wonnerup South to identify the presence of sulfidic material using the substantial data set already obtained for the Wonnerup Deposit (Aurora Environmental, 2012a).

5.2 CONCEPTUAL SITE MODEL

The purpose of developing this CSM is to consider the potential impacts of pyrite oxidation at the site in terms of sources, pathways and receptors. The field screening assessment data provides an indication of the potential ASS hazard while the Site environmental setting provides information on potential sensitive receptors as well as transport mechanisms and uptake pathways. For a risk to be posed there needs to be full linkage between the source material, transport and uptake (exposure) pathways and receptors.

5.2.1 Source

The potential source of impact is oxidised sulfide minerals that are currently present below the groundwater table. If exposed to the atmosphere, the sulfide minerals will oxidise and generate sulfidic acidity. Oxidation of sulfide minerals is likely to occur during extraction of ore containing ASS or as a result of dewatering.

It should be noted that this CSM only considers residual *in situ* ASS exposed to oxidation by dewatering and does not consider the fate of ASS material removed for processing as ore. Sulfidic acidity from material removed as ore is managed during the ore slurry processes.

If groundwater is acidified, additional groundwater contamination could result from the reduced pH conditions which could mobilise soil-bound heavy metals. Mobilised heavy metals are therefore a secondary source of contamination.

5.2.2 Pathways

If the oxidation of *in situ* ASS generates sulfidic acidity then groundwater is the initial pathway by which impacts may migrate. Acidity could therefore be mobilised downwards by leachate, upwards with groundwater rebound, or laterally by groundwater migration. If acidic groundwater mobilises heavy metals they will migrate along the same pathways.

Abstraction of affected groundwater is a secondary pathway. On-site abstraction could lead to possible exposure of workers and environments in contact with water circuit processes. Human or environmental exposure could also result if impacted off-site groundwater is pumped for domestic non-potable or irrigation uses.

5.2.3 Receptors

Potential human and ecological receptors have been identified within the site bounds. These comprise Site workers and the Sabina River. Off-site impacts could be received by the Vasse-Wonnerup Wetland system.

5.2.4 Complete Linkage Pathways

If oxidation of the sulfidic sediments takes place, acidity and possibly heavy metals may be released. Lateral migration of shallow groundwater could transport ASS impacts towards sensitive ecological receptors both on-site and off-site. Local groundwater is already naturally slightly acidic however, so the slightly acid conditions are not likely to pose an immediate risk to ecological receptors. In relation to metals, due to the clayey nature of the sediments, it is likely that some natural attenuation would occur, therefore reducing the potential hazard with increasing distance from site. If acidity and heavy metals were able to migrate a significant distance off-site, the Vasse Wonnerup Wetland, some 2km down gradient, could be a potential ecological receptor.

Due to the high salinity and low yields of groundwater from the shallow aquifers, it is unlikely that the off-site shallow groundwater is abstracted to irrigate crops and livestock, and even less likely that it is abstracted for domestic non-potable purposes. Therefore, it is unlikely that if affected, the off-site shallow groundwater would lead to direct impact to human receptors, crops or livestock.

One of the means of reducing the risk of impacts affecting groundwater includes regular groundwater monitoring. This would allow early detection of on-site impacts and provide an opportunity to minimise the offsite migration of impacted groundwater, which could potentially affect ecological receptors. In addition, the distance to the estuary system also reduces the risk of uncontrolled impacts affecting this feature. On-site management protocols will reduce the potential for Site workers to be affected by impacted groundwater.

5.3 SOIL INVESTIGATION

Aurora Environmental undertook a targeted soil investigation at Wonnerup South on 23 April 2013. Sample collection was achieved using a direct push drill rig (the same drilling method used for the Wonnerup Deposit) to obtain soil samples. Soil bore (SB) locations were designated SB1 to SB6, and samples were collected at 0.5m intervals within the proposed Wonnerup South mine pits (Figure 2). Drilling depths ranged from 4mBGL to 9mBGL, approximately 1m below the anticipated maximum depth of disturbance.

The soil profile was logged and a total of 70 soil samples were collected for initial screening via field testing (pH_F and pH_{FOX}). Samples were placed in clearly labelled ziplock bags with air excluded and placed in an esky with ice, whilst on site. The samples were initially analysed in the field for pH_F at 0.5m intervals. All samples were then transported to the laboratory and assessed for pH_{FOX} on the same day as drilling. The procedure used for field testing is discussed in detail in Hey *et al.* (2000) and DEC (2013). All samples were then stored in a deep freezer pending decisions about further analytical requirements.

5.4 FIELD SCREENING ASSESSMENT CRITERIA

The results of the field screening assessment are utilised to give an indication of which samples may represent ASS material. The guidelines for urban development (DEC, 2013) recommend that soils which have low pH values (pH_F <4 or pH_{FOX} <3), or which exhibit a significant change in pH (ΔpH, as $pH_F - pH_{FOX}$) may indicate a soil with ASS characteristics. However, when considering whether sufficient pyrite exists to present a significant risk of oxidation by mineral sands mining activities, DEC (2012) uses the following assessment criteria:

- pH_F <4 in more than 10% of borehole locations; or
- pH_{FOX} <3 in more than 10% of the samples tested.

Should either of these assessment criteria be triggered, then active management of soil and water will be required to mitigate the risk of further environmental harm.

Aurora Environmental has adopted the DEC (2012) assessment criteria as the primary criteria used to determine whether sufficient pyrite is present in soils to cause significant acidification if oxidised through mining and dewatering activities.

5.5 WONNERUP SOUTH FIELD SCREENING RESULTS

The field screening results for Wonnerup South (provided in Appendix 1) in comparison to the DEC (2012) assessment criteria for all 70 samples (six locations) shows the following:

- No sample from any borehole recorded a pH_F <4 (0%); and
- Two samples recorded a pH_{FOX} <3 (2.9%).

5.6 COMBINED FIELD SCREENING RESULTS

Field screening results for Wonnerup South were compared to the Wonnerup Deposit field results listed in Section 3.1.1 and provided in Appendix 2, in order to confirm that the two sites share similar ASS characteristics. Table B provides a comparison of these results.

TABLE B: COMPARISON OF FIELD TEST RESULTS

FIELD SCREENING RESULTS	WONNERUP SOUTH	WONNERUP DEPOSIT	COMBINED RESULTS
Number of samples	70	544	614
Number of locations	6	52	58
Average pH_F	6.16	6.08	6.10
Number of boreholes with pH_F <4	0	1	1
Boreholes with pH_F <4 (%)	0%	2.12%	1.89%
Average pH_{FOX}	4.97	5.06	5.05
Number of samples with pH_{FOX} <3	2	5	7
Samples with pH_{FOX} <3 (%)	2.86%	0.92%	1.14%

A review of these results confirms that the ASS characteristics are similar between the sites and that it is appropriate to combine and compare all results to the DEC (2012) assessment criteria. The combined results show the following:

- One sample from one borehole recorded a pH_F <4 (1.89%); and
- Seven samples (1.14%) recorded a pH_{FOX} <3.

5.7 INTERPRETATION OF RESULTS AND SULFIDE OXIDATION RISK

Comparison of both the Wonnerup South and the combined field screening results to the DEC (2012) assessment criteria shows that the results do not exceed the assessment criteria. It is therefore considered that a significant risk of sulfide oxidation hazard does not exist at the site. Consequently, it is not necessary to complete the additional risk assessment measures detailed in Steps 2-5 of the framework. Furthermore, it is considered that although some sulfide oxidation hazard exists, there is a low risk that a significant issue will occur with potential to impact receptors.

The CSM has identified the potential pathways and receptors that may be affected by the ASS hazard/source at the site. However, the results indicate that the risk from potential oxidation of sulfides is low. Only 1.14% of all soil samples recorded a pH_{FOX} <3 which indicates that significant potential acidity is not present in the sampled material. In addition, as only 1.89% of sample locations recorded a pH_F <4 it is likely that insignificant pyrite oxidation has already occurred. Although the ASS hazard has a low risk and does not exceed the DEC (2012) assessment criteria a groundwater monitoring and contingency plan is required to be implemented (DEC, 2012).

6 MONITORING AND CONTINGENCY PLANS

Monitoring and contingency plans are required to assess the effect of mining on groundwater quality and provide management actions to protect sensitive environmental receptors if groundwater quality is affected (DEC, 2012). The following sections detail the planned monitoring and contingency actions for the site.

6.1 WONNERUP SOUTH GROUNDWATER ASSESSMENT

In order to develop a groundwater monitoring plan, a baseline groundwater quality assessment monitoring was undertaken by Aurora Environmental as part of the ASS investigation. The purpose of the assessment was to measure the groundwater levels in the existing wells and to assess the vulnerability of the groundwater to acidification.

The groundwater quality assessment was undertaken using six wells that are understood to have been installed at the site by a drilling sub-contractor to Cristal Mining Australia Limited in May 2013. The wells are labelled WNMB18 to WNMB23 (see Figure 2), and a summary is provided in Table C.

TABLE C: SUMMARY OF GROUNDWATER WELLS

GROUNDWATER WELL ID	LOCATION OF GROUNDWATER WELL RELATIVE TO PROPOSED MINING AREA	DEPTH OF BORE (MBGL)	CONVERTED GROUNDWATER LEVEL* (MBGL)
WNMB18	Down-gradient	6.8	1.83
WNMB19	Down-gradient	2.8	1.69
WNMB20	Up-gradient	4.0	0.63
WNMB21	Down-gradient	4.6	0.69
WNMB22	Down-gradient	4.2	2.93
WNMB23	Down-gradient	7.2	2.48

*Converted groundwater levels are approximate and calculated from the depth to groundwater measured from the top of well casing, less 0.5m (+/- 0.2m) to allow for well riser.

Aurora Environmental measured groundwater levels and collected groundwater quality samples from the six shallow groundwater wells at the site on 3 July 2013. Groundwater sampling sheets and laboratory documentation for the groundwater monitoring event are provided in Appendix 3. It should be noted that Aurora Environmental referred to the wells using a shortened prefix and hence Aurora Environmental documentation and the laboratory certificates refer to MB18 to MB23. It should be noted WNMB19 contained very little groundwater and yielded less than ~5L before being purged dry. WNMB19 did not recharge sufficiently to collect samples for analysis during the site visit.

6.2 GROUNDWATER QUALITY ASSESSMENT CRITERIA

The vulnerability of groundwater to acidification can be assessed by comparison of the analytical results to criteria published in DEC (2011). DEC (2011) requires that the following indicator values are used to assess whether groundwater may have been affected by the oxidation of sulfides:

- pH less than five;
- pH less than six in combination with alkalinity below 60mg$CaCO_3$/L;
- Sulfate: alkalinity ratio greater than 0.2;
- Sulfate: chloride ratio greater than 0.5; and
- Soluble aluminum concentration greater than 1mg/L.

These guidelines and indicators have been selected to assess the quality of groundwater at the site.

6.3 GROUNDWATER MONITORING RESULTS

Table D provides a summary of the laboratory results analysed from the initial groundwater quality monitoring event.

TABLE D: ANALYTICAL RESULTS OF INITIAL GROUNDWATER QUALITY MONITORING

SAMPLE LOCATION	pH (no units)	TOTAL ACIDITY	TOTAL ALKALINITY	CHLORIDE	SULFATE	SULFATE/CHLORIDE RATIO	SULFATE/ALKALINITY RATIO	ALUMINIUM (DISSOLVED)	ARSENIC	IRON (DISSOLVED)	ZINC
WATER ASSESSMENT CRITERIA (MG/L)											
ASS Indicators	5	40	NV	NV	NV	0.5	0.2	1	NV	NV	NV
LABORATORY RESULTS (MG/L)											
WNMB18	7.4	13	100	150	51	0.34	0.51	<0.01	<0.001	0.88	<0.005
WNMB19	Not Analysed										
WNMB20	5.8	42	14	140	35	0.25	2.5	1.1	<0.001	0.7	0.015
WNMB21	5.8	55	16	430	120	0.28	7.5	0.02	<0.001	11	<0.005
WNMB22	6.7	120	87	170	65	0.38	0.78	1.4	<0.081	1.0	<0.005
WNMB23	7.0	39	130	810	82	0.10	0.63	0.02	0.002	0.24	<0.005

A comparison of the laboratory results to the DEC (2011) ASS indicator values indicates the following:

- The pH ranged from neutral to slightly acidic, but was more alkaline than the ASS indicator value of five at all locations;
- Low alkalinity and pH values less than six were recorded at WNMB20 and WNMB21 which indicates that the buffering capacity of groundwater at these locations is inadequate to maintain acceptable pH;
- The sulfate: chloride ratios at all locations were below the indicator value (0.5);
- The calculated sulfate: alkalinity ratios at all locations exceeded the indicator value (0.2) which suggests that groundwater may be affected by sulfide oxidation, particularly at WNMB21; and
- The dissolved aluminium concentration at WNMB20 and WNMB22 exceeds the indicator value (1mg/L).

The collected data indicates that groundwater quality has been impacted by regional ASS processes and has the potential to be further impacted if ASS disturbance is not managed appropriately. Consequently, management and monitoring of the dewatering effluent and site groundwater is considered necessary. The following sections detail the proposed water management and contingency plans.

6.4 DEWATERING MANAGEMENT PLAN

6.4.1 Dewatering Process and Operating Strategy

No active dewatering is proposed as part of mining activities at Wonnerup South. Dewatering to the required depth of excavation will occur passively as groundwater enters the mining excavation. This water will be directed to dewatering sumps within the pits before being pumped to the existing Wonnerup Deposit infrastructure and process water dam. The water process circuit is discussed in Section 4.1.2.

6.4.2 Dewatering Monitoring Program

Dewatering water from Wonnerup South is proposed to be treated at the Wonnerup Deposit by existing infrastructure and therefore the proposed dewatering monitoring program for Wonnerup South is the same as the Wonnerup Deposit. Monitoring of the dewatering water will occur in the pit dewatering sumps at Wonnerup South and at the existing process water dam located at the Wonnerup Deposit.

The following monitoring program is currently being implemented at the Wonnerup Deposit (DEC Licence: L8739/2013/1) and it is proposed that the same program will be applied to the pit dewatering sumps (pre-treatment) and process water dam (post-treatment) to assess groundwater quality in the vicinity of Wonnerup South:

- Field testing for pH, electrical conductivity (EC), total acidity and total alkalinity will occur three times a week (Monday, Wednesday and Friday) (Cable Sands, 2011);

- Monthly laboratory analysis for pH, EC, TDS, total titratable acidity, total alkalinity, dissolved aluminium, dissolved iron and dissolved manganese. If total aluminium is above 1mg/L then additional laboratory analysis will be required for the following total metals; arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium and zinc; and
- The process water dam will also be monitored via a real time pH meter which will feed results to the wet separation plant control room.

6.4.3 Dewatering Trigger Values

Groundwater at Wonnerup South has neutral to mildly acidic pH levels (5.8 to 7.4) and a maximum total acidity of 120mg$CaCO_3$/L. This water quality is similar to the Wonnerup Deposit which has acidic pH, ranging between an average of 5.6 and 6.7, and with varying levels of total acidity (range of 21mg$CaCO_3$/L to 425mg$CaCO_3$/L). As the water quality at Wonnerup South is considered to be of similar quality to the Wonnerup Deposit and dewatering treatment will occur at the existing Wonnerup Deposit, it is proposed to utilise the same dewatering trigger values which are currently in practice at the Wonnerup Deposit. These practices are consistent with Cristal Mining Australia Limited's Dewatering Operating Strategy (Cable Sands, 2011).

The following trigger values will be applied to the dewatering water, monitored from the dewatering sumps located within each pit (i.e. pre-treatment):

- Field pH less than 5.5; or
- Field-measured total acidity greater than 40mg$CaCO_3$/L; or
- Field-measured total alkalinity less than 30mg$CaCO_3$/L.

As the process water circuit is a closed system unless discharge is occurring, the circuit will be monitored using a real time pH meter located within the process water dam and via samples which are analysed for pH, total acidity and total alkalinity. In the event that the water within the dam falls below 5.5 and total alkalinity decreases below 60mg$CaCO_3$/L, active management of process water prior to re-infiltration (via clay fines and sand tails) or discharge from the water circuit will be required.

6.4.4 Dewatering Contingency Plan

In the event that the untreated dewatering water exceeds a trigger criteria listed in Section 6.4.3, the initial response will be to increase the dewatering monitoring schedule listed in Section 6.4.2 to daily field testing and weekly laboratory testing of the affected areas.

If the trigger values listed in Section 6.4.3 are exceeded at the process water dam (i.e. post-treatment), the initial contingency measure will be to treat the process water through the addition of a suitable alkaline material to the thickener until pH is above the trigger value of 5.5 and total alkalinity is greater than 60mg$CaCO_3$/L. If the process water in the dam exceeds the trigger values the following actions will be implemented:

- Discharge of process water off site will cease;
- Weir boards will be used to increase the storage capacity of the dam until the water is of an acceptable quality; and

- If necessary, excess process water will be diverted to a fines dam for storage until further treatment can occur and water quality targets can be met.

In addition, any off-site emergency discharge of water from the process water dam should be managed and monitored in accordance with Cristal Mining Australia Limited's Dewatering Management Strategy (Cable Sands, 2011) and through DEC licensing under Part V of the *Environmental Protection Act 1986* before any process water is discharged.

Monitoring the quality of water in the pit dewatering sumps will provide an initial indication that neutralisation treatment is likely to be required at the process water dam. Additional contingencies which may be implemented, if appropriate, include:

- Expedite the backfill of the pit to reduce the amount of time ASS are exposed;
- Cease dewatering immediately after the completion of mining (i.e. hold water back in the pit); and
- Add neutralising material to tailings and/or fines when backfilling in the affected area.

6.5 GROUNDWATER MONITORING PLAN

6.5.1 Groundwater Monitoring Bores

The groundwater monitoring network comprises five shallow wells that are considered suitable for on-going monitoring of the groundwater quality in the superficial aquifer (WNMB18, WNMB20, WNMB21, WNMB22 and WNMB23). Well WNMB19 is likely to be unsuitable for monitoring as it yielded a low volume of groundwater and displayed slow recharge during the initial groundwater monitoring event.

Well WNMB20 is located up-gradient of the mining areas and outside of the area of dewatering drawdown (0.1m contour) and therefore the water from this location is considered to represent the quality of groundwater migrating onto the site. The remaining wells are generally down-gradient of the mining areas, but are located within the modelled area of dewatering drawdown (i.e. within the cone of depression). Consequently, it is anticipated that groundwater quality data from these wells should reflect impacts to groundwater quality arising from site activities.

6.5.2 Groundwater Monitoring Program

The following monitoring program will be conducted during dewatering operations for the five groundwater monitoring wells WNMB18, WNMB20, WNMB21, WNMB22 and WNMB23:

- Monthly monitoring of groundwater levels;
- Monthly field testing for pH, EC, total acidity, total alkalinity and temperature; and
- Monthly laboratory analysis for pH, EC, TDS, total titratable acidity, total alkalinity, chloride, sulfate, dissolved aluminium, dissolved iron and dissolved manganese (If Al >1 mg/L, then the sample will also be analysed for arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium and zinc).

At the completion of dewatering operations the monitoring program will continue as above for six months (or until any adverse trends have stabilised) and then on a quarterly basis for an additional 12 months.

6.5.3 Groundwater Assessment Criteria

It is proposed that site-specific groundwater assessment criteria will be developed for each of the monitoring wells using background data that is to be collected at least quarterly in the 12 month period preceding the commencement of mining. The assessment criteria will be set in accordance with guidance provided in DEC (2012), which stipulates using either the maximum value recorded during pre-mining monitoring, or on a statistical basis in accordance with SEPA (2005).

6.5.4 Groundwater Contingency Plan

Should groundwater results exceed the assessment criteria, the initial response will be to increase the frequency of laboratory monitoring from monthly to weekly for the same suite of analytes until the concentration returns to background concentrations. The results will be considered against previously established baseline values, and other guidelines detailed in *Assessment levels for soils, sediment and water* (DEC, 2010) that are appropriate for potential groundwater receivers in the vicinity and/or down gradient from the affected groundwater.

The effects of dewatering will be mitigated by accelerating backfill in adjacent pits and/or ceasing dewatering in that area as soon as mining is completed. If groundwater quality does not show any improvement, such as return to baseline concentrations, the DER and DoW will be notified. Dewatering may need to cease until groundwater quality returns to acceptable levels either naturally or through the implementation of remedial measures.

7 CONCLUSION AND RECOMMENDATIONS

Aurora Environmental was commissioned by Cristal Mining Australia Limited to conduct an ASS investigation for Wonnerup South. Wonnerup South is located approximately 8km east of Busselton on Mining Tenement M70/785 within Lot 3819 Bussell Highway, Yalyalup. The north east portion of the site contains the Sabina River which flows in a north westerly direction towards the Vasse-Wonnerup Wetland system, which is approximately 2km north of the site. Groundwater beneath the site is shallow and also flows in a north westerly direction. The site is on the Swan Coastal plain and abuts Cristal Mining Australia Limited's Wonnerup Deposit, which commenced operation in 2013. Previous investigation and management of ASS at the adjoining Wonnerup Deposit is reported in Aurora Environmental (2012a).

Prior to the ASS investigation, Aurora Environmental conducted a desktop assessment in order to assess the similarities that exist between Wonnerup South and the Wonnerup Deposit and to develop an appropriate SAP. The SAP (Aurora Environment, 2012b) reported that Wonnerup South and the Wonnerup Deposit have similar ASS risk mapping (Landgate, 2013), similar geological mapping (Belford, 1987) and similar proposed mining disturbances (i.e. mining to 7mBGL and dewatering). On this basis it is considered that the Wonnerup South mineral sand resource is a spatial extension of the Wonnerup Deposit separated only by land tenure details (i.e. land ownership, public roads and mining tenements).

Due to the proximity and similarity of the sites, results of the ASS investigation for the Wonnerup Deposit (Aurora Environmental, 2012a) were considered in developing an appropriate SAP to investigate ASS at Wonnerup South. The SAP (Aurora Environmental, 2012b) recommended a targeted ASS investigation that would allow confirmation that the ASS characteristics are comparable between the two lease areas.

Subsequently, Aurora Environmental has conducted a targeted ASS investigation involving limited drilling (six locations) within the proposed Wonnerup South mine pits (Figure 2) to confirm that the sites share similar ASS characteristics and to assess the ASS hazard and risk at Wonnerup South. Field results (pH_F and pH_{FOX}) recorded from the targeted drilling program were compared to field results from the Wonnerup Deposit (see Table B) and comparison of the results indicated that both sites exhibit similar ASS characteristics. As such, it was considered appropriate to incorporate the significant data set from the Wonnerup Deposit to assess ASS hazard and risk at Wonnerup South.

Assessment of the ASS hazard at Wonnerup South was conducted in accordance with the DEC (2012) framework, which commenced with the development of a CSM and a field screening assessment (i.e. Step 1). The combined results show that only one sample from one borehole recorded a pH_F <4 (1.89% of all boreholes), and 1.14% of samples recorded a pH_{FOX} <3.

The results of the combined field screening assessment do not exceed the DEC (2012) assessment criteria and clearly indicate that a very low proportion of soil samples contain sulfide minerals which would generate acidic conditions upon oxidation.

Accordingly, soil at the site is not considered to present a significant environmental hazard due to the potential generation of acidity via oxidation during mining activities, and does not require additional laboratory analyses or additional sampling to further characterise the risk of ASS. As such, monitoring and contingency plans (Step 6 of DEC, 2012) have been developed to assess the effect of mining on groundwater quality and provide management actions to protect sensitive environmental receptors if groundwater quality is affected.

It is recommended that pre-mining background water quality is collected at least quarterly in the 12 month period preceding the commencement of mining. This will allow the development of site-specific groundwater assessment criteria.

8 REFERENCES

Ahern, C.R, McLnea, A.E and Sullivan, L.A (2004), *Acid Sulfate Soils Laboratory Methods Guidelines*, in Queensland Acid Sulfate Soils Manual 2004: Department of Natural Resources, Mines and Energy, Indooroopilly, QLD.

Aurora Environmental (2012a), *Acid Sulfate Soil Management Plan - Lot 100 Wonnerup South Road, Yalyalu.* Unpublished report prepared for Bemax Resources Limited.

Aurora Environmental (2012b), *Acid Sulfate Soil Sampling and Analysis Plan Wonnerup South Mineral Sands Deposit Lot 3819 Bussell Highway, Yalyalup.* Unpublished report prepared for Cristal Mining Australia Limited 25 October 2012.

Belford, S.M (1987), *Busselton Sheet 1930*, Environmental Geology Series, Geological Survey of Western Australia.

Cable Sands (WA), (2011), *CD427 Operating Strategy for Groundwater Dewatering Wonnerup Mineral Sands Mine* (Rev 0).

DEC (2010), *Assessment levels for soils, sediment and water*, Contaminated Sites Management Series, Department of Environment and Conservation (DEC), Perth, Western Australia.

DEC (2011), *Treatment and management of soils and water in acid sulfate soil landscapes*. Acid Sulfate Soils Guideline Series. Department of Environment and Conservation, Perth, WA.

DEC (2012), *Investigation and Management of Acid Sulfate Soil Hazards Associated with Silica and Heavy Mineral Sand Mining Operations*. Department of Environment and Conservation (DEC), Perth Western Australia.

DEC (2013), *Identification and investigation of acid sulfate soils and acidic landscapes*. Acid Sulfate Soils Guideline Series. Department of Environment and Conservation (DEC), Perth (previously DEC, 2009).

Hey, K.M., Ahern, C.R and Watling, K.M (2000), *Using chemical field tests to identify acid sulphate soils likelihood in Acid Sulfate Soils*: Environmental Issues, Assessment and Management, Technical Papers edited by C.R Ahern, K. M Hey, K.M Watling and V.J Eldershaw: Queensland Department of Natural Resources.

Hirschberg, K-J.B. (1989), *Busselton Shallow-Drilling Groundwater Investigation, Perth Basin*. Report 25 Professional Papers, Geological Survey of Western Australia (GSWA). National Library of Australia Card Number and ISBN 0 7309 1130 6.

Landgate (2009), *(https://www2.landgate.wa.gov.au/bmvf/app/waatlas/#,)* accessed 9 September 2009. Western Australian Land Information Authority, Perth, WA.

Landgate (2013), *(https://www2.landgate.wa.gov.au/bmvf/app/waatlas/#,)* accessed 30 July 2013. Western Australian Land Information Authority, Perth, WA.

SEPA (2005), *Hydrogeological Risk Assessment for Landfills and the Derivation of Control and Trigger Levels*, Scottish Environment Protection Agency (SEPA) Technical Guidance Note, V2.12 available at web site www.sepa.org.uk.

URS (2008), *Groundwater Impact Assessment – Wonnerup Deposit*. Prepared for Bemax Resources, April 2008.

URS (2013), *Wonnerup and Wonnerup South Projects Addendum for Concurrent Mining Plans.* Prepared for Cristal Mining Australia Limited, August 2013

FIGURES

Aurora environmental

Cristal Mining Australia Limited
ACID SULFATE SOILS INVESTIGATION AND MANAGEMENT PLAN
WONNERUP SOUTH

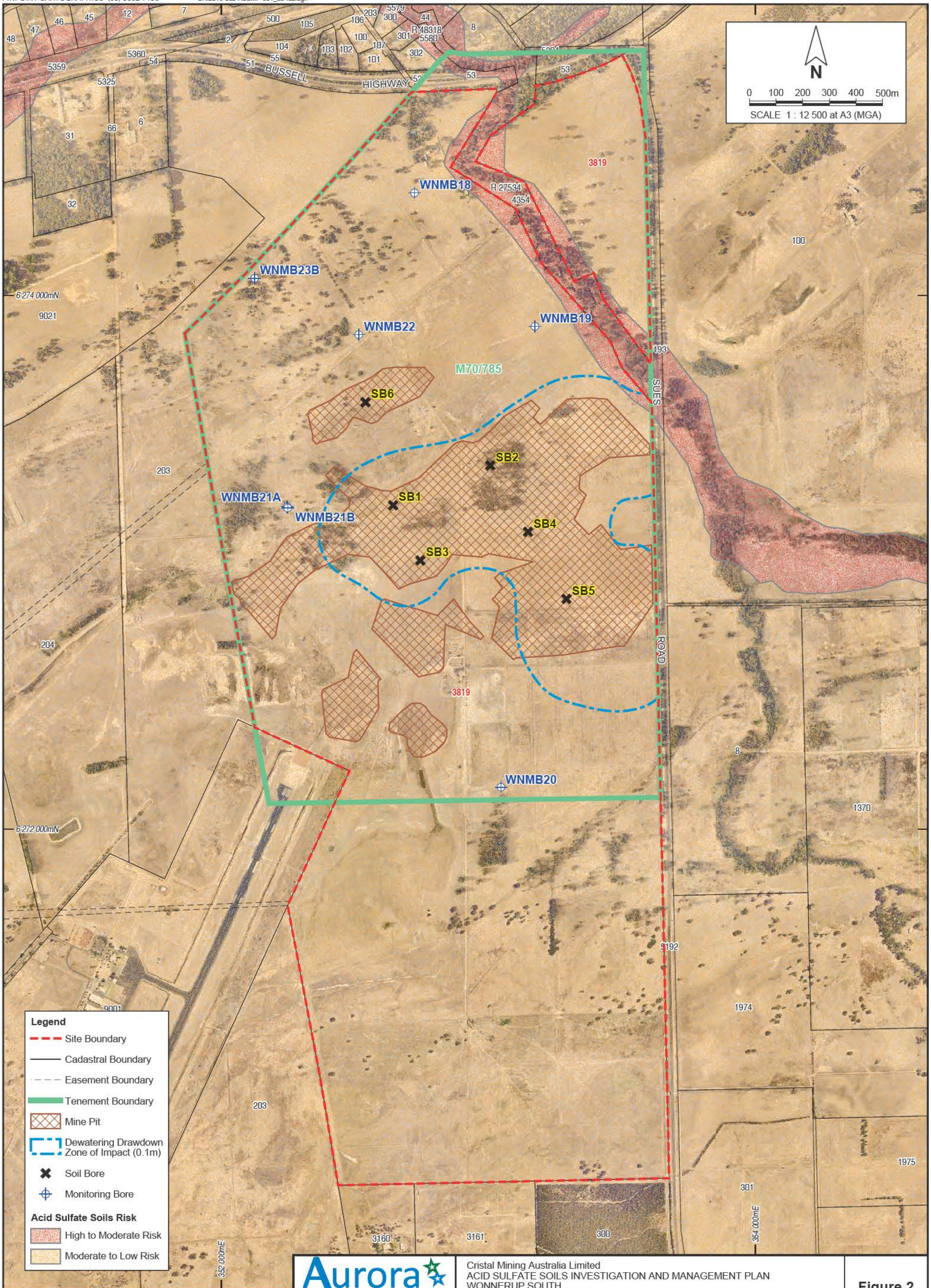
Figure 1

REGIONAL SITE LOCATION

Drawn: D. Bourke | Date: 21 Jul 2013 | Job: CRI2013-002

PINPOINT CARTOGRAPHICS (08) 9562 7136 CRI2013-002-ASSMP-001_db-f01.dgn

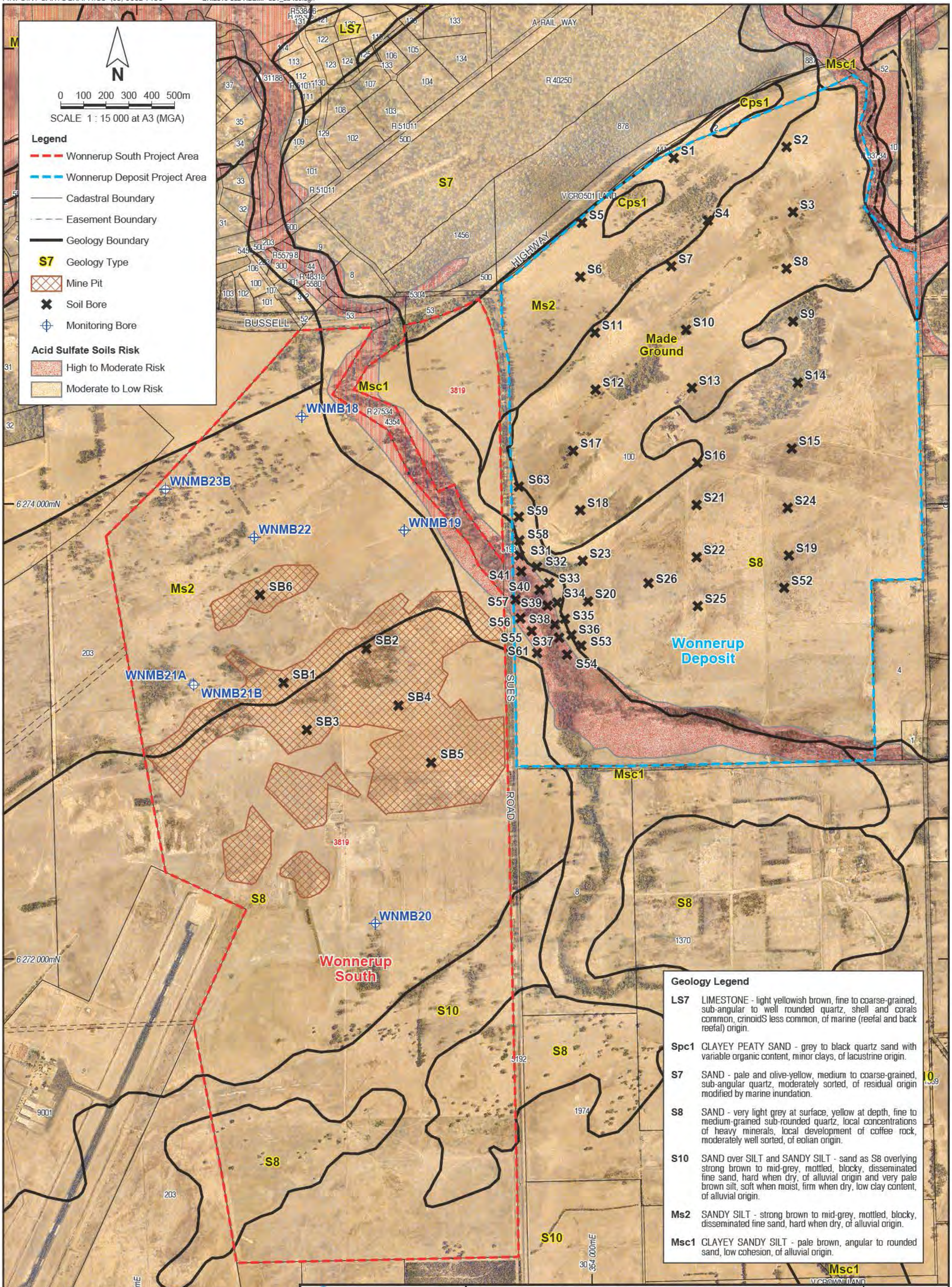
PINPOINT CARTOGRAPHICS (08) 9562 7136 CRI2013-002-ASSMP-001_db-f02.dgn



TENEMENT SOURCE: DMP, July 2013.
ACID SULFATE SOILS SOURCE: DPI, 2007.
CADASTRAL SOURCE: Landgate, October 2012.
AERIAL PHOTOGRAPH SOURCE: NearMap, flown February 2012.
GROUNDWATER DRAWDOWN SOURCE: URS, Job No. 42908187, 07/07/2013.

Aurora environmental	Cristal Mining Australia Limited ACID SULFATE SOILS INVESTIGATION AND MANAGEMENT PLAN WONNERUP SOUTH	Figure 2
Drawn: D. Bourke / Date: 10 Oct 2013	WONNERUP SOUTH SITE LOCATION	Job: CRI2013-002

PINPOINT CARTOGRAPHICS (08) 9562 7136 CRI2013-002-ASSMP-001_db-f03.dgn



Aurora environmental

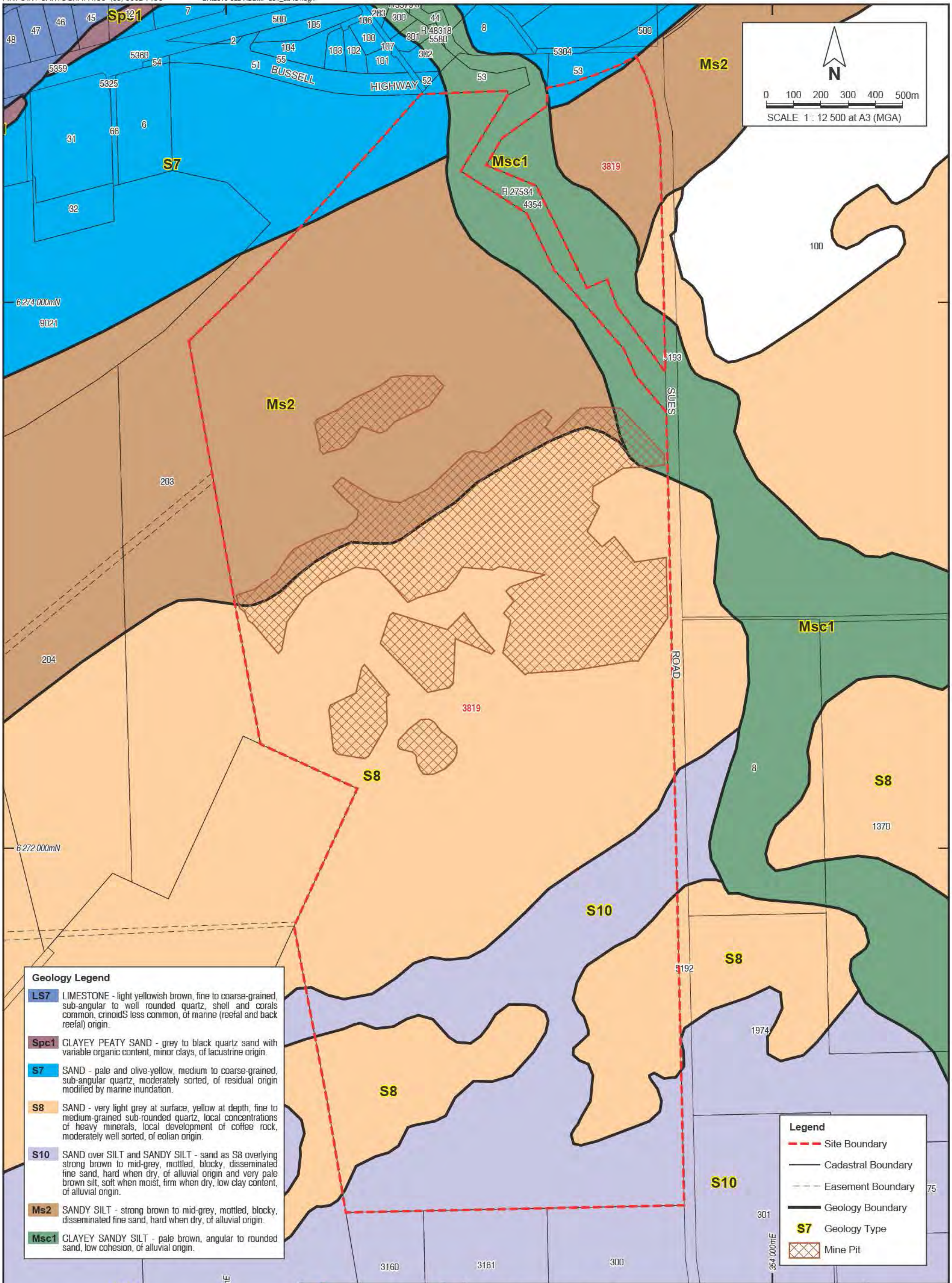
Cristal Mining Australia Limited
ACID SULFATE SOILS INVESTIGATION AND MANAGEMENT PLAN
WONNERUP SOUTH

Figure 3

WONNERUP SOUTH AND WONNERUP DEPOSIT LOCATIONS

Drawn: D. Bourke | Date: 6 Aug 2013 | Job: CRI2013-002

PINPOINT CARTOGRAPHICS (08) 9562 7136 CRI2013-002-ASSMP-001_db-f04.dgn



ACID SULFATE SOILS SOURCE: DPI, 2007.
CADASTRAL SOURCE: Landgate, October 2012.
AERIAL PHOTOGRAPH SOURCE: NearMap, flown February 2012.
GEOLOGY SOURCE: Geological Survey of WA 1:50 000 Environmental Geology Series.

Aurora environmental

Drawn: D. Bourke | Date: 21 Jul 2013

Cristal Mining Australia Limited
ACID SULFATE SOILS INVESTIGATION AND MANAGEMENT PLAN
WONNERUP SOUTH

WONNERUP SOUTH GEOLOGY

Figure 4

Job: CRI2013-002

PINPOINT CARTOGRAPHICS (08) 9562 7136 GRI2013-002-ASSMP-001_db-f05.dgn

CADASTRAL SOURCE: Landgate, October 2012.
AERIAL PHOTOGRAPH SOURCE: NearMap, flown February 2012.
GROUNDWATER CONTOUR SOURCE: URS, Job No. 42906378, 22/06/2007.

Aurora environmental

Cristal Mining Australia Limited
ACID SULFATE SOILS INVESTIGATION AND MANAGEMENT PLAN
WONNERUP SOUTH

Figure 5

Drawn: D. Bourke | Date: 26 Oct 2012

WONNERUP SOUTH HYDROGEOLOGY

Job: BRL2012-001

APPENDIX 1

Wonnerup South Field Screening Results

Wonnerup South
Preliminary Screening Results

				Field Test Results			
				pH_F	pH_{FOX}	ΔpH	Reaction Rate
			Limit of Detection	0.01	0.01	0.01	-
Physical Soil Description			*Criteria*	*<4*	*<3*	*3*	*NV*
Sample Location ID	**Soil Interval**	**Soil Colour (Hue, Chroma)**	**Field Texture**				
SB1	0-0.5	light grey	sand	5.89	4.9	0.99	nil
	0.5-1.0	light grey	sand	6.02	5.6	0.42	
	1.0-1.5	grey + yellow brown	sand	6.65	3.27	3.38	
	1.5-2.0	light grey + red brown	clayey sand	5.46	3.99	1.47	
	2.0-2.5	light grey + red brown	clayey sand	5.68	4.16	1.52	
	2.5-3.0	light grey + red brown	clayey sand	5.58	4.59	0.99	
	3.0-3.5	light grey	clayey sand	5.67	4.53	1.14	
	3.5-4.0	light grey	clayey sand	5.73	4.63	1.1	
SB2	0-0.5	dark grey	sand	5.3	4.22	1.08	
	0.5-1.0	moderate yellow and dark grey	sand	5.55	4.59	0.96	
	1.0-1.5	moderate yellow and dark grey	sand	5.81	4.88	0.93	
	1.5-2.0	becoming light grey	sand	5.65	5.22	0.43	
	2.0-2.5	light grey	sand	5.14	3.71	1.43	
	2.5-3.0	light bluish grey	sandy clay to clayey sand	5.91	3.3	2.61	
	3.0-3.5	light bluish grey	clayey sand	5.94	**2.99**	2.95	
	3.5-4.0	light bluish grey	sandy clay becoming clayey sand	5.45	4.23	1.22	
	4.0-4.5	light grey	clayey sand	5.68	4.9	0.78	
	4.5-5.0	light grey	sand to clayey sand	5.6	4.56	1.04	
SB3	0-0.5	light grey	sand	4.68	3.9	0.78	
	0.5-1.0	moderate yellow	sand	4.66	4.12	0.54	
	1.0-1.5	moderate yellow	sand	4.42	3.65	0.77	
	1.5-2.0	moderate yellow	sand	5.97	5.13	0.84	
	2.0-2.5	light grey	sand	6.22	4.62	1.6	
	2.5-3.0	light grey	sand	6.46	4.58	1.88	
	3.0-3.5	light grey + red brown	sand	6.55	5.05	1.5	
	3.5-4.0	light grey + red brown +	sand	6.25	4.67	1.58	
	4.0-4.5	light grey + red brown + yellow brown	sand to clayey sand	6.23	5.07	1.16	
	4.5-5.0	light grey + red brown + yellow brown	sand to clayey sand	5.99	4.67	1.32	
	5.0-5.5	light grey + red brown +	sand to clayey sand	6.02	4.81	1.21	
	5.5-6.0	light grey + red brown +	sandy clay to clayey sand	6.07	5.57	0.5	
	6.0-6.5	light bluish grey	sandy clay to clayey sand	5.68	6.72	1.04	
	6.5-7.0	light bluish grey	sandy clay to clayey sand	6.06	6.2	0.14	
	7.0-7.5	light bluish grey	sandy clay to clayey sand	5.8	5.29	0.51	v
	7.5-8.0	dark grey + yellow brown	clayey sand to sandy clay	5.99	5.3	0.69	v
	8.0-8.5	dark grey + yellow brown	sandy clay to clayey sand	6.31	5.42	0.89	v
	8.5-9.0	dark grey	sandy clay to clayey sand	6.57	5.57	1	v

Physical Soil Description				Field Test Results			
				pH_F	pH_{FOX}	ΔpH	Reaction Rate
			Limit of Detection	0.01	0.01	0.01	-
			Criteria	*<4*	*<3*	*3*	*NV*
SB4	0-0.5	black becoming grey	sand	4.2	4.12	0.08	
	0.5-1.0	light grey	sand	4.9	5.36	0.46	
	1.0-1.5	light grey	sand	6.78	5.65	1.13	
	1.5-2.0	light grey	sand to clayey sand	6.89	4.73	2.16	
	2.0-2.5	light grey	clayey sand	6.82	5.85	0.97	
	2.5-3.0	grey and dark brown	sand to clayey sand	7.16	5.72	1.44	
	3.0-3.5	bluish grey and moderate brown	clayey sand	7.28	5.97	1.31	
	3.5-4.0	yellow brown	sand	6.79	5.65	1.14	
	4.0-4.5	moderate yellow brown +	sand	6.33	5.77	0.56	
	4.5-5.0	moderate yellow brown +	sand	6.83	5.69	1.14	
	5.0-5.5	moderate yellow brown +	sand	6.9	5.71	1.19	
	5.5-6.0	light grey	sand to clayey sand	6.95	5.69	1.26	
	6.0-6.5	light grey	sand to clayey sand	6.63	5.64	0.99	
	6.5-7.0	light grey	sand to clayey sand	6.68	5.74	0.94	
SB5	0-0.5	black and dark grey	sand	5.41	3.66	1.75	
	0.5-1.0	light grey	sand	6	4.73	1.27	
	1.0-1.5	light greyish blue	sand	7.24	5.75	1.49	
	1.5-2.0	light grey	sand	6.2	3.62	2.58	
	2.0-2.5	light grey	sand to clayey sand	6.43	**2.66**	3.77	
	2.5-3.0	grey and reddish brown	sand to clayey sand	6.44	5.03	1.41	
	3.0-3.5	light grey	clayey sand	6.5	5.56	0.94	
	3.5-4.0	light grey	clayey sand	6.51	5.29	1.22	
	4.0-4.5	light grey	clayey sand	6.3	5.32	0.98	
	4.5-5.0	light grey	clayey sand	6.64	5.25	1.39	
SB6	0-0.5	black becoming grey	sand	7.79	5.93	1.86	
	0.5-1.0	light grey and yellow brown	sand to clayey sand	7.59	5.58	2.01	
	1.0-1.5	light grey and yellow brown	sand to clayey sand	6.99	5.86	1.13	
	1.5-2.0	light grey and yellow brown	sand to clayey sand	6.94	5.56	1.38	
	2.0-2.5	light grey and yellow brown	sand to clayey sand	6.88	5.45	1.43	
	2.5-3.0	light grey and yellow brown	sand to clayey sand	6.93	5.45	1.48	
	3.0-3.5	light grey and yellow brown	sand to clayey sand	6.49	5.36	1.13	
	3.5-4.0	light grey and yellow brown	sand to clayey sand	5.91	5.06	0.85	
	4.0-4.5	light grey and yellow brown	clay	5.94	5.05	0.89	
	4.5-5.0	light grey and yellow brown	clay	6.05	5.53	0.52	

APPENDIX 2

Wonnerup Deposit Field Screening Results

Physical Soil Description					*Field Test Results*	*Laboratory Test Results*			
Sample Location ID	Soil Interval	Soil Colour (Hue, Chroma)	Field Texture	Comment	pH_F	pH_F	pH_{FOX}	ΔpH	Reaction Rate
				Units			-		-
				Limit of Reporting	0.01	0.01	0.01	0.01	-
				Criteria	<4	<4	<3	3	NV
S1	0-0.25m	Dark yellowish brown	Clayey sand		5.82	5.5	4.3	1.2	Very vigorous
	0.25-0.60	Moderate brown	Medium grained sandy clay		8.24	7.6	6.1	1.5	Moderate
	0.6-0.75	Moderate brown	Clay		8.68	8.4	6.3	2.1	Slight
	0.75-1.25	Moderate brown	Clay	Saturated 1.0m	8.68	8.4	7.1	1.3	Very vigorous
					8.25	8.3	8.6	-0.3	Very vigorous
	1.25-1.50	Moderate yellow	Clay		7.80	8.3	8.5	-0.2	Very vigorous
S2	0-0.25m	Dark yellowish brown	Fine grained Sand		5.18	5.8	4.6	1.2	Slight
	0.25-1.00	Dark yellowish brown	Fine to medium grained sand		4.88	5.9	5.5	0.4	Slight
					5.07	6.1	5.4	0.7	Slight
	1.00-1.25	Yellowish grey	Medium grained sandy		5.74	6.7	5.7	1.0	Slight
	1.25-1.50	Moderate yellowish	Medium grained sandy		6.28	7.2	5.8	1.4	Slight
					5.93	6.9	5.6	1.3	Slight
S3	0-0.60m	Pale yellowish brown	Fine to medium grained silty sand		4.52	5.5	4.5	1.0	Slight
					4.39	5.5	4.7	0.8	Slight
	0.60-0.90	Pale yellowish brown	Medium grained silty sand, high mineral sands content		4.78	5.2	4.9	0.3	Slight
	0.90-1.30	Olive grey	Medium grained sand, high mineral sands content		6.13	7.4	7.3	0.1	Vigorous
	1.30-1.75	Greenish grey	Clay	Moist 1.75m	6.34	6.8	5.9	0.9	Vigorous
					7.04	6.9	5.9	1.0	Slight
					7.76	7.4	6.3	1.1	Slight
	1.75-2.30	Greenish grey	Sandy clay, small laterite pieces to 10mm diameter		6.79	6.9	5.8	1.1	Slight
					6.78	6.8	5.3	1.5	Slight
					6.68	6.5	5.3	1.2	Slight
	2.30-2.50	Greenish grey	Clay, very stiff		6.41	6.3	5.2	1.1	Slight
S4	0-0.50	Dark grey	Fine to medium grained sand		5.99	5.7	4.5	1.2	Slight
					6.36	6.2	5	1.2	Slight
	0.50-0.75	Medium grey	Medium grained sand		6.37	6.3	5.2	1.1	Slight
	0.75-1.50	Olive grey	Medium grained sand	Moist 1.50	6.50	6.4	5.3	1.1	Slight
					6.63	6.7	5.6	1.1	Vigorous
	1.50-1.80	Moderate grey	Medium grained clay sand	Mosit	6.85	5.0	3.8	1.2	Slight
					7.24	7.6	5.6	2.0	Slight
	1.80-2.25	Moderate brown	Medium grained sand	Moist to 2.25m	6.84	7.0	5.4	1.6	Slight
					6.74	7.0	5.5	1.5	Slight
	2.25-2.50	Pale yellowish brown	Medium grained sand		6.64	6.7	5.3	1.4	Slight
	2.50-2.80	Moderate brown	medium grained sand, some small laterite		6.51	6.5	5	1.5	Slight
	2.80-3.00	Light brown	Course grained sand		6.61	6.5	5	1.5	Slight
	3.00-3.75	Olive grey	Fine grained silty sand		6.27	6.5	5.7	0.8	Slight
					6.25	6.5	5.4	1.1	Slight
	3.75-4.10	Medium grey	Course grained silty sand		6.32	6.6	5.7	0.9	Slight
					6.61	6.7	5.4	1.3	Slight
	4.10-4.30	Moderate brown	Medium sand		6.44	6.2	5.2	1.0	Slight
	4.30-4.50	Olive grey	Medium silty sand		6.60	6.6	5.4	1.2	Slight
					6.68	6.6	5	1.6	Slight

Wonnerup Deposit
Preliminary Screening Results

Physical Soil Description					*Field Test Results*	*Laboratory Test Results*			
Sample Location ID	Soil Interval	Soil Colour (Hue, Chroma)	Field Texture	Comment	pH_F	pH_F	pH_{FOX}	ΔpH	Reaction Rate
				Units			-		-
				Limit of Reporting	0.01	0.01	0.01	0.01	-
				Criteria	<4	<4	<3	3	NV
S5	0-0.20	Pale yellowish brown	Medium grained sand		-	-	-	-	-
	0.20-0.75	Dark yellowish brown	Medium grained sandy clay, mineral sand	Saturated 0.50	7.04	6.4	5.6	0.8	Slight
					7.66	6.8	5.6	1.2	Slight
	0.75-1.25	Light brown	Clay, with gravel pieces	Moist at 0.75	7.61	7.1	5.8	1.3	Slight
					6.68	5.9	5.4	0.5	Slight
	1.25-1.50	Light brown	Medium grained clay sand, stiff		5.91	5.3	4.6	0.7	Slight
					5.60	4.8	4.4	0.4	Slight
S6	0-0.50	Moderate yellowish	Clay, stiff		7.42	6.8	6	0.8	Vigorous
					7.22	6.7	5.9	0.8	Slight
	0.50-1.50	Pale yellowish brown	Clay, stiff		6.09	5.8	4.8	1.0	Slight
					5.98	5.4	4.7	0.7	Slight
					6.23	5.3	4.7	0.6	Slight
					6.62	5.9	5.1	0.8	Slight
S7	0-0.25	Dark grey	Fine to medium grained sand, topsoil		5.31	5.6	4	1.6	Vigorous
	0.25-1.00	Medium grey	Medium grained sand, traces mineral sands, root material		5.73	6.3	5.2	1.1	Slight
					5.75	6.3	5.2	1.1	Slight
	1.00-1.50	Light grey	Medium grained sand, traces mineral sands	Moist at 1.30m	5.64	5.7	4.8	0.9	Slight
					5.54	5.8	4	1.8	Slight
	1.50-2.25	Pale yellowish brown	Medium grained clay sand	Saturated at 2.25m	6.04	7.1	5.4	1.7	Slight
					5.13	6.2	5.2	1.0	Slight
					5.28	6.5	5.7	0.8	Slight
					5.28	6.5	5.6	0.9	Slight
					5.82	6.4	5.7	0.7	Slight
	2.25-2.75	Pale yellowish brown	Medium grained clay sand		6.14	6.7	5.5	1.2	Slight
					6.24	6.6	5.5	1.1	Slight
	2.75-3.00	Medium grey	Medium grained clay sand, shell grit		5.87	6.8	5.5	1.3	Slight
	3.00-3.50	Greyish orange	Fine grained silty sand		6.07	6.6	5.5	1.1	Slight
					6.27	6.7	5.6	1.1	Slight
	3.50-3.75	Greyish orange	Medium grained silty sand		6.32	6.3	5.6	0.7	Slight
	3.75-4.25	Medium grey	Medium grained silty sand, small laterite pieces		6.60	6.3	5.6	0.7	Slight
	4.25-4.60	Light brown	Course sand		6.36	6.5	5.7	0.8	Slight
					6.16	6.1	5.5	0.6	Slight
	4.60-5.25	Moderate brown	Medium grained caly sand		6.67	6.5	5.5	1.0	Slight
					6.47	6.4	5.5	0.9	Slight
	5.25-5.5	Medium grey	Clay		6.60	6.4	5.5	0.9	Slight
					6.85	6.6	5.4	1.2	Slight
S8	0-0.50	Moderate yellowish	Fine to medium grained sand		6.50	4.5	4.8	-0.3	Slight
					5.34	5.2	4.7	0.5	Slight
	0.50-1.25	Moderate brown	Medium grained sand		5.97	6	5.5	0.5	Slight
					6.10	6.2	5.7	0.5	Slight
					6.27	6.3	5.6	0.7	Slight
	1.25-1.50	Light brown	Clay sand, iron coloured mottles		6.41	6.4	5.6	0.8	Slight
					6.46	6.4	5.4	1.0	Slight
	1.50-2.25	Greyish orange	Clay		6.29	6.2	5.4	0.8	Slight
					6.11	5.2	4.3	0.9	Slight
					6.02	4.7	3.7	1.0	Slight
	2.25-2.60	Greyish red	Silty clay, iron coloured mottles		5.35	3.9	2.6	1.3	Slight
	2.60-2.80	Medium grey	Clay, stiff		6.98	5.3	2.6	2.7	Very Vigorous
	2.80-2.90	Medium grey	Course grained sandy clay		-	-	-	-	-
	2.90-3.30	Medium grey	Course grained clay sand	Saturated at 3.0m	6.89	5.3	3.7	1.6	Slight
					6.75	4.4	3.5	0.9	Slight
	3.30-3.50	Olive grey	Clay, some gravel pieces to 10mm		6.31	4.7	4	0.7	Slight

Physical Soil Description					Field Test Results	Laboratory Test Results			
Sample Location ID	Soil Interval	Soil Colour (Hue, Chroma)	Field Texture	Comment	pH_F	pH_F	pH_{FOX}	ΔpH	Reaction Rate
				Units		-	-	-	-
				Limit of Reporting	0.01	0.01	0.01	0.01	-
				Criteria	<4	<4	<3	3	NV
S8	3.50-4.30	Moderate grey	Clay, stiff		6.52	5.1	2.1	3.0	Very Vigorous
					6.31	5.0	4.6	0.4	Moderate
					5.53	4.8	4.2	0.6	Slight
	4.30-4.60	Light brown	Course grained silty sand		5.25	5.1	4.7	0.4	Slight
	4.60-4.80	greyish red	Silty clay, small content of fine grained sand		5.54	5.1	4.9	0.2	Slight
	4.80-5.0	Greyish red	Silty clay, trace amount of medium grained sand		5.59	5.2	5.2	0.0	Slight
S9	0-0.25	Medium grey	Fine to medium grained sand		4.77	4.7	4	0.7	Slight
	0.25-1.10	Pale yellowish brown	Fine to medium grained sand, traces of mineral sands		4.84	4.9	4.9	0.0	Slight
					5.05	5.2	5.2	0.0	Slight
					5.55	5.5	5.5	0.0	Slight
	1.10-2.00	Moderate brown	Medium grained sand, traces of mineral sands	Saturated at 1.50m	5.84	5.8	5.4	0.4	Slight
					5.89	5.7	5.3	0.4	Slight
					5.85	5.9	5.4	0.5	Slight
	2.00-3.00	Light grey	Medium grained sand, traces of mineral sands		5.90	6.1	5.6	0.5	Slight
					6.28	6.4	5.6	0.8	Slight
					6.79	6.5	5.6	0.9	Slight
	3.00-3.25	Olive grey	Fine grained silty sand, traces of mineral sands		6.99	6.6	5.7	0.9	Slight
					7.12	7.0	5.3	1.7	Slight
	3.25-3.40	Greyish red	Medium grained silty sand, iron staining, mineral sands content		-	-	-	-	-
	3.40-4.0	Light brown	Medium grained silty clay sand		6.21	6.3	5.3	1.0	Slight
					6.06	6.1	5.4	0.7	Slight
					5.84	6.5	5.4	1.1	Slight
					5.97	6.2	5.6	0.6	Slight
S10	0-0.80	Pale yellowish brown	Fine to medium grained sand, minor mineral sand content		4.98	6.7	5.4	1.3	Slight
					5.62	6.5	5.5	1.0	Slight
					6.14	6.5	5.5	1.0	Slight
	0.80-1.20	Light brown	Fine silty clay		6.01	6	5.5	0.5	Slight
	1.20-1.50	Olive grey	Clay, wet and sticky		6.77	6.1	4	2.1	Moderate
					6.38	5.7	5.5	0.2	Slight
S11	0-0.25	Dark grey	Fine to medium grained sand		6.08	6.2	4.4	1.8	Vigorous
	0.25-0.75	Light grey	Medium grained sand, trace amount of mineral sands		6.15	5.8	4.9	0.9	Slight
					6.52	6.4	4.8	1.6	Slight
	0.75-1.00	Olive grey	Medium grained sand, trace mineral sands		6.48	5.4	2.8	2.6	Moderate
					-	5.2	4	1.2	Slight
	1.00-1.25	Greyish orange	Medium grained sand, trace mineral sands		7.85	5.9	2.8	3.1	Very Vigorous
	1.25-1.50	Dark greenish grey	Clay	Saturated at 1.25m	7.48	7.8	4.9	2.9	Moderate
	1.50-1.75	Dark greenish grey	Medium grained clay sand		7.61	7.6	4.2	3.4	Slight
	1.75-2.00	Medium grey	Medium grained sand		6.85	6.7	5.6	1.1	Slight
	2.00-2.50	Light brown	Medium grained clay sand		6.81	7.2	5.6	1.6	Slight
	2.50-2.75	Greyish orange	Medium grained sand		6.46	7.2	5.6	1.6	Slight
					6.44	6.9	5.6	1.3	Slight
	2.75-3.00	Light brown	Clay, gravel content, solid laterite at 3.00m - refusal		6.47	6.6	5.7	0.9	Slight
S12	0-0.10	Olive grey	Fine to medium grained sand		-	-	-	-	-
	0.10-1.50	Moderate yellowish	Medium grained sand with mineral		4.51	5.4	5.3	0.1	Slight
					4.80	4.7	4.6	0.1	Slight

Physical Soil Description					Field Test Results	Laboratory Test Results			
Sample Location ID	Soil Interval	Soil Colour (Hue, Chroma)	Field Texture	Comment	pH_F	pH_F	pH_{FOX}	ΔpH	Reaction Rate
				Units		-	-	-	-
				Limit of Reporting	0.01	0.01	0.01	0.01	-
				Criteria	<4	<4	<3	3	NV
S12		brown	sands bands between 1.00-1.25m		5.90	5.8	5.1	0.7	Slight
					6.14	5.2	5.1	0.1	Slight
					6.25	6.3	5.5	0.8	Slight
					6.24	6.2	5.2	1.0	Slight
S13	0-0.60	Dark yellowish brown	Fine to medium grained sand, some gravel pieces		6.05	6.2	5	1.2	Slight
					6.36	6.2	5.3	0.9	Slight
	0.60-0.70	Moderate yellowish brown	Fine to medium grained sand		-	-	-	-	-
	0.70-1.20	Moderate yellowish brown	Medium to course sand, some shell grit		6.71	6.5	5.3	1.2	Slight
					6.67	6.5	5.4	1.1	Slight
	1.20-1.50	Dark yellowish brown	Medium grained sand, with pieces of red rock to 25mm		6.69	6.7	5.4	1.3	Slight
					6.64	6.3	5.3	1.0	Slight
					6.68	6.3	5.4	0.9	Slight
	1.50-3.00	Moderate yellowish brown	Fine to medium grained sand, some minor silt		6.60	6.2	5.4	0.8	Moderate
					6.61	6.3	5.4	0.9	Slight
					6.68	6.4	5.4	1.0	Slight
					6.72	6.5	5.4	1.1	Slight
					6.69	6.5	5.4	1.1	Slight
					6.70	6.3	5.6	0.7	Slight
	3.00-4.50	Olive grey	Fine to medium grained silty sand, with consitent iron stained mottles throughout proflie		6.54	6.5	5.7	0.8	Slight
					6.33	6.4	5.7	0.7	Slight
					6.52	6.4	5.6	0.8	Slight
					6.47	6.2	5.6	0.6	Slight
					6.59	6.4	5.6	0.8	Slight
	4.50-4.75	Olive grey	Silty clay, with pieces of red rock to 50mm		6.80	6.3	5.6	0.7	Slight
					6.56	6.2	5.5	0.7	Slight
	4.75-4.85	Medium grey	Course silty sand, with pieces of red rock to 50mm		-	-	-	-	-
	4.85-5.60	Yellowish grey	Clay, stiff, some mineral sand content		6.61	5.9	5.6	0.3	Slight
					6.61	6.3	5.4	0.9	Slight
					6.85	5.7	5.4	0.3	Moderate
	5.60-7.10	Medium bluish grey	Clay, stiff		7.05	6.0	5.1	0.9	Moderate
					6.99	6.6	5.4	1.2	Moderate
					7.39	8.0	5.7	2.3	Moderate
					7.19	8.3	5.9	2.4	Moderate
					7.21	7.8	5.6	2.2	Moderate
					7.15	7.0	5.7	1.3	Moderate
					7.14	7.3	5.6	1.7	Moderate
	7.10-7.40	Moderate brown	Clay, stiff		6.91	7.1	5.5	1.6	Moderate
	7.40-7.50	Medium grey	Course grained sand		6.89	7.0	5.4	1.6	Moderate

Physical Soil Description					Field Test Results	Laboratory Test Results			
				Comment	pH_F	pH_F	pH_{FOX}	ΔpH	Reaction Rate
				Units		-			-
				Limit of Reporting	0.01	0.01	0.01	0.01	-
Sample Location ID	Soil Interval	Soil Colour (Hue, Chroma)	Field Texture	*Criteria*	<4	<4	<3	3	NV
S14	0-0.25	Medium grey	Fine to medium grained sand		5.00	5.2	5.2	0.0	Slight
	0.25-1.00	Pale yellowish brown	Medium grained sand		5.08	5.8	5.2	0.6	Slight
					5.43	5.3	5	0.3	Slight
	1.00-1.50	Moderate brown	Medium grained silty sand		5.50	6.1	5.3	0.8	Slight
					5.60	6.3	5.3	1.0	Slight
	1.50-3.00	Pale yellowish brown	Medium grained silty sand, some laterite to 50mm	Moist at 1.50m. Saturated at 2.0m	5.60	5.9	5.3	0.6	Slight
					6.53	6.8	5.7	1.1	Slight
					6.67	7.0	5.7	1.3	Slight
					6.30	6.6	5.6	1.0	Slight
					5.99	6.3	5.5	0.8	Slight
					5.97	6.3	5.4	0.9	Slight
	3.00-3.25	Olive grey	Sandy clay		5.99	5.8	4.9	0.9	Slight
					6.03	5.7	4.5	1.2	Slight
	3.25-5.75	Olive grey	Clay, stiff, red mottling, minor mineral sands throughout		5.98	5.6	5.1	0.5	Slight
					5.56	6.7	5.6	1.1	Moderate
					6.38	6.0	5.1	0.9	Moderate
					5.90	6.5	5.6	0.9	Slight
					5.73	6.5	5.4	1.1	Moderate
					5.75	5.9	5	0.9	Moderate
					5.97	6.2	5.4	0.8	Slight
					5.88	6.4	6	0.4	Slight
					7.25	8.7	7.4	1.3	Vigorous
					7.08	8.6	5.7	2.9	Moderate
	5.75-5.80	Medium grey	Clay, stiff		7.08	8.1	6.2	1.9	Very Vigorous
	5.80-6.00	Dark greenish grey	Silty clay		7.47	8.8	6.2	2.6	Very Vigorous
	6.00-6.40	Dark yellowish brown	Silty clay, gravel pieces to 5mm	Saturated at 6.00-6.40m	6.13	6.4	5.5	0.9	Moderate
	6.40-6.70	Medium grey	Clay, stiff		6.69	7.4	5.5	1.9	Moderate
	6.70-7.60	Moderate brown	Clay		6.46	6.3	5.2	1.1	Moderate
					6.57	6.3	5	1.3	Moderate
					6.50	6.4	5.1	1.3	Slight
					6.27	6.2	4.7	1.5	Moderate
	7.60-8.10	Medium grey	Clay, plastic		6.57	6.5	5.1	1.4	Moderate
					6.58	6.6	5.2	1.4	Slight
	8.10-8.30	Dark grey	Clay , stiff		6.60	6.7	4.9	1.8	Slight
	8.30-8.50	Moderate brown	Clay, stiff		6.76	7.1	5.4	1.7	Slight
S15	0-0.25	Pale yellowish brown	Fine to medium grained sand		4.82	5.8	5.1	0.7	Slight
	0.25-2.80	Moderate yellowish brown	Medium grained sand, mineral sands bands throughout, some quartz	Moist at 1.40m	4.92	5.5	5	0.5	Slight
					5.05	5.3	5.3	0.0	Slight
					4.45	5.6	5.3	0.3	Slight
					5.74	6.1	5.4	0.7	Slight
					6.04	6.3	5.4	0.9	Slight
					6.17	6.3	5.5	0.8	Slight
					6.19	6.4	5.5	0.9	Slight
					6.24	6.3	5.5	0.8	Slight
					6.29	6.5	5.6	0.9	Slight
					6.34	6.5	5.6	0.9	Slight
					6.42	6.5	5.5	1.0	Slight
	2.80-3.0	Moderate yellow brown	Medium to course grained sand		6.45	6.4	5.6	0.8	Slight

Physical Soil Description					Field Test Results	Laboratory Test Results			
Sample Location ID	Soil Interval	Soil Colour (Hue, Chroma)	Field Texture	Comment	pH_F	pH_F	pH_{FOX}	ΔpH	Reaction Rate
				Units			-		-
				Limit of Reporting	0.01	0.01	0.01	0.01	-
				Criteria	<4	<4	<3	3	NV
S16	0-0.20	Medium grey	Medium grained sand, quartz		-	-	-	-	-
	0.20-1.60	Moderate brown	Medium grained sand, quartz		5.90	6	5.1	0.9	Slight
					6.11	6.2	5.1	1.1	Slight
					6.23	6.3	5.3	1.0	Slight
					6.32	6.2	5.3	0.9	Slight
					6.26	6.1	5.4	0.7	Slight
					6.07	5.9	5.3	0.6	Slight
	1.60-1.75	Light brown	Medium grained silty sand, traces of mineral sands	Saturated at 1.60m	6.38	6.3	5.5	0.8	Slight
	1.75-3.00	Medium grey	Medium grained sand, traces of mineral sands		6.48	6.3	5.4	0.9	Slight
					6.64	6.4	5.6	0.8	Slight
					6.62	6.2	5.3	0.9	Slight
					6.63	6.4	5.3	1.1	Slight
					6.56	5.9	5.2	0.7	Slight
					6.49	5.8	4.9	0.9	Slight
	3.00-3.50	Pale yellowish brown	Medium to course grained sand, traces mineral sands		6.61	6.1	5.5	0.6	Slight
	3.50-3.60	Olive grey	Medium grained sand, traces of mineral sands		6.58	6.1	5.4	0.7	Slight
	3.60-4.4	Pinkish grey	Sandy clay, iron couored mottling throughout		6.71	5.9	5.5	0.4	Slight
					6.57	6.3	5.4	0.9	Slight
					6.31	6.1	5.4	0.7	Slight
	4.40-4.50	Medium grey	Clay, stiff		6.72	6.1	5.1	1.0	Slight
	4.50-4.80	Pale yellowish brown	Medium grained sand, moderate mineral sand content		6.11	6.0	5.1	0.9	Moderate
	4.80-5.25	Pinkish grey	Clay, stiff, traces of mineral sand		6.24	6.0	5.1	0.9	Slight
	5.25-5.60	Moderate yellowish	Silty clay, traces of mineral sand		5.95	6.0	5	1.0	Moderate
					5.99	5.8	5.1	0.7	Slight
	5.60-6.00	Medium bluish grey	Silty clay, traces of mineral sand		6.17	6.1	5	1.1	Moderate
					6.39	6.4	5.1	1.3	Moderate
	6.00-6.50	Medium bluish grey	Medium grained silty clay sand		6.21	6.2	5.1	1.1	Moderate
					6.09	5.8	5.2	0.6	Moderate
S17	0-0.50	Moderate yellowish brown	Medium grained sand, traces of mineral sand		5.21	5.1	3.9	1.2	Moderate
					5.45	5.6	4.6	1.0	Slight
	0.50-1.75	Light grey	Medium grained sand, traces of mineral sand		5.72	5.8	4.9	0.9	Slight
					5.39	5.6	4.9	0.7	Slight
					5.66	5.9	4	1.9	Slight
					5.94	5.7	5	0.7	Slight
					5.86	5.4	5	0.4	Slight
	1.75-2.25	Olive grey	Medium to course grained sand, traces mineral sands		6.21	6.5	5.6	0.9	Slight
					6.43	6.2	4.7	1.5	Slight
					6.27	6.1	5.5	0.6	Slight
	2.25-2.50	Olive grey	Medium to course grained clay sand		5.83	6.0	4.9	1.1	Slight

Physical Soil Description					*Field Test Results*	*Laboratory Test Results*			
Sample Location ID	**Soil Interval**	**Soil Colour (Hue, Chroma)**	**Field Texture**	Comment	pH_F	pH_F	pH_{FOX}	ΔpH	Reaction Rate
				Units		-	-	-	-
				Limit of Reporting	0.01	0.01	0.01	0.01	-
				Criteria	<4	<4	<3	3	NV
S18	0-0.10	Moderate brown	Medium grained sand, gravel pieces to 10mm		-	-	-	-	-
	0.10-2.0	Moderate yellow	Medium grained sand, bands of mineral sands		5.51	5.9	3.3	2.6	Slight
					5.77	6.1	3.1	**3.0**	Slight
					5.99	6.1	4.4	1.7	Slight
					5.97	6	5.4	0.6	Slight
					6.01	5.2	5.1	0.1	Slight
					6.13	5.5	5.1	0.4	Slight
					6.20	6.2	5.4	0.8	Slight
					6.16	6.2	4.5	1.7	Slight
S19	0-0.60	Moderate yellowish	Medium grained sand		5.07	5	5.2	-0.2	Slight
					5.49	5.8	5.5	0.3	Slight
	0.60-1.50	Moderate	Medium to course grained sand	Moist at 1.00m/ Saturated at 1.30m	6.31	6.3	5.6	0.7	Slight
					6.46	6.4	5.6	0.8	Slight
					6.59	6.4	5.7	0.7	Slight
					6.32	5.7	5.5	0.2	Slight
S20	0-0.15	Dark grey	Fine to medium grain sand, topsoil		-	-	-	-	-
	0.15-1.40	Pale yellowish brown	Fine to medium grained silty sand	Saturated at 0.65m	5.88	6.8	5.3	1.5	Slight
					6.07	6.1	5.3	0.8	Slight
					6.12	5.8	5.5	0.3	Slight
					6.02	6	5.4	0.6	Slight
					5.91	6.1	5.5	0.6	Slight
	1.40-1.50	Light brown	Fine to medium grained silty sand		5.94	6.2	5.4	0.8	Slight
	1.50-1.70	Pale yellowish brown	Fine to medium grained silty sand, traces of mineral sand		-	-	-	-	-
	1.70-2.40	Pale yellowish brown	Medium grained silty sand		5.06	4.6	5.1	-0.5	Slight
					5.40	5.0	5.1	-0.1	Slight
					5.99	5.6	5.2	0.4	Slight
	2.40-2.50	Greyish orange	Medium grained silty sand, small gravel pieces to 10mm		6.08	5.6	4.2	1.4	Slight
S21	0-0.10	Dark grey	Fine grained sand, topsoil		-	-	-	-	-
	0.10-0.40	Light brown	Fine grained silty sand		6.87	7.1	5.2	1.9	Slight
	0.40-0.80	Light brown	Medium grained silty sand	Moist at 0.50m	7.18	7.9	5.5	2.4	Slight
					7.71	8.3	5.8	2.5	Slight
	0.80-1.50	Light brown	Medium to course grained silty sand	Saturated at 0.80m	7.74	8.0	6.1	1.9	Slight
					7.17	7.6	5.9	1.7	Slight
					6.73	7.4	5.7	1.7	Slight
					6.35	6.6	5.6	1.0	Slight
S22	0-0.15	Dark grey	Fine to medium grained sand		-	-	-	-	-
	0.15-0.60	Moderate brown	Fine to medium grained silty sand		4.73	4.4	4.3	0.1	Slight
					4.52	4.4	4.7	-0.3	Slight
	0.60-1.50	Moderate yellowish brown	Fine to medium grained silty sand	Saturated at 0.75m	4.53	4.3	4.5	-0.2	Slight
					5.59	5.5	5.3	0.2	Slight
					6.09	6.2	5.5	0.7	Slight
					6.38	6.2	5.5	0.7	Slight
					6.40	6.2	5.5	0.7	Slight
	1.50-2.10	Light brown	Clay, stiff		6.32	6.1	5.6	0.5	Slight
					6.38	6.0	5.4	0.6	Slight
	2.10-2.30	Olive grey	Course grained sand		6.38	5.5	5.2	0.3	Slight
	2.30-2.50	Light grey	Course grained sandy clay		6.64	5.5	5.2	0.3	Slight

Physical Soil Description					*Field Test Results*	*Laboratory Test Results*			
				Comment	pH_F	pH_F	pH_{FOX}	ΔpH	Reaction Rate
				Units			-		-
				Limit of Reporting	0.01	0.01	0.01	0.01	-
Sample Location ID	Soil Interval	Soil Colour (Hue, Chroma)	Field Texture	*Criteria*	<4	<4	<3	3	NV
S23	0-0.40	Moderate brown	Medium grained sand		5.78	6.3	4.4	1.9	Moderate
	0.40-1.20	Medium grey	Medium grained sand		6.33	6.5	5.3	1.2	Moderate
					6.50	7.1	5.4	1.7	Slight
					6.53	7.2	5.3	1.9	Slight
	1.20-2.20	Light brown	Medium grained sand	Saturated at 1.40m	6.45	7.0	5.5	1.5	Slight
					6.18	6.6	5.5	1.1	Slight
					6.15	6.6	5.6	1.0	Slight
					6.37	6.7	5.5	1.2	Slight
	2.20-2.60	Greyish red	Medium grained sand, traces of mineral sands, gravel pieces to 40mm		6.46	6.7	5.4	1.3	Slight
					6.11	6.3	5.1	1.2	Slight
	2.60-3.00	Light grey	Course grained sand		6.13	6.1	5.3	0.8	Slight
	3.00-3.20	Light grey	Medium to course grained clay sand		6.45	6.4	5.3	1.1	Slight
	3.20-3.40	Moderate red	Course grained sand		6.09	6.3	5.4	0.9	Slight
	3.40-3.90	Light grey	Medium grained sandy clay		6.28	6.3	5.4	0.9	Slight
					6.21	6.6	5.4	1.2	Slight
	3.90-4.00	Moderate red	Medium to course grained clay sand		6.48	6.8	5.5	1.3	Slight
					6.59	6.7	5.7	1.0	Slight
	4.00-4.50	Pinkish grey	Medium grained sandy clay, stiff, iron mottling		6.43	6.1	5.5	0.6	Slight
					6.45	6.5	5.4	1.1	Slight
	4.50-5.00	Light brown	Clay, plastic		6.41	6.7	5.3	1.4	Slight
					6.50	6.2	5.3	0.9	Slight
S24	0-0.20	Light brown	Medium grained sand, traces of mineral sands		-	-	-	-	-
	0.20-1.25	Moderate yellowish brown	Medium grained sand, traces of mineral sands		5.09	5.7	5.1	0.6	Slight
					5.22	5.8	5.3	0.5	Slight
					5.59	5.9	5.4	0.5	Slight
					5.86	5.3	5.4	-0.1	Slight
	1.25-1.60	Dark yellowish brown	Medium grained sand, large content of mineral	Saturated at 1.50m	6.26	6.4	5.4	1.0	Slight
					6.49	6.6	5.6	1.0	Slight
	1.60-2.00	Moderate brown	Clay, sticky plastic		6.78	6.3	3.7	2.6	Moderate
					6.77	6.2	4.2	2.0	Slight
S25	0-0.60	Dark grey	Fine to medium grained sand		4.21	4.8	4.5	0.0	Slight
					4.49	4.8	4.6	0.2	Slight
	0.60-1.50	Light grey	Medium grained sand, some green sand particles between 1.00-1.30m		4.56	5	4.8	0.2	Slight
					4.35	4.7	4.8	-0.1	Slight
					4.55	4.7	5.1	-0.4	Slight
					5.31	4.7	5.3	-0.6	Slight
					5.69				Slight
S26	0-0.60	Moderate yellowish	Medium grained sand, quartz		4.60	4.7	5.2	-0.5	Slight
					4.62	4.6	6	-1.4	Slight
	0.60-1.50	Moderate yellowish brown	Medium to course grained sand, quartz	Moist at 1.00m Saturated at 1.25m	4.58	4.6	5.1	-0.5	Slight
					5.58	5.6	5	0.6	Slight
					6.30	5	5.7	-0.7	Slight
	1.50-2.10	Moderate brown	Clay, plastic		6.89	6.1	4.3	1.8	Moderate
					6.89	5.9	4.2	1.7	Moderate
					6.82	6.5	3.9	2.6	Moderate
					6.34	6.3	5	1.3	Slight
	2.10-3.00	Moderate brown	Silty clay		6.41	6.3	5.6	0.7	Slight
					6.79	6.5	4.5	2.0	Moderate
					6.84	6.6	4.1	2.5	Moderate

Physical Soil Description					Field Test Results	Laboratory Test Results			
Sample Location ID	Soil Interval	Soil Colour (Hue, Chroma)	Field Texture	Comment	pH_F	pH_F	pH_{FOX}	ΔpH	Reaction Rate
				Units		-	-	-	-
				Limit of Reporting	0.01	0.01	0.01	0.01	-
				Criteria	<4	<4	<3	3	NV
S31	0-0.40	Greyish orange	Fine to medium grained sand		5.39	5.7	4.5	1.2	Moderate
	0.40-1.00	Light brown	Fine to medium grained sand, traces of mineral sands		5.93	6.7	5	1.7	Slight
					6.20	6.7	5.3	1.4	Slight
					6.28	6.6	5.5	1.1	Slight
					6.41	6.8	5.3	1.5	Slight
	1.00-1.30	Light brown	Medium grained sand		6.34	6.4	5.4	1.0	Slight
	1.30-1.50	Dark greenish grey	Medium grained sandy clay, stiff		7.19	6.3	4.2	2.1	Moderate
S32	0-0.75	Moderate brown	Fine to medium grained sand		5.55	5.4	3.7	1.7	Moderate
					6.24	6.9	5.4	1.5	Slight
					6.78	6.3	5.8	0.5	Slight
	0.75-1.50	Olive grey to moderate red	Clay, stiff		7.10	6.8	5.9	0.9	Slight
					7.12	7	3.7	**3.3**	Vigorous
					7.12	6.9	6.1	0.8	Slight
S33	0-0.60	Light to medium grey	Fine grained silty sandy clay		4.74	5.1	3.9	1.2	Moderate
					5.37	6.3	4.8	1.5	Moderate
	0.60-1.50	Pale yellowish brown	Fine silty sandy clay, some orange mottles between 1.30-1.50m		5.45	5.7	4.9	0.8	Slight
					5.66	6.1	5.1	1.0	Slight
					5.60	5.9	5.2	0.7	Slight
					5.81	5.7	5	0.7	Slight
S34	0-1.00	Olive grey	Fine grained sand		4.84	5.1	4.7	0.4	Slight
					4.22	4.5	4.4	0.1	Slight
					3.96	4.2	3.7	0.5	Slight
					4.06	4.2	3.5	0.7	Slight
	1.00-1.50	Light grey	Clay, stiff		5.38	5.6	5.5	0.1	Slight
					5.87	6	5.3	0.7	Slight
					-	6.3	5.5	0.8	Slight
S35	0-0.20	Light grey	Fine grained sand		-	-	-	-	-
	0.20-1.00	Pale yellowish brown	Fine to medium grained sand		4.28	5.6	4.4	1.2	Slight
					4.82	4.6	4.5	0.1	Slight
					4.74	5	4.8	0.2	Slight
					6.24	5.9	5.7	0.2	Slight
	1.00-1.50	Light brown	Fine grained sandy clay		6.43	7.0	5.4	1.6	Slight
					6.59	6.6	5.5	1.1	Slight
S36	0-0.50	Olive grey	Fine grained silty sand		4.37	4.5	**2.8**	1.7	Moderate
					4.22	4.5	4.2	0.3	Slight
	0.50-1.50	Light grey to moderate brown	Clay		6.22	6.5	6.1	0.4	Moderate
					6.31	6.4	5.6	0.8	Slight
					5.69	5.8	4.9	0.9	Slight
					5.10	5.2	4.1	1.1	Slight
S37	0-0.70	Dark yellowish brown	Fine grained silty sand		4.21	4.8	3.3	1.5	Vigorous
					4.39	4.3	3.8	0.5	Slight
	0.70-1.50	Light brown	Fine to medium grained sandy silty clay		5.67	5.7	4.8	0.9	Slight
					6.02	6.4	5.1	1.3	Slight
					4.89	4.8	3.8	1.0	Slight
					4.74	5.1	3.9	1.2	Slight
S38	0-1.00	Light brown	Fine grained sand		4.29	5.3	3.7	1.6	Moderate
					4.83	5.3	4.2	1.1	Moderate
					4.93	5.6	4.2	1.4	Slight
					5.60	6	4.9	1.1	Slight
					5.69	6.2	5.1	1.1	Slight
	1.00-1.50	Greyish orange	Clay, plastic		5.24	5.5	4.6	0.9	Slight
					4.71	4.9	3.7	1.2	Slight

Physical Soil Description					Field Test Results	Laboratory Test Results			
				Comment	pH_F	pH_F	pH_{FOX}	ΔpH	Reaction Rate
				Units		-			-
				Limit of Reporting	0.01	0.01	0.01	0.01	-
Sample Location ID	Soil Interval	Soil Colour (Hue, Chroma)	Field Texture	*Criteria*	<4	<4	<3	3	NV
S39	0-0.20	Light brown	Fine grained silty sand		-	-	-	-	-
	0.20-0.70	Light brown	Medium grained sand		4.66	4.9	3.1	1.8	Moderate
					4.90	5.3	4.2	1.1	Slight
	0.70-1.50	Olive grey	Medium grained sandy clay		4.95	5.5	3.7	1.8	Moderate
					4.90	5.5	4.2	1.3	Slight
					4.82	5.1	4.4	0.7	Slight
					4.56	5.0	4.2	0.8	Slight
S40	0-1.00	Dark grey	Fine grained silty clay, stiff	Saturated at 0.25m	4.91	5.3	3.5	1.8	Vigorous
					4.86	5.1	3.6	1.5	Vigorous
					5.25	5.7	3.9	1.8	Moderate
					5.71	6.2	4.7	1.5	Slight
	1.00-1.50	Moderate brown	Medium grained sand		5.77	6.3	4.7	1.6	Slight
					6.05	6.6	5	1.6	Slight
S41	0-0.10	Dark grey	Fine to medium grained sand		-	-	-	-	-
	0.10-1.00	Moderate brown	Fine to medium grained sand		4.81	5.2	3.8	1.4	Moderate
					5.02	5.2	4.3	0.9	Slight
					5.01	5.2	4.5	0.7	Slight
					6.04	6.4	5	1.4	Slight
					6.32	6.3	4.9	1.4	Slight
	1.00-1.50	Olive grey	Clay		6.70	7.5	5.7	1.8	Slight
					7.20	7.7	5.8	1.9	Slight
S52	0-0.10	Dark grey	Fine grained sand, topsoil		-	-	-	-	-
	0.10-0.60	Pale yellowish brown	Fine to mdium grained silty sand		5.68	6.1	5.2	0.9	Slight
					6.17	6.4	5.4	1.0	Slight
	0.60-1.50	Light grey to pale yellowish brown	Fine to medium grained silty sand, medium mineral sand content	Saturated at 1.10m	6.38	6.5	5.4	1.1	Slight
					6.43	6.5	5.5	1.0	Slight
					6.49	6.5	5.5	1.0	Slight
	1.50-1.75	Pale yellowish brown	Medium grained silty sand, medium mineral sand content		6.42	6.4	5.5	0.9	Slight
	1.75-2.10	Light grey	Medium grained silty sand, traces of mineral sands		5.99	4.9	5.4	-0.5	Slight
					6.00	5.3	3.8	1.5	Slight
	2.10-2.30	Olive grey	Fine to medium grained silty sand		6.11	5.1	3.4	1.7	Moderate
	2.30-3.00	Greyish orange	Fine grained silty clay, bands of mineral sands throughout		6.05	5.5	4.6	0.9	Slight
					6.31	5.4	3.4	2.0	Slight
					6.34	5.6	4.8	0.8	Slight
S53	0-1.25	Yellowish grey	Medium grained sand		4.64	4.6	3.3	1.3	Vigorous
					4.60	4.7	4.1	0.6	Slight
					4.78	5.1	4.4	0.7	Slight
					5.40	5.5	4.7	0.8	Slight
					5.94	4.9	4.9	0.0	Slight
	1.25-1.50	Olive grey	Clay, stiff		6.18	6.5	5.1	1.4	Moderate
S54	0-0.80	Dark yellowish brown	Fine grained silty sand		4.46	4.7	3.2	1.5	Moderate
					3.96	4.1	4	0.1	Slight
					3.92	**4**	3.6	0.4	Slight
	0.80-1.50	Moderate brown	Clay		4.18	4.3	4.3	0.0	Slight
					5.96	6.3	5.1	1.2	Slight
					6.06	6.2	5	1.2	Slight
S55	0-1.40	Moderate brown	Fine grained sand		4.56	5	4.3	0.7	Moderate
					4.53	4.9	4.4	0.5	Moderate
					4.56	5	4.3	0.7	Slight
					4.73	5.2	4.5	0.7	Slight
					6.14	5.9	5	0.9	Slight
	1.40-1.50	Olive grey	Fine to medium grained clay sand		5.07	5.8	4.9	0.9	Slight

Physical Soil Description					Field Test Results	Laboratory Test Results			
Sample Location ID	Soil Interval	Soil Colour (Hue, Chroma)	Field Texture	Comment	pH_F	pH_F	pH_{FOX}	ΔpH	Reaction Rate
				Units			-		-
				Limit of Reporting	0.01	0.01	0.01	0.01	-
				Criteria	<4	<4	<3	3	NV
S56	0-1.00	Dark grey	Fine grained silty sandy clay		4.77	5.4	5.1	0.3	Slight
					5.60	6	5	1.0	Slight
					5.61	6.1	5.5	0.6	Slight
	1.00-1.50	Olive grey	Fine grained silty sandy clay		5.27	5.9	5	0.9	Slight
					5.04	5.1	4.5	0.6	Slight
					4.75	5	4.9	0.1	Slight
S57	0-0.70	Pale yellowish brown	Fine grained sand		7.58	7.4	6.1	1.3	Moderate
					6.89	7.3	5.9	1.4	Moderate
	0.70-1.50	Dark yellowish brown	Fine grained silty clay sand		6.51	6.6	5.2	1.4	Moderate
					6.15	6.3	5	1.3	Slight
					5.54	6.1	5.1	1.0	Slight
					6.46	6.8	5.9	0.9	Slight
S58	0-0.75	Light grey	Fine to medium grained sand		5.18	5.6	4.2	1.4	Moderate
					5.30	5.1	5.1	0.0	Slight
	0.75-1.50	Light olive grey	Clay		5.85	6.2	5.3	0.9	Slight
					5.92	6.1	5.2	0.9	Slight
					6.10	6.1	4.9	1.2	Slight
					6.00	6	4.8	1.2	Slight
S59	0-1.00	Medium grey	Fine to medium grained sand		5.50	5.8	4.3	1.5	Slight
					5.74	4.9	4.9	0.0	Slight
					5.99	6.3	5.2	1.1	Slight
					6.63	6.7	**3**	**3.7**	Slight
	1.00-1.50	Pale yellowish brown	Fine to medium grained sand		6.64	7.1	5.4	1.7	Slight
					6.83	6.7	5.3	1.4	Slight
S61	0-1.00	Moderate brown	Fine grained silty sand	Saturated at 0.50m	6.25	6.5	5.6	0.9	Slight
					5.59	5.8	5.4	0.4	Slight
					5.15	5	4.8	0.2	Slight
					4.87	4.8	4.7	0.1	Slight
	1.00-1.50	Medium grey	Fine to medium grained sand		4.40	4.8	4.7	0.1	Slight
					4.37	4.6	4.1	0.5	Slight
S63	0-0.50	Light brown	Fine grained silty sand		6.40	5.5	3.1	2.4	Moderate
					5.55	5.9	4.5	1.4	Slight
	0.50-1.50	Light grey to light brown	Clay		4.94	7.3	5.4	1.9	Slight
					6.54	7.6	5.8	1.8	Slight
					6.92	7.8	5.8	2.0	Slight
					7.13	7.9	5.9	2.0	Slight

APPENDIX 3

Groundwater Sampling Sheets and Laboratory Documentation

Environmental and Analytical Laboratory

LABORATORY REPORT

Job Number: 13-4868
Revision: 00
Date: 19 July 2013

ADDRESS: **Aurora Environmental**
149-151 Kensington St
East Perth WA 6004

ATTENTION: Glen Alexander

DATE RECEIVED: 9/07/2013

YOUR REFERENCE: N/A

PURCHASE ORDER:

APPROVALS:

DouglasTodd
Laboratory Manager

REPORT COMMENTS:

Samples are analysed on an as received basis unless otherwise noted.

METHOD REFERENCES:

ARL No. 29/402/403	Metals in Water by AAS/ICPOES/ICPMS
ARL No. 040	Arsenic by Hydride Atomic Absorption
ARL No. 029	Metals in Water by AAS
ARL No. 305	Chloride in Water by Discrete Analyser
ARL No. 301	Sulphate in Water by Discrete Analyser
ARL No. 021	Acidity in Water
ARL No. 037	Alkalinity in Water
ARL No. 014	pH in Water
ARL No. 019	Conductivity and Salinity in Water
ARL No. 017	Total Dissolved Solids (At 105^{o}C)

NATA
WORLD RECOGNISED ACCREDITATION
This document is issued in accordance with NATA's accreditation requirements
Accreditation No. 2377

Analytical Reference Laboratory (WA) Pty. Ltd.
46-48 Banksia Road, Welshpool, Western Australia 6106 Telephone 08 6253 4444 Facsimile 08 6253 4440
www.arlwa.com.au ABN: 91 050 159 898

LABORATORY REPORT

Aurora Environmental

ARL Job No: *13-4868* *Revision:* *00* *Date:* 19 July 2013

Environmental and Analytical Laboratory

Metals in Water Sample No: Sample Description:	LOR	UNITS	13-4868-1 MB 18	13-4868-2 MB 20	13-4868-3 MB 21	13-4868-4 MB 22	13-4868-5 MB 23
Aluminium - Dissolved	0.01	mg/L	<0.01	1.1	0.02	1.4	0.02
Aluminium - Total	0.01	mg/L	<0.01	1.1	0.02	1.4	0.02
Arsenic - Dissolved	0.001	mg/L	<0.001	<0.001	<0.001	0.081	0.002
Cadmium - Dissolved	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium - Dissolved	0.001	mg/L	<0.001	0.002	<0.001	0.008	0.002
Iron - Dissolved	0.01	mg/L	0.88	0.70	11	1.0	0.24
Iron - Total	0.01	mg/L	1.1	0.76	11	1.0	0.28
Manganese - Dissolved	0.01	mg/L	0.14	0.12	0.15	0.06	0.22
Sodium - Dissolved	0.1	mg/L	98	35	160	200	350
Nickel - Dissolved	0.001	mg/L	<0.001	0.001	0.001	0.001	<0.001
Selenium - Dissolved	0.001	mg/L	<0.001	<0.001	0.005	<0.001	<0.001
Zinc - Dissolved	0.005	mg/L	<0.005	0.015	<0.005	<0.005	<0.005

Ions by Discrete Analyser Sample No: Sample Description:	LOR	UNITS	13-4868-1 MB 18	13-4868-2 MB 20	13-4868-3 MB 21	13-4868-4 MB 22	13-4868-5 MB 23
Chloride	5	mg/L	150	140	430	170	810
Sulphate	3	mg/L	51	35	120	65	82

Physical Parameters Sample No: Sample Description:	LOR	UNITS	13-4868-1 MB 18	13-4868-2 MB 20	13-4868-3 MB 21	13-4868-4 MB 22	13-4868-5 MB 23
Acidity	5	mg$CaCO_3$/L	13	42	55	120	39
Alkalinity	5	mg$CaCO_3$/L	100	14	16	87	130
pH	0.1	pH units	7.4	5.8	5.8	6.7	7.0
Conductivity	0.01	mS/cm	0.71	0.86	1.5	1.1	2.7
Total Dissolved Solids	5	mg/L	410	700	850	870	1,800

Result Definitions

LOR Limit of Reporting
[NT] Not Tested
[ND] Not Detected at indicated Limit of Reporting
[NR] Analysis Not Requested
(SS) Surrogate Standard Compound - Used for QC purposes. Acceptance Criteria is 60-120%.

Analytical Reference Laboratory (WA) Pty. Ltd.
46-48 Banksia Road, Welshpool, Western Australia 6106. Telephone: 08 6253 4444 Facsimile: 08 6253 4440
www.arlwa.com.au ABN: 91 050 159 898

Groundwater Sampling Field Work Sheet

Project: Wonnerup St CAI-2013-002

Contact: Sampled by GMA Date sampled: 030713

Bore#	Depth (m)	SWL (m)	Column (Depth-SWL)	Factor	Purge Volume (L) (FactorxColumn)	Time Collected	pH	EC	~~Redox~~ TTA	mg/L CaCO3 ~~DO~~ Alk	Temp	Comments
WNMB23	7.50	2.980	4.5	11.789724	50L.	9:00	6.22	3999*	80 (0.50 Cl)	195 mg/L	18.4	clear, no SS, no odour
WNMB22	5.00	3.428				9:30/11:00	6.14	952	110	100	17.7	purge dry c≈ 5L then returned to sample
MB21(shallow)	5.40	1.192	4.2		50L.	10:00	6.54	1126	65	72	17.1	purge dry ≈ 25L.
MB20	4.50	1.130	3.40		40	10:30	5.42	920	50	25	16.4	purge dry ~20L (Brown, no odour)
MB19	3.40	2.188	1.2		20.	11:30	5.69	2524	300	130	17.0	purge dry - 5L.
MB18	7.0	2.325	4.7		60	12:10	6.44	907	15	150	17.6	

Don't forget Duplicate, Rinse Blank and/or Field Blank.

Factor = (bore radius)^2 x 22/7x 1000 x 6 (15x for 75mm bore)

Groundwater Sampling Field Work Sheet

Project: Wonnerup St CL1-2013-002

Contact: Sampled by GMA Date sampled: 030713

Bore#	Depth (m)	SWL (m)	Column (Depth-SWL)	Factor	Purge Volume (L) (FactorxColumn)	Time Collected	pH	EC	~~Redox~~ TTA	mg/L CaCO3 ~~DO~~ Alk	Temp	Comments
WNMB23	7.50	2.980	4.5	11.789724	50L.	9:00	6.22	3999*	80 (0.50256mL)	195 mg/L	18.4	clear, no SS, no odour
WNMB22	5.00	3.428				9.30/11:00	6.14	952	110	100	17.7	purge dry ~5L then returned to sample
MB21(shallow)	5.40	1.192	~~38~~ 4.2		~~50~~ 50L.	10:00	6.54	1126	65	72	17.1	Purge dry ≈ 25L
MB20	4.50	1.130	3.40		40	10:30	5.42	920	50	25	16.4	Purge dry ~20L (Brownish, no odour)
MB19	3.40	2.188	1.2		20	11:30	5.69	2524	300	130	17.0	purge dry – 5L.
MB18	7.0	2.325	4.7		60	12:10	6.44	902	15	150	17.6	

Don't forget Duplicate, Rinse Blank and/or Field Blank.

Factor = (bore radius)^2 x 22/7x 1000 x 6 (15x for 75mm bore)