Soils Report B

Baseline Soil Assessment

EASTERN LEASES PROJECT

Prepared for Hansen Bailey
on behalf of South32 Pty Ltd
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GTenvironmental

PO Box 2462, New Farm, QLD 4005
www.gtenvironmental.com.au

File name:	GE-14 GEMCO Soils Rpt
Author:	Reece McCann
Project manager:	Graham Tuck
Name of organisation:	Hansen Bailey
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TABLE OF CONTENTS

GLOSSARY OF TERMS

The following descriptions are of terms used in the text of this report.

Acid Sulfate Soils. Acid sulfate soil is the common name for soils that contain metal sulfides. In an undisturbed and waterlogged state, these soils may pose no or low risk. However, when disturbed or exposed to oxygen, acid sulfate soils undergo a chemical reaction known as oxidation. Oxidation produces sulfuric acid which has led to these soils being called acid sulfate soils.

AHD. Australian Height Datum.

ALC. Anindilyakwa Land Council.

Alluvial. Describes material deposited by, or in transit in, flowing water.

Apedal. Describes a soil in which none of the soil material occurs in the form of peds or soil aggregates in the moist state.

Apedal massive. Soil occurring as a coherent mass with no distinct arrangement of soil particles.

ASC. Australian Soil Class.

ASPAC. Australasian Soil and Plant Analysis Council.

ASRIS. Australian Soil Resources Information System.

ASS. Acid Sulfate Soils.

Cation Exchange Capacity (CEC). The maximum positive charge required to balance the negative charge on colloids (clays and other charged particles). The units are milli-equivalents per 100 grams of material, or centimoles of charge per kilogram of exchanger. CEC is often used as a measure of soil fertility and nutrient retention capacity.

Clay. A soil material composed of particles finer than 0.002 mm. When used as a soil texture group such soils contain at least 35% clay.

Chromosol. Soils other than Hydrosols with a clear or abrupt textural B horizon and in which the major part of the upper 0.2 m of the B2 horizon (or the major part of the entire B2 horizon if it is less than 0.2 m thick) is not sodic and not strongly acid. Soils with strongly subplastic upper B2 horizons are also included even if they are sodic.

Dispersion. A process by which species in solution mix with a second solution, thus reducing in concentration. In the case of sodic soils it will predispose the soil material to lose structure and disseminate into the solution.

Effective Soil Depth. The depths of which vegetation roots may readily penetrate the soil profile and have access to water and nutrients.

EIS. Environmental Impact Statement.

Electrical Conductivity (EC). The EC of water is a measure of its ability to conduct an electric current. The EC of soils will vary depending on the texture and amount of moisture held by the soil particles. Electrical conductance increases with soluble salt content and thus allows simple interpretation of salinity.

ELR. Exploration Licence in Retention.

Exchangeable Sodium Percentage (ESP). The amount of sodium as a proportion of all cations in a soil is termed the Exchangeable Sodium Percentage. It is calculated by dividing the exchangeable

sodium by the cation exchange capacity (CEC), multiplied by 100. ESP values greater than 6% are considered sodic, with values greater than 15% considered very sodic.

Field pH. The measurement of the pH in the field by utilising Manutec Pty Ltd, Soil pH Test Kit. This kit consists of pH dye indicator, Barium Sulphate and reference colour chart.

GPS. Global Positioning System.

Gradational. The lower boundary between soil layers (horizons) has a gradual transition to the next layer. The solum (soil horizon) becomes gradually more clayey with depth.

Gradient. The rate of inclination of a slope. The degree of deviation from the horizontal.

Gully erosion. The displacement of soil by running water that forms clearly defined, narrow channels that generally carry water only during or after heavy rain.

Horizon. An individual soil layer, based on texture and colour, which differs from those above and below.

Hydrosols Soils other than Organosols, Podosols and Vertosols in which the greater part of the profile is saturated for at least 2-3 months in most years.

Infiltration. The passage of water under the influence of gravity from the land surface into the subsurface.

Kandosols. Soils other than Hydrosols which have B2 horizons in which the major part is massive or has only a weak grade of structure; a maximum clay content in some part of the B2 horizon which exceeds 15% (ie. heavy sandy loam, SL+); do not have a tenic B horizon; do not have clear or abrupt textural B horizons; and are not calcareous throughout the solum, or below the A1 or Ap horizon or to a depth of 0.2m if the A1 horizon is only weakly developed.

Land condition. In the context of this report refers to a subjective visual assessment of the degradation status of the surface soil.

Loam. A medium textured soil of approximate composition 10-25% clay, 25-50% silt and >50% sand.

Massive. Refers to the condition of the soil layer in which the layer appears to be as a coherent or solid mass which is largely devoid of peds.

Meter pH. The measurement of the pH in the field by utilising a TPS Aqua-CP/A meter.

mbgl. Refers to metres below ground level.

Mottles. Areas of contrasting colour within the overall soil colour which are caused by anerobic conditions as a result of poor aeration. Usually an indicator of poor drainage and retention of water.

Northern EL. Northern Eastern Lease (ELR28161).

Ped. An individual natural soil aggregate. In an undisturbed state peds will group together to form larger aggregates.

Pedal. Describes a soil in which some or all of the soil material occurs in the form of peds in the moist state.

pH. A logarithmic index for the concentration of hydrogen ions in an aqueous solution, which is used as a measure of acidity.

Profile. The solum. This includes the soil A and B horizons and is basically the depth of soil to weathered rock.

Project Site. The area comprising the Northern EL, Southern EL, and Haul Road Corridor.

PSA. Particle Size Analysis.

Representative Site. A location deemed to be representative of the soil mapping unit for which detailed characterisation is to be done.

Rudosols. Soil with negligible (rudimentary) pedologic organisation apart from a minimal development of an Al horizon, or the presence of less than 10% of B horizon material (including pedogenic carbonate) in fissures in the parent rock or saprolite. The soils are apedal or only weakly structured in the A1 horizon and show no pedological colour changes apart from the darkening of an A1 horizon. There is little or no texture or colour change with depth unless stratified or buried soils are present.

SMU. Soil Mapping Unit. Soils grouped into a single management unit on the basis of similar morphology, position on the landscape, substrate and chemistry.

Sheet erosion. The removal of surface material from a wide area of gently sloping or graded land by broad continuous sheets of running water rather than by streams.

Sodic. Also commonly referred to as a non-saline alkali soil. It is a soil that contains sufficient exchangeable sodium and does not contain appreciable quantities of soluble salts. A term given to soil with a level of exchangeable sodium cations greater than 10-15% of the soils cation exchange capacity (CEC), or soluble sodium cations greater than 10-15 times the square root of soluble calcium and magnesium cations.

Soil Variant. A soil with one or more profile attributes outside the usual range for a defined soil profile class, but because of its restricted distribution (or because the varying properties are not considered to have particular management significance), it is not defined as a separate soil profile class.

Southern EL. Southern Eastern Lease (ELR28162).

Subsoil. Subsurface material comprising the B and C horizons of soils with distinct profiles. They often have brighter colours and higher clay content than topsoils.

Tenosols. Tenosols have a weakly developed soil profile which is typically very sandy and without obvious horizons. Generally, tenosols have a very low agricultural potential with very low chemical fertility, poor structure and low water-holding capacity.

Texture. The size of particles in the soil. Texture is divided into six groups, depending on the amount of coarse sand, fine sand, silt and clay in the soil.

Topsoil. Part of the soil profile, typically the A1 horizon, containing material which is usually darker, more fertile and better structured than the underlying layers.

1 INTRODUCTION

1.1 Project Details

GT Environmental Pty Ltd (GTE) was commissioned by Hansen Bailey on behalf of BHP Billiton Manganese Australia Pty Ltd to complete a baseline soils assessment as part of the Environmental Impact Statement (EIS) for the Eastern Leases Project (the project).

The project proponent is the Groote Eylandt Mining Company Pty Ltd (GEMCO), which has two shareholders, namely South32 Pty Ltd (60%) and Anglo Operations (Australia) Pty Ltd (40%). BHP Billiton Manganese Australia Pty Ltd was previously a shareholder in GEMCO, however its interest is now represented by South32.

The project involves the development of a number of open cut mining areas to the east of the existing GEMCO manganese mine on Groote Eylandt in the Gulf of Carpentaria, approximately 650 km south-east of Darwin (Figure 1). The proposed additional mining areas are located on the Eastern Leases, which are two Exploration Licences in Retention (ELRs). ELR28161 is termed the Northern Eastern Lease (Northern EL) and ELR28162 is termed the Southern Eastern Lease (Southern EL).

The Eastern Leases are located 2 km east of the existing GEMCO mine at the closest point. The township of Angurugu is located approximately 6 km to the north-west of the Eastern Leases, and is the closest residential community (Figure 2). The Eastern Leases are located on Aboriginal land, scheduled under the *Aboriginal Land Rights (Northern Territory) Act 1976*. The land within the Eastern Leases comprises natural bushland, with the Emerald River and a small section of the Amagula River traversing the Northern EL and Southern EL respectively.

The project involves:

- developing a number of open cut mining areas (termed "quarries") within the Eastern Leases and mining manganese ore by the same mining methods that are in use at the existing GEMCO mine;
- constructing limited mine related infrastructure in the Eastern Leases (dams, water fill points, crib hut, truck park up areas and laydown storage areas); and
- transporting the ore by truck on a new haul road to be constructed between the existing GEMCO mine and the Eastern Leases.

Ore will be processed at the concentrator at the existing GEMCO mine and the concentrate would be transported to market via the existing port (Figure 2). No changes or upgrades to the existing GEMCO mine facilities are required as a result of the project. Ore mined from the Eastern Leases will supplement production from the existing GEMCO mine, but the project will not increase GEMCO's annual production rate of approximately 5 Million tonnes per annum of product manganese. The EIS does not include any assessment of operations within the existing GEMCO mine, given that these operations are subject to existing environmental approvals, and will not be altered by the project.

The project site for the purposes of the EIS is the Northern and Southern ELs and the new section of haul road linking the Eastern Leases to the existing GEMCO mine. The project site is approximately 4,600 ha.

1.2 Scope of Report

This report provides a baseline assessment of the soils within the project site and includes:

- a description of the regulatory requirements relevant to the project;
- a review of available background material;
- identification and description of soil types within the project site; and
- a description of available topsoil resources.

This report is limited to discussing the potential available topsoil resources within the project site. It does not take into consideration environmental factors that may influence topsoil availability, such as presence of waterways, archaeological features, or existing roads or tracks, etc.

2 BACKGROUND

2.1 Regulatory Requirements

The EIS Terms of Reference do not provide any specific guidance with respect to standards or requirements for the baseline soil assessment. Consequently the assessment made use of the best practice techniques, as described in this section.

This soil survey was scoped and conducted in accordance with the *Guidelines for Surveying Soils and Land Resources* (McKenzie *et al*., 2008). These Guidelines were developed to provide a consistent approach to soil survey methodology across Australia. Soil Characteristics and Soil Profiles have been described in accordance with the *Australian Soil and Land Survey Handbook* (National Committee on Soil and Terrain, 2009 and Gunn *et al*., 1988).

Soils have been grouped according to their parent material and position in the landscape, and classified in accordance with the *Australian Soil Classification* (Isbell, 2002). Soils have also been correlated to soils identified within key regional soil assessments, the major one being *Land Systems of the Northern Part of the NT* (Lynch 2012).

Collection of soil samples for laboratory analysis was undertaken in line with the Land Suitability Assessment Techniques within the *Technical Guidelines for Environmental Management of Exploration and Mining in Queensland* (Department of Minerals and Energy, 1995).

2.2 Local Setting

2.2.1 Land Use

The land within and surrounding the project site comprises natural bushland, that is mainly eucalypt dominated open forest, woodland and shrubland. The most common eucalypts are Darwin Woollybutt and Stringybarks, but a wide variety of other native plants occur. Other vegetation types include forms of swamp forest and rainforest.

No farming or agriculture activities are undertaken within, or in the vicinity of the project site.

GEMCO has been undertaking manganese exploration activities across the Eastern Leases site since 2001.

2.2.2 Topography and Hydrology

The topography across the project site varies from level to undulating plains, to sandy colluvial footslopes with rugged uplands. Elevations range from approximately 10m Australian Height Datum (AHD) to 120m AHD.

Several drainage lines traverse the project site, including sections of the Emerald and Amagula Rivers, and their tributaries.

2.2.3 Regional Geology

Groote Eylandt was formed on a stable basement of Proterozoic quartzite. This basement quartzite forms extensive elevated outcrops in the centre of the island.

A blanket of Cretaceous marine sediments was subsequently deposited over the paleosurface of basement and reworked basement materials in the west of the island. The distribution of the Cretaceous marine sediments is generally confined to the western plains and valleys of the island. The upper Cretaceous sediments contain the manganese ore. The manganese ore is a sedimentary layer, consisting of manganese strata occurring between clay and sand beds.

Much of the Cretaceous sediment profile (including some of the manganese ore) has been extensively modified by a long period of tropical weathering (or laterisation) during the Tertiary period. This has resulted in the development of thick laterite profiles up to 25 m thick.

In summary, the surface geology of the project site broadly comprises lateritic deposits between Proterozoic basement outcrops (i.e. exposed quartzite). Localised areas of quaternary sediments are also present at the site. Figure 3 shows the surface geology of the project site.

3 METHODOLOGY

The methodology for the baseline soil assessment, which involved a desktop review and field surveys, is described below.

3.1 Desktop Review

GTE reviewed the available soils and land resources information for the project site to develop preliminary soil mapping units and distribution, and to inform the development of the field survey program.

3.1.1 Regional Soils Reports and Available Documentation

The following references were utilised for determining potential field sampling locations:

- Northcote *et al*. (1960-1968), *Atlas of Australian Soils*;

The indicated soil classifications of the project site, as contained in the *Atlas of Australian Soils*, include Kandosols, Tenosols, Rudosols, Chromosols and Hydrosols. Although these classifications are mapped at a very broad scale (1:2,000,000), they are useful for identifying specific variants of these soil classes.

- Lynch (2012), *Land systems of the Northern part of the NT (1:250,000)*;

Land systems are landscape patterns comprising areas of generally uniform geology but with variable landforms, soils and vegetation. Within each land system are individual 'units' which describe the range of individual soil types and vegetation.

Based on Lynch (2012), the project site is described as level to gently undulating plains, rugged dissected plateaux on quartz sandstone with sandy colluvial footslopes.

3.1.2 Aerial Photography

Aerial photography from 2013 (as provided by GEMCO) was reviewed as part of the desktop evaluations. Initial map units and boundaries were identified using Google Earth imagery (accessed on 05/06/2014).

3.1.3 Acid Sulfate Soils Assessment

A desktop assessment was undertaken to identify the likelihood of the presence of Acid Sulfate Soils (ASS) on the project site. Online ASS maps (such as Australian Soil Resources Information System [ASRIS], and the National Acid Sulfate Soils Atlas) were reviewed, along with the elevation, geology, topography and aerial photograph patterns of ancient floodplains and swamps in the area. According to ASRIS, there is a very low probability of ASS being present within the project site.

3.1.4 Preliminary Soils Mapping

A preliminary soils map was created based on the aerial photography and GIS information available from Lynch (2012). This preliminary mapping provided an initial understanding of the different types of soil and landscapes likely to occur across the project site and provided a basis for planning the field work and determining survey locations. Table 1 lists the land systems and soil types that were anticipated to be found on site, and these are also shown in Figure 4.

Table 1 Expected Soil Units / Types

Landform (Lynch 1998)	Indicated Soil Types (Northcote *et al*, 1960-1968)	Vegetation (Lynch, 1998)
Level to gently undulating plains **Land System**: Yrw Yarrawirrie	Red earths Kandosols and Orthic Tenosols	Tall sparse shrubland to low open woodland of *Eucalyptus. tetrodonta*
Rugged dissected plateaux on quartz sandstone **Land System**: Grt Groote	Bare rock and Leptic Rudosols	Mid high to tall open woodland of *E. tetrodonta* and *E. ferruginea*
Sandy colluvial footslopes below elevated quartz sandstone plateaux **Land System**: Bnd Bundah	Leptic and Orthic Tenosols	Tall open woodland of *E. tetrodonta* with *E. miniata*, *Callitris intratropica* and *E. polycarpa*
Level to gently undulating alluvial floodplains **Land System**: Efg Effington	Kandosolic, Tenosolic and Chromosolic Redoxic Hydrosols	Mid high open woodland of *Melaleuca viridiflora* and *E. polycarpa*
Gently undulating sandy plains **Land System:** Que Queue	Orthic Tenosols	Tussock grass open woodland consisting of *E. tetrodonta*, *E. miniata* and *Corymbia ferruginea* trees with *Acacia mimulain* the mid-storey

3.2 Field Work

3.2.1 Survey Timing

A detailed field survey was undertaken from the 13 to 16 June 2014. Permission to access the project site for the purpose of undertaking field surveys was obtained from the Anindilyakwa Land Council (ALC).

The area surveyed covered 4,582 ha, encompassing the Eastern Leases and the haul road corridor to the existing GEMCO mine.

3.2.2 Survey Techniques

Survey techniques were based upon pre-determined sampling locations derived from the desktop review of background information, existing available soils information and an examination of aerial photography patterns.

Free survey techniques (McKenzie *et al*., 2008 and Gunn *et al.*, 1988) were used to verify proposed soil types and assign boundaries to each type. Free survey is a well recognised method commonly used in broader scale land assessment as it enables flexibility in site selection (over grid mapping techniques), to achieve a more accurate and time effective result. It is suited to detailed-scale surveys and enables appropriate sampling locations to be selected dynamically whilst in the field. The specific locations of the survey sites were therefore further refined in the field based on available site access, and the location being a sound representation of the soil unit being described.

Two types of site were surveyed – detailed sites and observation sites.

Photographs were taken at all detailed sites and at selected observation sites to assist with final interpretation of soils. Survey site locations were recorded

using a global positioning system (GPS) data logger, set to the site survey datum. The project site was mapped at a 1:50,000 scale.

Detailed Sites

Detailed sites were undertaken at 27 locations (Figure 5). These sites were used to describe the range of soil profile morphological attributes as per the National Committee on Soil and Terrain guidelines (2009) (including soil colour as per *Munsell Soil Colour Charts*, 2009), in addition to landform, slope, surface conditions, rock cover and major vegetation. At each detailed site an assessment was made of the quality, depth and quantities of reusable topsoil that may be excavated in the future.

Soil profiles were primarily sampled using 50 mm hand augers, with two sites utilising the push tube drilling method. The hand auger was used in favour of other methods, such as test pitting with backhoes, given the difficulties accessing parts of the project site due to the challenging terrain. The hand auger method is a technically suitable method, and was undertaken in accordance with the *Guidelines for Surveying Soil and Land Resources* (McKenzie *et al*., 2008).

Soil samples were collected from five detailed sites for laboratory analysis. Sampling of soil profiles was conducted as per McKenzie *et al*. (2008), with samples taken at standard depths incorporating the surface and every horizon change within the soil profile (typically at nominated depths of 0.0-0.10m, 0.30-0.40m, 0.60-0.70m and 0.90-1.00m). These depths were modified for sites in which field observations revealed soil horizons intersecting these nominated depths, to ensure samples were collected within each separate horizon, and not across multiple horizons or in sub-horizon boundaries.

The information recorded from detailed sites included:

- location (GDA94) and type of soil observation (e.g. erosion exposed cutting or hand auger);
- major vegetation types;
- landform type, position of the site and slope gradient;
- surface condition (e.g. presence of cracks, surface crust, rocks, stones and cobbles, erosion status, micro-relief);
- types and vertical extent of soil horizons;
- colour (per *Munsell Soil Colour Charts*, 2009) and mottling of each horizon;
- observations of field texture, pH, presence and abundance of segregations, coarse fragments, structure, consistence and pedality and moisture content for each horizon;
- presence of organic matter, roots and prevalence of biological activity;
- presence of gleyed horizons, iron staining, jarosite presence and field pH (for ASS assessment); and
- photographs of the soil profile and surrounding landscape.

Observation Sites

Observation sites were undertaken at 95 locations (Figure 5). These sites were used to confirm map unit type and refine mapped soil boundaries. Where necessary, augering was undertaken to determine soil type (e.g. depth to clay, B horizons). Basic soil attributes were recorded to confirm the soil mapping unit, and surface conditions including rock, slope percentage, landform type and position, major vegetation and land condition were also noted.

3.2.3 Laboratory Analysis

Soil samples collected from the five sites considered to be the most representative of the SMUs found within the project site were submitted for laboratory analysis.

Laboratory analysis was undertaken to assist in determining the overall characterisation of the soils and to determine the physical and chemical limitations of surface soils for use in rehabilitation works. Laboratory testing was also used to identify soils that may require specific management measures.

Samples were analysed at Environmental Soil Solutions Australia Pty Ltd (ESSA), Brisbane, certified by Australasian Soil and Plant Analysis Council (ASPAC). For each soil type, the surface soil horizon was sampled and analysed for the following parameters:

- pH (1:5);
- Electrical Conductivity (EC [1:5]);
- Chloride;
- Bicarbonate extractable P;
- Exchangeable Cations (Ca, Mg, Na, K);
- Cation Exchange Capacity (CEC);
- Ca/Mg Ratio;
- Exchangeable Sodium Percentage (ESP);
- Total N, Nitrates;
- Organic matter content;
- Particle Size Analysis (PSA) – Hydrometer Method (Coarse Sand [CS], Fine Sand [FS], Silt, Clay);
- R1 Dispersion;
- Air Dry Moisture Content (ADMC);
- Emerson aggregate test;
- Sulfate; and
- Metals - Total (Mn, B, Cu, Fe, Zn, Al).

Subsequent samples lower in the soil profile were also analysed for a limited suite of parameters (pH, EC, chloride, exchangeable ions, CEC, Ca/Mg Ratio, and ESP) sufficient to determine reuse potential for rehabilitation of disturbed areas.

In addition, calculations were undertaken to determine the exchangeable sodium percentage and the calcium to magnesium ratio. The rationale for the selection of individual analyses is presented in Table 2.

The laboratory analytical results were used in conjunction with the field assessment results to determine the depth of soil material that is suitable for stripping and reuse during rehabilitation. The laboratory results are summarised in Section 3 and detailed in Appendix C (Laboratory Certificates).

Table 2: Analytical Program and Number of Samples

Test	Number of Samples Tested	Application	Justification
In situ measurements: Field pH; and pH, EC using portable TPS meter	Field pH – 8.3 Meter pH – 1.7 Meter EC – 1.7	Indication of possible limitations from salinity and pH	Used for 'on the spot' estimates of possible salinity or pH problems and to confirm the effective soil depth.
pH	1.7	Nutrient availability, nutrient fixation, toxicities (Al, Mn), liming, sodicity and correlation with other physical, chemical and biological properties	Measurement of pH is a useful indicator of various soil properties (e.g. values >8.5 usually indicate high exchangeable sodium levels and the presence of carbonates and nutrient availability limitations).
Electrical Conductivity	17	Appraisal of salinity hazard in soil substrates or groundwater and total soluble salts	The measure of electrical conductivity is used as a means of appraising soil salinity. The electrical conductance increases with soluble salt content and thus allows simple interpretation of salinity.
Chloride Content	17	The concentration of chloride is usually an indicator of the severity of potential salinity	The chloride anion is usually present in soil associated with sodium. It is highly mobile making it a valuable indicator of salt and water movement. It provides additional confirmation of salinity risk.
Bicarbonate Extractable Phosphorus	5	Measurement of the total phosphorus in the soil	While both acid extractable P (acid extr. P) and bicarbonate extractable P (bicarb. extr. P) are routinely measured, only bicarb. extr. P has been used to assess P fertility. Because the bicarb. extr. P test provides reliable and consistent data across a wide range of pH values from strongly acid to strongly alkaline, it is far more useful than the acid extr. P.
CEC, Exchangeable Cations, Ca/MG ratio, ESP	17	Fertile soils have moderate to high CEC. Infertile soils have low CEC. Nutrient status, calculation of ESP, assessment of other physical and chemical properties, dispersivity, shrink – swell, water movement and aeration	The amounts and relative proportions of the exchangeable cations in soil have important effects on both physical and chemical properties. High levels of exchangeable sodium cause dispersion and increased swelling, reducing water movement and affecting near surface aeration whereas exchangeable calcium flocculates colloids and will reduce swelling tendencies. Excessively high or low concentrations of one or the other of the cations may impact buffering capacity and as a result, soil nutrient availability.
Available Nitrogen	5	Presence of nitrogen in an available form for plant uptake	Testing provides an indication of the general fertility of soils and thus their suitability as a topdressing agent.
Organic Matter	5	Soil organic matter comprises an accumulation of partially disintegrated and decomposed plant and animal residues and other organic compounds synthesized by the soil microbes as the decay occurs. Soil organic matter forms a substantial reserve of potentially mineralizable nitrogen, sulfur and other nutrients.	Testing for soil organic matter provides an indication of the general fertility of soils and thus suitability as a topdressing agent. It also provides information on stored potential nutrients which may not yet be accessible to plants but may become available in the future.
PSA (<2 mm)	5	Nutrient retention, exchange properties, erodibility, doughtiness, workability, permeability, sealing, drainage, interpretation of most other physical and chemical properties and soil qualities	Particle size distribution data provides an assessment of the composition of a soil (based upon the dominant grain size within a soil). This assists with confirmation of field observations as well as providing better grounds for identification of soil types and water holding capacity.
R1 Dispersion	5	Measurement of the amount of silt and clay that disperses during testing	The measure of R1 dispersion is useful when used in conjunction with ESP and the Ca/Mg ratio for predicting soil physical behaviour.
Aggregate Stability Emerson Aggregate Test	5	Susceptibility to surface sealing under rainfall or irrigation, effect of raindrop impact and slaking, permeability, infiltration, aeration, seedling emergence and correlation with other properties	An Emerson Aggregate Class number is determined using the results of this test. The method for this test is provided in Australian Standard (AS) 1289.3. 8.1 - 1997. Soils are divided into seven classes on the basis of their coherence in water, with a further class distinguished by the presence of calcium-rich minerals. This test provides an indication of dispersivity and slaking behavior of soil and its preponderance to becoming erosive under natural conditions. Therefore it is a useful test in assessing options for ongoing management for excavated and stockpiled materials.
Selected Metals	5	Detection of heavy metals	The analysis of aluminum, copper, zinc, manganese and iron will assess potential natural concentrations of these select heavy metals in the soil as well as any phytotoxicity issues that may exist.
Sulfate	5	Measurement of total sulfur in soil	Total levels of sulfur help identify whether organic matter or gypsum are present in a profile.

4 RESULTS

4.1 Soil Mapping Units

Six soil mapping units (SMUs), inclusive of one soil variant, were identified across the project site on the basis of 122 investigation sites, incorporating 27 detailed sites and 95 observation sites (as shown in Figure 5). Descriptions of the detailed and observation sites are presented within Appendix A and Appendix B.

The SMUs are summarised in Table 3, and have been grouped according to basic soil morphology, position in the landscape, and parent material. Individual soil types have been classified in accordance with the *Australian Soil Classification* (Isbell, 2002). Comparable land systems, as described by Lynch (2012), are also provided in Table 3.

Figure 5 illustrates the spatial distribution of all mapped soil units within the study area and detailed descriptions of each SMU are provided in the following sections.

Table 3: Soil Types

SMU	Concept	Land System (Lynch, 2012)	Major Vegetation (Lynch, 2012)	Detailed sites (* lab site)
B1	Dark brown to reddish brown loamy sands on undulating plains	Bundah	Tall open woodland of *E. tetrodonta* with *E. miniata*, *Callitris intratropica* and *E. polycarpa*	1, 2, 4, 5*, 8, 9, 12, 13, 14, 15, 16, 17, 18, 20, 25, 26
B1v	Light brownish grey to yellow brown loamy sands on undulating plains			6*
B2	Brownish black loamy sands on level to undulating plains	Yarrawirrie	Tall sparse shrubland to low open woodland of *Eucalyptus. tetrodonta*	3, 7*, 11, 27
V1	Very dense rocky undulating plain with dense vegetation	-	Monsoonal vine thicket^	22, 23, 24
Q1	Rugged uplands on quartz sandstone with minor Leptic Rudosols	Groote	Mid high to tall open woodland of *E. tetrodonta* and *E. ferruginea*	10*
A1	Alluvial floodplains and gully areas in level to gently undulating plains	Effington	Mid high open woodland of *Melaleuca viridiflora* and *E. polycarpa*	19*, 21

^ Vegetation as observed in the field (i.e., not from Lynch, 2012)

4.1.1 Soils of Level to Undulating Sand Plains: Soil Mapping Unit *B1*

Overview

This SMU is predominant across the project site and typically occurs along the boundaries and footslopes of the surrounding rugged upland areas. Vegetation includes tall open woodland throughout. SMU *B1* is located on level to gently undulating plains. Soils are considered to be firm dark brown to brown reddish loamy sands extending to 1.0m below the surface.

Soil Characteristics and Chemistry

This soil unit is a low to moderate quality soil with low dispersive qualities. It has a slightly acidic profile and non sodic conditions within the topsoil profile as indicated in the representative laboratory site data.

The available data indicate that this SMU has the following characteristics:

- a high sand content throughout the profile;
- pH is slightly acidic throughout;
- electrical conductivity is very low throughout;
- very low cation exchange capacity throughout the profile;
- non sodic;
- very high to moderate Ca to Mg ratios with depth;
- low dispersive qualities; and
- overall fertility is low.

Representative Site

Site 5 was chosen as representative of this SMU for chemical analysis.

A site description is presented in Table 4, and a soil profile morphology summary is presented in Table 5. The soil chemistry results for this site are presented in Table 6.

Table 4: Site Description

SMU	***B1***	**Representative Site Number**	**Site 5**
Representative Site photograph			
Site survey type	Detailed. 50 mm hand auger.	**Main vegetation**	Stringybark, Darwin Woollybutt, Cypress Pine
Location	665639mE 8449753mN	**Disturbance**	No effective disturbance
Landform element and pattern	Gentle Undulating Plain	**Micro relief**	None
		Permeability	Highly permeable
Slope (%)	3.0	**Drainage**	Rapid drainage
Surface coarse fragments	No coarse fragment	**Surface condition**	Surface is firm and dry
ASC Order (s) present in SMU	Brown Tenosol	**Land use**	Native Vegetation
Land System (Lynch (2012)	Bundah	**Substrate**	Sandstone
Effective Soil Depth	1.0m+	**Estimated Soil Water Storage**	40mm
Erosion potential (Bourne and Tuck 1993)	The SMU is generally located on long, low-gradient sloping areas with a sandy surface. It has a low to medium water erosion hazard.		
Soil quality for mine rehabilitation	Recommended Topsoil Strip Depth: 0.4m		
Land condition	Good condition		
Total area (ha)	3524		

Table 5: Soil Profile Morphology Summary

Representative Site Number: Site 5	**HORIZON, DEPTH (m), BOUNDARY**	**COLOUR, MOTTLES, BLEACH**	**MOISTURE, IN SITU MEASUREMENTS DEPTH (m): pH and EC (mS)**	**TEXTURE, STRUCTURE, STRENGTH**	**COARSE FRAGMENTS, SEGREGATIONS, ROOTS**
	*Horizon:* A11 *Horizon Depth:* 0.0-0.40 *Boundary:* Diffused	*Colour:* 7.5YR3/4, Dark Brown *Mottle:* No Mottle *Bleach:* No Bleach	*Moisture:* Dry *Depth 0.05m:* Field pH 6.5 Meter pH 7.94 Meter EC 0.00 *Depth 0.30m:* Field pH 6.5 Meter pH 7.68 Meter EC 0.00	*Texture:* Loamy Sand *Structure:* Massive *Strength:* Loose	*Coarse Fragments:* <2%, 2-6mm *Segregations:* No segregations *Roots:* Fine, very few
	Horizon: A12 *Horizon Depth:* 0.40-1.00	*Colour:* 2.5YR3/4, Dark Reddish Brown *Mottle:* No Mottle *Bleach:* No Bleach	*Moisture:* Dry *Depth 0.60m:* Field pH 6.5 Meter pH 7.74 Meter EC 0.00 *Depth 0.90m:* Field pH 6.5 Meter pH 7.52 Meter EC 0.00	*Texture:* Loamy Sand *Structure:* Massive *Strength:* Loose	*Coarse Fragments:* <2%, 2-6mm *Segregations:* No segregations *Roots:* Fine, very few

Table 6: Soil Chemistry Results for Representative Site 5

Analysis (Unit)	**Representative Site Number: Site 5 Sample Depth (m)**			
	0.00-0.10	**0.30-0.40**	**0.60-0.70**	**0.90-1.00**
Soil pH	6.4	6.3	6.2	6.1
Soil EC (dS/m)	0.02	0.01	0.01	0.01
Soil Cl (mg/kg)	16	27	24	18
P(Olsen) (mg/kg)	7	-	-	-
Exch.Ca (meq/100g)	1.18	0.73	0.48	0.33
Exch. Mg (meq/100g)	0.41	0.46	0.41	0.32
Exch. Na (meq/100g)	<0.08	<0.08	<0.08	<0.08
Exch. K (meq/100g)	0.04	0.04	0.03	0.02
CEC (meq/100g)	1.7	1.3	1.0	0.8
Ca/Mg (ratio)	2.9	1.6	1.2	1.0
ESP %Na/CEC	1	1	2	1
Total N (%)	<0.01	-	-	-
Nitrate N (%)	2	-	-	-
OrgMatter (%)	1.8	-	-	-
PSA-CS (%)	75	-	-	-
PSA-FS(%)	13	-	-	-
PSA-Silt (%)	1	-	-	-
PSA-Clay (%)	13	-	-	-
Disp Ratio (R1)	0.63	-	-	-
ADMC (%)	2.2	-	-	-
Emerson (Number)	5	-	-	-

Analysis (Unit)	Representative Site Number: Site 5 Sample Depth (m)			
	0.00-0.10	**0.30-0.40**	**0.60-0.70**	**0.90-1.00**
Sulfate-S (mg/kg)	2	-	-	-
Mn (mg/kg)	33.1	-	-	-
Boron (mg/kg)	0.4	-	-	-
Copper (mg/kg)	0.2	-	-	-
Iron (mg/kg)	39	-	-	-
Zinc (mg/kg)	0.2	-	-	-
Al (meq/100g)	0.07	0.03	0.05	0.1
Al/CEC (%)	4	2	5	13

"-" indicates sample not tested for the selected analyte

4.1.2 Soils of Level to Undulating Sand Plains: Soil Mapping Unit *B1v*

Overview

This SMU is a variant of *B1* and situated in a very localised area in the north eastern part of the Northern Eastern Lease. The soils consist of gradational brownish grey sands and greyish yellow loamy sands to a dull orange sandy clay loam extending to 1.0m below the surface.

Soil Characteristics and Chemistry

This soil unit is similar to the SMU *B1* with a low to moderate quality soil. The moderate dispersive qualities and non sodic conditions indicate a moderate to stable soil structure and type. The profile is slightly acidic with a very low cation exchange capacity as indicated in the representative laboratory site data.

The available data indicate that this SMU has the following characteristics:

- high sand content throughout profile;
- pH is acidic throughout;
- electrical conductivity is very low throughout;
- very low cation exchange capacity throughout profile;
- non sodic;
- high Ca to Mg ratios within the topsoil horizon;
- moderate dispersive qualities; and
- overall fertility is low.

Representative Site

Site 6 was chosen as representative of this SMU for chemical analysis.

A site description is presented in Table 7, and a soil profile morphology summary is presented in Table 8. The soil chemistry results for this site are presented in Table 9.

Table 7: Site Description

SMU	*B1v*	**Representative Site Number**	Site 6
Representative site Photograph			
Site survey type	Detailed. 50 mm hand auger.	**Main vegetation**	Stringybark, Darwin Woollybutt, Cypress Pine
Location	665414mE 8449066mN	**Disturbance**	No effective disturbance
Landform element and pattern	Gentle Undulating Plain	**Micro relief**	None
		Permeability	Highly permeable
Slope (%)	1.5	**Drainage**	Rapid drainage
Surface coarse fragments	No coarse fragment	**Surface condition**	Surface is firm and dry
ASC Order (s) present in SMU	Grey Tenosol	**Land use**	Native Vegetation
Land System (Lynch (2012)	Bundah	**Substrate**	Sandstone
Effective Soil Depth	1.0m+	**Estimated Soil Water Storage**	42mm
Erosion potential (Bourne and Tuck 1993)	The SMU is generally located on long, low-gradient sloping areas with a sandy surface. It has a low to medium water erosion hazard.		
Soil quality for mine rehabilitation	Recommended Topsoil Strip Depth: 0.20m		
Land condition	Good condition		
Total area (ha)	13		

Table 8: Soil Profile Morphology Summary

Representative Site Number: Site 6	**HORIZON, DEPTH (m), BOUNDARY**	**COLOUR, MOTTLES, BLEACH**	**MOISTURE, IN SITU MEASUREMENTS DEPTH (m): pH and EC (mS)**	**TEXTURE, STRUCTURE, STRENGTH,**	**COARSE FRAGMENTS, SEGREGATIONS, ROOTS**
	*Horizon:* A11 *Horizon Depth:* 0.0-0.20 *Boundary:* Diffused	*Colour:* 10YR6/1, Brownish Grey *Mottle:* No mottle *Bleach:* No bleach	*Moisture:* Dry *Depth 0.05m:* Field pH 6.5 Meter pH 7.92 Meter EC 0.00	*Texture:* Sand *Structure:* Massive *Strength:* Loose	*Coarse Fragments:* No coarse fragments *Segregations:* No segregations *Roots:* Few, very fine
	Horizon: A12 *Horizon Depth:* 0.20-0.90 *Boundary:* Gradual	*Colour:* 10YR6/2, Greyish yellow brown *Mottle:* No mottle *Bleach:* No bleach	*Moisture:* Dry *Depth 0.30m:* Field pH 6.5 Meter pH 7.58 Meter EC 0.00 *Depth 0.60m:* Field pH 6.5 Meter pH 7.40 Meter EC 0.00	*Texture:* Loamy Sand *Structure:* Massive *Strength:* Very weak	*Coarse Fragments:* No coarse fragments *Segregations:* No segregations *Roots:* Few, Very fine
	Horizon: A2 *Horizon Depth:* 0.90-1.15	*Colour:* 5YR6/3, Dull orange *Mottle:* No mottle *Bleach:* No bleach	*Moisture:* Dry *Depth 0.95m:* Field pH 6.5 Meter pH 7.22 Meter EC 0.00	*Texture:* Sandy Clay Loam *Structure:* Weak *Strength:* Very weak	*Coarse Fragments:* <40%, 2-6mm coarse fragments *Segregations:* No segregations *Roots:* No roots observed

Table 9: Soil Chemistry Results for Representative Site 6

Analysis (Unit)	**Representative Site Number: Site 6 Sample Depth (m)**			
	0.00-0.10	**0.30-0.40**	**0.60-0.70**	**0.90-1.00**
Soil pH	5.5	5.6	5.6	5.8
Soil EC (dS/m)	0.01	0.01	0.01	0.01
Soil Cl (mg/kg)	14	17	18	20
P(Olsen) (mg/kg)	4	-	-	-
Exch.Ca (meq/100g)	0.53	<0.1	<0.1	0.03
Exch. Mg (meq/100g)	0.32	0.41	0.67	1.83
Exch. Na (meq/100g)	<0.08	<0.08	<0.08	0.09
Exch. K (meq/100g)	0.02	0.02	<0.01	0.03
CEC (meq/100g)	1.0	0.9	0.9	2.1
Ca/Mg (ratio)	1.7	0.0	-	0.0
ESP %Na/CEC	1	2	2	4
Total N (%)	<0.01	-	-	-
Nitrate N (%)	2	-	-	-
OrgMatter (%)	0.8	-	-	-
PSA-CS (%)	74	-	-	-
PSA-FS(%)	22	-	-	-
PSA-Silt (%)	2	-	-	-
PSA-Clay (%)	6	-	-	-

Analysis (Unit)	Representative Site Number: Site 6 Sample Depth (m)			
	0.00-0.10	**0.30-0.40**	**0.60-0.70**	**0.90-1.00**
Disp Ratio (R1)	0.52	-	-	-
ADMC (%)	0.3	-	-	-
Emerson (Number)	5	-	-	-
Sulfate-S (mg/kg)	1	-	-	-
Mn (mg/kg)	7.6	-	-	-
Boron (mg/kg)	0.2	-	-	-
Copper (mg/kg)	0.1	-	-	-
Iron (mg/kg)	13	-	-	-
Zinc (mg/kg)	0.2	-	-	-
Al (meq/100g)	0.09	0.42	0.19	0.08
Al/CEC (%)	9	48	21	4

"-" indicates sample not tested for the selected analyte

4.1.3 Soils of Level to Undulating Sand Plains: Soil Mapping Unit *B2*

Overview

This SMU is generally located adjacent to SMU *B1*, in areas of level and gently undulating plains. Soils are firm brownish black loamy sands into a sandy clay loam extending to 1.0m below the surface.

Soil Characteristics and Chemistry

This soil unit is a low to moderate quality soil capable of supporting native vegetation. The decreasing Ca/Mg ratio with depth, and an emerson class number of 5, indicate a slightly unstable soil structure within the topsoil horizon. The soils are typically non sodic and have very low salinity. The profile is slightly acidic with a very low cation exchange capacity as indicated in the representative laboratory site data. Soil water storage potential is higher than the SMUs *B1* and *B1v* due to the B horizon consisting of sandy clay loam within 0.30m of the soil profile.

The available data indicate that this SMU has the following characteristics:

- high sand content throughout profile;
- pH is acidic throughout;
- electrical conductivity and chloride is very low throughout;
- very low cation exchange capacity throughout profile;
- non sodic;
- very high to very low Ca to Mg ratios throughout profile;
- low to moderate dispersive qualities; and
- overall fertility is low to moderate.

Representative Site

Site 7 was chosen as representative of this SMU for chemical analysis.

A site description is presented in Table 10, and a soil profile morphology summary is presented in Table 11. The soil chemistry results for this site are presented in Table 12.

Table 10: Site Description

SMU	***B2***	**Representative Site Number**	**Site 7**
Representative site photograph			
Site survey type	Detailed. 50 mm hand auger.	**Main vegetation**	Stringybark, Cypress Pine
Location	664316mE 8447989mN	**Disturbance**	No effective disturbance
Landform element and pattern	Gentle Undulating Plain	**Micro relief**	None
		Permeability	Highly permeable
Slope (%)	3.5	**Drainage**	Rapid drainage
Surface coarse fragments	<10% 2-6mm coarse fragments	**Surface condition**	Surface is firm and dry
ASC Order (s) present in SMU	Brown Kandosol	**Land use**	Native Vegetation
Land System (Lynch (2012)	Yarrawirrie	**Substrate**	Sandstone
Effective Soil Depth	1.0m+	**Estimated Soil Water Storage**	68mm
Erosion potential (Bourne and Tuck 1993)	The SMU is generally located on low-gradient sloping areas with a sandy surface. It has a low to medium water erosion hazard.		
Soil quality for mine rehabilitation	Recommended Topsoil Strip Depth: 0.15m		
Land condition	Good condition		
Total area (ha)	435		

Table 11: Soil Profile Morphology Summary

Representative site number: Site 7	**HORIZON, DEPTH (m), BOUNDARY**	**COLOUR, MOTTLES, BLEACH**	**MOISTURE, IN SITU MEASUREMENTS DEPTH (m): pH and EC (mS)**	**TEXTURE, STRUCTURE, STRENGTH**	**COARSE FRAGMENTS, SEGREGATIONS, ROOTS**
	*Horizon:* A11 *Horizon Depth:* 0.0-0.20 *Boundary:* Abrupt	*Colour:* 10YR3/2, Brownish Black *Mottle:* No mottle *Bleach:* No Bleach	*Moisture:* Dry *Depth 0.10m:* Meter pH 7.87 Meter EC 0.00	*Texture:* Loamy sand *Structure:* Massive *Strength:* Loose	*Coarse Fragments:* No coarse fragments *Segregations:* No segregations *Roots:* Few, very fine
	Horizon: A12 *Horizon Depth:* 0.20-0.30 *Boundary:* Abrupt	*Colour:* 10YR4/2 , Greyish yellow brown *Mottle:* No mottle *Bleach:* No Bleach	*Moisture:* Dry *Depth 0.30m:* Meter pH 7.05 Meter EC 0.00	*Texture:* Loamy Sand *Structure:* Massive *Strength:* Very weak	*Coarse Fragments:* No coarse fragments *Segregations:* No segregations *Roots:* Few, very fine
	Horizon: B2 *Horizon Depth:* 0.30-1.15	*Colour:* 10YR2/2, Brownish black *Mottle:* No mottle *Bleach:* No bleach	*Moisture:* Dry *Depth 0.60m:* Meter pH 7.36 Meter EC 0.00 *Depth 0.90m:* Meter pH 7.29 Meter EC 0.00	*Texture:* Sandy Clay Loam *Structure:* Weak *Strength:* Very weak	*Coarse Fragments:* <40%, 2-6mm coarse fragments *Segregations:* No segregations *Roots:* No roots observed

Table 12: Soil Chemistry Results for Representative Site 7

Analysis (Unit)	**Representative Site Number: Site 7 Sample Depth (m)**			
	0.00-0.10	**0.20-0.30**	**0.60-0.70**	**0.90-1.00**
Soil pH	6.1	5.8	5.8	5.9
Soil EC (dS/m)	0.02	0.01	0.01	0.01
Soil Cl (mg/kg)	12	12	8	9
P(Olsen) (mg/kg)	4	-	-	-
Exch.Ca (meq/100g)	2.64	0.32	0.37	0.43
Exch. Mg (meq/100g)	0.84	0.32	0.76	1.13
Exch. Na (meq/100g)	<0.08	<0.08	<0.08	<0.08
Exch. K (meq/100g)	0.07	0.04	0.07	0.04
CEC (meq/100g)	3.6	0.8	1.2	1.7
Ca/Mg (ratio)	3.1	1.0	0.5	0.4
ESP %Na/CEC	1	1	3	2
Total N (%)	0.02	-	-	-
Nitrate N (%)	2	-	-	-
OrgMatter (%)	2.2	-	-	-
PSA-CS (%)	68	-	-	-
PSA-FS(%)	22	-	-	-
PSA-Silt (%)	5	-	-	-
PSA-Clay (%)	6	-	-	-

Analysis (Unit)	Representative Site Number: Site 7 Sample Depth (m)			
	0.00-0.10	**0.20-0.30**	**0.60-0.70**	**0.90-1.00**
Disp Ratio (R1)	0.99	-	-	-
ADMC (%)	2.2	-	-	-
Emerson (Number)	5	-	-	-
Sulfate-S (mg/kg)	3	-	-	-
Mn (mg/kg)	53.8	-	-	-
Boron (mg/kg)	0.4	-	-	-
Copper (mg/kg)	0.3	-	-	-
Iron (mg/kg)	16	-	-	-
Zinc (mg/kg)	0.3	-	-	-
Al (meq/100g)	0.03	0.08	<0.02	0.04
Al/CEC (%)	1	10	<1	2

"-" indicates sample not tested for the selected analyte

4.1.4 Soils of Level to Undulating Sand Plains: Soil Mapping Unit *V1*

Overview

This SMU is the smallest SMU within the project site, and is located within a densely vegetated monsoonal vine thicket situated to the south of the Southern Eastern Lease. The area is located on a gently undulating plain just off a ridge, adjacent to SMU *B1*. SMU *V1* contains a high proportion of surface rocks and gravel, with manganese deposits visible immediately to the north of the SMU, and fresh organic material and debris on the rock surface.

Soils were not accessible due to the sandstone substrate. As such, a soil sample could not be collected and the description of the SMU is therefore limited.

Soil Characteristics and Chemistry

The SMU was considered to be a minor soil type with no obtainable sample; therefore, no soil chemistry results are available.

Representative Site

Site 22 was chosen as representative of this SMU. A site description is presented in Table 13, and a soil profile morphology summary is presented in Table 14.

Table 13: Site Description

SMU	***V1***	**Representative Site Number**	Site 22
Representative site photograph			
Site survey type	Detailed. Hand trowel	**Main vegetation**	Monsoonal Vine Thicket
Location	665359mE 8440001mN	**Disturbance**	No effective disturbance
Landform element and pattern	Undulating Plain	**Micro relief**	None
		Permeability	-
Slope (%)	6.0	**Drainage**	-
Surface coarse fragments	>95% 0-200mm coarse fragments and boulders	**Surface condition**	Organic Matter/leaf matter
ASC Order (s) present in SMU	Brown Tenosol	**Land use**	Native Vegetation
Land System (Lynch (2012)	Bundah	**Substrate**	Sandstone
Effective Soil Depth	0.0	**Estimated Soil Water Storage**	n/a
Erosion potential (Bourne and Tuck 1993)	-		
Soil quality for mine rehabilitation	Recommended Topsoil Strip Depth: 0.00m		
Land condition	Good condition		
Total area (ha)	1		

Table 14: Soil Profile Morphology Summary

Representative site number: **Site 22**	**HORIZON, DEPTH (m), BOUNDARY**	**COLOUR, MOTTLES, BLEACH**	**MOISTURE, IN SITU MEASUREMENTS DEPTH (m): pH and EC (mS)**	**TEXTURE, STRUCTURE, STRENGTH**	**COARSE FRAGMENTS, SEGREGATIONS, ROOTS**
	*Horizon:* O1 *Horizon Depth:* 0.0-0.02	*Colour:* No colour *Mottle:* No mottle *Bleach:* No bleach	*Moisture:* Humid *Depth 0.02m:* Meter pH 7.17 Meter EC 0.05	*Texture^:* - *Structure^:* - *Strength^:* -	*Coarse Fragments:* >95% 0-200mm *Segregations:* No segregations *Roots:* No roots

^ Note: no soil sample was able to be collected at this site.

4.1.5 Uplands with Sandy Earths and Lithosols: Soil Mapping Unit *Q1*

Overview

This SMU is found typically in areas toward the boundary of the Eastern Leases with one large expanse located within the centre of the Southern Eastern Lease. The SMU comprises rugged dissected uplands on quartz sandstone with little disturbance. Soils are shallow, if non-existent, gravelly and often rocky clayey sand over quartz sandstone below 0.02m depth.

Soil Characteristics and Chemistry

This soil unit is a low to moderate quality soil. Dispersion levels indicate a stable soil structure within the available topsoil horizon. The soils are typically non sodic and have very low salinity. The profile is slightly acidic with a very low cation exchange capacity as indicated in the representative soil chemistry results.

The available data indicate that this SMU has the following characteristics:

- fine and coarse sand content dominates the profile;
- pH is acidic throughout;
- electrical conductivity and chloride is very low throughout;
- low cation exchange capacity throughout profile;
- non sodic;
- non dispersive; and
- very high Ca to Mg ratios throughout profile.

Representative Site

Site 10 was chosen as representative of this SMU for chemical analysis.

A site description is presented in Table 15, and a soil profile morphology summary is presented in Table 16. The soil chemistry results for this site are presented in Table 17.

Table 15: Site Description

SMU	***Q1***	**Representative site number**	**Site 10**
Representative site photograph			
Site survey type	Detailed. Hand Trowel	**Main vegetation**	Stringybark, Cypress Pine
Location	659747mE 8443219mN	**Disturbance**	No effective disturbance
Landform element and pattern	Undulating Plains	**Micro relief**	None
		Permeability	Highly permeable
Slope (%)	6.5	**Drainage**	Rapid drainage
Surface coarse fragments	<30% <6mm <30% <20mm <20% >20mm Coarse fragments/ boulders/quartz	**Surface condition**	Surface is soft and dry
ASC Order (s) present in SMU	Grey Tenosol	**Land use**	Native Vegetation
Land System (Lynch (2012)	Groote	**Substrate**	Sandstone
Effective Soil Depth	<0.02m	**Estimated Soil Water Storage**	n/a
Erosion potential (Bourne and Tuck 1993)	This SMU generally located on low-gradient sloping areas with a sandy surface It has a low to medium water erosion hazard.		
Soil quality for mine rehabilitation	Recommended Topsoil Strip Depth: 0.00m		
Land condition	-		
Total area (ha)	471		

Table 16: Soil Profile Morphology Summary

Representative site number: **Site 10**	**HORIZON, DEPTH (m), BOUNDARY**	**COLOUR, MOTTLES, BLEACH**	**MOISTURE, IN SITU MEASUREMENTS** **DEPTH (m): pH and EC (mS)**	**TEXTURE, STRUCTURE, STRENGTH**	**COARSE FRAGMENTS, SEGREGATIONS, ROOTS**
	*Horizon:* A1 *Horizon Depth:* 0.0-0.02	*Colour:* 10YR7/1, Light Grey *Mottle:* No mottle *Bleach:* No bleach	*Moisture:* Dry *Depth 0.02m:* Field pH 6.5 Meter pH 6.24 Meter EC 0.00	*Texture:* Clayey Sand *Structure:* Massive *Strength:* Loose	*Coarse Fragments:* <30% <6mm; <30% <20mm; <20% >20mm; and Quartz *Segregations:* No segregations *Roots:* Few, very fine

Table 17: Soil Chemistry Results for Representative Site 10

Analysis (Unit)	**Representative Site Number: Site 10** **Sample Depth (m)**
	0.00-0.02
Soil pH	5.9
Soil EC (dS/m)	0.03
Soil Cl (mg/kg)	16
P(Olsen) (mg/kg)	6
Exch.Ca (meq/100g)	4.34
Exch. Mg (meq/100g)	1.9
Exch. Na (meq/100g)	<0.08
Exch. K (meq/100g)	0.08
CEC (meq/100g)	6.4
Ca/Mg (ratio)	2.3
ESP %Na/CEC	1
Total N (%)	0.09
Nitrate N (%)	1
OrgMatter (%)	3.3
PSA-CS (%)	50
PSA-FS(%)	41
PSA-Silt (%)	3
PSA-Clay (%)	6
Disp Ratio (R1)	0.83
ADMC (%)	1.4
Emerson (Number)	5
Sulfate-S (mg/kg)	6
Mn (mg/kg)	44.2
Boron (mg/kg)	0.4
Copper (mg/kg)	0.2
Iron (mg/kg)	27
Zinc (mg/kg)	0.3
Al (meq/100g)	0.02
Al/CEC (%)	<1

"-" indicates sample not tested for the selected analyte

4.1.6 Soils of Drainage Channels and Alluvial Plains: Soil Mapping Unit *A1*

Overview

This SMU is associated with active drainage pathways within the project site. Landforms are flat to very gently undulating plains with drainage lines and soils that are brownish black to dark black sandy clay loams to silty loams often with a firm to hard setting surface. Soils throughout the profile area are apedal with moderate to good drainage occurring within the first metre.

Soil Characteristics and Chemistry

This soil unit is a low to moderate quality soil capable of supporting native vegetation. Soils are typically non sodic and have very low salinity. The profile is slightly acidic with a very low cation exchange capacity and moderate dispersive qualities as indicated in the representative laboratory site data.

The available data indicate that this SMU has the following characteristics:

- fine and coarse sand content dominates the top profile with an increase in clay content with depth;
- pH is acidic throughout;
- electrical conductivity and chloride is very low throughout;
- very low cation exchange capacity throughout profile;
- non sodic;
- moderate to low Ca to Mg ratios throughout profile;
- moderate dispersive qualities; and
- overall fertility is low.

Representative Site

Site 19 was chosen as representative of this SMU for chemical analysis.

A site description is presented in Table 18, and a soil profile morphology summary is presented in Table 19. The soil chemistry results for this site are presented in Table 20.

Table 18: Site Description

SMU	***A1***	**Representative site number**	**Site 19**
Representative site photograph			
Site survey type	Detailed. 50 mm hand auger.	**Main vegetation**	Paperbark, Stringybark
Location	661131mE 8444231mN	**Disturbance**	No disturbance
Landform element and pattern	Gentle undulating plain, lower slope, gully nearby	**Micro relief**	Nil
		Permeability	Moderate
Slope (%)	2.0%	**Drainage**	Well drained
Surface coarse fragments	No coarse fragments	**Surface condition**	Soft, moist
ASC Order (s) present in SMU	Grey Chromosol	**Land use**	Native Vegetation
Land System (Lynch (2012)	Effington	**Substrate**	Sandstone
Effective Soil Depth	1.0m	**Estimated Soil Water Storage**	62mm
Erosion potential (Bourne and Tuck 1993)	This SMU has a high susceptibility to erosion if the surface is exposed.		
Soil quality for mine rehabilitation	Recommended Topsoil Strip Depth: 0.15m		
Land condition	Good condition		
Total area (ha)	138		

Table 19: Soil Profile Morphology

Representative site number: Site 19	**HORIZON, DEPTH (m), BOUNDARY**	**COLOUR, MOTTLES, BLEACH**	**MOISTURE, IN SITU MEASUREMENTS DEPTH (m): pH and EC (mS)**	**TEXTURE, STRUCTURE, STRENGTH**	**COARSE FRAGMENTS, SEGREGATIONS, ROOTS**
	*Horizon:* A1 *Horizon Depth:* 0.0-0.15 *Boundary:* Diffuse	*Colour:* 10YR2/1, Black, *Mottle:* No mottle *Bleach:* No bleach	*Moisture:* Moist *Depth 0.10m:* Field pH 6.5 Meter pH 7.02 Field EC 0.00	*Texture:* Sandy loam *Structure:* Weak *Strength:* Weak	*Coarse Fragments:* No coarse fragments *Segregations:* No segregations *Roots:* Very fine, Common
	Horizon: A2 *Horizon Depth:* 0.15-0.48 *Boundary:* Abrupt	*Colour:* 10YR3/1, Brownish black *Mottle:* No mottle *Bleach:* No bleach	*Moisture:* Moist *Depth 0.30m:* Field pH 6.0 Meter pH 6.72 Meter EC 0.00	*Texture:* Loamy sand *Structure:* Weak *Strength:* Weak	*Coarse Fragments:* No coarse fragments *Segregations:* No segregations *Roots:* Very fine, Common
	Horizon: B21 *Horizon Depth:* 0.48-0.85 *Boundary:* Abrupt	*Colour:* 10YR5/1, Brownish grey *Mottle:* Mottle <25% 2.5YR4/8 *Bleach:* No bleach	*Moisture:* Wet *Depth 0.60m:* Field pH 6.0 Meter pH 6.62 Meter EC 0.00	*Texture:* Clay loam *Structure:* Weak *Strength:* Moderate	*Coarse Fragments:* No coarse fragments *Segregations:* No segregations *Roots:* Very fine, Common
	Horizon: B22 *Horizon Depth:* 0.85-1.00	*Colour:* 10YR3/2, Brownish black *Mottle:* No mottle *Bleach:* No bleach	*Moisture:* Wet *Depth 0.90m:* Field pH 6.0 Meter pH 6.82 Meter EC 0.00	*Texture:* Clay loam, *Structure:* Weak, *Strength:* Moderate	*Coarse Fragments:* <10% <20mm coarse fragments *Segregations:* No segregations *Roots:* No Roots

Table 20: Soil Chemistry Results for Representative Site 19

Analysis (Unit)	**Representative Site Number: Site 19 Sample Depth (m)**			
	0.00-0.10	**0.30-0.40**	**0.60-0.70**	**0.90-1.00**
Soil pH	5.5	5.6	6	5.9
Soil EC (dS/m)	0.03	0.01	0.01	0.01
Soil Cl (mg/kg)	24	19	18	11
P(Olsen) (mg/kg)	7	-	-	-
Exch.Ca (meq/100g)	0.8	0.39	1.16	0.78
Exch. Mg (meq/100g)	1.04	0.89	2.71	1.89
Exch. Na (meq/100g)	0.11	<0.08	0.09	<0.08
Exch. K (meq/100g)	0.07	0.02	0.03	0.03
CEC (meq/100g)	3.3	1.7	4.5	2.9
Ca/Mg (ratio)	0.8	0.4	0.4	0.4
ESP %Na/CEC	3	2	2	2
Total N (%)	0.08	-	-	-
Nitrate N (%)	<1	-	-	-
OrgMatter (%)	5.1	-	-	-

Analysis (Unit)	Representative Site Number: Site 19 Sample Depth (m)			
	0.00-0.10	**0.30-0.40**	**0.60-0.70**	**0.90-1.00**
PSA-CS (%)	39	-	-	-
PSA-FS(%)	34	-	-	-
PSA-Silt (%)	11	-	-	-
PSA-Clay (%)	13	-	-	-
Disp Ratio (R1)	0.61	-	-	-
ADMC (%)	4.0	-	-	-
Emerson (Number)	3	-	-	-
Sulfate-S (mg/kg)	7	-	-	-
Mn (mg/kg)	11.5	-	-	-
Boron (mg/kg)	0.3	-	-	-
Copper (mg/kg)	0.5	-	-	-
Iron (mg/kg)	52	-	-	-
Zinc (mg/kg)	0.5	-	-	-
Al (meq/100g)	1.29	0.41	0.55	0.09
Al/CEC (%)	39	24	12	3

"-" indicates sample not tested for the selected analyte

4.2 Acid Sulfate Soils Assessment

No evidence of ASS was found during the field surveys, and the risk of ASS occurring within the project site is considered to be extremely low, given the geological origins, elevation and landforms found within the project site.

5 TOPSOIL STRIPPING DEPTH ASSESSMENT

5.1 Topsoil Stripping

Areas to be disturbed as a result of mining activities and construction of the proposed haul road will require stripping of topsoil for reuse in mine rehabilitation activities. All soil types within the study area have been assessed to determine their suitability for stripping and reuse in rehabilitation of these areas.

The recommended topsoil stripping depths for each SMU were determined based primarily on the change in CEC and the Ca/Mg ratio and observed texture changes through the soil profile. Changes in these parameters provide an indication of the change in fertility and dispersive qualities of the soil profile, and help indicate the change from topsoil to lesser fertile subsoils.

5.2 Summary of Soil Types and Recommended Topsoil Stripping Depths

The project site contains various soils from uniform to gradational sandy earths and loams, to minor texture contrast clay soil types. These soil types are summarized below.

Uniform to Gradational Sandy to Sandy Loam Earths (*B1, B1v, B2*)

These SMUs include deep brown, grey and grey yellow earths (*B1, B1v and B2*) of generally firm sandy loams to sandy clay loams ranging from uniform to gradational soils. These soils have a low to moderate erosion potential, and although are generally low in fertility, these soils are considered suitable to support native vegetation.

- ***SMU B1***

  Laboratory results for this SMU show levels of CEC and Ca/Mg decreasing after approximately 0.4mbgl in the soil profile. This indicates a decrease in fertility and increased dispersive qualities of the soil profile from this depth.

  The recommended topsoil stripping depth for SMU *B1* is therefore 0.4m.

- ***SMU B1v***

  Laboratory results for this SMU show that levels of Ca/Mg decrease significantly after approximately 0.3mbgl in the soil profile. This increases the dispersive qualities of the soil profile from this depth. In addition, a texture grade was observed to change after 0.2mbgl.

  The recommended topsoil stripping depth for SMU *B1v* is therefore 0.2m.

- ***SMU B2***

  Laboratory results for this SMU show that levels of CEC and Ca/Mg decrease significantly after approximately 0.1mbgl in the soil profile. This indicates a decrease in fertility and increased dispersive qualities of the soil profile from this depth. In addition, texture colour was observed to change after 0.2mbgl.

  The recommended topsoil stripping depth for SMU *B2* is therefore 0.15m.

Rocky outcrop with surface gravels and organic matter within monsoonal vine thicket (*V1*)

Soils from this SMU were not accessible due to the high proportion of surface rock and gravels. Therefore, it is not recommended to utilise this SMU to recover any topsoil resources.

Very Shallow Clayey Sand over Quartz Sandstone and Rock (*Q1*)

Soil mapping unit *Q1* is a very shallow gravelly clayey sand overlying rocky outcrop formations. The landform is rugged with jump ups and steeper slopes, which would limit the amount of topsoil able to be recovered, if any. Laboratory data of the representative site indicated minimal topsoil resources, with stripping likely to be limited to less than 0.05m based on field observations. Therefore, it is not recommended to utilise this SMU to recover any topsoil resources.

Texture Contrast Sandy to Clay Loam Earths (*A1*)

The quality of this texture contrast soil is similar to the uniform and gradational sandy earths and loams.

Laboratory results for this SMU show levels of Ca/Mg decrease from approximately 0.3mbgl in the soil profile. This increases the dispersive qualities of the soil profile from this depth. In addition, a texture grade was observed to change after 0.15mbgl.

The recommended topsoil stripping depth for SMU *A1* is therefore 0.15m.

5.2.1 Recommended Topsoil Stripping Depths

Table 21 presents the recommended topsoil stripping depths for each SMU. The distribution of the topsoil stripping depths is shown in Figure 6.

Table 21: Soil Mapping Unit Summary

SMU	Percentage of total project site (%)	Description	Recommended Topsoil Stripping Depth (mbgl)
B1	76.91	Dark brown to reddish brown loamy sands on undulating plains	0.40
B1v	0.28	Light brownish grey to yellow brown loamy sands on undulating plains	0.20
B2	9.49	Brownish black loamy sands on level to undulating plains	0.15
V1	0.02	Very dense rocky undulating plain with dense vegetation	0.00
Q1	10.28	Rugged uplands on quartz sandstone with minor Leptic Rudosols	0.00
A1	3.01	Alluival floodplains and gully areas in level to gently undulating plains	0.15

6 CONCLUSION

The following conclusions have been made:

- Six soil mapping units, including one variant, are present within the project site, *B1, B1v, B2, V1, Q1* and *A1*.
- The project site is dominated by areas of deep brown to light grey brown sandy earths, loams and gradational contrast soils (*B1, B1v, B2*), with minor areas of clay loam subsoils relating to active drainage pathways (*A1*), rugged upland areas with very shallow soils and dense rocky outcrops (*Q1*) and a densely vegetated monsoonal vine thicket (*V1*).
- The majority of topsoil from the deep sandy loam SMUs (*B1*, *B1v*, *B2* and *A1*) would be suitable for rehabilitation use. No topsoil would be able to be recovered from the rugged uplands or monsoonal vine thicket SMUs of *Q1* and *V1*.
- No evidence of ASS was found during the field surveys, and the risk of ASS occurring within the project site is considered to be extremely low, given the geological origins, elevation and landforms found within the project site.

7 REFERENCES

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8 FIGURES

Figure 1 Project Location

Figure 2 Local Setting

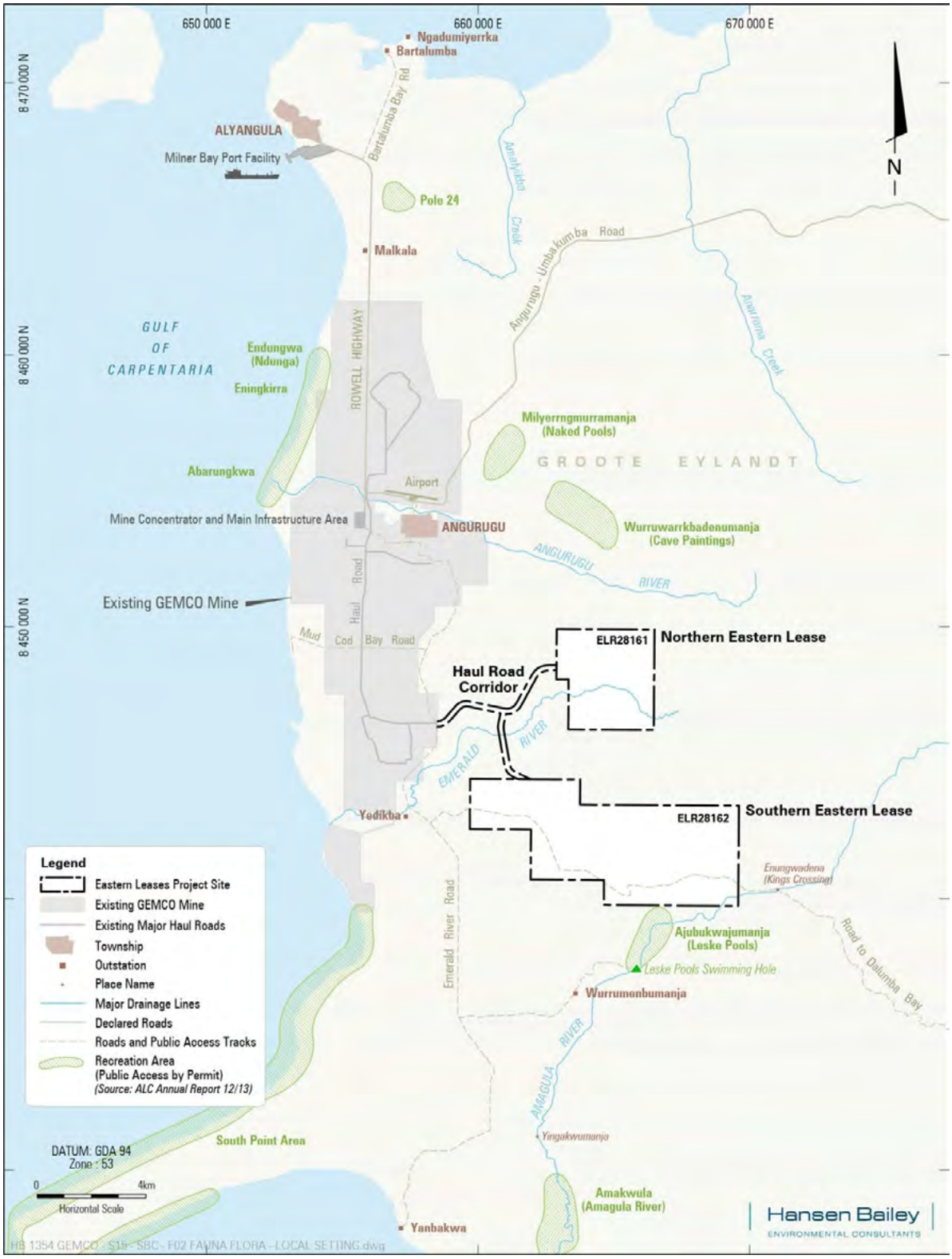


Figure 3 Surface Geology

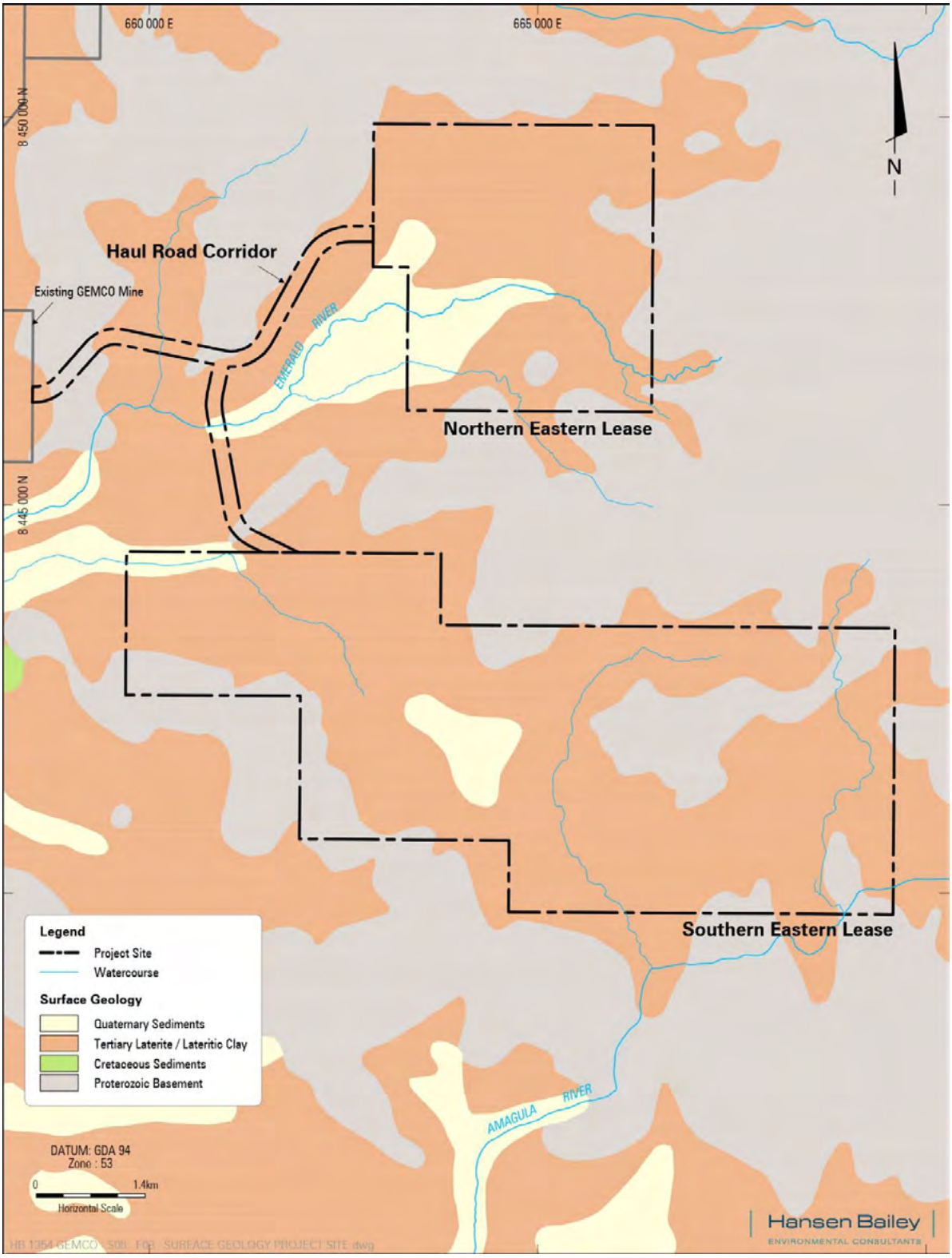


Figure 4 Land Systems

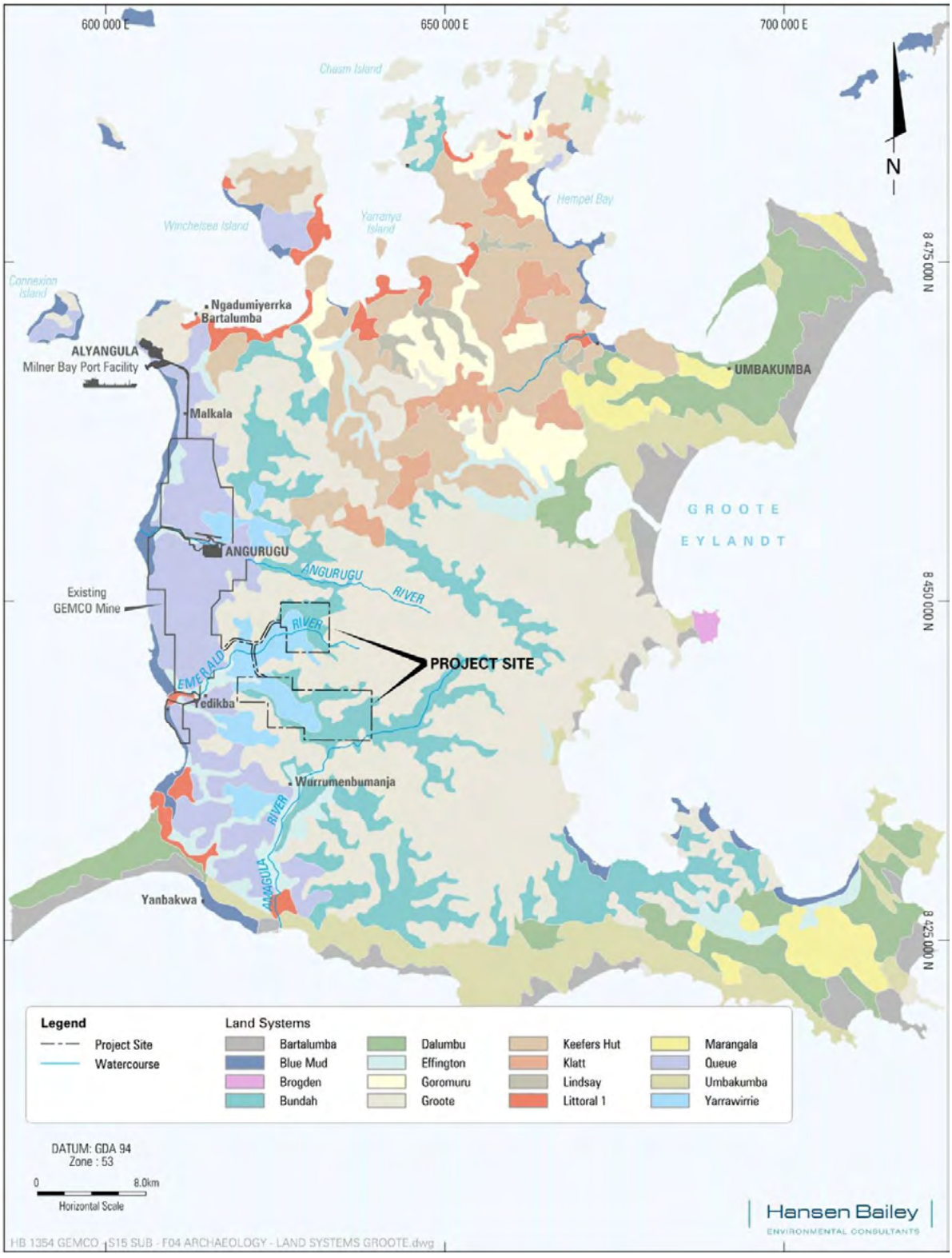
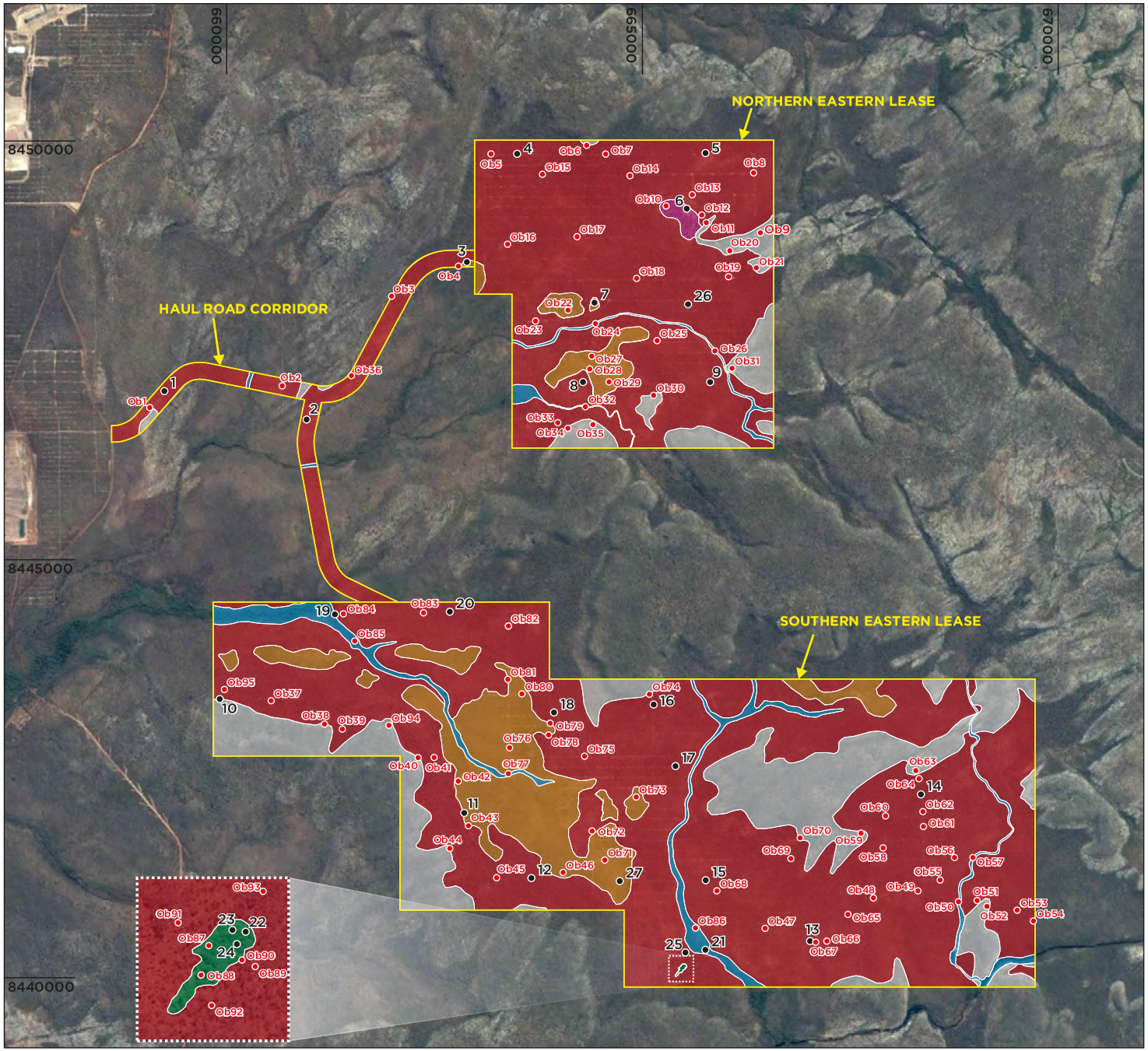


Figure 5: Soil Mapping Units

Baseline Soil Assessment
GEMCO EASTERN LEASES PROJECT

09/09/2014

0 2000
Metres
Projection: GDA94 Zone 53
Scale 1 : 20,000



Legend

- Soil Study Area
- Detailed Site
- Observation Site

B1	Dark Brown to reddish brown loamy sands on undulating plains
B1v	Light Brownish grey to yellow brown loamy sands on undulating plains
B2	Brownish black loamy sands on level to undulating plains
V1	Very dense rocky undulating plain with dense vegetation
Q1	Rugged uplands on quartz sandstone with minor Leptic Rudosols
A1	Alluvial floodplains and gully areas in level to gently undulating plains

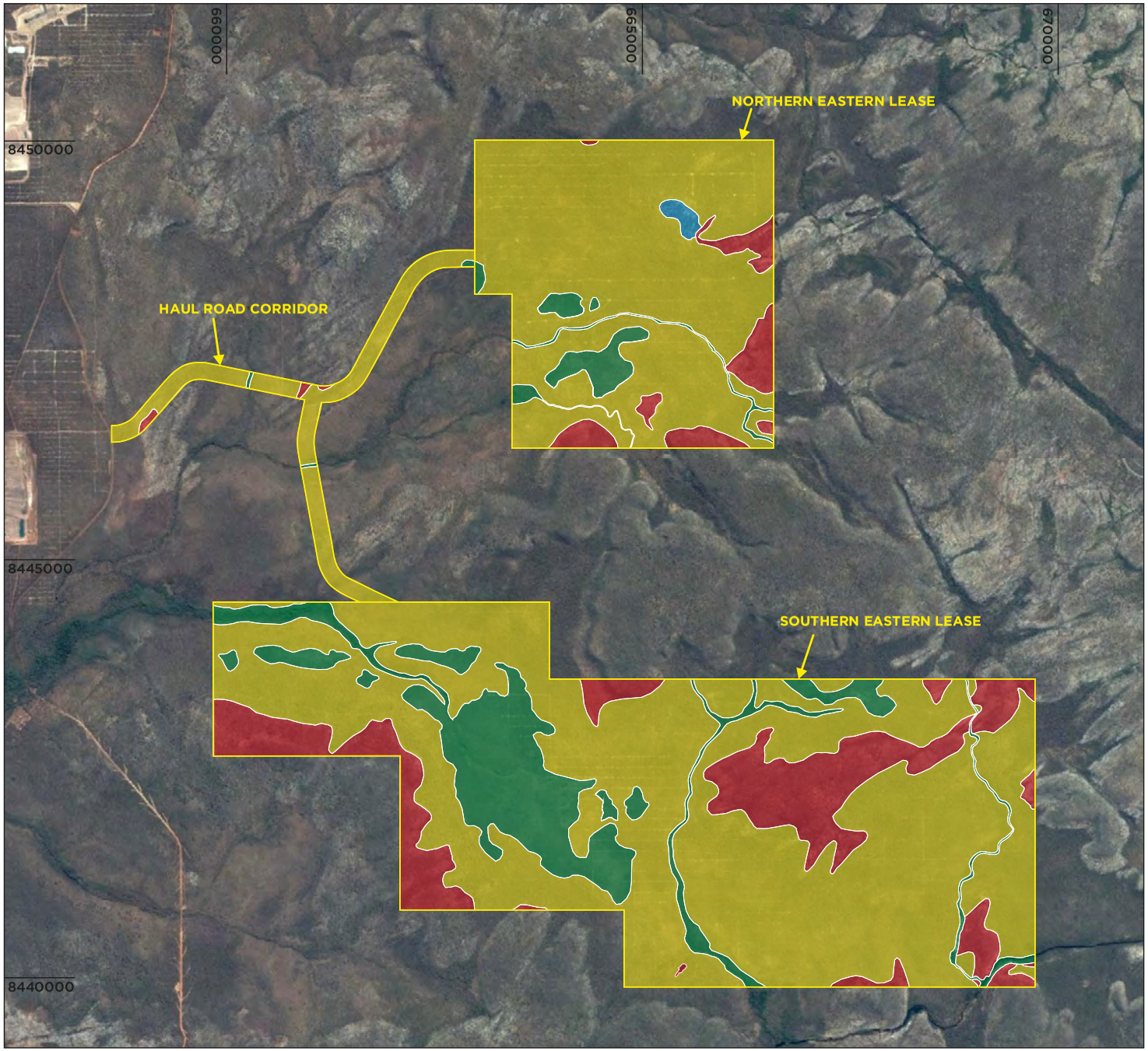
GTenvironmental

Figure 6: Topsoil Stripping Depths

Baseline Soil Assessment
GEMCO EASTERN LEASES PROJECT

09/09/2014

0 2000
Metres
Projection: GDA94 Zone 53
Scale 1 : 20,000



Legend

- Soil Study Area
- 0.00 metres
- 0.15 metres
- 0.20 metres
- 0.40 metres

GTenvironmental

9 APPENDICES

Appendix A **Detailed Survey Site Descriptions**

Appendix B **Observation Survey Site Descriptions**

Appendix C **Laboratory Certificates**

APPENDIX A DETAILED SURVEY SITE DESCRIPTIONS

SITE 1

Soil Mapping Unit:	Land Systems, Lynch (2012):	Location (GDA ZONE 53):	Aust. Soil Class. :	Site Survey Type:	Survey Date:
B1	Bundah	659124mE 8446957mN	Brown Tenosol	Detailed - 50mm hand auger	13/06/2014

Landscape

Surface

Soil Profile

Land use Landform Pattern, Element, Slope	Natural Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle	Moisture, Drainage	Roots	Depth (m) / Field pH	Sample (m)	Observations
Native Vegetation Gentle Undulating Plain Midslope 3.5%	Tall open woodland including Eucalypts 20% cover Native Shrubs and grasses	Nil microrelief Nil Disturbance Nil Erosion	Soft, sandy, no coarse fragment observed	A11 0.00-0.68 Diffuse	Sand	Massive, Loose	<2% <5mm Manganese nodules	10YR4/3 Brown Nil mottle	Dry, rapid	Very fine, very few roots	0.05 - 7.0pH/ EC 0.30 - 7.0pH/ EC 0.60 - 7.0pH/ EC	0.0-0.10 0.30-0.40 0.60-0.68	-
				A2 0.68-1.15	Loamy Sand	Massive, Very weak	<2% <5mm Manganese nodules	5YR5/8 Yellowish red Mottle <40% 10YR4/3 Brown	Dry, rapid	No roots observed	0.90 - 7.0pH/ EC	1.0-1.10	

SITE 2

Soil Mapping Unit:	Land Systems, Lynch (2012):	Location (GDA ZONE 53):	Aust. Soil Class. :	Site Survey Type:	Survey Date:
B1	Bundah	660821mE 8446560mN	Brown Tenosol	Detailed - 50mm hand auger	13/06/2014

Landscape

Surface

Soil Profile

Land use Landform Pattern, Element, Slope	Natural Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle	Moisture, Drainage	Roots	Depth (m) / Field pH	Sample (m)	Observations
Native Vegetation Gentle Undulating Plain Flat Plain 0.5%	Tall open woodland including Eucalypts 20% cover Native Shrubs and grasses	Nil microrelief Nil Disturbance Nil Erosion	Firm, sandy, <5% 2-6mm coarse fragments	A11 0.0-0.40 Clear	Loamy Sand	Massive, very weak	<2%, 2-6mm coarse fragments	10YR3/2 Very dark greyish brown Nil mottle	Dry, Rapid	Fine, few	0.10 - 6.5pH 0.30 – 6.5pH	0.0-0.10 0.30-0.40	-
				A12 0.40-0.70 Abrupt	Loamy Sand	Massive, very weak	<5%, 5-20mm coarse fragments	10YR2/2 Very dark brown Nil mottle	Dry, Rapid	Fine, few	0.60 - 6.5pH	0.60-0.70	
				A2 0.70-1.00	Loamy Sand	Massive, very weak	<20%, 0-5mm coarse fragments <20%, 0-5mm Manganese	10YR2/1 Black Nil mottle	Dry, Rapid	-	0.90 - 6.5pH	0.90-1.00	

SITE 3

Soil Mapping Unit:	Land Systems, Lynch (2012):	Location (GDA ZONE 53):	Aust. Soil Class. :	Site Survey Type:	Survey Date:
B2	Yarrawirrie	662772mE 8448457mN	Brown Kandosol	Detailed - 50mm hand auger	13/06/2014

Landscape

Surface

Soil Profile

Land use Landform Pattern, Element, Slope	Natural Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle	Moisture, Drainage	Roots	Depth (m) / Field pH	Sample (m)	Observations
Native Vegetation Gentle Undulating Plain Mid slope 3.0%	Tall open woodland including Eucalypts 20% cover Native Shrubs and grasses	Nil microrelief Nil Disturbance Nil Erosion	Soft, sandy, No coarse fragments	A1 0.0-0.20 Abrupt	Sand	Massive, loose	<2%, 2-6mm coarse fragments	10YR4/1 Dark gray Nil mottle	Dry, Rapid	Very fine, few	0.05 – 7.0pH	-	-
				B2 0.20-1.00	Sandy Clay Loam	Massive, very weak	<2%, 2-6mm coarse fragments	10YR6/4 Light yellowish brown Nil mottle	Dry, Rapid	Very fine, few	0.30 - 7.0pH 0.60 - 7.0pH 0.90 - 7.0pH		

SITE 4

Soil Mapping Unit:	Land Systems, Lynch (2012):	Location (GDA ZONE 53):	Aust. Soil Class. :	Site Survey Type:	Survey Date:
B1	Bundah	663439mE 8449735mN	Brown Tenosol	Detailed - 50mm hand auger	13/06/2014

Landscape

Surface

Soil Profile

Land use Landform Pattern, Element, Slope	Natural Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle	Moisture, Drainage	Roots	Depth (m) / Field pH	Sample (m)	Observations
Native Vegetation Gentle Undulating Plain Mid slope 4.0%	Tall open woodland including Eucalypts 20% cover Native Shrubs and grasses	Nil microrelief Nil Disturbance Nil Erosion	Firm, sandy, No coarse fragments	A1 0.0-0.40 Abrupt	Sand	Massive, loose	-	10YR4/1 Dark gray Nil mottle	Dry, Rapid	Very fine, few	0.05 – 7.0pH 0.30 - 7.0pH	-	-
				A2 0.40-1.00	Loamy Sand	Massive, very weak	-	10YR6/4 Light yellowish brown Nil mottle	Dry, Rapid	Very fine, few	0.60 - 7.0pH 0.90 - 7.0pH		

SITE 5

Soil Mapping Unit:	Land Systems, Lynch (2012):	Location (GDA ZONE 53):	Aust. Soil Class. :	Site Survey Type:	Survey Date:
B1	Bundah	665639mE 8449753mN	Brown Tenosol	Detailed - 50mm hand auger	13/06/2014

Landscape

Surface

Soil Profile

Land use Landform Pattern, Element, Slope	Natural Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle	Moisture, Drainage	Roots	Depth (m) / Field pH / Meter pH Meter / EC (mS)	Sample (m)	Observations
Native Vegetation Gentle Undulating Plain Mid slope 3.0%	Tall open woodland including Eucalypts 20% cover Native Shrubs and grasses	Nil microrelief Nil Disturbance Nil Erosion	Firm, sandy, No coarse fragments	A11 0.0-0.40 Diffused	Loamy sand	Massive, loose	<2%, 2-6mm coarse fragments	7.5YR3/4 Dark brown Nil mottle	Dry, Rapid	Fine, very few	0.05 – 6.5pH/ 7.94pH / 0.00 0.30 – 6.5pH/ 7.68pH / 0.00	0.0-0.10 0.30-0.40	-
				A12 0.40-1.00	Loamy Sand	Massive, loose	<2%, 2-6mm coarse fragments	2.5YR3/4 Dark reddish brown Nil mottle	Dry, Rapid	Fine, very few	0.60 – 6.5pH/ 7.74pH / 0.00 0.90 – 6.5pH/ 7.52pH / 0.00	0.60-0.70 0.90-1.00	

SITE 6

Soil Mapping Unit:	Land Systems, Lynch (2012):	Location (GDA ZONE 53):	Aust. Soil Class. :	Site Survey Type:	Survey Date:
B1v	Bundah	665414mE 8449066mN	Grey Tenosol	Detailed - 50mm hand auger	13/06/2014

Landscape

Surface

Soil Profile

Land use Landform Pattern, Element, Slope	Natural Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle	Moisture, Drainage	Roots	Depth (m) / Field pH / Meter pH Meter / EC (mS)	Sample (m)	Observations
Native Vegetation Gentle Undulating Plain Mid slope 1.5%	Tall open woodland including Eucalypts AND Casuarinas <20% cover Native Shrubs and grasses	Nil microrelief Nil Disturbance Nil Erosion	Firm, light grey sandy, No coarse fragments	A11 0.0-0.20 Diffused	Sand	Massive, loose	-	10YR6/1 Brownish Gray Nil mottle	Dry, Rapid	Very fine, few	0.05 – 6.5pH/ 7.92pH / 0.00	0.0-0.10	-
				A12 0.20-0.90 Gradual	Loamy Sand	Massive, very weak	-	10YR6/2 Light brownish gray Nil mottle	Dry, Rapid	Very fine, few	0.30 – 6.5pH/ 7.58pH / 0.00 0.60 – 6.5pH/ 7.40pH / 0.00	0.30-0.40 0.60-0.70	
				A2 0.90-1.15	Sandy Clay Loam	Weak, very weak	<40%, 2-6mm coarse fragments	5YR6/3 Dull orange Nil mottle	Dry, Rapid	-	0.95 – 6.5pH/ 7.22pH / 0.00	0.95-1.00	

SITE 7

Soil Mapping Unit:	Land Systems, Lynch (2012):	Location (GDA ZONE 53):	Aust. Soil Class. :	Site Survey Type:	Survey Date:
B2	Yarrawirrie	664316mE 8447989mN	Brown Kandosol	Detailed - 50mm hand auger	13/06/2014

Landscape

Surface

Soil Profile

Land use Landform Pattern, Element, Slope	Natural Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle	Moisture, Drainage	Roots	Depth (m) Meter pH Meter / EC (mS)	Sample (m)	Observations
Native Vegetation Gentle Undulating Plain Mid slope 3.5%	Tall open woodland including Eucalypts AND Casuarinas <20% cover Native Shrubs and grasses	Nil microrelief Nil Disturbance Nil Erosion	Firm, <10% 2-6mm coarse fragments	A11 0.0-0.20 Abrupt	Loamy sand	Massive, loose	-	10YR3/2 Very dark greyish brown Nil mottle	Dry, Rapid	Very fine, few	0.10 –7.87pH / 0.00	0.0-0.10	-
				A12 0.20-0.30 Abrupt	Loamy Sand	Massive, very weak	-	10YR4/2 Dark grayish brown Nil mottle	Dry, Rapid	Very fine, very few	0.30 –7.05pH / 0.00	-	
				B2 0.30-1.15	Sandy Clay Loam	Weak, very weak	<40%, 2-6mm coarse fragments	10YR2/2 Very dark brown Nil mottle	Dry, Rapid	-	0.60 –7.36pH / 0.00 0.90 –7.29pH / 0.00	0.30-0.40 0.60-0.70 0.95-1.00	

SITE 8

Soil Mapping Unit:	Land Systems, Lynch (2012):	Location (GDA ZONE 53):	Aust. Soil Class. :	Site Survey Type:	Survey Date:
B1	Bundah	664175mE 8446998mN	Brown Tenosol	Detailed - 50mm hand auger	13/06/2014

Landscape

Surface

Soil Profile

Land use Landform Pattern, Element, Slope	Natural Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle	Moisture, Drainage	Roots	Depth (m) / Field pH	Sample (m)	Observations
Native Vegetation Gentle Undulating Plain Flat Plain <0.5%	Tall open woodland including Eucalypts Native Shrubs and grasses	Nil microrelief Nil Disturbance Nil Erosion	Hard setting, <2% 2-6mm coarse fragments <2% 2-6mm Manganese	A1 0.0-0.40 Abrupt	Clayey Sand	Massive, loose	-	10YR3/3 Dark Brown Nil mottle	Dry, Rapid	Very fine, few	0.10 – 6.5pH 0.30 – 6.5pH	-	-
				A21 0.40-1.00 Abrupt	Loamy Sand	Very weak, loose	-	10YR5/3 Brown Nil mottle	Dry, Rapid	Very fine, very few	0.60 – 6.5pH		
				A22 1.00-1.10	Loamy Sand	Very weak, loose	<5%, 2-6mm manganese nodules	10YR5/3 Brown Nil mottle	Dry, Moderate	-			

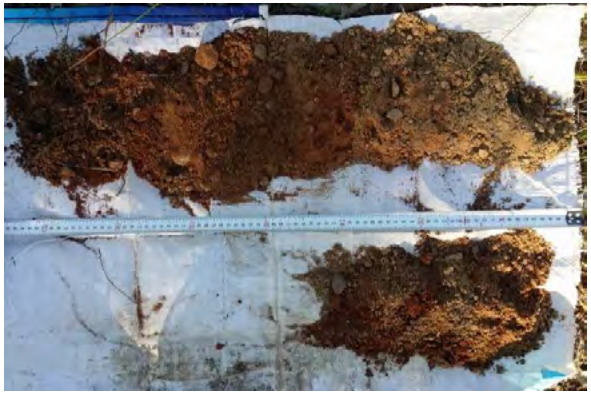
SITE 9

Soil Mapping Unit:	Land Systems, Lynch (2012):	Location (GDA ZONE 53):	Aust. Soil Class. :	Site Survey Type:	Survey Date:
B1	Bundah	665692mE 8446994mN	Brown Tenosol	Detailed - 50mm hand auger	13/06/2014

Landscape

Surface

Soil Profile



Land use Landform Pattern, Element, Slope	Natural Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle	Moisture, Drainage	Roots	Depth (m) / Field pH	Sample (m)	Observations
Native Vegetation Gentle Undulating Plain Flat Plain 2.5%	Tall open woodland including Eucalypts Native Shrubs and grasses	Nil microrelief Nil Disturbance Nil Erosion	Firm, <10% 2-6mm coarse fragments <5% 2-6mm Manganese	A11 0.0-0.30 Abrupt	Loamy sand	Massive, loose	<10%, 2-6mm coarse fragments	10YR5/3 Brown Nil mottle	Dry, Rapid	Very fine, few	0.10 – 6.5pH	0.0-0.10	-
				A12 0.30-1.00	Loamy Sand	Massive, loose	<30%, 2-6mm <2% >10mm coarse fragments	5YR5/3 Reddish brown Mottle 10YR5/3 Brown<20%	Dry, Rapid	-	0.30 – 6.5pH 0.60 – 6.5pH 0.90 – 6.5pH	0.30-0.40 0.60-0.70 0.90-1.00	

SITE 10

Soil Mapping Unit:	Land Systems, Lynch (2012):	Location (GDA ZONE 53):	Aust. Soil Class. :	Site Survey Type:	Survey Date:
Q1	Groote	659747mE 8443219mN	Grey Tenosol	Detailed - 50mm hand auger	14/06/2014

Landscape

Surface

Soil Profile

Land use Landform Pattern, Element, Slope	Natural Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle	Moisture, Drainage	Roots	Depth (m) / Field pH / Meter pH Meter / EC (mS)	Sample (m)	Observations
Native Vegetation Gentle Undulating Plain Mid slope 6.5%	Tall open woodland including Eucalypts Native Shrubs and grasses	Nil microrelief Nil Disturbance Nil Erosion	Soft, <30% <6mm <30% <20mm <20% >20mm Coarse fragments/ boulders/ quartz	A1 0.0-0.02	Clayey Sand	Massive, loose	As surface	10YR7/1 Light Gray Nil mottle	Dry, Rapid	Fine, few	0.02 – 6.5pH / 6.24pH / 0.00	0.0-0.02	Rocky outcrop

SITE 11

Soil Mapping Unit:	Land Systems, Lynch (2012):	Location (GDA ZONE 53):	Aust. Soil Class. :	Site Survey Type:	Survey Date:
B2	Yarrawirrie	662706mE 8441798mN	Brown Kandosol	Detailed - 50mm hand auger	14/06/2014

Landscape

Surface

Soil Profile

Land use Landform Pattern, Element, Slope	Natural Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle	Moisture, Drainage	Roots	Depth (m) / Field pH	Sample (m)	Observations
Native Vegetation Gentle Undulating Plain Mid slope 3.0%	Tall open woodland including Eucalypts Native Shrubs and grasses	Nil microrelief Nil Disturbance Nil Erosion	Soft, light yellow brown, sandy, no coarse fragments	A11 0.0-0.15 Abrupt	Loamy sand	Massive, loose	-	10YR3/2 Very dark greyish brown Nil mottle	Dry, Rapid	Fine, few	0.05 – 6.5pH	0.0-0.05	-
				A12 0.15-0.53 Abrupt	Loamy Sand	Massive, weak	-	7.5YR3/4 Dark brown Nil mottle	Dry, Rapid	Very fine, few	0.30 – 6.5pH	0.30-0.40	
				A21 0.53-0.85 Abrupt	Loamy sand	Massive, weak	-	2.5YR4/4 Reddish brown Nil mottle	Dry, Rapid	-	0.60 – 6.5pH	0.60-0.70	
				A22 0.85-1.10	Loamy sand	Massive, weak	-	2.5YR3/4 Dark reddish brown Nil mottle	Dry, Rapid	-	0.90 – 6.5pH	0.90-1.00	

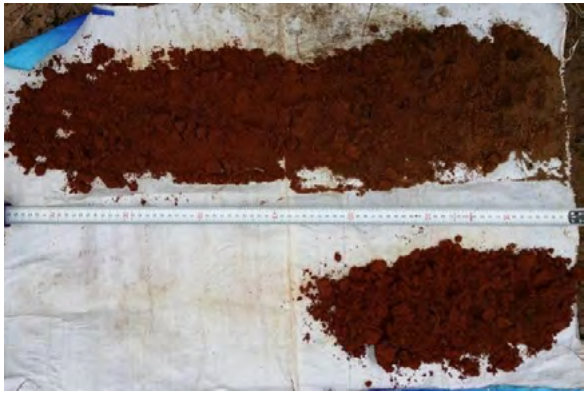
SITE 12

Soil Mapping Unit:	Land Systems, Lynch (2012):	Location (GDA ZONE 53):	Aust. Soil Class. :	Site Survey Type:	Survey Date:
B1	Bundah	663470mE 8441043mN	Brown Tenosol	Detailed - 50mm hand auger	14/06/2014

Landscape

Surface

Soil Profile



Land use Landform Pattern, Element, Slope	Natural Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle	Moisture, Drainage	Roots	Depth (m) / Field pH	Sample (m)	Observations
Native Vegetation Gentle Undulating Plain Flat plain <0.5%	Tall open woodland including Eucalypts Native Shrubs and grasses	Nil microrelief Nil Disturbance Nil Erosion	Soft, light yellow brown, sandy, no coarse fragments	A11 0.0-0.15 Abrupt	Loamy sand	Massive, loose	-	10YR3/2 Very dark greyish brown Nil mottle	Dry, Rapid	Fine, few	0.05 – 6.5pH	-	-
				A12 0.15-0.40 Abrupt	Loamy Sand	Massive, weak	-	10YR3/4 Dark yellowish brown Nil mottle	Dry, Rapid	Very fine, few	0.30 – 6.5pH		
				A21 0.40-0.80 Abrupt	Loamy sand	Massive, weak	-	2.5YR4/4 Reddish brown Nil mottle	Dry, Rapid	-	0.60 – 6.5pH		
				A22 0.80-1.00	Loamy sand	Massive, weak	-	2.5YR3/4 Dark reddish brown Nil mottle	Dry, Rapid	-	0.90 – 6.5pH		

SITE 13

Soil Mapping Unit:	Land Systems, Lynch (2012):	Location (GDA ZONE 53):	Aust. Soil Class. :	Site Survey Type:	Survey Date:
B1	Bundah	666850mE 8440234mN	Brown Tenosol	Detailed - 50mm hand auger	14/06/2014

Landscape

Surface

Soil Profile

Land use Landform Pattern, Element, Slope	Natural Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle	Moisture, Drainage	Roots	Depth (m) / Field pH	Sample (m)	Observations
Native Vegetation Gentle Undulating Plain Midslope 5.0%	Tall open woodland including Narrow trunk Eucalypts Native Shrubs and grasses	Nil microrelief Nil Disturbance Minor sheet erosion observed	Firm, sandy, <30% 10-50mm coarse fragments	A11 0.0-0.40 Abrupt	Loamy sand	Massive, loose	<5%, 5-10mm coarse fragments	10YR2/2 Very dark brown Nil mottle	Dry, Rapid	Fine, few	0.10 – 6.5pH 0.30 – 6.5pH	0.0-0.10	Manganese outcrops nearby. Five borehole attempts. Refusal at 0.20-0.30m at four locations.
				A12 0.40-0.60 Abrupt	Loamy Sand	Massive, loose	<10%, 5-10mm coarse fragments	10YR2/2 Very dark brown Nil mottle	Dry, Rapid	Fine, few	0.50 – 6.5pH	0.40-0.50	

SITE 14

Soil Mapping Unit:	Land Systems, Lynch (2012):	Location (GDA ZONE 53):	Aust. Soil Class. :	Site Survey Type:	Survey Date:
B1	Bundah	668205mE 8441987mN	Brown Tenosol	Detailed - 50mm hand auger	14/06/2014

Landscape

Surface

Soil Profile

Land use Landform Pattern, Element, Slope	Natural Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle	Moisture, Drainage	Roots	Depth (m) / Field pH	Sample (m)	Observations
Native Vegetation Gentle Undulating Plain Midslope 3.0%	Tall open woodland including Eucalypts Native Shrubs and grasses	Nil microrelief Nil disturbance Nil erosion	Sandy, <2% 2-6mm Manganese nodules	A11 0.0-0.07 Abrupt (Ab)	Loamy sand	Massive, loose	-	10YR4/2 Dark grayish brown Nil mottle	Dry, Rapid	Very fine, very few	0.05 – 7.0pH	-	-
				A12 0.07-0.40 Ab	Loamy Sand	Massive, loose	-	10YR5/4 Yellowish brown Nil mottle	Dry, Rapid	Very fine, very few	0.30 – 7.0pH		
				A21 0.40-0.70 Ab	Loamy Sand	Weak, polyhedral	-	5YR5/6 Yellowish red Mottle <5% 10YR3/2 Very dark greyish brown	Dry, Rapid	Very fine, very few	0.60 – 6.5pH		
				A22 0.70-0.90 Ab	Loamy Sand	Weak, polyhedral	<2% 2-6mm Manganese nodules	7.5YR5/6 Yellowish red Nil mottle	Dry, Rapid	-	0.80 – 6.5pH		
				A23 0.90-1.00	Loamy Sand	Weak, polyhedral	<2% 2-6mm Mg nodules	5YR4/6 Yellowish red Nil mottle	Dry, Rapid	-	1.00 – 6.5pH		

SITE 15

Soil Mapping Unit:	Land Systems, Lynch (2012):	Location (GDA ZONE 53):	Aust. Soil Class. :	Site Survey Type:	Survey Date:
B1	Bundah	665608mE 8441000mN	Brown Tenosol	Detailed - 50mm hand auger	14/06/2014

Landscape

Surface

Soil Profile

Land use Landform Pattern, Element, Slope	Natural Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle	Moisture, Drainage	Roots	Depth (m) / Field pH	Sample (m)	Observations
Native Vegetation Gentle Undulating Plain Midslope 1.0%	Tall open woodland including Eucalypts Native Shrubs and grasses	Nil microrelief Nil disturbance Nil erosion	Firm, Sandy, <2% 2-6mm Coarse fragments and Manganese nodules	A1 0.0-0.40 Abrupt	Loamy sand	Weak, very weak	<2% 2-6mm Manganese	10YR2/2 Very dark brown Nil mottle	Dry, Rapid	Very fine, very few	0.10 – 6.5pH 0.30 – 6.5pH	0.00-0.10 0.30-0.40	Site similar to site 13 however no Mg outcrops observed
				A2 0.40-0.80 Abrupt	Clayey sand	Weak, weak	<2% 2-6mm Manganese	5YR3/3 Dark reddish brown Nil mottle	Dry, Rapid	Very fine, very few	0.60 – 6.5pH	0.60-0.70	
				A3 0.80-1.00	Loamy Sand	Weak, Very weak	<10% 2-6mm Manganese	5YR3/3 Dark reddish brown Nil mottle	Dry, Rapid	-	0.90 – 6.5pH	0.90-1.00	

SITE 16

Soil Mapping Unit:	Land Systems, Lynch (2012):	Location (GDA ZONE 53):	Aust. Soil Class. :	Site Survey Type:	Survey Date:
B1	Bundah	664991mE 8443126mN	Brown Tenosol	Detailed - 50mm hand auger	14/06/2014

Landscape

Surface

Soil Profile

Land use Landform Pattern, Element, Slope	Natural Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle	Moisture, Drainage	Roots	Depth (m) / Field pH	Sample (m)	Observations
Native Vegetation Gentle Undulating Plain Upper slope 3.0%	Tall open woodland including Eucalypts Native Shrubs and grasses	Nil microrelief Nil disturbance Nil erosion	Firm, Sandy, <2% 2-6mm Coarse fragments and manganese nodules	A11 0.0-0.12 Abrupt	Loamy sand	Massive, weak	<2% 2-6mm Manganese nodules	10YR4/2 Dark grayish brown Dark grayish brown Nil mottle	Dry, Rapid	Very fine, very few	0.05 – 7.0pH	-	-
				A12 0.12-0.40 Diffuse	Loamy sand	Weak, polyhedral very weak	<2% 2-6mm Manganese nodules	7.5YR5/4 Brown Nil mottle	Dry, Rapid	Very fine, very few	0.30 – 7,0pH		
				A21 0.40-0.70 Abrupt	Clayey sand	Weak, polyhedral very weak	-	2.5YR5/6 Yellowish red Nil mottle	Dry, Rapid	-	0.60 – 7.0pH		
				A22 0.70-1.00	Clayey sand	Weak, polyhedral very weak	-	2.5YR4/6 Yellowish red Nil mottle	Dry, Rapid	-	0.90 – 7.0pH		

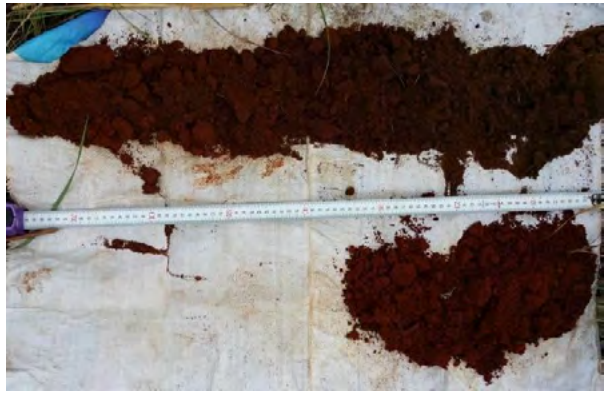
SITE 17

Soil Mapping Unit:	Land Systems, Lynch (2012):	Location (GDA ZONE 53):	Aust. Soil Class. :	Site Survey Type:	Survey Date:
B1	Bundah	665261mE 8442373mN	Brown Tenosol	Detailed - 50mm hand auger	14/06/2014

Landscape

Surface

Soil Profile



Land use Landform Pattern, Element, Slope	Natural Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle	Moisture, Drainage	Roots	Depth (m) / Field pH	Sample (m)	Observations
Native Vegetation Gentle Undulating Plain Flat plain 0.5%	Tall open woodland including narrow trunk Eucalypts Native Shrubs and grasses	Nil microrelief Nil disturbance Nil erosion	Firm, Sandy, No coarse fragments	A1 0.0-0.20 Gradual	Loamy sand	Weak, very weak	<2% 2-6mm Manganese	10YR2/2 Very dark brown Nil mottle	Dry, Rapid	Very fine, very few	0.10 – 6.5pH	-	Site similar to Site 15
				A2 0.20-0.50 Abrupt	Clayey sand	Weak, weak	<2% 2-6mm Manganese	5YR3/3 Dark reddish brown Nil mottle	Dry, Rapid	Very fine, very few	0.30 – 6.5pH		
				A3 0.50-1.00	Loamy Sand	Weak, Very weak	<10% 2-6mm Manganese	5YR3/3 Dark reddish brown Nil mottle	Dry, Rapid	-	0.60 – 6.5pH 0.90 – 6.5pH		

SITE 18

Soil Mapping Unit:	Land Systems, Lynch (2012):	Location (GDA ZONE 53):	Aust. Soil Class. :	Site Survey Type:	Survey Date:
B1	Bundah	663771mE 8443007mN	Brown Tenosol	Detailed - 50mm hand auger	14/06/2014

Landscape

Surface

Soil Profile

Land use Landform Pattern, Element, Slope	Natural Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle	Moisture, Drainage	Roots	Depth (m) / Field pH	Sample (m)	Observations
Native Vegetation Gentle Undulating Plain Mid slope 2.0%	Tall open woodland including narrow trunk Eucalypts Native Shrubs and grasses	Nil microrelief Nil disturbance Nil erosion	Soft, Sandy, No coarse fragments	A1 0.0-0.35 Clear	Loamy sand	Massive, very weak	-	10YR3/2 Very dark greyish brown Nil mottle	Dry, Rapid	Very fine, very few	0.05 – 7.0pH 0.30 – 6.5pH	-	-
				A21 0.35-0.80 Abrupt	Clayey sand	Weak, weak	<5% <10mm Manganese nodules	10YR4/3 Brown Nil mottle	Dry, Rapid	Very fine, very few	0.60 – 7.0pH		
				A22 0.80-1.00	Clayey sand	Massive, Very weak	<30% <10mm Manganese nodules	10YR4/2 Dark grayish brown Nil mottle	Dry, Rapid	-	0.90 – 6.5pH		

SITE 19

Soil Mapping Unit:	Land Systems, Lynch (2012):	Location (GDA ZONE 53):	Aust. Soil Class. :	Site Survey Type:	Survey Date:
A1	Effington	661131mE 8444231mN	Grey Chromosol	Detailed - 50mm hand auger	15/06/2014

Landscape

Surface

Soil Profile

Land use Landform Pattern, Element, Slope	Natural Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle	Moisture, Drainage	Roots	Depth (m) / Field pH / Meter pH Meter / EC (mS)	Sample (m)	Observations
Native Vegetation Gentle Undulating Plain Lower slope, Gully depression nearby 2.0%	Tall open woodland including Eucalypts Native Shrubs and grasses Area recently submerged	Nil microrelief Nil disturbance Nil erosion	Soft, moist No coarse fragments	A1 0.0-0.15 Diffuse	Sandy loam	Weak, weak	-	10YR2/1 Black Black Nil mottle	Moist, Rapid	Very fine, common	0.10 – 6.5pH / 7.02pH / 0.00	-	Water table observed at 0.45m
				A2 0.15-0.48 Abrupt	Loamy sand	Weak, weak	-	10YR3/1 Brownish black Nil mottle	Moist, Rapid	Very fine, common	0.30 – 6.0pH / 6.72pH / 0.00		
				B21 0.48-0.85 Abrupt	Clay loam	Weak, moderate	-	10YR5/1 Brownish gray Mottle <25% 2.5YR4/8 Red	Wet, Moderate	Very fine, common	0.60 – 6.0pH/ 6.62pH / 0.00		
				B22 0.85-1.00	Clay loam	Weak, moderate	<10% <20mm Coarse fragments	10YR3/2 Very dark greyish brown Nil mottle	Wet, moderate	-	0.90 – 6.0pH / 6.82pH / 0.00		

SITE 20

Soil Mapping Unit:	Land Systems, Lynch (2012):	Location (GDA ZONE 53):	Aust. Soil Class. :	Site Survey Type:	Survey Date:
B1	Bundah	662498mE 8444249mN	Brown Tenosol	Detailed - 50mm hand auger	15/06/2014

Landscape

Surface

Soil Profile

Land use Landform Pattern, Element, Slope	Natural Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle	Moisture, Drainage	Roots	Depth (m) / Field pH	Sample (m)	Observations
Native Vegetation Gentle Undulating Plain Wide ridge 2.0%	Tall open woodland including Eucalypts and Pandenas Native Shrubs and grasses	Nil microrelief Nil disturbance Nil erosion	Firm No coarse fragments	A11 0.0-0.08 Abrupt	Loamy sand	Massive, weak	-	10YR3/2 Very dark greyish brown Nil mottle	Dry, Rapid	Few, fine	0.10 – 6.5pH	-	-
				A12 0.08-0.40 Abrupt	Loamy sand	Massive, weak	-	10YR5/2 Grayish brown Nil mottle	Dry, Rapid	Few, fine	0.30 – 6.0pH		
				A13 0.40-0.80 Abrupt	Loamy sand	Weak, polyhedral	-	10YR5/3 Brown Nil mottle	Dry, Rapid	Few, very fine	0.60 – 6.0pH		
				A2 0.80-1.00	Loamy sand	Massive, moderate	-	10YR3/1 Very dark gray Nil mottle	Dry, Rapid	-	0.90 – 6.0pH		

SITE 21

Soil Mapping Unit:	Land Systems, Lynch (2012):	Location (GDA ZONE 53):	Aust. Soil Class. :	Site Survey Type:	Survey Date:
A1	Effington	665606mE 8440158mN	Grey Chromosol	Detailed - 50mm hand auger	15/06/2014

Landscape

Surface

Soil Profile

Land use Landform Pattern, Element, Slope	Natural Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle	Moisture, Drainage	Roots	Depth (m) pH/EC	Sample (m)	Observations
Native Vegetation Gully depression, creek nearby	Tall open woodland including Eucalypts and Pandenas Native Shrubs and grasses	Nil microrelief Nil disturbance Nil erosion	Firm No coarse fragments	A11 0.0-0.20 Abrupt	Sandy Loam	Massive, weak	-	10YR3/2 Very dark greyish brown Nil mottle	Moist, Rapid	Common, fine	-	-	-
				A12 0.20-0.90 Abrupt	Sandy Loam	Massive, weak	-	10YR2/1 Black Nil mottle	Humid, Rapid	Few, fine	-		
				A2 0.90-1.00	Sandy Loam	Weak, very weak	-	10YR4/2 Dark grayish brown Mottle <20% 10YR5/4 Yellowish brown	Humid, Rapid	Few, very fine	-		

SITE 22

Soil Mapping Unit:	Land Systems, Lynch (2012):	Location (GDA ZONE 53):	Aust. Soil Class. :	Site Survey Type:	Survey Date:
V1	n/a	665359mE 8440001mN	n/a	Detailed - 50mm hand auger	15/06/2014

Landscape

Surface

Soil Profile

Land use Landform Pattern, Element, Slope	Natural Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle	Moisture, Drainage	Roots	Depth (m) / Field pH / Meter pH Meter / EC (mS)	Sample (m)	Observations
Native Vegetation Gentle Undulating Plain Lower slope 6.0%	Monsoonal Vine Thicket	Nil microrelief Nil disturbance Nil erosion	Organic Matter/leaf matter >95% 0-2000mm coarse fragments and boulders	O1 0.0-0.02	Organic Matter	-	As per surface	-	Humid, moderate	Common, fine	0.02 –7.17pH / 0.05 EC	0.00-0.02	No borehole was able to be augered due to the density of the surface rock.

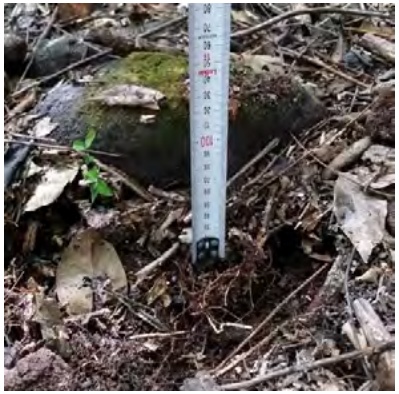
SITE 23

Soil Mapping Unit:	Land Systems, Lynch (2012):	Location (GDA ZONE 53):	Aust. Soil Class. :	Site Survey Type:	Survey Date:
V1	n/a	665336mE 8440003mN	n/a	Detailed - 50mm hand auger	15/06/2014

Landscape

Surface

Soil Profile



Land use Landform Pattern, Element, Slope	Natural Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle	Moisture, Drainage	Roots	Depth (m) / pH/EC	Sample (m)	Observations
Native Vegetation Gentle Undulating Plain Lower slope 6.0%	Monsoonal Vine Thicket	Nil microrelief Nil disturbance Nil erosion	Organic Matter/leaf matter >90% 0-2000mm coarse fragments and boulders	O1 0.0-0.02	Organic Matter	-	As per surface	-	Humid, moderate	Common, fine	-	-	No borehole was able to be augered due to the density of the surface rock.

SITE 24

Soil Mapping Unit:	Land Systems, Lynch (2012):	Location (GDA ZONE 53):	Aust. Soil Class. :	Site Survey Type:	Survey Date:
V1	n/a	665345mE 8439982mN	n/a	Detailed - 50mm hand auger	15/06/2014

Landscape

Surface

Soil Profile

Land use Landform Pattern, Element, Slope	Natural Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle	Moisture, Drainage	Roots	Depth (m) / pH / EC	Sample (m)	Observations
Native Vegetation Gentle Undulating Plain Lower slope 6.0%	Monsoonal Vine Thicket	Nil microrelief Nil disturbance Nil erosion	Organic Matter/leaf matter >90% 0-2000mm coarse fragments and boulders	O1 0.0-0.02	Organic Matter	-	As per surface	-	Humid, moderate	Common, fine	-	-	No borehole was able to be augered due to the density of the surface rock.

SITE 25

Soil Mapping Unit:	Land Systems, Lynch (2012):	Location (GDA ZONE 53):	Aust. Soil Class. :	Site Survey Type:	Survey Date:
B1	Bundah	665398mE 8440122mN	Brown Tenosol	Detailed - 50mm hand auger	15/06/2014

Landscape

Surface

Soil Profile

Land use Landform Pattern, Element, Slope	Natural Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle	Moisture, Drainage	Roots	Depth (m) / pH / EC	Sample (m)	Observations
Native Vegetation Gentle Undulating Plain Midslope 2.0%	Tall open woodland including Eucalypts and Pandenas Native Shrubs and grasses	Nil microrelief Nil disturbance Nil erosion	Hard setting, <2% <10mm No coarse fragments	A1 0.0-0.20 Abrupt	Loamy sand	Massive, weak	<2% <10mm coarse fragments	5YR4/3 Reddish brown Nil mottle	Dry, Rapid	Few, fine	-	0.0-0.10	First borehole refusal at 0.40m Second borehole refusal at 0.18m Third borehole refusal at 0.40m and sampled
				A2 0.20-0.40 Abrupt	Loamy sand	Massive, weak	-	5YR4/3 Reddish brown Nil mottle	Dry, Rapid	Few, fine	-	0.30-0.40	

SITE 26 (Common location to *GC02*)

Soil Mapping Unit:	Land Systems, Lynch (2012):	Location (GDA ZONE 53):	Aust. Soil Class. :	Site Survey Type:	Survey Date:
B1	Bundah	665464mE 8447935mN	Brown Tenosol	Detailed – Drill Rig	15/06/2014

Landscape

Surface

Soil Profile

Land use Landform Pattern, Element, Slope	Natural Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle	Moisture, Drainage	Roots	Depth (m) / Field pH	Sample (m)	Observations
Native Vegetation Gentle Undulating Plain Midslope 2.0%	Tall open woodland including Eucalypts and Pandenas Native Shrubs and grasses	Nil microrelief Nil disturbance Nil erosion	Soft No coarse fragments	A11 0.0-0.20 Abrupt	Loamy sand	Massive, weak	-	5YR4/3 Reddish brown Nil mottle	Dry, Rapid	Very few, very fine	-	-	GEMCO Geo Borehole profile GTE conducted site surface check.
				A12 0.20-0.40 Abrupt	Loamy sand	Weak, very weak	-	5YR4/3 Reddish brown Nil mottle	Humid, Rapid	Very few, very fine	0.30 – 7.0pH		
				A13 0.40-1.00	Loamy sand	Weak, very weak	-	5YR3/3 Dark reddish brown Nil mottle	Moist, Rapid	Very few, very fine	0.60 – 7.0pH 0.90 – 7.0pH		

SITE 27 (Common location to *GC05*)

Soil Mapping Unit:	Land Systems, Lynch (2012):	Location (GDA ZONE 53):	Aust. Soil Class. :	Site Survey Type:	Survey Date:
B2	Yarrawirrie	664677mE 8441002mN	Brown Kandosol	Detailed – Drill Rig	15/06/2014

Landscape

Surface

Soil Profile

Land use Landform Pattern, Element, Slope	Natural Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle	Moisture, Drainage	Roots	Depth (m) / Field pH	Sample (m)	Observations
Native Vegetation Gentle Undulating Plain Midslope 2.0%	Tall open woodland including Eucalypts and Pandenas Native Shrubs and grasses	Nil microrelief Nil disturbance Nil erosion	Soft No coarse fragments	A11 0.0-0.08 Abrupt	Sandy Loam	Massive, weak	-	10YR3/2 Very dark greyish brown Nil mottle	Dry, Rapid	Very few, very fine	-	-	GEMCO Geo Borehole profile GTE conducted site surface check.
				A12 0.08-0.15 Abrupt	Sandy Loam	Weak, polyhedral	-	10YR3/2 Very dark greyish brown Nil mottle	Humid, Rapid	Few, medium	0.10 – 6.5pH		
				A21 0.15-0.30 Abrupt	Loamy sand	Weak, very weak	<2% <6mm manganese nodules	7.5YR3/2 Dark brown Nil mottle	Humid, Rapid	Very few, very fine	0.30 – 6.5pH		
				A22 0.30-0.60	Loamy sand	Weak, very weak	<2% <6mm coarse fragments	7.5YR4/3 Reddish brown Nil mottle	Humid, Rapid	Very few, very fine	0.60 – 7.0pH		

APPENDIX B OBSERVATION SURVEY SITE DESCRIPTIONS

Site No.	Location (GDA94 Zone 53)	Soil Mapping Unit	Surface	Landform	Comments / Pictures
Ob1	658975mE 8446731mN	B1	Soft, sandy, No coarse fragments	Gentle Undulating Plain Mid slope 2%	Tall open woodland including Eucalypts 20% cover
Ob2	660538mE 8446959mN	B1	Soft, sandy, No coarse fragments	Gentle Undulating Plain Mid slope 2%	-
Ob3	661915mE 8448074mN	B1	Firm, sandy, <5% 2-6mm coarse fragments	Gentle Undulating Plain Mid slope 1%	Tall open woodland including Eucalypts 20% cover
Ob4	662680mE 8448411mN	B1	Firm, sandy, <5% 2-6mm coarse fragments	Gentle Undulating Plain Mid slope 2%	-
Ob5	663014mE 8449736mN	B1	Soft, sandy, No coarse fragments	Gentle Undulating Plain Mid slope 3.5%	
Ob6	664220mE 8449812mN	Boundary B1/Q1	Increasing quartz rocky outcrops, 50%+cover	Lower slope 5%	-
Ob7	664420mE 8449739mN	B1	Soft, sandy, No coarse fragments	Gentle Undulating Plain	-

Site No.	Location (GDA94 Zone 53)	Soil Mapping Unit	Surface	Landform	Comments / Pictures
Ob8	666243mE 8449493mN	B1	Firm, sandy, No coarse fragments	Gentle Undulating Plain	Tall open woodland including Eucalypts 20% cover
Ob9	666300mE 8448780mN	Q1	Rocky outcrops, 100% cover	Ridge	-
Ob10	665174mE 8449100mN	B1v	Soft, sandy, No coarse fragments, light grey colour	Flat plain	Tall open woodland including Eucalypts <10% cover, immediate (B1v) area less overall vegetation cover than nearby (b1) areas with Eucalypt density, as per picture 'Ob12'
Ob11	665656mE 8448890mN	Boundary B1/Q1	Increasing quartz rocky outcrops, 50%+cover	Lower slope	

Site No.	Location (GDA94 Zone 53)	Soil Mapping Unit	Surface	Landform	Comments / Pictures
Ob12	665597mE 8448963mN	Boundary B1/B1v	Sandy with no course fragments, light grey to the west, light yellow/brown to the east	Gentle Undulating Plain, slope <0.5%	
Ob13	665499mE 8449248mN	B1	Soft, sandy, No coarse fragments	Gentle Undulating Plain Mid slope 2.5%	
Ob14	664756mE 8449497mN	B1	Firm, sandy, No coarse fragments	Gentle Undulating Plain Mid slope 2.5%	Tall open woodland including Eucalypts 20% cover
Ob15	663658mE 8449489mN	B1	Soft, sandy, No coarse fragments, light yellow/brown surface colour	Gentle Undulating Plain Mid slope 1%	-
Ob16	663260mE 8448659mN	B1	Soft, sandy, No coarse fragments, light yellow/brown surface colour	Gentle Undulating Plain Lower slope 1.5%	Paperbark, swamp-like in wet season
Ob17	664116mE 8448738mN	B1	Soft, sandy, No coarse fragments	Gentle Undulating Plain Mid slope 2%	Tall open woodland including Eucalypts 20% cover

Site No.	Location (GDA94 Zone 53)	Soil Mapping Unit	Surface	Landform	Comments / Pictures
Ob18	664907mE 8448236mN	B1	Soft, sandy, No coarse fragments, light yellow/brown surface colour	Gentle Undulating Plain Mid slope 2.5%	-
Ob19	665951mE 8448237mN	B1	Firm, sandy, No coarse fragments	Gentle Undulating Plain Mid slope 2.5%	Tall open woodland including Eucalypts 20% cover
Ob20	665959mE 8448549mN	Q1	Increasing quartz rocky outcrops, 50%+cover	Upper slope, ridge, 10%+ slope	-
Ob21	666279mE 8448347mN	Q1	Increasing quartz rocky outcrops, 50%+cover	Upper slope, ridge, 10%+ slope	-
Ob22	664005mE 8447836mN	B2	Soft, sandy, No coarse fragments	Lower slope <1%	Short medium shrubs and trees as opposed to other immediate areas, minimal Eucalyptus
Ob23	663575mE 8447745mN	B1	Soft, sandy, No coarse fragments	Gentle Undulating Plain Mid slope 2.5%	-
Ob24	664294mE 8447681mN	A1	Soft, sandy, No coarse fragments	Active creek line	-
Ob25	665100mE 8447488mN	B1	Firm, sandy, No coarse fragments, light brown surface colour	-	Tall open woodland including Eucalypts 20% cover
Ob26	665749mE 8447386mN	A1	Soft, sandy, No coarse fragments	Active creek line	-
Ob27	664282mE 8447314mN	B2	Soft, sandy, No coarse fragments	Gentle Undulating Plain Mid slope 1%	Shorter shrubs and trees, minimal Eucalyptus, B1/B2 boundary nearby to the north
Ob28	664261mE 8447164mN	B2	Firm, sandy, <5% 2-6mm coarse fragments	Lower slope 2%	Shorter shrubs and trees, minimal Eucalyptus
Ob29	664477mE 8446991mN	B2	Firm, sandy, <5% 2-6mm coarse fragments	Gentle Undulating Plain Mid slope 1%	Shorter shrubs and trees, minimal Eucalyptus
Ob30	665037mE 8446859mN	Q1	Light colour rocky outcrops	Ridge, 40m+ height	-

Site No.	Location (GDA94 Zone 53)	Soil Mapping Unit	Surface	Landform	Comments / Pictures
Ob31	665966mE 8447151mN	Q1	Light colour rocky outcrops	Ridge, 40m+ height	-
Ob32	664186mE 8446712mN	A1	-	Active creek line	-
Ob33	663925mE 8446500mN	B1	Red/yellow sandy surface	-	Tall open woodland including Eucalypts 20% cover
Ob34	663983mE 8446445mN	Q1	90%+ rocky quartz outcrop	Ridge, 40m+ height	-
Ob35	664304mE 8446505mN	Q1	90%+ rocky quartz outcrop	Ridge, 40m+ height	-
Ob36	661368mE 8447093mN	B1	Red/yellow sandy surface	-	Tall open woodland including Eucalypts 20% cover, rocky outcrop (Q1) 50-100m north-west
Ob37	660431mE 8443174mN	B1	Sandy, yellow/grey surface, no coarse fragments or rocks	Gentle Undulating Plain Mid slope 1.5%	Tall open woodland including Eucalypts 30% cover
Ob38	661064mE 8442943mN	Boundary B1/Q1	Increasing quartz rocky outcrops, 50%+cover	Mid slope, ridge	

Site No.	Location (GDA94 Zone 53)	Soil Mapping Unit	Surface	Landform	Comments / Pictures
Ob39	661291mE 8442859mN	B1	Sandy, yellow/grey surface, no coarse fragments or rocks	Gentle Undulating Plain Lower slope 3%	Tall open woodland including Eucalypts 30% cover
Ob40	662184mE 8442507mN	Boundary B1/Q1	Increasing quartz rocky outcrops, 80%+cover	Lower slope, ridge	
Ob41	662341mE 8442507mN	B1	Sandy, yellow/light brown surface, no coarse fragments	Gentle Undulating Plain Mid slope 1%	Tall open woodland including Eucalypts 20% cover
Ob42	662622mE 8442232mN	B2	Sandy, yellow/light brown surface, no coarse fragments	Gentle Undulating Plain Mid slope 3%	Native shrubs and grasses, Eucalyptus not present in immediate area (0-20m)
Ob43	662753mE 8441680mN	Boundary B1/B2	-	-	Change in vegetation; Shrubs and grasses to the north, Eucalyptus begins towards the south
Ob44	662536mE 8441435mN	Boundary B1/Q1	Rocky outcrops	Bottom of ridge, 30-40m high	-
Ob45	663106mE 8441044mN	B1	Sandy, yellow/grey surface, no coarse fragments	Gentle Undulating Plain Mid slope 1%	Tall open woodland including Eucalypts 20% cover
Ob46	663857mE 8441123mN	B2	Sandy, light brown surface, 2-6mm coarse fragments, <2% cover	Gentle Undulating Plain Mid slope 2%	Native shrubs and grasses, Eucalyptus not present in immediate area (0-20m)

Site No.	Location (GDA94 Zone 53)	Soil Mapping Unit	Surface	Landform	Comments / Pictures
Ob47	666334mE 8440410mN	B1	Sandy, yellow/grey surface, no coarse fragments	Gentle Undulating Plain Mid slope 1%	Tall open woodland including Eucalypts 20% cover
Ob48	667607mE 8440761mN	B1	Sandy, yellow/grey surface, no coarse fragments	Gentle Undulating Plain Mid slope 1%	Tall open woodland including Eucalypts 20% cover
Ob49	668187mE 8440849mN	B1	Sandy, yellow/grey surface, no coarse fragments	Gentle Undulating Plain Mid slope 1%	Tall open woodland including Eucalypts 20% cover
Ob50	668660mE 8440734mN	A1	50% rock, 50% yellow/light brown sandy	Active creek line over manganese rocky outcrop	

Site No.	Location (GDA94 Zone 53)	Soil Mapping Unit	Surface	Landform	Comments / Pictures
Ob51	668890mE 8440758mN	B1 (nearby Q1 boundary)	Light grey sandy surface, 20%+ rocks – manganese, quartz	Light grey rocky outcrop nearby to the south east	
Ob52	669021mE 8440688mN	Q1	Increasing quartz rocky outcrops, 50%+cover	Upper slope, ridge, 10%+ slope	-
Ob53	669411mE 8440655mN	B1	Sandy, yellow/grey surface, no coarse fragments	Gentle Undulating Plain Mid slope 1%	Tall open woodland including Eucalypts 20% cover

Site No.	Location (GDA94 Zone 53)	Soil Mapping Unit	Surface	Landform	Comments / Pictures
Ob54	669583mE 8440511mN	B1	Firm, light brown/red surface, no coarse fragments or rocks	Gentle Undulating Plain Mid slope 1.5%	
Ob55	668452mE 8440993mN	B1	Sandy, light brown surface, 2-6mm coarse fragments, <2% cover	Gentle Undulating Plain Mid slope 2%	Tall open woodland including Eucalypts 20% cover
Ob56	668621mE 8441254mN	B1	Sandy, yellow/grey surface, no coarse fragments	Gentle Undulating Plain Mid slope 1%	Tall open woodland including Eucalypts 20% cover

Site No.	Location (GDA94 Zone 53)	Soil Mapping Unit	Surface	Landform	Comments / Pictures
Ob57	668834mE 8441249mN	A1	Medium brown colour, sandy, soft, moist adjacent to creek	Active creek line	
Ob58	667766mE 8441353mN	B1	Firm, light brown surface, 2-6mm coarse fragments, <2% cover	Gentle Undulating Plain Mid slope 2%	Tall open woodland including Eucalypts 20% cover
Ob59	667529mE 8441576mN	Q1	Increasing quartz rocky outcrops, 50%+cover	Upper slope, ridge, 10%+ slope	-
Ob60	667758mE 8441746mN	B1	Firm, light brown surface, 2-6mm coarse fragments, <2% cover	Gentle Undulating Plain Mid slope 2%	Tall open woodland including Eucalypts 20% cover
Ob61	668238mE 8441595mN	B1	Firm, light brown surface, 2-6mm coarse fragments, <2% cover	Gentle Undulating Plain Mid slope 2%	Tall open woodland including Eucalypts 20% cover
Ob62	668217mE 8441897mN	B1	Grey/yellow sandy surface	-	Tall open woodland including Eucalypts 20% cover

Site No.	Location (GDA94 Zone 53)	Soil Mapping Unit	Surface	Landform	Comments / Pictures
Ob63	668146mE 8442291mN	Q1	80% rock/quartz cover	Mid slope 6+%	
Ob64	668156mE 8442175mN	B1	Grey/yellow sandy surface	-	Tall open woodland including Eucalypts 30% cover
Ob65	667245mE 8440463mN	B1	Beginning of common small manganese outcrops to the west	Gentle Undulating Plain Mid slope 2%	-
Ob66	667098mE 8440256mN	B1	Manganese outcrops, 10% cover in immediate area	Gentle Undulating Plain Mid slope 4%	-

Site No.	Location (GDA94 Zone 53)	Soil Mapping Unit	Surface	Landform	Comments / Pictures
Ob67	666867mE 8440256mN	B1	Manganese outcrops	Upper slope 4%	
Ob68	665760mE 8440879mN	B1	Brown sandy surface	Gentle Undulating Plain Mid slope 1%	
Ob69	666586mE 8441248mN	B1	Brown sandy surface	Gentle Undulating Plain Mid slope 1%	
Ob70	666754mE 8441508mN	Boundary B1/Q1	80% rock/quartz cover	Mid slope 6+%	

Site No.	Location (GDA94 Zone 53)	Soil Mapping Unit	Surface	Landform	Comments / Pictures
Ob71	664403mE 8441239mN	B2	Manganese 50-200mm, 20%+ cover	-	
Ob72	664239mE 8441624mN	B1	Soft, sandy, no coarse fragments	Swamp area in wet season	Paperbark
Ob73	664777mE 8441994mN	B2	-	-	Medium shrubs, minimal eucalyptus in immediate area

Site No.	Location (GDA94 Zone 53)	Soil Mapping Unit	Surface	Landform	Comments / Pictures
Ob74	664926mE 8443217mN	Boundary B1/Q1	Increasing Quartz rock cover at Q1 boundary	Mid slope 6%+	
Ob75	664163mE 8442501mN	B1	Light brown/grey surface		Eucalyptus 20%+ cover
Ob76	663251mE 8442625mN	B2	Firm, light brown surface, 2-6mm coarse fragments, <2% cover	-	Medium shrubs, no eucalyptus in immediate area
Ob77	663248mE 8442311mN	A1	-	Creek line	-
Ob78	663750mE 8442769mN	Boundary B1/B2	-	-	Vegetation changes from short/medium shrubs to tall eucalypt heading to the south
Ob79	663745mE 8442920mN	Boundary B1/B2	-	-	Vegetation changes from short/medium shrubs to tall eucalypt heading to the north
Ob80	663464mE 8443252mN	B2	-	-	Medium and short shrubs, no eucalyptus in immediate area
Ob81	663251mE 8443403mN	Boundary B1/B2	-	-	Vegetation changes from short/medium shrubs to tall eucalypt heading to the west

Site No.	Location (GDA94 Zone 53)	Soil Mapping Unit	Surface	Landform	Comments / Pictures
Ob82	663247mE 8444068mN	B1	Firm, sandy, No coarse fragments	Gentle Undulating Plain Mid slope 1.5%	Tall open woodland including Eucalypts 20% cover
Ob83	662278mE 8444251mN	B1	Firm, sandy, No coarse fragments	Gentle Undulating Plain Mid slope 2.5%	Tall open woodland including Eucalypts 20% cover
Ob84	661258mE 8444241mN	B1	Starting to become darker brown as in creek/A1 area	-	Thick 1m+native grasses, <10% Eucalyptus
Ob85	661411mE 8443911mN	A1	-	Active creek line	
Ob86	665521mE 8440456mN	A1	-	Active creek line	-

Site No.	Location (GDA94 Zone 53)	Soil Mapping Unit	Surface	Landform	Comments / Pictures
Ob87	665299mE 8439970mN	V1	80%+ rock cover	Inside monsoonal vine thicket, Mid slope 3-4%	
Ob88	665293mE 8439926mN	V1	80%+ rock cover	Inside monsoonal vine thicket, Mid slope 5%	

Site No.	Location (GDA94 Zone 53)	Soil Mapping Unit	Surface	Landform	Comments / Pictures
Ob89	665368mE 8439944mN	B1	Rocky outcrops throughout area, 80% cover	Upper slope / crest from 5% slope, 15m outside monsoonal vine thicket	
Ob90	665353mE 8439946mN	B1	Rocky outcrops throughout area, 80% cover	Mid slope 4%, 4m outside monsoonal vine thicket	

Site No.	Location (GDA94 Zone 53)	Soil Mapping Unit	Surface	Landform	Comments / Pictures
Ob91	665256mE 8440007mN	B1	20% rock cover	Mid slope 3%, 4m outside monsoonal vine thicket	
Ob92	665322mE 8439869mN	B1	10% rock cover	Mid slope 3%, 4m outside monsoonal vine thicket	-
Ob93	665403mE 8440058mN	B1	Light brown, sandy, 2% coarse fragments	-	-
Ob94	661821mE 8442898mN	Q1	Light colour quartz rocky outcrops	Ridge 30m+ high	-
Ob95	659769mE 8443318mN	B1	Yellow/grey surface	Gentle Undulating Plain Mid slope 1.5%	-

APPENDIX C LABORATORY CERTIFICATES

ESSA Pty Ltd /Phosyn (ASPAC certified)

For Info Refer ESSA Pty Ltd
PO Box 442 Sunnybank Q 4109

Phone: 0403245560

email: e.s.s.a@bigpond.net.au

Reference: **14/48:B74603** Sheet 1 of 4

Date Received: 21/06/2014
Date Completed: 02/07/2014

FINAL REPORT

Project:

Project - Gemco Eastern Leases

All results in this report relate only to the items tested. Results are expressed on an "as received basis".

Client Name: GTEnvironmental

Contact: Mr Reece Mc Cann

Sample Type: Soil

Number of samples: 17

ESSA /Phosyn Pty Ltd **(ASPAC Approved)**

Soil Analysis Report
Batch Number: 14/48:74603

Date Received: 21/06/2014
Date Completed:02/07/2014

Client: GTE Gemco- Results Page 1 of 2

ESSA Ref	Site ID	field ref	Soil pH	Soil EC	Soil Cl	P(Olsen)	Exch.Ca	Exch. Mg	Exch.Na	Exch. K	CEC	Ca/Mg	ESP	Total N	Nitrate N	OrgMatter
		Depth (m)		dS/m	mg/kg	mg/kg	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	Ratio	%Na/CEC	%	(%)	(%)
SBD0345	5	0-00-0.10	6.4	0.02	16	7	1.18	0.41	<0.08	0.04	1.7	2.9	1	<0.01	2	1.8
SBD0346	5	0.30-0.40	6.3	0.01	27		0.73	0.46	<0.08	0.04	1.3	1.6	1			
SBD0347	5	0.60-0.70	6.2	0.01	24		0.48	0.41	<0.08	0.03	1.0	1.2	2			
SBD0348	5	0.90-1.00	6.1	0.01	18		0.33	0.32	<0.08	0.02	0.8	1.0	1			
SBD0349	6	0.00-0.10	5.5	0.01	14	4	0.53	0.32	<0.08	0.02	1.0	1.7	1	<0.01	2	0.8
SBD0350	6	0.30-0.40	5.6	0.01	17		<0.1	0.41	<0.08	0.02	0.9	0.0	2			
SBD0351	6	0.60-0.70	5.6	0.01	18		<0.1	0.67	<0.08	<0.01	0.9		2			
SBD0352	6	0.90-1.00	5.8	0.01	20		0.03	1.83	0.09	0.03	2.1	0.0	4			
SBD0353	7	0.00-0.10	6.1	0.02	12	4	2.64	0.84	<0.08	0.07	3.6	3.1	1	0.02	2	2.2
SBD0354	7	0.20-0.30	5.8	0.01	12		0.32	0.32	<0.08	0.04	0.8	1.0	1			
SBD0355	7	0.60-0.70	5.8	0.01	8		0.37	0.76	<0.08	0.07	1.2	0.5	3			
SBD0356	7	0.90-1.00	5.9	0.01	9		0.43	1.13	<0.08	0.04	1.7	0.4	2			
SBD0357	10	0.00-0.02	5.9	0.03	16	6	4.34	1.9	<0.08	0.08	6.4	2.3	1	0.09	1	3.3
SBD0358	19	0.00-0.10	5.5	0.03	24	7	0.8	1.04	0.11	0.07	3.3	0.8	3	0.08	<1	5.1
SBD0359	19	0.30-0.40	5.6	0.01	19		0.39	0.89	<0.08	0.02	1.7	0.4	2			
SBD0360	19	0.60-0.70	6	0.01	18		1.16	2.71	0.09	0.03	4.5	0.4	2			
SBD0361	19	0.90-1.00	5.9	0.01	11		0.78	1.89	<0.08	0.03	2.9	0.4	2			

Client: GTES Gemco - Results Page 2 of 2

Lab No	Site ID	field ref	PSA-CS	PSA-FS	PSA-Silt	PSA-Clay	Disp Ratio	ADMC	Emerson	Sulfate-S	Mn	Boron	Copper	Iron	Zinc	Al	Al/CEC(%)
		Depth (m)	%	%	%	%	R1	%	Number	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	meq/100g	%
SBD0345	5	0-00-0.10	75	13	1	13	0.63	2.2	5	2	33.1	0.4	0.2	39	0.2	0.07	4.3
SBD0346	5	0.30-0.40														0.03	2.1
SBD0347	5	0.60-0.70														0.05	5.4
SBD0348	5	0.90-1.00														0.1	13.2
SBD0349	6	0.00-0.10	74	22	2	6	0.52	0.3	5	1	7.6	0.2	0.1	13	0.2	0.09	9.1
SBD0350	6	0.30-0.40														0.42	47.8
SBD0351	6	0.60-0.70														0.19	21.4
SBD0352	6	0.90-1.00														0.08	4
SBD0353	7	0.00-0.10	68	22	5	6	0.99	2.2	5	3	53.8	0.4	0.3	16	0.3	0.03	0.9
SBD0354	7	0.20-0.30														0.08	9.9
SBD0355	7	0.60-0.70														<0.02	<1
SBD0356	7	0.90-1.00														0.04	2.4
SBD0357	10	0.00-0.02	50	41	3	6	0.83	1.4	5	6	44.2	0.4	0.2	27	0.3	0.02	<1
SBD0358	19	0.00-0.10	39	34	11	13	0.61	4	3	7	11.5	0.3	0.5	52	0.5	1.29	38.9
SBD0359	19	0.30-0.40														0.41	23.7
SBD0360	19	0.60-0.70														0.55	12.1
SBD0361	19	0.90-1.00														0.09	3.1

All results for particle size analysis and R1 are reported on oven-dried basis (no pre-treatment applied to test samples)

ESSA / Phosyn Pty Ltd (ASPAC Approved)

METHOD DESCRIPTIONS

Soil

Methods used to Analyse Samples

Analyte	ALHS*	Uncertainty %	LOQ	Unit	Name	Method Description
pH	4A1	1.1	0.1	pH	pH	1:5 water extr, pH meter
EC	3A1	5.4	0.01	dS/m	Electrical conductivity	1:5 water extr, EC meter
Cl	5A2	10.0	10.0	mg/kg	Chloride	1:5 water extr, (AA) colorimetric
NO3-N	7C2	6.7	1.0	mg/kg	Nitrate-nitrogen	1:5 water extr, (AA) colorimetric
NH4-N	7C2	7.8	0.6	mg/kg	Ammonium-nitrogen	1M KCl extr, (AA) colorimetric
Bicarb.P	9B2	16.8	1.0	mg/kg	Bicarb.ext.phosphorus	0.5M NaHCO3 @ pH 8.5, (AA) colorimetric
Exch.Ca	15C1	7.2	0.18	meq/100g	Exchangeable calcium	1M NH4OAc @ pH 7.0 leach, AAS
Exch.Mg	15C1	4.7	0.31	meq/100g	Exchangeable magnesium	1M NH4OAc @ pH 7.0 leach, AAS
Exch.Na	15C1	9.6	0.09	meq/100g	Exchangeable calcium	1M NH4OAc @ pH 7.0 leach, AAS
Exch.K	15C1	4.8	0.02	meq/100g	Exchangeable calcium	1M NH4OAc @ pH 7.0 leach, AAS
CEC	15I3	5.7	1.0	meq/100g	Cation Exchange Capacity	KNO3 + Ca(NO3)2 extr, (AA) colorimetric
DTPA-Cu	12A1	17.1	0.26	mg/kg	DTPA ext. copper	DTPA extraction, AAS
DTPA-Zn	12A1	16.4	0.10	mg/kg	DTPA ext. zinc	DTPA extraction, AAS
DTPA-Mn	12A1	9.0	0.32	mg/kg	DTPA ext. manganese	DTPA extraction, AAS
DTPA-Fe	12A1	13.0	0.23	mg/kg	DTPA ext. iron	DTPA extraction, AAS
ADMC	2A1	11.9	0.4	%	Air Dried Moisture Content	Gravimetric oven dry @ 105C
R1	NA	20.2	NA		Dispersion Ratio	Ratio [Aqueous dispersible (Silt + Clay):Total (Silt + Clay)]
SO4-S	10B3	11.5	0.6	mg/kg	Sulfate sulfur	Ca(H2PO4)2 @ pH 4.0 extractable sulfate-sulfur, ICPOES
Sand	no ref	22.1	1.0	%	Particle size, sand	Hydrometer, gravimetric & Sieve
Silt	no ref	16.6	1.0	%	Particle size, silt	Hydrometer, gravimetric
Clay	no ref	12.7	1.0	%	Particle size, clay	Hydrometer, gravimetric
TN	7A2	12.9	0.01	%	Total Kjeldahl Nitrogen	Sulphuric acid digest, (AA) colorimetric

*** Australian Laboratory Handbook of Soil and Water Chemical Methods (1992)**

For Manager Analytical Services: **D E Baker BSc MASSSI**

ESSA / Phosyn Pty Ltd(ASPAC Approved)

QUALITY CONTROL DATA

Soil

Reference: 14/48:B74603
Page: 4 of 4

*** Australian Laboratory Handbook of Soil and Water Chemical Methods (1992)**

Test Method	Units		Actual Value	Acceptance Criteria [Range]
pH	pH	B		5.0 - 5.3
EC	dS/m	B		0.27 - 0.32
Cl	mg/kg	B		10 - 35
NO3-N	mg/kg	B		10 - 16
NH4-N	mg/kg	NA		NA
Bicarb.P	mg/kg	B		51 -75
Total Kjeldahl N	%	ASPAC 34	0.110	.100 - .120
Total P	%	ASPAC 34	0.02	.019 - .021
Organic Carbon	%	B		1.82 - 2.3
Ca (Exch. cations)pH7	meq/100g	B		6.96 - 8.04
Mg (Exch. cations)pH7	meq/100g	B		1.88 - 2.22
Na (Exch. cations)pH7	meq/100g	B		.057 - .182
K (Exch. cations)pH7	meq/100g	B		1.209 - 1.411
Exch. Acidity	meq/100g			NA
ECEC	meq/100g	A		NA
CEC	meq/100g	S12		58 - 73
ESP	%	A		NA
Coarse sand	%	B	17.0	17.3 - 22.4
Fine Sand	%	B	22.0	20.0 - 25.7
Silt	%	B	16.0	10.5 - 19.8
Clay	%	B	44.0	37.9 - 48.9
R1		B		0.23 - 0.38

Test Method	Units	Test Soil	Actual Value	Acceptance Criteria [Range]
DTPA-Cu	mg/kg	SB		2.37 - 3.25
DTPA-Zn	mg/kg	SB		3.15 - 3.81
DTPA-Mn	mg/kg	SB		97.7 - 149.0
DTPA-Fe	mg/kg	SB		24.3 - 32.6
0.33 Bar	%	G		32 - 51
15 Bar	%	G		23 - 30
Ca (Exch. cations)pH8.5	meq/100g	S12		27.7 - 35.4
Mg (Exch. cations)pH8.5	meq/100g	S12		22.88 - 24.5
Na (Exch. cations)pH8.5	meq/100g	S12		2.0 - 2.28
K (Exch. cations)pH8.5	meq/100g	S12		1.64 - 2.09