Earl Grey Lithium Deposit
Soil and Landform Assessment

Prepared for:

Kidman Resources Limited

May 2017

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EARL GREY LITHIUM DEPOSIT
SOIL AND LANDFORM ASSESSMENT

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EXECUTIVE SUMMARY

Kidman Resourced Limited (Kidman) is the owner of the Earl Grey Lithium Project (the Project), located 105 km south-southeast of Southern Cross in the Yilgarn Mineral Field of Western Australia. The Project is situated within the abandoned Mt Holland Mine Site which was operated between 1988 and 2001, and comprises a number of open pits, an underground mine, a processing plant, waste rock dumps, tailings storage facilities and other infrastructure that is largely unrehabilitated and currently a liability of the State of Western Australia. In 2016, Kidman announced the discovery of a significant lithium pegmatite deposit located west of Bounty Mine, within the historic Earl Grey open pit area and extending approximately 1.5 km to the south on Mining Lease M77/1080. The Earl Grey Lithium Deposit (Earl Grey) has a maiden resource of 128 Mt at 1.44% Li_2O (1.84 Mt lithium oxide) that was announced in December 2016.

Kidman is currently completing a feasibility study to develop the Earl Grey Lithium Deposit, which will comprise open pit mining and processing of lithium-bearing ore. It is proposed that waste rock produced from open pit mining will be both stockpiled in a surface waste rock dump and backfilled progressively into the mine void as mining progresses from south to north across the deposit.

MBS Environmental (MBS) was engaged by Kidman to undertake a soil and landform assessment to inform environmental approvals and closure planning practices. The primary objective of the study was to determine the suitability of topsoils and subsoils for use during rehabilitation of land disturbances in the Project area.

The scope of work included a site investigation and submission of topsoil and subsoil samples collected within the proposed footprint of the Project to ChemCentre, for a range and physical and geochemical tests.

The Project area is characterised by subdued relief, comprising gently undulating uplands dissected by broad valleys with bands of low greenstone hills and numerous saline playa lakes. The vegetation is dominated by Eucalyptus woodlands, shrublands of *Allocasuarina* and *Acacia*, and mixed heath of *Melaleuca* and *Acacia*.

A review of aerial photographs and site investigations identified the following two soil and landform units within the Project area:

- Gently undulating sandplain landform in which the dominant soil type is a duplex sandy gravel (DAFWA Soil Group 302).
- Broad valleys and drainage line landform in which the dominant soil type is a yellow/brown loamy duplex (DAFWA Soil Group 508).

Duplex sandy gravel soil profiles consist of a shallow gravelly sand A-horizon over compacted lateritic gravel in sandy clay matrix B-horizon. This soil type is present on topographically elevated areas and usually identified by association with sandplain heath vegetation, with sparse to scattered low eucalypts. Its typical profile is naturally acidic throughout (with lower pH in the B-horizon), non-saline and low sodicity. Deeper sand phases, indicated by the presence of *Banksia* species, may become water repellent when dry.

Yellow/brown loamy duplex soil profiles consist of a shallow sandy loam A-horizon over a compacted sandy clay to clay loam B-horizon. This soil type is present on lower lying landscapes and drainage lines within the project area and usually identified by association with low eucalypt woodland and *Melaleuca* shrubs. The duplex character of profiles of this soil type is reflected by a circum-neutral, non-saline A-horizon over an alkaline, saline and highly sodic B-horizon.

Surface soil from both soil types were identified as being suitable for rehabilitation purposes. Topsoil (A-horizon) of both soil types and root-bearing gravels of the duplex sandy gravel soil type within the footprint of the proposed open pit and waste rock dump should be stockpiled for subsequent rehabilitation of disturbed areas at mine closure. A minimum of 200 mm of topsoil is expected to be available across the project area, providing

approximately 2,000 m³/ha of topsoil resources. There is no need to segregate excavated topsoils of the two soil types.

Although the gravelly subsoil material from the duplex sandy gravel soil type is not considered a highly valued rehabilitation material by virtue of high natural acidity and a lack of coarse gravel, it may be suitable as a gravelly material for road base and construction of the ROM Pad and bunds. This material should be stockpiled separately.

Subsoil clay material from the yellow/brown loamy duplex soil type is not suitable for mine site rehabilitation because of its alkaline, saline and highly sodic characteristics. Unless it is required for construction requirements (providing it has acceptable geotechnical properties), excavated material from the open pit footprint can be managed as mine waste.

All harvested topsoil and root-bearing gravel materials are expected to be suitable for rehabilitation of flat and very gently sloping disturbed areas at mine closure. The minimum thickness of this topsoil layer is predicted to be 200 mm.

As a consequence of very low extractable phosphorus levels and high C/N values, plants other than endemic Proteaceous species (which are adapted to very low nutrient conditions) may respond favourably to applications of low rates of a balanced fertiliser. MBS recommends a mine closure program based on field trials and progressive rehabilitation to optimise cover design, species selection and fertiliser application rates.

TABLE OF CONTENTS

TABLES

FIGURES

PLATES

CHARTS

APPENDICES

1. INTRODUCTION

Kidman Resourced Limited (Kidman) is the owner of the Earl Grey Lithium Project (the Project), located 105 km south-southeast of Southern Cross in the Yilgarn Mineral Field of Western Australia (Figure 1). The Project situated within the abandoned Mt Holland Mine Site, which was operated between 1988 and 2001, and comprises a number of open pits, an underground mine, a processing plant, waste rock dumps, tailings storage facilities and other infrastructure that is largely unrehabilitated and currently a liability of the State of Western Australia.

In 2016, Kidman announced the discovery of a significant lithium pegmatite deposit located west of Bounty Mine, within the historic Earl Grey open pit area and extending approximately 1.5 km to the south on Mining Lease M77/1080. The Earl Grey lithium deposit has a maiden resource of 128 Mt at 1.44% Li_2O (1.84 Mt lithium oxide) that was announced in December 2016. A conceptual pit design shows shallow expression of mineralised pegmatite at the southern end of the deposit, with an average thickness of 70 m.

Scale: 1:3300000
Original Size: A4
Grid: MGA94(50)

0 100 km

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Figure 1

Location

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MBS ENVIRONMENTAL

W:\Kidman\Earl Grey\Soil and Landform Report\Drawings\Figure 1 Earl Grey Location Plan ver 2.map 16/02/2017 Layout

2. OBJECTIVES AND SCOPE OF WORK

2.1 OBJECTIVES

MBS was engaged by Kidman to undertake a soil and landform assessment to inform environmental approvals and closure planning practices. The primary objective of the study was to determine the suitability of topsoils and subsoils for use during rehabilitation of land disturbances in the project area.

2.2 SCOPE OF WORKS

The scope of work comprised:

- Providing a description of natural landforms within the project area and surrounds.
- Collect samples and provide field descriptions of topsoil and subsoil from representative sites within the footprint of the proposed open pit, waste rock stockpile and other operational areas.
- Submission of selected topsoil and subsoil samples to ChemCentre (Bentley, Western Australia) for a range of physical and geochemical tests (including particle size distribution, Emerson Aggregate Class, pH, electrical conductivity (EC), organic carbon, nutrients, both plant available and total environmentally available metals and metalloids and cation exchange properties).
- Preparation of this report, tailored to provide a set of conclusions and recommendations relating to suitability of topsoil and subsoil materials for use in rehabilitation of land disturbances in the project area.

This study does not include an assessment of the geotechnical properties of soils required for construction or engineering purposes. An assessment of the suitability of oxide waste rock for rehabilitation purposes is included in a separate geochemical waste rock characterisation report (MBS 2017).

3. PROJECT DESCRIPTION

Kidman is currently completing a feasibility study for the Project. The current scope comprises open pit mining of lithium bearing ore and site processing.

It is proposed that waste rock produced from open pit mining will be both stockpiled in surface waste rock stockpiles and backfilled progressively into the mine void as mining progresses from the south to the north of the deposit. Opportunity also exists for waste rock to be used to cover the historic TSF, immediately south of the deposit. This TSF is a liability of the State of Western Australia as the gold tailings are potentially acid forming (PAF), the TSF is uncovered and has zero freeboard. Kidman proposes to assess an option to cover the TSF with waste rock, which is expected to deliver a substantial environmental benefit by reducing oxidation of sulfide minerals, thereby reducing the volume and improving the quality of tailings seepage and contaminated runoff.

Other infrastructure for the Project will include a Run-of-Mine (ROM) pad, gravity processing plant, water supply infrastructure, office and workshop facilities and an accommodation village (to be established at the historic camp site).

4. EXISTING ENVIRONMENT

4.1 REGIONAL SETTING

The Project is located in the Southern Cross subregion of the Coolgardie Interim Biogeographic Regionalisation for Australia (IBRA) Bioregion. The bioregion is characterised by subdued relief, comprising gently undulating uplands dissected by broad valleys with bands of low greenstone hills and numerous saline playa lakes. The vegetation is dominated by Eucalyptus woodlands, shrublands of *Allocasuarina* and *Acacia*, and mixed heath of *Melaleuca* and *Acacia*.

The Project area is highly disturbed from previous mining operations. There are no pastoral leases or other significant land uses within the vicinity of the Project.

4.2 CLIMATE

A desktop assessment of available climate data was completed by Groundwater Resource Management (2014). The regional climate is one of extremes, where droughts and major floods can occur within a few years of each other. The Bureau of Meteorology (BoM) Lake Carmody rainfall station (No. 10670) is located approximately 51 km southwest of the Project and provides 77 complete years of data.

The climate is semi-arid with a mean annual rainfall varying from 300 mm to approximately 350 mm, with mean and median annual rainfalls of 332 and 329 mm respectively. The rainfall that occurs during the early winter months of June and July tends to be more reliable and generally of a greater total amount than the less dependable, but more intense, summer rainfalls from January to March. Remnant tropical cyclones and associated depressions can occasionally bring heavy rains to the region; however they are erratic in nature and occur infrequently. Minimum and maximum annual rainfalls of 156.2 and 558.3 mm, respectively, have been recorded at the Lake Carmody rainfall station.

On average, there are approximately 66 rain days each year, although this may be as low as 15 days and as high as 130 days. The longest period without rain was 138 days, between 1 November 1920 and 19 March 1921.

Temperatures recoded at the BoM Hyden synoptic station, situated approximately 88 km west-southwest of the Project indicate the following:

- Mean daily maximum temperatures range from 33.7°C in January to 16.4°C in July.
- Mean daily minimum temperatures range from 15.9°C in February to 4.6°C in July.
- Highest and lowest daily temperatures of 48.6°C and -5.6°C have been recorded in February (2007) and July (1982) respectively.
- Typically there will be in the order of 10 days each year with daily maximum temperatures in excess of 40°C, approximately 8.5 of which will occur in December, January and February.
- On average, minimum temperatures will be 2°C or less and light ground frosts are possible for 31 days each year. Two thirds of such days will occur in June, July and August.

In the absence of a local evaporation records, the average of pan evaporation data for the Merredin and Salmon Gums Research Stations has been applied to the Project. This provides a mean annual pan evaporation of approximately 1,867 mm.

4.3 GEOLOGY

4.3.1 Regional Geology

The Mt Holland Gold Field covers southern sections of the Archaean Southern Cross – Forrestania Greenstone Belt. The Belt extends over 300 km and generally strikes NNW (Kidman 2017). Regional mapping identified two distinct lithostratigraphic units within the Belt; an ultramafic metavolcanic suite, and a sequence of overlying immature clastic metasediments. These units are regionally folded with a north plunging synform, steep east and shallow west limbs (East and West ultramafic-mafic domains) with a core of Package One ultramafic-mafic-sedimentary rocks) (Kidman 2017).

The greenstones are predominantly mafic and ultramafic flows, generally intercalated with banded iron formations (BIF), cherts, and clastic sediments. Regional metamorphism is recorded at amphibolite grade, with local areas of retrograde chlorite metamorphic facies. The Belt is enclosed by syntectonic granitoids.

The Eastern Domain mafic-ultramafic basal rocks comprise a thick sequence of tholeiitic basalts with minor high-magnesium basalts and exhalative sediments. The basal rocks overlie a granitoid basement, and are overlain by the Bounty sequence. The Bounty sequence is approximately 600 m thick and consists of komatiitic peridotite flows and basalts which are intercalated with BIFs. This sequence is host to the Bounty Gold mine and the nickel mineralisation within the Forrestania Belt. A dolerite sill overlies the Bounty sequence and is the basal unit of the uppermost ultramafic suite, which also contains tholeiitic basalts and minor exhalative sediment horizons.

The basal rocks of the Western Domain consist of clastic metasediments which lie upon a younger intrusive granitoid (west). Stratigraphically above the basal metasediments are a thick package of (from bottom to top) komatiitic high MgO olivine orthocumulate; then a low MgO pyroxenite with locally developed dolerite-gabbro differentiates and intercalated flow sediments; then finally a unit of high MgO basalts with intercalated flow sediments (Kidman 2017).

The Central Domain consists mainly of pelitic and psammitic schists (± garnet), thin BIF lenses and bands of graphitic schists. Two major shear zones in the Forrestania Belt separate the three domains. The Mt Holland Shear defines the Central and Eastern Domains. Likewise, the Van Uden Shear separates the Central and Western Domains. Additional shear zones are recorded as parallel and crosscutting stratigraphy dominantly orientated north south; and north north-west to south southeast (Kidman 2017).

Lastly, NNE striking sets of Proterozoic dykes cut the three domains.

4.3.2 Project Geology

Within the Mt Holland District three basic varieties of pegmatite have been recognised historically. These include;

- Complex zoned pegmatite containing spodumene and albite in addition to coarse perthite and quartz.
- Albitic aplite rich in black tourmaline and commonly containing cassiterite.
- Coarse cleavelanditic albite veins with minor apatite and spodumene.

These pegmatites appear to be abundant on the eastern margin of the Forrestania Greenstone belt, where several of Kidman's tenements occur. Amongst these are the known Bounty lithium-bearing pegmatites and the voluminous, but currently untested, Texas pegmatites.

4.4 LANDFORMS AND SOIL SYSTEMS

The Project is located in the Kalgoorlie Province, which has been described at the regional level (Tille 2006) as undulating plains, with some sandplains, hills and salt lakes, on granitic rocks and greenstone of the Yilgarn

Craton. The Kalgoorlie Province is located in the southern Goldfields between Paynes Find, Menzies, Southern Cross and Balladonia.

At the next level of soil and landform mapping hierarchy adopted by the Department of Agriculture and Food (DAFWA) (Tille 2006), the Project is located within the Southern Cross Zone, with the border of the Norseman Zone approximately 6 km to the east. The Southern Cross Zone is characterised by undulating plains and uplands (with some salt lake and low hills) on deeply weathered mantle, colluvium and alluvium over greenstone and granitic rocks, and is located in the eastern Wheatbelt/south-western Goldfields between Bullfinch and Mt Holland. The Norseman Zone is characterised by undulating plains and uplands (with some sandplains and salt lakes) on granitic rocks of the Yilgarn Craton, located in the southern Goldfields between Koolyanobbing, Menzies, Zanthus (Trans-Australian Railway), Norseman and Lake Hope.

Two soil and landform units are associated with the Southern Cross Zone; 261AC1 and 261Ya28. Descriptions of these units, as well as 266DD10 and 266SV2 within the Norseman Zone, are summarised in Table 1 and shown in Figure 2.

Table 1: Descriptions of Regional Soil and Landform Systems

Unit	Landforms	Vegetation	Soil Types
Southern Cross Zone			
261Ya28	Sandy plains with some clay pans and small salt lakes, dunes, and lunettes.	Salmon gum-redwood-merrit-red mallee-gimlet woodland with acacia/casuarina thickets.	Duplex sandy, gravelly soils, occasionally saline. Some calcareous earths and various unconsolidated soils on small dunes and lunettes.
261AC1	Gently sloping to gently undulating plateau areas, or uplands, on granites, gneisses, and allied rocks, with long gentle slopes and, in places, abrupt erosional scarps, some granitic bosses, and tors; and irregularly traversed by narrow shallow valleys and flats.	Acacia/casuarina thickets (and some mallee, scrub-heath and halophytic shrublands).	Yellow earthy sands and sandy yellow earths on depositional sites and ironstone gravel erosional sites where they are underlain by hardened mottled-zone material.
Norseman Zone			
266DD10	Plains with some clay pans and small salt lakes, dunes, and lunettes.	Salmon gum-redwood-merrit-red mallee-gimlet woodland with acacia/casuarina thickets (and some mulga shrublands and spinifex grasslands).	Brown and grey-brown calcareous earths.
266SV2	Saline valleys with some dunes including barchan forms -- salt lake channels.	Halophytes.	Salt lakes and their fringing areas mostly devoid of true soils. Common soils include gypseous and saline loams, together with grey-brown highly calcareous earths.

The soil and landform units 261AC1, 261Ya28, 266DD10 and 266SV2 correspond approximately to distinct Australian Soil Classification Orders (ASRIS 2017) as follows:

- 261AC1, Tenosols. Tenosols are described as soils with generally only weak pedologic organisation apart from the A-horizons.
- 261Ya28, Sodosols. Sodosols are described as soils with a strong texture contrast between A-horizons and sodic B-horizons, which are not strongly acid.
- 266SV2, Calcarosols. Calcarosols are characterised by the presence of calcium carbonate minerals, and therefore moderately alkaline, throughout the profile.
- 266DD10, Tenosols.

4.5 VEGETATION

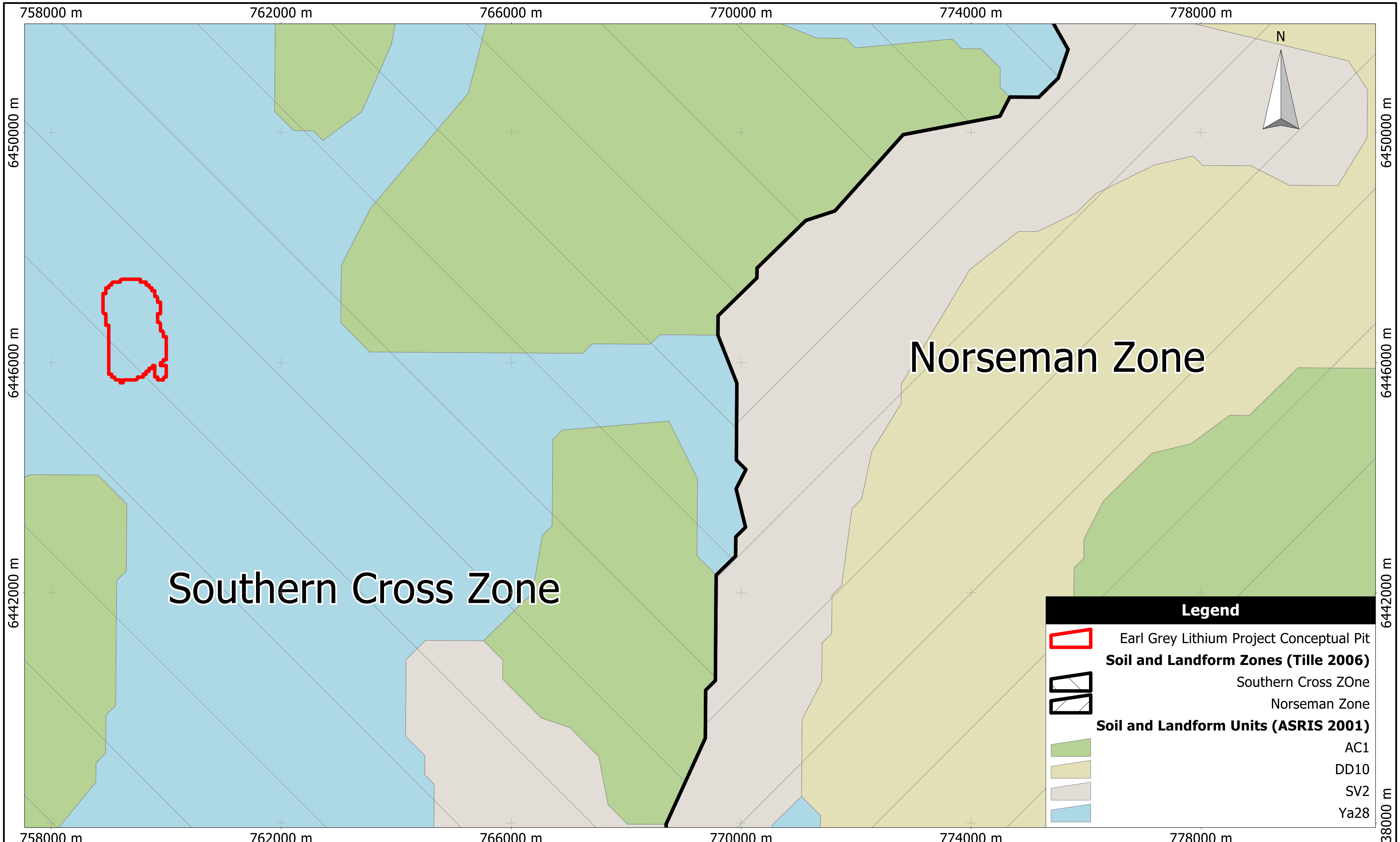
The Project is situated within the Coolgardie Botanical District, near its boundary with the Roe Botanical District (Mallee Region) (Beard 1990).

The major greenstone belts in the Coolgardie Botanical District are dominated by species including *Allocasuarina acutivalvis*, *Casuarina campestris* and *Banksia arborea*. The slopes of these banded ironstone hills are home to mallee species, such as *Eucalyptus gardneri*, *Eucalyptus redunca*, *Eucalyptus loxophleba* and *Eucalyptus sheathiana*. The slopes and flats generally consist of woodlands in which *Eucalyptus longicornis*, *Eucalyptus salmonophloia*, *Eucalyptus corrugata* and *Eucalyptus sheathiana* are common. The understorey in these woodlands may be either sclerophyllous, with shrubs such as *Melaleuca pauperiflora*, or where the soils are more alkaline or saline, soft-leaved shrubs such as *Atriplex vesicaria* and *Atriplex nummularia* are dominant.

Mallee, in the context of the Roe Botanical District, refers to a shrub-eucalypt formation. The most typical form of mallee is a closed community of mallee habit rising to 3 - 4.5 m, with an understorey of small *Melaleuca* shrubs. Elsewhere, the understorey may consist of mixed shrubs belonging to the scrub-heath, where there is a transition to the latter formation, or saltbush under alkaline soil conditions, or of hummock grass on sandy soil types.

In the mallee formation, *Eucalyptus eremophila* is the most consistent species, being nearly always present, but it has numerous associates, which include *Eucalyptus longicornis*, *Eucalyptus loxophleba*, *Eucalyptus micranthera*, *Eucalyptus oleosa*, *Eucalyptus redunca*, *Eucalyptus sheathiana*, *Eucalyptus transcontinentalis* and others. The understorey is most commonly dominated by one or more species of *Melaleuca*, forming a more or less continuous layer with other casual species.

Woodland areas consist of mixtures of large mallees including *Eucalyptus salubris*, *Eucalyptus gracilis*, *Eucalyptus loxophleba*, *Eucalyptus oleosa*, *Eucalyptus sheathiana*, *Eucalyptus flocktoniae*, *Eucalyptus annulata* and *Eucalyptus spathulata*. A saltbush (*Atriplex* sp.) understorey may be present, otherwise scattered woody shrubs of *Acacia*, *Eremophila*, *Pittosporum* and some grasses predominate.



Scale: 1:85000
Original Size: A4
Grid: MGA94(50)

0 4 km

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Earl Grey Lithium Project
Soil and Landform Assessment

Figure 2

Regional Soil and Landform Units

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W:\Kidman\Earl Grey\Soil and Landform Report\Drawings\Figure 2 Earl Grey Soil and Landform Units.map 16/02/2017 Figure 3 Soil and Landform Units

4.6 SURFACE WATER AND DRAINAGE

The Project is located within the Swan/Avon/Yilgarn Catchment of the Avon River Basin. No significant surface water features or watercourses occur within the vicinity of the project. Minor ephemeral drainage lines are present, but only flow for short periods following intense rainfall events. Runoff from the Project area generally drains offsite as sheet flow and shallow concentrated flow in these minor watercourses, flowing in a northeasterly direction.

4.7 REGIONAL HYDROGEOLOGY AND GROUNDWATER QUALITY

The Project is within the Westonia Groundwater Area of the Southern Cross Province. The main groundwater sources in the Southern Cross Province are derived from:

- Regional catchment controlled flow systems in fresh and weathered fractured rock.
- Tertiary palaeochannel sands.
- Calcrete units that commonly overlie palaeochannel deposits.
- Shallow alluvium.

Significant aquifer types in the Southern Cross region are derived from palaeochannel, calcrete and shallow alluvial deposits. Groundwater quality varies with salinity, generally increasing downstream along the drainage lines. The lowest salinity groundwater typically occurs beneath catchment divides. In the vicinity of Earl Grey, tertiary palaeochannel sediments comprise gypsiferous silt and sands to the east of the Project area.

The deep weathering profile of the ultramafic and basaltic sequences, characteristic of the Southern Cross region, comprises a thick siliceous caprock. Modest supplies of groundwater can be derived from fractured rock aquifers within this weathered zone. Fractured basement aquifers are characterised by secondary porosity and permeability, resulting in complex fracturing enhanced by chemical dissolution. The storage capacity and hydraulic conductivity of these aquifers is largely related to the degree of fracture intensity. In the vicinity of the Project area, fracturing below the caprock is prevalent, with the development of siliceous magnesite veins. The groundwater supplies are typically saline to hypersaline.

Small quantities of potable water are known to occur in fractures within granite outcrops. Typically the limited exposure of granite indicates there is limited recharge potential and consequently the supply is not considered sustainable as a Project supply. No fresh water supplies have been identified near the Project area.

Historic water quality data from various production and dewatering bores in the area indicates that natural groundwater quality can be characterised as follows:

- Circumneutral to slightly acidic, with pH values varying between 6.1 and 7.1.
- Hypersaline, with total dissolved solids (TDS) varying between approximately 70,000 mg/L and 120,000 mg/L.
- Relatively consistent major ion composition, with sodium and chloride as the dominant ions. Sulfate, bicarbonate, calcium and magnesium are also present in elevated concentrations and the water is therefore classified as very hard.
- Elevated boron and manganese concentrations that exceed long term irrigation trigger levels (ANZECC 2000).
- Slightly elevated concentrations of other metals and metalloids including aluminium, beryllium, and copper, which are not of environmental significance.

5. FIELD AND LABORATORY METHODS

5.1 SOIL PROFILE ASSESSMENT AND SAMPLING

A total of 30 samples of topsoil (0 to 100 mm) and subsoil (B1 or B2 horizons) from 21 locations within the Earl Grey deposit area were collected from unused exploration drill hole sumps by MBS personnel during a site visit on 8 to 10 October 2016. Sample locations are shown in Figure 3.

Soil profile characteristics were described and assessed using methodologies described in the Australian Soil and Land Survey Handbook (McDonald and Isbell 2009) and Department of Agriculture and Food, Resource Management Technical Report 280 (DAFWA 2004). Soil attributes described included:

- Depth of soil horizons, including “hardpan” layers.
- Soil colour.
- Soil texture.
- Soil fabric, including level of compaction.
- Moisture content.
- Presence or absence of plant roots at depth.
- Presence of distinctive soil genesis features such as mottling, gleying, calcrete and ferruginous pisoliths.

Relevant landscape features including topography (slope), vegetation and surface conditions (leaf litter, woody debris, rock fragments, cryptogamic crusts, surface cracking) were also recorded.

5.2 LABORATORY TESTS

A program of laboratory testing was undertaken to characterise physical and chemical properties of the soils and assess their suitability for use as cover materials for rehabilitation. For this reason, the test program focused on parameters relating to physical stability and plant nutrition characteristics.

The following tests were undertaken by ChemCentre (Bentley, Western Australia), generally using in-house modifications of standard soil tests described by Rayment and Lyons (2011):

- pH and electrical conductivity (EC).
- Exchangeable cations (calcium, sodium, potassium and sodium) and relative sodicity.
- Organic carbon and total nitrogen.
- Particle size (gravel content, greater than 2 mm).
- Potential for dispersion (Emerson Class, AS 1289 C8.1 1980).
- Nutrients and plant available heavy metals (Mehlich extract, Mehlich 1984).
- Ten element heavy metals and metalloids screen to calculate site-specific Ecological Investigation Levels (EILs) in accordance with NEPM (NEPC 2013) guidelines.

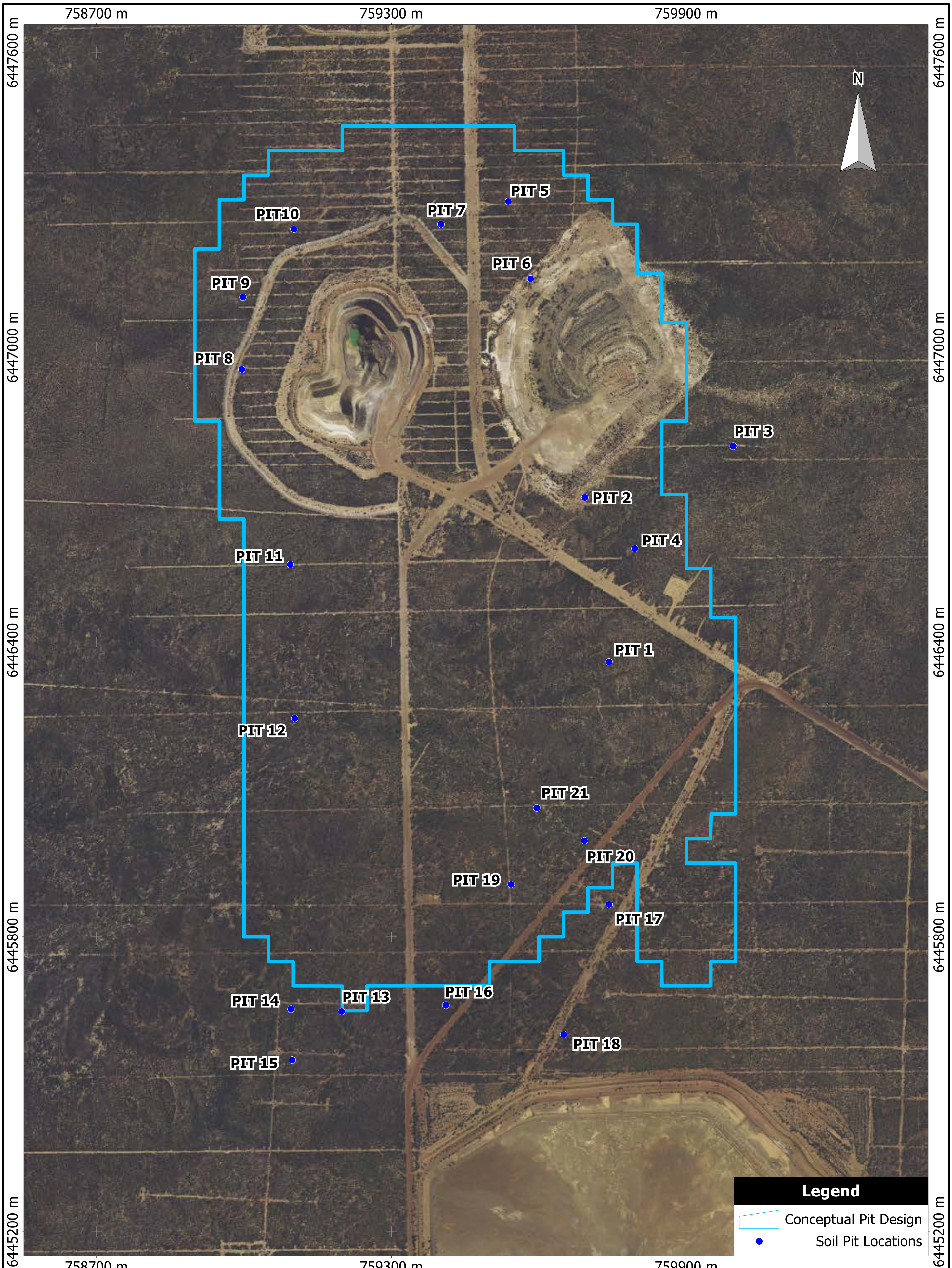
5.3 INTERPRETATION OF RESULTS

The following sources of information were used to assess the significance of laboratory test results:

- Soil Analysis: An Interpretation Manual (Peverill *et al*. 1999).

- Interpreting Soil Test Results. What do all the numbers mean? (Hazelton and Murphy 2007).
- Soil Guide. A handbook for understanding and managing agricultural soils. DAFWA Bulletin 4343 (DAFWA 1998).
- Soil-Landscape Mapping in South-Western Australia, Overview of methodology and outputs. Resource Management Technical Report 280 (DAFWA 2004).
- The author's experience from coordinating chemical analysis for DAFWA soil surveys conducted between 1988 and 1998.

A summary of the information sources and ratings tables used for this assessment is presented in Appendix 1.



Scale: 1:10000
Original Size: A4
Air Photo Date: May 2014
Grid: MGA94(50)
0 300 m

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Earl Grey Lithium Project
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Figure 3

Soil Pit Locations

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W:\Kidman\Earl Grey\Soil and Landform Report\Drawings\Figure 2 Earl Grey Soil Pit Locations.map 16/02/2017 Figure 3 Pit Locations

6. DESCRIPTIONS AND SOIL PROFILES

6.1 SOIL AND LANDFORM MAPPING UNITS

A review of aerial photographs and site observations identified the following soil and landform units within the Project area:

- Gently undulating sandplain.
- Broad valleys and drainage lines.

These soil and landform units are further described in Sections 6.1.1 and 6.1.2. Figure 4 shows the distribution of these units within the project area. The dominant soil type, using descriptions presented in Schoknecht and Pathan (2013), and associated vegetation descriptions are presented in Table 2.

Table 2: Soil and Landform Unit Descriptions

Soil and Landform Unit	Dominant Soil Type	Vegetation
Gently undulating sandplain.	Duplex sandy gravel (Soil Group 302)	Sandplain heath (melaleuca, banksia, acacia, grevillea and hakea) with sparse to scattered eucalypts
Broad valleys and drainage lines.	Yellow/brown loamy duplex (Soil Group 508)	Low eucalypt woodland

The topography of the Project area is gently undulating at 435 to 450 m RL AHD and slopes gently to the northeast. Mt Holland is a small hill, elevation approximately 477 m RL AHD, located 9 km south southwest of the Earl Grey pit.

6.1.1 Gently Undulating Sandplain

The dominant soil and landform mapping unit within the Project area and immediate surrounds is described as "gently undulating sandplain characterised by broad sandy and gravelly rises supporting low heath, dominated by *Melaleuca* and *Acacia* shrubs, with minor *Banksia*, *Grevillia* and *Hakea*". Plate 1 shows typical vegetation and associated sandy surface soils with minor ironstone gravel lag. This mapping unit is considered a sub-unit within the regional DAFWA soil and landform unit 261Ya28 (Table 1).

6.1.2 Broad Valleys and Drainage Lines

A second soil and landform mapping unit, described as "broad valleys and drainage lines", is located with the southern section of the Project area. Soils within this unit are characterised by higher clay and lower ironstone gravel contents throughout the profile (Section 6.2), which supports low eucalypt woodland vegetation communities (Plate 2). This mapping unit is also considered as a sub-unit within the regional DAFWA soil and landform unit 261Ya28 (Table 1).

Plate 1: Gently Undulating Sandplain Landscape

Plate 2: Low Eucalypt Woodland in Broad Valley Landscape

6.2 SOIL PROFILE DESCRIPTIONS

6.2.1 Duplex Sandy Gravel

The dominant soil type within the gently undulating sandplain mapping unit was a duplex sandy gravel, corresponding to Soil Group 302 in the DAFWA soil groups of Western Australia (Schoknecht and Pathan, 2013).

As shown in Plate 3, a typical profile of this soil type consists of:

- Almost bare surface apart from scattered ironstone gravel lag and sparse leaf litter near the base of small shrubs, dominated by *Acacia* and *Melaleuca* species. Weakly developed cryptogamic crusts were observed at some, but not all, test locations.

- A shallow sandy A-horizon with increasing amounts of small, rounded gravel with increasing depth. A-horizon depths varied from 100 to 400 mm. Soils were typically fine to medium textured yellow/brown sands. They are prone to dust generation and minor water repellence when dry, especially when *Banksia* species are present.
- A B1-horizon to a maximum depth of 400 to 600 mm below surface level. The B1-horizon contains increasing amounts of sub-rounded lateritic gravels in a fine sand to sandy clay matrix.
- An underlying B2-horizon of difficultly friable to indurated ferruginous hardpan. The hardpan layer generally provides a major impediment to root penetration.

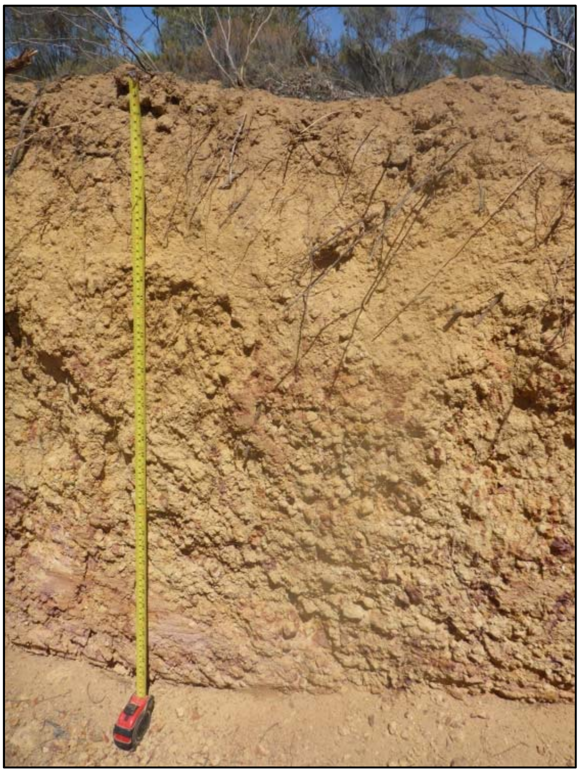


Plate 3: Duplex Sandy Gravel Soil Profile

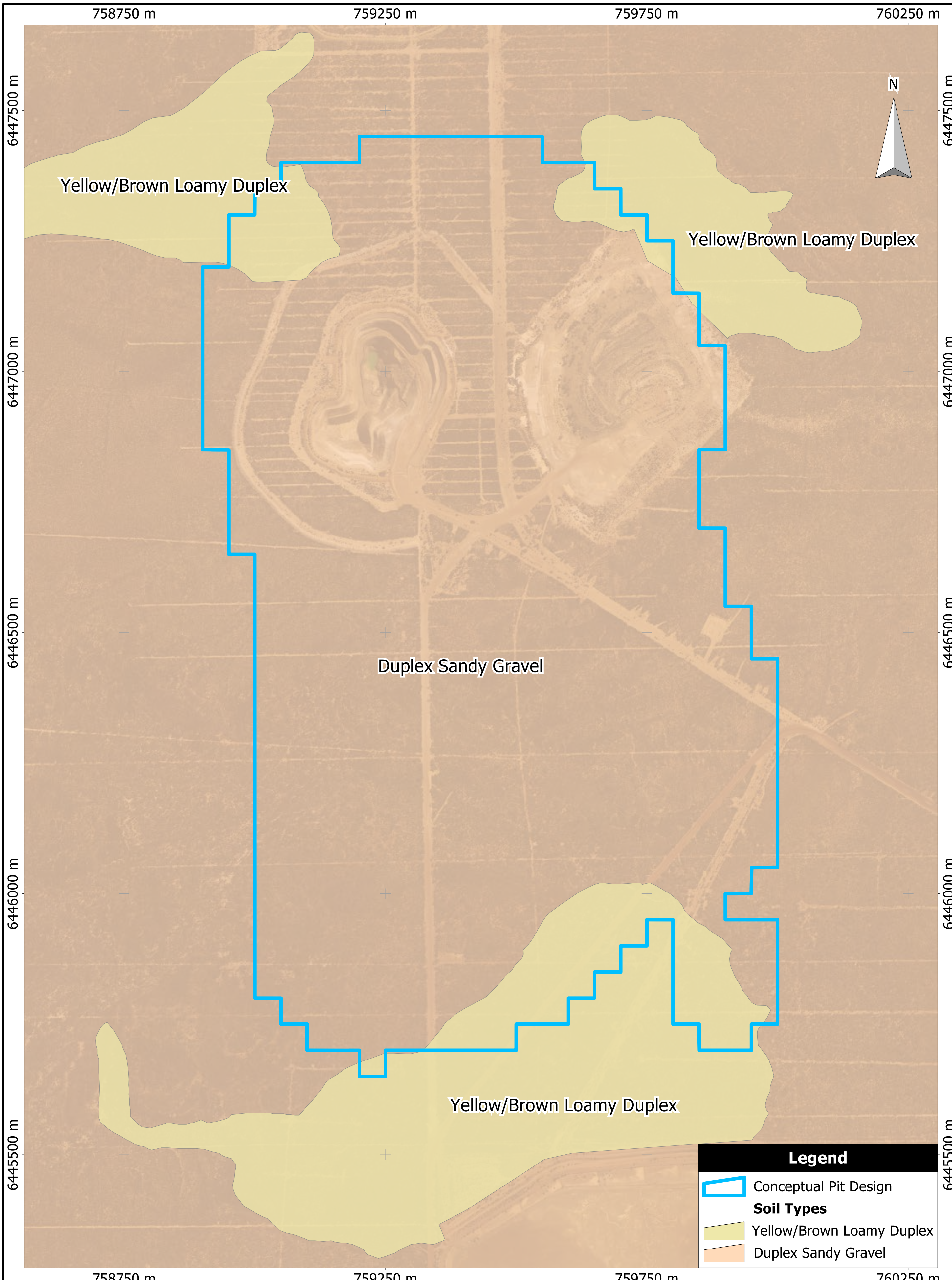
6.2.2 Yellow/Brown Loamy Duplex

The major soil type within the broad valleys and drainage lines mapping unit is a yellow/brown loamy duplex, corresponding to Soil Group 508 in the DAFWA soil groups of Western Australia (Schoknecht and Pathan, 2013). The boundary between this soil type and the duplex sandy gravel also present within the broad valleys and drainage lines mapping unit is diffuse and several profiles (notable Pits 13, 17 and 18) had characteristics of both soil types. Figure 4 shows the distribution of these soil types within the Project area and immediate surrounds.

The A-horizon of the yellow/brown loamy duplex soil type contains higher silt and clay contents, but with significantly less gravel. As a consequence of a higher density of eucalypt trees present, there are greater densities of leaf litter and coarse woody debris. Surface crusting is common, both as cryptogams and easily friable silty crusts.

The underlying B-horizon (Plate 4) is characterised by increasing clay content with relatively little gravel. Clays vary from bleached kaolin-rich layers to mottled ferruginous sandy clays. Unlike the duplex sandy gravel soil (Section 6.2.1), roots are able to penetrate deeper into the B-horizon, although elevated salinity levels are often associated with the subsoils of this soil type (Section 7.2.1).

Plate 4: Yellow/Brown Loamy Duplex Soil Profile



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Air Photo Date: May 2014
Grid: MGA94(50)
0 250 m

Kidmand Resources Limited
Earl Grey Lithium Project
Soil and Landform Assessment

Figure 4

Project Area Soil Types

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W:\Kidman\Earl Grey\Soil and Landform Report\Figures\Figure 4 Project Area Soil Types A4.map 16/02/2017 Figure 4 Project Area Soil Types Layout

7. PHYSICAL AND CHEMICAL SOIL PROPERTIES

Results for physical and chemical laboratory analysis of soil samples described in Section 5.1 are presented in Appendix 3. A copy of the complete laboratory report is presented in Appendix 4.

7.1 PHYSICAL PROPERTIES

7.1.1 Gravel Content and Texture

Results for gravel content, expressed as "Stones" (passing a 2 mm mesh screen) are presented in Table A3-1 of Appendix 3. A summary of results based on soil type and soil horizon (surface soil and subsoil) is presented in Table 3.

The mean gravel contents of surface soils for both soil types were relatively low (12.2% and 15.6% for the duplex sandy gravel and yellow/brown loamy duplex soils, respectively). Gravel contents increased with increasing soil depth in both soil types, with the B-horizon of the duplex sandy gravel soil containing significantly more gravel than that of the yellow/brown loamy duplex soil (mean values of 40.1% and 28.1%, respectively).

Table 3: Summary of Gravel Content Data

Soil Type	Horizon	Range (%)	Mean (%)
302 duplex sandy gravel	Surface soil	1.3 to 39.5	12.2
302 duplex sandy gravel	Subsoil	11.5 to 63.7	40.1
508 yellow/brown loamy duplex	Surface soil	2.0 to 36.2	15.6
508 yellow/brown loamy duplex	Subsoil	1.0 to 62.2	28.1

Particle size distribution data for two surface soils (pits 16 and 18, yellow/brown loamy duplex) and three subsoils (pits 3 and 7, duplex sandy gravel and pit 18, yellow/brown loamy duplex) are presented in Table A3-3 of Appendix 3. Key findings are summarised as follows:

- The yellow/brown loamy duplex surface soils (16A and 18B) contain significant amounts of silt and clay. Based on results for sand, silt and clay in the less than 2 mm sieved fractions, the textures of these soils are classified as loam and clay loam, respectively.
- Based on field assessment (Appendix 2), surface soil textures for the duplex sandy gravel soil type range from sand to silty sand.
- The B-horizons of both soil types contained significant clay contents, with values of 17.5 and 42.0% for the duplex sandy gravel and 39.0% for the yellow/brown loamy duplex.
- The B-horizon of the duplex sandy gravel soil type contained relatively little silt, with values ranging from 2.5 to 7%. The corresponding sample for the yellow/brown loamy duplex (pit 18) contained 22.0% silt.
- All samples assessed contained relatively little coarse gravel. Only one sample (pit 3, duplex sandy gravel) contained gravel greater than 16 mm in diameter, although the portion of material in this size fraction was low (1.6%).

7.1.2 Emerson Class

All samples were assessed for potential of clay dispersion using the Emerson Aggregate Test. Results are presented in Table A3-4 of Appendix 3.

Results were variable, with Emerson Classes ranging from 1 (natural soil aggregate prone to spontaneous slaking and dispersion) to 8 (natural soil aggregates do not slake or disperse). Three samples (surface samples 19A, 20A and 21A) were unsuitable for Emerson Class assignment as they did not contain suitable natural soil aggregates for testing.

Chart 1 compares Emerson Class with Exchangeable Sodium Percentage (ESP), which is considered an important factor for clay dispersion (Appendix 1). Key findings are summarised as follows:

- Ten samples were assigned Emerson Class 1, indicating very high potential for clay dispersion. Nine of these samples were yellow/brown loamy duplex samples.
- Eleven samples were assigned Emerson Class 2, indicating moderate potential for clay dispersion. Five of these samples were yellow/brown loamy duplex (four surface soils and one subsoil). Six samples, all surface samples, were duplex sandy gravel soils.
- Four samples were assigned Emerson Class 3, indicating slight potential for clay dispersion. Three were duplex sandy gravel soils.
- No samples were assigned Emerson Class values of 4, 5, 6 or 7. Two samples, both duplex sandy gravels from pit 3, were assigned an Emerson Class value of 8, indicating natural soil aggregates did not slake or disperse, and therefore had the highest soil strength.
- Factors other than ESP, especially for yellow/brown loamy duplex soil, need to be considered when predicting potential for dispersion. Soil texture and low inherent soil strength factors also need to be considered.

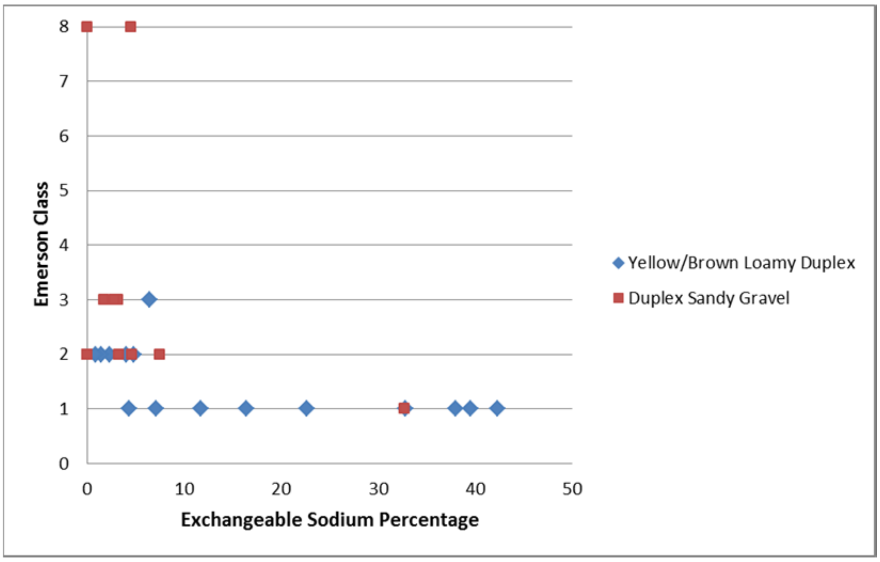

Chart 1: Comparison of Emerson Class and Exchangeable Sodium Percentage

7.2 CHEMICAL PROPERTIES

7.2.1 pH and Salinity

Results for pH and EC of 1:5 soil to water extracts are presented in Table A3-2 of Appendix 3.

Chart 2 presents histograms of pH ranges for surface and subsoils of both soil types. There is strong evidence for pedological factors playing an important role in soil pH, as summarised below:

- Surface duplex sandy gravel soils have pH values ranging from 4.7 to 6.2, indicating very strongly acidic to slightly acidic conditions according to criteria presented in Table A1-3 of Appendix 1.

- Duplex sandy gravel subsoils generally have lower pH values, with two of the three samples assessed having values of 4.2 and 4.5. The other subsoil sample assessed, sample 7B from pit 7, was moderately alkaline with a pH value of 8.4. The soil profile description of pit 7 (Appendix 2) indicates differences to other profiles of the duplex sandy gravel soil type; the subsoil contains alluvial terrace gravel, suggesting profile development over an old drainage line rather an elevated lateritic landscape.
- Surface yellow/brown loamy duplex soils have higher pH values, ranging from between 6.0 to 8.0. Most of these soils are classified as slightly acidic to circum-neutral according to criteria presented in Table A1-3 of Appendix 1.
- Yellow/brown loamy duplex subsoils have variable pH values ranging from 4.9 to 9.6. Only one sample (13B from pit 13) was very strongly acidic. The other six samples assessed were either circum-neutral to very strongly alkaline.

Chart 3 presents histograms of EC ranges for surface and subsoils of both soil types. As was observed for pH results discussed above, salinity levels are also strongly influenced by soil pedology. Key findings are summarised below:

- All surface duplex sandy gravel soils have very low EC values, with a maximum of 4 mS/m. Based on these values, the salinity rating is nil by criteria presented in Table A1-4 of Appendix 1.
- Two of the three duplex sandy gravel subsoil samples assessed also had very low EC values (3 and 6 mS/m). As was observed for pH assessment, the subsoil sample from pit 7 was anomalous, with a much higher (180 mS/m) EC. The salinity of this material is rated as extreme by criteria presented in Table A1-4 of Appendix 1.
- Yellow/brown loamy duplex surface soils had higher EC values than the duplex sandy gravel surface soils, with measured values ranging from 3 to 34 mS/m. The salinity risk ratings of these soils (Table A1-4 of Appendix 1) are nil to slight.
- Yellow/brown loamy duplex subsoils have variable EC values ranging from 3 to 350 mS/m. Only one sample (13B from pit 13) had an EC value below 20 mS/m. The other six samples assessed recorded salinity risk ratings (Table A1-4 of Appendix 1) of high to extreme, and therefore of minimal value for mine site rehabilitation.

7.2.2 Cation Exchange Characteristics

Results for exchangeable cations (including exchangeable lithium) and calculated Effective Cation Exchange Capacity (ECEC) and ESP values are presented in Table A3-5 of Appendix 3.

Chart 4 shows the ECEC ratings, based on criteria presented in Table A1-5 of Appendix 1, for surface and subsoils of both soil types. Key findings are summarised below:

- All surface duplex sandy gravel soils have relatively low ECEC, with values ranging from 0.9 to 6.6 cmol(+)/kg. Ten of the eleven samples assessed were classified as having low ECEC according to criteria presented in Table A1-4 of Appendix 1. Low ECEC values are consistent with descriptions of these surface soils as possessing sandy textures with low organic matter contents (Appendix 2).
- Yellow/brown loamy duplex surface soils had higher ECEC values, ranging from 2.6 to 32.5 cmol(+)/kg. Two samples, from pits 16 and 19, had high ECEC, with values of 28.9 and 32.5 cmol(+)/kg. Results suggest these loamy and clayey sand surface soils are “reactive clay minerals” such as illite or smectite (Appendix 1).
- As was observed with pH and EC results, duplex sandy gravel subsoil sample from pit 7 was anomalous by comparison with the other two subsoils of this soil type in that it had a much higher ECEC (15.6 cmol(+)/kg) than the other two gravelly subsoils (2.8 and 1.6 cmol(+)/kg). The low ECEC values for samples 1B and 3B are consistent with the presence of “low activity clay” (LAC) minerals. LAC minerals, mainly quartz and kaolinite, are typical of highly weathered lateritic soil profiles in WA.

- Yellow/brown loamy duplex subsoils generally had high ECEC values, ranging from 5.2 to 26 cmol(+)/kg. Results suggest these clay-rich B-horizon subsoils contain “reactive clay minerals” such as illite or smectite (Appendix 1), rather than the LAC minerals dominant in the lateritic sandplain profiles.
- Acidic surface samples, particularly the more acid duplex sandy gravel soils contained significant amounts of exchangeable aluminium (0.04 to 0.81 cmol(+)/kg)). Very high concentrations of exchangeable aluminium were present in the extremely acidic subsoil samples, with values of 2.5 and 1.3 cmol(+)/kg) in the acidic duplex sandy gravel subsoils, and 2.5 cmol(+)/kg) in the only acidic yellow/brown loamy duplex subsoil (pit 13). Exchangeable aluminium is considered phytotoxic to plant species not tolerant to acidic soil conditions and is likely to play an important role in plant species diversity on these soil types.
- Exchangeable aluminium concentrations in the acidic yellow/brown loamy duplex surface soils were lower than those of the duplex sandy gravel surface soils, with values ranging from 0.02 to 0.11 cmol(+)/kg. These values are unlikely to be phytotoxic (Table A1-5 of Appendix 1).
- Exchangeable manganese concentrations in acidic duplex sandy gravel surface were very low, with a maximum value of 0.02 cmol(+)/kg. Slightly higher concentrations (maximum 0.06 cmol (+)/kg) were present in acidic yellow/brown loamy duplex surface soils, but the levels were unlikely to be problematic to plants (Table A1-5 of Appendix 1).
- Exchangeable lithium concentrations are very low and provided no significant contribution to ECEC. Concentrations ranged from <0.0001 to 0.027 cmol(+)/kg and correlate with exchangeable sodium concentrations.

Chart 5 shows the ESP ratings, based on criteria presented in Table A1-5 of Appendix 1, for surface and subsoils of both soil types. ESP is a measure of sodicity, which is one of several factors influencing structural stability of soil. Key findings are summarised below:

- All but four of the 20 surface soils assessed were classified as non-sodic. Exceptions were:
  - Sample 7A (pit 7), a duplex sandy gravel surface soil, recording an ESP of 7.5% (moderately sodic). The anomalous pH, EC and profile characteristics for this location have been noted previously.
  - Samples 15A and 18A of yellow/brown loamy duplex soil. ESP values were 6.5% and 7.1%, respectively, classifying both samples as moderately sodic (Appendix 1).
  - Sample 6A from pit 6. This sample was collected near the toe of the WRD and was noted to contain silty oxide waste rock sediment.
- The lateritic gravelly subsoils from pits 1B and 3B, both within the duplex sandy gravel soil type, had very low ESP values (3.2% and 4.5%, respectively) and are classified as non-sodic (Appendix 1). The atypical alluvial terrace gravel subsoil (pit 7) situated in the same soil type (Figure 4) had an ESP of 32.7% and was therefore classified as highly sodic.
- Five of the seven yellow/brown loamy duplex subsoils were classified as highly sodic as a result of ESP values between 16.4% and 42.3%. Exceptions were sample 13B (also noted as being anomalous for this soil type) and 6B (pit 6 near the toe of the WRD) were classified as non-sodic (ESP 4.1%) and moderately sodic (ESP 11.7%), respectively.

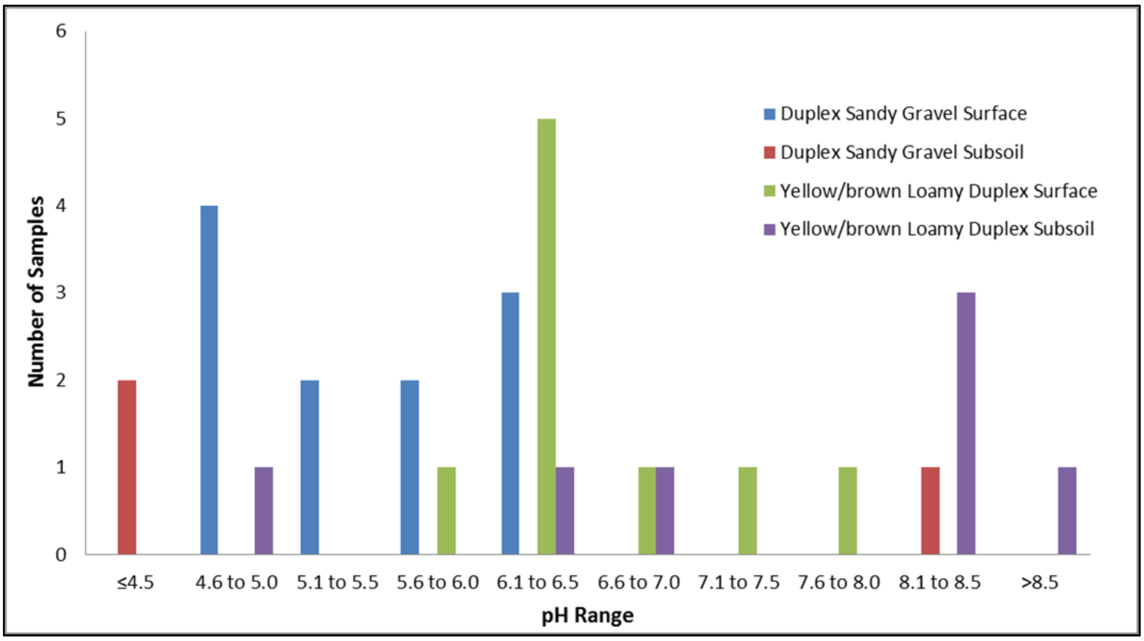

Chart 2: Distribution of pH Results

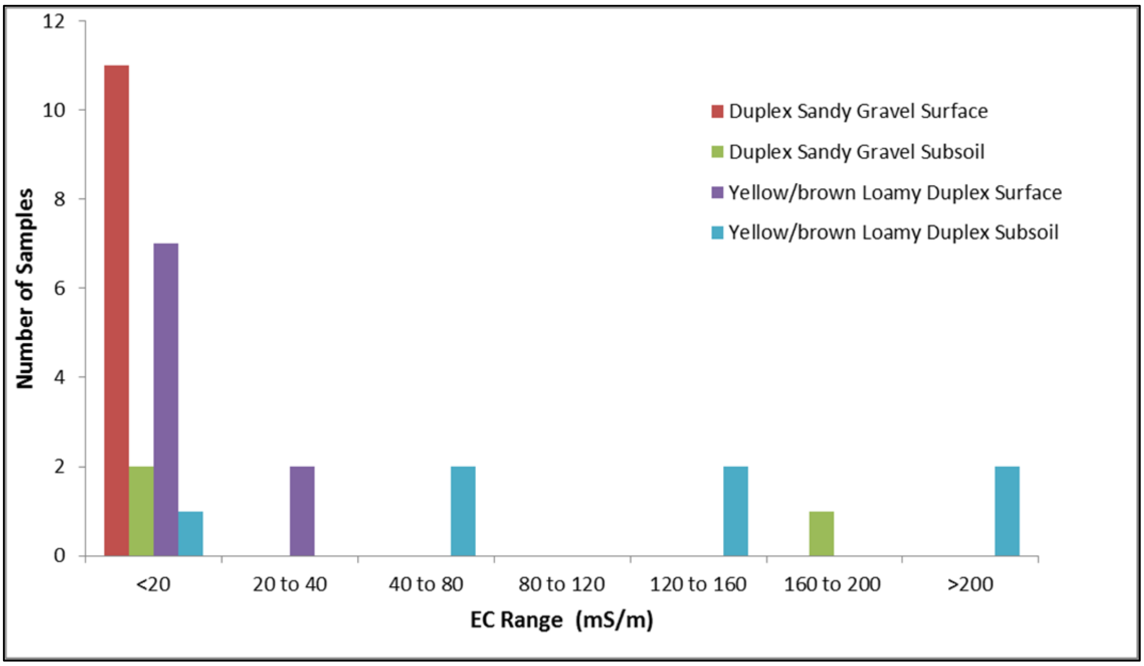

Chart 3: Distribution of EC Results

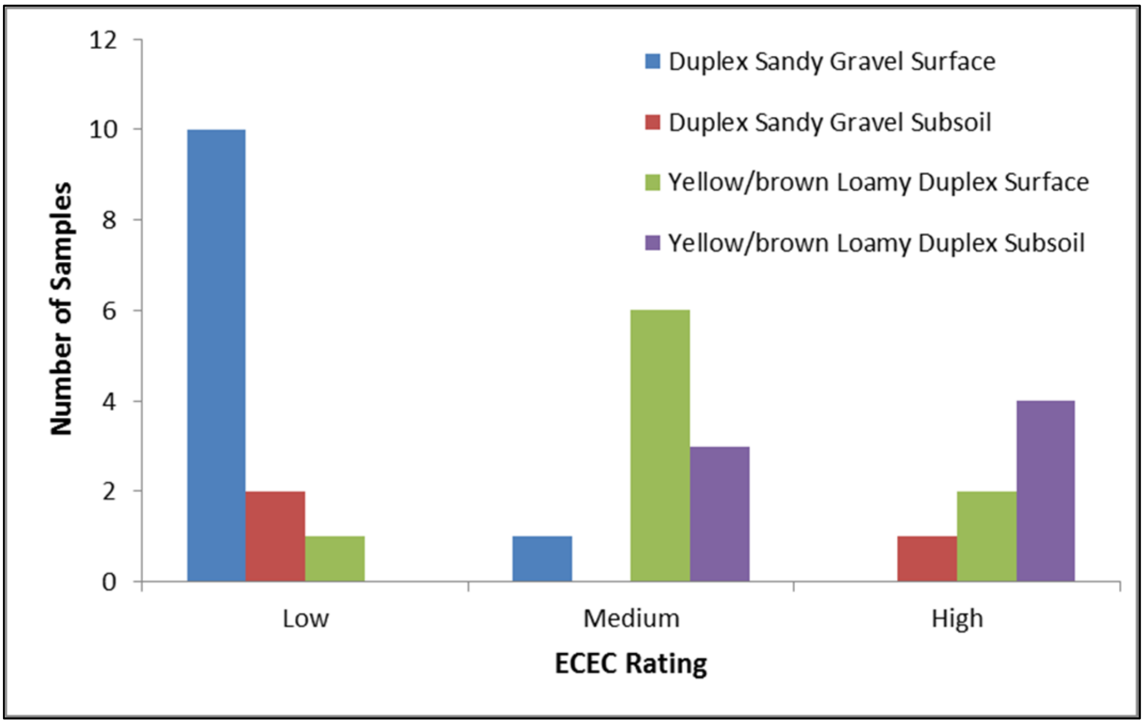

Chart 4: Distribution of ECEC Ratings

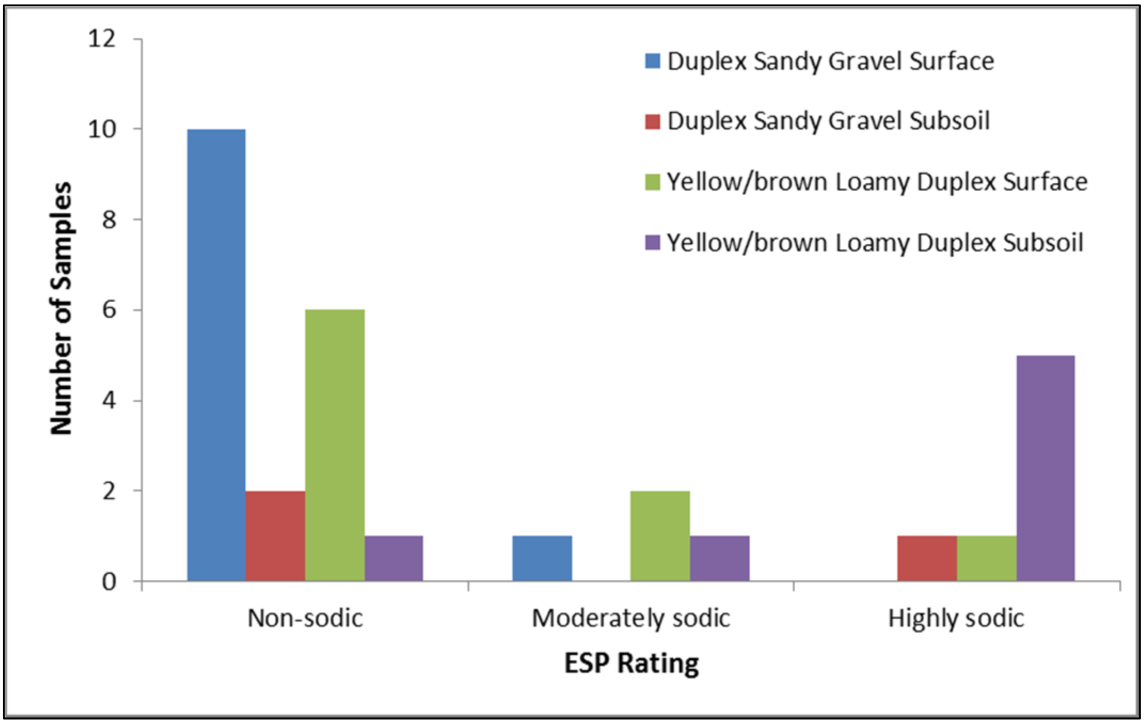

Chart 5: Distribution of ESP (Sodicity) Ratings

7.2.3 Organic Carbon and Nutrients

Results for organic carbon and extractable major nutrients in surface soil samples are presented in Table A3-6 of Appendix 3.

Organic carbon concentrations ranged from 0.61% to 1.90%, which are mainly within the medium range for eastern regions of WA (Table A1-6 of Appendix 1). The mean value for duplex sandy gravel surface soils (0.89%) was significantly lower than that for yellow/brown loamy duplex surface soils (1.26%). Higher organic carbon contents of the latter soil type are consistent with site descriptions (Appendix 2), which indicate substantially larger amounts of surface leaf litter and woody debris from eucalypt trees and shrubs.

Total nitrogen concentrations ranged from 0.024% to 0.084%, which are mainly within the medium range for eastern regions of WA (Table A1-6 of Appendix 1).

Carbon to nitrogen ratios (C/N) ranged from 15.5 to 28.1, which are rated as high by WA standards (Table A1-6 of Appendix 1). High C/N values are often associated with organic matter derived by fungal decay of carbon-rich plant debris, which is consistent with site observations (Appendix 2).

Extractable phosphorus concentrations were very low, ranging from <1 to 2 mg/kg. These results are consistent with site observations (Appendix 2) where the abundance of Proteaceous plant species was noted. Proteaceous species, such as *Banksia, Grevillia* and *Hakea*, are well adapted to very low phosphorus concentrations in WA sandy soils (Appendix 1).

Concentrations of extractable potassium, calcium, magnesium, copper, iron and manganese were within typical ranges associated with unfertilised WA soil types (Table A1-7 of Appendix 1).

Several surface soil samples, especially duplex sandy gravel soils, contained low concentrations of extractable boron and zinc, and to a lesser degree, sulfur. These nutrients are often present in very low concentrations in highly leached lateritic sandy soils in southern WA and endemic plant species have adapted to these conditions.

7.2.4 Metals and Metalloids

Concentrations of eight environmentally significant metals and metalloids for 11 selected surface soil samples are presented in Table A3-7 of Appendix 3. A statistical summary of these results is presented below in Table 4.

All concentrations are considered low by comparison with guideline values for contaminated site assessment (NEPM 1999), and therefore of no environmental significance. Samples were analysed to provide an indication of average background concentrations, which may be used to inform any future site investigations.

As with other physical and chemical soil properties, there is a significant pedological influence on metal and metalloid concentrations in the two soil types within the Project area. Concentrations of arsenic, chromium, manganese, nickel, lead and zinc were significantly higher in the yellow/brown loamy duplex soils and have a distinct geochemical signature of mafic and ultramafic rock types (AIMM 2001). While there was no evidence of (exchangeable) lithium enrichment from the pegmatite lithology, there is evidence of enrichment of arsenic, chromium and copper from gold mineralisation within the suite of mafic rock overlying the pegmatite.

Zinc concentrations in the duplex sandy gravel surface soils (<5 to 7 mg/kg) were unusually low, but consistent with low concentrations of extractable zinc available for plant nutrition (Section 7.2.3)

Table 4: Metal and Metalloid Concentrations Summary (mg/kg)

Element	As	Cd	Cr	Cu	Mn	Ni	Pb	Zn
Duplex Sandy Gravel Surface Soils								
Minimum	2	<0.05	23	1.8	10	5	3.0	<5
Maximum	7	<0.05	120	4.9	67	30	6.9	7
Mean	3.9	<0.05	69	2.5	29	15	4.2	<5
Duplex Sandy Gravel Surface Soils								
Minimum	5	<0.05	120	3.6	41	24	10	7
Maximum	51	<0.05	270	25	140	47	19	16
Mean	27	<0.05	228	12	88	36	13.6	11.4

8. CONCLUSIONS

8.1 PHYSICAL AND CHEMICAL SOIL PROPERTIES

Two physically and chemically distinctive soil types were identified within the Project area:

- Duplex sandy gravel (DAFWA Soil Group 302).
- Yellow/brown loamy duplex (DAFWA Soil Group 508)

Duplex sandy gravel soil profiles consist of a shallow gravelly sand A-horizon over a compacted lateritic gravel B-horizon. This soil type is present on topographically elevated areas and usually identified by association with sandplain heath vegetation with sparse to scattered low eucalypts. It is typically naturally strongly acidic[1] throughout (with lower pH in the B-horizon), non-saline and low in sodicity. Deeper sand phases, indicated by the presence of *Banksia* species, may become water repellent when dry.

Yellow/brown loamy duplex soil profiles consist of a shallow sandy loam A-horizon over a compacted sandy clay to clay loam B-horizon. This soil type is present on lower lying landscapes and drainage lines and usually identified by association with low eucalypt woodland and *Melaleuca* shrubs. The duplex character of profiles of this soil type is reflected by a circum-neutral, non-saline A-horizon over an alkaline, saline and highly sodic B-horizon.

Surface soils of both soil types are characterised by very low concentrations of plant-available phosphorus and relatively high C/N values.

8.2 IMPLICATIONS FOR SOIL MANAGEMENT

8.2.1 Soil Harvesting

Surface soil from both soil types is suitable for rehabilitation purposes. Topsoil of both soil types and root-bearing gravels of the duplex sandy gravel soil type within the footprint of the proposed open pit and WRD should be stockpiled for subsequent rehabilitation of disturbed areas at mine closure. A minimum of 200 mm of topsoil is expected to be available across the project area, providing approximately 2,000 m^3/ha of topsoil resources. There is no need to segregate excavated topsoils of the two soil types.

Although the gravelly B-horizon material from the duplex sandy gravel soil type is not considered a highly valued rehabilitation material by virtue of very high natural acidity and a lack of coarse gravel (>16 mm), it may be suitable as a gravelly material for road base and construction of the ROM Pad. This material should be stockpiled separately to topsoil.

B-horizon material from the yellow/brown loamy duplex is not suitable for mine site rehabilitation because of its alkaline, saline and highly sodic characteristics. Unless it is required for construction requirements (providing it has acceptable geotechnical properties), it is recommended that excavated material from the open pit footprint be managed as mine waste.

Although some of the sandier topsoil materials have potential for water repellence, this is not expected to require specific management measures for stockpiled topsoil. Such materials are expected to be inherently blended with

[1] Natural strongly acidic soils are widespread throughout the semi-arid areas of southwestern Australia. The natural acidity was caused by extended periods of intense leaching during geological periods associated with formation of lateritic landscapes. In agricultural regions, these soils are referred to as 'Wodjil' soils.

non-water repellent sands and loams during topsoil harvesting and re-spreading for rehabilitation of disturbed areas.

8.2.2 Waste Landform Rehabilitation and Mine Closure

All harvested topsoil and root-bearing gravel materials are expected to be suitable for rehabilitation of flat and very gently sloping disturbed areas at mine closure. The minimum thickness of this topsoil layer is predicted to be 200 mm.

As a consequence of very low extractable phosphorus levels and high C/N values, plants other than endemic Proteaceous species (which are adapted to very low nutrient conditions) may respond favourably to applications of low rates of a balanced fertiliser. MBS recommends a mine closure program based on field trials and progressive rehabilitation to optimise cover design, species selection and fertiliser application rates.

As a consequence of a lack of coarse gravel (greater than 16 mm) in both surface soils and non-saline subsoils, none of the soil types within the Project area are considered suitable for rehabilitation of steeply sloping waste landform surfaces. As the Project will be based on progressive open pit mining of a gently dipping lithium resource over a very large footprint, progressive backfilling of the pit void with dispersive oxide mine waste would present a very favourable scenario for effective mine closure.

Cover design for steeply sloping landforms will require blending with benign, competent mine waste and/or gravel rejects. As stated above, MBS recommends a mine closure program based on field trials and progressive rehabilitation to optimise cover thickness and soil – waste rock blend ratios. Although the surface soils generally have low sodicity, they are predicted to have very low wet soil strength as a consequence of their sandy texture and therefore be easily erodible on a sloping surface. For this reason, the soil cover on steeply sloping surfaces should be as thin as practicable, as determined through trials, and blended with a minimum of 60% by weight of non-acid forming (NAF), low salinity, competent waste rock.

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APPENDICES

APPENDIX 1: SOIL ASSESSMENT METHODOLOGY

SOIL ASSESSMENT METHODOLOGY

1. INTRODUCTION

1.1 SOIL TEST METHODOLOGY

Understanding the physical, chemical and biological properties of soils is dependent on the ability of scientists and land managers to critically evaluate and assess data provided by meaningful soil tests. A multitude of different soil tests, often intended to measure the same soil quality parameter, have been developed over many years for various reasons, including:

- Characterisation of the diversity of soil types around the world with widely different physical and chemical properties.
- Cost - market forces by land managers, especially farmers, have driven development of soil tests that are simple, rapid and cheap to form, even though technically superior procedures exist.
- Speed of assessment: Rapid advances in laboratory automation, technical capabilities of modern instruments and data management systems.
- Increasing demands to deal with emerging issues of natural resource management including sustainability issues, environmental protection, soil health and food safety.

Unlike water and geological analysis, total elemental composition of soils generally provides will little predictive capacity for assessing the ability of soil to provide necessary levels of nutrients for good plant growth. For this reason, different soil tests for specific nutrients have been developed using extracting solutions that mimic the role of plant roots for taking up nutrients from soil.

In recent times, there have been attempts by various organisations to standardise laboratory methods throughout Australia. Most government and commercial soil testing laboratories in Australia now use standard methods, or validated variations derived from the following sources:

- Chemical analysis for agriculture and land management: Soil Chemical Methods – Australian (Rayment and Lyons 2011).
- Environmental assessment: NEPM. 2013. National Environment Protection (Assessment of Site Contamination) Measure. Guideline on Laboratory Analysis of Potentially Contaminated Soil. Schedule B3. National Environment Protection Council.
- Physical and engineering properties of soil: Australian Standard AS 1289.0-2000.

MBS Environmental provides soil characterisation assessments, mainly for the mining industry in WA and other Australian states, to inform pre-feasibility studies, mining proposals and closure planning to meet regulators' requirements. Soil test data and interpretation is provided to meet the following objectives:

- Properties of regional and project areas soils in terms of:
  - Physicochemical attributes including acidity, alkalinity, salinity, sodicity, texture, fertility and structural stability.
  - An indication of the volumes of suitable topsoils and subsoils that can be harvested and stockpiled for rehabilitation activities.
  - Ability to assimilate potential environmental contaminants such as hydrocarbons, metals, metalloids, nutrients, salts, acidity and pathogens.
- Achieving acceptable mine closure outcomes to provide a land surface that is:
  - Structurally stable and safe.
  - Non-polluting (surface water run-off, groundwater and air quality).

- Compatible with post-mineral land use requirements.

Note that MBS Environmental does not offer geophysical and geotechnical soil assessment for engineering purposes such as constructions of roads, structures and water storages.

1.2 INFORMATION SOURCES

Interpretation of laboratory and field soil testing results and observations requires not only accurate data, but also a "Decision Support System" that provides meaningful predictions of soil properties and behaviour. A reliable Decision Support System needs to be:

- Developed and validated for local conditions including soil types, climate and land use.
- Able to predict soil constraints that may limit productivity and health of vegetation including:
  - Crop plants for agricultural land use on different soil types and environmental settings.
  - Pasture and feed value for pastoral land use.
  - Native plants for rehabilitation of degraded or disturbed areas, especially for WA plant species that are specially adapted to low nutrient and poorly structured soils.
- Able to quantify the risk of ecological and human health impacts for a specific location relating to:
  - Heavy metals and metalloids.
  - Nutrient runoff and leaching.
  - Petroleum hydrocarbons.
  - Agro-chemicals including insecticides and herbicides.

There is an enormous volume of interpretative soil test information available in response to the diversity of soil test methods and differences in soil types throughout the world. However, it is important that the information used be validated against local conditions and for this reason, much of the information published by reputable authorities in overseas countries is not applicable to Australian conditions.

The following sources of information are used by MBS Environmental to assess the significance of laboratory test results:

- Soil Analysis: An Interpretation Manual (Peverill *et al.* 1999). This reference was compiled by specialists from CSIRO and State Government agricultural research agencies. It is biased towards agricultural production, mainly in the eastern states, although it does reference large volumes of research provided by WA researchers between 1960 and 1998.
- Interpreting Soil Test Results. What do all the numbers mean? (Hazelton and Murphy 2007). This document was written specifically for officers in the former Soil Conservation Service of NSW, but is now used widely by soil professionals in other Australian States.
- Soil Guide. A handbook for understanding and managing agricultural soils. DAFWA Bulletin 4343 (DAFWA 2001). This document was prepared specifically for WA agricultural land use.
- Land Evaluation Standards for Land Resource Mapping (assessing land qualities and determining land capability in south-western Australia). DAFWA Resource Management Technical Report 298 (DAFWA 2006). This report describes the standard method for attributing and evaluating conventional land resource survey maps in the south-west agriculture region of Western Australia so that strategic decisions about the management, development and conservation of land resources can be based on the best information available.

- Soilquality.org.au website, with contributions from the University of Western Australia, DAFWA, Wheatbelt Natural Resource Management, Grains Research & Development Corporation, South Coast Natural Resource Management and the Grower Group Alliance.

MBS Environmental also draws upon the author's experience from coordinating physical and chemical laboratory analysis for DAFWA and DPaw soil and biological surveys conducted between 1988 and 2008. These include:

- Reference soils of south-western Australia (McArthur 1991). This publication presents soil profile descriptions and laboratory analysis of samples from the O, A and B soil horizons from 161 locations between Geraldton and Esperance in south-western Australia.
- Laboratory soil test results for about 10,000 soil samples from soil surveys of WA conducted by DAFWA between 1989 and 2007. Details of these surveys are presented in DAFWA Resource Management Technical Report 280, Soil-Landscape Mapping in South-Western Australia, Overview of methodology and outputs (DAFWA 2004).
- Soil analysis data to support the following biological surveys conducted by the Department of Parks and Wildlife (DPaW):
    - Pilbara region biological survey, 2002-2007 (George *et al*. 2009).
    - Floristic surveys of the banded iron formation ranges of the Yilgarn, 2005 to 2008 (Meissner and Caruso, 2008).
    - Wetland flora and vegetation of the WA wheatbelt, 2004.

2. PHYSICAL PROPERTIES

2.1 PARTICLE SIZE AND TEXTURE

2.1.1 Field Measurements

Soil texture describes the proportions of sand, silt and clay particles; the particle size distribution. Sands are mineral particles with an effective diameter between 0.02 and 2 mm, silt from 0.002 to 0.02 mm and clay less than 0.002 mm.

The field (or hand texture) of soil can be assigned by describing the behaviour of a sample of field sieved (<2 mm) soil when moistened to field capacity and kneaded into a ball or bolus and then pressed out between the thumb and forefinger to form a ribbon (bolus) (McDonald *et al.* 1990). The behaviour of the soil during bolus formation and the length of the ribbon define the field texture grade, as summarised in Table A1-1.

Table A1-1: Field Texture Grades

Texture Grade	Behaviour of Moist Bolus	Approximate Clay Content
Sand	Nil to very slight coherence; cannot be moulded; single sand grains adhere to fingers	<5%
Loamy sand	Slight coherence; can be sheared between thumb and forefinger to give a small ribbon (~5 mm)	About 5%
Clayey sand	Slight coherence; sticky when wet; many sand grains stick to fingers, discolours fingers with stain; ribbon 5 to 15 mm	5-10%
Sandy loam	Coherent bolus but very gritty; dominant sand grains of medium size and readily visible; ribbon of 15 to 25 mm	10-20%

Texture Grade	Behaviour of Moist Bolus	Approximate Clay Content
Loam	Bolus coherent and spongy; no obvious grittiness or silkiness; ribbon about 25 mm	About 25%
Sandy clay loam	Strongly coherent bolus; sandy to touch; ribbon of 25 to 40 mm	20-30%
Clay loam	Coherent plastic bolus; smooth to manipulate; ribbon of 40 to 50 mm	30-35%
Clay loam, sandy	Coherent plastic bolus; sand grains visible in finer matrix; ribbon of 40 to 50 mm	30-35%
Light clay	Plastic bolus; smooth to touch; slight resistance to shearing; ribbon of 50 to 75 mm	35-40%
Light medium clay	Ribbon of about 75 mm; slight to moderate resistance to ribboning shear	40-45%
Medium clay	Smooth plastic bolus; can be moulded into rods without fracture; moderate resistance to ribboning shear; ribbons 75 mm of longer	45-55%
Medium heavy clay	Ribbons of 75 mm or longer; moderate to firm resistance to ribboning shear	≥50%
Heavy clay	Extremely plastic; firm resistance to ribboning shear; ribbons of 75 mm or longer	≥50%

2.1.2 Laboratory Measurements

Soil texture assessment can be undertaken by two distinct laboratory methodologies:

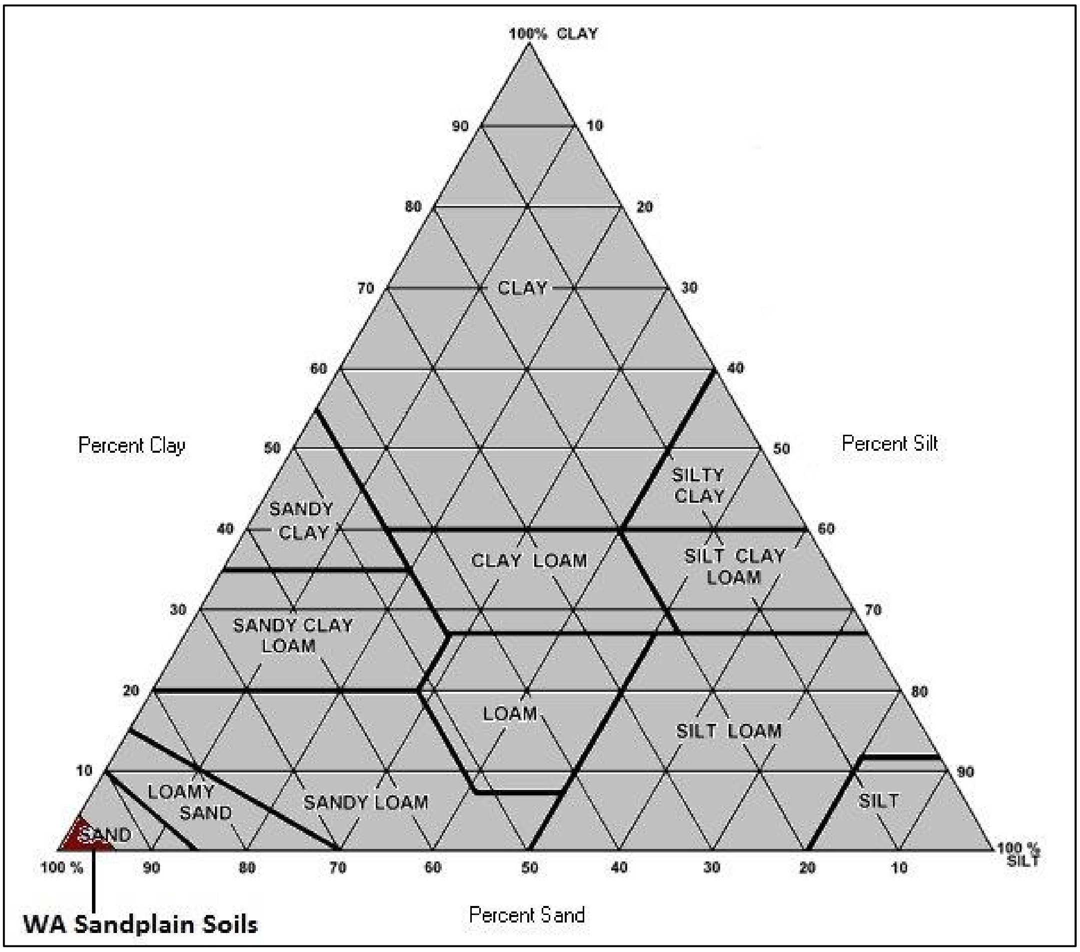
- Particle size determination. This method involves determination of the relative proportions of and, silt and clay sized particles, usually by a combination of sedimentation (hydrometer measurements) and sieving, and classifying the sol texture using the "soil texture triangle" (Figure 1). The method is preferred by land capability and land management professionals.
- Atterberg limits. This methodology, favoured by engineers, classifies soil on the basis of measurements for:
    - Plastic limit, defined as the amount of water added to dry soil to reach a plastic state.
    - Liquid limit, defined as the amount of water added to dry soil to reach a fluid state.
    - Plasticity Index, defined as the difference between the liquid limit (% by weight, dry soil basis) and plastic limit ((% by weight, dry soil basis).

In most cases, field texture grades align well with laboratory based classifications. Poor correlation is occasionally observed for unusual soil types, especially highly saline soils and compacted ferruginous soils (plinthites).

Soil texture information based on laboratory particle size measurements is often used to predict other soil physical characteristics such as hydraulic permeability and water holding capacity (DAFWA 2004). Although laboratory tests are available for direct measurement of these properties, the methodology is comparatively expensive and requires specific sample collection and preservation techniques.

The southwest and arid interior of WA is represented by vast tracts of sandplain, especially dune fields in the Great Sandy and Great Victoria Deserts and coastal plains between Geraldton and Esperance. The sandy nature of these soils in indicated in Figure 1.

Figure 1: Soil Texture Triangle



2.2 DISPERSION POTENTIAL

The structural stability of loams and clay soils can be assessed by a simple field test referred to as the Emerson aggregate test (AS 1289 C8.1 1980). The test involves observation of the behaviour of natural soil aggregates (peds) and subsamples of soil remoulded at field capacity when placed in deionised water. Poorly structured soils, often containing sodic clays (Section 3.3), exhibit low strength when wet, resulting in rapid slaking of aggregates and dispersion of fine clays, resulting in a cloudy halo when placed in deionised water.

The Emerson Aggregate Test provides an Emerson class number ranging from 1 to 8, with Emerson class number 1 indicating soils with weak structure and high potential for clay dispersion, while Emerson class number 8 indicating soils that do not slake, swell or disperse when placed in water. Soil aggregates that slake and disperse readily (Emerson class numbers 1, 2 and 3) indicate weak structure that is easily disrupted by raindrop impact or mechanical disturbance and therefore prone to water erosion, especially on sloping landforms.

The Emerson aggregate test requires submission of a field sample in which natural aggregates have been preserved and not destroyed by crushing and grinding. For this reason, samples provided by reverse circulation drilling are not suitable.

Description of Emersion class numbers are presented in Table A1:2.

Table A1:2: Emerson Aggregate Test Class Numbers

Class Number	Description
Class 1	Dry aggregates slake and completely disperse within several hours.
Class 2	Dry aggregates slake and partly disperse after 24 hours.
Class 3a	Dry aggregates slake but do not disperse. Remoulded soil disperses completely.
Class 3b	Dry aggregates slake but do not disperse. Remoulded soil partly disperses.
Class 4	Dry aggregates slake but do not disperse. Remoulded soil does not disperse. Soil contains free carbonate minerals and / or gypsum.
Class 5	Dry aggregates slake but do not disperse. Remoulded soil does not disperse. No carbonates or gypsum present. 1:5 suspension in water remains dispersed
Class 6	Dry aggregates slake but do not disperse. Remoulded soil does not disperse. No carbonates or gypsum present. 1:5 suspension in water flocculates.
Class 7	Dry aggregates do not slake. Aggregates swell.
Class 8	Dry aggregates do not slake. Aggregates do not swell.

3. CHEMICAL PROPERTIES

3.1 PH

As with many measurements on soil, pH values vary with the procedure used. Being a solution measurement, pH of dry soil is effectively meaningless. Soil pH estimates are undertaken in the laboratory by shaking a sample of dry, sieved soil with a standard volume of either deionised water or a dilute salt solution, followed by pH measurement with a calibrated pH meter. pH measurements using deionised water at a sample : solution ratio of 1:5 are widely used for land capability assessment, while use of 0.01 M calcium chloride as the equilibrating solution is preferred for agricultural purposes as this method has been shown by researchers as a superior indicator of phytotoxicity of soil.

The soil pH rating Table adopted for use by MBS Environmental is presented in Table A1-3. The rating table applies to measurements using the 1:5 deionised water extraction method.

Table A1-3: Soil pH Rating Table

pH Range	Rating
1.8 - 3.4	Ultra acid
3.5 - 4.4	Extremely acid
4.5 - 5.0	Very strongly acid
5.1 - 5.5	Strongly acid
5.6 - 6.0	Moderately acid
6.1 - 6.5	Slightly acid
6.6 - 7.3	Circum-neutral
7.4 - 7.8	Slightly alkaline
7.9 - 8.4	Moderately alkaline
8.5 - 9.0	Strongly alkaline
9.1 - 10	Very strongly alkaline
>10	Ultra alkaline

From Rayment and Lyons (2011), adapted from Bruce and Rayment 1982 and USDA 2004.

3.2 ELECTRICAL CONDUCTIVITY AND SALINITY

Measurement of electrical conductivity (EC) of recovered soil porewater, or more commonly either porewater recovered after wetting the sample to saturation or using the 1:5 soil:water extract from pH measurement. EC of the saturation extract is referred to as ECe, while EC of the 1:5 soil:water extract is referred to as EC (1:5).

ECe is considered to be the superior indication of salinity; values of <200 mS/m indicate very low salinity, while values >1,600 indicate high salinity, regardless of the soil type. However, measurement of ECe involves a labour intensive test method and therefore not commonly requested. Salinity risk assessment based on EC (1:5) measurements need to consider the soil type. Table A1-4 presents soil salinity rating classes used by MBS Environmental for sand, loam and clay soil types.

Table A1-4: Salinity Rating Table

Soil Type	Salinity Rating Based on EC (1:5) (mS/m)				
	Nil	Slight	Moderate	High	Extreme
Sand	0 – 15	15 - 25	25 – 50	50 – 100	>100
Loam	0 – 20	20 – 35	35 – 70	70 – 150	>150
Clay	0 - 25	25 - 50	50 - 100	100 - 200	>200

3.3 EXCHANGEABLE CATIONS

The ability of soil to behave as a cation exchange material has been known for more than a century. The major soil cations fall into two distinct groups:

- Basic soil cations comprising Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}.
- Acidic cations comprising H^{+}, Al^{3+} and Mn^{2+}. The sum of these cations is referred to as either “exchangeable” or “titratable” acidity.

At a fixed pH, the sum of all soil cations (when expressed in units of centimoles of positive charge per kilogram, cmol(+)/kg) is constant. This value is referred to as the Cation Exchange Capacity (CEC), which is measured at either pH 7 for circum-neutral soils or pH 8.5 for soils containing free calcium carbonate.

The main soil components contributing to CEC are organic matter and clay minerals. CEC values typically range from <2 cmol(+)/kg) for highly weathered siliceous sands, to 10 cmol(+)/kg) for clay loam soils containing kaolinite as the dominant clay mineral, to greater than 50 cmol(+)/kg) for soils containing clay minerals belonging to the smectite (montmorillonite) or illite group. CEC is an important property for productive agricultural soils as it plays a major role in retention of essential plant nutrients and influencing the physical structure of clay rich soil types.

While most laboratories provide cost-effective methods for measuring soil CEC, it is more common to measure the individual soil cations after extraction with ammonium chloride solution (at either pH 7 or pH 8.5). These procedures are effective at extracting the basic soil cations, but the acidic soil cations are not extracted. For circum-neutral and alkaline soil types, the sum of the concentrations of basic soil cations is very close to the measured CEC. In such cases, the sum of the basic soil cations (expressed in units of cmol(+)/kg)) is referred to as Effective CEC (ECEC).

For acidic soils, the contribution of the acidic soil cations becomes increasingly significant. In such cases, ECEC calculation requires inclusion of the ‘exchangeable acidity” component. Alternatively, use of unbuffered 0.1 M barium chloride as the cation displacing extractant allows for measurement of extraction aluminium and manganese, in addition to the basic soil cations. Although exchangeable hydrogen has not been measured, this sum of the basic cations plus exchangeable aluminium and manganese provides an acceptable estimate of ECEC.

The relative proportions of the four basic cations play a major role on the structure of clay rich soil type. Calcium, magnesium and potassium are essential plant nutrients and contribute to good soil structure by allowing effective exchange of air and water into the soil matrix during both wetting and drying cycles. Exchangeable sodium, however, is not conducive to good soil structure and sodium rich (sodic) clays are prone to spontaneous dispersion (Section 2.2), resulting in hard-setting soils when dry and highly erodible soils when saturated.

The acidic soil cations are also undesirable components of a healthy soil, particularly the aluminium component as soluble aluminium is phytotoxic to plants. Elevated concentrations of soluble manganese, which is associated with high concentrations of exchangeable manganese in acidic soils, may also be phytotoxic.

Two important derived parameters from exchangeable cation soil measurements are Base Saturation Percentage (BS%) and Exchangeable Sodium Percentage (ESP). BS% is the sum of the basic soil cations divided by the measured CEC (or ECEC if exchangeable acidity has been measured) and expressed as a percentage. Circum-neutral and alkaline soils have very high BS% values, while acidic soils may have much lower BS% values. BS% provides a better indication of potential soil acidity problems than pH measurements. For example, a soil with a pH of 4.5 and BS% of 30% is likely to be toxic to plants, while a soil with pH of 4.5 and BS% of 80% may not be toxic.

ESP is the exchangeable sodium concentration divided by the measured CEC (or ECEC for circum-neutral and alkaline soils) and expressed as a percentage. ESP values as low as 6% can be responsible for poor structure. ESP values greater than 6% identify sodic soils (Northcote and Skene 1972), which are highly susceptible to structural degradation and erosion.

Table A1-5: Ratings for Exchangeable Cations and Related Parameters

Parameter	Units	Rating		
		Low	Medium	High
CEC	cmol(+)/kg	<5	5 - 15	>15
Calcium	cmol(+)/kg	<5	5 - 10	>10
Magnesium	cmol(+)/kg	<1	1 - 5	>5
Sodium	cmol(+)/kg	<0.3	0.3 – 1.0	>1.0
Potassium	cmol(+)/kg	<0.5	0.5 -2.0	>2.0
Aluminium	cmol(+)/kg	<0.1	0.1 – 1.0	>1.0
Manganese	cmol(+)/kg	<0.02	0.02 – 1.0	>1.0
BS%	%	<20	20 - 60	>60
ESP	%	<6 (non-sodic)	6 – 15 (moderately sodic)	>15 (highly sodic)

Adapted from DAFWA 2004.

3.4 ORGANIC CARBON AND SOIL NITROGEN

Soil organic matter is a critical component of a healthy soil. It plays a major role in maintaining good soil structure, retaining moisture and nutrients and a source of food and energy for soil microbial activity.

Soil organic matter contains 45% to 55% carbon, with most of the balance being oxygen, hydrogen and nitrogen, with lower but still important concentrations of phosphorus and sulfur. There are two reliable laboratory methods for measuring soil organic carbon, which is a very good indicator of soil organic matter content:

- Wet oxidation, with the Walkley and Black method (Walkley and Black 1934) being the most common variation.
- Combustion, occasionally referred to as LECO® Total Organic Carbon.

By international standards, WA soils contain low concentrations of organic carbon. Organic carbon content is dependent upon soil texture and climate, with sandy soils and soil from tropical northern WA and arid central WA containing lower carbon contents (typically <1% in topsoil) compared to clay and loam soils from the temperature southwest corner of WA.

Soil organic matter is also responsible for most of the total nitrogen content of soil, with the remainder (typically <5% of total nitrogen) being in the mineral ammonium (NH_4^+) and nitrate (NO_3^-) forms. Mineralisation of soil organic matter by microbial activity can convert some of this organic nitrogen into mineral nitrogen, which is then available for uptake by plants. However, the amount of nitrogen that can be released by mineralisation is variable and determined largely by the ratio of organic carbon to nitrogen (C/N ratio). For soils with low C/N ratios, mineralisation of soil organic matter releases substantial amounts of mineral nitrogen. Alternatively, microbes breaking down carbon rich soil organic matter require more nitrogen than is available from organic matter, resulting in removal of mineral forms of nitrogen naturally present in soil. This is known as “nitrogen drawdown” and is common when carbon rich woody mulch or leaf litter is added to soil as a soil conditioner or water retentive mulch. Ratings descriptions for organic carbon, total nitrogen and C/N ratio are presented in Table A1-6.

Table A1-6: Ratings Table for Organic Carbon, Total Nitrogen and C/N Ratio

Parameter	Rating		
	Low	Medium	High
Organic carbon, A1 horizon, northern and eastern WA	<0.5%	0.5 – 1.5%	>1.5%
Organic carbon, A2 and B horizon, northern and eastern WA	<0.05%	0.05 – 0.3%	>0.3%
Organic carbon, A1 horizon, southwest WA	<1%	1 – 2%	>2%
Organic carbon, A2 and B horizon, southwest WA	<0.1%	0.1 – 0.5%	>0.5%
Total nitrogen, A1 horizon, northern and eastern WA	<0.05%	0.05 – 0.3%	>0.3%
Total nitrogen, A1 horizon, southwest WA	<0.1	0.1 – 0.5%	>0.5%
Total nitrogen, A2 and B horizons	Generally not measured		
C/N ratio	<10	10 - 16	>16

Adapted from DAFWA 2004.

3.5 BIOAVAILABLE NUTRIENTS

Soil testing is widely used for diagnosing potential nutrient deficiencies and imbalances in soils used for agriculture. Large fertiliser companies often provide cost-effective soil testing packages that provide fertiliser recommendations based on soil test results.

The decision support systems required for provision of reliable fertiliser recommendations based on soil test require a large volume of calibration data based on field trials conducted over many years for different crop plants and on different soil types. The soil tests used also vary for different nutrients as summarised below:

- Phosphorus and potassium use 0.5 M sodium bicarbonate.
- Sulfur uses 0.25 M potassium chloride.
- Boron uses extraction with hot 0.01 M calcium chloride solution.
- Multi-element test for micro-nutrients (Cu, Fe, Mn and Zn) uses 0.005 M DTPA solution.

With the exception of phosphorus (Handreck 1997a and 1997b), there is very little published information available that relates nutrient soil test results with the health of Australian native plants. Also, native plant establishment on disturbed WA soil types is considered to be limited mainly of constraints such as low water holding capacity, salinity or elevated acidity/alkalinity rather than nutrient deficiencies or imbalances. Even in circumstances where nutrient deficiency has been identified as a potential limitation for rehabilitating disturbed sites with WA native plants, land managers are often reluctant to apply additional nutrients in the form of organic or chemical fertilisers on the potential for promoting weed establishment.

MBS Environmental has adopted the Mehlich 3 multi-element soil test methodology (Mehlich 1984) as a cost-effective alternative method to the suite of nutrient soil tests listed above to assess mine site soils for potential nutrient deficiencies, toxicity or imbalance that may affect revegetation outcomes. Concentrations assigned to low, typical and elevated ranges presented in Table A1-7 were derived from the following information:

- Correlations between calibrated single nutrient soil test values (specific for each nutrient) and plant response, typically crop plants under glasshouse or controlled field experiments (Peverill et al. 1999).
- Correlations between Mehlich 3 and calibrated single nutrient soil test results (Walton and Allen 2004). Most of the single nutrient tests correlate well the Mehlich 3 test for acidic, neutral and slightly alkaline (but non-calcareous) WA soil types.
- Results for surface samples analysed from DAFWA and DPaW soil surveys (Section 1.2) and previous mine site surveys conducted by MBS Environmental.

The "Low" rating corresponds approximately to the lowest fifth percentile of unfertilised WA surface soil types and indicates conditions that may result in deficiency to plants not adapted to very low nutrient concentrations in soils. These soil types are often highly weathered siliceous sands in moderate to high rainfall areas in the southwest of WA.

The "Elevated" rating corresponds approximately to the 95th percentile of unfertilised WA surface soil types and may indicate conditions resulting in either nutrient imbalances or toxicities to plant not adapted to high nutrient (especially micronutrients such as boron) concentrations.

Table A1-7: Ratings Table for Bio-available Nutrients (mg/kg), Mehlich 3 Test

Nutrient	Rating		
	Low	Typical Range	Elevated
Phosphorus	<2	2 - 10	>10
Potassium	<10	10 - 300	>300
Calcium	<50	50 – 5,000	>5,000
Magnesium	<20	20 – 2,000	>2,000
Sulfur	<5	5 - 200	>200
Boron	<0.1	0.1 - 2	>2
Copper	<0.1	0.1 - 5	>5
Iron	<10	10 – 200	>200
Manganese	<5	5 - 100	>100
Molybdenum	<0.01	0.01 – 0.05	>0.05
Zinc	<0.2	0.2 - 5	>5

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APPENDIX 2: SOIL PROFILE DESCRIPTIONS

Site	Pit 1	**GPS Coordinates**	50H	759743 6446360	mE mS	Page 1 of 21
Locality	Earl Grey	**Date**	9-Nov-16		**Time**	7:30

Vegetation and Landscape	
Slope:	Gently undulating, slope <5º to north-east. Elevation 435 mAHD
Vegetation:	Acacia shrubland to 1.5m over low Melaleuca open heath. Plant roots concentrated in A horizon with some penetration into B horizon.
Landscape:	Sand plain

Pit Notes

Horizon	*Description*
Surface	Thick leaf litter. Weakly crusting surface. Yellow/brown loamy sand. Sparse sub-rounded gravel to 20 mm.
A 0 - 150 mm	Yellow/brown, Loamy sand. 15% gravel, mainly fine (2-5mm) and rounded. Not sticky. Apedal.
B1 150 - 600 mm	Very firm, yellow/brown loamy sand with red mottling. Difficultly friable. Ferruginous. Not sticky.
B2 600 - 1000 mm	Less gravel, mottled (ferruginous), very firm and compact. Slightly sticky. Loamy sand. 15% clay.
Spoil	Minimal structure.
Sample Register	1A 0 -100 mm 1B 150 - 600 mm

Photo 1: Soil Profile

Photo 2: Landscape

Site	Pit 2	GPS Coordinates	50H	759694 6446694	mE mS	Page 2 of 21
Locality	Earl Grey	**Date**	9-Nov-16		**Time**	8:34AM

Vegetation and Landscape

Slope:	Flat. Elevation 446 mAHD.
Vegetation:	Rehabilitated. Mixed Acacia and Melaleuca open shrubland with scattered Eucalyptus sp.
Landscape:	Sand plain adjacent (ca. 100 m) to waste dump. Rehabilitated.

Pit Notes

Horizon	*Description*
Surface	Minimal leaf litter. Very sparse gravel lag.
A1	Loose, fine, yellow/brown sand. Weak pedal development. Sparse gravel.
B1	Yellow/brown loamy sand matrix. Compacted and gravelly. Good to tough, massive structure.
B2	Loamy sand matrix. More ferruginous mottling, difficultly friable gravel.
Spoil	Minimal structure.
Sample Register	

Photo 1: Soil Profile

Photo 2: Landscape

Site	Pit 3	**GPS Coordinates**	50H 759996 mE 6446799 mS		Page 3 of 21
Locality	Earl Grey	**Date**	9-Nov-16	**Time**	9:02AM

Vegetation and Landscape	
Slope:	Gentle slope to south <1%. Elevation 441 mAHD.
Vegetation:	Acacia low open heath with scattered Callitris and Eucalyptus spp.
Landscape:	Sand plain

Pit Notes

Horizon	*Description*
Surface	No crust. No gravel lag.
A1 0 - 100 mm	Fine/medium yellow/brown sand. Very little gravel (<5%). Reasonable dust generation. Not water repellent. Genuine sand. Cannot make bolus. Wind blown, poorly sorted.
A2 100 - 400 mm	Yellow/brown fine sand. Very loose. Virtually all sand with a little fine gravel.
B1 400 - 800 mm	Uniform yellow/grey sub-rounded gravel in fine sand.
B3 ≥800 mm	Ferruginous base. Tough. Indurated. Lightly compact. Genuine hardpan.
Spoil	Mostly sand with some gravel
Sample Register	3A 0 - 100 mm 3B 500 - 600 mm

Photo 1: Soil Profile

Photo 2: Landscape

Site	Pit 4	**GPS Coordinates**	50H 759795 mE 6446590 mS		Page 4 of 21
Locality	Earl Grey	**Date**	9-Nov-16	**Time**	9:31AM

Vegetation and Landscape

Slope:	Gently undulating. Slight slope to south. Elevation 444 mAHD.
Vegetation:	Acacia shrubland over Melaleuca low open heath.
Landscape:	Sand plain.

Pit Notes

Horizon	*Description*
Surface	Some leaf litter. Weak cryptogamic crust. Very little organic horizon other than crust. Slight dust potential.
A1 0 - 250 mm	Silty sand. Gradation colour change from brown/grey to brown/yellow to depth. Loose with some consolidation at depth. Very little gravel; where it occurs it is sub-rounded and very fine (2-4 mm). Stickier than other samples.
B1 250 - 600 mm	Compacted by friable gravel in a silty sand matrix. Weakly mottled.
B2 ≥600 mm	Difficultly friable. Ferruginous sandy gravel.
Sample Register	4A 0 - 100 mm

Photo 1: Soil Profile

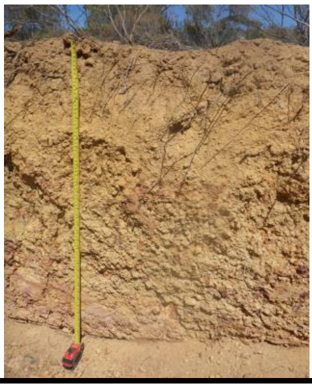

Photo 2: Landscape

Site	Pit 5	**GPS Coordinates**	**50H**	759537 6447296	mE mS	
Locality	Earl Grey	**Date**	9-Nov-16		**Time**	10:09AM

Vegetation and Landscape

Slope:	Gentle slope 5º to south.
Vegetation:	Low open Eucalyptus woodland over Melaleuca shrubland.
Landscape:	Sand plain.

Pit Notes

Horizon	*Description*
Surface	Thick cryptogamic crust. Surface not cracking. Medium gravel surface lag. Some find leaf litter. Gravel 30 - 40%. Fine, sub-rounded to sub-angular gravel. Sandy loam.
A1 0 - 200 mm	No organic matter. Yellow/orange/brown sandy loam.
B1 200 - 500 mm	Compacted, friable, firm, sandy clay.
B2 ≥500 mm	Diffuse boundary between B1 and B2 horizons. Weakly mottled siliceous sandy clay. Increasingly compacted with depth.
Spoil	Platey structure. Cracking in test pit floor.
Sample Register	5A 0 - 50 mm 5B 500 - 600 mm

Photo 1: Soil Profile

Photo 2: Landscape

Site	Pit 6	**GPS Coordinates**	50 H 759584 mE 6447139 mS		Page 6 of 21
Locality	Earl Grey	**Date**	9-Nov-16	**Time**	10:45AM

Vegetation and Landscape

Slope:	Relatively flat, slight slope away form waste dump. Elevation 447 mAHD.
Vegetation:	Adjacent to rehabilitated waste dump characterised by scattered Eucalyptus. Surrounding vegetation comprised low open Eucalyptus woodland over open Melaleuca shrubland.
Landscape:	Rehabiliated sand plain adjacent to rehabilitated waste dump.

Pit Notes

Horizon	*Description*
Surface	Some leaf litter present. Colluvium from waste dump.
A1 0 - 100 mm	Light grey/brown silty sand. Colluvium form waste dump.
B1 100 - 600+ mm	Medium brown clayey sand. Very compacted with next to no gravel. Heavily disturbed - no pedogenic development.
Sample Register	6A 0 - 100 mm 6B 500 - 600 mm

Photo 1: Soil Profile

Photo 2: Landscape

Site	Pit 7	**GPS Coordinates**	50H 759401 mE 6447250 mS		Page 7 of 21
Locality	Earl Grey	**Date**	9-Nov-16	**Time**	11:27AM

Vegetation and Landscape

Slope:	Elevation 452 mAHD.
Vegetation:	Scattered Eucalyptus over Melaleuca shrubland.
Landscape:	No longer active alluvial plain.

Pit Notes

Horizon	*Description*
Surface	Weak silty, slightly cryptogamic crust. Sparse rounded ferruginous gravel lag. Very loose and dusty.
A1 0 - 150 mm	Uniform medium sand. Sparse rounded ferruginous gravel lag.
B1 150 -300 mm	Bleached layer with sub-rounded terrace gravel. Firm silty sandy matrix. Very grey bleached horizon.
B2 300 800+ mm	Grey/brown light clayey sand. Very hard and compacted. Weakly mottled siliceous pan layer. Approximately 15% friable gravel.
Sample Register	7A 0 - 100 mm 7B 500 - 600 mm

Photo 1: Soil Profile

Photo 2: Landscape

Site	Pit 8	**GPS Coordinates**	**50H**	758996 mE 6446955 mS		Page 8 of 21
Locality	Earl Grey	**Date**	9-Nov-16		**Time**	12:00PM

Vegetation and Landscape

Slope:	Gentle slop to south. Elevation 461 mAHD.
Vegetation:	Scattered Melaleuca and Eucalyptus over Melaleuca open heath.
Landscape:	Gravel plain - approximately 30% gravel.

Pit Notes

Horizon	*Description*
Surface	Loamy sand. Ferruginous gravel lag 20% cover. Weak cryptogamic crust.
A1 0 - 100 mm	Loamy sand. Loose to slightly compacted. Mixed gravel (30%). Ferruginous gravel lag (20%). Gravel non-friable.
B1 100 - 500 mm	Slightly compacted gravel in silty sand.
B2 ≥500 mm	Indurated ironstone. Goethite and hematite staining.
Sample Register	8A 0 - 100 mm

Photo 1: Soil Profile

Photo 2: Landscape

Site	Pit 9	GPS Coordinates	758998 mE 6447102 mN	Page 9 of 21
Locality	Earl Grey	**Date**	9-Nov-16	**Time** 12:15PM

Vegetation and Landscape

Slope:	Gentle slope to south. Elevation 456 mAHD.
Vegetation:	Scattered Ecualyptus over Acacia and Melaleuca open heath.
Landscape:	Sand plain.

Pit Notes

Horizon	*Description*
Surface	Weak cryptogamic crust with a 5 mm sparse gravel lag. Very little leaf litter.
A1 0 - 150 mm	Yellow/brown loamy fine sand. Consolidated to firm. Approximately 30% gravel.
B1 150 - 400 mm	Yellow/brown fine sand. Gravelly compacted layer with sub-rounded hard gravel to 20 mm.
B2 400 - 600+ mm	Yellow/brown sandy silt with slight motling. Compacted with traces of fine gravel.
Sample Register	9A 0 - 100 mm

Photo 1: Soil Profile

Photo 2: Landscape

Site	Pit 10	GPS Coordinates	50 H	759101 6447240	mE mS	Page 10 of 21
Locality	Earl Grey	**Date**	9-Nov-16		**Time**	12:45PM

Vegetation and Landscape	
Slope:	Gentle slop to the south. Elevation 453 mAHD.
Vegetation:	Scattered Eucalyptus over Acacia open heath.
Landscape:	Sand plain.

Pit Notes

Horizon	*Description*
Surface	No crusting. Firm, red/brown sandy loam.
A1 0 - 100 mm	Red/brown sandy loam. <10% gravel.
B1 Depth not recorded	Red/brown sandy silt. Very blocky and very heavily compacted. Friable with tough aggregates.
Sample Register	10A 0 - 100 mm.

Photo 1: Soil Profile

Photo 2: Landscape

Site	Pit 11	**GPS Coordinates**	50 H	759094 6446558	mE mS	Page 11 of 21	
Locality	Earl Grey	**Date**	9-Nov-16		**Time**	1:56PM	

Vegetation and Landscape

Slope:	Gentle slope south. Elevation 454 mAHD.
Vegetation:	Scattered Grevllea sp. and Casuarina over Acacia open heath.
Landscape:	Sand plain.

Pit Notes

Horizon	*Description*
Surface	Heavy cryptogamic crust. Sparse gravel (0 - 10mm).
A1 0 - 200 mm	Yellow/Brown medium sand. Relatively firm.
B1 200 - 1000 mm	Uniform orange sandy matrix with a friable gravel.
B2 ≥1000 mm	Moderately motledred/brown ogrance. Partially weathered felsic.
Sample Register	11A 0 - 100 mm

Photo 1: Soil Profile

Photo 2: Landscape

<table>
<tr><td>Site</td><td>Pit 12</td><td>GPS Coordinates</td><td>50H</td><td>759094 mE
64465458 mS</td><td>Page 12 of 21</td></tr>
<tr><td>Locality</td><td>Earl Grey</td><td>Date</td><td>9-Nov-16</td><td>Time</td><td>1:56PM</td></tr>
</table>

Vegetation and Landscape

Slope:	Gentle slope south. Elevation 454 mAHD.
Vegetation:	Open Eucalyptus woodland over Melaleuca low shrubland.
Landscape:	Sand plain.

Pit Notes

Horizon	*Description*
Surface	Leaf litter and fallen timber/debris abundant. Firm cryptogamic crust. Very sparse gravel. Pale brown loamy sand.
A1 0 - 200 mm	Pale brown loamy sand. <5% gravel (0 - 10 mm).
B1 200 - 400	Red/brown compacted loamy sand. 5% gravel 2 - 15 mm. Difficultly friable.
B2 400mm	Red/brown sandy clay. Heavily compacted. Massive. Blocky.
Sample Register	12A 0-100 mm

Photo 1: Soil Profile

Photo 2: Landscape

Site	Pit 13	**GPS Coordinates** 50H	mE mS		Page 13 of 21
Locality	Earl Grey	**Date**	9-Nov-16	**Time**	2:45PM

Vegetation and Landscape

Slope:	Elevation 457 mAHD.
Vegetation:	Scattered Eucalyptus over scatttered Casuarina over mixed Melaleuca closed heath.
Landscape:	Sand plain.

Pit Notes

Horizon	*Description*
Surface	Cryptogamic crust and abundant leaf litter. Sparse gravel.
A1 0 - 200 mm	Light red/brown loamy sand. 10% sub-angular gravel up to 20 mm. Very firm. Weak peds.
B1 200 - 400 mm	Diffuse boundary to B1. Red/brown sand loam. Friable. Weak motling. Gravel in lone matrix.
B2 400 - 700+ mm	Difficultly friable red/brown sandy loam with significant motling. Copacted with 60% gravel. Furrugenous and hard rock gravel.
Sample Register	13A 0 - 100 mm 13B 500 - 600 mm

Photo 1: Soil Profile

Photo 2: Landscape

Site	Pit 14	GPS Coordinates	mE mS	Page 14 of 21
Locality	Earl Grey	**Date** 9-Nov-16	**Time**	3ooPM

Vegetation and Landscape

Slope:	Gently undulating, low slope to south (5%). Elevation 457.
Vegetation:	Scattered Eucalyptus over scattered Grevillea and Casuarina over Acacia open heath with scattered Banksia over low Melaleuca shrubland.
Landscape:	Sand plain.

Pit Notes

Horizon	*Description*
Surface	Cryptogamic silty crust. Mderate amount of leaf litter. Sparse fine surface gravel.
A1 0 - 250 mm	Yellow/brown fine sandy loam. Loose below crust, grading to firm. Approximately 25% graded sub-rounded/sun-angular gravel. Diffuse boundary with increasing gravel to 250 mm.
B1 250 - 600 mm	Yellow/brown sandy laom. Large(up to 40 mm) sub-rounded/sub-angular hard gravel.
B2 600 - 800+ mm	More cemented. Lateritic gravel. Not heavily furrugenous. Firm and compacted. Difficultly friable. Proably terrace gravel.
Sample Register	14A 0 - 100 mm

Photo 1: Soil Profile

Photo 2: Landscape

Site	Pit 15	**GPS Coordinates** 50H	mE mS		Page 15 of 21
Locality	Earl Grey	**Date**	9-Nov-16	**Time**	3:36PM

Vegetation and Landscape

Slope:	Gentle slope south. Elevation 458 mAHD.
Vegetation:	Low Eucalyptus Woodland over mixed low open heath.
Landscape:	Sand plain.

Pit Notes

Horizon	*Description*
Surface	Firm cryptogamic crust with moderate amount of leaf litter.
A1 0 - 180 mm	Red/brown loam with firm compacted sub-sooil. Friable. Graded sub-roounded/sub-angular gravel 2 - 10 mm.
B1 180 - 350 mm	Red/brown loam to sandy clay. Firm. Blocky strcture. Very fine gravel.
B2 350 - 700 mm	Red/brown sandy clay. Weakly motled. Firm. Lateritic. Firm. More compacted, bleached and silicious. Gravely.
B3 ≥700 mm	Red/brown indurated, silicious matrix. Lightly copacted. Furrugenous concretions.
Sample Register	14A 0 -100 mm 14B 350 - 500 mm

Photo 1: Soil Profile

Photo 2: Landscape

Site	Pit 16	GPS Coordinates	50H	759410 mE 6445661 mS	Page 16 of 21
Locality	Earl Grey	**Date**	9-Nov-16	**Time**	4:10PM

Vegetation and Landscape

Slope:	Sloping to south-east 5 - 10%. Elevation 450.
Vegetation:	Eucalyptus woodland over Melaleuca closed heath
Landscape:	Sand plain.

Pit Notes

Horizon	*Description*
Surface	Very uniform gravel. Some ash. Abundant woody material/fallen timber.
A1	Red/brown loam. Firm to compacted at depth. 20% gravel to approximately 200 mm.
Spoil	Medium to heavy clay that contains small blocky peds. Relatively Uniform.
Sample Register	16A 0 - 100 mm

Photo 1: Soil Profile

Photo 2: Landscape

Site	Pit 17	**GPS Coordinates**	50H 759743 mE 6445866 mS		Page 17 of 21
Locality	Earl Grey	**Date**	9-Nov-16	**Time**	4:38PM

Vegetation and Landscape	
Slope:	Slight slope east. Elevation 447 mAHD
Vegetation:	Open Eucalyptus woodland over Melaleuca open low heath
Landscape:	Sand plain.

Pit Notes

Horizon	*Description*
Surface	Large amount of leaf litter and fallen timber. Not much crust. Where present crust is silty.
A1 0 - 150 mm	Pale brown fine sandy loam. Firmly loose. Gravel lag, minor/medium gravel. Graded gravel (0 - 10mm). Organic rich horizon at 100 - 150 mm.
A2 150 - 250 mm	Sandy bleached horizon. Gravelly, but not friable. Tree roots penetrating.
B1 250 - 900 mm	Furrugenous pesolith in silicious lateritic matrix. <2 mm fraction clayey sand. 40% fines. Diffucultly friable.
B2 ≥900 mm	Furrugenous silcrete. Difficultly friable.
Sample Register	17A 0 - 100 mm 17B 700 - 900 mm

Photo 1: Soil Profile

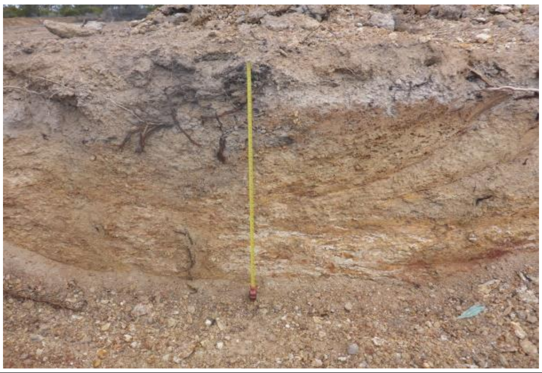

Photo 2: Landscape

Site	Pit 18	**GPS Coordinates**	50H	759650 mE 6445601 mS		Page 28 of 21
Locality	Earl Grey	**Date**	10-Nov-16		**Time**	7:20AM

Vegetation and Landscape

Slope:	Sloping outh-east 5 - 10%. Elevation 446 mAHD.
Vegetation:	Eucalyputus woodland over low closed myrtaceous heath.
Landscape:	Sand plain.

Pit Notes

Horizon	*Description*
Surface	Some hexagonal cracking. Sparse cryptogamis crust. Abundanct leaf litter and fallen timber and debris. Sparse surface gravel.
A1 0 - 100 mm	Red/brown silty clay loam. Blocky structure. Firm. 10% fine gravel (0 - 10 mm).
B1 250 - 600+ mm	White clay with motling. 10 - 15% fine graded gravel (2 - 5 mm)
Sample Register	18A 0 - 100 mm 18B 500 - 600 mm

Photo 1: Soil Profile

Photo 2: Landscape

Site	Pit 19	**GPS Coordinates**	50H 759543 mE 6445907 mS		Page 19 of 21
Locality	Earl Grey	**Date**	10-Nov-16	**Time**	8:06AM

Vegetation and Landscape

Slope:	Gently undulating. Sloping south-east <5%.
Vegetation:	Low open Eucalyptus woodland over low open Melaleuca shrubland
Landscape:	No longer active alluvial plain.

Pit Notes

Horizon	*Description*
Surface	Thick (2 - 4 mm) cryptogamic crust. Sparse graded gravel, subrounded. Firm.
A1 0 - 150 mm	Yellow/brown clayey sand. Firm crust with underlying soil comprising silty sand. Loose. Graded gravel (2 - 10 mm).
A2 150 - 250 mm	Abrupt change in horizon. Bleached clayey sand similar to A1 horizon. Higher content of pesolithic rounded furrugenous gravels.
B1 250 - 800+ mm	Yellow/nrpwm clayey sand. Weak motiling. Firm laterite. Friable. 60% graded (2 - 15 mm) gravel. Pesolithic gravel.
Sample Register	19A 0 - 100 mm 19B 500 - 600 mm

Photo 1: Soil Profile

Photo 2: Landscape

Site	Pit 20	**GPS Coordinates**	50H	mE mS	Page 20 of 21
Locality	Earl Grey	**Date**	10-Nov-16	**Time**	8:39AM

Vegetation and Landscape

Slope:	Gentle, 5% slope to the east.
Vegetation:	Low Eucalyptus woodland over Melaleuca low open heath.
Landscape:	Sand plain.

Pit Notes

Horizon	*Description*
Surface	Firm thick (2 mm) crust. Moderate amount of leaf litter and fallen timber/debris. Pale brown loam.
A1 0 - 50 mm.	Pale brown clay loam. Friable with <5% gravel.
A2 50 - 300 mm	Pale brown clay loam. Hard. Massive. Blocky. No gravel. Cracking.
B1 300 - 600 mm	Pale brown structured blocky clay. Low gravel.
B2 ≥600 mm	Pale brown gritty sandy clay. Weak furrugenous motling. Extensively weathered with 50% saprock fragments to 30 mm.
Sample Register	20A 0 - 100 mm

Photo 1: Soil Profile

Photo 2: Landscape

Site	Pit 21	**GPS Coordinates**	50H 759596 mE 6446062 mS		Page 21 of 21
Locality	Earl Grey	**Date**	10-Nov-16	**Time**	9:05AM

Vegetation and Landscape	
Slope:	Gently undulating slope <5% to the east. Elevation 449 mAHD.
Vegetation:	Eucalyptus woodland over Myrtaceous shrubland.
Landscape:	Infrequently indundated alluvial plain.

Pit Notes

Horizon	*Description*
Surface	Cryptogamic crust. Abundant leaf litter and fallen timber/debris. Moss on surface.
A1 0 - 200 mm	Grey/brown loose fine sand. Less than 5% fine gravel (2 - 5 mm)
A2 200 - 400	Bleached sandy gravel. Ferrugenous gravel. Penetrated by tree roots.
B1 400 - 900 mm	Grey/brown sandy clay. Hard and compacted with low water holding capacity. Massive. Difficultly friable. 40% mapic, angular/sub-angular gravel.
B2 ≥900 mm	Grey/brown furrugenous gravel pesolith. Similar to B1 horizon.
Sample Register	21A 0 - 100 mm

Photo 1: Soil Profile

Photo 2: Landscape

APPENDIX 3: DATA TABLES

LIST OF APPENDIX TABLES

Table A3-1: Soil Sample Descriptions

Sample	Location	Depth (m)	Description	Soil Group[1]	Stones (%)
1A	Pit 1	0 to 0.1	Loamy sand	302	3.8
1B	Pit 1	0.15 to 0.6	Gravelly loamy sand	302	63.7
3A	Pit 3	0 to 0.1	Sand	302	1.3
3B	Pit 3	0.5 to 0.6	Fine gravelly sand	302	45.0
4A	Pit 4	0 to 0.1	Silty sand	302	6.0
5A	Pit 5	0 to 0.05	Sandy loam	302	24.3
5B	Pit 5	0.5 to 0.6	Sandy clay	508	1.2
6A	Pit 6	0 to 0.1	Silty sand	508	3.0
6B	Pit 6	0.5 to 0.6	Clayey sand	508	1.0
7A	Pit 7	0 to 0.1	Sand	302	17.3
7B	Pit 7	0.5 to 0.6	Clayey sand	302	11.5
8A	Pit 8	0 to 0.1	Loamy sand	302	39.5
9A	Pit 9	0 to 0.1	Loamy sand	302	5.9
10A	Pit 10	0 to 0.1	Sandy loam	508	8.7
11A	Pit 11	0 to 0.1	Sand	302	8.8
12A	Pit 12	0 to 0.1	Loamy sand	302	4.0
13A	Pit 13	0 to 0.1	Gravelly loamy sand	508	20.1
13B	Pit 13	0.5 to 0.6	Sandy loam	508	7.3
14A	Pit 14	0 to 0.1	Gravelly sandy loam	302	21.0
15A	Pit 15	0 to 0.1	Gravelly loam	508	25.5
15B	Pit 15	0.35 to 0.5	Lateritic sandy clay	508	56.2
16A	Pit 16	0 to 0.1	Gravelly loam	508	17.9
17A	Pit 17	0 to 0.1	Gravelly sandy loam	508	24.3
17B	Pit 17	0.7 to 0.9	Gravelly sandy clay	508	60.3
18A	Pit 18	0 to 0.1	Silty clay loam	508	2.0
18B	Pit 18	0.5 to 0.6	White clay	508	8.8
19A	Pit 19	0 to 0.1	Gravelly clayey sand	508	36.2
19B	Pit 19	0.5 to 0.6	Lateritic clayey sand	508	62.2
20A	Pit 20	0 to 0.1	Clay loam	508	2.3
21A	Pit 21	0 to 0.1	Fine sand	302	2.3

1 DAFWA Soil Group codes:

302 duplex sandy gravel

508 yellow/brown loamy duplex

Table A3-2: pH and EC, 1:5 Water Extracts

Sample	pH (H_2O)	EC
	pH units	mS/m
1A	4.9	3
1B	4.2	6
3A	5.5	1
3B	4.5	3
4A	5.0	2
5A	6.2	3
5B	8.5	230
6A	6.3	34
6B	7.0	66
7A	5.9	3
7B	8.4	180
8A	5.6	3
9A	4.9	2
10A	6.0	4
11A	5.2	2
12A	6.2	3
13A	6.3	7
13B	4.9	3
14A	4.7	4
15A	6.2	13
15B	6.5	130
16A	8.0	24
17A	6.3	3
17B	8.1	350
18A	7.5	19
18B	9.6	77
19A	6.3	3
19B	8.1	150
20A	6.7	3
21A	6.2	1

Table A3-3: Particle Size Distribution

Sample	Less than 2 mm Fraction (% of <2 mm fraction)			Greater than 2 mm Fraction (% of whole sample)			
	Sand (>20 µm)	Silt (2 to 20 µm)	Clay (<2 µm)	2 to 4 mm	4 to 8 mm	8 to 16 mm	>16 mm
3B	80.0	2.5	17.5	9.3	21.0	13.1	1.6
7B	51.0	7.0	42.0	5.4	3.4	2.5	<0.1
16A	69.0	12.0	19.0	10.2	6.7	1.0	<0.1
18A	44.0	19.0	37.0	1.2	0.5	0.3	<0.1
18B	39.0	22.0	39.0	5.9	1.4	1.3	<0.1

Table A3-4: Emerson Class

Sample	Emerson Class
1A	3
1B	3
3A	8
3B	8
4A	2
5A	1
5B	1
6A	1
6B	1
7A	2
7B	1
8A	2
9A	2
10A	2
11A	2
12A	2
13A	2
13B	2
14A	3
15A	3
15B	1
16A	2
17A	2
17B	1
18A	1
18B	1
19A	Sample not suitable
19B	1
20A	Sample not suitable
21A	Sample not suitable

Table A3-5: Exchangeable Cations

Sample	Ca	Mg	Na	K	Li	Al	Mn	ECEC	ESP
		centimoles (+)/kg							%
1A	0.63	0.32	0.03	0.10	0.0006	0.63	<0.02	1.7	1.8
1B	0.05	0.12	0.09	0.03	0.0009	2.5	<0.02	2.8	3.2
3A	0.53	0.19	<0.02	0.04	0.0004	0.33	<0.02	1.1	<2
3B	0.06	0.10	0.07	0.02	0.0007	1.3	<0.02	1.6	4.5
4A	0.37	0.22	<0.02	0.11	0.0006	0.81	<0.02	1.5	<2
5A	1.2	2.4	0.17	0.11	0.0012	0.04	<0.02	3.9	4.3
5B	2.3	8.7	2.2	0.23	0.0001	-	-	13	16.4
6A	1.0	5.9	2.1	0.21	0.0015	0.02	<0.02	9.2	22.7
6B	3.1	6.5	1.3	0.22	0.0006	-	-	11	11.7
7A	0.85	0.32	0.11	0.06	0.0004	0.12	<0.02	1.5	7.5
7B	2.2	7.7	5.1	0.58	<0.0001	-	-	16	32.7
8A	0.68	0.41	0.07	0.10	0.0003	0.25	<0.02	1.5	4.6
9A	0.25	0.08	<0.02	0.04	0.0005	0.52	<0.02	0.9	<2
10A	3.8	3.6	0.18	0.22	0.0012	0.11	0.04	8.0	2.3
11A	0.31	0.15	<0.02	0.04	0.0001	0.37	<0.02	0.9	<2
12A	3.7	2.5	0.22	0.12	0.0015	0.08	0.02	6.6	3.3
13A	3.2	4.9	0.42	0.17	0.0029	0.03	0.04	8.8	4.8
13B	0.04	2.4	0.21	0.03	0.0027	2.5	<0.02	5.2	4.1
14A	0.22	0.20	0.04	0.07	0.0009	0.89	<0.02	1.4	2.8
15A	3.3	5.2	0.61	0.19	0.0011	0.03	0.06	9.4	6.5
15B	1.5	11	6.2	0.2	0.0012	-	-	19	32.8
16A	23	4.3	0.44	1.2	0.0098	-	-	29	1.5
17A	3.8	1.2	0.05	0.11	0.0020	0.06	0.05	5.3	0.9
17B	0.49	9.8	6.5	0.3	0.0006	-	-	17	38.0
18A	16	12	2.3	2.2	0.0270	-	-	32	7.1
18B	3.6	9.8	11	1.6	0.0170	-	-	26	42.3
19A	1.5	0.79	0.08	0.13	0.0019	0.06	0.04	2.6	3.1
19B	0.63	11	7.8	0.32	0.0006	-	-	20	39.5
20A	2.9	2.5	0.24	0.22	0.0008	-	-	5.9	4.1
21A	1.8	0.26	<0.02	0.04	0.0004	0.07	0.02	2.2	<1

Table A3-6: Nutrients

Sample	Organic C	Total N	C/N ratio	Extr. P	Extr. K	Extr. S	Extr. B	Extr. Cu	Extr. Fe	Extr. Mn	Extr. Zn
	%	%		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
1A	0.89	0.051	17.5	<1	51	35	0.3	0.2	84	4.1	0.1
3A	0.79	0.046	17.2	<1	26	6	0.1	0.1	100	5.1	<0.1
5A	0.61	0.024	25.4	1	53	2	<0.1	0.5	39	5.7	<0.1
7A	1.21	0.043	28.1	1	32	7	<0.1	<0.1	73	4.5	<0.1
9A	0.85	0.050	17.0	<1	21	29	<0.1	0.2	120	1.0	0.1
11A	0.81	0.050	16.2	<1	27	12	<0.1	0.2	140	2.4	0.1
13A	0.79	0.051	15.5	1	84	9	0.5	3.6	45	36	0.3
15A	1.45	0.072	20.1	2	96	16	0.7	2.1	63	21	0.4
17A	1.90	0.084	22.6	1	52	6	0.1	0.2	79	27	0.3
19A	0.90	0.048	18.8	2	61	7	<0.1	0.2	89	15	0.2
21A	1.04	0.050	20.8	2	20	3	<0.1	0.2	53	17	0.2

Table A3-7: Metals and Metalloids

Sample	As	Cd	Cr	Cu	Mn	Ni	Pb	Zn
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
1A	6.0	<0.05	120	4.9	23	30	6.9	7
3A	2.0	<0.05	46	1.8	26	14	3.0	<5
5A	5.4	<0.05	120	7.3	41	24	11	7
7A	2.5	<0.05	56	1.7	33	14	5.3	<5
9A	2.7	<0.05	68	2.2	10	13	3.6	<5
11A	7.0	<0.05	100	2.5	15	14	3.2	<5
13A	24	<0.05	270	25	140	47	16	16
15A	28	<0.05	230	22	77	38	19	14
17A	51	<0.05	270	3.7	110	41	10	10
19A	27	<0.05	250	3.6	70	29	12	10
21A	3.0	<0.05	23	2.0	67	5	3.1	<5

APPENDIX 4: LABORATORY REPORT

ChemCentre
Inorganic Chemistry Section
Report of Examination

PO Box 1250, Bentley Delivery Centre
Bentley WA 6983
T +61 8 9422 9800
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www.chemcentre.wa.gov.au
ABN 40 991 885 705

Purchase Order: KRLEGMC
Your Reference:
ChemCentre Reference: 16S1209 R0

MBS Environmental
4 Cook Street
West Perth WA 6005

Attention: David Allen

Final Report on 40 samples of soil received on 17/11/2016

LAB ID	Client ID and Description
16S1209 / 001	1A
16S1209 / 002	1B
16S1209 / 003	3A
16S1209 / 004	3B
16S1209 / 005	4A
16S1209 / 006	5A
16S1209 / 007	5B
16S1209 / 008	6A
16S1209 / 009	6B
16S1209 / 010	7A
16S1209 / 011	7B
16S1209 / 012	8A
16S1209 / 013	9A
16S1209 / 014	10A
16S1209 / 015	11A
16S1209 / 016	12A
16S1209 / 017	13A
16S1209 / 018	13B
16S1209 / 019	14A
16S1209 / 020	15A
16S1209 / 021	15B
16S1209 / 022	16A
16S1209 / 023	17A
16S1209 / 024	17B
16S1209 / 025	18A
16S1209 / 026	18B
16S1209 / 027	19A
16S1209 / 028	19B
16S1209 / 029	20A
16S1209 / 030	21A
16S1209 / 031	22 3-11
16S1209 / 032	32 3-7
16S1209 / 033	32 34-36
16S1209 / 034	25 6-11
16S1209 / 035	25 15-18
16S1209 / 036	26 44-45

LAB ID	Client ID and Description
16S1209 / 037	27 17-25
16S1209 / 038	50 13-19
16S1209 / 039	96 6-10
16S1209 / 040	14 15-20

Analyte		As	As	Cd	Cr	Cu	Mn
Method		iMET2SAICP	iMET2SAMS	iMET2SAMS	iMET2SAICP	iMET2SAMS	iMET2SAICP
Unit		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Lab ID	Client ID						
16S1209/001	1A		6.0	<0.05	120	4.9	23
16S1209/003	3A		2.0	<0.05	46	1.8	26
16S1209/006	5A		5.4	<0.05	120	7.3	41
16S1209/010	7A		2.5	<0.05	56	1.7	33
16S1209/013	9A		2.7	<0.05	68	2.2	10
16S1209/015	11A		7.0	<0.05	100	2.5	15
16S1209/017	13A		24	<0.05	270	25	140
16S1209/020	15A		28	<0.05	230	22	77
16S1209/023	17A	51		<0.05	270	3.7	110
16S1209/027	19A	27		<0.05	250	3.6	70
16S1209/030	21A		3.0	<0.05	23	2.0	67

Analyte		Ni	Pb	Zn	Stones	EC	pH
Method		iMET2SAICP	iMET2SAICP	iMET2SAICP	(>2mm)	(1:5)	(H2O)
Unit		mg/kg	mg/kg	mg/kg	%	mS/m	
Lab ID	Client ID						
16S1209/001	1A	30	6.9	7	3.8	3	4.9
16S1209/002	1B				63.7	6	4.2
16S1209/003	3A	14	3.0	<5	1.3	1	5.5
16S1209/004	3B				45.0	3	4.5
16S1209/005	4A				6.0	2	5.0
16S1209/006	5A	24	11	7	24.3	3	6.2
16S1209/007	5B				1.2	230	8.5
16S1209/008	6A				3.0	34	6.3
16S1209/009	6B				1.0	66	7.0
16S1209/010	7A	14	5.3	<5	17.3	3	5.9
16S1209/011	7B				11.5	180	8.4
16S1209/012	8A				39.5	3	5.6
16S1209/013	9A	13	3.6	<5	5.9	2	4.9
16S1209/014	10A				8.7	4	6.0
16S1209/015	11A	14	3.2	<5	8.8	2	5.2
16S1209/016	12A				4.0	3	6.2
16S1209/017	13A	47	16	16	20.1	7	6.3
16S1209/018	13B				7.3	3	4.9
16S1209/019	14A				21.0	4	4.7
16S1209/020	15A	38	19	14	25.5	13	6.2
16S1209/021	15B				56.2	130	6.5
16S1209/022	16A				17.9	24	8.0
16S1209/023	17A	41	10	10	24.3	3	6.3
16S1209/024	17B				60.3	350	8.1
16S1209/025	18A				2.0	19	7.5
16S1209/026	18B				8.8	77	9.6
16S1209/027	19A	29	12	10	36.2	3	6.3
16S1209/028	19B				62.2	150	8.1
16S1209/029	20A				2.3	3	6.7
16S1209/030	21A	5	3.1	<5	2.3	1	6.2
16S1209/031	22 3-11					120	5.4
16S1209/032	32 3-7					160	3.9

Analyte		Ni	Pb	Zn	Stones	EC	pH
Method		iMET2SAICP	iMET2SAICP	iMET2SAICP	(>2mm)	(1:5)	(H2O)
Unit		mg/kg	mg/kg	mg/kg	%	mS/m	
Lab ID	Client ID						
16S1209/033	32 34-36					27	7.4
16S1209/034	25 6-11					180	4.5
16S1209/035	25 15-18					280	5.2
16S1209/036	26 44-45					23	7.7
16S1209/037	27 17-25					78	4.2
16S1209/038	50 13-19					170	4.0
16S1209/039	96 6-10					210	4.4
16S1209/040	14 15-20					140	4.9

Analyte		Sand.	Silt.	Clay.	OrgC	Emerson	N
Method		fraction	fraction	fraction	(W/B)	Class	(total)
Unit		%	%	%	%		%
Lab ID	Client ID						
16S1209/001	1A				0.89	3	0.051
16S1209/002	1B					3	
16S1209/003	3A				0.79	8	0.046
16S1209/004	3B	80.0	2.5	17.5		8	
16S1209/005	4A					2	
16S1209/006	5A				0.61	1	0.024
16S1209/007	5B					1	
16S1209/008	6A					1	
16S1209/009	6B					1	
16S1209/010	7A				1.21	2	0.043
16S1209/011	7B	51.0	7.0	42.0		1	
16S1209/012	8A					2	
16S1209/013	9A				0.85	2	0.050
16S1209/014	10A					2	
16S1209/015	11A				0.81	2	0.050
16S1209/016	12A					2	
16S1209/017	13A				0.79	2	0.051
16S1209/018	13B					2	
16S1209/019	14A					3	
16S1209/020	15A				1.45	3	0.072
16S1209/021	15B					1	
16S1209/022	16A	69.0	12.0	19.0		2	
16S1209/023	17A				1.90	2	0.084
16S1209/024	17B					1	
16S1209/025	18A	44.0	19.0	37.0		1	
16S1209/026	18B	39.0	22.0	39.0		1	
16S1209/027	19A				0.90		0.048
16S1209/028	19B					1	
16S1209/029	20A					0	
16S1209/030	21A				1.04		0.050
16S1209/031	22 3-11	71.0	11.5	17.5		2	
16S1209/032	32 3-7	61.0	8.0	31.0		6	
16S1209/033	32 34-36					1	
16S1209/034	25 6-11	68.5	12.5	19.0		6	
16S1209/035	25 15-18					6	
16S1209/036	26 44-45	78.0	13.5	8.5		1	

Analyte Method Unit Lab ID	 Client ID	Sand. fraction %	Silt. fraction %	Clay. fraction %	OrgC (W/B) %	Emerson Class	N (total) %
16S1209/038	50 13-19					6	
16S1209/039	96 6-10	42.5	23.0	34.5		5	
16S1209/040	14 15-20	52.5	24.0	23.5		1	

Analyte Method Unit Lab ID	 Client ID	Al (exch) cmol(+)/kg	Ca (exch) cmol(+)/kg	Mg (exch) cmol(+)/kg	Na (exch) cmol(+)/kg	K (exch) cmol(+)/kg	Mn (exch) cmol(+)/kg
16S1209/001	1A	0.63	0.63	0.32	0.03	0.10	<0.02
16S1209/002	1B	2.5	0.05	0.12	0.09	0.03	<0.02
16S1209/003	3A	0.33	0.53	0.19	<0.02	0.04	<0.02
16S1209/004	3B	1.3	0.06	0.10	0.07	0.02	<0.02
16S1209/005	4A	0.81	0.37	0.22	<0.02	0.11	<0.02
16S1209/006	5A	0.04	1.2	2.4	0.17	0.11	<0.02
16S1209/007A	5B		2.3	8.7	2.2	0.23	
16S1209/008	6A	0.02	1.0	5.9	2.1	0.21	<0.02
16S1209/009	6B		3.1	6.5	1.3	0.22	
16S1209/010	7A	0.12	0.85	0.32	0.11	0.06	<0.02
16S1209/011	7B		2.2	7.7	5.1	0.58	
16S1209/012	8A	0.25	0.68	0.41	0.07	0.10	<0.02
16S1209/013	9A	0.52	0.25	0.08	<0.02	0.04	<0.02
16S1209/014A	10A	0.11	3.8	3.6	0.18	0.22	0.04
16S1209/015	11A	0.37	0.31	0.15	<0.02	0.04	<0.02
16S1209/016	12A	0.08	3.7	2.5	0.22	0.12	0.02
16S1209/017	13A	0.03	3.2	4.9	0.42	0.17	0.04
16S1209/018	13B	2.5	0.04	2.4	0.21	0.03	<0.02
16S1209/019	14A	0.89	0.22	0.20	0.04	0.07	<0.02
16S1209/020	15A	0.03	3.3	5.2	0.61	0.19	0.06
16S1209/021A	15B		1.5	11	6.2	0.20	
16S1209/022	16A		23	4.3	0.44	1.2	
16S1209/023	17A	0.06	3.8	1.2	0.05	0.11	0.05
16S1209/024	17B		0.49	9.8	6.5	0.30	
16S1209/025	18A		16	12	2.3	2.2	
16S1209/026	18B		3.6	9.8	11	1.6	
16S1209/027	19A	0.06	1.5	0.79	0.08	0.13	0.04
16S1209/028A	19B		0.63	11	7.8	0.32	
16S1209/029	20A		2.9	2.5	0.24	0.22	
16S1209/030	21A	0.07	1.8	0.26	<0.02	0.04	0.02
16S1209/031	22 3-11	<0.02	<0.02	0.15	0.09	<0.02	<0.02
16S1209/032	32 3-7	0.73	0.03	2.5	1.4	0.28	<0.02
16S1209/033	32 34-36		0.77	12	9.2	0.55	
16S1209/034	25 6-11	0.20	0.05	4.3	1.9	0.39	<0.02
16S1209/035A	25 15-18	0.10	0.09	3.4	0.71	0.29	<0.02
16S1209/036	26 44-45		1.5	14	9.2	0.59	
16S1209/037	27 17-25	0.05	1.2	5.2	3.1	0.34	0.09
16S1209/038	50 13-19	0.35	0.05	1.8	3.9	0.20	<0.02
16S1209/039	96 6-10	0.61	0.11	3.0	7.5	0.26	<0.02
16S1209/040	14 15-20	0.49	0.59	3.6	10	0.28	<0.02

Analyte Method Unit Lab ID	 Client ID	Al (M3) mg/kg	B (M3) mg/kg	Ca (M3) mg/kg	Cd (M3) mg/kg	Co (M3) mg/kg	Cu (M3) mg/kg
16S1209/001A	1A	>550	0.3	130	<0.01	0.04	0.2
16S1209/003	3A	>550	0.1	110	<0.01	0.06	0.1
16S1209/006	5A	>550	<0.1	230	<0.01	0.15	0.5
16S1209/010	7A	>550	<0.1	170	<0.01	0.05	<0.1
16S1209/013	9A	>550	<0.1	50	<0.01	0.04	0.2
16S1209/015A	11A	>550	<0.1	61	<0.01	0.05	0.2
16S1209/017	13A	>550	0.5	580	0.01	1.1	3.6
16S1209/020	15A	>550	0.7	640	<0.01	0.48	2.1
16S1209/023	17A	>550	0.1	570	<0.01	0.13	0.2
16S1209/027	19A	>550	<0.1	280	<0.01	0.15	0.2
16S1209/030A	21A	420	<0.1	350	<0.01	0.06	0.2

Analyte Method Unit Lab ID	 Client ID	Fe (M3) mg/kg	K (M3) mg/kg	Mg (M3) mg/kg	Mn (M3) mg/kg	Mo (M3) mg/kg	Na (M3) mg/kg
16S1209/001	1A	84	51	43	4.1	<0.01	4
16S1209/003	3A	100	26	23	5.1	<0.01	6
16S1209/006	5A	39	53	280	5.7	<0.01	37
16S1209/010	7A	73	32	41	4.5	0.01	24
16S1209/013	9A	120	21	17	1.0	<0.01	8
16S1209/015	11A	140	27	22	2.4	<0.01	4
16S1209/017	13A	45	84	560	36	<0.01	83
16S1209/020	15A	63	96	640	21	<0.01	140
16S1209/023	17A	79	52	120	27	0.01	9
16S1209/027	19A	89	61	95	15	<0.01	17
16S1209/030	21A	53	20	34	17	<0.01	4

Analyte Method Unit Lab ID	 Client ID	Ni (M3) mg/kg	P (M3) mg/kg	S (M3) mg/kg	Zn (M3) mg/kg	As (M3) mg/kg	Pb (M3) mg/kg
16S1209/001A	1A	0.1	<1	35	0.1	0.1	1.4
16S1209/003	3A	0.1	<1	6	<0.1	<0.1	0.8
16S1209/006	5A	0.2	1	2	<0.1	0.1	1.1
16S1209/010	7A	0.1	1	7	<0.1	0.2	1.0
16S1209/013	9A	0.1	<1	29	0.1	0.1	0.8
16S1209/015A	11A	0.1	<1	12	0.1	<0.1	0.7
16S1209/017	13A	0.6	1	9	0.3	0.2	1.1
16S1209/020	15A	0.6	2	16	0.4	0.2	1.4
16S1209/023	17A	0.4	1	6	0.3	0.2	1.8
16S1209/027	19A	0.2	2	7	0.2	0.1	0.7
16S1209/030A	21A	0.2	2	3	0.2	<0.1	0.7

Analyte Method Unit Lab ID	 Client ID	Se (M3) mg/kg	misctst misc 	+2.00 mm Sieve %	+4.00 mm Sieve %	+8.00 mm Sieve %	+16 mm Sieve %
16S1209/001	1A	<0.1	1.0				

Analyte		Se	misctst	+2.00 mm	+4.00 mm	+8.00 mm	+16 mm
Method		(M3)	misc	Sieve	Sieve	Sieve	Sieve
Unit		mg/kg		%	%	%	%
Lab ID	Client ID						
16S1209/002	1B		1.0				
16S1209/003	3A	<0.1	1.0				
16S1209/004	3B		1.0	9.3	21.0	13.1	1.6
16S1209/005	4A		1.0				
16S1209/006	5A	<0.1	1.0				
16S1209/007A	5B		1.0				
16S1209/008	6A		1.0				
16S1209/009	6B		1.0				
16S1209/010	7A	<0.1	1.0				
16S1209/011	7B		1.0	5.4	3.4	2.5	<0.1
16S1209/012	8A		1.0				
16S1209/013	9A	<0.1	1.0				
16S1209/014A	10A		1.0				
16S1209/015	11A	<0.1	1.0				
16S1209/016	12A		1.0				
16S1209/017	13A	<0.1	1.0				
16S1209/018	13B		1.0				
16S1209/019	14A		1.0				
16S1209/020	15A	<0.1	1.0				
16S1209/021A	15B		1.0				
16S1209/022	16A		1.0	10.2	6.7	1.0	<0.1
16S1209/023	17A	<0.1	1.0				
16S1209/024	17B		1.0				
16S1209/025	18A		1.0	1.2	0.5	0.3	<0.1
16S1209/026	18B		1.0	5.9	1.4	1.3	<0.1
16S1209/027	19A	<0.1	1.0				
16S1209/028A	19B		1.0				
16S1209/029	20A		1.0				
16S1209/030	21A	<0.1	1.0				
16S1209/031	22 3-11		1.0				
16S1209/032	32 3-7		1.0				
16S1209/033	32 34-36		1.0				
16S1209/034	25 6-11		1.0				
16S1209/035A	25 15-18		1.0				
16S1209/036	26 44-45		1.0				
16S1209/037	27 17-25		1.0				
16S1209/038	50 13-19		1.0				
16S1209/039	96 6-10		1.0				
16S1209/040	14 15-20		1.0				

Analyte	Method	Description
Stones	(>2mm)	Stones - sieved particles greater than 2 mm (sample preparation method manual 3.3.2)
EC	(1:5)	Electrical conductivity of 1:5 soil extract at 25 C by in-house method S02
K	(exch)	Potassium, K exchangeable (ref. Rayment & Lyons 2011)
Mg	(exch)	Magnesium, Mg exchangeable (ref. Rayment & Lyons 2011)
Mn	(exch)	Manganese, Mn exchangeable (ref. Rayment & Lyons 2011)
Na	(exch)	Sodium, Na exchangeable (ref. Rayment & Lyons 2011)
Al	(exch)	Aluminium, Al exchangeable (ref. Rayment & Lyons 2011)
Ca	(exch)	Calcium, Ca exchangeable (ref. Rayment & Lyons 2011)
pH	(H2O)	pH of 1:5 soil extract in water by in-house method S01
S	(M3)	Sulphur, S extracted by Mehlich No 3 - method S42
Se	(M3)	Selenium, Se extracted by Mehlich No 3 - method S42
Fe	(M3)	Iron, Fe extracted by Mehlich No 3 - method S42
P	(M3)	Phosphorus, P extracted by Mehlich No 3 - method S42
Pb	(M3)	Lead, Pb extracted by Mehlich No 3 - method S42
Zn	(M3)	Zinc, Zn extracted by Mehlich No 3 - method S42
Ca	(M3)	Calcium,Ca extracted by Mehlich No 3 - method S42
Cd	(M3)	Cadmium,Cd extracted by Mehlich No 3 - method S42
B	(M3)	Boron,B extracted by Mehlich No 3 - method S42
Co	(M3)	Cobalt,Co extracted by Mehlich No 3 - method S42
Al	(M3)	Aluminium,Al extracted by Mehlich No 3 - method S42
As	(M3)	Arsenic, As extracted by Mehlich No 3 - method S42
Na	(M3)	Sodium, Na extracted by Mehlich No 3 - method S42
Ni	(M3)	Nickel, Ni extracted by Mehlich No 3 - method S42
Mn	(M3)	Manganese, Mn extracted by Mehlich No 3 - method S42
Mo	(M3)	Molybdenum, Mo extracted by Mehlich No 3 - method S42
Mg	(M3)	Magnesium, Mg extracted by Mehlich No 3 - method S42
K	(M3)	Potassium, K extracted by Mehlich No 3 - method S42
Cu	(M3)	Copper,Cu extracted by Mehlich No 3 - method S42
N	(total)	Nitrogen N, total by method S10
OrgC	(W/B)	Organic Carbon C, Walkley and Black method S09.
Emerson	Class	Emerson class number by AS 1289 C.8.1
Clay.	fraction	Clay, less than 0.002mm by method S06. ref. Australian Standard AS1289.C6.3
Silt.	fraction	Silt, 0.02 to 0.002mm by method S06. ref. Australian Standard AS1289.C6.3
Sand.	fraction	Sand, 0.02 to 2.0mm by method S06. ref. Australian Standard AS1289.C6.3
Pb	iMET2SAICP	Lead, dry basis
Zn	iMET2SAICP	Zinc, dry basis
Cr	iMET2SAICP	Chromium, dry basis
As	iMET2SAICP	Arsenic, dry basis
Mn	iMET2SAICP	Manganese, dry basis
Ni	iMET2SAICP	Nickel, dry basis
Cu	iMET2SAMS	Copper, dry basis
As	iMET2SAMS	Arsenic, dry basis
Cd	iMET2SAMS	Cadmium, dry basis
misctst	misc	See request from client for details
+16 mm	Sieve	Particle size distribution by sieving, method S07.
+2.00 mm	Sieve	Particle size distribution by sieving, method S07.
+4.00 mm	Sieve	Particle size distribution by sieving, method S07.
+8.00 mm	Sieve	Particle size distribution by sieving, method S07.

The results apply only to samples as received. This report may only be reproduced in full.

Unless otherwise advised, the samples in this job will be disposed of after a holding period of 30 days from the report date shown below.

Barry Price
Team Leader
Scientific Services Division
19-Jan-2017