Soils Report

TELLUS

Soils Investigation Report

Tellus Holdings Ltd

Chandler Salt Mine Project – Stage 1

EL29018 (Maryvale)

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October 2013

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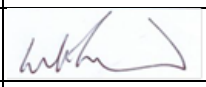
Signed:	
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DISCLAIMER

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ABBREVIATIONS AND ACRONYMS

Coffey	Coffey Environments Pty Ltd
EIA	Environmental Impact Assessment
EL	Exploration Lease
EPBC	*Environment Protection and Biodiversity Conservation Act* (Commonwealth)
LES	Low Ecological Services Pty Ltd
PPL	Perpetual Pastoral Lease
PPF	Principal Profile Form
Tellus	Tellus Holdings Ltd
TPWC	*Territory Parks and Wildlife Conservation Act* (Northern Territory)

1 INTRODUCTION

1.1 PROJECT AREA

Tellus Holdings Ltd (Tellus) proposes to develop Australia's first underground rock salt mine and storage warehousing within underground mined voids. The project area is located approximately 120 km south of Alice Springs in the Northern Territory on Exploration Lease (EL) 29018 (North Mt Charlotte Block, 127.7km^2). The site is situated over the 500 million year old Chandler Salt Formation in the Amadeus Basin and Tellus own 100 percent of the mineral rights over the lease.

The proposed development area is located on the north-western edge of the Simpson Desert. The Alice Springs – Tarcoola Railway line also services the area and comes within 30 km of the North Mt Charlotte Block (EL29018). Tellus also holds EL28900, which links the Mt Charlotte Block to EL27974 in which the railway line is situated.

The Mt Charlotte Block is approximately 20 km west of Titjikala (Maryvale) and lies within the perpetual pastoral lease of Maryvale station (PPL1063) which is primarily used for cattle grazing. The natural tourism attraction, Chambers Pillar Reserve, is located 10 km to the west of the Mt Charlotte Block and attracts approximately 6500 visitors per year.

Key topographical features in the surrounding area include the Finke River and its associated floodplain, the Hugh River and other ephemeral watercourses, Charlotte Range, Maryvale Hills, Chambers Pillar and various ridges and saltpans.

Tellus plan to develop the rock salt mine in two stages.

Stage 1 – Proposed Operations:

- Establish and acquire data from two seismic lines (5 km each);
- Drill three diamond drill holes; and
- Construct temporary camp in which to accommodate personnel during Stage 1 operations.

Figure 1 shows the general location of EL29018 as well as locations of the proposed Stage 1 operations.

Stage 2 – Proposed Operations:

- Drill five additional step-out wells;
- Construct accommodation suitable for fly-in fly-out personnel;
- Construct underground mine accessed via a decline shaft;
- Construct a processing and packaging plant;
- Construct haul road to railway line and rail siding for loading facilities;
- Construct access road to Maryvale road; and
- Construct diesel/solar-salt battery power station.

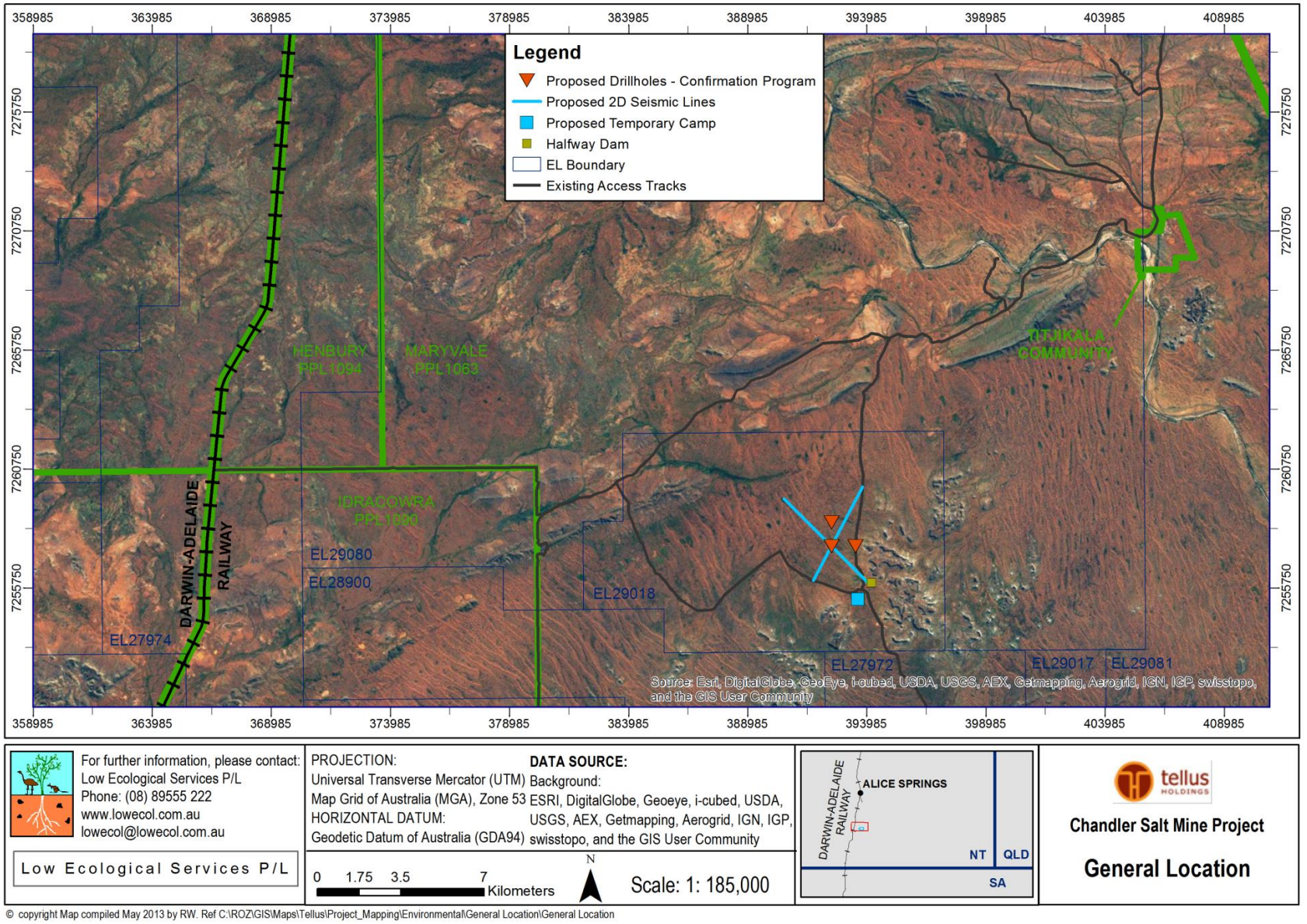

Figure 1 General Location of EL29018 and Stage 1 Proposed Operations in relation to existing tracks, surrounding tenure and railway

1.2 PURPOSE AND SCOPE OF WORKS

In 2013, Coffey Environments (Coffey) were appointed by Tellus to prepare an Environmental Impact Statement for the project. Coffey sub-contracted Low Ecological Services P/L (LES) to conduct a soils investigation of the Stage 1 development and project area. All stage 1 operations are restricted to EL29018.

The purpose of the soils investigation is to provide impact assessment information to support the preparation of the environmental impact statement (EIS) for the Chandler Salt Mine Project. This ground study has characterised the soils likely to be disturbed during Stage 1 operations.

A comprehensive desktop survey of soils was completed by Aurora Environmental in April 2012. The desktop survey utilized the Atlas of Australian Soils to classify soils for the Mount Charlotte area and the Maryvale Hills. This soils ground study evaluates the proposed project area to determine the validity of the findings from the desktop survey and to provide more site-specific information on the nature and behaviour of the soils.

2 SITE LOCATIONS

The proposed project area falls within EL29018. Soil samples were collected from selected locations within EL29018 that represent different land units as well as potential disturbance sites expected during Stage 1 of the project. This includes three proposed drill sites and a proposed temporary camp. The location and description of the samples are presented in Table 1. Site locations are shown in Figure 1.

Table 1: **Soil samples collected on September 2013 Survey**

Sample ID	Site Location	GPS Coordinates	Elevation	Site Description
S04-DLF	S-04	-24° 46’ 14.8”, 133° 53’ 16.8”	NR*	Reticulate Dune Fields
S04-DU	S-04	-24° 46’ 16.9”, 133° 55’ 16.3”	436	Reticulate Dune Fields
S04-DM	S-04	-24° 46’15.6”, 133° 56’ 16.5”	NR*	Reticulate Dune Fields
S04-EV5	S-04	NR*	NR*	Reticulate Dune Fields
S08-1-0	S-08	-24° 47’ 41.6”, 133° 56’ 34.6”	461	Sand plain watercourse
S08-2-0	S-08	-24° 47’ 41.7”, 133° 56’ 35.1”	461	Sand plain watercourse
S08-3-0	S-08	-24° 47’ 43.4”, 133° 56’ 36.4”	457	Sand plain watercourse
S08-4-0	S-08	-24° 47’ 44.6”, 133° 56’ 39.1”	458	Sand plain watercourse
S10-1-0	S-10	-24° 47’ 03.7”, 133° 55’ 49.4”	443	Strike Ridge
S10-2-0	S-10	-24° 47’ 04.1”, 133° 53’ 49.4”	445	Strike Ridge
S10-3-0	S-10	-24° 47’ 7.5”, 133° 53’ 54.0”	443	Strike Ridge
S11-1-0	S-11	-24° 48’ 52.9”, 133° 57’ 34.5”	474	High Mesa Terrain
S11-2-0	S-11	-24° 48’ 53.1”, 133° 57’ 35.3”	473	High Mesa Terrain
S11-3-0	S-11	-24° 48’ 52.5”, 133° 57’ 36.0”	475	High Mesa Terrain
S11-4-0	S-11	-24° 48’ 52.1”, 133° 57’ 37.1”	478	High Mesa Terrain
S11-5-0	S-11	-24° 48’ 52.1”, 133° 57’ 37.1”	482	High Mesa Terrain
S11-6-0	S-11	-24° 48’ 52.1”, 133° 57’ 37.6”	483	High Mesa Terrain
CNP01-1-top	CNPO-1	-24° 47’ 35.3”, 133° 56’ 46.1”	413	Proposed drill site
CNP01-2-top	CNPO-1	-24° 47’ 35.6”, 133° 56’ 45.9”	418	Proposed drill site
CNP01-3-top	CNPO-1	-24° 47’ 34.9”, 133° 56’ 45.2”	415	Proposed drill site
CNP01-1-bottom	CNPO-1	-24° 47’ 35.3”, 133° 56’ 46.1”	413	Proposed drill site
CNP01-2-bottom	CNPO-1	-24° 47’ 35.6”, 133° 56’ 45.9”	418	Proposed drill site
CNP01-3-bottom	CNPO-1	-24° 47’ 34.9”, 133° 56’ 45.2”	415	Proposed drill site
CNP02-1	CNPO-2	-24° 47’ 35.4”, 133° 56’ 10.9”	417	Proposed drill site
CNP02-2	CNPO-2	-24° 47’ 35.6”, 133° 56’ 12.3”	417	Proposed drill site
CNP02-3	CNPO-2	-24° 47’ 36.9”, 133° 56’ 11.1”	419	Proposed drill site
CNP03-1	CNPO-3	-24° 46’ 57.3”, 133° 56’ 16.0”	411	Proposed drill site
CNP03-2	CNPO-3	-24° 46’ 58.5”, 133° 56’ 17.2”	416	Proposed drill site
CNP03-3	CNPO-3	-24° 46’ 58.5”, 133° 56’ 15.8”	412	Proposed drill site
CMP-1	Camp	-24° 48’ 48.5”, 133° 56’ 50.1”	434	Proposed camp site
CMP-2	Camp	-24° 48’ 44.4”, 133° 56’ 56.7”	437	Proposed camp site

*NR – Not recorded

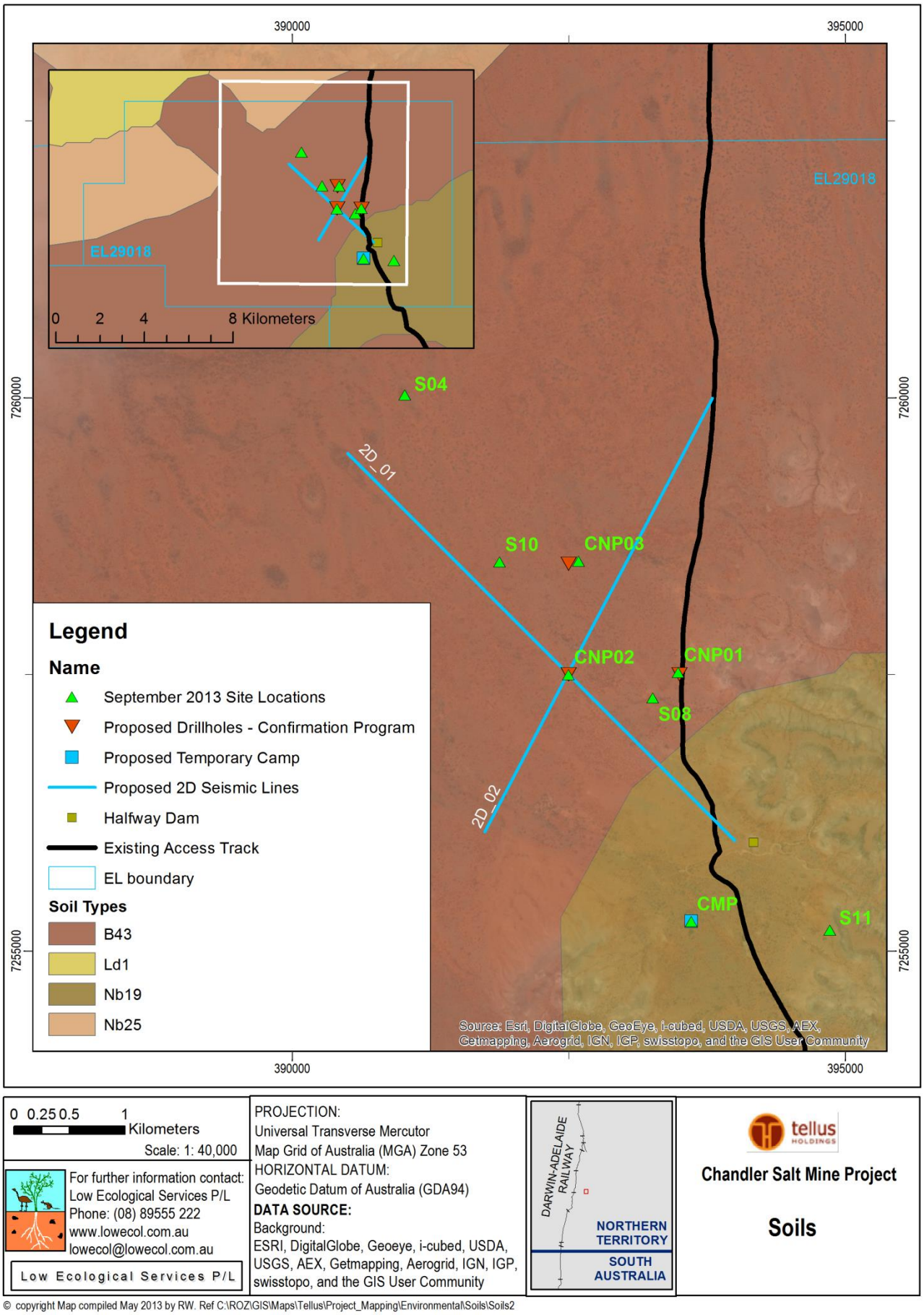

Figure 2: Site locations in relation to soil types and proposed Stage 1 operations

3 METHODOLOGY

3.1 SAMPLING

Soil samples were obtained on September 4th and 5th, 2013 during the September 2013 Landscape, Flora and Fauna survey of the Chandler Salt Mine Project. Samples were collected according to the Australian Soil and Land Survey Field Handbook (CSIRO Publishing and National Commitee on Soil and Terrian (Australia), 2009). For each site location, three unique samples were collected. However, where a site showed a high degree of variability, additional samples were collected. At site CNP01, soils were sampled from two depths: 5-10 cm and 30-50 cm. Evidence from this site and other exposed soil profiles evaluated during the survey showed soils to be uniform with depth; with little to no structural development. Therefore all other samples were collected from the first 5-10 cm.

A GPS way-point was made at each sample collection location. The jars were labelled in the field and information regarding the general location and date of collection was recorded in the field notebook. In the office, the location data for each jar was transferred from the notebook into an excel spread sheet.

3.2 SOIL CLASSIFICATION

The Australian Soil Resource Information System (ASRIS) (ASRIS, 2011) was used to pre-determine the principal profile forms (PPF) and soil orders for the soils contained within EL29018. A surface soil assessment, field texture analysis, and pH and salinity assessment of each investigation site were then conducted to determine if the classification provided by ASRIS was appropriate.

Principal profile forms and soil orders are classifications from two different classification schemes; The Factual Key (Northcote, et al., 1975) and the Australian Soil Classification (Isbell & CSIRO Publishing, 2002). The Factual Key was the most widely used soil classification until it was replaced by the Australian Soil Classification in 1996 (Isbell & CSIRO Publishing, 2002). The Factual Key is a 5 level hierarchical scheme with the PPF being the most detailed level. The Australian Soil Classification also consists of 5 categorical levels which are: *order*, *suborder*, *great group*, *subgroup*, and *family.* While the Australia Soil Classification is the currently adopted classification system in Australia, PPF from the Factual Key are also used to describe the soils in this report because the electronic source of soils data required to map the soils for this area is based on this classification scheme.

3.3 TEXTURE

Soil texture affects a wide range of properties including but not limited to soil strength, aggregation, drainage and infiltration, cation exchange capacity, water and nutrient availability. Field texture classes were determined according to Australian Soil and Land Survey Handbook (CSIRO Publishing and National Commitee on Soil and Terrian (Australia), 2009). A small amount of soil was moistened with water and kneaded by hand to form a sticky bolus which approximates the field moisture capacity of the soil. The bolus of soil was pressed between the thumb and forefinger to form a ribbon. The behaviour of the bolus and the length of the formed ribbon characterize the field texture of the soil according to the descriptions in Table 2.

Table 2: Field texture classes adapted from McDonald *et al* (1984)

Field Texture Grade	Behaviour of moist bolus	Approximate clay content (percentage)
Sand	Coherence nil to very slight, cannot be moulded; single sand grains adhere to fingers	Less than 10% and commonly less than 5%
Loamy sand	Slight coherence; can be sheared between thumb and forefinger to give minimal ribbon of about 5 mm	5-10%
Clayey sand	Slight coherence; sticky when wet, many sand grains stick to fingers; will form minimal ribbon of 5-15 mm; discolours fingers with clay stain.	5-10%
Sandy loam	Bolus just coherent but very sandy to touch; will form ribbon of 15	10-15%
Loam	Bolus coherent and rather spongy; smooth feel when manipulated but with no obvious sandiness or 'silkiness'; may be somewhat greasy to the touch if much organic matter present; will form ribbon of about 25 mm.	25%
Silt loam	Coherent plastic bolus, smooth to manipulate; will form ribbon of 40-50 mm	25%
Sandy clay loam	Strongly coherent bolus, sandy to touch; medium size sand grains visible in finer matrix; will form ribbon of 25-40 mm	20-30%
Clay loam	Coherent plastic bolus, smooth to manipulate; will form ribbon of 40-50 mm	30-35%
Silty Clay loam	Coherent smooth bolus, plastic and silky to the touch; will form ribbon of 40-50 mm	30-35%
Sandy clay	Plastic bolus; fine to medium sand grains can be seen, felt or heard in clayey matrix; will form ribbon of 50-75 mm	35-40%
Silty clay	Plastic bolus; smooth and silky to manipulate; will form ribbon of 50-75 mm	35-40%
Light clay	Plastic bolus; smooth to touch ; slight resistance to shearing between thumb and forefinger; will form ribbon of 50-75 mm	35-40%
Light medium clay	Plastic bolus; smooth to touch; slightly greater resistance to ribboning shear than light clay; will form ribbon of about 75 mm	40-45%
Medium clay	Smooth plastic bolus; handles like plasticine and can be moulded into rods without fracture; has some resistance to ribboning shear; will form ribbon of 75 mm or more	45-55%
Heavy clay	Smooth plastic bolus; handles like stiff plasticine; can be moulded into rods without fracture; has firm resistance to ribboning shear; will form ribbon of 75 mm or more	50% or more

3.4 pH

Soil pH is measured to determine the acidity or alkalinity which affects the availability of nutrients and the microbial activity of a soil. Sample treatment generally followed the methods of (Rayment and Higgison, 1992). A 20g air-dry soil sample was mixed with 100mL deionised (DI) water to create a 1:5 Soil:Water suspension. The pH meter used was a YSI Professional Plus handheld multi-parameter meter and was calibrated according to manufacturer's instructions. The soil solution was vigorously shaken for 15 min before immersing the pH electrode into the sample. The pH value obtained once the equilibrium was reached, while mechanically stirring, was recorded. The probe was rinsed with de-ionised (DI) water between samples and dipped in and out of the next sample 2-3 times in order to ensure the solution inside the probe cover was not diluted. The results were recorded onto data sheets and entered into an excel spread sheet. Means and standard deviations were calculated for all groupings of samples and the results were graphed using excel spread sheets.

3.5 Salinity

Dissolved salt concentrations are measured indirectly by determining the Electrical Conductivity (EC) of the sample; EC can be measured a number of ways. Sample treatment followed the methods of Hunt and Gilkes (1992) to determine a 1:5 soil:water suspension $EC_{1:5}$ value. A 20g air-dried soil sample was mixed with 100mL DI to create a 1:5 dilution. The soil water solution was vigorously shaken to dissolve all salts that may be present in the soils. The sample was left to sit for 15 min before the EC reading was taken. Readings were also taken after 3-4 hours and 96 hours later. Multiple readings were taken over time because it has been shown that the $EC_{1:5}$ of samples increases due to low solubility ions coming into solution over time (Ghee, Fuller and Low, 2008). Samples were shaken again prior to each reading. The salinity meter used was a YSI Professional Plus handheld multi-parameter meter and was calibrated according to manufacturer's instructions. The probe was rinsed with DI water between samples and dipped in and out of the next sample 2-3 times in order to ensure the solution inside the probe cover was not diluted. The results were recorded onto data sheets and entered into an excel spread sheet. Means and standard deviations were calculated for all groupings of samples and the results were graphed using Excel spread sheets.

4 RESULTS

4.1 S04

Table 3: Surface Soil Assessment S04

Parameter	Description	Class	Interpretation
Soil Cover	1-15%	2	Low rain splash protection
Basal & Canopy Cover	1% or less	1	No below ground contribution
Litter Cover	<10%	1	-
Cryptogram Cover	N/A	0	No stable crust present
Crust Brokenness	-	4	Crust present but intact, smooth
Erosion Type Severity	Sheeting	4	Insignificant
Deposited Material	5-20%	3	Slight amount of material available
Surface Roughness	-	3	Deeper depressions 8-25 mm, dense tussock grasslands moderate retention
Surface Nature	Crust is hard and brittle	4	Needs a metal implement to break the surface; forming amorphous fragments and/or powder. The sub-crust is also very hard, coherent and brittle.

Table 4: Physical and Chemical Analysis S04

				Salinity (ds/m)		
Sample ID	**Slake Test**	**Texture Class**	**pH**	**15 min**	**3-4 hours**	**96 hours**
SL 4-DLF	Unstable	Light sandy clay loam	8.10	0.043	0.047	0.052
SL 4-DM	Very unstable	Sandy loam	8.13	0.037	0.041	0.043
SL 4-DU	Very unstable	Loamy sand	8.13	0.042	0.045	0.047
SL4-EV5	Unstable	Sandy loam	7.95	0.067	0.073	0.095
Average			**8.08**	**0.047**	**0.052**	**0.059**
Standard Deviation			**0.09**	**0.013**	**0.09**	**0.024**

Other notable characteristics of the site:

Soils sampled from S04 were collected from an inter-dunal area with 10 m dunes on either side of the site (Plate 1). Scattered low shrubs (*Senna*, *Eremophila)*, tall shrub (*Acacia kempeana*, *A. aneura*) and low trees (*Hakea divaricata*, *Corimbia opaca*) were present across the ground cover. The site consisted of very deep sands that extended beyond 1 m depth. There was no presence of an A horizon. The profile was fairly uniform with the exception of an increase in the intensity of red soil colour with depth.

Photographs:

Plate 1: S04 Sand dune

4.2 S08

Table 5: Surface Soil Assessment S08

Parameter	Description	Class	Interpretation
Soil Cover	15-30%	3	Moderate rain splash protection
Basal & Canopy Cover	1-10%	2	Low below ground contribution
Litter Cover	25-50%	3	-
Cryptogram Cover	1% or less	1	No contribution
Crust Brokenness	-	2	Crust present but moderately broken
Erosion Type Severity	Sheeting	4	Insignificant
Deposited Material	0-5%	4	None or small amount of material available
Surface Roughness	-	3	Deeper depressions 8-25 mm, dense tussock grasslands moderate retention
Surface Nature	Easily broken	2	Surface is easily penetrated with finger pressure. Surface may have a weak physical crust and sub-crust is non-coherent.

Table 6: Physical and Chemical Analysis S08

				Salinity (ds/m)		
Sample ID	**Slake Test**	**Texture Class**	**pH**	**15 min**	**3-4 hours**	**96 hours**
S08-1-0	Very unstable	Sandy loam	8.00	0.058	0.063	0.084
S08-2-0	Very unstable	Sandy loam	7.97	0.107	0.112	0.117
S08-3-0	Unstable	Sandy loam	7.99	0.081	0.089	0.109
S08-4-0	Moderately stable	Sandy loam	7.80	0.057	0.062	0.071
Average			**7.94**	**0.076**	**0.082**	**0.095**
Standard Deviation			**0.09**	**0.024**	**0.09**	**0.021**

Other notable characteristics of the site:

S08 consisted of a sandy plain at the base of a rocky ridge. There sand plain consisted of very deep uniform sands with the exception of an increase in the intensity of red soil colour with depth (Plate 3). There was no presence of an A horizon and minimal soil development. Depth to bedrock is unknown and extends beyond 1 m depth.

Located at 24° 47’ 44.4”, 133° 56’ 37.6” (Elevation 457 m) is evidence of water erosion (Plate 5). A gully 200 mm in depth and ranging from 0.5 to 5 m wide is present. A calcrete layer was also present within 0.5 m of the ridge from which sample S08-1-0 was taken.

Photographs:

Plate 2: S08 General view

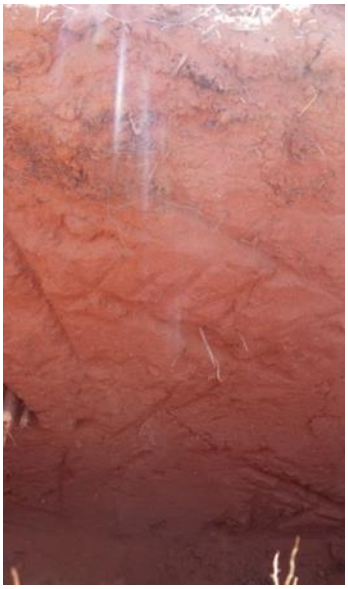

Plate 3: S08 Soil profile from sample S08-2-0

Plate 4: S08 Evidence of calcium carbonate

Plate 5: S08 Evidence of water on soil surface

4.3 S10

Table 7: Surface Soil Assessment S10

Parameter	Description	Class	Interpretation
Soil Cover	30-50%	4	High rain splash protection
Basal & Canopy Cover	10-20%	3	Moderate below ground contribution
Litter Cover	25-50%	3	-
Cryptogram Cover	1-10%	2	Slight contribution
Crust Brokenness	-	3	Crust present but slightly broken
Erosion Type Severity	Sheeting	4	Insignificant
Deposited Material	5-20%	3	Slight amount of material available
Surface Roughness	-	3	Deeper depressions 8-25 mm, dense tussock grasslands moderate retention
Surface Nature	Moderately hard	3	Surface has a physical crust and moderately hard, needing a plastic tool to pierce, breaking into amorphous fragments or powder; the sub-crust is coherent.

Table 8: Physical and Chemical Analysis S10

				Salinity (ds/m)		
Sample ID	**Slake Test**	**Texture Class**	**pH**	**15 min**	**3-4 hours**	**96 hours**
S10-0-0	Unstable	Sandy loam	7.82	0.046	0.045	0.046
S10-2-0	Very unstable	Sandy loam	7.81	0.042	0.046	0.048
S10-3-0	Unstable	Sandy loam	7.71	0.039	0.041	0.043
Average			**7.78**	**0.042**	**0.044**	**0.046**
Standard Deviation			**0.06**	**0.004**	**0.06**	**0.003**

Other notable characteristics of the site:

The soils at S10 contained uniform sand profiles with the exception of an increase in the intensity of red soil colour with depth. There was no presence of an A horizon (Plate 7) and there is minimal soil development. Slightly domed sand plain present on site (Plate 8).

Photographs:

Plate 6: S10 General view

Plate 7: S10 Soil profile

Plate 8: S10 Slightly domed sand plain

4.4 S11

Table 9: Surface Soil Assessment S11

Parameter	Description	Class	Interpretation
Grassland			
Soil Cover	1-15%	2	Low rain splash protection
Basal & Canopy Cover	10-20%	3	Moderate below ground contribution
Litter Cover	1-10%	1	-
Cryptogram Cover	1-10%	2	Slight contribution
Crust Brokenness	-	3	Crust present but slightly broken
Erosion Type Severity	Sheeting	4	Insignificant
Deposited Material	5-20%	3	Slight amount of material available
Surface Roughness	-	3	Deeper depressions 8-25 mm, dense tussock grasslands moderate retention
Surface Nature	Moderately hard	3	Surface has a physical crust and moderately hard, needing a plastic tool to pierce, breaking into amorphous fragments or powder; the sub-crust is coherent.
Bottom Line Slope			
Soil Cover	100%	5	Very high rain splash protection
Basal & Canopy Cover	1-10%	2	Low below ground contribution
Litter Cover	10-25%	2	-
Cryptogram Cover	N/A	0	No stable crust present
Crust Brokenness	-	4	Crust present but intact, smooth
Erosion Type Severity	Sheeting	4	Insignificant
Deposited Material	0-5%	4	None or small amount of material available
Surface Roughness	-	3	Deeper depressions 8-25 mm, dense tussock grasslands moderate retention
Surface Nature	Moderately hard	3	Surface has a physical crust and moderately hard, needing a plastic tool to pierce, breaking into amorphous fragments or powder; the sub-crust is coherent.

Table 10: Physical and Chemical Analysis S11

				Salinity (ds/m)		
Sample ID	**Slake Test**	**Texture Class**	**pH**	**15 min**	**3-4 hours**	**96 hours**
Grassland						
S-11-1-0	Very unstable	Sandy loam	8.20	0.067	0.071	0.086
S-11-2-0	Moderately stable	Sandy loam	8.24	0.063	0.067	0.078
S-11-3-0	Unstable	Sandy loam	8.34	0.065	0.069	0.081
Average			**8.26**	**0.065**	**0.069**	**0.082**
Standard Deviation			**0.07**	**0.002**	**0.07**	**0.005**
Bottom Line Slope						
S-11-4-0	Very stable	Sandy clay loam	8.13	0.148	0.156	0.204
S-11-5-0	Moderately stable	Clay loam	8.24	0.088	0.099	0.125
S-11-6-0	Very stable	Sandy loam	7.87	0.117	0.129	0.193
Average			**8.08**	**0.118**	**0.128**	**0.174**
Standard Deviation			**0.19**	**0.030**	**0.19**	**0.043**

Other notable characteristics of the site:

Open grassland extended within this site to the base of a very rocky hill (Plate 9). Six soil samples were taken in total, three within the grassland and three up the side of the rocky hillside. A surface soil assessment was conducted for both the grassland and hillside portion of the landscape. There is minimal soil development within the grassland area and there is shallow soil depth along the rocky hillside. An isolated case of rill erosion was present next to sample site S-11-3-0 that was roughly 1 m deep and 2 m wide (Plate 12).

Photographs:

Plate 9: S11 Looking onto grassland from the base of the rocky hill slope

Plate 10: S11 Rocky hillside slope

Plate 11: S11 Soil surface on grassland portion of site

Plate 12: S11 Evidence of water rill erosion

4.5 CNP01

Table 11: Surface Soil Assessment CNP01

Parameter	Description	Class	Interpretation
Soil Cover	30-50%	4	High rain splash protection
Basal & Canopy Cover	10-20%	3	Moderate below ground contribution
Litter Cover	25-50%	3	-
Cryptogram Cover	1-10%	2	Slight contribution
Crust Brokenness	-	2	Crust present but moderately broken
Erosion Type Severity	Sheeting	4	Insignificant
Deposited Material	5-20%	3	Slight amount of material available.
Surface Roughness	-	3	Deeper depression 8-25 mm, dense tussock grasslands. Moderate retention
Surface Nature	Moderately hard	3	Surface has physical crust and moderately hard, needing a plastic tool to pierce, breaking into amorphous fragments or powder; the sub-crust is coherent.

Table 12: Physical and Chemical Analysis CNP01

				Salinity (ds/m)		
Sample ID	**Slake Test**	**Texture Class**	**pH**	**15 min**	**3-4 hours**	**96 hours**
Depth 5-10 cm						
CNPO1-1-top	Very unstable	Loamy sand	8.04	0.057	0.057	0.064
CNPO1-2-top	Very unstable	Loamy sand	7.77	0.125	0.137	0.245
CNPO1-3-top	Very unstable	Sandy loam	7.94	0.058	0.060	0.066
Average			**7.92**	**0.080**	**0.085**	**0.125**
Standard Deviation			**0.14**	**0.039**	**0.14**	**0.104**
Depth 30-50 cm						
CNPO1-1-bottom	Very unstable	Sandy loam	8.07	0.060	0.060	0.061
CNPO1-2-bottom	Very unstable	Sandy loam	8.08	0.061	0.062	0.067
CNPO1-3-bottom	Unstable	Sandy loam	7.98	0.056	0.058	0.058
Average			**8.04**	**0.059**	**0.06**	**0.062**
Standard Deviation			**0.06**	**0.003**	**0.06**	**0.005**

Other notable characteristics of the site:

Sand hummocks present (Plate 13). No presence of bedrock within 50 cm of sample CNPO1-1 or within 40 cm of sample CNPO1-2.

Photographs:

Plate 13: CNP01 General view

Plate 14: CNP01 Soil surface

Plate 15: CNP01 Soil profile

4.6 CNP02

Table 13: Surface Soil Assessment CNP02

Parameter	Description	Class	Interpretation
Soil Cover	30-50%	4	High rain splash protection
Basal & Canopy Cover	10-20%	3	Moderate below ground contribution
Litter Cover	10-25%	2	-
Cryptogram Cover	1% or less	1	No contribution
Crust Brokenness	-	1	Crust present but extensively broken
Erosion Type Severity	Sheeting	4	Insignificant
Deposited Material	0-5%	4	Non or small amount of material available
Surface Roughness	-	3	Deeper depressions 8-25 mm, dense tussock grasslands. Moderate retention
Surface Nature	Loose sandy surface	1	Surface is not crusted, easily penetrated by finger pressure to about second knuckle joint. Sub-surface is non-coherent.

Table 14: Physical and Chemical Analysis CNP02

				Salinity (ds/m)		
Sample ID	**Slake Test**	**Texture Class**	**pH**	**15 min**	**3-4 hours**	**96 hours**
CNPO2-1	Very unstable	Loamy sand	8.33	0.057	0.060	0.069
CNPO2-2	Very unstable	Sandy loam	8.05	0.064	0.064	0.073
CNPO2-3	Unstable	Sandy loam	7.98	0.074	0.080	0.088
Average			**8.12**	**0.065**	**0.068**	**0.077**
Standard Deviation			**0.19**	**0.009**	**0.19**	**0.010**

Other notable characteristics of the site:

Sand mounds with 1 m relief are located across site landscape (Plate 16).

Photographs:

Plate 16: CNP02 General view

Plate 17: CNP02 Soil surface

4.7 CNP03

Table 15: Surface Soil Assessment CNP03

Parameter	Description	Class	Interpretation
Soil Cover	30-50%	4	High rain splash protection
Basal & Canopy Cover	10-20%	3	Moderate below ground contribution
Litter Cover	10-25%	2	-
Cryptogram Cover	1-10%	2	Slight contribution
Crust Brokenness	-	3	Crust present but slightly broken
Erosion Type Severity	Sheeting	4	Insignificant
Deposited Material	0-5%	4	None or small amount of material available
Surface Roughness	-	3	Deeper depressions 8-25 mm dense tussock grassland Moderate retention
Surface Nature	Easily broken	2	Surface is easily penetrated with finger pressure. Surface may have a weak physical crust and sub-crust is non-coherent.

Table 16: Physical and Chemical Analysis CNP03

				Salinity (ds/m)		
Sample ID	**Slake Test**	**Texture Class**	**pH**	**15 min**	**3-4 hours**	**96 hours**
CNPO3-1	Unstable	Sandy loam	8.16	0.040	0.041	0.046
CNPO3-2	Very unstable	Sandy loam	8.06	0.051	0.053	0.059
CNPO3-3	Very unstable	Sandy loam	8.15	0.041	0.044	0.051
Average			**8.12**	**0.044**	**0.046**	**0.052**
Standard Deviation			**0.06**	**0.006**	**0.06**	**0.007**

Other notable characteristics of the site:

The landscape has previously been burned. An erosion rill was located at 24° 47’ 49.1”, 133° 56’ 27.7” (Plate 18).

Photographs:

Plate 18: CNP03 Erosion rill

4.8 CMP

Table 17: Surface Soil Assessment CMP

Parameter	Description	Class	Interpretation
Soil Cover	1-15%	2	Low rain splash protection
Basal & Canopy Cover	1-10%	2	Low below ground contribution
Litter Cover	10-25%	2	-
Cryptogram Cover	1% or less	1	No contribution
Crust Brokenness	-	2	Crust present but moderately broken
Erosion Type Severity	Sheeting	4	Insignificant
Deposited Material	5-20%	3	Slight amount of material available
Surface Roughness	-	2	Shallow depressions 3-8 mm relief. Low retention.
Surface Nature	Crust is very hard and brittle	4	Needs a metal implement to break the surface, forming amorphous fragments or powder. The sub-crust is also very hard, coherent and brittle.

Table 18: Physical and Chemical Analysis CMP

				Salinity (ds/m)		
Sample ID	**Slake Test**	**Texture Class**	**pH**	**15 min**	**3-4 hours**	**96 hours**
CMP1-1	Unstable	Light sandy clay	7.81	0.091	0.092	0.130
CMP1-2	Very unstable	Sandy loam	7.89	0.065	0.068	0.089
Average			**7.85**	**0.078**	**0.08**	**0.110**
Standard Deviation			**0.06**	**0.018**	**0.06**	**0.029**

Other notable characteristics of the site:

Sample CMP1-1 is located in a floodplain/drainage depression (Plate 19). Sample CMP1-2 (Plate 20) is located on a lower sand ridge that contains an adjacent mulga swale.

Photographs:

Plate 19: CMP Potential camp site 1 in drainage depression

Plate 20: CMP Potential camp site 2 on the lower sand ridge

5 DISCUSSION

5.1 SOIL CHARACTERIZATION

Table 2 summarises the soil types in EL29018 as shown in Figure 2 utilising Principal Profile Forms (PPF) of Northcote (1979). The majority of Stage 1 operations are situated in soil map units B43 with some located in Nb19.

Table 19: Description of Soil Map Units in EL29018 (Northcote, 1979)

Map Units	Description
B43 ASC: Rudosol	Dune fields with dunes generally trending NW. to SE.; dune crests are inclined to drift readily; narrow inter-dune swales and corridor plains: chief soils are red siliceous sands (Uc1.23), but yellow (Uc1.22) and white (Uc1.21) siliceous sands and also some (Uc5.1) sands occur too. In general there is a grading from red to yellow and white sands from north to south; white sands are more common also in proximity to drainage-ways, pans, and lakes and grade through yellow to red sands away from these situations. Soils of the inter-dune areas are variable, and include sands such as deep (Uc1.43) and (Uc5.21); earths such as (Gn2.12); cracking clays such as (Ug5.2) and (Ug5.3); other clays such as (Uf6.12); and other soils including (Dy) soils. There are also small inclusions of sandstone hills, mesas, clay pans and clay flats.
Nb19 ASC: Sodosol	Dissected stony plateaux with silcrete cappings on shale, claystone, and sandstone; surfaces are mantled by siliceous gravels and stones: chief soils are crusty loamy soils (Dr1.33, Dr1.32), (Dr1.13), and (Dr1.43) that occur on plateau summits and pediment slopes. Associated are brown clays (Ug5.38) in gilgai depressions on plateau summits; various shallow stony soils such as (Uc1.4), (Um1.4), and (Um5.11) on areas of strong relief; and (Uc5.21) soils on fringing plains.
Nb25 ASC: Sodosol	Flat-topped hills, mesas, and cuestas on shales, limestones, and sandstones and stony lowlands all covered by dense silcrete stone and gravel pavements: chief soils are crusty loamy soils (Dr1.33, Dr1.32), (Dr1.13), and (Dr1.43). Associated are shallow sandy soils (Uc1.3) and (Uc1.4) with rock outcrop on areas of strong relief. Small areas of (Uc5.21), (Gn2.1), and (Dr1) soils occur in the narrow valleys, and (Gc) soils may occur locally.
Ld1 ASC: Calcarosol	Undulating to hilly limestone country: chief soils are calcareous earths (Gc1.22) and (Gc2.12). Associated are (Uc1.3) and (Um5.11) soils on steep sites. Areas of (Dr1.33) and (Dr1.43) soils and also (Gn2.13) soils may occur locally.

[1] ASC – Conversion of Atlas of Australian Soils to Australian Soil Classification (Ashton and McKenzie, 2001)

Soil map units are derived from The Atlas of Australian Soil which is based on the Factual Key and no longer the accepted classification system utilized in Australia. While a detailed description of each PPF can be found in Northcote, 1979; Table 20 provides a summary description of the ones mentioned in these map units.

Table 20 Principal Profile Forms in EL29018 (Northcote, 1979)

U	Soils with Uniform Texture Profiles
Uc	**Sands**
Uc1.2	Loose Siliceous Sands-
Uc1.21	whitish
Uc1.22	yellow
Uc1.23	red
Uc1.3	Firm Calcareous Sands
Uc1.4	Firm Siliceous Sands-
Uc1.41	whitish
Uc1.42	yellow
Uc1.43	red
Uc5.1	Loose Brownish Sands-
Uc5.11	no cemented layers
Uc5.12	carbonate pan in subsoil
Uc5.13	earthy pan in subsoil
Uc5.2	Sands with Coherent Earthy Subsoil-
Uc5.21	red
Um	**Loams**
Um1.4	Firm Shallow Calcareous Loams
Um5.1	Powdery Calcareous Loams-
Um5.11	shallow
Uf	**Non-cracking Clays**
Uf6.1	Shallow Friable Clays with Rough-ped Fabric
Uf6.12	brown
Ug	**Cracking Clays**
Ug5.2	Grey, Self-mulching
Ug5.3	Brown and Red, self-mulching
Ug5.38	deep, red

G	Soils with Gradational Texture Profiles
Gn	**Non-calcareous Earths**
Gn2	Massive Earths-
Gn2.1	Red
Gn2.12	neutral
Gn2.13	alkaline
Gc	**Calcareous Earths**
Gc1.1	Apedal, Highly Calcareous
Gc1.2	Apedal, Calcareous-
Gc1.22	brown

D	Duplex- Soils with Texture Contrast Profiles
Dr	**Red Duplex Soils**
Dr 1	Crusty Red Duplex Soils
Dr 1.1	No A_2 Horizon-
Dr1.13	alkaline
Dr 1.3	Sporadically Bleached A A_2 Horizon-
Dr1.32	neutral
Dr1.33	alkaline
Dr 1.4	Bleached A_2 Horizon-
Dr1.43	alkaline
Dy	**Yellow and Yellow-Grey Duplex Soils**

The Atlas was digitized in 1991 and is the most readily available electronic source of soils data and is therefore continually utilized for mapping purposes. However, because the currently accepted classification system is the Australian Soil Classification (Isbell, 2002) a conversion from the Atlas of Australian Soils to Australian Soil Classification was developed. The conversion estimates soils orders for each mapping unit. Soil orders are shown with their corresponding mapping unit is Table 19 and these soil orders are defined according to the Australian Soil Classification in Table 21.

Table 21 Description of Soil Orders in EL29018 (Isbell, 2002)

Soil Order	Definition
Rudosol	Soil with negligible (rudimentary) pedologic organisation apart from (a) minimal development of an A1 horizon or (b) the presence of less than 10% of *B horizon* material (including pedogenic carbonate) in fissures in the parent rock or saprolite. The soils are apedal or only weakly structured in the A1 horizon and show no pedological colour changes apart from the darkening of an A1 horizon. There is little or no texture or colour change with depth unless stratified or buried soils are present.
Sodosol	Soils with a *clear or abrupt textural B horizon* and in which the major part of the upper 0.2 m of the B2 horizon (or the major part of the entire B2 horizon if it is less than 0.2 m thick) is *sodic* and not *strongly acid*. Hydrosols and soils with strongly subplastic upper B2 horizons are excluded.
Calcarosol	Soils that are *calcareous* throughout the solum - or *calcareous* at least directly below the A1 or Ap horizon, or a depth of 0.2 m (whichever is shallower). Carbonate accumulations must be judged to be pedogenic (either current or relict), and the soils do not have *clear or abrupt textural B horizons*. Hydrosols, Organosols and Vertosols are excluded.

The soils in the exploration lease EL29018 fall within soil classes B43 (Rudosols), Nb19 (Sodosols), Nb25 (Sodosols) and LD1 (Calcarosols) (Figure 2) (ASRIS, 2011). It was found during the site survey that B43 dominates the investigation sites within project area EL29018. Although S11 and CMP sites were located within soil type Nb19, results were more representative of soil type B43. Sodosol soils must exhibit a sodic B horizon which is defined as a soil with an exchangeable sodium percentage of 6 or more. Exchangeable sodium was not measured on these soils, however, based on the lack of morphological evidence for a clear or abrupt textural B horizon it is assumed these sites are also classified as Rudosols. There was evidence of calcium carbonate at site 08 but because this was only observed at 1 of the 3 sample locations for the site and the soil was not calcareous through the solum, the classification remains as Rudosol. The other two soil types mapped for EL29018 are NB25 (Sodosol), in the north and west and LD1 (Calcarosol) in the far northwest corner of the EL. These soil types are not likely to be impacted by proposed Stage 1 operations.

5.2 Physical and Chemical Analysis

5.2.1 Texture

All sites, with the exception of CMP-1 and the rocky hill slope of S11, were found to be either loamy sand or sandy loam in texture with very little structure or stability. Sand grains were readily visible, samples were very sandy to the

touch, there was only slight coherence of the bolus and samples generally did not form a ribbon greater than 15 mm in length. A slight increase in clay content was found along the rocky ridge of S11 and within CMP-1.

5.2.2 pH

All soils were found to be slight to moderately alkaline with the pH ranging from 7.78 to 8.12 (Figure 3). This finding is also supported by the calcium carbonate that was found at S08.

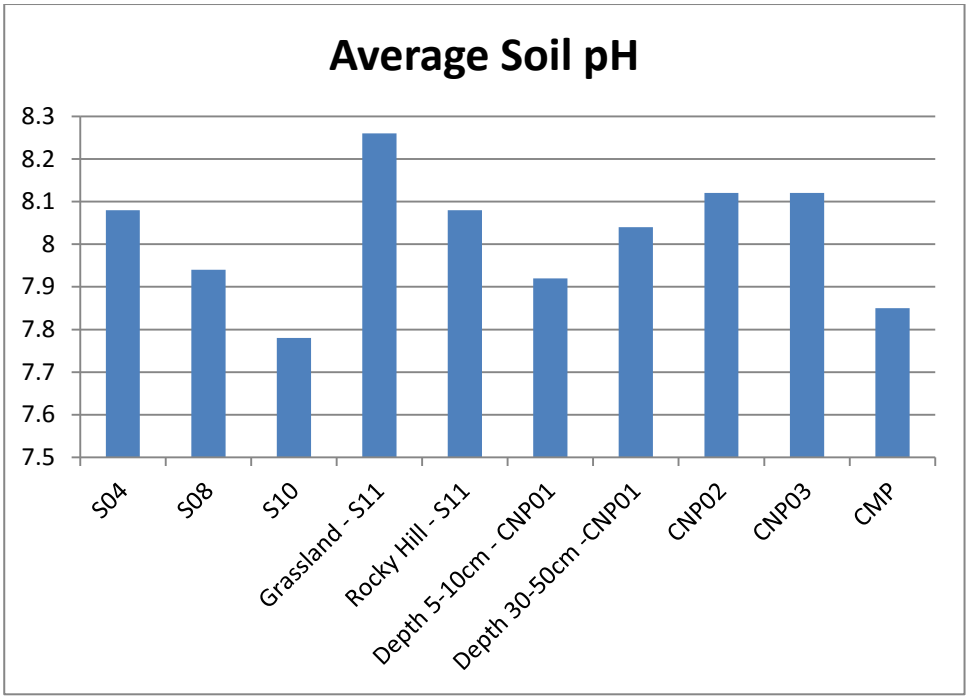

Figure 3: Average soil pH by site

5.2.3 Salinity

Samples were measured at three time intervals (15 minutes, 3-4 hours and 96 hours) because it has been shown that the EC of samples increases over time due to low solubility ions coming into solution. The electrical conductivity of samples ranged from 0.037 to 0.148 ds/m after 15 minutes, from 0.041 to 0.156 ds/m after 3-4 hours and from 0.043 to 0.245 ds/m after 96 hours. While samples from S10, and S04, CNP01-bottom and CNP03 generally remained stable over time. Figure 4 illustrates that the salinity increased with time for the remaining samples indicating that, for these samples, increased salt ions were mobilised in solution.

The texture of the soil influences the interpretation of EC values. Sandy soils do not hold as much salt as clayey soils and therefore tend to give a lower reading. Sandy and loamy soils are considered moderately saline if their $EC_{1:5}$ is greater than 0.3 ds/m while clay soils are considered moderately saline if their $EC_{1:5}$ is greater than 0.6 ds/m (Watling, 2007). The rocky ridge slope of S11, CMP01, CNP01-2-top and S08-2 had increased salinity values relative to the other samples; however, no single $EC_{1:5}$ value exceeds 0.3 ds/m. Therefore, there is little evidence that any of the soils evaluated are saline.

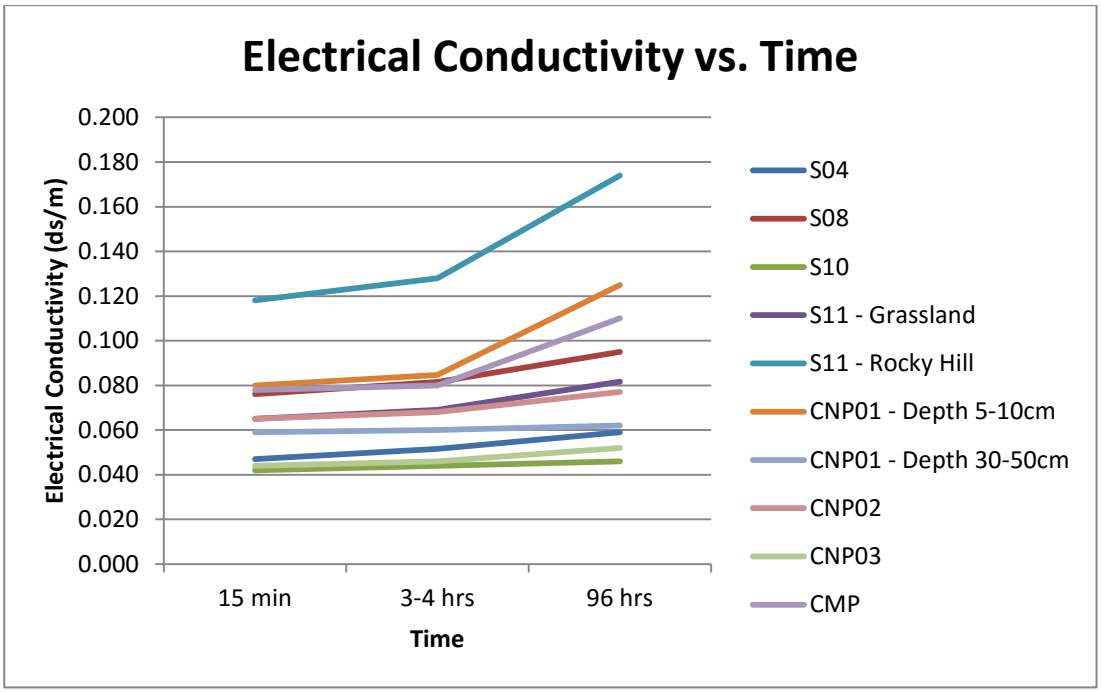

Figure 4: Changes in electrical conductivity over time by site

5.3 Potential Considerations for Environmental Impact:

5.3.1 Erosion

Localized water erosion was occurring at sites CNP03, S11-grasslands, S08 indicating a potential for further erosion with disturbance.

Sand dunes and hill slopes are present across EL29018. Linear structures within the dune will have the potential to cause erosion. The drill site soils (CNP01, CNP02 and CNP03) have high rain splash protection due to generally high soil cover (30-50%) with moderate below ground contributions (10-20%) from basal and canopy cover. The ground is also covered with more than 10% to 50% litter. However, as the drill sites will be cleared this rain splash protection will be reduced. The soils have relatively low crust, easily penetrated surfaces and high infiltration rates significantly reducing their erosion potential. Care will need to be taken to ensure there is no impedance to overland sheet flow. S04, S08, S10, and S11 have less ground protection and would be more susceptible to erosional forces.

5.3.2 Acidity

There is no potential concern for acid generation. These soils are alkaline and do not contain any potential acidic sulfate material such as iron sulfide minerals which when exposed to oxygen, through soil disturbances such as excavation, form acidic soils.

5.3.3 Construction Considerations

Two camp sites were proposed. CMP1-1 is located in a floodplain/drainage depression which would be unsuitable for a campsite. CMP1-2 is located on a lower sand ridge that contains an adjacent mulga swale. This site is more suitable for locating a campsite.

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