MARTINICK BOSCH SELL PTY LTD
ABN 60 102 614 479
MBS ENVIRONMENTAL
environmental and geoscience consultants

4 Cook Street
West Perth WA 6005
Australia

Telephone +61 8 9226 3166
Email: info@mbsenvironmental.com.au

MEMORANDUM

Attention:	Sarah Thomas	From:	Gary Asmaryan and Gert du Plessis
Company:	Consolidated Minerals Ltd	Date:	17 December 2019
Subject:	Woodie Land Systems and Landforms Desktop Review	Project:	Woodie Continued Operations Project

1. PROJECT AREA OVERVIEW

Located in the eastern Pilbara along the Oakover River between Noreena Downs and Warrawagine Stations, the project area is situated within the Warrawagine Hills Zone of the Fortescue Province. The Fortescue Province has been described at the regional level as being comprised of hills and ranges, coupled with associated alluvial plains and sandplains. Red loamy earths and red shallow loams constitute the dominant regional soil type, alongside red/brown non-cracking clays and red deep sands and sandy duplexes (Tille 2006).

Landforms and associated soils in the Warrawagine Hills Zone are characterised by mesas, hills and stony plains, situated on a combination of volcanic and sedimentary rocks of the eastern Hamersley Basin. Soil types of the Warrawagine Hills Zone predominantly consist of stony soils and red shallow loams with minor red shallow and deep sands, calcareous shallow loams and red loamy earths. Spinifex grasslands and acacia shrubs are the main vegetation types occupying the region, with scattered mulga shrublands and eucalypts (Tille 2006).

2. REGIONAL AND PROJECT LANDFORMS

The Western Australian Environmental Protection Authority (EPA 2018) defines landforms as:

The distinctive, recognisable physical features of the earth's surface having a characteristic shape produced by natural processes. A landform is defined by the combination of its geology (composition) and morphology (form).

Landforms are considered a component of the landscape, which is considered to be: *All the features of an area that can be seen in a single view, which distinguish one part of the earth's surface from another part.*

The EPA's environmental objective for the factor, Landforms, is: *To maintain the variety and integrity of significant physical landforms so that environmental values are protected.*

The following criteria may be used in determining whether a landform is significant:

- **Variety.** The landform is a particularly good or important example of its type. The landform is not well represented over the local, regional or national scale or differs from other examples at these scales, either naturally or as a result of cumulative impacts from existing and reasonably foreseeable activities, developments and land uses.
- **Integrity.** The landform is intact, being largely complete or whole and in good condition.
- **Ecological importance.** The landform has a distinctive or exclusive role in maintaining existing ecological and physical processes; for example, by providing a unique microclimate, source of water flow, or shade. The landform supports endemic or highly restricted plants or animals.

- **Scientific importance.** The landform provides evidence of past ecological processes or is an important geomorphological or geological site. The landform is of recognised scientific interest as a reference site or an example of where important natural processes are operating.
- **Rarity.** The landform is rare or relatively rare, being one of the few of its type at a national, regional or local level.
- **Social importance.** The landform supports significant amenity, cultural or heritage values linked to its defining physical features.

2.1 REGIONAL LANDFORM CONTEXT

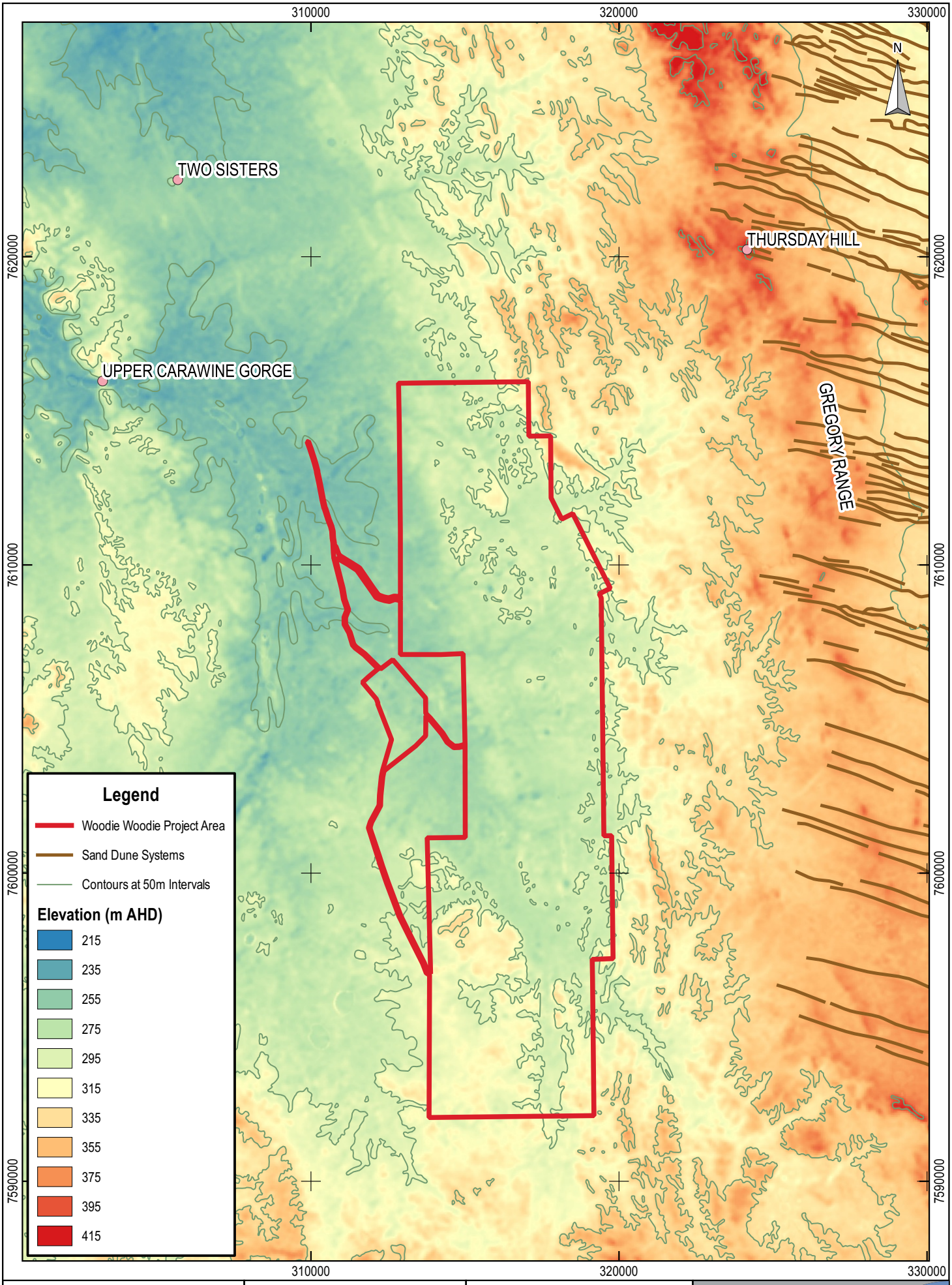
A local assessment unit (LAU) was defined in order to capture the regional landform context for the project area. The LAU extends from the maximum project area extent by between 20 and 21 km. At the LAU scale, landforms were identified using a digital elevation model (DEM with 20 m resolution) as shown in Figure 1. The Department of Mines, Industry Regulation and Safety (DMIRS) GeoView online database (DMIRS 2019) was also used to identify notable landmarks and areas of interest.

The major landforms (i.e. obvious landscape features) within the LAU as shown in Figure 1 are:

- Gregory Range: 9 km east of the project area (elevation up to 415 metres Australian Height Datum (m AHD)).
- Mount Sydney: 16 km north of the project area (350 m AHD),
- Thursday Hill: 9 km northeast of the project area (415 m AHD).
- Carawine and associated Upper Carawine Gorge (240 and 265 m AHD respectively).

Other notable landforms (i.e. referenced in regional scale maps) include sparsely situated hills such as the Hill -Z, Hill -Y and Tanguin Hill, which are respectively located 35, 40 and 39 km northeast of the project area. To the southeast of the project area are Lookout Rocks (27 km) and Hacking Range (26 km).

None of these notable major and minor landforms will be impacted by the project as they are located outside of the project area and as such their significance has not been assessed.



Scale: 1:160000
Original Size: A4
Grid: GDA94 / MGA zone 51

0 2.5 5 km

Consolidated Minerals Pty Ltd
Woodie Woodie

Figure 1

Regional Landform Context

Martinick Bosch Sell Pty Ltd
4 Cook St
West Perth WA 6005
Australia
t: +61 8 9226 3166
info@mbsenvironmental.com.au
www.mbsenvironmental.com.au

MBS ENVIRONMENTAL

W:\CMPL\Woodie\Approvals\EPA Referral\Land Systems and Landforms Memo\GIS\Figure 1 Woodie Woodie Soil and Landfoms.qgz

2.2 LANDFORMS IN THE PROJECT AREA

The project area is mainly associated with mild to low relief and isolated hilly terrain in the north with elevations typically varying between 250 and 330 m AHD (Figure 1). The landscape in low relief areas consists of extensive flat and undulating areas, with gullies located in between, carved by fluvial processes within the region. To the south, gently sloping alluvial plain deposition is evident, likely sourced from higher relief topography further south.

Numerous waste rock dumps and open pits exist within the project area as a result of historic and current mining activity. There are no banded iron formations, dunes, dunefields or ridgelines within the Development Envelope.

2.2.1 Variety, Rarity and Integrity of Impacted Landforms

The alluvial and sand plains that occur within the project area are widely represented. Current mining activity is targeted towards mid to lower relief regions, which will not permanently or significantly impact on their integrity.

Using the EPA criteria for determining whether a landform is significant, the landforms within the project area are not considered to be significant as:

- Landforms that may potentially be impacted (primarily alluvial plains) are well represented over the local and regional scale and are not considered to be rare at either scale.
- No landforms have been identified that could be considered to be an important example of their type.

2.2.2 Ecological Functions of Impacted Landforms

The project area is not floristically unique and is well represented throughout the wider Warrawagine Hills Zone. No Threatened Flora listed under the *Environmental Protection and Biodiversity Conservation (EPBC) Act* 1999 and the *Biodiversity Conservation Act 2016* were located within the project.

In addition, as landforms identified within the project area are well represented at the regional level, ecological impacts from landform disturbance are not expected to be significant.

2.2.3 Scientific or Evolutionary Values of Impacted Landforms

Landforms with significant scientific or evolutionary values in WA are identified as geoheritage sites or reserves. A State register of all geoheritage sites and reserves is managed by the Executive Director of the Geological Survey of Western Australia (GSWA) to assist in managing, preserving and protecting exceptional geological features. Geoheritage focuses on the diversity of minerals, rocks, fossils, and features that indicate the origin and/or alteration of minerals, rocks and fossils. It also includes landforms and other geomorphological features that illustrate the effects of present and past effects of climate and earth forces (McBriar 1995 as cited in Brocx and Semeniuk 2007).

There are no known scientific or evolutionary values associated with the landforms within the project area. The closest geoheritage site to the project area is Glaciated pavements, which is located northeast of Carawine Pool and 16 km northwest of the project within the Canning Basin. It is unlikely that landforms within the project area or the LAU would be considered to be geoheritage sites, given they are not unique or restricted to this area.

Using the EPA criteria for determining whether a landform is significant, the landforms within the project area are not considered to be significant as:

- The landforms within the project area do not specifically provide evidence of past ecological processes.
- The landforms within the project area are not known to be important geomorphological or geological sites.
- The landforms within the project area are not of recognised scientific interest as reference sites or examples of where important natural processes are operating.

2.2.4 Social Importance of Impacted Landforms

Landforms may be of social importance if they support significant amenity, cultural or heritage values linked to their defining physical features (EPA 2018).

The project is located within the Njamal Native Title Claim, which is registered with the National Native Title Tribunal. Numerous surveys have been completed for the project area.

A review of registered Aboriginal Heritage Places (GeoVIEW WA, DMIRS 2019) indicated that there are ten registered sites within the project area, which comprise:

- Locations of engravings.
- Rock shelters.
- Man-made structures.
- Artefact scatter.

Rock shelters and engraving locations are the only sites that are directly related to landform features.

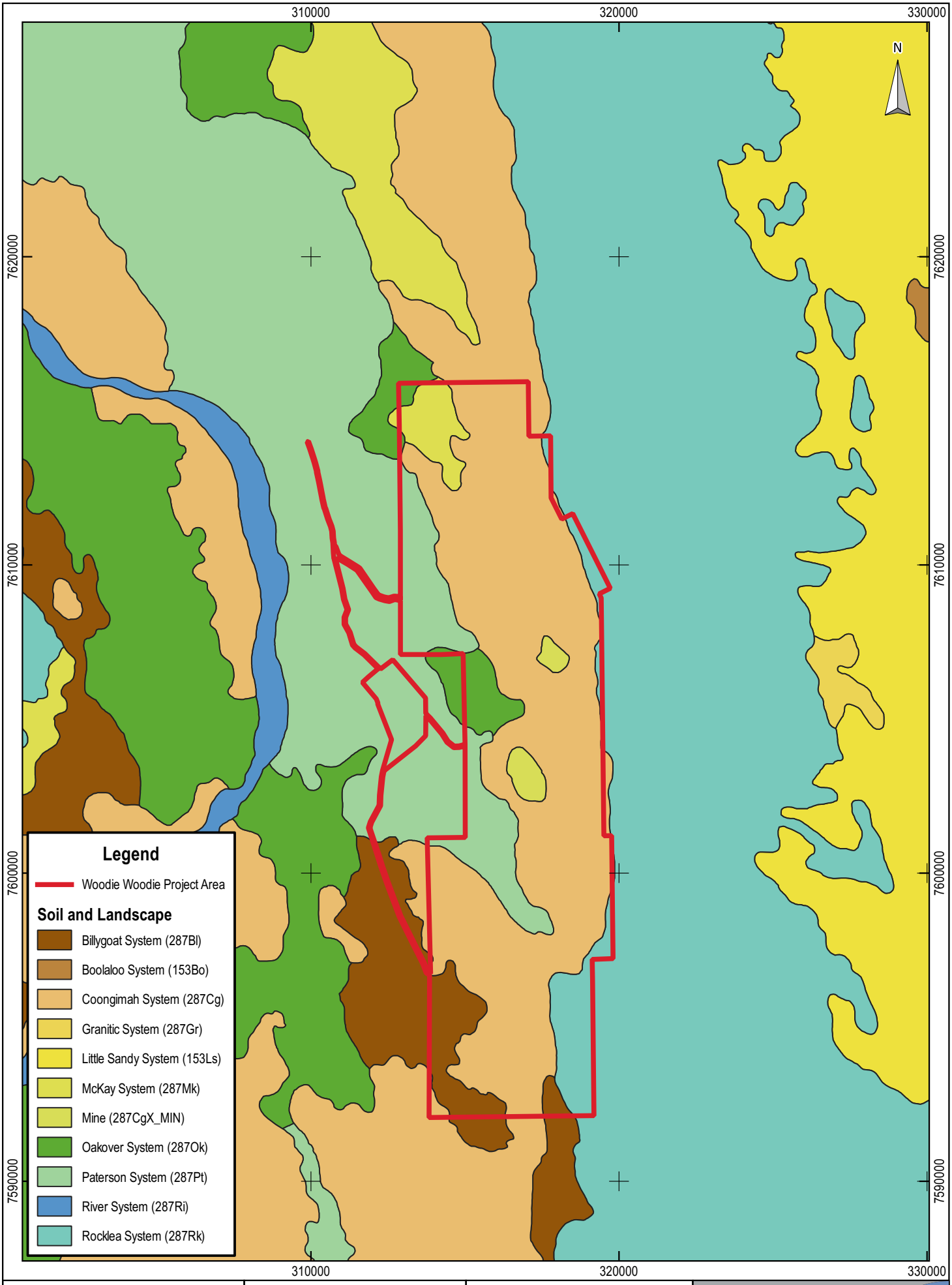
3. LAND SYSTEMS AND SOILS

A desktop review of Land Systems was undertaken using spatial data made available through the Department of Primary Industries and Regional Development (DPIRD, amalgamation of former Departments of Food and Agriculture Western Australia (DAFWA) and Fisheries and Regional Development) (DPIRD 2019). Figure 2 shows the regional Land System Units in relation to the project extent.

Eleven Land Systems are represented in the broader region as shown in Figure 2. Dominant regional Land Systems include the Coongimah, Rocklea, Little Sandy, Oakover and Paterson Systems, with minor inclusions of the Billygoat, Boolaloo, Granitic, Mckay and River Systems. Of these, the Coongimah System occupies the largest area within the project extent, which comprises plateau surfaces, low hills with steep slopes and undulating uplands developed on either siliceous caprock, lateritised colluvium, chert breccias or minor dolomite. The dominant vegetation unit present within the Coongimah System is spinifex grasslands. The Paterson System occupies the second largest area within the project, which has developed from Quaternary sandy and gravelly eluvium, colluvium and minor alluvium, Permian sandstone and conglomerate sediments. Minor Land Systems represented at the project include the Billygoat, Oakover, Mckay, Mine and Rocklea Systems. Table 1 shows the seven major and minor Land Systems represented within the project area.

Four distinct soil types are represented within the major Land Systems at the project, as summarised below:

- **Stony soils**. Non-calcareous soils, which contain coarse gravelly, stony or rocky fragments throughout the profile. Stony soils are typically located on hills, ridges, slopes and breakaways.
- **Red shallow sands**. Uniform medium to coarse textured sands. Three sub-groups are recognised, depending on the geological substrate (typically granite, basalt or calcrete). Soils developed over granite tend to have a weakly acidic to neutral soil reaction, while those developed on calcrete are alkaline throughout the profile.
- **Red shallow loams**. These soils are shallow loams often overlying weathered rock on low slopes or plains. The thin (one to 100 millimetres) topsoils range from sandy loam to clay loam and overlie thin to medium (100 to 300 millimetres) subsoils of sandy clay loam or clay loam.
- **River bed soils**. Poorly developed soils of recent alluvial deposits associated with active drainage channels, levees, or flood plains of major and minor creek or river systems. These soils exhibit sediment layers of coarse loose sand, clayey sand, silty sand and silty clay.



Scale: 1:160000
Original Size: A4
Grid: GDA94 / MGA zone 51

0 2.5 5 km

Consolidated
Minerals Pty Ltd
Woodie Woodie

Figure 2

Regional Land Systems

Martinick Bosch Sell Pty Ltd
4 Cook St
West Perth WA 6005
Australia
t: +61 8 9226 3166
info@mbsenvironmental.com.au
www.mbsenvironmental.com.au

MBS ENVIRONMENTAL

W:\CMPL\Woodie\Approvals\EPA Referral\Land Systems and Landforms Memo\GIS\Figure 1 Woodie Woodie Soil and Landfoms.qgz

Table 1: Project Land Systems

System Name	System Code	Description
Major Land Systems		
Coongimah System	287Cg	Plateau surfaces, low hills with steep slopes and undulating uplands supporting hard spinifex grasslands.
Paterson System	287Pt	Stony and sandy plains with isolated low hills of sandstone or conglomerate supporting hard spinifex (and occasionally soft spinifex) grasslands and minor tussock grasslands.
Minor Land Systems		
Billygoat System	287Bi	Dissected plains and gravelly slopes supporting hard spinifex grasslands.
Mckay System	287Mk	Hills, ridges, plateaux remnants and breakaways of meta sedimentary and sedimentary rocks supporting hard spinifex grasslands with acacias and occasional eucalypts.
Mine	287CgX_MN	Disturbed area, mines, mullock dumps etc
Oakover System	2870k	Breakaways, mesas, plateaux and stony plains of calcrete supporting hard spinifex shrubby grasslands.
Rocklea System	287Rk	Basalt hills, plateaux, lower slopes and minor stony plains supporting hard spinifex and occasionally soft spinifex grasslands with scattered shrubs.

4. SITE CHARACTERISATION OF PROJECT SOILS

4.1 BACKGROUND AND LOCATIONS

In a previous study conducted by MBS Environmental in 2009 for Landloch Pty. Ltd. (MBS 2009), 14 representative project soil samples were assessed from field survey in December 2008 at nine prospect locations at Woodie (Table 2). These were assessed for their geochemical and physical properties to determine with suitability for rehabilitation purposes (MBS 2009). Topsoils were sampled to a depth of approximately 100 millimetres. Subsoil samples were generally collected at depths of 300 to 500 millimetres. At each location, samples were collected from at least two locations, thoroughly mixed and the composite samples delivered to MBS. The samples collected typify the soils which were planned to be stripped within the then proposed pit and waste rock stockpile footprints.

Table 2: Woodie Woodie Soil Samples (MBS 2009)

Location	Samples
Austin	Topsoil
Hunter	Topsoil
Harris	Topsoil
Sat/Nat	Topsoil
Lox	topsoil and subsoil
Windy Hill	topsoil and subsoil
Demon	topsoil and subsoil
Whodowe	topsoil and subsoil (hard, rocky ground)
Greensnake	topsoil and subsoil

4.2 SUMMARY OF GEOCHEMICAL AND PHYSICAL SOIL CHARACTERISTICS

A summary of results of analyses conducted on soils within areas of the Woodie project area are presented in Table 3 and Table 4. The following conclusions were drawn from the data:

- The soils in the Woodie Woodie project area were characterised as gravelly, loamy sands to loams with a clay (<0.002 mm) content of between 10% and 22%.
- All of the soils that were analysed were non-dispersive, having Emerson Class values of four to six. Soils were moderately alkaline with a pH range between eight and nine. This was a reflection of the high calcium carbonate content derived from the presence of dolomite in the parent material.
- Salinity of the soil, as indicated by the EC (1:5) values, were low and within the range anticipated for these soil types and was considered not to be limiting to growth rates.
- Plant available soil phosphorus levels, as assessed by the Colwell soil test method, was rated as low but these levels were typical of unfertilised topsoils in Western Australia.
- Carbon to nitrogen ratios were all less than 25, which indicated that no decomposition limitations existed within the soil and no additional nitrogen was required when undertaking revegetation (Hazelton & Murphy, 2007).
- Soil sodicity, as indicated by the relative proportion of sodium to calcium and magnesium, was rated as low. No plant toxicities or deficiencies in regard to trace metal constituents (Cu, Fe, Mn, Mo and Zn) were evidenced in these results. Overall, these soils should provide a suitable medium for re-establishment of local vegetation species.
- Overall the physical and chemical properties of Woodie Woodie soils indicate they are well suited for rehabilitation purposes.

Table 3: All Woodie Woodie Soil and Subsoil Samples pH and EC (MBS 2009)

Location	Profile	pH (H_2O)	EC	Emerson Class
		pH units	mS/m	Class
Hunter	topsoil	8.8	7	4
Harris	topsoil	7.8	2	4
Eat	topsoil	9.1	7	4
Sat/Nat	topsoil	8.8	7	4
Lox	topsoil	8.0	5	5/6
Lox	subsoil	7.5	4	5/6
Windy Hill	topsoil	7.1	2	5
Windy Hill	subsoil	6.8	2	5
Demon	topsoil	8.7	11	5
Demon	subsoil	8.8	12	5
Whodowe	topsoil	9.2	13	6
Whodowe	subsoil	9.1	20	6
Greensnake	topsoil	9.0	8	4
Greensnake	subsoil	9.0	7	4

Table 4: Results of Physical and Chemical Analyses of Selected Soils (MBS 2009)

Analyte	Units	Mining Proposal Area			
		Austin	Hunter	Harris	Sat/Nat
EC	mS/m	7	7	2	7
pH		9.1	8.8	7.8	8.8
Sand	%	62.5	74.5	84.5	74
Silt	%	15.5	8.5	5.0	8
Clay	%	22	17	10.5	18
Texture		Loam	Loamy sand	Loamy sand	Loamy sand
Emerson Class		4	4	4	4
Org C	%	0.14	0.31	0.17	0.2
N	%	0.022	0.035	0.022	0.024
C/N ratio		8.9	7.7	6.4	8.3
Colwell-P	mg/kg	2	2	4	2
As	mg/kg	9	6	9	11
B	mg/kg	25	12	26	19
Ba	mg/kg	790	190	870	140
Ca	mg/kg	23000	12000	27000	6500
Cd	mg/kg	<0.05	<0.05	<0.05	<0.05
Co	mg/kg	16	11	17	11
Cr	mg/kg	46	41	49	53
Cu	mg/kg	71	25	76	95
Fe	mg/kg	49000	24000	56000	38000
K	mg/kg	4000	2100	4200	2300
Mg	mg/kg	5400	8500	6000	1200
Mn	mg/kg	8600	1900	9600	1700
Mo	mg/kg	<0.5	<0.5	<0.5	1.5
Na	mg/kg	140	78	140	78
Ni	mg/kg	25	22	27	17
Pb	mg/kg	150	16	170	16
S	mg/kg	62	56	69	39
V	mg/kg	43	41	48	49
Zn	mg/kg	32	25	36	16

Sand = *particle diameters between 0.020 and 2.0mm*

Silt = *particle diameters between 0.002 and 0.02mm*

Clay = *particle diameters <0.002mm*

Colwell-P = *phosphorus (P) extracted by 0.5 M $NaHCO_3$*

4.3 CONCLUSIONS

Rehabilitation of waste dumps and other mining infrastructure areas has occurred since 1998 using standard site practices for Woodie Woodie. Topsoil and shallow subsoil, where available, has been used as the soil cover to the rehabilitated landforms. Vegetation is well established on these rehabilitated landforms with similar soils to the project area demonstrating the suitability of the local materials for rehabilitation. These site observations are consistent with assessment outlined above that harvestable soils from the project area were well suited for rehabilitation.

Yours sincerely
MBS Environmental

Gary Asmaryan
Graduate Environmental Geochemist

Gert du Plessis
Environmental Geochemist

5. REFERENCES

Brocx, M., and Semeniuk, V. 2007. Geoheritage and geoconservation – history, definition, scope and scale. *Journal of the Royal Society of Western Australia* 90: 53-87.

DMIRS. 2019. GeoVIEW WA Interactive Geological Map. Department of Mines, Industry Regulation and Safety, Perth. https://geoview.dmp.wa.gov.au/GeoViews/?Viewer=GeoVIEW (accessed 10 October 2019).

DPIRD. 2019. *Soil-landscape mapping – Best Available (DPIRD-064)*. Government of Western Australia, Department of Primary Industries and Regional Development. https://catalogue.data.wa.gov.au/dataset/soil-landscape-mapping-systems (accessed 10 October 2019).

EPA. 2018. Environmental Factor Guideline: Landforms. Government of Western Australia Environmental Protection Authority (EPA). http://www.epa.wa.gov.au/sites/default/files/Policies_and_Guidance/Guideline-Landforms-29062018.pdf (accessed 10 October 2019).

Hazelton, P., and Murphy, B. 2007. *Interpreting Soil Test Results, What Do All the Numbers Mean?* Collingwood: CSIRO Publishing.

MBS. 2009. Woodie Woodie Soil and Waste Rock Characterisation Memorandum. Internal document prepared for Landloch Pty Ltd by MBS Environmental. Perth. June 2009.

Tille, P. 2006. Soil-landscapes of Western Australia's Rangelands and Arid Interior. Resource Management Technical Report 313. Perth: DAFWA.